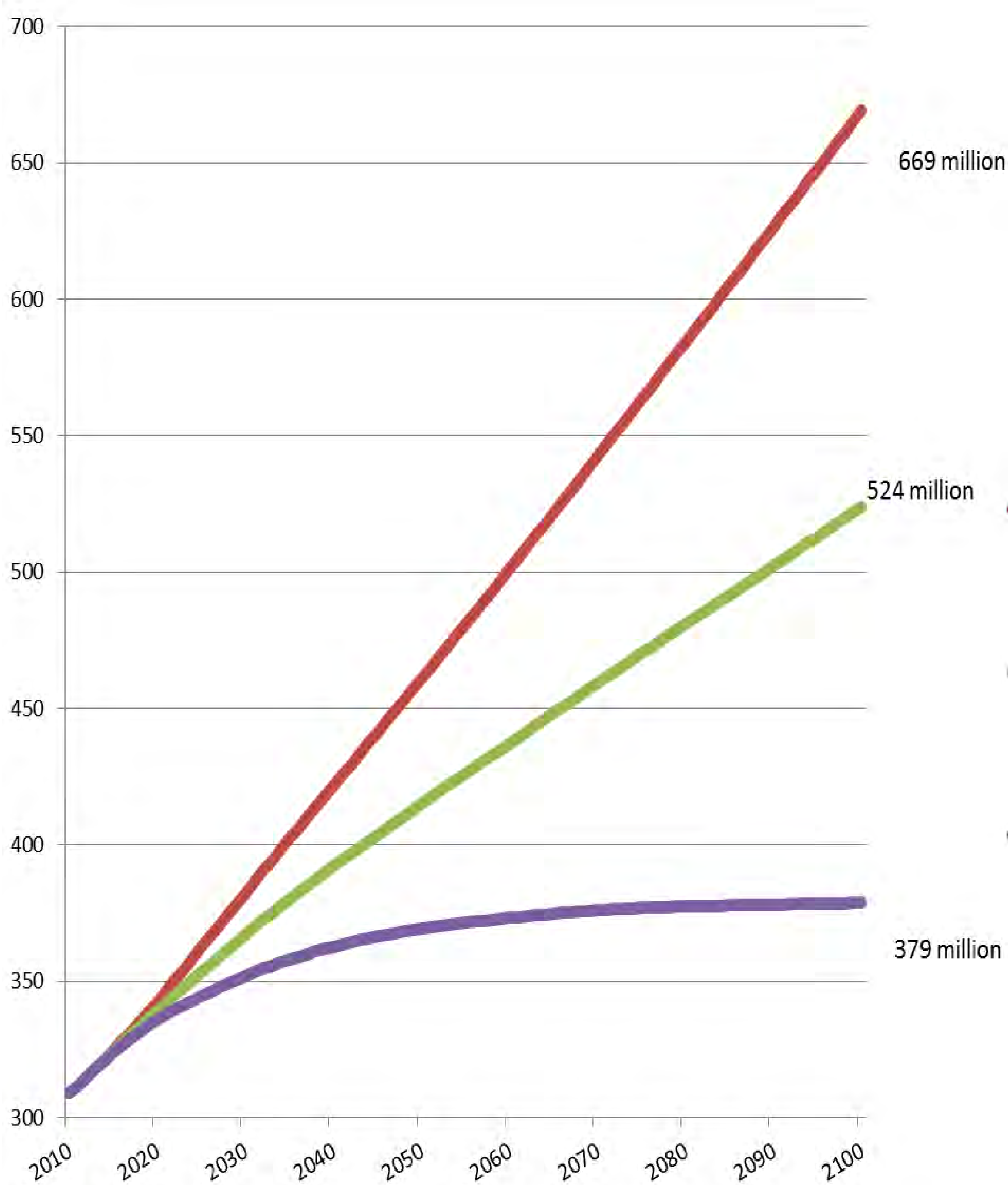
United States Immigration Policy

ENVIRONMENTAL IMPACT STATEMENT

Progressives for Immigration Reform



Cover: The critically endangered Mission Blue Butterfly is found only in the San Francisco Bay Area, where its habitat has been developed because of population growth in the Bay Area.

United States Immigration Policy

ENVIRONMENTAL IMPACT STATEMENT

May 2016

Progressives for Immigration Reform
1701 Pennsylvania Avenue NW
Suite 300
Washington, DC 20006

Progressives
for Immigration Reform


"You don't have a conservation policy, unless you have a population policy."
David Brower, former Executive Director of the Sierra Club


Our current rate of growth is not sustainable, leaving little behind for future generations.
Learn more »


U.S. population growth accelerates deforestation, increases sprawl, and intensifies the nation's dependence on nonrenewable fossil fuels.
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ABSTRACT

The National Environmental Protection Act (NEPA) of 1969 requires that any federal program, policy, or project that might entail potentially significant environmental impacts undergo an Environmental Impact Statement (EIS). Because immigration has a large influence on the overall size of the U.S. population, and because population numbers can be an important factor in determining a variety of environmental impacts, federal immigration policy would seem to be a likely subject for NEPA review. NEPA itself acknowledges the importance of population growth, stating at the outset that Congress recognizes "the profound influences of population growth" on the natural environment (Title I, Section 101a). However, immigration policy has never been subjected to such an analysis.

In this Programmatic Environmental Impact Statement (PEIS), the Washington, D.C.-based non-governmental organization (NGO) Progressives for Immigration Reform (PFIR) assesses six types of potential long-term environmental impacts associated with three alternative immigration scenarios: 1) No Action Alternative, in which current immigration rates of approximately 1.25 million per year would be maintained to the year 2100; 2) Expansion Alternative, or 2.25 million annual immigration; and 3) Reduction Alternative, or 0.25 million (250,000) annual immigration into the United States.

U.S. population size was projected to the year 2100 under the three alternative immigration scenarios. Fertility and mortality rates were held steady under all three alternatives, at the levels used by the U.S. Census Bureau in its 2008 projections.

The No Action Alternative would lead to a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) over the 2010 population of 309 million. The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) above the 2010 population of 309 million. The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) above the 2010 population of 309 million.

Potential environmental impacts for each of the three alternatives were assessed in six pertinent topic areas: 1) urban sprawl and loss of farmland; 2) habitat loss and impacts on biodiversity; 3) water demands and withdrawals from natural systems; 4) carbon dioxide emissions and resultant climate change; 5) energy demands and national security implications; 6) international ecological impacts of U.S. immigration policies.

In general, the No Action Alternative (1.25 million annual immigration) and the Expansion Alternative (2.25 million annual immigration) would result in significant, long-term, widespread adverse environmental impacts on all resource topics analyzed. The Expansion Alternative in particular would result in major, highly adverse environmental impacts on a number of resources, even taking enhanced conservation and efficiency measures into account. The Reduction Alternative would still entail higher environmental impacts than at present, but much less than the other two alternatives.

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United States Immigration Policy Environmental Impact Statement

Table of Contents

List of Figures

List of Tables

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EXECUTIVE SUMMARY

The National Environmental Protection Act (NEPA) of 1969 requires that any federal program, policy, or project that might entail potentially significant environmental impacts undergo an Environmental Impact Statement (EIS). Almost since NEPA's enactment on January 1, 1970, and implementation in the early 1970's, some environmentalists have argued that this requirement should be applied to U.S. immigration policy. Because immigration has a large influence on the overall size of the U.S. population, and because population numbers can be an important factor in determining a variety of environmental impacts, federal immigration policy would seem to be a likely subject for NEPA review. This landmark statute (42 USC § 4321 *et. seq*.) itself acknowledges the importance of population growth, stating at the outset that Congress recognizes "the profound influences of population growth" on the natural environment (Title I, Section 101a).

In this Programmatic Environmental Impact Statement (PEIS), the Washington, D.C.-based non-governmental organization (NGO) Progressives for Immigration Reform (PFIR) assesses six types of potential long-term environmental impacts associated with three alternative immigration scenarios: 1) No Action Alternative, in which current immigration rates of approximately 1.25 million per year would be maintained to the year 2100; 2) Expansion Alternative, or 2.25 million annual immigration; and 3) Reduction Alternative, or 0.25 million (250,000) annual immigration into the United States. This range of reasonable alternatives corresponds to approximate actual immigration rates at present (the No Action Alternative), as well as proposals and legislation for either increasing or decreasing immigration rates. The three alternatives each vary by one million immigrants annually.

Using a projection tool developed by Decision Demographics, Inc. and the Center for Immigration Studies, U.S. population size was projected to the year 2100 under the three alternative immigration scenarios. Fertility and mortality rates were held steady under all three alternatives, at the levels used by the U.S. Census Bureau in its 2008 projections.

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) over the 2010 population of 309 million (Table ES-1). Under the Expansion Alternative, 2.25 million annual immigration would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) above the 2010 population of 309 million. Under the Reduction Alternative, 250,000 (0.25 million) annual immigration would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) above the 2010 population of 309 million (Figure ES-1).

Table ES-1. Population projections to 2100 of the three immigration scenarios used in this EIS			
Average annual net migration	**U.S. population in 2010**	**U.S. population in 2050**	**U.S. population in 2100**
250,000	309 million	369 million	379 million
1.25 million	309 million	415 million	524 million
2.25 million	309 million	460 million	669 million

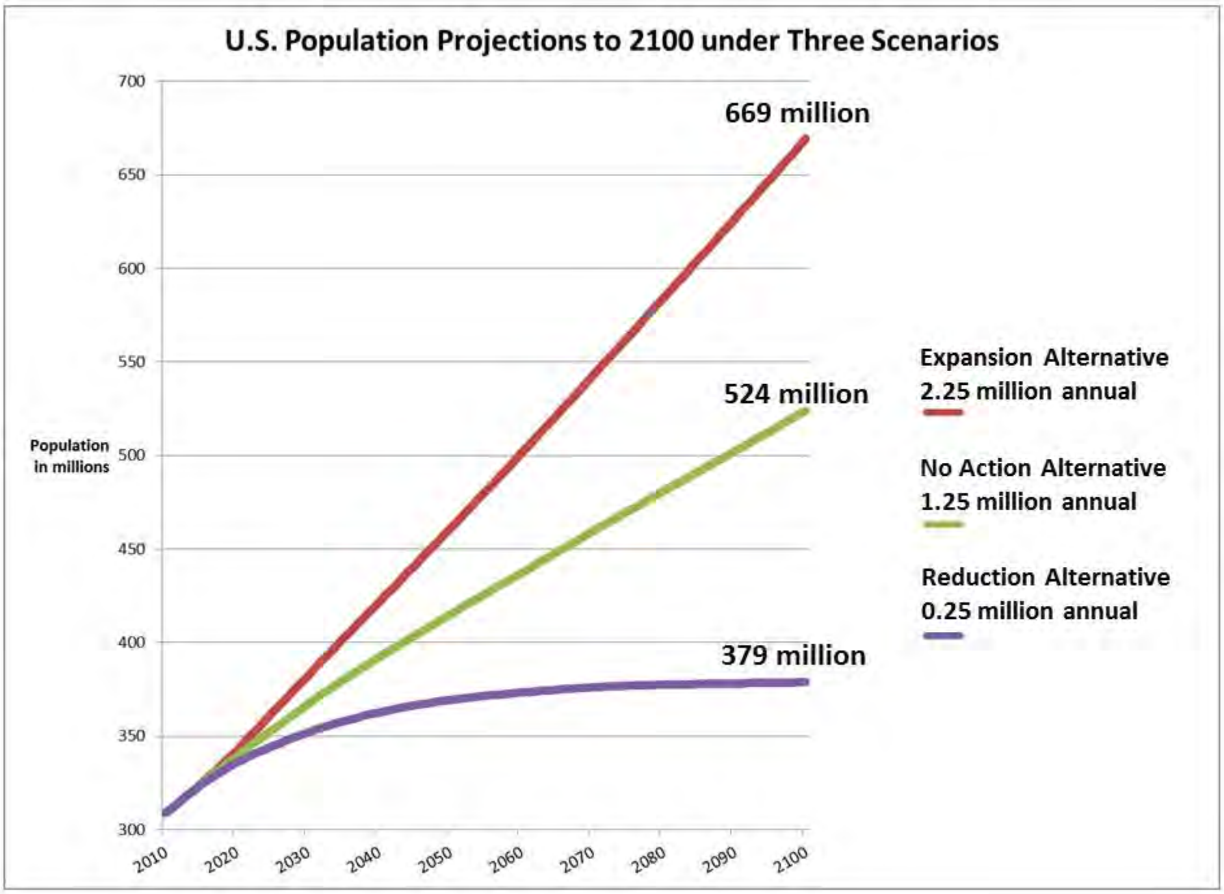


Figure ES-1. U.S. population projections to 2100 under the three immigration scenarios or alternatives used in this EIS

Scoping is the process of soliciting input from stakeholders at the outset of a NEPA analysis. PFIR solicited public comments at the commencement of our Environmental Impact Statement on United States immigration policy. The initial comment or "scoping" period ran from August 1 through October 31, 2012. PFIR received a little over two dozen formal comments on the EIS proposal. In a related effort, PFIR contacted approximately 3,000 environmental leaders around the country, including about 1,800 mid-level Sierra Club leaders at the state chapter and local group levels.

Based on comments received during scoping, potential environmental impacts for each of the three alternatives were assessed in six pertinent topic areas: 1) urban sprawl and loss of farmland; 2) habitat loss and impacts on biodiversity; 3) water demands and withdrawals from natural systems; 4) carbon dioxide emissions and resultant climate change; 5) energy demands and national security implications; 6) international ecological impacts of U.S. immigration policies.

Urban Sprawl and Loss of Farmland

<u>No Action Alternative – 1.25 million annual immigration</u>

The addition of 215 million new Americans under the No Action Alternative would entail the development of 79 million additional acres or 123,438 square miles of formerly rural land, an area larger than New Mexico, our 5th largest state. Alternatively, it approximates the combined size of Kentucky, Indiana, South Carolina and West Virginia. About 90 percent of this sprawl would be due directly to population growth, while about 10 percent would be correlated with increasing per capita land consumption.

In 2010 there were 113 million acres of developed land in the United States. Thus, increasing this by 79 million acres would push the total amount of developed land to 192 million acres or 300,000 square miles in 2100, substantially larger than our second largest state (Texas, at 268,597 square miles). Large swaths of America would lose their rural character and "feel."

The No Action Alternative would have indirect and cumulative impacts on sprawl as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the No Action Alternative on suburban sprawl would be *adverse, significant, and long-term.*

Accommodating 215 million new Americans would require substantial space and land area – almost 80 million acres' worth. Because farmland tends to be flat, and flatlands are easier and cheaper to build on than hillsides, and because of the proximity of much farmland to urban areas, where it lies directly in the path of development, much of the acreage for the new development necessitated by 215 million more residents will likely come from the nation's agricultural land base.

Interpolating and extrapolating from the average recent rates of cropland loss and population growth, it can be inferred that under the No Action Alternative, cropland per capita would decrease from 1.18 acre/person in 2010 to 0.32 acre/person in 2100. At these rates, in 2100 each American would have only 27 percent of the cropland that he or she enjoyed in 2010. Another way of stating this is that agricultural yields (food produced per acre) would have to increase almost four-fold just to maintain per capita food production.

The impact of farmland and cropland loss due to immigration-induced population growth could potentially be alleviated or mitigated by continuing advances in agricultural technology that raise productivity or yield per acre (although there could be diminishing returns from these endeavors) as well as sharpening America's commitment to implementing Smart Growth programs and farmland protection policies of the sort advocated by conservation groups. Each of these policies, if successfully implemented at scale, would have the net effect of increasing population density on both existing and future developed land. Americans would have to be willing to accept relatively more apartments and condominiums and relatively fewer and smaller single detached homes with yards. Just how politically and culturally feasible this large shift in public attitudes would be remains to be seen.

The No Action Alternative would have indirect and cumulative impacts on farmland loss as follows:

- Duration of Impact*:* *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the No Action Alternative on farmland loss would be *adverse, significant, and long-term.* This alternative would substantially reduce future U.S. food security.

<u>Expansion Alternative – 2.25 million annual immigration</u>
Under the Expansion Alternative, the 2100 U.S. population of 669 million would exceed the No Action Alternative population of 524 million by 145 million. In this alternative, 113 million acres of developed land in 2010 are projected to increase to 245 million acres or 383,000 square miles by 2100. This would be about equal in area to Texas and New Mexico combined, that is, our second and fifth largest states. Still larger swaths of Rural America would forever be converted to Urbanized Areas and lose their rustic character and "feel" than in the No Action Alternative. Even extensive areas of the country that would still be officially designated "rural" under the classification systems of the Census

Bureau and the Natural Resources Conservation Service (NRCS) would nonetheless be under the influence of adjacent developed areas and would lose some of their rural feel.

The Expansion Alternative would have indirect and cumulative impacts on sprawl as follows:

- Duration of Impact*: Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the Expansion Alternative on suburban sprawl would be *adverse, significant, and long-term.* It would result in the permanent conversion of 132 million additional acres or 206,250 square miles of open space and natural habitat to urbanization – the essentially irreversible process of converting rural land into developed or urbanized land. Urbanized or developed land would increase from 7.6% of all non-federal lands in 2010 to 17 percent in 2100 (compared to 13 percent under the No Action Alternative).

As noted above, because farmland tends to be flat, and because flatlands are easier and cheaper to build on than hillsides, much of the acreage for the new development necessitated by 360 million more residents will likely come from the nation's agricultural land base. Table ES-2 shows projected losses of cropland under the three alternatives considered in this EIS. Over 52 million acres of cropland are projected to be lost by 2100 under the Expansion Alternative, compared to 31 million in the No Action Alternative.

Table ES-2. Projected cumulative cropland loss by 2050 and 2100 under the three immigration scenarios (alternatives) used in this EIS

Alternative	Average annual net migration	U.S. cropland in 2010 (acres)	Cropland lost to development by 2050 (acres)	Cropland lost to development by 2100 (acres)
Reduction	250,000	361 million	8.7 million	10.2 million
No Action	1.25 million	361 million	15.4 million	31.2 million
Expansion	2.25 million	361 million	21.9 million	52.2 million

The Expansion Alternative would have indirect and cumulative impacts on farmland loss as follows:

- Duration of Impact*: Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the Expansion Alternative on farmland loss would be *highly adverse, significant, and long-term.* It would likely be associated with the permanent disappearance of tens of millions of additional acres of farmland (cropland, pastureland, and rangeland) to urbanization. While the sustainability of many current agricultural practices is questionable, surviving farmland and soils remaining in cultivation or under grazing regimes would be subjected to even more intensive pressures and practices in order to maintain productivity at all costs. In itself, this is likely untenable and unsustainable over the long run. This alternative would drastically reduce future U.S. food security.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>
Under the Reduction Alternative, the 2100 U.S. population of 379 million would exceed the 2010 population of 309 million by 70 million or 23 percent; it would be 145 million – or 28 percent – less than the 524 million of the No Action Alternative population. As of 2010, there were 113.3 million acres (177,031 square miles) of developed land in the United States. With population growth of 70 million by 2100 under the Reduction Alternative, this built-up area would expand by 25.7 million acres to 139 million acres in aggregate at the end of this century. Table ES-3 compares the total area of all development acreage for all three alternatives in 2050 and 2100.

Table ES-3. Projected area of total developed land in 2050 and 2100 under the three immigration scenarios (alternatives) used in this EIS

Alternative	Average annual net migration	Developed land in 2010 (millions of acres)	Developed land in 2050 (millions of acres)	Developed land in 2100 (millions of acres)
Reduction	250,000	113.3	135.3	139.0
No Action	1.25 million	113.3	152.2	192.1
Expansion	2.25 million	113.3	168.7	245.3

The Reduction Alternative would have indirect and cumulative impacts on sprawl as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Moderate*
- Likelihood of Impact: *Probable*

Overall, the effect of the Reduction Alternative on suburban sprawl would be *adverse, significant, and long-term.* Even though all three alternatives are rated as "adverse, significant, and long-term," the Reduction Alternative is quantitatively and qualitatively much less adverse than the No Action and Expansion alternatives.

Accommodating 70 million new Americans – more than the current combined populations of our two most populous states, California and Texas – would still require significant space and land area – but not nearly as much as in the No Action and Expansion alternatives. As shown in Table ES-2, barring major breakthroughs in the political acceptability of high density development and stringent Smart Growth measures, this alternative would directly cause the urban development of 10.2 million acres of cropland by 2100. Somewhat smaller, but still substantial areas – in the millions of acres – of pastureland and rangeland would also be developed because of the population growth induced by the Reduction Alternative.

The Reduction Alternative would have indirect and cumulative impacts on farmland loss as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Moderate*
- Likelihood of Impact: *Probable*

Overall, the effect of the Reduction Alternative on farmland loss would be *adverse, significant, and long-term.* Of the three alternatives, this one would have the least negative impact on future U.S. food security.

Habitat Loss and Impacts on Biodiversity

On the optimistic side, this EIS will assume a net 30 percent lower per capita impact from each American, so that if today's per capita impact is set at 1.0, by 2100 it would be reduced to 0.7. On the pessimistic side, per capita impact would be 30 percent higher, or 1.3 by 2100. This range from 0.7 to 1.3 may be too cautious, but it is also realistic and reasonable.

<u>No Action Alternative – 1.25 million annual immigration</u>
Under the No Action Alternative – leading to a U.S. population of 524 million in 2100 – the net, aggregate effect on habitats and biodiversity would range from approximately 1.2 to 2.2 times greater than it is today. This is not to say that 1.2 to 2.2 times the number of wildlife species would necessarily be threatened with extinction, or that habitats would be reduced by 1.2 to 2.2 times. Rather, a first-order approximation of the general impacts or demographic pressures on habitats and biodiversity of this immigration-induced population growth is that these impacts and pressures would range from 1.2 to 2.2 times greater than they are at present.

Figure ES-2 is a schematic which illustrates the broad types of effects that each American resident/consumer, and by extension all American consumers in aggregate, would have on habitats and biodiversity from the increased U.S. population size induced by immigration rates under the No Action Alternative. These "pathways to perdition" depict some of the more important routes by which increased aggregate American consumption from a population that is 70 percent larger would cause additional harm to natural habitats, wildlife, and biodiversity. This diagram is not meant to be thorough or exhaustive, merely suggestive. It divides impacts into two broad categories: 1) those flowing from consuming or using natural resources – including energy, water, raw materials such as minerals, and land – and 2), those flowing from residuals or wastes excreted back into the environment by economic processes.

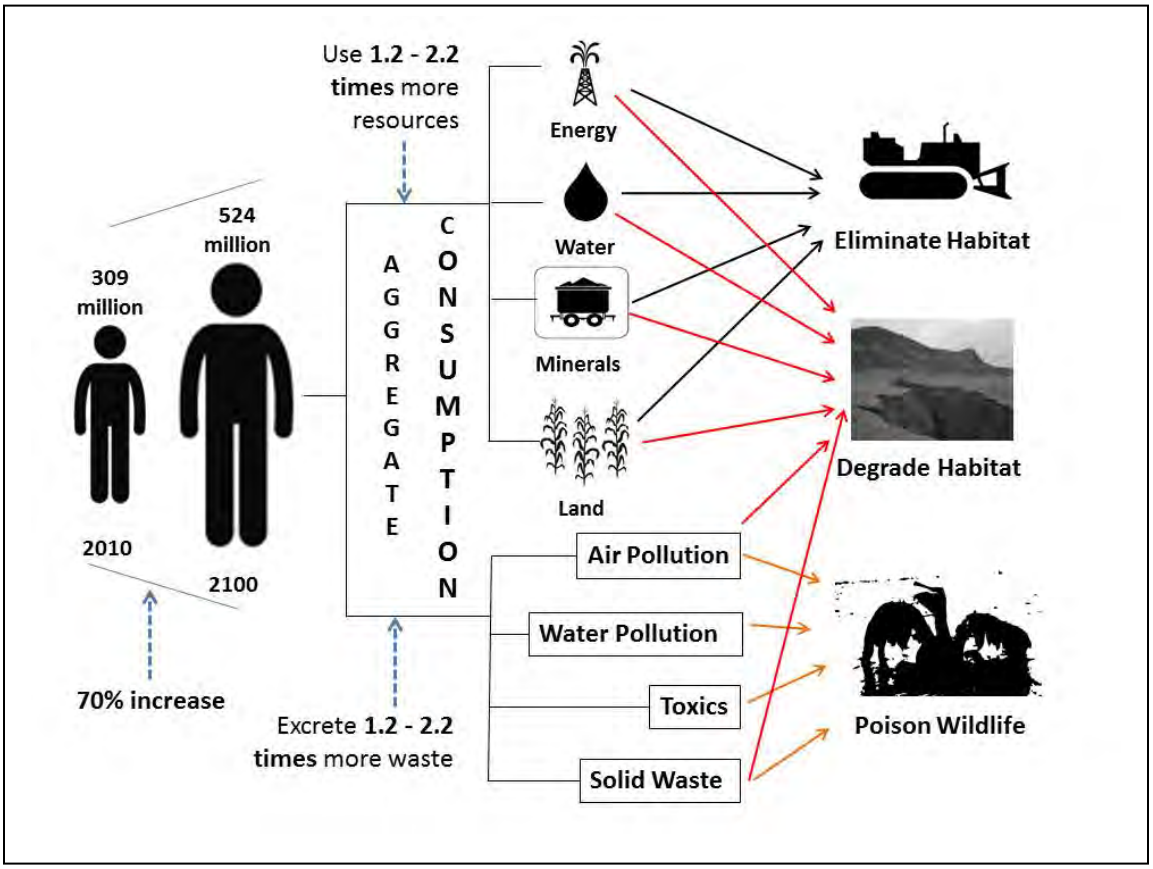


Figure ES-2. Illustration some of the routes by which the No Action Alternative would adversely affect habitats, wildlife, and biodiversity

The No Action Alternative would have indirect and cumulative impacts on habitat and biodiversity as follows:

- Duration of Impact*:* *Long-term to permanent*
- Extent of Impact: *Large*

- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the No Action Alternative on suburban sprawl would be *adverse, significant, and long-term.* It would likely be associated with the permanent loss of at least an additional 50-75 million acres (80,000 to 120,000 square miles) of wildlife habitat directly to development (sprawl and urbanization). A much larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 70 percent larger.

<u>Expansion Alternative – 2.25 million annual immigration</u>
The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) from the 2010 population of 309 million. A U.S. population that is more than twice as large as our current population would generally be expected to exert considerably greater pressure and stress on all natural resources and on all facets of the environment. The net, aggregate effect on habitats and biodiversity would range from approximately 1.5 - 3 times greater than it is today. This is not to say that 1.5 to 3 times the number of wildlife species would necessarily be threatened with extinction, or that habitats would be reduced by 1.5 - 3 times. Rather, a first-order approximation of the general impacts or demographic pressures on habitats and biodiversity of this immigration-induced population growth is that these impacts and pressures would range from about 1.5 - 3 times greater than they are at present. The same caveats discussed in Chapter 3 for the No Action Alternative are also applicable for the Expansion Alternative.

The Expansion Alternative would have indirect and cumulative impacts on habitat and biodiversity as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the effect of the Expansion Alternative on habitats and biodiversity would be *highly adverse, significant, and long-term.* It would likely be associated with the permanent loss of at least an additional 65-120 million acres (100,000 to 190,000 square miles) of wildlife habitat directly to development (sprawl and urbanization). A much larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 117 percent (2.2 times) larger.

Increasingly, the more pressing needs and demands of human beings are likely to be pitted against those of wilderness, wildlife, and biodiversity, and in these instances, when push comes to shove, wilderness, wildlife, and biodiversity tend to lose out, because they have no votes or political and economic clout of their own.

In sum, if the U.S. Congress were to endorse the Expansion Alternative – opting to increase immigration levels up to 2.25 million per year – impacts on habitat and biodiversity would be highly significant and adverse. These impacts would be much greater than those of the No Action Alternative, which would also be significantly adverse.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>
The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) from the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

The net, aggregate effect on habitats and biodiversity would range from approximately 0.8 – 1.6 times what it is today. The "0.8" means that under optimistic assumptions as to the interaction of economic growth and efficiency improvements, as well as the most optimistic population projection of this EIS (although one that still leads to population growth of 70 million people by 2100), overall aggregate human pressures on natural habitats and biodiversity would actually ease by about 20 percent between now and 2100.

The Reduction Alternative would have indirect and cumulative impacts on habitat and biodiversity as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Moderate*
- Likelihood of Impact: *Probable*

Overall, the effect of the Reduction Alternative on habitats and biodiversity would still be *adverse, significant, and long-term*. It would likely be associated with the permanent loss of at least an additional 35-65 million acres (55,000 to 100,000 square miles) of wildlife habitat directly to development (sprawl and urbanization) – but this is much less than the predicted habitat losses of the No Action and Expansion alternatives. A still larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 23 percent larger than our present population.

In sum, if the American people and the federal government were to endorse the Reduction Alternative – opting to decrease overall immigration levels to 0.25 million per year – impacts on habitat and biodiversity would still be significantly adverse and likely greater than they are at the present time. However, these impacts would be much less than those of the No Action Alternative or the Expansion Alternative. Furthermore, by 2100, the U.S. population would have stopped growing and stabilized under the Reduction Alternative, whereas under both the No Action and Expansion alternatives, it would still be growing rapidly with no end in sight. Thus, in the other two alternatives, the demographic component of increasing anthropogenic stresses on wildlands, wilderness, habitat and biodiversity would also still be growing with no end in sight.

Water Demands and Withdrawals from Natural Systems

For the purposes of this EIS, it is assumed that water efficiency, conservation, recycling, and reuse – can reduce aggregate per capita consumption of water by 25 percent, the amount by which California cities are to reduce their consumption in 2015 because of the prolonged, severe drought in that state.

No Action Alternative – 1.25 million annual immigration

The No Action Alternative would lead to a U.S. population of 524 million in 2100, 70 percent higher than the 2010 population of 309 million. Assuming an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 27 percent between 2010 and 2100 under the No Action Alternative (Figure ES-3). Demand is differentiated from actual consumption, because due to likely shortages, it may well not be possible to meet actual demand, or pressure to consume.

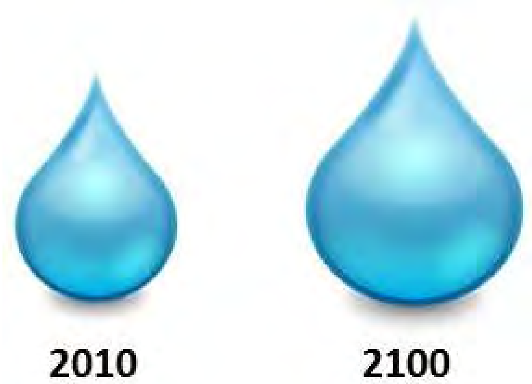


Figure ES-3. Total nationwide water demand would likely increase by 27 percent under the No Action Alternative

Combining precipitation and water availability projections with regional demographic projections and the assumptions of the No Action Alternative, it is immediately apparent that under this alternative, two rapidly growing regions in the country – the Southwest and the Southeast – will experience very

grave problems with water availability that will have significant adverse effects on urban areas, agriculture, and the already beleaguered aquatic ecosystems of these areas. Other regions of the country would face more manageable scenarios with regard to water resources. While demographic pressures on water quantity and quality would also increase in most of these other regions, the potential for increased water efficiency and conservation, as well as more stringent pollution control measures and improved technologies, offer real prospects for meeting human water demands while maintaining or perhaps enhancing the integrity of aquatic ecosystems.

The No Action Alternative would have indirect and cumulative impacts on water resources as follows:

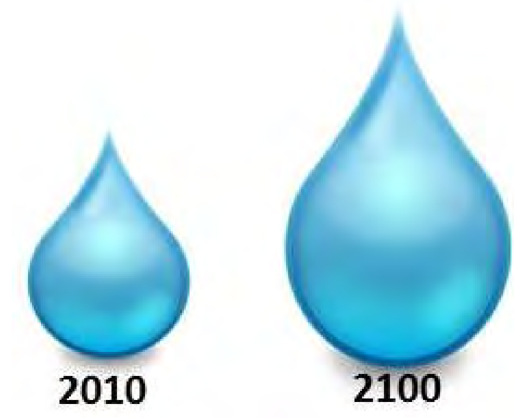
- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Moderate to Major*
- Likelihood of Impact: *Probable*

Overall, the net effect of the No Action Alternative on water demands and withdrawals from natural systems would be *adverse, significant, and long-term*. The degree of severity of this effect would vary from region to region, with impacts in the Southwest and Southeast being the most severe and other regions less so. While water-saving practices and technologies could to an appreciable extent ameliorate the adverse effects on water resources of adding 215 million more Americans, they would not entirely eliminate them. If population were not growing so robustly, then savings from widespread implementation of water conservation and efficiency would allow more water to be retained in rather than withdrawn from aquatic ecosystems. This in turn would benefit the flora and fauna of these natural systems as well as restoring and enhancing the diminished levels of ecosystem services they currently furnish to society.

<u>Expansion Alternative – 2.25 million annual immigration</u>

The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) from the 2010 population of 309 million. Assuming an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 62 percent between 2010 and 2100 under the No Action Alternative (Figure ES-4). Demand is differentiated from actual consumption, because due to likely shortages, it may well not be possible to meet actual demand, or pressure to consume.

Figure ES-4. Total nationwide water demand would likely increase by 62 percent under the Expansion Alternative



If: 1) the Expansion Alternative is chosen by the United States, and 2) regional demographic trends of the past half-century persist for the remainder of this century (to 2100), then both the Southwest and Southeast would undergo a tripling or more of their current populations at the same time that each region has less water available, and in the case of the Southwest, much less water available, than at present. Both of these regions are already experiencing severe water quantity and quality problems. In the future, these problems for the two most rapidly growing regions in the country would intensify enormously under the Expansion Alternative.

The Expansion Alternative would have indirect and cumulative impacts on water resources as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the net effect of the Expansion Alternative on water demands and withdrawals from natural systems would be *highly adverse, significant, and long-term*. The degree of severity of this effect would vary from region to region, with impacts in the Southwest and Southeast being the most severe and other regions less so. While water-saving practices and technologies could to some extent ameliorate the adverse effects on water resources of adding 360 million more Americans – more than a doubling of our current population – they would come nowhere near to eliminating them. If population were not growing so rapidly, then savings from widespread implementation of water conservation and efficiency technologies and practices would allow more water to be retained in rather than withdrawn from aquatic ecosystems. This in turn would benefit the flora and fauna of these natural systems as well as restoring and enhancing the now-diminished levels of ecosystem services they currently provide to American society.

In coastal areas, especially in Texas, California, and Florida – all of them experiencing population growth at much higher rates than the national average – pressure to build numerous desalination plants using reverse osmosis or some as-yet-unidentified-and-undeveloped technology, is likely to increase. The water emerging from these plants would likely be much costlier than water is at present, and whether or not future Texans, Californians, and Floridians would be rich enough to afford it is an open question. Concentrated salt (brine) that has been removed in the desalination process would require disposal in the least environmentally damaging fashion. Removing salt from seawater is inherently energy-intensive, and carbon dioxide would be emitted to the atmosphere, exacerbating the buildup of this gas, and resultant global warming, if fossil fuels were to be burned to provide the needed energy. The rapid population growth to the end of the century – and beyond – to which Americans would be committing their country under the Expansion Alternative, would force these hard choices and others.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>

The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million or 23 percent from the 2010 population of 309 million. Assuming, as in the other two alternatives, an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total aggregate nationwide water demand (as opposed to actual consumption) would actually decrease by eight percent between 2010 and 2100 under the No Action Alternative (Figure ES-5). This is the only one of the three alternatives considered in this EIS that actually leads to a net reduction in the total aggregate nationwide water demand and perhaps consumption as well by the year 2100. In this alternative, aggregate nationwide water demand is more likely to equal actual aggregate nationwide water consumption because the U.S. would have a more realistic probability of actually supplying enough water to meet the demand, due to less overall pressure on water resources.

Figure ES-5. Total nationwide water demand would likely decrease by 8 percent under the Reduction Alternative

While the net reduction in nationwide demand for water in the Reduction Alternative would be a beneficial impact, two regions – the Southwest and the Southeast – would still encounter difficulties in meeting likely demand because they would have faster

population growth than the national average and because, according to climate modeling, they would have less water availability than at present. However, these difficulties would be much more manageable than under either the No Action Alternative or the Expansion Alternative.

The Reduction Alternative would have indirect and cumulative impacts on water resources as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Minor, Moderate, and Major*
- Likelihood of Impact: *Probable*

Overall, the net effect of the Reduction Alternative on water demands and withdrawals from natural systems – provided that per capita water consumption were actually decreased by 25 percent as assumed – would be *modestly but significantly beneficial*. With the notable exception of two regions in particular, the Southwest and the Southeast, demands on the water resource, and subsequent withdrawals from aquatic ecosystems, would actually remain approximately constant or even decrease under the Reduction Alternative (or in the case of the Pacific Northwest, still be capable of being met even with projected population growth). This would allow more water to be retained "in-stream," increasing the flow not just of surface freshwater but also of ecosystems services provided to society by waters of the U.S., including wetlands.

Carbon Dioxide Emissions and Resultant Climate Change

"Recent warming coincides with rapid growth of human-made greenhouse gases," stated James E. Hansen, Ph.D., former NASA climatologist. Carbon dioxide (CO_2) is the most important of the anthropogenic greenhouse gas emissions influencing the climate. There is a widely shared scientific consensus that greenhouse gas emissions, in particular CO_2, are already changing the global climate, with ecological and economic ramifications that extend centuries into the future. Continued and climbing CO_2 emissions will only accelerate and exacerbate global warming and climate change. The United States itself, like every other country on the planet, is already experiencing the incipient symptoms of climate change, which include prolonged droughts and heat waves, changed precipitation patterns, stress on agriculture and ecosystems, intensified and expanded forest fires in the Northwest, Southwest, Rocky Mountain States and Alaska, sea level rise, and more intense and common extreme weather events, including hurricanes.

The "global human enterprise," reflecting growing population, economic production, and consumption supported by rising fossil fuel consumption (and deforestation), has now

reached such a scale or magnitude that it is tipping the balance or affecting the equilibrium of the global carbon cycle.

The Kaya identity, named for Japanese energy economist Yoichi Kaya, states that aggregate climate-forcing CO_2 emissions to the atmosphere can be expressed as the product of four factors or inputs: population, Gross Domestic Product (GDP) per capita, energy use per unit of GDP, and CO_2 emissions per unit of energy consumed. In the Kaya identity, population size serves as a multiplier of each of the other factors.

$$\text{Total emissions} = \text{population} \times (\text{GDP/population}) \times (\text{energy/GDP}) \times (\text{emissions/energy})$$

Or

$$\text{Total Emissions} = \cancel{\text{Population}} \times \frac{\cancel{\text{GDP}}}{\cancel{\text{Population}}} \times \frac{\cancel{\text{Energy}}}{\cancel{\text{GDP}}} \times \frac{\text{Emissions}}{\cancel{\text{Energy}}}$$

Unsurprisingly then, U.S. population growth is broadly correlated with growing American CO_2 emissions.

<u>No Action Alternative – 1.25 million annual immigration</u>

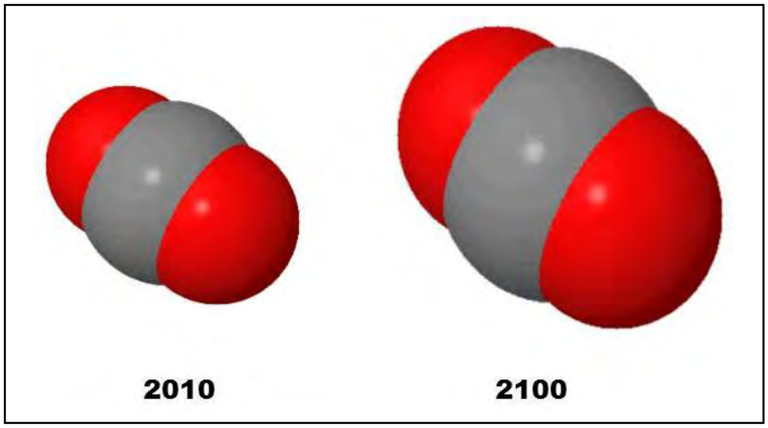
The No Action Alternative would lead to a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) over the 2010 population of 309 million. The environmental consequences related to CO_2 emissions under this alternative would be indirect and cumulative, not direct. Also, because climate change is a global phenomenon being caused by other peoples and countries as well as Americans, to a great extent, unless there is concerted international action led and supported by the United States, the U.S. will suffer the consequences of global warming regardless of the size of its own CO_2 and other greenhouse gas emissions.

Given the complexity and uncertainty surrounding the absolute values of the factors in the Kaya identity, especially up to 85 years in the future, all this EIS can predict and quantify with some confidence is the magnitude of upward pressure on CO_2 emissions exerted by the U.S. population growth that would occur under each of the three alternatives under consideration. As stated above, the No Action Alternative would entail a U.S. population of 524 million in 2100, an increase of 215 million or 70 percent above the 2010 population of 309 million. *Thus, there would be 70 percent greater upward pressure on CO_2 emissions under this alternative.*

In other words, if there were no change at all in any of the other three factors, or these changes cancelled each other out, American CO_2 emissions would be approximately 70 percent larger in 2100 (Figure ES-6). This should be compared with the call of

climatologists for an 80 percent or more reduction in CO_2 emissions by 2050 – and eventually a complete elimination of all CO_2 emissions by 2100 if not beforehand – if our climate is to be stabilized at a temperature of, say, two degrees Celsius (3.6°F) above preindustrial levels.

Figure ES-6. Graphic illustration representing magnitude of upward pressure exerted on American CO_2 emissions (symbolized by model of CO_2 molecule) under the No Action Alternative



The No Action Alternative in the U.S. would more or less correspond to the "Business As Usual" (BAU) scenario in terms of global CO_2 and other GHG emissions. The BAU scenario appears headed to push the planet towards an average warming of 4°C or more by 2100. The effects of a 4°C warming would be asymmetrical (unevenly distributed) around the world; nor would these effects merely be a simple extension of those experienced at a 2°C average warming.

There would likely be a dramatic increase in the intensity and frequency of extreme temperatures and severe weather events. Extreme and lethal heat waves such as that which struck Russia in 2010 and Europe in 2003 will probably become "the new normal" summer in a 4°C warmer world. Over the past decade, such extreme heat waves have caused severe impacts, including many thousands of heat-related deaths, widespread forest fires, and large crop losses. The impacts of the extreme heat waves projected for a 4°C warmer world are anticipated to dwarf the consequences that have been felt to date. They could well exceed the adaptive capacities of many societies and ecosystems.

A warming of 4°C or higher by 2100 would correspond to an increase of about 150 percent in the acidity of the ocean. The observed and projected rates of change in ocean acidity over the next century appear to be unparalleled in the known history of the Earth. Evidence is already accumulating of the adverse effects of acidification for marine organisms and ecosystems, combined with the adverse effects of ocean warming, overfishing, and habitat destruction. In particular, coral reefs are acutely sensitive to changes in water temperatures and pH, as well as the intensity and frequency of tropical cyclones. Coral reefs provide essential habitat for many species of fish and other marine

organisms, in addition to providing protection against coastal floods, storm surges, and wave damage.

By 2100, warming of 4°C would likely signify a sea-level rise of 0.5 to 1 meter (20 to 39 inches), and possibly more; in addition, several additional meters of rise would occur in the coming centuries, already locked into place by past warming (an example of a lag effect which doesn't occur immediately). This compares to 20 cm (8 inches) of sea-level rise in 2100 if warming were limited to 2°C.

The risks of a 4°C warmer world to agriculture and food production, freshwater availability, ecosystems and human health would be severe. In addition, the risk of ecosystem disruption as a result of ecosystem shifts, wildfires, and forest dieback would be significantly higher. Increased exposure to heat and drought would stress entire forest ecosystems and likely lead to increased mortality and species extirpation and extinction (of both flora and fauna). Ecosystems would be affected by more frequent weather extremes.

Taking all of this into account, and recognizing that the United States bears only partial responsibility (although an extremely important part) for the future condition of the climate, the No Action Alternative would have indirect and cumulative impacts on CO_2 emissions and resultant climate change as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the net effect of the No Action Alternative on CO_2 emissions and global climate change would be *adverse, significant, and long-term*. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the No Action Alternative would be entirely responsible for U.S. CO_2 emissions in 2100, nor the cumulative increase of CO_2 in the atmosphere by that date, nor the cumulative impact of those elevated CO_2 and other GHG concentrations on global warming and the myriad, wide-ranging and long-term adverse environmental impacts linked to higher atmospheric temperatures and ocean acidification.

While U.S. and global population size and growth rates are a key, underlying factor in determining the magnitude of national and global CO_2 emissions, population is but one of several factors. Furthermore, while the U.S. is responsible for far more cumulative CO_2 emissions than any other single country on Earth, it is no longer the world's largest CO_2 emitter; the U.S. share of aggregate global CO_2 emissions is decreasing and is likely to be

smaller still in 2100 than today. Even so, with a population of more than half a billion that would result under the No Action Alternative, it would be much more difficult for America to sharply reduce its CO_2 emissions, and thereby make a constructive contribution to the global partnership urgently needed to address the climate predicament.

Expansion Alternative – 2.25 million annual immigration

The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) above the 2010 population of 309 million. Predicting the exact level, or even a reasonable range, of U.S. CO_2 emissions in the year 2100 under the Expansion Alternative – 85 years into the future – is all but impossible for the same reasons discussed under the No Action Alternative. However, it can be stated with 100% certainty that under the Expansion Alternative, upward pressure on U.S. CO_2 emissions would be substantially higher than under the No Action Alternative, to wit, 117 percent greater versus 70 percent greater. That is, if each of the other three factors in the Kaya identity were to remain unchanged, U.S. CO_2 emissions in 2100 would be 117 percent higher than they are today. This outcome is depicted graphically in Figure ES-7 by the proportionally larger CO_2 molecule.

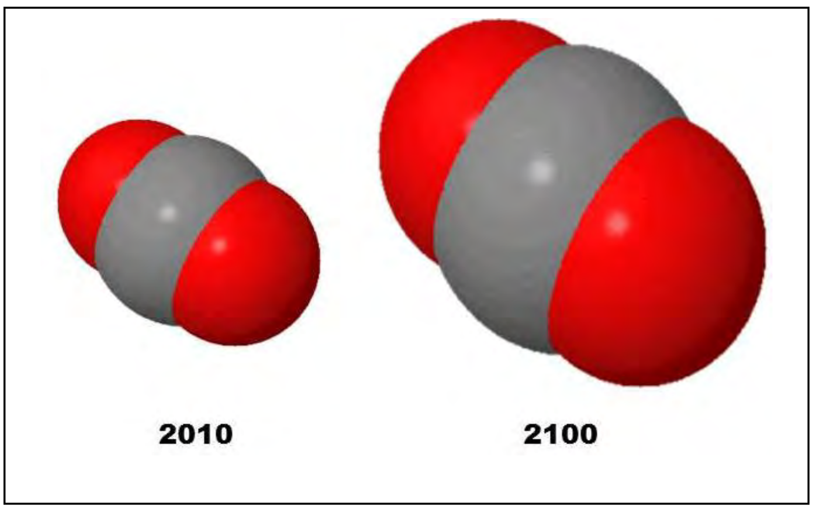


Figure ES-7. Graphic illustration representing magnitude of upward pressure exerted on American CO_2 emissions under the Expansion Alternative

The same adverse and destabilizing climatic and ecological effects described under the No Action Alternative would also occur under the Expansion alternative, probably to an even greater degree, although to a large extent, that would depend on actions and activities in the rest of the world.

The Expansion Alternative would have indirect and cumulative impacts on CO_2 emissions and resultant climate change as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*

- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

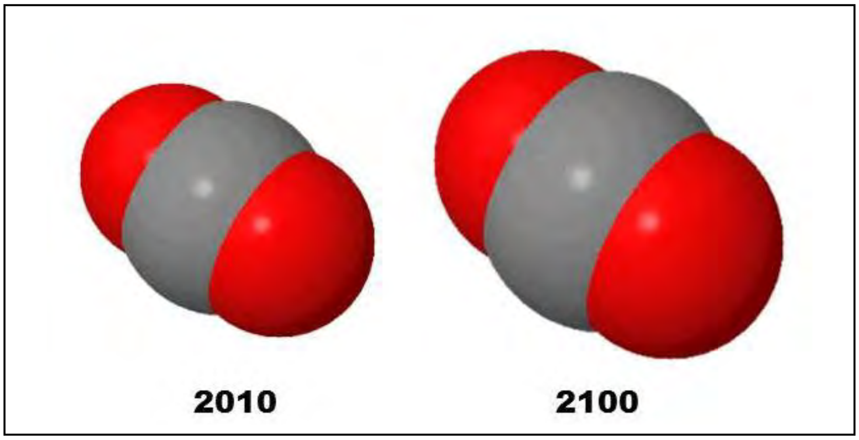
Overall, the net effect of the Expansion Alternative on CO_2 emissions and global climate change would be *adverse, significant, and long-term*. To reiterate and underscore, neither the higher immigration rates nor the concomitant accelerated U.S. population growth associated with the Expansion Alternative would be entirely responsible for U.S. CO_2 emissions in 2100, nor the cumulative increase of CO_2 in the atmosphere by that date, nor the cumulative impact of those elevated CO_2 and other GHG concentrations on global warming and the myriad, wide-ranging and long-term adverse environmental impacts linked to higher atmospheric temperatures and ocean acidification.

While U.S. and global population size and growth rates are a key, underlying factor in determining the magnitude of national and global CO_2 emissions, population is but one of several factors. Furthermore, while the U.S. is responsible for far more cumulative CO_2 emissions than any other single country on Earth, it is no longer the world's largest CO_2 emitter; the U.S. share of aggregate global CO_2 emissions is decreasing and is likely to be smaller still in 2100 than today. Even so, with a population more than double that of today's (669 million vs. 320 million), which would result under the Expansion Alternative, it would be extremely difficult, if not impossible, for the United States to drastically reduce its CO_2 emissions, and thus make a constructive contribution to the global partnership urgently needed to address the climate predicament.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>
The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) over the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Using the same assumptions as with the previous two alternatives, under the Reduction Alternative, upward pressure on U.S. CO_2 emissions would be substantially lower than under either the No Action Alternative or the Expansion Alternative, to wit: 23 percent greater for the Reduction Alternative, versus 70 percent greater for the No Action Alternative, and 117 percent greater for the Expansion Alternative. That is, if each of the other three factors in the Kaya identity were to remain unchanged, under the Reduction Alternative, U.S. CO_2 emissions in 2100 would be 23 percent higher than they are today. This outcome is depicted graphically in Figure ES-8 by the proportionally bigger CO_2 molecule.

Figure ES-8. Graphic illustration depicting the magnitude of upward pressure exerted on American CO_2 emissions under the Reduction Alternative



The Reduction Alternative would have indirect and cumulative impacts on CO_2 emissions and resultant climate change as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Probable*

Overall, the net effect of the Reduction Alternative on CO_2 emissions and global climate change would be *adverse, significant, and long-term*. To reiterate and underscore, the lower immigration rates of this alternative would lead to a substantial slowdown in the rate of U.S. population growth. Nevertheless, population size would still increase by 70 million or 23 percent from 2010 to 2100 because of demographic momentum. Consequently, the Reduction Alternative would still produce upward demographic pressure on U.S. CO_2 emissions, although this upward pressure would be much less than with the No Action Alternative and the Expansion Alternative.

With a 2100 U.S. population of 379 million, 70 million or 23 percent larger than the 2010 population of 308 million, it would be somewhat more difficult for the United States to drastically reduce its CO_2 emissions than with a stable, non-growing population. Nevertheless, under the Reduction Alternative, in contrast to the No Action and Expansion alternatives, it would be far more feasible for the United States to make a constructive contribution to the global partnership urgently needed to address the climate predicament.

Energy Demands and National Security Implications

Energy animates both natural ecosystems and the human economy. Solar energy activates virtually all life, both terrestrial and aquatic, at the surface of the Earth. Beginning in the

1800's, humanity began to exploit the vast deposits of Earth's fossil fuels on a significant scale – first coal, then oil, and finally natural gas. The rapid increase or "population explosion" in the number of human beings on Earth coincides very closely with the huge amounts of energy made available via exploitation of the fossil fuels. Today these non-renewable, exhaustible fuels furnish 80 percent or more of America's and the world's primary commercial energy. In the United States, total primary energy consumption more than tripled over the past six decades, jumping from 31 quadrillion Btu's (quads) in 1949 to 97 quads in 2011. Both the production and consumption of energy, in all its diverse forms, entail a myriad of environmental impacts that vary by energy source. When a nation becomes overly dependent on imports of a critical energy source such as oil, especially when that oil is produced in and exported from politically volatile or hostile countries and regions, that nation's energy, economic, and national security are at risk.

The amount of energy used by the United States in 2050 and 2100 will be a function of the size of the population and the economy, as well as "energy intensity," that is, the amount of energy use per capita and per dollar of GDP.

For the purposes of this EIS analysis, it is assumed that EIA's reference case for decreasing energy intensity per capita continues through 2050 and all the way to the year 2100. This being the case, per capita energy consumption in 2100 would be approximately 70 percent of what it was in 2010. In other words, as a result of continually increasing energy efficiency, structural changes in the economy and changing lifestyles, the average American in 2100 would consume 30 percent less primary energy every year than in 2010, in spite of economic growth, which tends to increase the production and consumption of goods and services that use energy.

<u>No Action Alternative – 1.25 million annual immigration</u>
The No Action Alternative would lead to a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) over the 2010 population of 309 million.

Total U.S. primary energy consumption in 2010 was approximately 98 quads. If energy intensity (per capita energy use) were the same in 2100, there would be a corresponding 70 percent increase in consumption, with all the attendant impacts associated with both production and consumption of energy, due to projected population growth under the No Action Alternative. Primary energy consumption would be 167 quads. However, due to the assumed reduction in overall national energy intensity (energy consumption per capita) because of ongoing future efficiency improvements, conservation, structural economic changes, and the like, consumption would rise to 117 quads by 2100, an increase of "only" 19 percent.

It is highly doubtful whether this level of aggregate national energy consumption is sustainable. While with technical advances and breakthroughs, as well as sustained political and public commitment, the nation could perhaps conceivably meet this level of energy consumption entirely with renewables, this would occur at great cost to land and visual resources, habitat, and wildlife. In addition, components of renewables such as wind, solar, and advanced batteries are made of scarce, non-renewable and exhaustible raw materials (rare earth elements and other rare and costly metals). Their long-term durability has yet to be persuasively established.

In the coming decades and perhaps for the next half century or so, U.S. security and the domestic economy will be increasingly at risk to disruptions in the flow of oil from politically turbulent and war-torn regions of the world such as the Middle East, where most of the world's remaining conventional oil reserves and resources are located. Other oil-exporting countries such as Russia and Venezuela have tense and often hostile relations with the United States and U.S. allies and could well use oil (and natural gas in the case of Russia) as a geopolitical weapon; they have done so before.

The domestic fracking boom that has recently increased U.S. crude oil output and provided somewhat of a hiatus from high prices and a reprieve from import dependency is not expected to last more than a couple of decades, after which our vulnerability will worsen once more. Furthermore, rapidly growing demand for oil by China, India, and other developing countries will increase competition for the world's remaining relatively low-cost conventional oil. Rapid population growth under the No Action Alternative will increase demand for oil and exacerbate U.S. insecurity and vulnerability. However, by the year 2100, both domestic and foreign sources of oil will have largely been exhausted and there will be little or nothing left to fight over.

The No Action Alternative would have indirect and cumulative impacts on energy demands and national security as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Possible to Probable*

Overall, the net effect of the No Action Alternative on energy would be *adverse, significant, and long-term*.

<u>Expansion Alternative – 2.25 million annual immigration</u>
The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) above the 2010 population of 309 million.

If energy intensity (per capita energy use) were the same in 2100, there would be a corresponding 117 percent increase in aggregate U.S. consumption – more than a doubling – with all the attendant impacts associated with both production and consumption of energy, due to the accelerated population growth anticipated under the Expansion Alternative. Primary energy consumption would be 213 quads. However, due to the assumed 30 percent reduction in overall national energy intensity (energy consumption per capita) due to ongoing and future efficiency improvements, conservation, structural economic changes, and the like, consumption would rise to 149 quads by 2100, an increase of 52 percent over 2010 energy consumption.

It is highly implausible that this level of aggregate national energy consumption will be attainable or sustainable. For one thing, while 149 quads represent a 52 percent increase in aggregate consumption from 2010, it would require a doubling of domestic energy production (from about 75 quads to 149 quads). By 2100, the oil imports that now cover the deficit between domestic energy production and consumption will have essentially ceased, so that all energy consumed in the United States will have to be produced here.

In 85 years, economic reserves of the non-renewable fossil fuels that now comprise about 80 percent of U.S. energy production and consumption will be largely if not entirely exhausted. Thus, if 149 quads of primary energy are to be produced, it would have to be from some combination of nuclear power, biofuels, and non-hydroelectric renewable energy sources. (There is very little scope for increasing largescale hydroelectric capacity; hydroelectricity generated in 2100 will probably decline as reservoirs gradually lose water storage due to sedimentation.) Nuclear power and biofuels are tightly constrained for different reasons. In 2010, non-hydroelectric renewables accounted for about *two quads*. To suggest that energy production from solar, wind, and other sources could increase on the order of ***50-75 times*** over the coming 85 years to reach a total of 149 quads strains credulity.

Even more so than in the case of the No Action Alternative, while through the miracle of innovation the U.S. might possibly be able to attain this level of energy production entirely with renewables, this would happen only by converting a large fraction of the American landscape into a colossal electricity generator harnessing clean and renewable wind and photons. That is, much of the countryside would have to be covered with solar panels, wind turbines, and transmission lines. Components of wind turbines, solar panels, and advanced batteries depend upon scarce, unevenly distributed, non-renewable raw materials subject to depletion such as europium, terbium, neodynium, and lithium. The multi-generational longevity and sustainability of these devices has yet to be demonstrated. Indeed, some geochemists refer to photovoltaic solar as "semi-

renewable," because "the energy collected is renewable, but the materials in the technology are not."

One likely casualty, among many wildlife species, of renewable energy development on this colossal scale is the golden eagle. Spinning wind turbine blades and power lines are even now, at current scale, major sources of mortality for this raptor. An order of magnitude or more increase in the presence of these artificial structures on the Western landscape would surely have a pronounced harmful effect on the golden eagle population.

In the coming decades and perhaps for the next half century or so, until foreign oil resources are too depleted to produce and export, U.S. national security will be even more compromised under the Expansion Alternative because of the much larger population and oil demand it would result in.

The Expansion Alternative would have indirect and cumulative impacts on energy demands and national security as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Major*
- Likelihood of Impact: *Possible to Probable*

Overall, the net effect of the Expansion Alternative on energy would be *highly adverse, significant, and long-term*. An alternative that more the doubles the number of energy consumers in the United States would exert much greater stress on our energy resources and generate far greater impact on the American environment from the intensified exploitation of those resources that would be necessary to meet the expectations of consumers and the economy.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>
The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) over the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

If energy intensity (energy use per capita) were the same in 2100, there would be a corresponding 23 percent increase in aggregate U.S. consumption – more than a doubling – with all the attendant impacts associated with both production and consumption of energy, due to the accelerated population growth anticipated under the Expansion Alternative. Primary energy consumption would be 121 quads. However, due to the assumed 30 percent reduction in overall national energy intensity (energy consumption

per capita) because of ongoing and future efficiency improvements, conservation, structural economic changes, and so forth, consumption under the No Action Alternative would actually fall to 85 quads by 2100, a decrease of 13 quads or about 13 percent from 2010 energy consumption.

Annual energy consumption of 85 quads in 2100 is a much more favorable and manageable situation – and one with much lower environmental impact – than under the No Action Alternative (117 quads) or the Expansion Alternative (149 quads). However, even this level of energy consumption may not be realistic over the long term when one considers that more than four out of every five quads of our energy consumption today come from fossil fuels, which will need to have been largely replaced by 2100.

The Reduction Alternative would have indirect and cumulative impacts on energy demands and national security as follows:

- Duration of Impact: *Long-term to permanent*
- Extent of Impact: *Large*
- Magnitude of Impact: *Moderate*
- Likelihood of Impact: *Possible to Probable*

Overall, the net effect of the Reduction Alternative on energy would be *adverse, moderately significant, and long-term*. Of the three alternatives considered, this one would entail by far the fewest adverse impacts related to energy resources and their development. It would also have the most favorable implications for national and energy security, reducing demand for and dependence on foreign oil in the coming decades, although by the year 2100, there will be little or no foreign oil left to import at affordable prices.

International Ecological Impacts of U.S. Immigration Policies

U.S. consumption and population growth impact the natural resources and environment not just of U.S. territory itself but of the lands, natural resources, environments and (often indigenous or tribal) residents of other countries and continents. Many of the raw materials, resources, and manufactured products used directly or indirectly by American consumers originate overseas and are imported into the U.S. as part of international trade.

American industry and consumers are "outsourcing" the pollution, GHG emissions, environmental damage, and human health effects associated with an enormous amount of drilling, digging, blasting, mining, manufacture, and harvesting – often under primitive conditions with little environmental oversight – that provides goods and services for our

domestic consumption. More Americans will raise demand for imports and trigger more associated impacts in those countries that export to us.

Similarly, U.S. consumption itself, primarily of the fossil fuels, releases large amounts of carbon dioxide that are contributing to climate change and concomitant widespread detrimental ecological effects around the biosphere. Many of these effects are being experienced most acutely in the developing world and by poorer, marginalized populations.

No Action Alternative – 1.25 million annual immigration
The No Action Alternative would lead to a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) over the 2010 population of 309 million.

The potential for international ecological impacts from aggregate U.S. consumption in 2100 would be up to 70 percent greater than in 2010. The U.S. economy would likely import more raw materials, food, and manufactured goods, the production of which would entail substantial adverse environmental effects in the countries of origin.

Effects would include the impacts of mining and forestry activities on the landscape, wildlife habitat, water quality, human health and the wellbeing of indigenous peoples, whose traditional tribal lands are often exploited for their resources without the express consent of their longtime inhabitants, or material benefits flowing to those inhabitants in the form of jobs, income, or rents/royalties. Impacts would also occur on air quality and human health from pollutants emitted by factories producing goods for export to the United States. Furthermore, there would likely be a comparable increase in U.S. carbon dioxide and other GHG emissions, as well as upward pressure on our ecological footprint, both of which have international or global ramifications.

Overall international ecological effects of this alternative would be *adverse, significant, and long-term.*

Expansion Alternative – 2.25 million annual immigration
The Expansion Alternative would result in a U.S. population of 669 million in 2100, an increase of 360 million (117 percent) above the 2010 population of 309 million.

Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be more than twice (approximately 117 percent) as great as in 2010. With a much larger population, all of the effects under the No Action Alternative would be magnified even further in order to just maintain U.S. consumption and living standards, to say nothing of increasing them. While there would likely be positive economic effects

in exporting countries from supplying much larger U.S. imports, there would be correspondingly larger environmental impacts as well. Furthermore, it is by no means assured that economic benefits would be widely shared among the exporting countries' populations as a whole because of endemic corruption and social inequities.

Overall, the international ecological effects of the Expansion Alternative would be *highly adverse, significant, and long-term*. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the Expansion Alternative would be entirely responsible for international ecological impacts of the United States in the year 2100. That said, an alternative that more than doubles the number of resource consumers and waste emitters in the United States would exert much greater stresses and generate far greater widespread impacts that extend well beyond U.S. borders into the rest of the biosphere and world.

<u>Reduction Alternative – 250,000 (0.25 million) annual immigration</u>

The Reduction Alternative would lead to a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) over the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be about a quarter (approximately 23 percent) larger than in 2010. Nonetheless, these effects would be substantially smaller than for the No Action Alternative and the Expansion Alternative.

Overall, the international ecological effects of the Reduction Alternative would be *adverse, moderately significant, and long-term*. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the Reduction Alternative would be entirely responsible for international ecological impacts emanating from the United States in the year 2100. Of the three alternatives considered, this one would entail by far the lowest level of adverse international ecological impacts.

Chapter 1
INTRODUCTION, PURPOSE AND NEED

1.1 Why an EIS on Immigration Policy

In recent decades, some leading American environmentalists have pondered and debated whether or not to weigh in on U.S. immigration policies – specifically on immigration rates or levels. Key questions in deciding whether to do so include:

- What roles do immigration and resultant U.S. population growth actually play in driving the problems environmentalists want to solve?
- Can we solve these problems *without* addressing immigration and immigration-driven population growth?
- What are our actual choices with regard to immigration policy, and how can we choose fairly and wisely among them?

With this Programmatic Environmental Impact Statement (PEIS), Progressives for Immigration Reform (PFIR) aims to help concerned environmentalists and policy-makers answer these questions.

The National Environmental Protection Act (NEPA) of 1969 (P.L. 91-190) (42 USC § 4321 *et. seq.*) requires that any federal program or policy change that generates potentially significant environmental impacts undergo an EIS. Almost since NEPA's implementation in the early 1970's, some environmentalists have argued that this requirement should be applied to U.S. immigration policy. Because immigration has a large impact on the overall size of the U.S. population, and because population numbers can be an important factor in determining a variety of environmental impacts, federal immigration policy would seem to be a likely subject for NEPA review. This landmark statute itself acknowledges the importance of population growth, stating at the outset that Congress recognizes "the profound influences of population growth" on the natural environment (Title I, Section 101a).

To date, however, the relevant government agencies and Congress itself have declined to undertake such a review of immigration policy or population policy more generally. This EIS represents an initial attempt to fill this void in public policy. A "programmatic" EIS evaluates the general potential for environmental impacts of broad federal government programs as opposed to the more defined impacts of site-specific projects.

1.2 National Environmental Policy Act

Enacted by Congress in 1969, and signed into law by President Nixon on January 1, 1970 (Figure 1-1), the U.S. National Environmental Policy Act (NEPA) is arguably the nation's single most important environmental statute. Indeed, it is sometimes referred to as the "Magna Carta" of America's environmental laws. It requires all federal agencies to give serious consideration to the potential environmental impacts of projects they approve, fund, or carry out.

Figure 1-1. President Richard M. Nixon at the signing ceremony for NEPA on January 1, 1970

Prior to the enactment of NEPA, federal agencies were not legally required to consider the impacts of agency actions on the environment. NEPA changed this. Under NEPA, all federal agencies are required to consider and review the environmental implications of an agency action whenever the action "significantly affects the quality of the human environment."

NEPA establishes a national policy to use all practicable means and measures "to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans." Among NEPA's primary goals is to achieve a "balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities" (NEPA § 101a and 101b).

NEPA creates a systematic process to help and/or force federal decision-makers to meaningfully consider the environmental aspects of important federal projects and legislation. Under NEPA, federal agencies and policy-makers must consider the environmental impacts of their actions, and provide an opportunity for public input into the decision-making process. Crucially, NEPA requires consideration of reasonable alternatives to proposed actions and to the status quo.

NEPA represents a commitment to environmental protection and to participatory democracy. At a time when many Americans are cynical about the political process, including the influence of big money and the shallow tone of much political debate, the premise of NEPA is that citizens can understand the issues facing them and discuss them intelligently, weighing their pros and cons, benefits and costs, both tangible and intangible. NEPA affirms that the government, working with and for the nation's citizens, can enact policies and put in place programs that further the common good.

To learn more about NEPA, readers may visit the National Environmental Policy Act (NEPA) website.

1.3 The Environmental Impact Statement Process

The primary means of ensuring adequate consideration of environmental issues under NEPA are preparation of an Environmental Assessment (EA) or an Environmental Impact Statement (EIS).

An EA is generally a less thorough, less lengthy, less time-consuming, and less costly document than an EIS. Lead agencies may initially opt to prepare an EA if they are reasonably certain that the environmental impacts of a proposed action, while adverse (negative), are unlikely to be "significantly adverse." Alternatively, an EA may be prepared if the lead agency is uncertain as to the magnitude of the potential impacts or the public's reaction to those impacts, and wishes to conduct an initial study or preliminary investigation of these. Upon concluding the EA process, the lead agency either 1) prepares a Finding of No Significant Impact (FONSI), if it has concluded that the proposed action does not entail significant impacts, or 2) prepares and publishes in the *Federal Register* a Notice of Intent (NOI) to prepare an EIS.

An EIS is a detailed study of the potential consequences a given federal action, plan, policy, or project may have on the environment. Under NEPA, after a determination is made that an agency action may significantly affect the human environment, the federal agency is required to prepare an EIS. The impact statement must discuss the environmental effects of the proposed federal action as well as plausible alternatives to that action, including the least environmentally harmful alternative. The term "action"

has been broadly defined to include federal projects and plans, state and local programs funded by the federal government, and private or public development authorized by federal permits.

To prepare an EIS, competent professionals examine existing environmental conditions, such as land use patterns, traffic levels, air and water quality, cultural and archeological resources, visual resources or aesthetics, vegetation and habitat, and wildlife populations and trends. Collectively, these existing conditions are referred to as the "affected environment" in NEPA. Data are then gathered and analyzed to identify how the proposed action and reasonable alternatives might change current conditions. Agencies must also examine the impacts of the "no action alternative," that is, of not implementing the proposed action or any other action alternative. Issues most likely to be of concern to the public are identified in a process known as "scoping," and then addressed in the EIS.

The EIS process includes several defined steps. These are:

- <u>Purpose and Need</u>: An agency identifies the purpose and need for action and develops a project, plan, or policy proposal. If the agency finds that the proposed action may result in potentially significant environmental impacts, an EIS is required.
- <u>NOI publication</u>: Published in the *Federal Register*, this provides a short overview of the proposed project.
- <u>Scoping</u>: An early opportunity for public review that allows the general public, relevant federal, state, and local agencies, and other interested parties (in sum, "stakeholders") to comment on the intended project. Scoping helps to determine the scope of the EIS analysis, that is, what it will address, both in terms of issues and alternatives that should be covered.
- <u>Data Gathering, Analysis, and Drafting of the EIS</u>: The interdisciplinary study team gathers relevant data (and *only* relevant data, in that an EIS is not supposed to be an encyclopedic document), conducts appropriate analyses, and drafts the EIS. The main sections are typically: 1) Introduction and Purpose and Need; 2) Proposed Action and Alternatives; 3) Affected Environment; and 4) Environmental Consequences, including cumulative effects. This "statement" of environmental impacts typically runs several hundred pages or more (when appendices are included), although there is a wide range in the length of EIS's.
- <u>Draft EIS Publication</u>: Considers public scoping comments and lays out the main analysis and findings regarding the likely environmental impacts of alternative courses of action. When the EIS is released to the public, a Notice of Availability (NOA) is published in the *Federal Register*. Stakeholders are typically informed by other means as well, such as newspaper notices or display ads, public service announcements (PSAs) on the radio, mass emails, announcements on agency websites, individual mailings, and word-of-mouth.

- DEIS Comment Period: A review period for interested parties to comment on the draft EIS, which may include public hearings or meetings.
- Final EIS Publication: Incorporates and formally responds to public comments received on the draft EIS, discusses additional alternatives and issues (if necessary), makes corrections and other changes to the draft EIS (if necessary), and identifies the agency's preferred alternative for implementation.
- Record of Decision (ROD): Provides the public record of the agency's decision, describes public involvement and the agency decision-making process, and presents commitments to reduce unavoidable environmental impacts (if necessary). These "commitments" are called mitigation measures.

Because PFIR is not a federal agency but a 501(c) (3) non-profit advocacy organization, it is neither necessary nor possible to carry out each of the steps above. For example, PFIR could not and did not publish an NOI in the Federal Register, announcing our intent to prepare an EIS on federal immigration policy. However, to the extent possible, PFIR has followed well-established and proven methods for developing a useful and comprehensive environmental impact statement. For example, extensive scoping efforts were undertaken, which will be discussed later in this chapter, to determine legitimate issues for analysis. The draft EIS will also be subject to extensive public and expert comment prior to finalizing the document.

1.4 U.S. Demographic History

This section draws upon an early draft of Cafaro (2015). The first official U.S. decadal census, in 1790, returned a national population of a little under four million (USCB 2013a). The most recently completed decadal census, in 2010, totaled America's population at 309 million (USCB 2013b). This represents an increase of 7,725% but a mere six-plus doublings in the number of Americans. Up-to-date estimates of the current population of the United States and the world are available at the population counter on the homepage of the Census Bureau website. When accessed on January 4, 2014 at 2:07 p.m. Eastern Standard Time, the U.S. population stood at 317,316,298. That makes the United States the third most populous nation in the world, behind China and India. Figure 1-2 graphs U.S. population growth from 1790-2010.

So far, the U.S. population trend has been ever upward. The largest decadal increases in absolute terms were also the most recent: from 1990 to 2000 the U.S. population grew by 33 million people, while from 2000 to 2010 population grew by 28 million. At 13% and 12%, however, these were not the highest decadal rates of growth in American history. For example, from 1830 to 1840, the U.S. population grew by 33%, from just under 13 million to more than 17 million people. However, this growth was on a much lower base

population. Thus, while the U.S. grew at a much higher rate over the course of the 19th century, most growth in total numbers occurred in the 20th century. From 1900 to 2010, the U.S. population more than quadrupled, from 76 million to 309 million people. Figure 1-3 is bar chart depicting U.S. population growth from 1900 to 2010.

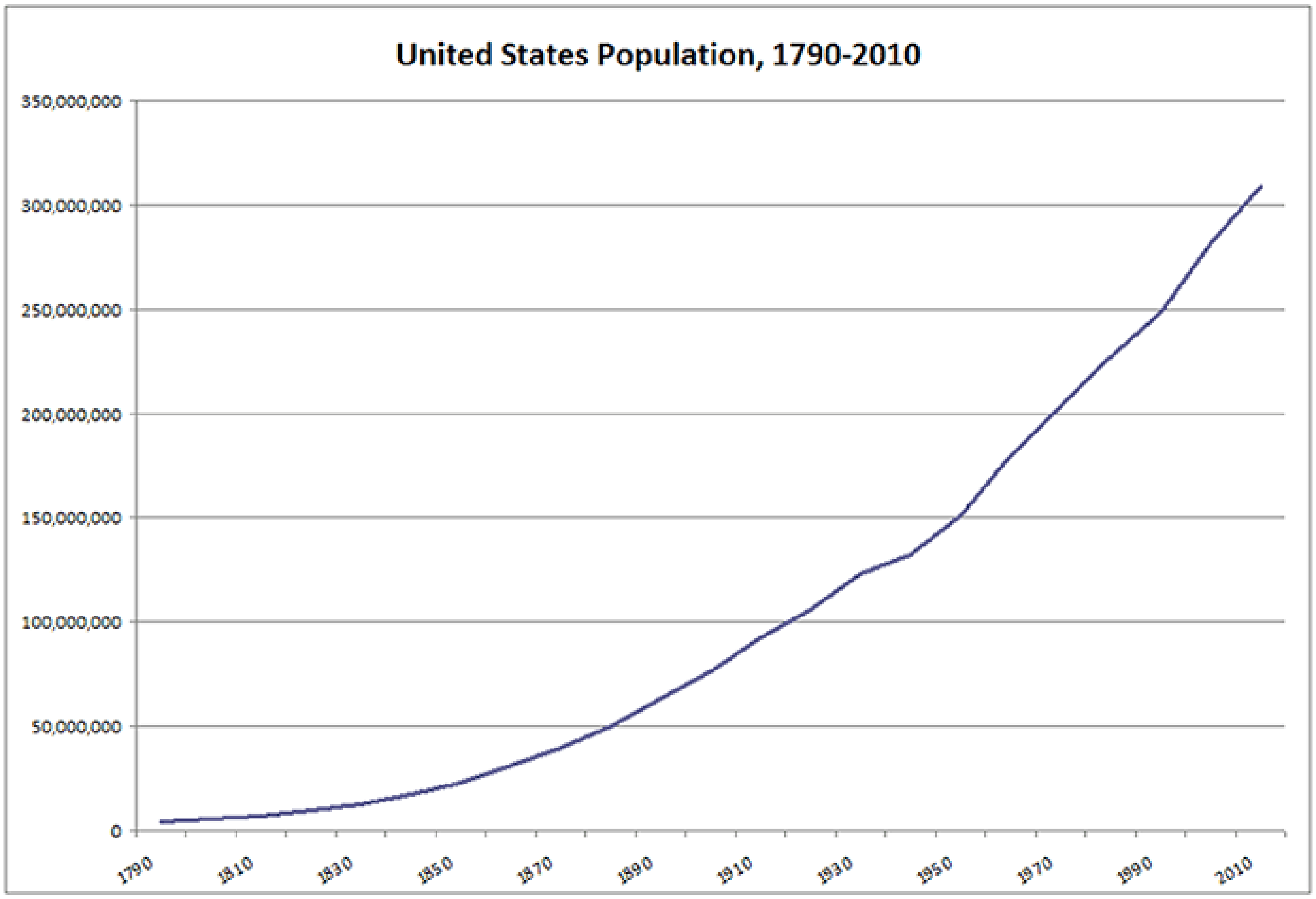


Figure 1-2. Historic U.S. population growth, 1790-2010

Note: This curve generally becomes steeper as it moves from left to right, suggestive of exponential growth in U.S. population during portions of this 220-year period. The increasing steepness of the curve representing U.S. population size indicates larger increments of population being added as one moves through time. In the 20th century (1901-2000) more than three times as many people were added to the U.S. population as in the 19th century (1801-1900).

From 1900 to 1910, the decadal rate of increase of the U.S. population was 21.0 percent. From 1990 to 2000, the decadal rate of increase of the U.S. population was 13.1 percent, significantly less than the 1900-1910 rate 90 years earlier. However, the percentage rate of increase in a population can be misleading to the demographically uninitiated. In particular, if a lower percentage rate of increase is applied to a much larger population base, the actual or absolute, incremental growth in numbers can still be greater. This is what we observe in comparing the 1900-1910 decade to the 1990-2000 decade. While the percentage rate of increase from 1900-1910 was much greater than the 1990-2000

decade (21% vs. 13.1%), in fact, population growth from 1900 to 1910 was "just" 16 million compared to 32.7 million from 1990 to 2000, or about half.

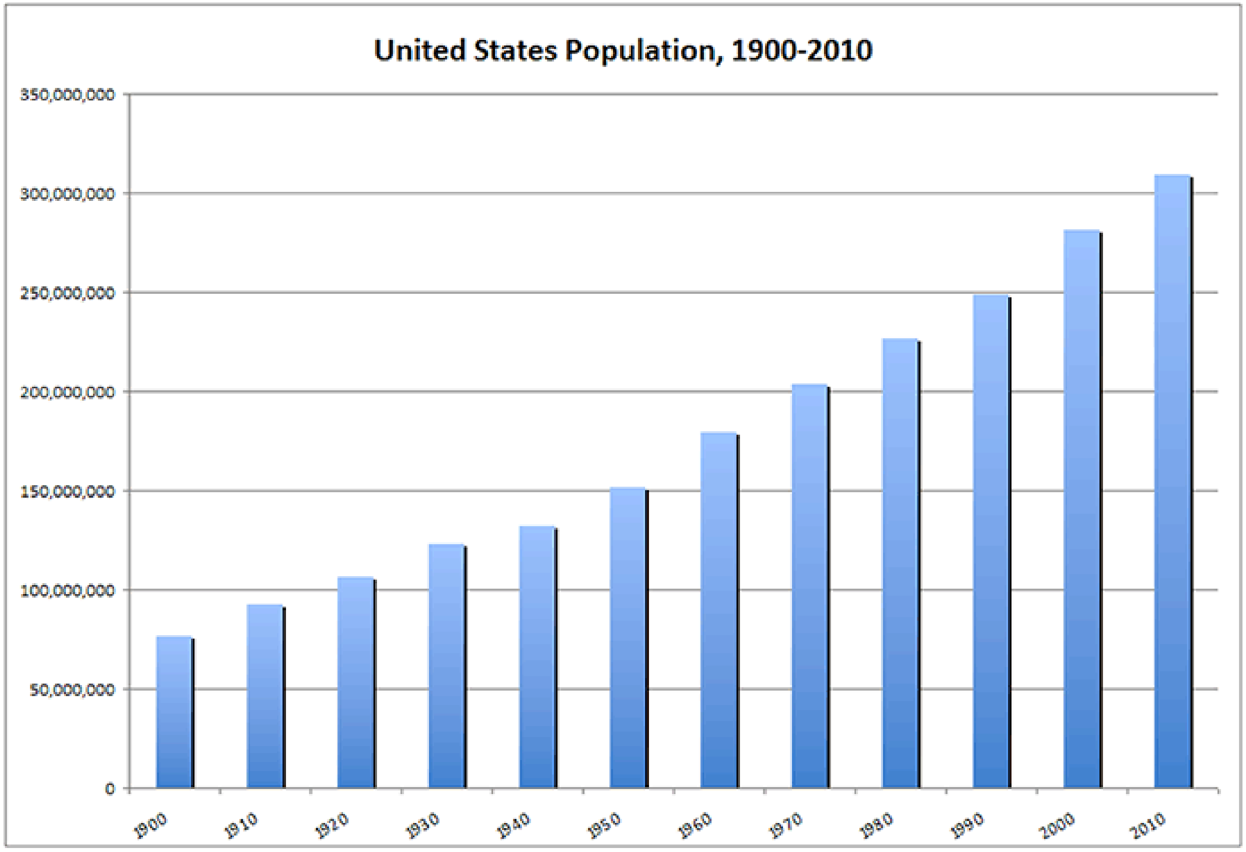


Figure 1-3. Bar chart of historic U.S. population growth, 1790-2010

In contrast to the steady rise in total U.S. population size, immigration numbers have fluctuated sharply throughout American history. The bar chart in Figure 1-4, also based on Census Bureau figures, shows decadal immigration numbers since 1820 (when the federal government began keeping such figures).

There has always been some immigration, but immigration levels have varied greatly, primarily due to changes in immigration policy. For example, between 1900 and 1910, net immigration (total immigration into the U.S. minus emigration from the U.S.) averaged about 900,000 annually. Between 1950 and 1960, net annual immigration was much lower, at around 250,000. And between 2000 and 2010, expansive immigration policies and lax enforcement of immigration laws pushed immigration numbers to their highest levels ever: net legal migration (immigration minus emigration) averaged more than one million, while net illegal migration fluctuated between zero and half a million, depending on the state of the economy.

As suggested by the figure above, America's immigration history can be divided into four main periods: a laissez-faire century, with initially low and then accelerating numbers of immigrants; the "Great Wave" of mass immigration, primarily from southern and eastern Europe, lasting for five decades around the turn of the last century; a Great Pause from large-scale immigration, for about four decades during the mid-twentieth century; and a Second Wave of mass immigration, over the past fifty years, which continues unabated to this date, this time with a majority of immigrants coming from Latin America.

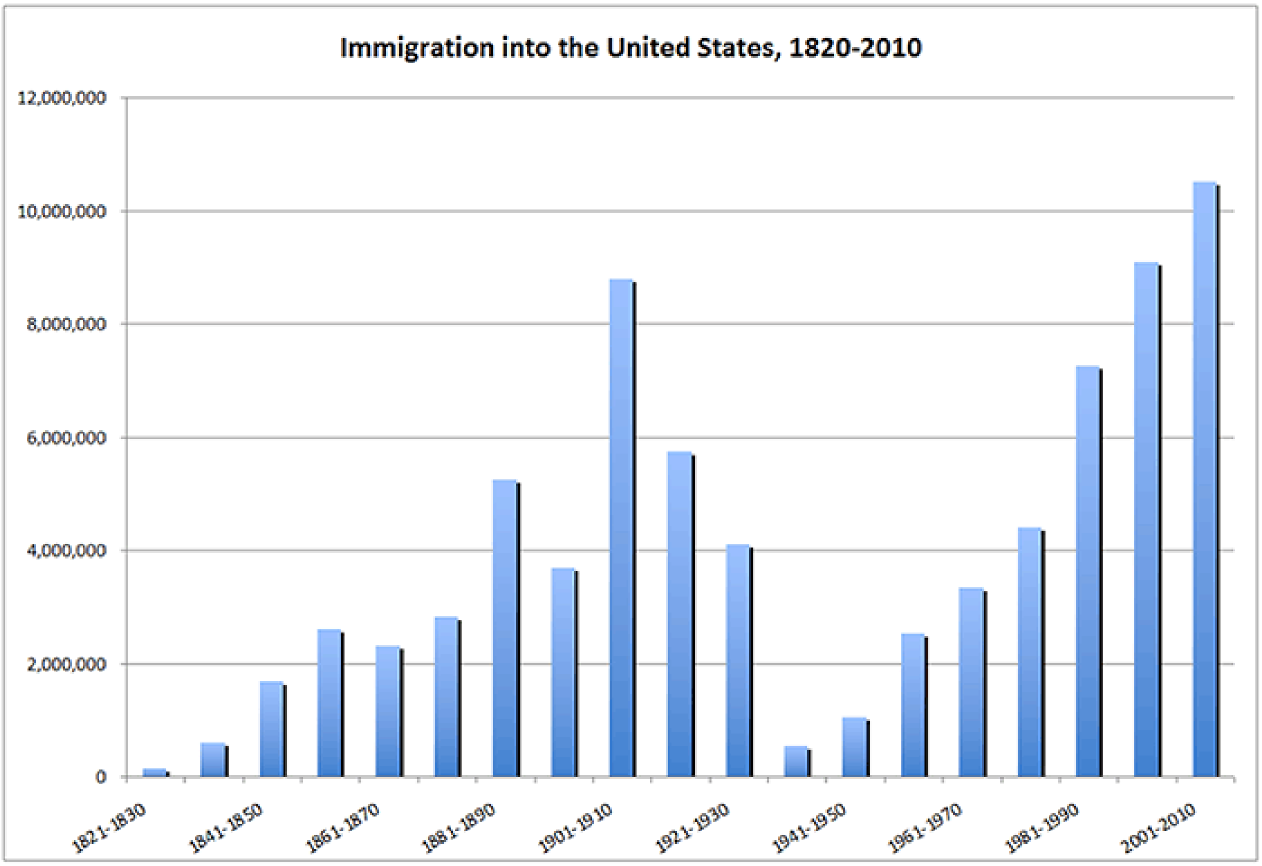


Figure 1-4. Immigration to the United States by decade, 1820 to 2010

Briefly reviewing this history confirms the importance of immigration policy in determining how many people are allowed to enter and remain in the U.S. The following review of U.S. immigration and immigration policy draws from a number of standard histories. Particularly useful have been Graham (2004) and Martin (2011).

1.4.1 Immigration and Immigration Policy

1789-1880. During our first century, American immigration policy was set by the individual states, which largely limited themselves to testing incoming immigrants for communicable diseases in a few major ports, quarantining and in some instances sending back those deemed a threat to public health. In practice, this meant a laissez-faire immigration policy: those who could afford to book passage to America could enter, settle down and look for work. Acquiring citizenship ("naturalization") when desired was relatively straight-forward, and in any case the children of immigrants were deemed citizens automatically when born on American soil (birthright citizenship).

Over its first ninety years, immigration into the U.S. rose from what was probably a few thousand per year at the start of the period to several hundred thousand per year by its end. The potato famine in Ireland and political repression in the aftermath of the European revolutions of 1848 briefly drove the numbers from 100,000 to over 400,000 for a few years before the Civil War. Generally speaking, in the post-war era (latter third of the 19th century) the "push" of Europe's century-long population surge combined with the "pull" of newly-opened agricultural lands and factory jobs kept immigration relatively elevated.

Meanwhile, post-Civil War, large numbers of Chinese immigrants were brought to California, at first to build the railroads, later branching out into other areas of the economy. In the 1870s and 1880s, white settlers in California (many of them recent immigrants from Europe) began agitating against continued immigration of Chinese people into the state. Many proponents of restriction argued that Chinese laborers displaced white workers and drove down their wages – a position that resonated particularly strongly during the recurring recessions and depressions of the period. Others claimed that the Chinese were racially inferior; still others, that cultural differences made it difficult for them to assimilate, hence creating a threat to social stability and progress. In 1882, Congress heeded these calls and passed the Chinese Exclusion Act, slowing Chinese immigration to a trickle. Several years previously, the U.S. Supreme Court had ruled that individual states could <u>not</u> regulate immigration; the Exclusion Act helped establish the political principle that the federal government <u>should</u> make immigration law for the country as a whole, bringing a long period of *de facto* laissez-faire immigration policy to a close.

1881-1924. In 1881, immigration topped half a million for the first time in American history. From the 1880s through the mid-1920s, America experienced an immigration boom – "the Great Wave" – during which immigration averaged nearly 600,000 annually. This was the period during which the U.S. fully industrialized, creating a huge demand for factory workers. The demand was filled primarily by American farmers, displaced by

depressed commodity prices and technological innovations in agriculture, and by European immigrants, particularly, during its second half, by immigrants from southern and Eastern Europe (Italians, Greeks, Poles, Russians and others). This period of immense wealth creation was, somewhat paradoxically, also a period of great suffering for workers and of greatly increased economic inequality. Unions were founded and sometimes organized impressive numbers of workers, but they tended to be weak and found it hard to win major concessions. From Pennsylvania's steel mills to Colorado's coal mines, unions struck for better wages, hours and working conditions. They were usually defeated, often with the help of immigrant strikebreakers.

Throughout this period, as in the previous one, immigration policy was limited to sending back would-be immigrants for reasons of health or their likelihood of becoming "public charges"; no limits were placed on the overall numbers of immigrants. The Chinese example, however, suggested the possibility of more comprehensive immigration restrictions, and limiting immigration from Europe was debated with ever-greater seriousness. Throughout the period, many labor leaders argued for reduced immigration into the United States, in order to facilitate their efforts to improve conditions for workers – although then as now, some disagreed, believing that opposition to mass immigration risked alienating the immigrants they needed to organize. Samuel Gompers, head of the American Federation of Labor and himself an immigrant, over time came to see reducing immigration as essential to creating a strong union movement, because organizing workers or winning concessions was so difficult under flooded labor markets. In a letter to Congress in the 1920s, he wrote (Gompers 1924):

> Every effort to enact immigration legislation must expect to meet a number of hostile forces and, in particular, two hostile forces of considerable strength.
>
> One of these is composed of corporation employers who desire to employ physical strength (broad backs) at the lowest possible wage and who prefer a rapidly revolving labor supply at low wages to a regular supply of American wage earners at fair wages.
>
> The other is composed of racial groups in the United States who oppose all restrictive legislation because they want the doors left open for an influx of their countrymen regardless of the menace to the people of their adopted country.

Such pro-labor arguments appealed to the left. On the right, cultural and racial arguments were made, regarding the swamping of "Anglo-Saxon stock" or the decline of traditional political and social institutions. Meanwhile, citizens of all political persuasions often sensed that the country was changing too quickly (from rural to urban, northern to southern European, etc.) and saw immigration reduction as one way to hit the brakes. Repeatedly during the first two decades of the twentieth century, one or both houses of Congress passed restrictive immigration legislation, only to have it die in the other house,

or by Presidential vetoes. But in 1921 and 1924 the restrictionists finally succeeded. Congress enacted the first comprehensive quota system to limit overall immigration into the U.S. and the Great Wave came to an end.

1924-1965. The system put in place in 1924 had two key features. First, for those concerned about the numbers of immigrants entering America, it set an annual limit of 155,000 for immigrants from outside the Western hemisphere. Intra-hemispheric immigration made up a small portion of the total at this time, and quotas for lands south of the border were not seen as necessary (Graham 2004) represented a huge decrease: six times during the first two decades of the 20th century, annual immigration had topped one million. Second, for those worried about the changing ethnic makeup of the country, the legislation set quotas for individual sender countries based on their contribution to America's ethnic make-up as of 1890. During the following decades, this led to most available "slots" being allocated to immigrants from northern Europe.

For the next forty years, from 1925 to 1965, this relatively restrictive immigration policy allowed about 175,000 people into the country annually. Overall numbers were also held down by the Great Depression and World War II. Demographers sometimes call this period "the Great Pause," although at the time, most Americans thought of it as permanent. Speaking in 1936 at the rededication ceremony celebrating the 50th anniversary of the Statue of Liberty, President Franklin Roosevelt praised immigrants' contributions to America, saying:

> For over three centuries, a steady stream of men, women and children followed the beacon of liberty which this light symbolizes. They brought to us strength and moral fiber developed in a civilization centuries old but fired anew by the dream of a better life in America….They not only found freedom in the new world, but by their effort and devotion they made the new world's freedom safer, richer, more far reaching, more capable of growth.

But Roosevelt also said:

> Within this present generation that stream from abroad has largely stopped. We have within our shores today the materials out of which we shall continue to build an even better home for liberty (Roosevelt 1936).

Most Americans shared President Roosevelt's views. Mass immigration had helped build the country and made us who we were. But times had changed, and the era of mass immigration was over.

In retrospect, the Great Pause corresponded with a golden age for American labor, despite encompassing the Great Depression. Labor markets tightened, eventually, and union organizing boomed. After World War II, salaries rose, work hours decreased and

fringe benefits improved, as employers chased relatively scarce labor. This included hiring African-Americans into industrial occupations from which they had previously been excluded. America created the world's first mass middle-class society, with a relatively egalitarian sharing of wealth, and relatively prosperous and secure workers throughout many sectors of the economy. Toward the end of this period, the nation took significant steps toward redressing its historic wrongs against African-Americans, with President Truman integrating the armed forces, the Supreme Court ruling segregated schooling unconstitutional, and Congress passing major civil rights legislation in 1964 and 1965. Throughout this period, there was no groundswell for a return to the relatively high levels of immigration of half a century earlier.

1965-present. Nevertheless, aspects of the "national origins" policy of 1924 rankled, particularly its explicit preference for immigrants from northern and western Europe. Although proponents argued that this simply preserved the existing ethnic make-up of the country, opponents decried it as discriminatory against other racial and ethnic groups: a relic of more racist times, ripe for reform in the civil rights era. In 1965, in response, Congress passed the Hart-Cellar immigration bill, replacing quotas that had favored European immigrants with a new system that instead allotted immigration slots to individual countries based on their proportion of total world population. Rather than mirror the existing ethnic or racial make-up of the United States, new immigrants would (in theory) mirror the world as a whole.

Proponents of the new policy took pains to assure Americans that it would not substantially increase total immigration, or radically change the existing ethnic composition of the country. "Our cities will not be flooded with a million immigrants annually," assured Edward Kennedy, the bill's chief Senate sponsor, on the Senate floor: "Under the proposed bill, the present level of immigration remains substantially the same" (Graham 2004). In fact, however, the new bill nearly doubled official quota levels from 155,000 to 290,000. It removed hard caps regarding refugee resettlement. Most important of all, in hindsight, is that Hart-Cellar split out "family reunification" – broadly interpreted to include not just spouses and children, but also parents and siblings – as a separate immigration category that no longer counted against the annual country quotas and that had no legal limit. Family reunification subsequently became the country's largest immigration category, accounting for over half a million immigrants annually, the majority coming from Mexico in a recurring "chain migration." Within three decades, legal immigration into the United States had more than tripled, from 300,000 to 900,000 annually.

Meanwhile, <u>illegal</u> immigration also increased significantly. In 1986, in response to this increase, Congress, for the first time, made it a crime for employers to knowingly hire

illegal workers. It also granted amnesty and citizenship to about three million illegal residents, presenting this as a one-time measure to "clear the books." This and subsequent amnesties, however, along with weak enforcement of employer sanctions, encouraged even more illegal immigration, which rose to a peak of perhaps half a million net annually in the first few years of the 21st century. Total numbers of illegal immigrants in the country continued to climb: from an estimated one to two million in 1965, that population grew to five to six million in 1986, and then to ten to twelve million illegal inhabitants by 2010.

Subsequent federal actions have tended to extend this generally expansive immigration policy. Country quotas were increased in 1980 and 1990. New categories of legal immigration were created: H1-B visas for highly-skilled workers, temporary work visas for agricultural workers (who often overstayed and joined the ranks of the illegal), 50,000 slots in an annual "diversity lottery" directed at citizens from "under-represented" sender countries, and numerous others. Meanwhile, illegal immigration dropped sharply, probably due to the 2007 recession and subsequent economic slowdown. Over the last several years, annual immigration numbers have broken down approximately as shown in Table 1-1:

Table 1-1. Approximate annual immigration by category, 2008-2011	
Family sponsored	710,000
Employment-based	145,000
Diversity program	50,000
Refuges and asylum seekers	160,000
Other categories	25,000
Total legal immigration	**1,090,000**
Illegal immigration (uncertain and highly variable)	~200,000
Total immigration (legal and illegal)	**~1,300,000**
Source: Office of Immigration Statistics, "Annual Flow Report, U.S. Legal Permanent Residents: 2011" (Washington, DC: Department of Homeland Security, 2012), table 2.	

Again, it seems important to note that these policy changes were not enacted as part of a groundswell of popular support for increased immigration. Quite the contrary: for the past half century, public opinion polls have typically found Americans split, about 40% to 40%, between those wanting to decrease immigration and those wanting to keep it at current levels. Typically, only 10% to 15% of poll respondents have favored an increase

(The Polling Company 2006). Every legislative change that has increased immigration numbers has been presented to the public as something else: in 1965, as a civil rights measure to do away with racist preferences for white Europeans; in 1986 and 1990, as part of more "comprehensive" legislative packages aiming to increase the enforcement of immigration laws. This suggests a large difference between elite opinion and general public opinion regarding immigration policy (Beck and Camarota 2002).

In any event, 1965 initiated a second "Great Wave" of mass immigration, which continues today. During the 1990s, legal immigration averaged 900,000 annually, increasing to about one million per year during the next decade. That was the highest number in U.S. history and more than five times the average during the "Great Pause" around the middle of the previous century (although once again, it was not the highest rate of immigration: as a percentage of total U.S. population, rates were higher at the height of the first Great Wave than they are today).

During this time, particularly due to the emphasis on "family reunification," immigration from Mexico and the rest of Latin America has come to predominate, along with relatively high immigration numbers from South and East Asia. This period, like the era of the first Great Wave, has been a time of technological innovation and rapidly expanding wealth, increased racial and ethnic diversity, identity group politics (particularly in our larger cities), weak labor unions, stagnating wages for lower-income Americans, and increasing economic inequality.

1.4.2 A Demographic Note on the Causes of Population Growth

Comparing the previous figures showing population growth and immigration numbers might cause some confusion. How is it that the U.S. population has climbed steadily, while immigration has varied so greatly over the past hundred years? The answer is that population growth is a function of both immigration rates and birth rates (among both native born and immigrants). More precisely, demographers see four primary factors determining the overall growth rate for any population: birth rates, death rates, immigration into a population, and emigration out of it. All four factors help determine whether a population grows or declines, and by how much. Good introductions to basic demography include Yaukey et al. (2007) and Poston, Jr. and Bouvier (2010).

During the first Great Wave, from 1880 to the mid-1920s, America's population grew rapidly, due to a combination of high birth rates and high levels of immigration. U.S. population increased from 50 million in 1880 to 116 million in 1925. During the Great Pause, U.S. population continued to grow substantially – from 116 million to 194 million people in 1965 – but now primarily due to high birth rates. During the 1950s, for example, American women had an average of 3.5 children each, far above the 2.1 total

fertility rate (TFR) necessary to maintain a stable population for a nation with modern health care and sanitation. Population still grew, and rapidly, but by tens of millions less than would have been the case, if pre-1925 immigration levels had continued.

By the 1970s, American women were having fewer babies. In 1976 the TFR stood at its lowest-ever – 1.7 – and it has remained near replacement level since then, fluctuating from year to year and decade to decade close to 2.1. Thus, the United States was well-positioned to transition from a growing to a stable population. By the 1980s, the Census Bureau's demographers had taken note of this downswing in one of the fundamental demographic factors, and incorporated it into the assumptions of their long-term projections. These indicated that the United States population would crest in the first half of the 21st century. One study found that without post-1970 immigration, the U.S. population would have leveled off below 250 million by around 2030 (Lytwak 1999). At steady pre-1965 immigration levels, America's population would have taken longer to stabilize and would have stabilized at a higher number, but broadly speaking the trajectory would have been the same.

If we had taken such a stabilization path, the U.S. would have been in good company. Germany, Italy, Great Britain, France, Japan and most countries in the developed world made this "demographic transition" in the decades after World War II and greatly slowed their rates of growth (USCB 2012a), as shown in Table 1-2.

Table 1-2. Percentage population increase by country, 1950-2010 vs. 1990-2010

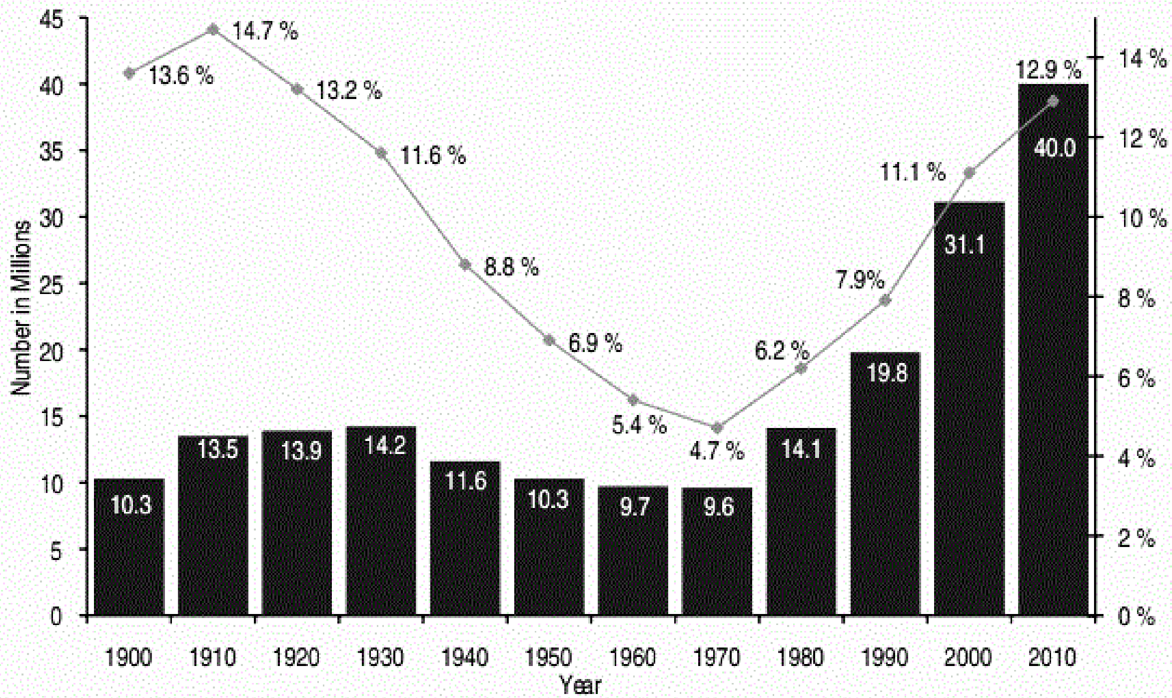
Country	Population increase, 1950-2010	Population increase, 1990-2010
France	55%	11%
Germany	19%	3%
Italy	29%	7%
Japan	52%	3%
United Kingdom	24%	9%
United States	**104%**	**24%**

Source: USCB 2012a

However, the United States did not take this path. Instead, as shown in Figure 1-5, we increased immigration just as native birthrates fell below replacement level, bringing in tens of millions of new residents (Camarota 2011).

Many of these new immigrants were women and men in their childbearing and child-raising years, coming from countries where large families remained the norm. This helped to raise U.S. fertility rates back up to (and for a while, above) replacement level. The number of births to immigrant mothers has increased quickly in recent decades, from 228,000 in 1970 to 916,000 in 2002, according to data from the National Center for Health Statistics (Camarota 2005a).

On average, immigrants to America actually had higher fertility rates than women in their countries of origin. In 2002, for example, immigrant women (legal and illegal) from the top-10 immigrant-sending countries had 2.9 children on average, 23 percent more than the average TFR of 2.3 children in their home countries (Camarota 2005b). One researcher concludes: "at the very time that the great majority of native-born Americans were voluntarily choosing to limit their family sizes to levels which could have led to the end of U.S. population growth, Congress was making changes in immigration policy which have ensured ever more growth. The result of these changes was the highest sustained immigration and greatest population growth in U.S. history" (Lytwak 1999).



Source: Decennial Census for 1900 to 2000 and the American Community Survey for 2010.

Figure 1-5. Number of immigrants in the U.S. and their percentage of the U.S. population, 1970-2010

As a result, since 1965, the U.S. population has climbed from 194 to 318 million. That's an increase of 124 million people, equal to the total population of the United States in 1928. Just as important, our population continues to grow rapidly, by approximately 2.5 to 3 million people annually. Indeed, the U.S. annual growth rate (0.96%) is much closer to that of developing countries such as Morocco, Vietnam, or Indonesia (all at 1.07%) than to other developed nations such as Denmark (0.25%), Taiwan (0.19%), or Belgium (0.07%) (CIA 2011). The main difference is that population growth in the developing world is driven by high fertility rates (and the widened gap between continued high birth rates and decreasing death rates thanks to improved food availability, medicine and vaccines), while population growth in the United States and the rest of the developed world is mostly a function of mass immigration.

Thus concludes this summary of the United States' demographic past. For a more detailed discussion of recent U.S. demographic history, see the Census Bureau publication Demographic Trends in the 20th Century (Hobbs and Stoops 2002).

1.5 U.S. Demographic Projections (Possible Futures)

The previous section considered the United States' demographic past. This section considers America's demographic future.

In the short term, continued growth is a near certainty. Currently, on average, the U.S. population is increasing by nearly three million people per year, or approximately 30 million per decade (32 million in the 1990s and 27 million in the 2000s). Our population grew by 2.3 million in 2013, which may represent a slowing trend but more likely signifies a low ebb in the annual and decadal fluctuations that mark our demographic growth. Over the long-term, however, a diverse number of potential and divergent demographic paths appear. Which one the United States follows will depend on the four main factors that determine change in any population: fertility (or the birth rate), mortality (or the death rate), immigration, and emigration.

This section reviews several recent U.S. population projections, mostly out to 2050 or 2060, but one out to 2100. Chapter 2 provides new population projections out to 2100. It is these projections to 2100 that will provide the basis for the alternatives that are analyzed in the full EIS on U.S. immigration policy.

While demographers use a number of different methods to project potential population changes, the most popular, particularly for long-term forecasting, is the "cohort-component" method. Essentially, a certain population starts with a particular age-structure. Then we take that population forward in time as it responds to four key

factors: births (fertility), deaths (mortality), immigration, and emigration. These last two factors are sometimes combined as “migration” or “net migration.” One introductory guide summarizes the method as follows:

> Initial populations for countries or regions are grouped into cohorts defined by age and sex, and the projection proceeds by updating the population of each age- and sex-specific group according to assumptions about three components of population change: fertility, mortality, and migration. Each cohort survives forward to the next age group according to assumed age-specific mortality rates. Five-year age groups (and five-year time steps) are commonly used (although not strictly necessary) for long-range projections.
>
> As an example, the number of females in a particular population aged 20-25 in 2005 is calculated as the number of females aged 15-20 in 2000 multiplied by the assumed probability of survival for females of that age over the time period 2000-2005. This calculation is made for each age group and for both sexes, and repeated for each time step as the projection proceeds.
>
> Migration can be accounted for by applying age- and sex-specific net migration rates to each cohort as well, and ensuring that immigration equals emigration when summed over all regions.
>
> The size of the youngest age group is also affected by the number of births, which is calculated by applying assumed age-specific fertility rates to female cohorts in the reproductive age span. An assumed sex ratio at birth is used to divide total births into males and females (O’Neill, et al. 2001).

All the recent population projections discussed here use the cohort-component method, as does this EIS. Additional information on demographic projection techniques and the cohort-component method is available at Yaukey, et al. (2007) and Poston, Jr. and Bouvier (2010).

1.5.1 U.S. Census Bureau Projections in 2000 to Year 2100

In 2000, the U.S. Census Bureau provided population projections out to 2100 (Hollmann, et al. 2000). This was a rare instance of the Bureau developing 100-year projections. The Census Bureau developed four main “series,” built in the standard way around different fertility, mortality, immigration, and emigration scenarios. The middle series incorporated what the Bureau believed to be the most likely scenarios regarding each of these factors. The lowest and highest series incorporated the lowest and highest plausible scenarios for each of these factors. Finally, the zero net international migration series combined the most likely fertility and mortality scenarios (according to the Bureau) with zero net migration (immigration exactly balanced by emigration). This procedure led to the projections shown in Table 1-3 (USCB 2000).

Because the three main series varied fertility, mortality and immigration simultaneously, they are of little value in distinguishing the relative contributions of each of these factors to population growth. However, the large variation between the lowest and highest series (a difference of 899 million people by 2100) does vividly convey the power of these demographic factors to shape the future in very different ways, relatively quickly (in this case, over a mere 100 years).

In addition, considering the zero net migration series shows that even without any net in-migration, the U.S. population is set to grow considerably over the coming century: by 103 million people, according to this projection. Meanwhile, comparison of the middle or "most likely" series with the zero net migration series demonstrates that immigration is ready to make an immense contribution to population growth, with the difference between the most likely series and zero immigration standing at 194 million people over the course of the 21st century (Table 1-3).

Table 1-3. Four series of U.S. population projections from 1999 to 2100 (in thousands)

Year	Lowest	Middle	Highest	Zero Net Migration
2000	**274,853**	**275,306**	**275,816**	**273,818**
2010	291,413	299,862	310,910	287,710
2020	303,664	324,927	354,642	301,636
2030	311,656	351,070	409,604	313,219
2040	314,673	377,350	475,949	321,167
2050	**313,546**	**403,687**	**552,757**	**327,641**
2060	310,533	432,011	642,752	334,724
2070	306,589	463,639	749,257	343,815
2080	300,747	497,830	873,794	354,471
2090	292,584	533,605	1,017,344	365,689
2100	**282,706**	**570,954**	**1,182,390**	**377,444**

Source: USCB 2000

1.5.2 U.S. Census Bureau Projections in 2008 to Year 2050

In 2008, the Census Bureau projected U.S. population numbers out to 2050, primarily by extrapolating out then-current trends regarding fertility rates, mortality rates, and immigration rates. Based in part on recent National Center for Health Statistics data on deaths and births, Bureau demographers predicted a 4-year to 5-year increase in the average American lifespan and nearly static average fertility rates during this period (with decreases in native fertility offset by greater numbers of immigrants, who tend to have higher fertility rates). They also assumed a steady rise in net international immigration, from 1.2 million in 2001 to over 2 million in 2050 (USCB 2008a).

Based on these predicted trends, Census Bureau demographers derived a medium (or "most likely") projection of 439 million people in 2050. This would represent a 158 million-person (56%) increase over 2000 (USCB 2008b).

1.5.3 U.S. Census Bureau Projections in 2009 to Year 2050

In 2009, the Census Bureau released additional projections to 2050. These followed the same basic parameters as the 2008 projections. This time, however, the Bureau held fertility rates and longevity constant among the different projections, while varying immigration levels between zero and two million annually (Ortman and Guarneri 2009). The 2009 projections came out as follows:

Table 1-4. U.S. Census Bureau projections in 2009 to year 2050

Average annual net immigration	Population in 2050
zero	323 million
1 million	399 million
1.5 million	423 million
2 million	458 million

Source: Ortman and Guarneri 2009

The 2009 Census Bureau projections demonstrate that the actual immigration rates that occur will make an immense difference to future U.S. population numbers. The difference between zero net immigration (in 2009) and the Bureau's most likely scenario (in 2008) was 116 million people (a number equal to the total U.S. population in 1925). The difference between zero net migration and two million annual net migration in the 2009 projections was 135 million people. According to

these projections, each additional million annual immigrants post-2009 added, on average, 67.5 million people to the United States population in 2050.

1.5.4 Pew Research Center Projections in 2008 to Year 2050

Other studies have confirmed the impact immigration is likely to have on America's future population. A study published by the Pew Research Center in 2008, "U.S. Population Projections: 2005–2050," reached the following conclusions:

- Between 2005 and 2050, the nation's population will increase to 438 million from 296 million, a rise of 142 million people that represents growth of 48%.
- Immigrants who arrive after 2005, and their U.S.-born descendants, account for 82% of the projected national population increase during the 2005–2050 period.
- Of the 117 million additional people attributable to the effect of new immigration, 67 million will be the immigrants themselves and 50 million will be their U.S.-born children and grandchildren (Passel and Cohn 2008).

In addition to their "main" or most likely projection, in which immigration averaged 1.7 million annually, the Pew researchers ran "lower immigration" and "higher immigration" projections, in order to see how future population numbers would change under different immigration scenarios. The lower immigration projection averaged 900,000 immigrants annually (about 50% lower than predicted) and the higher immigration scenario averaged 2.6 million annually (about 50% higher than predicted). These led to the following projected populations in 2050:

Table 1-5. Pew Research Center projections to year 2050 under different immigration scenarios

Average annual net immigration	Population in 2050
900,000	384 million
1.7 million	438 million
2.6 million	496 million
Source: Passel and Cohn 2008	

Once again, it is evident that changes in immigration levels make a large difference to future population numbers. The difference between a 50% decrease and a 50% increase in immigration, both well within the realm of policy options discussed in the

U.S. Congress during the past decade, was 112 million people more or less in 2050 (Passel and Cohn 2008).

1.5.5 Decision Demographics, Inc. Projections in 2012 to Year 2050

In December 2012, researchers at Decision Demographics, Inc., (DD) in consultation with the Center for Immigration Studies (CIS), recreated the U.S. Census Bureau's 2008 population projections, using data provided by the Census Bureau (Tordella, et al. 2012). Using the resulting projection tool, researchers at DD and CIS then varied the level of net migration to create a new series of projections, in order to better discern immigration's potential impact on the size of the future U.S. population. In summarizing their findings, one of the researchers concluded that: "If immigration continues as the Census Bureau expects, the nation's population will increase from 309 million in 2010 to 436 million in 2050 — a 127 million (41 percent) increase." He added: "The projected increase of 127 million is larger than the combined populations of Great Britain and France. It also exceeds the entire U.S. population in 1930" (Camarota 2012). Conversely, reducing immigration could significantly reduce population growth over this period (but could not eliminate it entirely), as shown in Figure 1-6.

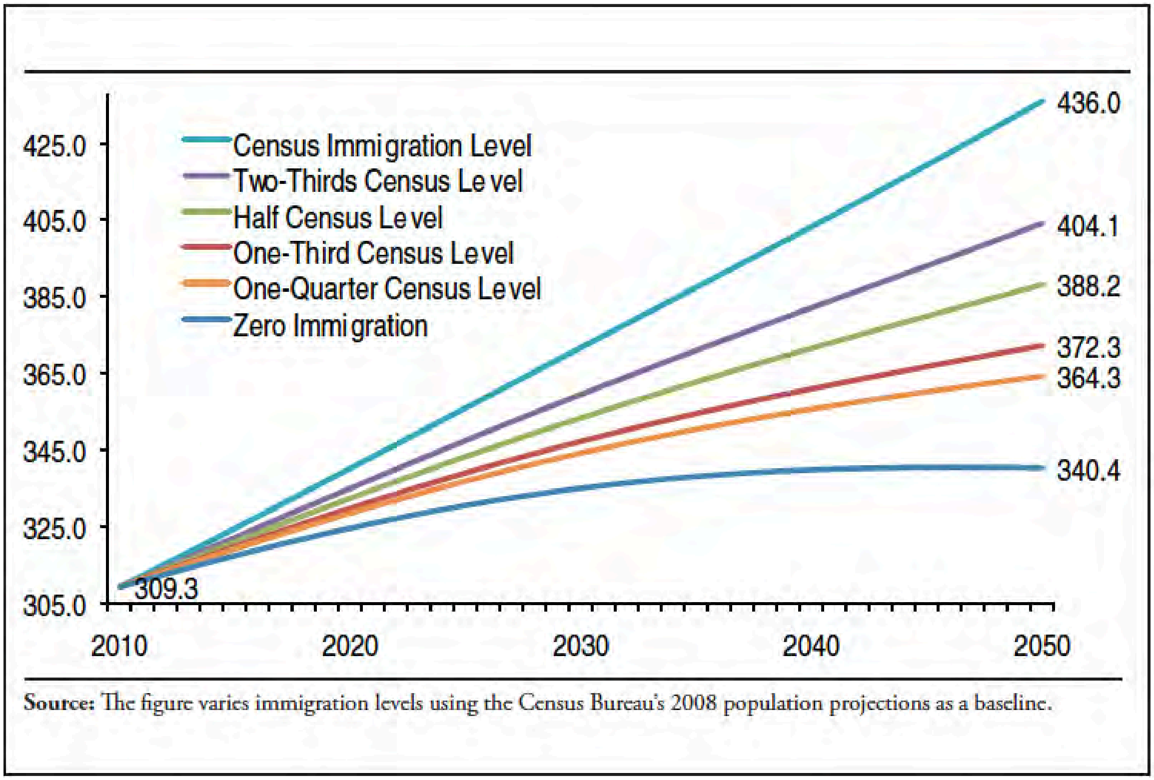
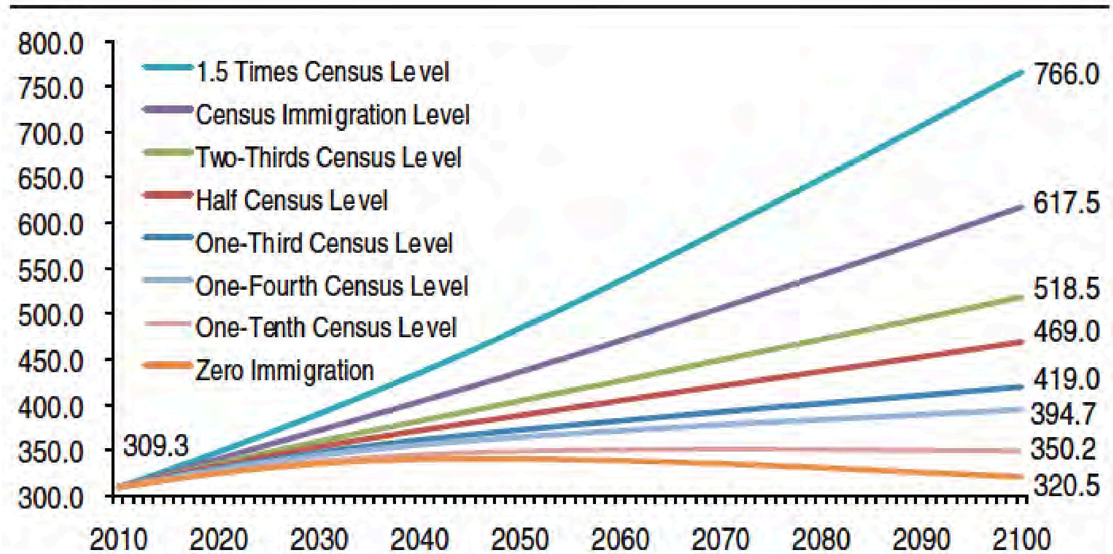


Figure 1-6. Impact of immigration on U.S. population size, 2010 to 2050, in millions
Source: Camarota 2012

While the 2008 Census Bureau projections only went out to 2050, it is possible to use the projection tool created by DD and CIS to generate projections out to 2100. To do so, researchers assumed that the levels of immigration, fertility, and mortality in 2050 foreseen by the Census Bureau continued to 2100. Then once again, they varied immigration levels, this time both above and below the Census Bureau projections, in order to isolate immigration's potential contribution to population growth. This generated the projections shown in Figure 1-7.

As Camarota summarizes their findings: "If the level of immigration the Census Bureau foresees in 2050 were to continue after that date, then the U.S. population would hit 506 million by 2070 and slightly more than 617 million by 2100. This means that the U.S. population would double during this century from slightly more than 309 million in 2010 to more than 600 million by 2100" (Camarota 2012). This would be equivalent to growing at the steady annual rate of approximately 0.8%.



Source: The figure varies immigration levels using the Census Bureau's 2008 population projections as a baseline through 2050. After 2050 immigration levels are assumed to continue at 2050 level or are varied from that level in the manner described in the text.

Figure 1-7. Impact of immigration on U.S. population size, 2010 to 2100, in millions
Source: Camarota 2012

While according to these projections a zero net immigration regime would stabilize the U.S. population at approximately our current numbers, immigration at even one-fourth the rate projected by the Census Bureau in 2008 would lead to a population 85 million larger in 2100 (and poised to continue growing). Camarota concludes: "It would take a

very substantial reduction in immigration to stabilize the size of the U.S. population by 2100. In fact, immigration at almost any level will cause the country to be a good deal larger by 2100 than it would be in the absence of immigration" (Camarota 2012).

1.5.6 U.S. Census Bureau Projections in 2012 to Year 2060

Also in December 2012, the U.S. Census Bureau released new "50-year" (actually 48-year) population projections out to 2060. According to the Census Bureau: "The [U.S.] population is projected to increase from 314 million in 2012 to 420 million in 2060." This would represent a 34% increase, or 106 million more people living in the U.S. in 2060 than in 2012 (USCB 2012b).

The new projections forecast significantly slower population growth than was predicted in the 2008 Census Bureau projections. According to the Census Bureau, "most of the difference is explained by decreases in the level of net international migration in the 2012 series compared to the 2008 series" (USCB 2012b). For example, the 2008 projections forecast net immigration of 1.377 million in 2015, while the 2012 projections forecast 794,000 net immigration: a difference of 583,000. This difference grows over time: by 2050, the 2008 projections forecast 2.047 million net immigration, while the 2012 projections forecast 1.204 million net immigration: a difference of 843,000 (USCB 2012b).

The Census Bureau's new projections appear to have been significantly influenced by the large decrease in illegal immigration into the U.S. in the wake of the 2007 recession. Whether lower levels of illegal and (more importantly) total immigration will continue in better economic times is a matter for debate; current proposals being considered by Congress and advocated by the Obama Administration could greatly increase annual immigration levels. What seems clear, once again, is that apparently small changes in annual immigration levels can lead to large changes in overall population numbers, in a relatively short time. Lowering projected immigration between 2012 and 2050 decreased the estimated U.S. population in 2050 by 39 million people (400 million in the 2012 projections, as compared to 439 million in the 2008 projections) (USCB 2012b).

1.6 Purpose and Need of the EIS

Typically, the "Purpose and Need" section of an EIS describes the purpose and need of the proposed action, that is, the project or plan being proposed, authorized (permitted), or funded by a U.S. government agency. What is the purpose of the proposed road or road expansion, transit project, dam and reservoir, power plant, power line, pipeline, mine, land transfer, or master plan, and what public need would be fulfilled by implementing or executing the action?

In the case of immigration to the United States, the purpose and need, as frequently stated by its supporters among immigrants themselves and their families, churches, politicians, business interests, economists, certain ethnic groups, and immigrant advocacy and humanitarian organizations, are 1) family reunification, 2) import of labor and talent needed to fill alleged domestic labor and talent shortages and thus sustain economic growth in the U.S., and 3) in the case of refugees and asylees, the humanitarian mission of providing sanctuary to persons who have a justifiable fear of systematic persecution in their home countries.

Each of these purposes and needs lends itself to a degree of scrutiny and skepticism. For example, the "need" for family reunification is usually initiated when an ambitious individual voluntarily departs his or her country of origin and legally or illegally enters and remains in the U.S. in search of a "better life," typically a more materially prosperous one. Once settled and at least modestly successful, this person seeks to bring into the U.S. those family members her or she of their own volition left behind. The "need" for reunification thus originates with the action of a foreign individual, not the U.S. government or Americans. Nevertheless, family reunification remains a powerful motivation for much, even most, of the immigration that has occurred over the last four decades of American history.

More broadly, many Americans, as immigrants themselves or descendants of immigrants, subscribe to the lofty idea that America is a "nation of immigrants." Recognizing how crucial historic and current immigration, both in rate and composition, have been to shaping what our country is and what it is becoming, these Americans are broadly supportive of maintaining immigration as one of the fundamental nation-forging processes that are part of the American experiment and experience.

Still others, who tend to be of a more liberal or progressive political persuasion, support high immigration rates as a key tool for reshaping America's image into one more representative of the world as a whole (i.e., the "browning of America"), or because they see it as atonement for how the capitalist "American Empire" has allegedly destabilized much of the developing world through the actions both of the U.S. government and military and private enterprise.

Most Americans would emphatically reject the notion of an American Empire that is the cause of most of the world's ills, seeing this analysis as infantilizing the rest of the world's peoples and depriving them of real agency in creating their own societies. They would also abjure the critique that it is morally incumbent upon the U.S. to accept any and all who seek to migrate to our shores because we ourselves are responsible in the first

place for their need to migrate. That said, there remains a deep-seated American sense of compassion for the underdog, as well as empathy towards those who seek a better life in our country. This reflects President Ronald Reagan's "shining city on a hill" vision. There is also a certain pride that Americans have fashioned the sort of free, stable, prosperous, reasonably just society that is the envy of so many in the world and the preferred destination of so many prospective migrants.

Microsoft co-founder Bill Gates, who for much of the past two decades has been world's richest person, has emphatically supported generous immigration policies as crucial to America's continuing economic success. In a 2013 essay, he touted the "foreign talent that came into the U.S. over the past three decades and added greatly to the U.S. economy" (Gates 2013).

While most of these purposes of immigration and the needs it fulfills are legitimate and even laudable, immigration has social, economic, and environmental consequences. These consequences – both positive and negative – tend to be proportionate with the scale or magnitude of immigration, that is, with the number of immigrants. This EIS is examining some of the long-term environmental consequences of different plausible immigration scenarios (i.e., the "alternatives" studied in this EIS), as a result of immigration's contribution to U.S. population growth.

Population growth is an underlying cause of many projects requiring Environmental Impact Statements. Common sense suggests that many new development projects might be driven by the increasing needs of a growing American population, one that in recent years has added about 30 million additional consumer-polluters per decade. The hypothesis that *population increase drives the need for many projects with significant environmental impacts* is examined below by reviewing the purposes and needs listed in recent federal EIS's for several major classes of projects.

1.6.1 Transportation

Transportation is one major area that routinely uses anticipated or planned population growth to justify new developments that have significant environmental and social impacts. For example, the Los Angeles Mid-City/Exposition LRT Project, Final EIS/EIR, a light rail mass transit project, has a 17-page "needs and purposes" section that uses the term "growth" several times to demonstrate the need for the proposed action. It states that: "This level of service is not expected to improve and may significantly worsen as a result of population growth and increased trip making in coming years" (Metro 2005). This EIS also contains specific mention of how the populations of certain areas adjacent to the proposed line are projected to grow in the future.

Figure 1-8. More people → more cars → more traffic → more congestion and air pollution

Similarly, the Lake Oswego to Portland transit project states: "The need for the project results from: Historic and projected increases in the traffic congestion in the Lake Oswego to Portland Corridor due to increases in regional and corridor population and employment" (Metro 2010).

Another category of transportation-related development is reflected by the Final Environmental Impact Statement, Tier 1: FAA Site Approval and Land Acquisition by the State of Illinois, Proposed South Suburban Airport. This EIS alleges that land acquisition is needed now, because of consistent increase in aviation demand in recent years, and growth of population in the area. The City of Chicago's forecasts: "predict 1.4 million aircraft operations by the year 2015 and an annual growth rate of 0.9 percent from 2000 to 2015" (FAA 2002). This continuing growth will make purchase of land more expensive, and cause much disruption of displaced businesses, unless the land is purchased soon before it can be developed for non-aviation purposes. Supporting evidence offered is that the local Will County population increased 40% from 1990 to 2000.

Of course, many of transportation's environmental impacts come from tailpipe or engine emissions due to use of vehicles (automobiles, sport utility vehicles, pickup or light trucks, recreational vehicles, tractor trailers, jets, and airplanes) and highway, road, and airport construction, which continue to consume land and generate pollution across the country. Such development alters or eliminates wildlife habitat, farmland and open space, by covering it with blacktop and concrete, and degrades further large areas through water runoff of pollutants associated with vehicle exhaust, tire rubber residue and leaked crankcase oil, and other toxic leakages. Such developments are represented by the US 36 Corridor Final Environmental Impact Statement, Boulder Colorado. This EIS states: "in 2005, the population was estimated to be 506,900 and is expected to grow to 649,100 in 2035 – a 28 percent increase." This growth provides the main "purpose and need" for the project's "improvements," that include road widening and other associated construction

(CDOT 2009). Countless similar projects, not all of which are subject to federal EIS's, are in process or in the planning stages throughout the U.S.

1.6.2 Energy

Energy-related EIS's include the Kangley-Echo Lake Transmission Line Project, Supplemental Draft Environmental Impact Statement. The "Purposes and Need for Action" section S.1 includes the statement: "As population grows . . . the need for electrical energy increases" (BPA 2003). There exists an extensive literature on the impacts of transmission line clear cuts, access roads and other linear developments that fragment and degrade wild lands and wildlife habitat.

The massive development rush associated with the new natural gas "fracking" boom, that threatens to degrade water resources and many relatively undeveloped wildlife habitats around the nation, is represented here by the Final EIS Atlantic Rim Natural Gas Field, Development Project, Carbon County, Wyoming. The purpose and need statement includes the phrase, "To meet the growing need for energy" (BLM 2006) and goes on to emphasize an increased need to use natural gas in power production in the U.S. Population growth is not explicitly mentioned, but the known need for more electricity, as well as gas for household heating every year (average of 1.5 million new homes built a year nationwide in recent decades) is likely due to population growth in areas of the country to which this mined gas will be transported. Our own EIS on U.S. Immigration Policy will attempt to quantify the degree to which new energy developments are driven by immigration-driven population growth.

Figure 1-9. Pumping jacks used in oil and gas production lined up on the Allegheny National Forest, Pennsylvania

The Alton Coal Tract LBA Draft EIS, Chapter 1 Purposes and Need, section 1.3, is more explicit about the underlying cause of the need for ever more energy in the United States. It states: "Given known technology and *demographic trends* overall, the United States demand for coal is expected to increase by approximately 0.4% per year through 2035" [italics added] (BLM 2011).

Figure 1-10. Mountaintop removal of coal in the Appalachian Mountains of West Virginia

The Alton Coal EIS cites a publication of the Energy Information Administration of the U.S. Department of Energy, the Annual Energy Outlook with projections to 2035, DOE/EIA-0383 (2010), April 2010. This document is even more forthcoming about the "demographic trends" that cause ever more energy to be needed in the U.S. The Department of Energy states: "*Growth in U.S. energy use is linked to population growth* through increases in demand for housing, commercial floorspace, transportation, manufacturing, and services" [italics added]. This report also notes that energy consumption per person in the U.S. is at the same time decreasing, due to efficiency improvements. However, in spite of these reductions in energy use per capita, the *Outlook* confirms the Alton need claim, stating: "Coal consumption increases by 0.4 percent per year in the Reference case" (EIA 2010).

The section entitled, "Purpose, Need for, and Benefit of the Action" in Chapter 1 of a 2006 EIS prepared jointly by the U.S. Department of Agriculture's Rural Utilities Service and the Montana Department of Environmental Quality on a proposed coal-fired 500-megawatt (MW) power plant near Great Falls and the Missouri River in Montana (Figure 1-11) stated: "The demand for electricity for residential customers is expected to increase for two reasons: increasing population and increasing use of electricity per household" (RUS/MDEQ 2006).

Figure 1-11. A 500-megawatt coal-fired power plant was proposed for these wheat fields under Montana's Big Sky to supply electricity to the state's growing population

More natural gas supply and demand predictably leads to a need for more pipeline capacity, so the Final Environmental Impact Statement on Ruby Pipeline Project (Dock No CP09-54-000) Section 1, issued January 8, 2010 was examined. The EIS reads: "According to Ruby, the need for the project arises from a growing demand for natural gas in Nevada and on the West Coast…." (FERC 2010). From what has been observed in other EIS need statements, much of this growing demand derives from projected increases in population if present demographic trends and immigration rates continue.

1.6.3 Water Supply

The Draft and Final EIS's for the Jackson County Lake Project on the Daniel Boone National Forest of the Appalachian highlands of eastern Kentucky examined the effects of constructing a water supply dam and reservoir on publicly owned and managed national forestland. These effects included permanent elimination of rich bottomland hardwood forest and wildlife habitat on a National Forest and possible impacts on endangered bat species, among others. Chapter 1 addresses the purpose and need for the proposed action under sections entitled Projected Demands and Population Projections. Under the former, the DEIS notes that: "To quantify water needs from now until the year

2050, two types of data are needed. The first type is water consumption rates per customer; the second is population projections" (RUS 2000; RUS 2001).

Chapter 1 of the Draft EIS for the Lower Bois d'Arc Creek Reservoir identified the purpose and need for this proposed new 16,641-acre (26-square mile) water supply reservoir on a tributary of the Red River in northeast Texas: "State population projections show the… service area population increasing from 1.6 million to 3.3 million by 2060." Chapter 1 specifies that although state-of-the-art water conservation, efficiency, reuse, and recycling measures can offset a large portion of the increase in municipal and residential water demand associated with a doubling of the service area population, they are insufficient to negate it entirely (USACE 2015).

An EIS for perhaps one of the last large American dam projects (Figure 1-12), a kind of development that has had immense environmental impacts on most rivers and their associated fish and wildlife throughout the contiguous 48 states, is the Narrows Project Final Environmental Impact Statement, Sanpete County, Utah. The EIS states the project is needed to "reduce the average annual shortages to irrigators in Sanpete County" and to supply "…an additional supply of municipal water to offset current shortages and accommodate *anticipated population growth* in Sanpete County" [italics added] (USBR 2012).

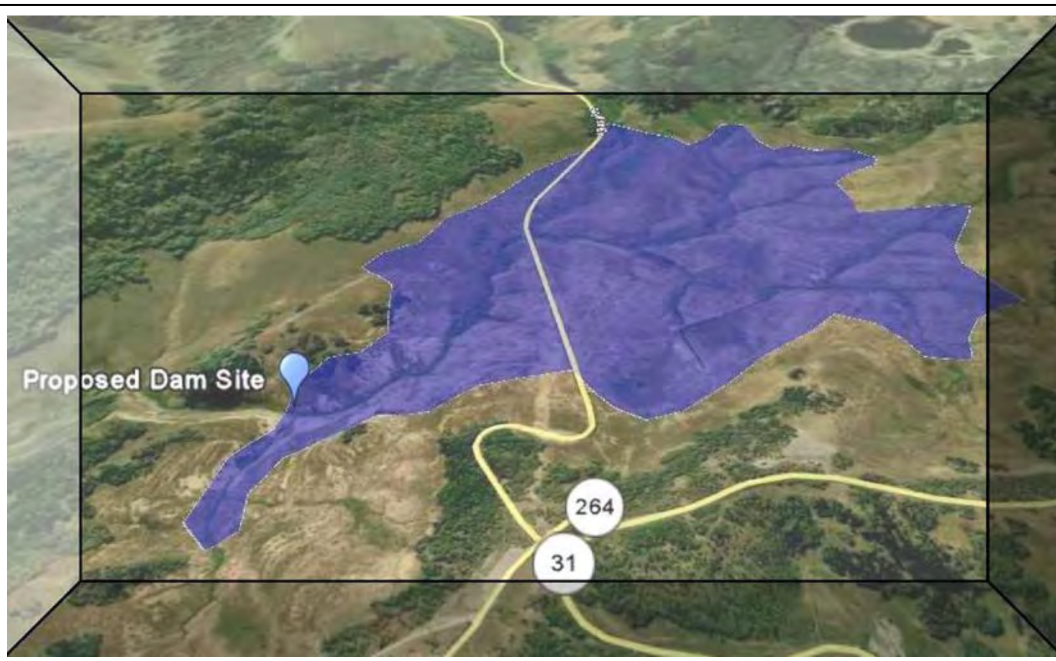


Figure 1-12. Narrows Project in Utah

1.6.4 Housing and Schooling

The Draft EIS for the Maybrook Glen Subdivision, Volume 1, was examined. Section D, Project Purpose, Need and Benefits, describes a need to: "Provide premium single-family detached housing…" This suggests that additional housing units may be needed due to an increase in the local population, or a desire of local business to increase the area's population (Village of Maybrook 2012).

New housing projects are an important cause of farm, forest and open space losses, and it makes intuitive sense that continual housing construction is necessitated by the need for ever more shelter for a U.S. population that has increased by almost 3 million a year in recent decades. But EIS's regarding such developments are relatively rare, because they are usually not subject to NEPA's disclosure requirements. This is because they usually do not affect public lands and are undertaken by private businesses rather than governmental agencies. In NEPA parlance, they lack a "federal nexus," in other words, no federal agency is proposing them, permitting them, or funding them. For these projects (as for most private developments), society is denied a full public environmental accounting of direct, indirect and cumulative impacts.

State laws and local regulations, proximity to public lands, and potential to affect the interests of indigenous peoples, however, may require some EIS's to be done for non-federal agency construction projects. One example comes from the new Kihei High School on Maui, Hawaii (Figure 1-13), for which a Final EIS was released on September

Figure 1-13. Portion of the project location map for the proposed Kihei High School in Hawai'i from the EIS Notice of Preparation

10, 2012. See also the Kihei High School Environmental Impact Statement Preparation Notice. The sub-paragraph on "Population Growth" details that population growth from 1990-2000 in the county was 50.8%, reaching a total of 16,749. It further states that: "Population projections for the Kihei-Makena Community Plan region anticipate that the year 2020 resident population will be approximately 33,227, while the 2030 population for the region is 38,757" (State of Hawai'i 2009).

Pretty clearly, population growth is the major cause for the need for this new high school, as it probably is for many schools, community centers, sports clubs and other new public and private facilities across the U.S. As noted in Figure 1-13, its construction would entail the permanent conversion of 77 acres of open space adjacent to an existing residential community to a high school campus, i.e., built-up land.

1.6.5 Other Types of Development

The Tappan Zee Hudson River Crossing Project (bridge replacement), Environmental Impact Statement states (regarding areas near the bridge): "Between 2010 and 2047, the *populations* of Rockland and Westchester Counties *are expected to increase* by 50,000 and 134,000 residents respectively. … This *growth in population and employment* will increase daily volumes across the Tappan Zee Bridge for the next thirty years" [italics added] (FHWA 2012).

Figure 1-14. Traffic gridlock on the Tappan Zee Bridge in New York due to an accident

Public lands generally considered safe from degradation due to development still may be subject to pressure to accommodate ever more visitors. The Final Environmental Impact Statement for the Middle Kyle Complex, on a proposed visitor recreation complex in the Spring Mountains in Nevada, was prepared by the U.S. Forest Service. It states that the project is necessary because: "The rapid population growth of Clark County, Nevada, is exerting pressure on existing recreational facilities in the SMNRA…in 2008 [the population was] 1,986,146…by 2035, the population of Clark County is expected to increase to 3.6 million" (USFS, 2009).

1.6.6 Conclusion

This review of the "purpose and need" sections of a wide range of Environmental Impact Statements has looked at several major categories of development. It suggests that population growth plays an important role in generating the "need" for various kinds of developments that entail adverse environmental impacts across the United States. Attempting to better quantify the role of population growth, and specifically the role of immigration-driven population growth, are the principal focus of this EIS on U.S. Immigration Policy.

In performing this analysis and reviewing the decisions made in each case, we are reminded that the EIS process, contrary to popular opinion, does *not* require or accomplish the elimination of environmental deterioration due to most kinds of development. Rather, at best, the process may lead to more informed decision-making and a reduction in the damage from each project under consideration.

A second, related observation is that by excluding most actions and developments in the U.S. from the EIS process, federal, state and local governments systematically underestimate the environmental costs of continued development and tend to ignore the environmental ramifications of continued population growth. No effective consideration of the cumulative environmental impacts of population growth is currently required or being accomplished by any governmental entity in the United States, at local, regional, or national scales. This has important and potentially dire long-term consequences for environmental protection, quality of life, and the pursuit of ecological sustainability in America.

1.7 Scoping

Scoping is the process of soliciting input from stakeholders at the outset of a NEPA analysis. Not only may the information obtained from interested and knowledgeable parties be of value in and of itself, but the perspectives and opinions as to which issues matter the most, and how or whether the lead agency should proceed with a given

proposed action are equally important. Input from scoping thus helps shape the direction that analysis takes, helping analysts decide which issues merit consideration. Public input also helps in the development of alternatives to the proposed action, which is an integral part of NEPA.

PFIR solicited public comments at the commencement of our Environmental Impact Statement on United States immigration policy. The initial comment or “scoping” period ran from August 1 through October 31, 2012. The main policy decision to be evaluated in this EIS is the following: at what level should Congress set annual immigration into the United States?

PFIR initially proposed to undertake detailed analyses examining the likely ecological impacts of different population sizes in six key areas:

- urban sprawl and farmland loss
- water demands and withdrawals from natural systems
- greenhouse gas emissions and resultant climate change
- habitat loss and impacts on biodiversity
- energy demands and national security implications
- and the *international* ecological impacts of U.S. immigration policies.

For the scoping process, suggestions regarding which environmental impacts to focus on and which specific alternatives to analyze in depth were particularly solicited, but comments regarding any aspect of the EIS or immigration policy were appreciatively received.

PFIR received a little over two dozen formal comments on the EIS proposal. These are all reproduced at PFIR’s immigration EIS website here, unedited, followed by a response from the principle investigators *in italics*.

PFIR believes these comments are a valuable compendium showing how Americans today think about the relationship between immigration, population growth and the environment.

In a related effort, PFIR contacted approximately 3,000 environmental leaders around the country, including about 1,800 mid-level Sierra Club leaders at the state chapter and local group levels. A selection of the Sierra Club leaders’ comments regarding the EIS project can be found here.

PFIR is grateful that so many of our fellow citizens (and even one commentator from Australia) took the time to review this proposed project and provide criticism, encouragement, or suggestions for its improvement.

1.8 Issues

Significant or key issues are intended to form the basis of the NEPA analysis. In other words, they define the scope of the analysis. Once the scope has been defined, the project purpose and need and key issues govern the range of reasonable alternatives that will be considered in the environmental analysis. Alternatives must address one or more of the key or significant issues. This section presents the key issues identified during scoping.

Human population growth, whether brought about by above replacement level fertility or above replacement level immigration, affects many aspects of the human and biophysical environments. As noted above in Section 1.1, Title I of NEPA itself highlights “the profound influences of population growth” on the natural environment. For example, an increase in the U.S. population, whether driven by fertility, immigration, or both, would likely increase aggregate noise levels, soil erosion, and traffic congestion. It would tend to aggravate water quality and air quality. It would also tend to increase adverse or negative impacts on cultural and historic resources such as archeological artifacts, historic architectural properties, and landscapes of historic significance.

An example of the latter is that battlefields, cemeteries, “hallowed grounds,” and other important, irreplaceable heritage sites associated with the 1861-1865 American Civil War are being lost permanently as a result of suburban sprawl, commercial and industrial development, and transportation projects. While some sites are protected and managed by the National Park Service (NPS) as National Battlefields, National Military Parks, and National Monuments, many unprotected, privately-owned sites are at risk (NPS 2005).

Even some already protected sites, such as Manassas National Battlefield Park in Northern Virginia, location of the first major engagement in the Civil War (July 21, 1861) and a subsequent battle in August 1862, have been or continue to be threatened by population growth and associated development. In 1993, for instance, the Walt Disney Company announced its intention to build a history-based theme park called Disney's America in Haymarket, just 3.5 miles from the Manassas battlefield (Zenzen 1998). Intense opposition from prominent historic preservationists helped scuttle this scheme, but as the Northern Virginia suburbs of Washington, D.C. more and more envelop the battlefield surroundings, it inevitably loses the rural character that it possessed at the time

of those decisive battles, and Americans lose the ability to fully appreciate an important part of our history and heritage.

The EIS investigating the 500-megawatt coal-fired power plant cited above in Section 1.6.2, proposed for construction near Great Falls and the Missouri River in Montana, disclosed that this proposed action would be located within a National Historic Landmark (NHL) associated with the Lewis and Clark Expedition, the so-called Great Falls Portage NHL (RUS/MDEQ 2006). This NHL recognizes the arduous one-month portage by the Corps of Discovery around a series of waterfalls – the Great Falls – on the Missouri River in June and July 1805; it has been described as "one of the most challenging ordeals" of the two-year expedition (NPS no date). Although this area had long since been converted from short-grass prairie and scrub trampled by vast bison herds and wolf packs, their "shepherds" in Lewis' evocative term, to wheat cultivation on a grand scale, it still maintained much of its empty Big Sky character, something that would be permanently tarnished by the presence of a large industrial facility in its midst.

Despite the importance of impacts like the foregoing, this EIS focus on six other environmental topics or issues in which effects from population growth are perhaps even more salient and at least to some extent quantifiable. These issues are addresses briefly in turn.

1.8.1 Urban Sprawl and Loss of Farmland

Each one of the 318 million residents who live in the United States as of mid-2014 directly or indirectly uses and/or is supported by a vast array of facilities and infrastructure, all of which occupy area and space, in other words – land. These facilities and infrastructure may be categorized as follows:

- Residential – detached single-family dwellings; townhouses; condominiums; apartments (low and high-rise); dormitories; managed, affiliated landscapes such as lawns, gardens, patios, plazas, and decks; etc.

- Transportation – driveways; surface streets; sidewalks; bicycle paths; bridges; freeways; interstates; interchanges; tunnels; highways; rural roads; service roads; parking structures; parking lots; airports and air strips; train tracks; bus and train stations; canals; ports; etc.

- Commercial/Institutional – Educational (K-12 schools, universities, institutes, academies); office buildings (public and private sector); hospitals and clinics; libraries; outdoor plazas; commercial districts; shopping malls and centers; museums; zoos; etc.

- Industrial – Factories and manufacturing plants; power plants; petrochemical facilities; sewage treatment plants; industrial parks; warehouses; waste management; landfills; etc.

- Utilities – Power lines (transmission and distribution) including towers; electrical substations; hydroelectric facilities; solar photovoltaic and thermal solar facilities; above and underground cables for TV, telephone, Internet, and other communication; cell phone and other communications towers; broadcast facilities, pipelines carrying water, wastewater, natural gas, and oil; flood control facilities; etc.

- Provision of Raw Materials and Extractive – Mines; quarries; gravel pits; water supply dams and reservoirs; etc.

- Recreation and Sports – Stadiums; arenas; coliseums; golf courses; tennis courts; sports fields (football, soccer, baseball, lacrosse, etc.); marinas; recreational ponds and lakes; fitness centers; etc.

This is not intended as an exhaustive list, but rather to convey the reality that each American resident is directly or indirectly connected to a large, diverse number of built facilities, each of which consumes land and takes up space. As U.S. population grows, the land area occupied by facilities and infrastructure that support each of us in our various roles as residents, students, consumers, commuters, workers, spectators, and recreationists would *a priori* be expected to increase as well.

Two extensive land uses or land cover types that are not listed above are forested lands (both public and private) and agricultural lands or farmland, all of which is privately owned, and which includes cultivated cropland, pastureland, and rangeland. These are excluded from the above listing because both forestland and farmland are considered open space and both provide amenities to the public as such. However, this is not to ignore that managing and harvesting forestland and farmland both have substantial, widespread environmental impacts in and of themselves. Nonetheless, both forestland and farmland are being displaced by built-up or developed land, because of the higher economic value of developed land per acre.

Two federal agencies have extensive datasets that allow investigators to calculate the rate of land conversion due to sprawl and development over a number of decades, and to correlate this with population growth. The two agencies are the U.S. Census Bureau (USCB) and the Natural Resources Conservation Service (NRCS) within the U.S.

Department of Agriculture (USDA). NRCS is the same agency that was formerly known as the Soil Conservation Service (SCS).

1.8.2 Habitat Loss and Impacts on Biodiversity

As noted in the previous section, every existing American and every new American use space, area, and natural resources. The production and consumption associated with each American consumer invariably impinge to some extent on natural habitats and ecosystems. These effects may take the form of completely eliminating natural habitats altogether, to make way for artificial or synthetic environments, e.g., residential, commercial, or industrial development. They can also take the form of intensively modifying natural habitats, which is what happens when forests are cleared for crop cultivation, pasture, or grazing, or when a watercourse and adjacent riparian habitat (e.g., bottomland hardwood forest or swamp) are converted to open water (i.e., a reservoir) when a dam is constructed and free-flowing water is impounded behind that dam. Another form of intensive habitat modification, as distinct from elimination, is conversion of native tallgrass or shortgrass prairie, dominated by perennial grasses, forbs, and herbs, to cultivated cropland, pasture, or rangeland. Yet another form is alteration and/or degradation of forest habitat by timber harvest, whether by clearcutting (removal of every woody tree trunk above a certain size) or selective harvest (removal of certain designated trees on the basis of size, species, form, or other characteristic).

Just as terrestrial habitats can be eliminated altogether or intensively modified, aquatic habitats such as streams, rivers, ponds, lakes, wetlands (e.g., bogs, marshes, swamps, vernal pools, wet prairies, muskegs, sloughs) can be as well. They can be filled in, dredged, channelized, armored (for flood control or bank protection), polluted, and subjected to hydrological and hydraulic modifications. Each of these actions affects the abundance, composition, and diversity of aquatic flora and fauna.

Wild flora and fauna (plants and animals) both comprise and reside in natural communities and ecosystems. In general, in terrestrial as opposed to aquatic settings, plant communities constitute habitats. Habitats in turn provide homes for wild animals, or wildlife, furnishing the three fundamental resources all wild animals must have to survive: 1) food; 2) water; and 3) cover. The types of natural habitats that evolve and persist over time in an area are a function of its climate, in particular seasonal precipitation and temperature patterns, its soils, and its topography. All of these features interact with one another. For example, soils and vegetative cover on steep slopes, if they occur at all, depend to be shallower (soils) and less robust (vegetation) because steeper slopes are more subject to gravity and erosion. Populations and communities of wildlife in turn evolve in particular habitats and depend on them for their survival. Healthy and

abundant habitats are directly linked to the size, vigor, and diversity of the wildlife populations they support.

Thus, whenever human beings eliminate or extensively modify habitats in pursuing economic activities related to our own survival, well-being, and prosperity, it results in direct and indirect impacts on natural habitats, and the wild flora and fauna that constitute and inhabit them. A human population's size and its spatial distribution are two key determinants of what impacts to habitats and biodiversity will be.

Biodiversity is short for biological diversity, which means the diversity, or variety, of wild plants and animals and other simpler organisms (neither plants nor animals) living in a particular region. Biodiversity also refers to the number or abundance of different species or higher taxa (genera, families, etc.) found within a particular region (California Biodiversity Council 2008). The Global Biodiversity Strategy defines biodiversity as the "totality of genes, species, and ecosystems in a region" (WRI et al. 19992). Harvard University Professor Emeritus of Entomology Edward O. Wilson, sometimes regarded as the "father of biodiversity," has written: "It is reckless to suppose that biodiversity can be diminished indefinitely without threatening humanity itself" (Wilson 1992). In a 1998 letter to the president of the Sierra Club, Wilson also wrote: "I have come to believe that population is so salient a factor in the future of the environment, and especially of biodiversity, that it should be faced squarely and openly whenever possible" (Wilson 1998).

1.8.3 Water Demands and Withdrawals from Natural Systems

Each person in the United States directly uses many gallons of potable (drinking quality) water every day for indoor domestic purposes, including drinking, food preparation, bathing, washing dishes and laundry, and flushing toilets. Exterior uses of municipal water in residential areas include irrigation for lawns and landscaping as well as ornamental and vegetable gardens. While there is a considerable variation from the drier to the wetter regions of the country (especially for outdoor uses), and between urban and suburban residential neighborhoods, per capita (per person) water use approaches 100 gallons per day.

Each day, the average American household uses more than 300 gallons of water at home. About 70 percent of this use takes place indoors, while outdoor water use accounts for 30 percent of household use. However, this percentage can be much higher in more arid regions as well as in more water-intensive landscapes. As a result of landscape irrigation, the dry West has some of the highest per capita residential water use.

Total per capita water use in the U.S. also includes indirect water use, that is, water withdrawn from surface and groundwater sources and used by agriculture, industry, institutions and businesses. These uses are vital to our economy, standard of living, and societal well-being.

"Water withdrawal" is distinct from "water consumption." The former is that which is extracted from surface and groundwater supplies, while the latter is that portion of the extracted water which is used up in the act of consuming it. Consuming this water, as opposed to merely using it, means it is permanently removed from the immediate hydrologic environment (e.g., a given river, lake, or aquifer). This removal typically takes the form of evaporation, transpiration, or incorporation into crops and products. "Return flow" is that portion of a water withdrawal that is actually not consumed, but is instead returned to a surface or ground water source from a point of use (EPA 2004). Return flow thus becomes available for additional use, although the water quality of return flows is often altered or compromised, requiring treatment.

According to the U.S. Geological Survey (USGS), approximately 410,000 million gallons per day (Mgal/d) of water was withdrawn for use in the United States during 2005, or about 1,414 gallons for each resident of the country. About 80 percent of these withdrawals were from surface water, and 20 percent from groundwater. About half of all these withdrawals were used for cooling in thermoelectric (coal and nuclear) power plants. Cooling is an example of a largely non-consumptive water use, so that most of this water was returned at a higher temperature to the water bodies from which it was withdrawn.

Withdrawing water from lakes, streams, and rivers frequently has significant effects on hydrology and aquatic ecology. Streams and rivers are often dammed to form reservoirs, or artificial lakes, which impound and store large volumes of water that can be withdrawn on demand for municipal use, crop irrigation, or industry. When a watercourse is dammed, not only is the area within the footprint of the impoundment permanently altered, but downstream reaches are as well, due to overall flow reduction, reduction or elimination of flooding and seasonal flow "pulses", changes in water temperature, stream bank and bed erosion patterns, and so forth.

When excessive quantities of water are removed from a river, or when its entire annual flow is claimed by holders of water rights, it is said to be "over-allocated." The Colorado River, the Rio Grande, and the Platte River are examples of rivers in this stressed condition.

A serious commitment to water conservation, efficiency, and reuse through a variety of methods and technologies can reduce human pressures on natural aquatic ecosystems. However, continuing population growth can more than offset or negate any gains from water conservation, efficiency and reuse.

1.8.4 Carbon Dioxide Emissions and Resultant Climate Change

The Intergovernmental Panel on Climate Change (IPCC) issued its Fifth Assessment Report in September 2013, concluding that "human influence on the climate system is clear" and that "warming in the climate system is unequivocal" (IPCC 2013a).

The IPCC states it is "extremely likely" that human influence has dominated observed global warming since the middle of the 20th century. More and better observations, improved understanding of climate system responses, and improved climate models have provided the evidence to support this conclusion. Concentrations of greenhouse gases have increased, global mean sea level has risen, the atmosphere and ocean have both warmed, and the amount of snow and ice has diminished (IPCC 2013a).

The Fifth Assessment projects the global surface air temperature increase from the 1850-1900 baseline to exceed 1.5°C (2.7°F) by 2100 in all but the lowest scenario considered; it is likely to surpass 2°C (3.6°F) for the two high scenarios. Heat waves will probably occur more frequently and last longer. Currently wet regions will receive even more rainfall, while currently arid regions such as the American Southwest are likely to receive even less precipitation. Global mean sea level will continue to rise, but at a faster rate than in the 20th century. As a result of humankind's past, present and expected future emissions of carbon dioxide (CO_2), the main greenhouse gas, the Earth is committed to climate change; effects of this change will persist for many centuries even if emissions of CO_2 were to stop tomorrow (IPCC 2013a).

While climate change is a global phenomenon, individual countries vary considerably both in their contribution to it and in the extent to which they are being and will be affected by it. The main source of anthropogenic CO_2 emissions is the combustion of fossil fuels – coal, oil, and natural gas. The large population and relative prosperity of the United States are underpinned by the consumption and combustion of these fossil fuels on a prodigious scale. In one recent year alone (2006), Americans burned 1.1 billion tons of coal, 7.6 billion barrels of petroleum, and 21.6 trillion cubic feet of natural gas (EIA 2007a, EIA 2007b, EIA 2008).

A fundamental consequence of the chemical combustion of coal, oil, and natural gas to generate electricity, propel vehicles, and heat buildings is the emission of CO_2 into the surrounding air and the atmosphere as a whole. Total U.S. emissions of CO_2 were the

highest in the world for the entire 20th century. However, after three decades of explosive economic growth, in 2006 China's aggregate CO_2 emissions surpassed those of the United States (Anon. 2007). While China's per capita CO_2 emissions were still only a fraction of America's, its large population (1.3 billion – four times the U.S. population) boosted its aggregate emissions to overtake those of the U.S.

In recent years U.S. per capita CO_2 emissions have held steady and the rise in overall U.S. emissions has been entirely due to population growth. Carbon emissions in the United States from fossil fuel combustion grew by almost 13 percent from 1990 to 2000. U.S. population grew by almost an identical amount — slightly over 13 percent in the same decade. Thus, the increase in greenhouse gas emissions closely matched the increase in population (Kolankiewicz 2002). In other words, emission increases were related to population growth, not rising per capita emissions.

More recently, the EPA reported that, "between 1990 and 2010, the increase in CO_2 emissions corresponded with increased energy use by an expanding economy and population, although the economic downturn starting in 2008 influenced the decrease in emissions in 2009" (EPA 2012a). Similarly, the U.S. Department of State, in projecting future emissions, noted: "These rising absolute levels of CO_2 emissions occur against a background of growing population and GDP" (U.S. Dept. State 2007).

Population size/growth is clearly one of the key factors determining aggregate CO_2 emissions. Indeed, population is one of the two primary causes of CO_2 emissions (Cafaro 2012). In its Fourth Assessment Report, the IPCC stated:

> GDP/per capita and population growth were the main drivers of the increase in global emissions during the last three decades of the 20th century….At the global scale, declining carbon and energy intensities have been unable to offset income effects and population growth and, consequently, carbon emissions have risen (IPCC 2007).

Thus, the future size of the United States population, which will largely be determined by immigration policy, will have a substantial bearing on future U.S. greenhouse gas emissions, particularly those of CO_2.

1.8.5 Energy Demands and National Security Implications

The United States is the third most populous country on Earth, following China and India (PRB 2013). The U.S. has the largest economy of any nation-state in the world, with a Gross Domestic Product (GDP) of $16.2 trillion in 2012, twice the size of second-place China and three times the size of third-place Japan (U.N. 2012).

It takes an enormous amount of energy to maintain our large population at a high standard of living or GDP. At present, annual primary energy consumption in the U.S. is approximately 100 quads or 100 quadrillion British thermal units (Btu's) (EIA 2014), or 95 exajoules (EJ's). In 2011, total per capita energy consumption) in the U.S. was 312 million Btu's, 13% less than the per capita consumption in 1978, which was the highest since 1949. World per capita consumption of energy in 2010 was 74 million Btu's, or about one-quarter (24%) of American per capita consumption (EIA 2013a).

With the size of both the U.S. population and economy continuing to grow, ever greater quantities of energy and/or ever higher levels of energy efficiency are required to maintain this growth. Both population and primary energy consumption are projected to grow as far as demographers and energy forecasters care or dare to peer into the future.

A country's energy intensity is defined as the amount of energy consumed per unit GDP. In the United States, it is measured as primary energy per real dollar of GDP. According to the U.S. Energy Information Administration (EIA) in the U.S. Department of Energy, energy intensity in the U.S. has been decreasing steadily since the early 1970s. From 1950 to 2011, U.S. energy intensity declined by 58% per real dollar of GDP. It continues to decline in EIA's long-term projection to 2040. Reduced energy intensity in the U.S. is due to greater efficiency and structural changes in the economy (EIA 2013b).

About 82 percent of primary U.S. energy consumption is from the combustion of the three fossil fuels (EIA 2012a) – oil (36% of total primary energy), natural gas (26%), and coal (20%). Most of the natural gas and coal the U.S. consumes is produced domestically. Oil, however, is another matter. Domestic oil production peaked in 1970, but domestic consumption continued to generally increase (except during the "energy crises" of 1973-74 and 1979-80 when oil prices spiked) until about the 2008 recession, and the difference was made up by growing oil imports. Figure 1-15 shows the growth in imports of crude oil from the mid-20th century into the past decade.

Btu's, Quads, Joules and Exajoules

Btu's, quads, joules and **exajoules** are all units of energy.

A **Btu** or British thermal unit is the amount of heat needed to raise the temperature of one pound of water at maximum density by one degree Fahrenheit; one Btu is equivalent to 1.055×10^3 (1,055) joules.

One **quad** equals one quadrillion (1,000,000,000,000,000 or 10^{15}) Btu's.

A **joule** (J) is a derived unit of energy, work or heat in the International System of Units. One J is the energy expended in applying a force of one newton (N) a distance of one meter (m).

An **exajoule** (EJ) is equal to one quintillion (10^{18}) joules

U.S. crude oil imports increased swiftly from the mid-20th century until the late 1970's but then fell sharply from 1979 to 1985, as a result of price hikes on the international market due to political turmoil in the Middle East. Crude oil imports resumed increasing from 1985 to 2005, and reached an all-time high of 10.1 million barrels per day in 2005. In 2011, crude oil imports averaged 8.9 million barrels per day, compared to 5.7 million barrels per day of domestic crude oil production.

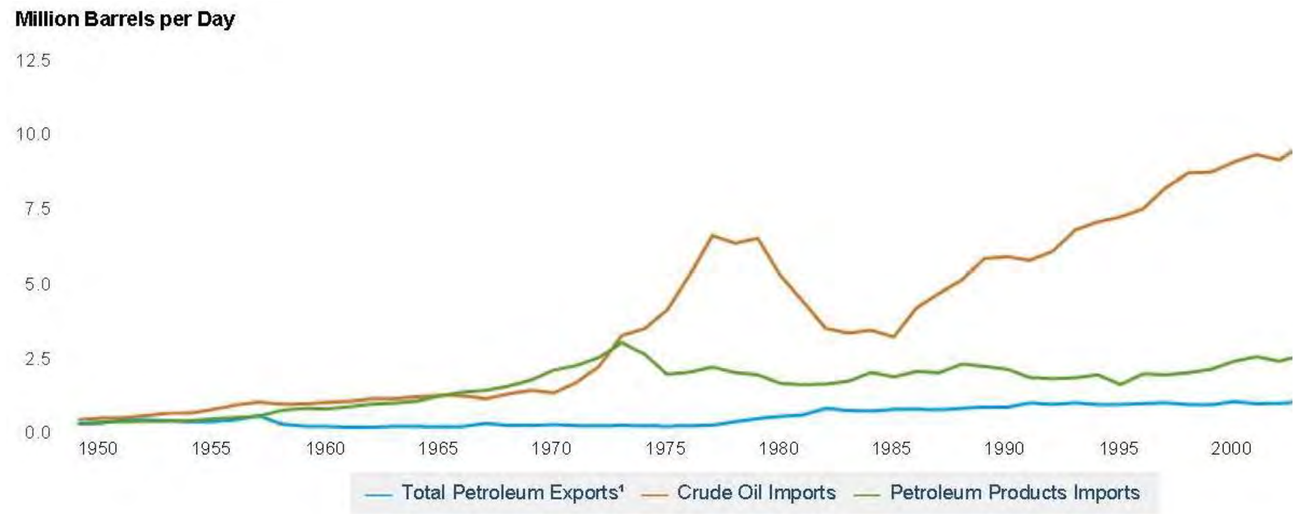


Figure 1-15. U.S. petroleum imports and exports, 1949-2011

The U.S. relied on net imports (imports minus exports) for about 40 percent of our petroleum (crude oil and petroleum products) consumption in 2012. Our dependence on foreign sources of oil has declined from its 2005 peak of over 50 percent, due to an increase in domestic production from hydraulic fracturing and related technologies and greater fuel efficiency. The top five countries upon which we rely for net crude oil and petroleum product imports are Canada (28% of net imports), Saudi Arabia (13%), Mexico (10%), Venezuela (9%), and Russia (5%). While each of these exporting countries have proved reliable commercial partners for years, considerable political, geopolitical, or cultural tensions exist between the U.S. and least three of them (EIA 2013c). American vulnerability to global price shocks and volatility, long-term price increases related to "peak oil" (i.e., declining production of relatively inexpensive conventional crude oil and declining exports as exporting nations consume more of their own output) and the potential for geopolitical instability to disrupt supply flows remain significant concerns.

Correlated with increasing energy demand are increasing environmental impacts from energy production and consumption. All forms of energy production entail a wide variety of environmental impacts, ranging from habitat destruction and fragmentation, to

acid mine drainage, localized air and water pollution, mortality of birds and bats (at wind farms), oil spills, and permanent alteration of landscapes from surface coal mining or mountaintop removal. Energy consumption often affects the environment as well, causing air pollution from tailpipe exhaust and power plant emissions, release and deposition of the toxic heavy metal mercury, and even water pollution from emissions of nitrogen oxides, which contribute to eutrophication of water bodies like Chesapeake Bay.

1.8.6 International Ecological Impact of U.S. Immigration Policies

A large and growing U.S. population affects the natural resources and environment not just of the United States territory itself but of territories, lands, resources, environments and peoples in other countries and continents. Many of the resources used by American consumers originate overseas and are imported into the U.S. as part of international trade. One example all Americans are familiar with is crude oil: America is the largest importer of crude oil in the world. In the late 2000s we were importing over 400 million barrels every month, over five billion barrels in 2005 alone (EIA 2013d). (By 2013 this had dropped to about 300 million barrels/month as a result of declining domestic demand due to the recession and improved fuel efficiency as well as a result of increased crude oil production domestically from fracking and horizontal drilling.)

Producing and transporting that oil has well-known and well-documented environmental impacts and risks (Figure 1-14). The United States also imports many other raw materials and processed or manufactured goods that originate in other countries. For about a decade until 2013, when Molycorps's mine reopened in Mountain Pass, California, the U.S. was importing, primarily from China, nearly all of 17 rare earth metals, used in a variety of new energy technologies, especially wind and solar, as well as in national security applications (Humphries 2013). Extracting and refining these ores is very polluting. A number of communities in China now face a legacy of substantial environmental contamination left behind by two decades of almost unregulated mining and processing of rare earth ores, and the Chinese government has begun spending the billions of dollars it will cost to clean up this contamination (Bradsher 2013).

Nearly all of the bauxite ore consumed in the U.S. to make aluminum is imported (Kelly 2002), 11 million tons of it in 2012; 90 percent of these imports come Jamaica, Guinea, Brazil and Guyana (USGS 2013).

While these commodities meet U.S. needs and provide jobs and income to exporting nations, many of which are developing countries, there are associated environmental impacts. In a very real sense, Americans "outsource" the pollution and environmental damage associated with a large amount of drilling, mining, manufacture, and harvesting

that supports our domestic consumption. More Americans will result in rising demand for imports and more impacts in those countries that export to us.

Figure 1-16. Thousands of loaded oil tankers ply the world's oceans daily but occasionally they don't reach their destinations

Similarly, U.S. consumption itself, primarily of the fossil fuels, releases large amounts of carbon dioxide that are contributing to climate change and concomitant widespread ecological effects around the biosphere.

Overall, an ever larger number of American consumers will generate ever larger international ecological effects from both production and consumption, although these effects need not be proportional if Americans can continue to improve resource and energy efficiency and intensity. One means of measuring the overall ecological impacts of a given population of consumers that has gained widespread acceptance and application over the last two decades is the Ecological Footprint (EF).

EF is a measure of the load that aggregate human demands impose on the biosphere, or "ecosphere." EF compares the demands of the human economy, or subsets of it, with the Earth's (or a given country's) ecological capacity for regeneration and renewal, that is, its "biocapacity." EF represents the amount of biologically productive land and water area needed to regenerate the renewable resources a given human population consumes and to absorb and render harmless, or assimilate, the corresponding waste or residuals it generates. The global EF now exceeds global biocapacity by some 50 percent (GFN

2011), which is not a sustainable situation over the long run; it means we are drawing down "natural capital" and running up an "ecological debt" (Kolankiewicz 2010).

Immigration is increasing America's population size and thus our national EF, forcing the United States deeper into ecological debt. If global per capita consumption of resources equaled American per capita consumption, humanity would need 4.05 earths to provide adequate biocapacity; in other words, the aggregate ecological footprint would be 4.05 earths (GFN 2012).

Chapter 2
ALTERNATIVES INCLUDING THE PROPOSED ACTION

2.1 Introduction

A crucial aspect in conducting an adequate environmental impact statement is properly selecting the alternatives for detailed analysis and comparison (CEQ 1981, Yost 1995, Eccleston 1999). Early in this investigation, the preparers determined that the alternatives to be studied and compared in depth would be specified primarily in terms of the annual immigration levels set under each alternative.

Making immigration policy involves other choices besides the overall level of immigration. These include the percentage of immigrants allotted to various "sender" countries, the skill and education levels desired, when and whether to grant citizenship to new arrivals, the parameters of a fair and just refugee policy, and more. These are important questions. However, there is no evidence that how they are answered makes a significant difference regarding the ecological issues that are the focus of this study. For example, there is no evidence that where immigrants come from significantly decreases or increases their U.S. descendants' energy or resource consumption levels.

Regarding environmental impacts, the key issue appears primarily to be one of numbers. Therefore, this EIS focuses on two primary questions: How will annual immigrant numbers influence <u>total</u> population numbers now and in the future? How are different future population numbers likely to affect a full spectrum of ecological impacts (including water withdrawals, sprawl development, greenhouse gas emissions, and loss of threatened and endangered species)?

For similar reasons, vexing questions regarding how to manage illegal immigration are not directly addressed in this study. For the purposes of the alternatives considered, <u>legal and illegal immigrants are treated equally</u>, with the analytic focus on <u>total</u> annual immigration, to which both legal and illegal immigration contribute. From both a demographic and ecological perspective it makes little difference whether immigrants are in the country legally or illegally, particularly since the children of illegal immigrants born in the U.S. are granted automatic U.S. citizenship.

Of course, choices regarding how to manage illegal immigration may have important demographic consequences. Illegal immigration probably accounted for between one-fifth to one-third of total immigration into the U.S. during the past three decades (Lytwak 1999, Camarota 2011, Pew Hispanic Center 2013a). Nevertheless, the alternatives in this study will be specified in terms of total annual immigration, with no consideration given to the percentages of legal and illegal immigration that might make up that total.

2.2 No Action Alternative

According to the National Environmental Protection Act (NEPA), every federal EIS must include a "no action" alternative in its detailed analysis. This is to ensure that the well-known managerial bias in favor of "doing something" does not lead to inadvisable actions, when doing nothing (or continuing to do whatever we are currently doing) would actually be preferable. For this EIS, the no action alternative is defined as a continuation of status quo immigration policies.

In recent years, legal immigration into the United States has averaged around 1.1 million people annually (Office of Immigration Statistics 2012). However, half a century of relative tolerance for illegal immigration (shown in widespread condemnation of enforcement efforts, periodic amnesties and grants of legal residence to illegal immigrants, and the continuation of "birthright citizenship" long after many nations around the world have discontinued it) suggests that illegal immigration's contribution to total immigration numbers should be treated as part of the political "status quo."

Illegal immigration is difficult to quantify. Having soared to perhaps half a million annually by the late 1990s, it dropped sharply after the 2007 recession, to perhaps a few hundred thousand net (Pew Hispanic Center 2013, Passel et al. 2012). However, by mid-2013 the rate of illegal immigration may have begun to increase again (Passel et al. 2013). Figure 2-1 provides an estimate of the growth in the population of unauthorized immigrants from 1990 to 2012. Estimating conservatively that illegal immigration has averaged 150,000 people annually over the past five decades, we add 150,000 to our baseline of 1.1 million annual legal immigrants. This sets the no action alternative at an annual immigration rate of 1.25 million.

2.3 Reduction Alternative (Proposed Action)

The proposed <u>reduction alternative</u> sets annual net immigration at 250,000. This represents a substantial (about 80%) decrease from current numbers, but not an impossible one. Assuming conservatively 100,000 annual emigrants <u>from</u> the U.S., this alternative would allow 350,000 annual immigrants <u>into</u> the country (for a total of

250,000 net immigration). Based on recent figures, 350,000 would be enough to fulfill the United States' moral responsibility to provide asylum for legitimate political refugees, to provide citizenship for foreign-born spouses and adopted children of American citizens, and to leave some spots open for immigrants with exceptional abilities to enter the United States on work-related visas.

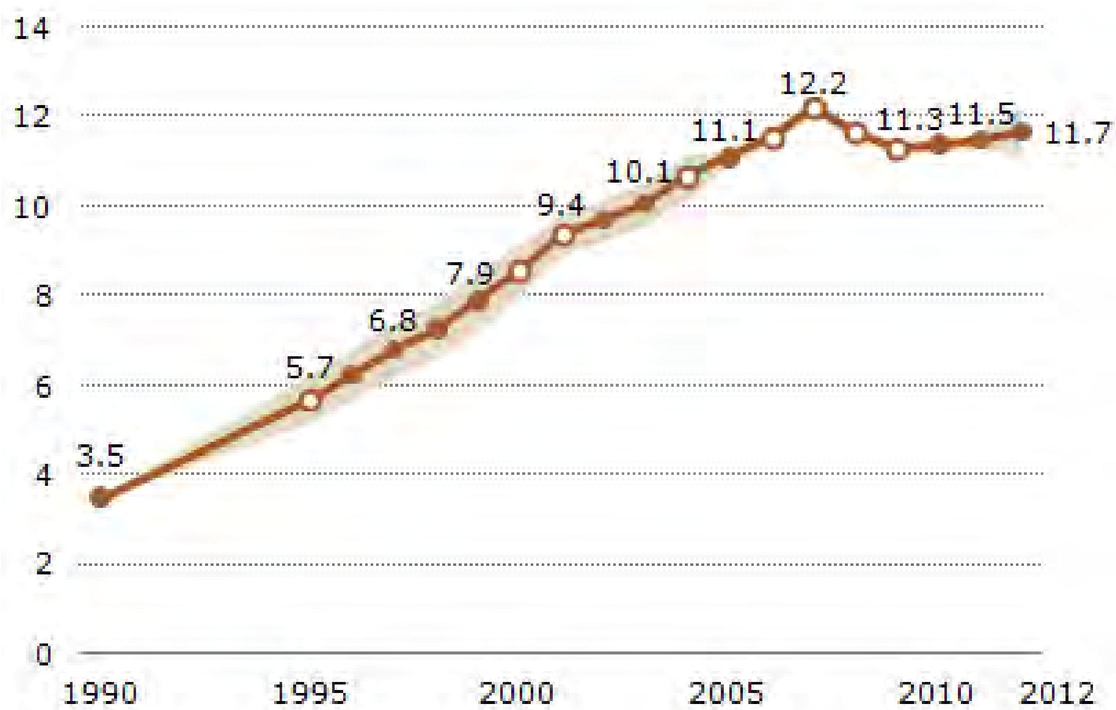


Figure 2-1. Estimates of the U.S. unauthorized immigration population, 1990-2012
Source: Pew Research Center (2013b).

While 250,000 net immigration is far below current immigration numbers, those numbers are the highest in U.S. history. One quarter of a million or 250,000 was approximately the annual immigration level for the four decades between 1925 and 1965, the "Great Pause" between the two "Great Waves" of mass immigration into the U.S.[1] It is actually a little higher than the average annual immigration over the entire history of the United States (Graham 2004). For these reasons, 250,000 net annual immigration is considered a reasonable alternative for analysis and is set forth as the proposed action.

2.4 Expansion Alternative

The proposed expansion alternative sets annual net immigration at 2.25 million. This represents a substantial (approximately 80%) increase over current numbers, but again, not an impossible one. Considerable pent-up demand exists around the world for

immigration into the United States; in recent years, the annual green card "diversity lottery" has garnered over 10 million applications to fill its 50,000 slots. Many millions of relatives of U.S. citizens and residents would welcome the opportunity to immigrate into the U.S. if it were made available.

2.25 million annual net immigration also has salience in terms of recent policy proposals. Some analyses of the "Secure Borders, Economic Opportunity and Immigration Reform Act of 2007" (S. 1348), co-sponsored by Senators Kennedy and McCain, asserted that it would have pushed annual immigration above two million. Recent "comprehensive immigration reform" proposals by the Obama administration and legislation drafted by the bipartisan "Gang of Eight" in the U.S. Senate – the Border Security, Economic Opportunity, and Immigration Modernization Act of 2013 (S. 744) – both advocate substantial increases over current immigration numbers (through legalizing illegal immigrants, greatly increased worker visa numbers, new "guest worker" programs, expedited "family reunification" programs, and additional means). A number of analysts and advocates claimed S. 744 would double current legal immigration levels (ATB 2013).

While 2.25 million may be too high a number for what this legislation or other proposals would lead to, it could just as easily be too low. In the projections made by the U.S. Census Bureau in 2000 to the year 2100, net migration in the "highest series" projection was considerably higher than 2.25 million (Hollmann et al. 2000) – ranging from 2.3 million in 2025 to 3.0 million by 2100. Thus, 2.25 annual net immigration into the U.S. is a reasonable alternative for analysis.

2.5 Population Projections to 2100

The <u>three main alternatives for detailed analysis</u> in this EIS are therefore the following:

- 250,000 annual net immigration into the U.S. (the proposed action and reduction alternative);
- 1.25 million annual immigration into the U.S. (the "no action" alternative); and
- 2.25 million annual immigration into the U.S. (the expansion alternative).

Initial population projections have been prepared for these three selected alternatives using the cohort-component method, the standard method used by demographers for national population projections (O'Neill, et al. 2001). In the cohort-component method, one starts with a certain size population with a particular age-structure (determined, in these projections, by the 2010 U.S. Census). Then one takes that population forward in time as it responds to four key factors: births (fertility), deaths (mortality), immigration,

and emigration. These last two factors are sometimes combined as “migration” or “net migration.”

As described in Chapter 1 (Section 1.5.5), this EIS utilizes a projection tool developed by Decision Demographics, Inc. and the Center for Immigration studies. As noted, these researchers replicated the model created by the U.S. Census Bureau for its 2008 and 2009 population projections (Camarota 2012, Tordella, et al. 2012). The resultant projection tool allows users to vary fertility levels and immigration levels; hence, it can take into account the Census Bureau’s revised 2012 projections. Use of the D.D./C.I.S. projection tool allows the EIS to ground its projections in the best available demographic data.

In creating the population projections for this EIS, fertility and mortality rates were held steady under all three alternatives, at the levels predicted by the U.S. Census Bureau in its 2008 projections. The rationales for these particular fertility and mortality rates may be found in the methodology statement for the Census Bureau’s 2008 projections, which should be compared to that for the Bureau’s 2012 projections (USCB 2008a, USCB 2012b). Then the proposed changes from current net immigration levels were phased in over six years, starting in 2014 and ending in 2020. After 2020, annual net immigration levels were held steady at 250,000, 1.25 million and 2.25 million, respectively, out to 2100. Table 2-1 shows the population projections for the three EIS immigration scenarios – the reduction alternative (250,000 net), the no action alternative (1.25 million net), and the expansion alternative (2.25 million net) – generated by this method.

Table 2-1. Population projections to 2100 of the three immigration scenarios used in this EIS

Average annual net migration	U.S. population in 2010	U.S. population in 2050	U.S. population in 2100
250,000	309 million	369 million	379 million
1.25 million	309 million	415 million	524 million
2.25 million	309 million	460 million	669 million

Figure 2-2 displays, in graphic form, the population projections to 2100, under the three immigration rate scenarios or alternatives selected for analysis in this Environmental Impact Statement.

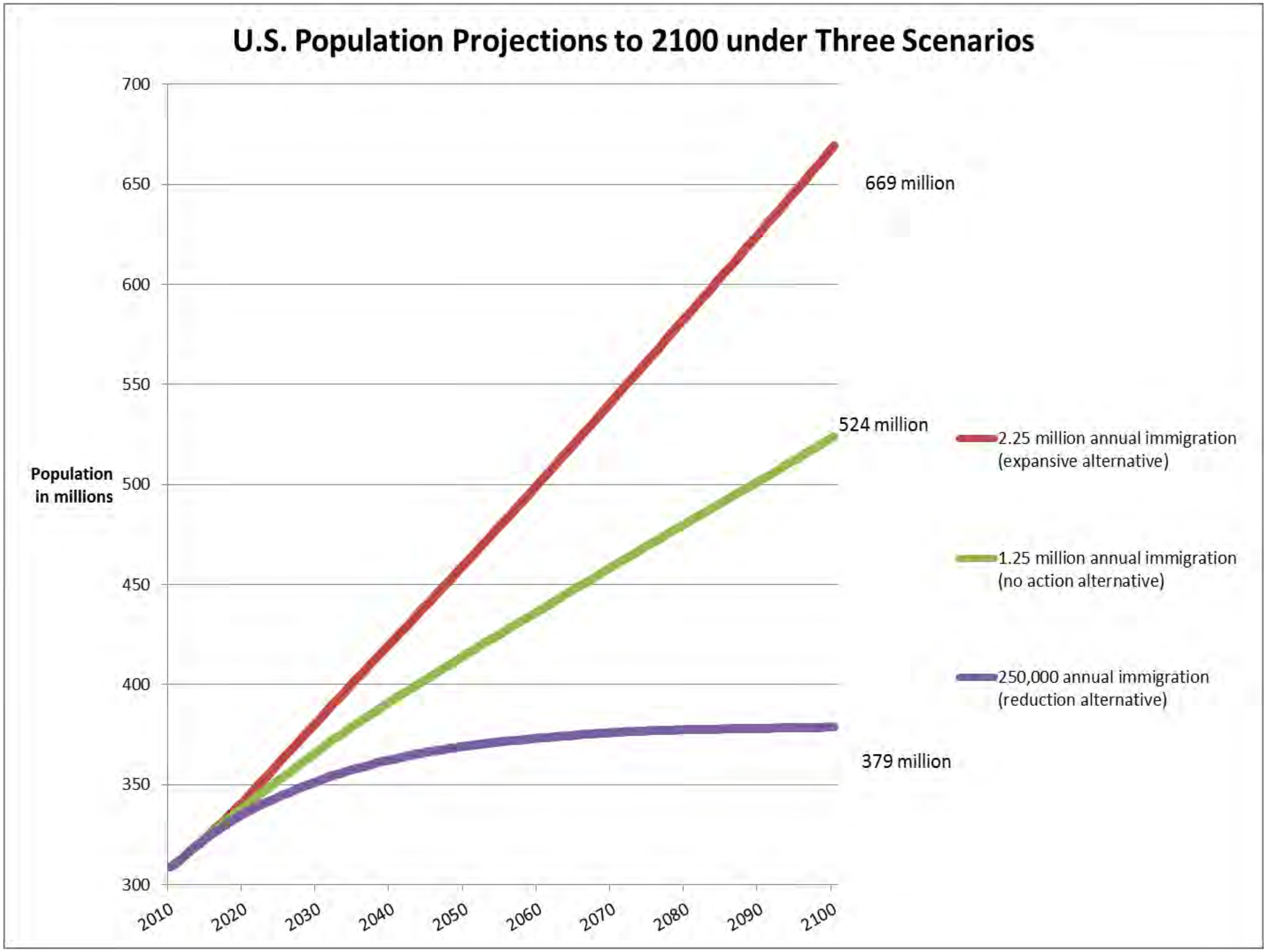


Figure 2-2. U.S. population projections to 2100 under the three immigration scenarios or alternatives used in this EIS

As can readily be seen, the population projections under our three alternatives point to three very different demographic futures for the United States. Most obviously, population grows by 70 million people over the course of the 21st century under the proposed action (reduced immigration alternative), by 215 million people during this same period under the no action alternative, and by 360 million people under the expansive immigration alternative.[2] This corresponds to a 23% population increase, a 70% population increase and a 117% population increase over the 2010 population, respectively. Perhaps just as important, while population stabilizes toward the end of the century under the reduced immigration alternative, under both the status quo or no action alternative and the expansive alternative, America's population trajectory in 2100 would likely ensure continued, substantial population growth far into the 22nd century.[3]

2.6 Population Projections to 2200

This EIS will analyze the potential ecological impacts of the three selected alternatives out to 2100. Focusing narrowly on impacts over a few decades, while perhaps appropriate for EIS's that analyze individual or relatively small-scale projects of limited scope, seems too short-sighted to provide a useful analysis of national population policy, most of the effects of which are cumulative. On the other hand, considering ecological impacts beyond 2100 has been judged too speculative. Over the course of nearly two centuries, there are just too many variables, imponderables, and feedbacks – ecological, social, and technological – that can appear or intervene over time in complex systems and completely alter the course of trajectories. (In the vernacular, these are sometimes dubbed "wild cards" or "game changers.")

Nevertheless, whether the U.S. population is closer to a quarter billion people or a billion people over the course of the 22nd century would make a significant difference to the environmental future of the United States and indeed perhaps the world as a whole. Thus, it is worth at least seeing where current or alternative demographic trends would take the U.S. were they to actually continue to the year 2200. Indeed, since the earliest days of its settlement more than three centuries ago, the country has experienced almost constant, if not steady, population growth in spite of extraordinary technological, social, and cultural changes that would have been virtually unimaginable to the earliest colonists, settlers, or the Founders of the late 18th century.

The speculative population projections out to 2200 below are provided for those interested in the longer-term demographic implications of the three alternatives under investigation in this EIS. These near-200-year projections were made by piggybacking onto the 90-year population projections for the three main alternatives.

Table 2-2. Existing population in 2010 and projected populations in 2100 for three immigration scenarios

Three Alternatives	Population in 2010	Population in 2100
Reduced immigration alternative (250,000 annual immigration)	309 million	379 million
No action alternative (1.25 million annual immigration)	309 million	524 million
Expansive immigration alternative (2.25 million annual immigration)	309 million	669 million

Next the percentage rate of population growth was calculated for the decade 2090-2100 under each of the three alternatives.

Table 2-3. Percentage population growth in 2090-2100 decade for three immigration scenarios

Three Alternatives	Percentage population change, 2090-2100
Reduced immigration alternative (250,000 annual net immigration)	+ 0.2%
No action alternative (1.25 million annual net immigration)	+ 4.2%
Expansive immigration alternative (2.25 million annual net immigration)	+6.6%

In the final step, the rate of growth from 2090 to 2100 under each alternative was projected out for another hundred years, applying it to the given populations under each alternative. This resulted in the population projections to 2200 shown in Table 2-4 and Figure 2-3.

Table 2-4. Population projections to 2200 of the three immigration scenarios used in this EIS

Three Alternatives	Population in 2010	Population in 2100	Population in 2200
Reduced immigration alternative (250,000 annual immigration)	309 million	379 million	386 million (0.386 billion)
No action alternative (1.25 million annual immigration)	309 million	524 million	801 million (0.801 billion)
Expansive immigration alternative (2.25 million annual immigration)	309 million	669 million	1,298 million (1.298 billion)

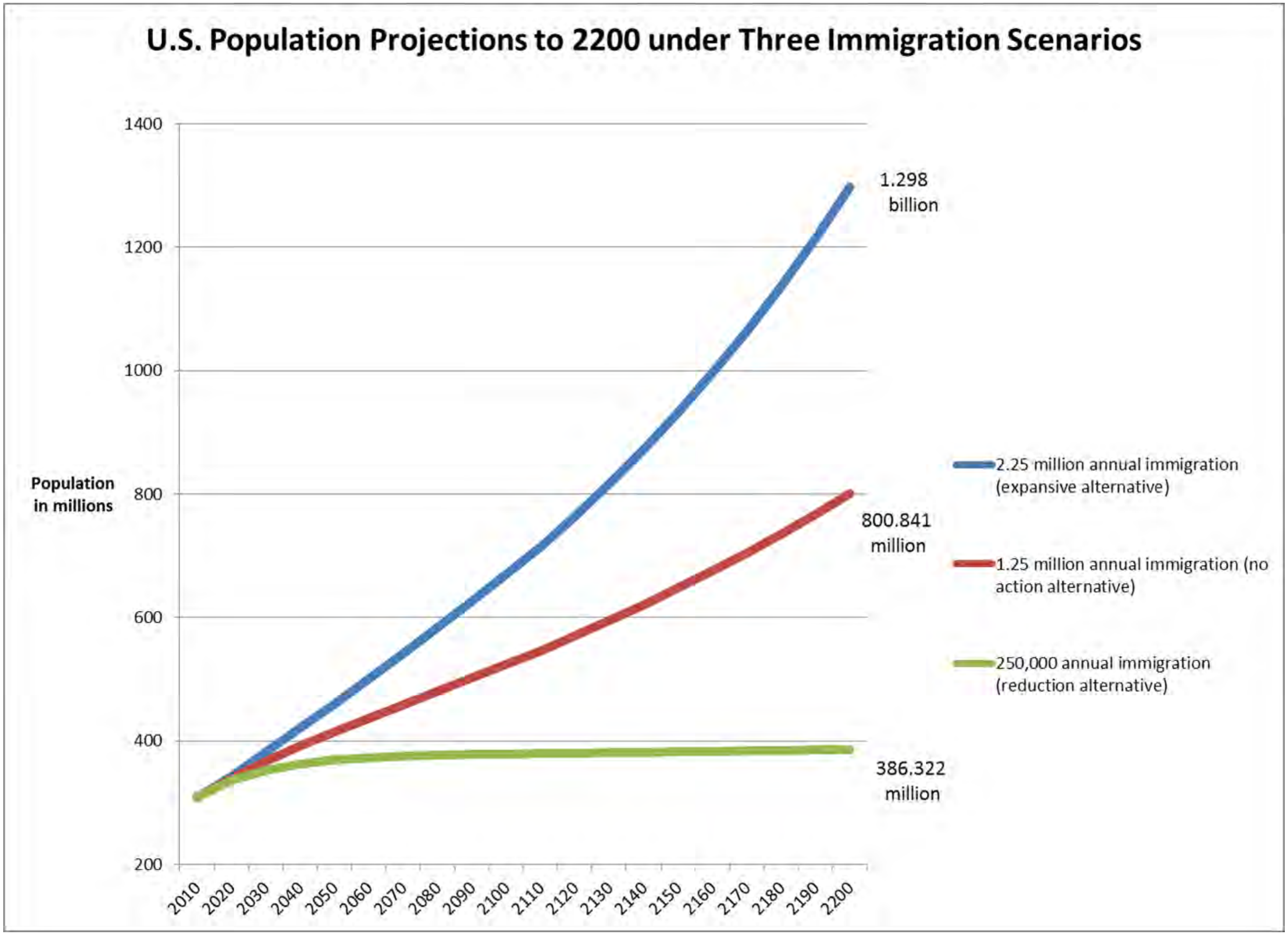


Figure 2-3. U.S. population projections to 2200 under three immigration scenarios

It is noteworthy that while the immigration reduction alternative leads to an essentially stable U.S. population below 400 million people, both the no action alternative and the immigration expansion alternative lead to immense population increases, on the order of hundreds of millions more Americans. The latter alternatives also lock in continued upward population trajectories.

Under the immigration reduction alternative, the U.S. population grows by 77 million people between 2010 and 2200, for a 25% population increase over the entire period. Under the no action or status quo alternative, the U.S. population grows by 492 million people between 2010 and 2200, for a 159% population increase. Finally, under the expansive immigration alternative, the U.S. population grows by 989 million people during this same period, for a 320% U.S. population increase.

Once again, these population projections out to 2200 are quite speculative. Nevertheless, they do allow those concerned about ecological sustainability to peer out across the recommended "seven generations" into the future and consider the implications for our descendants of the path that we are on.

Those who find the idea of 800 million or more Americans preposterous might ask what, exactly, is going to change, to keep the United States from reaching such an immense population. One hundred years ago, the idea of a billion people living in China or India might have seemed preposterous to the average Chinese or Indian person, when there were but 440 million Chinese and 250 million Indians. Today the populations of China and India both stand above one billion, with India set to reach one and a half billion within the next thirty years (USCB 2013c).

2.7 Alternatives Rejected for Detailed Study

In soliciting public input on this EIS on U.S. immigration policy during the scoping process (summarized in Chapter 1), the study team fielded a wide range of suggestions regarding which other alternatives to include. Many comments suggested "zero immigration" or "zero net migration" as alternatives. These options were sometimes proposed as the environmentally optimal or preferred alternatives. Sometimes they were proposed because commenters felt that including zero or zero net immigration options would make immigration-driven population growth's contribution to Americans' total ecological impact more clear.

At the other end of the spectrum, several comments suggested that a true "open borders" alternative be analyzed, allowing in any prospective immigrants without a criminal record. Given the enormous pent-up demand for emigration from poor countries into the U.S., such a policy might initially bring in many millions of new immigrants annually.

While some commenters proposed such an alternative as the morally right thing to do, others, who strongly disagreed with this moral judgment, nevertheless thought that widespread support for such an alternative meant that it deserved to be analyzed. Figure 2-4 depicts such an "open borders" or "no borders" alternative (the uppermost blue curve) alongside the other three already discussed. Assuming net immigration of 3.25 million annually, it would lead to a projected U.S. population of 814 million by 2100.

These very low and very high alternatives were rejected for detailed analysis in this EIS. This was not because each of them does not have significant numbers of advocates, or because they are strictly speaking impossible. Instead, these alternatives were rejected because they are unlikely to be considered seriously for adoption in the near future. NEPA requires that an EIS consider a range of "reasonable" alternatives, and the study team concluded that these alternatives did not qualify as reasonable. Like any EIS, this one aspires to inform actual decisions: in this case, public policy decisions in the immigration realm.

Similar practical considerations pointed to a need to limit the alternatives considered to a manageable number. Readers will be best served by a small number of alternatives that decrease or increase current immigration numbers, and that have a more than a negligible chance of being enacted. Two such alternatives have thus been selected for detailed study (in addition to the no action alternative described above): a substantial reduction alternative and a substantial expansion alternative, described above.

Since the 1970s, U.S. total fertility rates have been approximately at or slightly below the "replacement level" of 2.1. This means that if immigration had also been maintained at "replacement level," where in-migration (immigration) equals out-migration (emigration), that is, *net* migration of zero, U.S. population growth would already have begun to taper off and the U.S. population itself would crest within several decades, early in the 21st century, eventually beginning a gentle decline. Indeed, a projection by the distinguished demographer Leon Bouvier showed that that, without immigration, the population growth of the stock of 1970 residents of the U.S. and their descendants would have peaked at 247 million by 2030 (Beck 1991). The fact that average immigration rates have mounted to a level some five to ten times greater than emigration rates in recent decades is why immigration, and not fertility, unlike during the Baby Boom era from 1945-1964, is driving current and projected U.S. population growth.

Notwithstanding, in recent decades, many American population activists, including the Sierra Club Population Committee and the group formerly known as Zero Population Growth, Inc., or ZPG (now Population Connection) have sidestepped the controversial immigration issue by emphasizing that it would be possible to limit further U.S.

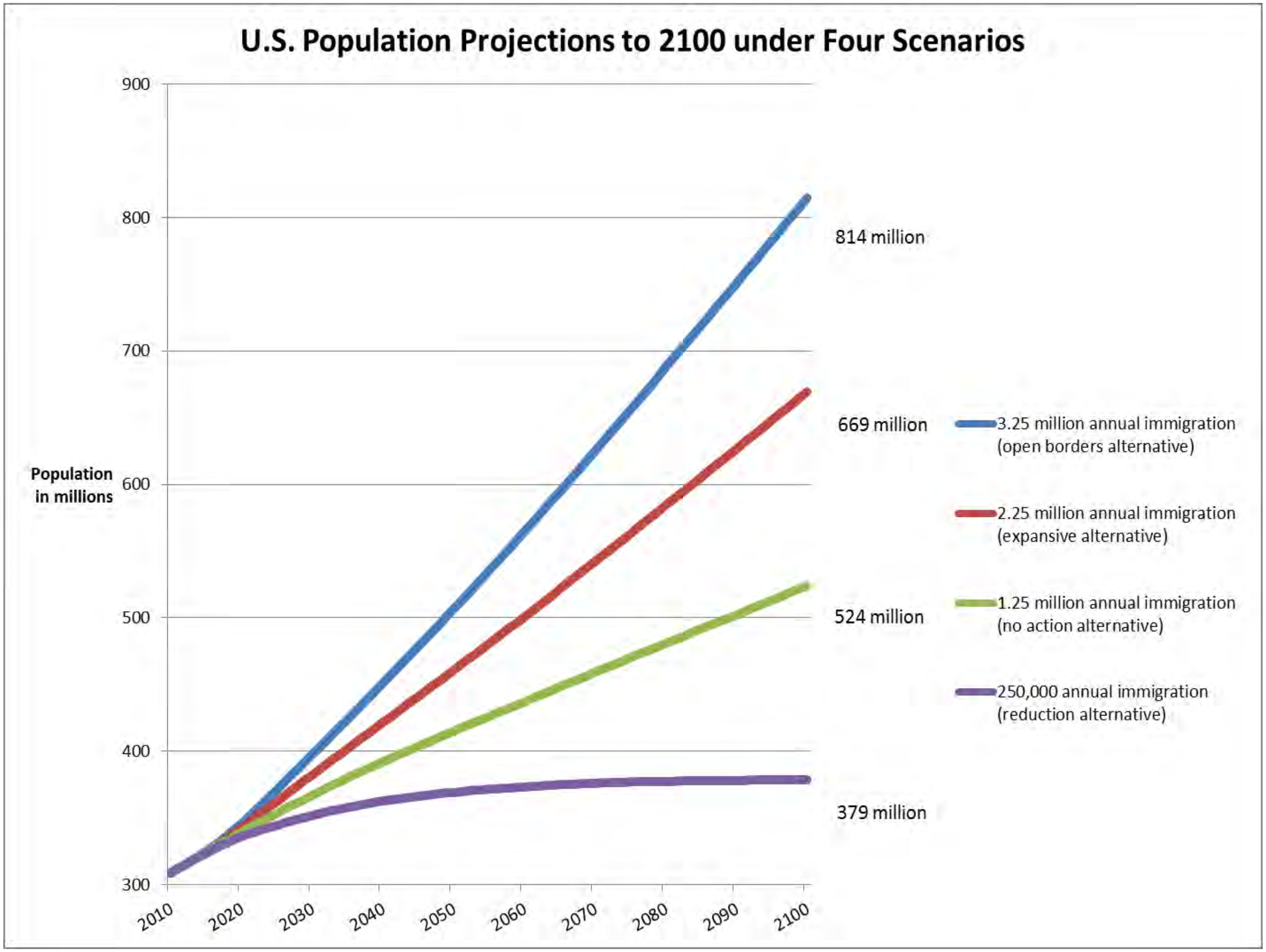


Figure 2-4. U.S. population projections to 2100 under four immigration scenarios, including the open borders alternative

population growth by additional reductions in the U.S. fertility rate. This hope is based on research indicating that about half (51%) of all pregnancies are unintended (mistimed or unwanted). Of these unintended pregnancies, 31 percent are mistimed and 20 percent are unwanted altogether (Guttmacher Institute 2013).

Since one out of every five pregnancies is unwanted, goes the reasoning, population activists could focus their efforts on progress towards eliminating these unwanted pregnancies rather than wading into the contentious, morally hazardous, and unproductive immigration quagmire.[4] On the other hand, a case can also be made for recognizing the value of efforts to reduce unintended pregnancies and thus the fertility rate as well as to reduce excessive, environmentally damaging levels of immigration. Reducing sub-replacement level fertility still further would reduce future population growth. Reducing above-replacement-level immigration somewhat would also reduce future population growth. Reducing both fertility and immigration would reduce it most of all. The following three graphs (Figures 2-5 and 2-6) illustrate the relative potential of both factors.

In Figure 2-5, several projections of the U.S. population to 2100 are shown. The blue (uppermost) curve maintains Census Bureau immigration and fertility assumptions. The red (second-highest) curve maintains immigration rates but assumes a 20 percent drop in the fertility rate (equivalent to eliminating unwanted pregnancies), while the green (second-lowest) curve maintains immigration but reduces fertility by 30 percent. It behooves noting that cutting U.S. fertility by 30 percent (nearly a third) would lower it into the realm currently experienced by many European countries, a number of which are concerned about ultra-low fertility (well below the replacement rate) and the perhaps destabilizing, rapid population decline it will eventually effect (or is already bringing about, in some cases). Figure 2-5 shows that reducing immigration to 250,000 would lead to less population growth than even reducing fertility by 30 percent.

Figure 2-6 depicts the results of projections that assume a concerted, joint effort to control U.S. population growth by reducing both fertility and immigration. By 2100, if net annual immigration were reduced to 250,000 and fertility could be reduced by 20 percent (both by the year 2020), the U.S. population would be at 266 million (50 million less than our 2014 population) and continuing to fall. This would certainly result in lower demographic pressures on the environment, but given political, cultural, and social realities at present, the likelihood of rational choice or public policy consensus (as opposed to negative ecological or economic feedbacks) leading to such an outcome is virtually nonexistent. There is little or no political will for pursuing such strong measures in concert.

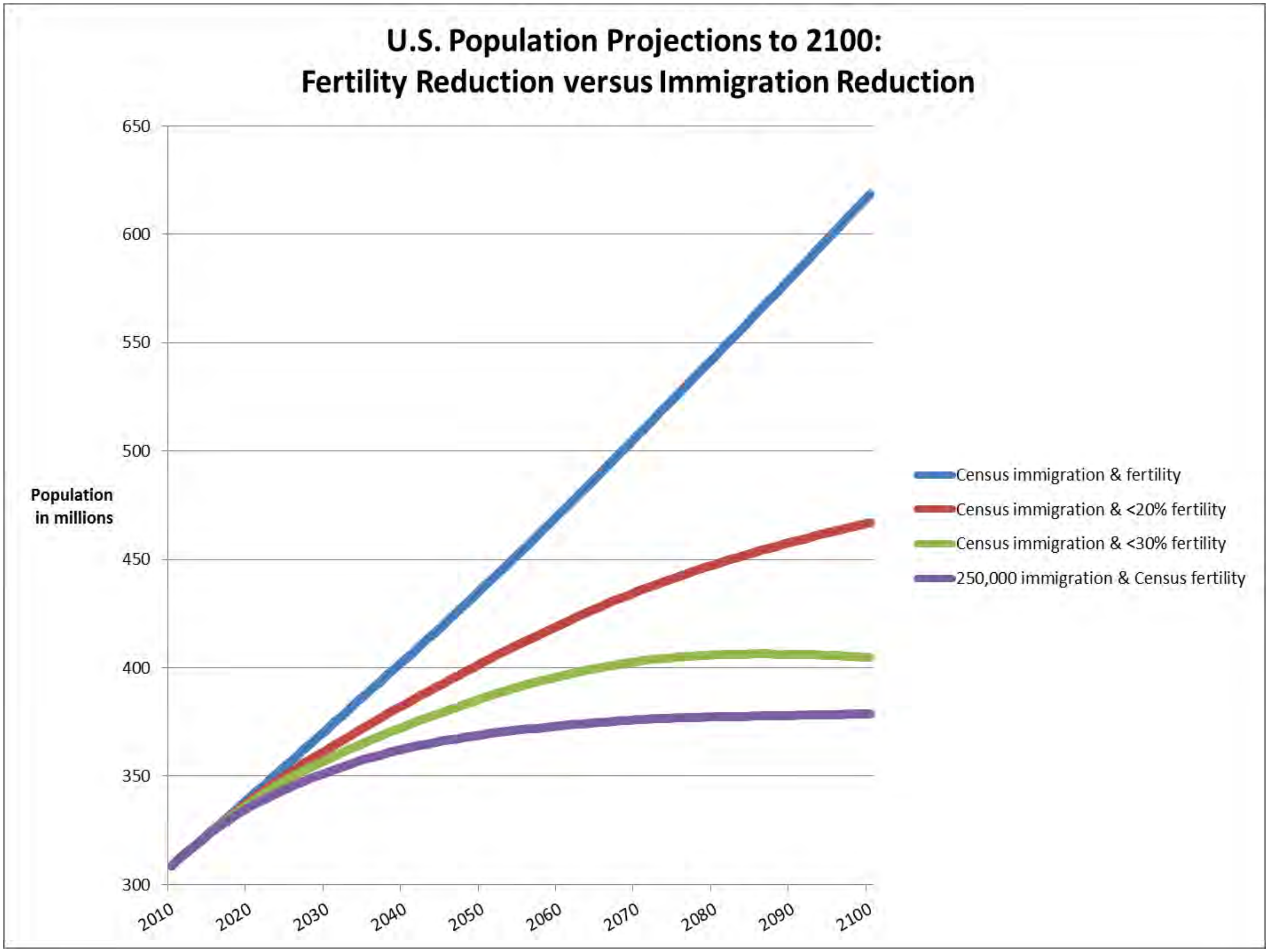


Figure 2-5. U.S. population projections to 2100: 20% & 30% fertility reductions vs. immigration reduction to 250,000

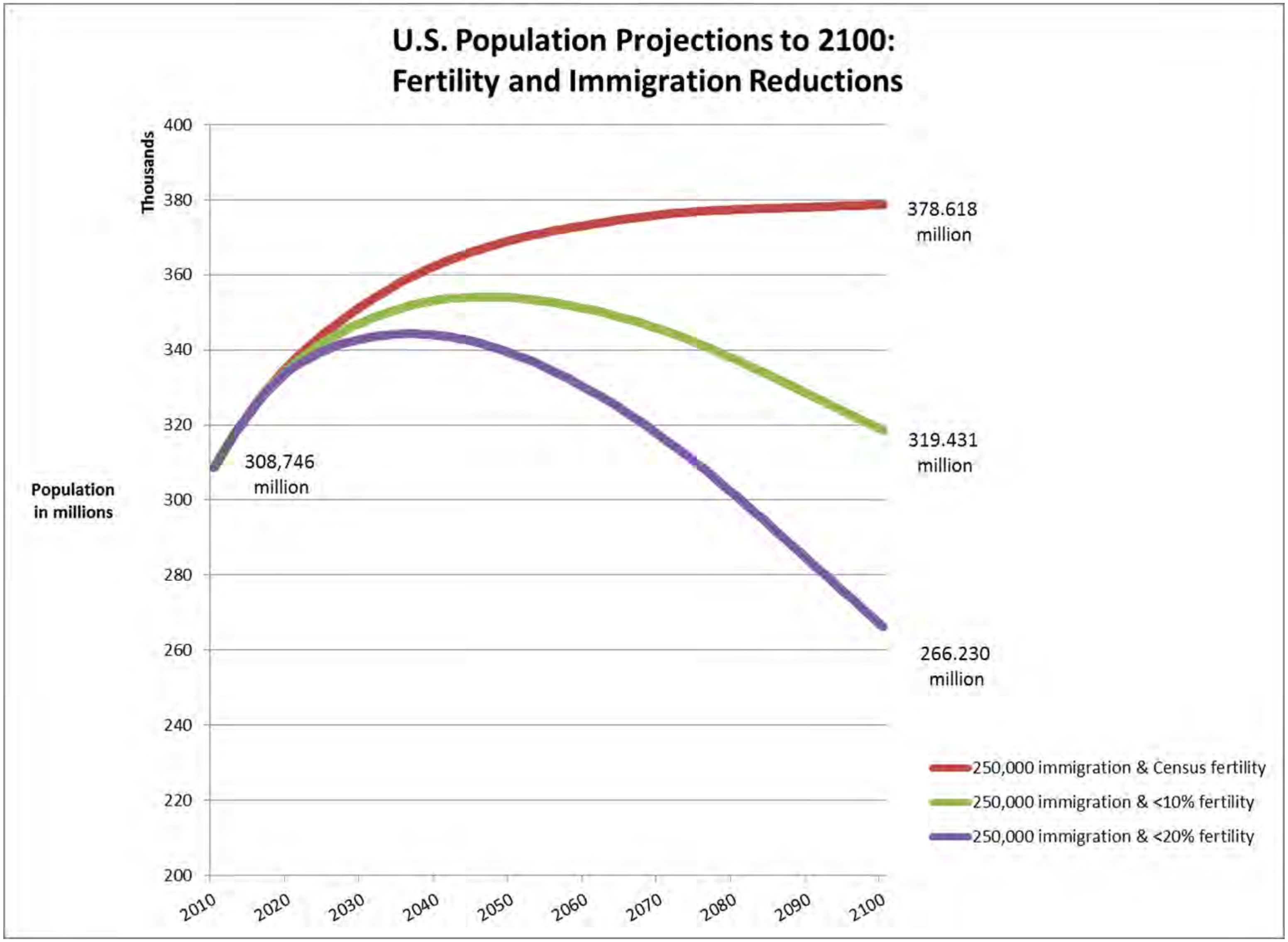


Figure 2-6. U.S. population projections to 2100 showing combined immigration and fertility reductions

In the mid-1990s, a fascinating and informative debate took place on the pages of the interdisciplinary journal *Population and Environment* between University of Colorado physicist Albert Bartlett and Edward Lytwak of the NGO Carrying Capacity Network on one side, and biologists Gretchen Daily (then at the University of California at Berkeley) and Anne Ehrlich and Paul Ehrlich of Stanford University on the other side (Bartlett and Lytwak 1995, Daily et al. 1995, Lytwak and Bartlett 1995). The debate centered on the feasibility, desirability and ethics of the specific measures – the combination of fertility and immigration cuts and foreign assistance – that it would have taken to rapidly achieve U.S. population stabilization. At that time U.S. population was growing by 1.1% per annum, with a doubling time of 64 years. Unfortunately, the debate was confined to the pages of that rather obscure scholarly journal, and since then, the United States population has added approximately 50 million residents.

2.8 Comparison of Impacts of Alternatives

Table 2-5 (next page) is a matrix that summarizes the effects of implementing each of the three alternatives studied in detail.

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Urban sprawl and loss of farmland	• Would entail the development of 79 million additional acres or 123,438 square miles of formerly rural land. • Large swaths of America would lose their rural character and "feel." • Overall effect on suburban sprawl would be *adverse, significant, and long-term.* • By 2100, cumulative additional cropland lost to development would be 31 million acres. • Interpolating and extrapolating conservatively from average recent rates of cropland loss and population growth, U.S. cropland per capita would decrease from 1.18 acre/person in 2010 to 0.63 acre/person in 2100. • Agricultural yields would have to double just to maintain per capita food production. • Adverse effects on farmland could be partially alleviated but not eliminated by agro-technology advances, Smart Growth, and higher density living. • Overall effect on farmland loss	• Would entail the development of 132 million additional acres or 206,250 square miles of formerly rural land. • Still larger swaths of Rural America would forever be converted to Urbanized Areas and lose their rustic character and "feel" than in the No Action Alternative. • Overall effect on suburban sprawl would be *adverse, significant, and long-term.* • By 2100, cumulative additional cropland lost to development would be 52 million acres. • Interpolating and extrapolating conservatively from average recent rates of cropland loss and population growth, U.S. cropland per capita would decrease from 1.18 acre/person in 2010 to 0.46 acre/person in 2100. • Agricultural yields would have to increase by 2.5 times to maintain per capita food production. • Overall effect on farmland loss would be *highly adverse,*	• Would entail the development of 26 million additional acres or 40,157 square miles of formerly rural land. • Overall effect on suburban sprawl would be *adverse, significant, and long-term.* • Even though all 3 alternatives are rated as "adverse, significant, and long-term," the Reduction Alternative is quantitatively and qualitatively much less adverse than the No Action and Expansion alternatives. • By 2100, cumulative additional cropland lost to development would be 10 million acres. • Interpolating and extrapolating conservatively from average recent rates of cropland loss and population growth, U.S. cropland per capita would decrease from 1.18 acre/person in 2010 to 0.95 acre/person in 2100. • Agricultural yields would not have to increase by nearly as much as other two alternatives to maintain per capita food production.

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Urban sprawl and loss of farmland (cont.)	would be *adverse, significant, and long-term.* • Would substantially reduce future U.S. food security.	*significant, and long-term.* • Would drastically reduce future U.S. food security.	• Overall effect on farmland loss would be *adverse, significant, and long-term.* • Would have the least negative impact on future U.S. food security.
Habitat loss and impacts on biodiversity	• Net, aggregate effect on habitats and biodiversity would range from approximately 1.2 to 2.2 times greater than it is today. • Would use 1.2 – 2.2 times more resources, eliminating and degrading habitats to provide greater amounts of energy, water, minerals, and land. • Would excrete 1.2 – 2.2 times more waste, including air and water, toxics, and solid waste, which would degrade habitats and poison wildlife. • Duration of impact would be long-term to permanent. • Extent of impact would be large. • Magnitude of impact would be major. • Overall effect on habitat and biodiversity would be adverse, significant, and long-term.	• Net, aggregate effect on habitats and biodiversity would range from approximately 1.5 to 3 times greater than it is today. • Would use 1.5 – 3 times more resources, eliminating and degrading habitats to provide greater amounts of energy, water, minerals, and land. • Would excrete 1.5 – 3 times more waste, including air and water, toxics, and solid waste, which would degrade habitats and poison wildlife. • Duration of impact would be long-term to permanent. • Extent of impact would be large. • Magnitude of impact would be major. • Overall effect on habitat and biodiversity would be highly adverse, significant, and long-term.	• Net, aggregate effect on habitats and biodiversity would range from approximately 0.8 to 1.6 times greater than it is today. • Would use 0.8 – 1.6 times more resources, eliminating and degrading habitats to provide greater amounts of energy, water, minerals, and land. • Would excrete 0.8 – 1.6 times more waste, including air and water, toxics, and solid waste, which would degrade habitats and poison wildlife. • Duration of impact would be long-term to permanent. • Extent of impact would be large. • Magnitude would be moderate. • Overall effect on habitat and biodiversity would be adverse, significant, and long-term. • Impacts would be much less than those of the No Action or Expansion Alternatives.

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Water demands and withdrawals from natural systems	• Assuming an aggregate decline in per capita water demand of 25 percent due to improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 27 percent between 2010 and 2100. • Two rapidly growing regions in the country – the Southwest and the Southeast – will experience very grave problems with water availability that will have significant adverse effects on urban areas, agriculture, and the already beleaguered aquatic ecosystems of these areas. • Other regions of the country would face more manageable scenarios with regard to water resources. • Overall net effect on water demands and withdrawals from natural systems would be *adverse, significant, and long-term*. • If population were not growing so robustly, then savings from widespread implementation of	• Assuming an aggregate decline in per capita water demand of 25 percent due to improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 62 percent between 2010 and 2100. • If the Expansion Alternative is chosen by the United States, and regional demographic trends of the past half-century persist, then both the Southwest and Southeast would undergo a tripling or more of their current populations at the same time that each region has less water available, and in the case of the Southwest, much less water available, than at present. • Overall net effect on water demands and withdrawals from natural systems would be *highly adverse, significant, and long-term*. • If population were not growing so rapidly, then savings from widespread implementation of water conservation and	• Assuming an aggregate decline in per capita water demand of 25 percent due to improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would actually decrease by 62 percent between 2010 and 2100. • This is the only alternative that actually leads to a net reduction in the total aggregate nationwide water demand and perhaps consumption as well by the year 2100. • While the net reduction in nationwide demand for water would be a beneficial impact, the Southwest and the Southeast would still encounter difficulties in meeting likely demand because they would have faster population growth than the national average and because, according to climate modeling, they would have less water availability than at present. • However, these difficulties would be much more manageable than under either the

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Water demands and withdrawals from natural systems (cont.)	water conservation and efficiency would allow more water to be retained in rather than withdrawn from aquatic ecosystems.	efficiency technologies and practices would allow more water to be retained in rather than withdrawn from aquatic ecosystems. • In coastal areas, especially Texas, California, and Florida – all of them experiencing population growth at much higher rates than the national average, pressure to build numerous desalination plants is likely to increase.	No Action Alternative or the Expansion Alternative. • Overall net effect on water demands and withdrawals from natural systems would be *modestly but significantly beneficial*. • More water could be retained "in-stream," increasing the flow not just of surface freshwater but also of ecosystems services provided to society by waters of the U.S., including wetlands.
Carbon dioxide emissions and resultant climate change	• There would be 70 percent greater upward pressure on CO_2 emissions. • This should be compared with the call of climatologists for an 80 percent or more reduction in CO_2 emissions by 2050. • Would more or less correspond to the "Business As Usual" (BAU) scenario in terms of global CO_2 and other GHG emissions. The BAU scenario appears headed to push the planet towards an average warming of 4°C or more by 2100. • There would likely be a dramatic	• Upward pressure on U.S. CO_2 emissions would be substantially higher than under the No Action Alternative, to wit, 117 percent greater versus 70 percent greater. • This should be compared with the call of climatologists for an 80 percent or more reduction in CO_2 emissions by 2050. • Would more or less correspond to the "Business As Usual" (BAU) scenario in terms of global CO_2 and other GHG emissions. The BAU scenario appears headed to push the planet towards an average warming of 4°C or more by	• Upward pressure on U.S. CO_2 emissions would be substantially lower than under either the No Action Alternative or the Expansion Alternative, to wit: 23 percent greater for the Reduction Alternative, versus 70 percent greater for the No Action Alternative, and 117 percent greater for the Expansion Alternative. • Nevertheless, population size would still increase by 70 million or 23 percent from 2010 to 2100 because of demographic momentum. Consequently, the Reduction Alternative would

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Carbon dioxide emissions and resultant climate change (cont.)	increase in the intensity and frequency of extreme temperatures and severe weather events. • Such extreme heat waves have caused severe impacts, including many thousands of heat-related deaths, widespread forest fires, and large crop losses. • The impacts of the extreme heat waves projected for a 4°C warmer world are anticipated to dwarf the consequences that have been felt to date. They could well exceed the adaptive capacities of many societies and ecosystems. • Warming of 4°C or higher by 2100 would correspond to an increase of about 150 percent in the acidity of the ocean. • By 2100, warming of 4°C would likely signify a sea-level rise of 0.5 to 1 meter (20 to 39 inches), and possibly more; in addition, several additional meters of rise would occur in the coming centuries, already locked into place by past warming. • The risks of a 4°C warmer world	2100. • There would likely be a dramatic increase in the intensity and frequency of extreme temperatures and severe weather events. • Such extreme heat waves have caused severe impacts, including many thousands of heat-related deaths, widespread forest fires, and large crop losses. • The impacts of the extreme heat waves projected for a 4°C warmer world are anticipated to dwarf the consequences that have been felt to date. They could well exceed the adaptive capacities of many societies and ecosystems. • Warming of 4°C or higher by 2100 would correspond to an increase of about 150 percent in the acidity of the ocean. • By 2100, warming of 4°C would likely signify a sea-level rise of 0.5 to 1 meter (20 to 39 inches), and possibly more; in addition, several additional meters of rise would occur in the coming centuries, already locked into	still produce upward demographic pressure on U.S. CO_2 emissions. • Overall net effect on CO_2 emissions and global climate change would be *adverse, significant, and long-term*. • In contrast to the No Action and Expansion alternatives, however, it would be far more feasible for the United States to make a constructive contribution to the global partnership urgently needed to address the climate predicament. • Economic and ecological effects of climate change on the U.S. would be qualitatively similar to those sketched for No Action and Expansion alternatives, but may be less drastic.

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Carbon dioxide emissions and resultant climate change (cont.)	to agriculture and food production, freshwater availability, ecosystems and human health would be severe. • In addition, the risk of ecosystem disruption as a result of ecosystem shifts, wildfires, and forest dieback would be significantly higher. • Overall net effect on CO_2 emissions and global climate change would be *adverse, significant, and long-term*.	place by past warming. • The risks of a 4°C warmer world to agriculture and food production, freshwater availability, ecosystems and human health would be severe. • In addition, the risk of ecosystem disruption as a result of ecosystem shifts, wildfires, and forest dieback would be significantly higher. • Overall net effect on CO_2 emissions and global climate change would be *adverse, significant, and long-term*.	
Energy demands and national security implications	• Due to the assumed reduction in overall national energy intensity (energy consumption per capita) because of ongoing future efficiency improvements, conservation, structural economic changes, and the like, aggregate national energy consumption would rise to 117 quads by 2100, an increase of "only" 19 percent above the 2010 energy consumption of 98 quads. • It is highly doubtful whether this level of aggregate national	• Due to the assumed reduction in overall national energy intensity (energy consumption per capita) because of ongoing future efficiency improvements, conservation, structural economic changes, and the like, aggregate national energy consumption would rise to 149 quads by 2100, an increase of "only" 52 percent above the 2010 energy consumption of 98 quads. • It is highly doubtful whether this level of aggregate national	• Due to the assumed reduction in overall national energy intensity (energy consumption per capita) because of ongoing future efficiency improvements, conservation, structural economic changes, and the like, aggregate national energy consumption would actually fall to 85 quads by 2100, a decrease of 13 quads or about 13 percent from 2010 energy consumption of 98 quads. • Annual energy consumption of 85 quads in 2100 is a much more

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
Energy demands and national security implications (cont.)	energy consumption is actually sustainable. • While with technical advances and breakthroughs, as well as sustained political and public commitment, the nation could perhaps conceivably meet this level of energy consumption entirely with renewables, this would occur at great cost to land and visual resources, habitat, and wildlife. • In addition, components of renewables such as wind, solar, and advanced batteries are made of scarce, non-renewable and exhaustible raw materials (rare earth elements and other rare and costly metals). Their own long-term durability has yet to be proven. • In the coming decades and perhaps for the next half century or so, U.S. security and the domestic economy will be increasingly at risk to disruptions in the flow of oil from politically turbulent and war-torn regions of the world such as the Middle East.	energy consumption is actually sustainable. • While with technical advances and breakthroughs, as well as sustained political and public commitment, the nation could perhaps conceivably meet this level of energy consumption entirely with renewables, this would occur at great cost to land and visual resources, habitat, and wildlife. • To suggest that energy production from solar, wind, and other sources could increase on the order of ***50-75 times*** over the coming 85 years to reach a total of 149 quads strains credulity. • Furthermore, components of renewables such as wind, solar, and advanced batteries are made of scarce, non-renewable and exhaustible raw materials (rare earth elements and other rare and costly metals). Their own long-term durability has yet to be proven. • In the coming decades and perhaps for the next half century or so, U.S. security and the	favorable and manageable situation – and one with much lower environmental impact – than under the No Action Alternative (117 quads) or the Expansion Alternative (149 quads). • However, even this level of energy consumption may not be realistic over the long term when one considers that more than four out of every five quads of our energy consumption today come from fossil fuels, which will have to have been largely replaced by 2100. • Overall, the net effect of the Reduction Alternative on energy would be *adverse, moderately significant, and long-term.* • Of the three alternatives considered, this one would entail by far the fewest adverse impacts related to energy resources and their development. • It would also have the most favorable implications for national and energy security, reducing demand for and dependence on foreign oil in the

Table 2-5. Impact Comparison Matrix

Impact Topic	No Action Alternative (1.25 million annual migration)	Expansion Alternative (2.25 million annual migration)	Reduction Alternative (250,000 annual migration)
Energy demands and national security implications (cont.)	• The domestic fracking boom which has recently increased U.S. crude oil output and provided somewhat of a hiatus from high prices and a reprieve from import dependency is not expected to last more than a couple of decades, after which our vulnerability will worsen once more. • Overall net effect on energy would be *adverse, significant, and long-term*.	domestic economy will be increasingly at risk to disruptions in the flow of oil from politically turbulent and war-torn regions of the world such as the Middle East. • The domestic fracking boom which has recently increased U.S. crude oil output and provided somewhat of a hiatus from high prices and a reprieve from import dependency is not expected to last more than a couple of decades, after which our vulnerability will worsen once more. • Overall net effect on energy would be *highly adverse, significant, and long-term*.	coming decades, although by the year 2100, there will be little or no foreign oil left to import at affordable prices.
International ecological impacts of U.S. immigration policies	• The potential for international ecological impacts from aggregate U.S. consumption in 2100 would be up to 70 percent greater than in 2010. • The U.S. economy would likely import more raw materials, food, and manufactured goods, the production of which would entail substantial adverse environ-mental effects in the countries of	• Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be more than twice (approximately 117 percent) as great as in 2010. • Under a much larger population, all of the effects under the No Action Alternative would be magnified even further in order to just maintain U.S. consump-	• Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be about a quarter (approximately 23 percent) larger than in 2010. • Nonetheless, these effects would be substantially smaller than for the No Action Alternative and the Expansion Alternative. • Overall international ecological

Table 2-5. Impact Comparison Matrix			
Impact Topic	**No Action Alternative (1.25 million annual migration)**	**Expansion Alternative (2.25 million annual migration)**	**Reduction Alternative (250,000 annual migration)**
	origin. • Effects would range from the impacts of mining and forestry activities on the landscape, wildlife habitat, water quality, human health and the wellbeing of indigenous peoples (where traditional tribal lands are exploited for their resources without express consent of their longtime inhabitants) to the impacts on air quality and human health from pollutants emitted by factories producing goods for export to the United States. • There would likely be a comparable increase in U.S. carbon dioxide and other GHG emissions, as well as upward pressure on our ecological footprint, both of which have international or global ramifications. • Overall, the international ecological effects would be *adverse, significant, and long-term.*	tion and living standards, to say nothing of increasing them. • While as noted above, there would likely be positive economic effects in exporting countries from supplying much larger U.S. imports, there would be correspondingly larger environmental impacts as well. • Overall, the international ecological effects would be *highly adverse, significant, and long-term.* • In sum, an alternative that more than doubles the number of resource consumers and waste emitters in the United States would exert much greater stresses and generate far greater widespread impacts that extend well beyond U.S. borders into the rest of the biosphere.	effects would be *adverse, moderately significant, and long-term.* • Of the three alternatives considered, this one would entail by far the lowest level of adverse international ecological impacts.

Endnotes

[1] Annual and decadal immigration numbers may be found in US Department of Homeland Security, "Yearbook of Immigration Statistics: 2011," table 1, "Persons Obtaining Legal Permanent Resident Status: Fiscal Years 1820 to 2011." Accessible on the Department of Homeland Security website: www.dhs.gov.

[2] This confirms the findings of Passel and Cohn (2008) that under a continuation of status quo immigration policies, post-2005 immigration will account for 82% of U.S. population increase between 2005-2050.

[3]Camarota (2012) makes a similar point in evaluating population projections through the middle of the current century.

[4] For example, at a 1998 speech in West Virginia, former congressman Peter Kostmayer, then executive director of Zero Population Growth, Inc., was questioned about immigration. He told the audience: "Let me be frank. You are a wealthy, middle-class community, and if you concentrate on the issue of immigration as a way of controlling population, you won't come off well. It just doesn't work. The population movement has an unhappy history in this regard." About the same time, in a handwritten note to a ZPG member inquiring about the group's immigration stance, Kostmayer wrote, "…it would be so, so counterproductive to be perceived as anti-immigrant."

Chapter 3
ENVIRONMENTAL ANALYSIS

3.1 Organization, Terminology, and Methodology

3.1.1 General Approach

This chapter analyzes the potential environmental impacts or consequences of the three alternatives under consideration in this EIS. As indicated in Chapter 1, the EIS examines the environmental implications of alternative immigration rates and subsequent U.S. population growth on six issues:

- Urban sprawl and loss of farmland
- Habitat loss and impacts on biodiversity
- Water demands and withdrawals from natural systems
- Carbon dioxide emissions and resultant climate change
- Energy demands and national security implications
- International ecological impacts of U.S. immigration policies

Each of these topics is considered in turn in separate and sequential sections. Every section is divided into two parts: 1) Affected Environment, and 2) Environmental Consequences. The affected environment section lays out relevant background facts and information, including current trends, pertaining to the topic under consideration. The NEPA statute and guidance from the White House Council on Environmental Quality (or CEQ, which is tasked with interpreting NEPA and prepared the NEPA regulations at 40 CFR Parts 1500-1508) stipulate that NEPA practitioners should focus on providing relevant information in a succinct manner rather than drafting encyclopedic or academic treatises. Therefore, the affected environment section is oriented toward those aspects of the environment that might actually be affected by the proposed action and alternatives rather than the environment in its entirety. This is followed by the environmental consequences section, which presents the potential environmental effects of each of the three alternatives.

In general, NEPA recognizes three types of environmental effects: 1) direct, 2) indirect, and 3) cumulative. **Direct** effects are immediate impacts caused by an action; they occur at approximately the same time and place as the action itself. An example of a direct effect is the runoff and erosion that can occur when a bulldozer strips away the protective

layer of vegetation covering the ground at a site in preparation for the construction of a housing subdivision.

Indirect effects are those impacts caused by the action(s) that take place at some distance in space and/or time from the action. Often this is by means of a longer chain of cause-and-effect linkages. Using the above example, one indirect impact of erosion from site clearing might be subsequent turbidity (murky water) and siltation in a watercourse downslope of the housing construction project. Other indirect effects still further removed from the original action (ground clearing) could result from this turbidity and siltation, such as stress, displacement, or mortality of resident fish populations and benthic macro invertebrates (e.g., flatworms, freshwater mussels, clams, snails, worms, crayfish, and larva of mayflies, stoneflies, and dragonflies) living on the substrate (stream bottom). This in turn might negatively affect recreational fishing opportunities and/or local populations of wading birds (e.g., herons, egrets) and raccoons that feed on small fish and aquatic invertebrates like crayfish.

Cumulative effects or impacts are defined by the CEQ regulations 40 CFR 1508.7 as "the impact on the environment which results from the incremental impact of the [proposed] action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time." Cumulative impacts include the direct and indirect impacts of a project together with the reasonably foreseeable future actions of other projects. According to CEQ's cumulative impacts guidance, cumulative impact analysis should focus on important issues at a national, regional, or local level. In this EIS, most cumulative impacts are discussed at the national scale.

Cumulative impacts are most evident over the long term.

Using this terminology, the environmental impacts of immigration mostly fall into the indirect and cumulative categories. The demographic and environmental differences between variable immigration rates really only diverge over the long term; in the short-term, there is little to distinguish the impacts of alternative immigration levels from each other.

NEPA also differentiates between **beneficial** or positive and **adverse** or negative impacts. Most actions incur both beneficial and adverse impacts; if they didn't have some positive effects, no one would be proposing them in the first place, and if they didn't have any adverse impacts, there would be no need to go to the trouble, time, and expense of conducting an EIS.

Projects and proposed actions can have a wide variety of impacts on different facets of the environment. The importance, or "significance," of each of these diverse impacts depends on several factors. Some of these factors are matters of objective fact. For example, if a Federal law would clearly be violated by any aspect of the proposed action, this would obviously constitute a significant impact. Other factors affecting significance are matters of professional or personal judgment, such as the importance of losing some amount of wildlife habitat. CEQ NEPA regulations (in the text box at right) furnish a list of factors to be considered in determining impact significance.

Other terms used to describe and characterize impacts are as follows:

- Magnitude of the impact (how much);
- Duration or frequency of the impact (how long or how often);
- Extent of the impact (how far);
- Likelihood of the impact occurring (probability)

Each of these terms has levels or degrees:

Duration of Impact:

Permanent – Impact is indefinite or everlasting and for all intents irreversible (e.g. extinction).

Long-term – Impact would likely last for a decade or more.

CEQ Regulations on Significance (40 CFR 1508.27)

The rating of an impact as "significant" in NEPA requires consideration of both the context and intensity of the impact.

Context: The significance of an action must be analyzed in several contexts, including society as a whole, the affected region, the affected interests, and the locality. Both short- and long-term effects on an action should be analyzed.

Intensity: Intensity refers to the severity of an impact. In evaluating the intensity of an impact of the proposed action, the following should be considered:

- Impacts that may be both beneficial and adverse;
- Effects on human health and safety;
- Unique characteristics of the geographic area;
- Highly controversial effects;
- Highly uncertain or risky effects;
- Potential for the action to set a precedence for future actions with significant effects;
- Cumulative effects;
- Adverse effects on significant scientific, cultural, or historic resources;
- Adverse effects on a threatened or endangered species or its habitat; and
- Whether the action violates or threatens a Federal, State, or local law or requirement.

Medium-term – Impact would last for up to approximately a decade.

Short-term – Impact would occur during a transition phase only, or in the range of days, weeks, months or several years, after which resource conditions are likely to return to pre-transition/construction conditions.

Intermittent – Impact would not be constant or continuous but may last indefinitely.

Extent of Impact:

Large – Impacts would affect a resource on a regional, national, or global scale.

Medium or Localized – Impacts would affect a resource only at the site of a specific project site or its immediate surroundings, and would not extend into the wider region.

Small or Limited – Impacts would affect a resource over a fraction of a project site.

Magnitude of Impact:

Major – Substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard.

Moderate – Noticeable change in a resource occurs, but the integrity of the resource remains intact.

Minor – Change in a resource area occurs, but no substantial resource impact results.

Negligible – The impact is at the lowest levels of detection – barely measurable and with no perceptible consequences.

Likelihood of Impact:

Probable – More likely than not to occur, i.e., approximately 50% likelihood or higher.
Possible – Some chance of occurring, but probably below 50%.
Unlikely – A non-zero but very small likelihood of occurrence.

The EIS will use the most recent information and data available – typically from official or other reputable sources – to make predictions about future resource and environmental impacts. The EIS will also make use of models, which are simplified, abstract views of the more complex real world. The population projections presented in Chapter 2 are demographic projections that predict future population size based on assumed rates of immigration, emigration, fertility and mortality. Climate models simulate dynamic interactions between the ice-free land surface, ice-covered areas (both on land in in the ocean), atmosphere, and oceans to make projections of future climatic conditions in response to variable emissions of greenhouse gases.

3.1.2 Limitations

"It's tough to make predictions, especially about the future," the late baseball great and homespun sage Yogi Berra once said. And the further into the future one peers, the more difficult it is. Demographers themselves are wary of making projections much beyond 50 years because they have learned the hard way that the longer the time frame, the greater the likelihood of one or more unanticipated phenomena wreaking havoc with the careful assumptions upon which their deceptively precise projections rest.

Every year, the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) issues updated Annual Energy Outlooks that examine key energy trends several decades into the future. The 2014 Annual Energy Outlook (EIA 2014b) contains projections to the year 2040, just two and a half decades away. Yet the EIA itself cautions about the many uncertainties associated with these projections.

Making predictions of future environmental trends, impacts, and conditions is even more fraught with risk because: 1) natural systems are highly complex and often behave in a counterintuitive or nonlinear manner; 2) our understanding of nature is incomplete and constantly evolving, and 3) the human factor – technological, socio-cultural, and political – is a continually moving target. One thing we do know about both natural and human systems is that both are capable of sudden, unexpected shifts, as well as gradual change, stasis, inertia, and lags.

Natural scientists use terminology such as "discontinuity," "tipping point," "state shift," and "phase shift" – some of which have entered the vernacular – to describe the precise moment when a system undergoes an abrupt change from one state or phase to another. Sometimes these sudden shifts are reversible – as when water evaporates into a gas only to condense again into a liquid – sometime not, as with species extinctions. Sometimes they produce new stable states or equilibria, while sometimes instability or chaos reigns.

In the social sciences, scholar Nassim Nicholas Taleb has coined the expression "black swan" as a metaphor of rare, unforeseen events with outsized, disruptive effects on history, politics, finance, science, and technology (Taleb 2007). The straw that broke the camel's back may have been a black swan.

The predictions of ecologists, other scientists, and environmentalists as to the future state of the world are like snowflakes – infinite in variety. No two are exactly alike.

In 1972, a team of young systems dynamics modelers at the Massachusetts Institute of Technology (MIT) under computer simulation modeling pioneer Professor Jay Forrester countered the widely accepted notion that continuing exponential population growth and

economic growth would result in a world that was ever more populated, polluted, and richer *ad infinitum*. Instead, *The Limits to Growth* warned that within a century, the likeliest outcome of the world system was "overshoot and collapse," in which human population and industrial output both contracted uncontrollably instead of either growing forever (which most economists believed) or stabilizing in an orderly, planned manner (which most ecologists and environmentalists advocated) (Meadows et al. 1972).

In the four decades since *Limits*, a number of analyses and scenarios have emerged to challenge the mainstream consensus – the received wisdom of both the mainstream environmental movement and the mainstream political/economic establishment – that the future will merely be an extrapolation of the recent past. A 2008 article in *New Scientist* asked whether the demise of civilization was inevitable due to the inherent unsustainability of ever more complex systems (MacKenzie 2008), a theory advanced in the 1980s by the anthropologist and historian Joseph Tainter, author of *The Collapse of Complex Societies* (Tainter 1988).

In 2012, in the prestigious British scientific journal *Nature*, a distinguished team of scientists from the United States, Canada, South America, and Europe warned that human population growth, extensive degradation and destruction of natural ecosystems, and climate change may be driving our biosphere toward an irreversible change, which they called "a planet-wide tipping point" (Sanders 2012, Barnosky, et al. 2012). The Association for the Study of Peak Oil and Gas (ASPO) warns of potentially severe economic, environmental, and social disruptions – "a time of great international tension" – related to what they believe to be the imminent peaking of worldwide crude oil production (Campbell 2008).

Most climate scientists, many advocacy groups, and even the World Bank and many present and former leaders of the U.S. military assert that climate change will become increasingly disruptive to weather, agriculture, ecosystems, the economy, and indeed civilization itself (Melillo et al. 2014, CNA 2014, IPCC 2013, AAAS no date, World Bank 2012). Author Chris Clugston in his 2012 book *Scarcity* and subsequent writings argues that ever-increasing global scarcity of scores of critical non-renewable natural resources threatens a "new normal" of geologically imposed austerity (Clugston 2012, 2013). Trend forecaster and best-selling author Chris Martenson offers "insights for prospering as our world changes" (Martenson 2011), while the Post Carbon Institute claims that economic growth is all but over and touts itself as "leading the transition to a more resilient, equitable, and sustainable world" (Post Carbon Institute no date). Post Carbon Institute fellow Richard Heinberg argues that humanity is entering an era of "peak everything" (Heinberg 2010).

In what Virginia Tech aquatic ecologist John Cairns, Jr. called a "prophetic statement" (Cairns 2008), UK atmospheric chemist and inventor James Lovelock – who not only created the so-called "Gaia Hypothesis" but was the first to detect that chlorofluorocarbons (CFCs) were accumulating in the atmosphere – wrote a quarter century ago:

> We are, quite literally, in a new world, a much more peculiar place than it seemed a few centuries back, harder to make sense of, riskier to speculate about, and alive with information which is becoming more accessible and bewildering at the same time (Lovelock 1988).

None of the above analysts and commenters believes that "business as usual" trends can prevail to the year 2100 because of what systems modelers term "negative feedback loops," some of which may already be underway.

However, the predictions of this EIS, to a large extent, do assume business-as-usual or 'reference' trends extrapolated and projected to 2100. The rationale is that making any firm or precise predictions at all as to the future state of the environment becomes highly problematic, if not impossible, when and if the global economic-energy-ecological-resource system enters a period of instability and freefall such as that predicted by the computer simulation model runs in *The Limits to Growth*.

Figure 2-1 shows the "standard run" scenario from that study. Note that the curves labelled 'food per capita,' 'industrial output per capita,' 'population,' and 'pollution' all increase steadily and more or less in tandem, while the 'resources' curve falls steadily and ever more steeply as resources are used up in support of exponential population and economic growth. However, the slope and direction of all of these curves change dramatically over the course of the two centuries presented on the graph. It is not possible to predict exactly when these "inflection points" (to borrow the term from calculus) will be reached in actuality.

It is also not possible to predict with great confidence the influence of a phenomenon such as global warming, which was not even addressed in *Limits* because climate science at that time was rudimentary and trends now gathering force were not yet evident. While 'pollution' in the graph in Figure 2-1 might be considered to serve as a stand-in or proxy for accumulating greenhouse gases of anthropogenic origin – principally carbon dioxide CO_2), methane (CH_4), and nitrous oxide (N_2O) – in the atmosphere (as well as all other forms of pollution in aggregate), in point of fact, atmospheric CO_2 concentrations would not begin to drop as soon as industrial output per capita peaked and began to fall. Climatologists state unequivocally that CO_2 released into the atmosphere from the

burning of fossil fuels and forests will remain there for centuries until it is eventually absorbed by the oceans.

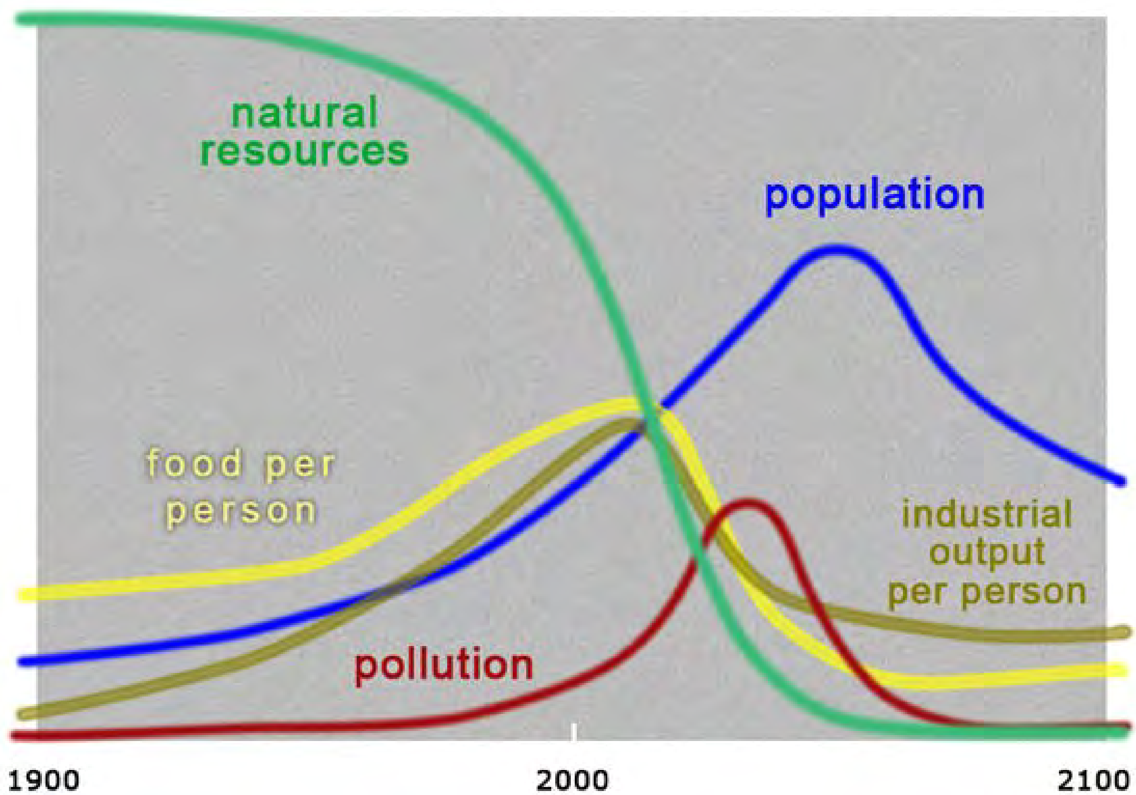


Figure 3-1. Standard run or "business as usual" scenario from *The Limits to Growth* (Meadows et al. 1972)

Yet these "devils in the details" missed by the *Limits* forecasts do not diminish its overall accuracy or robustness in capturing the general behavior of system components when exponential growth collides with finite resources on a finite planet. In essence, uninterrupted growth cannot and will not continue indefinitely, but it is impossible to predict exactly when growth will halt and reverse itself. System behavior once growth falters and halts is likely to be erratic, unpredictable, and at the present scale at least, beyond human experience.

In attempting to quantify environmental effects associated with population growth, this EIS does not merely assume that each and every numerical increase in population has an exactly proportional greater effect on the resource or environmental attribute in question. In recent decades, substantial strides have been made in reducing the energy, resource, and water intensity of our economy. That is, it takes less energy and water and fewer resources overall to generate a given dollar of Gross Domestic Product (GDP) as a result of improved energy, resource, and water efficiency. Average per capita energy and water

consumption have also declined modestly over the last several decades, even as per capita income has grown, as a result of higher prices, incentives, both institutional and individual conservation efforts, implementation of energy and water efficient technologies, and broader technological and structural changes in our economy.

Likewise, per capita land consumption has been declining in the last several years, in contrast to decades-long trends before that. Younger Americans in particular appear to be opting for higher-density living, partly in response to economic pressures associated with higher gasoline and energy costs (shorter commutes and smaller, attached homes entail less energy use and expense) and more generally because of relatively reduced economic and job prospects. Many cities are once again seen as "exciting" and full of social and economic opportunities by millennials, and this, at least, tends to reduce (but not eliminate) the pressures that lead to cities expanding or sprawling outward.

The net effect of all these improvements and shifts is not to eliminate entirely, but to reduce the marginal impact on the environment of each added increment of population. In some instances, this reduction is sufficient to offset, or almost offset, the added environmental load posed by a growing population. In other instances, population growth is of such a magnitude that it overwhelms the countervailing influence of conservation and efficiency measures. But even when population growth simply offsets reductions in aggregate impacts due to decreasing per capita environmental impacts, the fact remains that an increase in human population imposes a greater load or burden on the environment. Each human being directly and indirectly consumes resources and generates wastes – and this simple, ineluctable fact poses environmental consequences. These environmental consequences tend to increase roughly in proportion to the increase in the size of the population of resource consumers/waste generators.

3.1.3 IPAT, I=P x p, and the Kaya Identity

Human impacts on the environment have several fundamental causes or factors. The number of humans or population size is one such key factor.

IPAT is shorthand for I = P x A x T, which itself signifies Impact (I) = Population (P) x Affluence (A) x Technology (T). This equation emerged in the early 1970s from an acrimonious debate among scientists Barry Commoner, Paul Ehrlich and John Holdren over the relative importance of the various causes of growing human impact on the environment (Ehrlich and Holdren 1971, Ehrlich and Holdren 1972, Commoner 1972). The IPAT equation indicates that population growth (P), per capita consumption (affluence or A), and the resource intensiveness of a particular technology (T) that yields a given level of per capita consumption each contribute to environmental impact. What IPAT does not reveal is the relative weight of each factor in any given situation.

I=P x p signifies Impact (I) = Population size (P) x per capita consumption (p). This is a simplified version of IPAT, in which the Affluence and Technology and any other factors have been subsumed into the per capita consumption factor. The I=Pxp formulation has been used to study the relative roles of increasing population and increasing per capita consumption in driving the growth of energy consumption (Holdren 1991) and urban sprawl (Kolankiewicz and Beck 2001, Beck et al. 2003, Kolankiewicz et al. 2014) in the United States. For any given resource or impact, the relative importance of population growth or per capita consumption in driving that change in consumption or impact can be calculated and quantified for a given time period. It is evident that the relative importance of population growth versus rising per capita consumption varies by resource/impact and time period.

The **Kaya identity**, a formula named for Japanese energy economist Yoichi Kaya, who first developed it, is related to the previous two equations, but is applicable specifically to the case of carbon dioxide (CO_2) emissions. The Kaya identity states that aggregate climate-forcing CO_2 emissions to the atmosphere can be expressed as the product of four factors or inputs: population, Gross Domestic Product (GDP) per capita, energy use per unit of GDP, and CO_2 emissions per unit of energy consumed (Rosa and Dietz 2012).

Kaya Identity

Total emissions = population × (GDP/population) × (energy/GDP) × (emissions/energy)

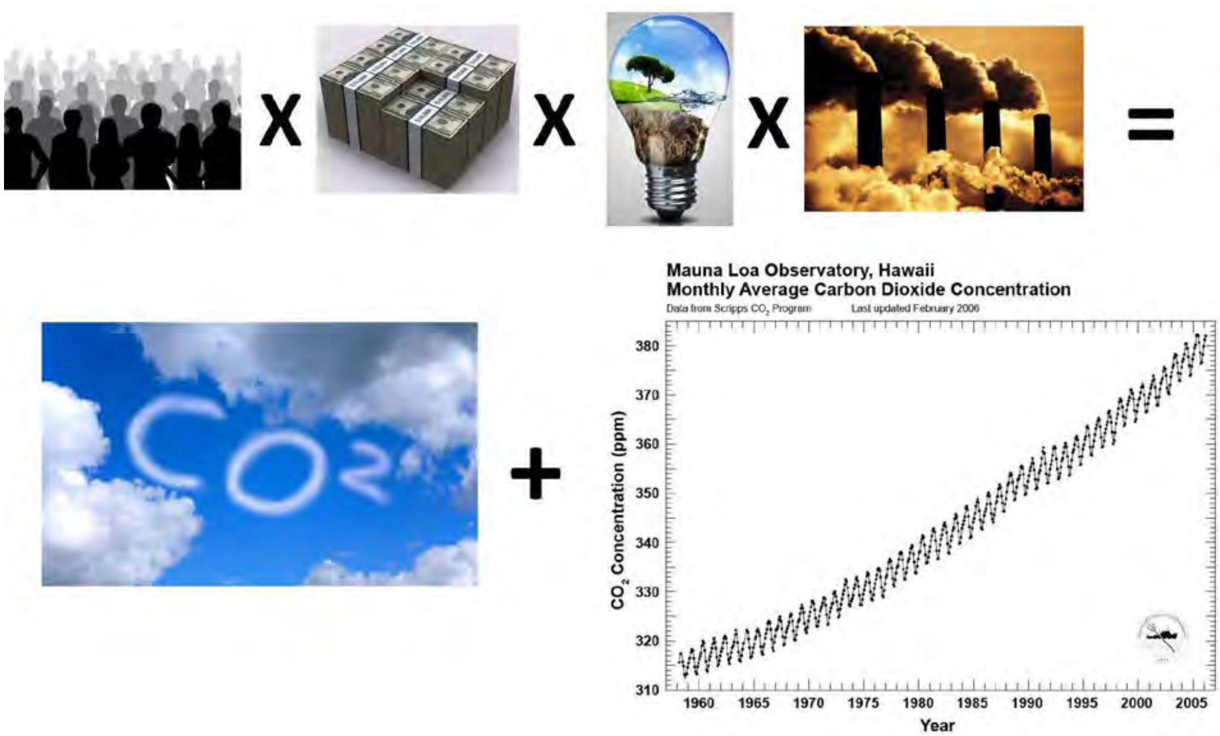


Figure 3-2. The Kaya identity

3.2 Urban Sprawl and Loss of Farmland

3.2.1 Affected Environment

3.2.1.1 Urban Sprawl

Using two entirely different methodologies, two distinct federal agencies – the U.S. Census Bureau (USCB) and the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) – have collected extensive data for decades that are useful in calculating the progressive loss of farmland and open space to urban sprawl over time. Since 1950, USCB has kept track of so-called Urbanized Land, consisting of Urbanized Areas (UA's) and Urban Clusters (UC's), in conjunction with the decennial censuses. The NRCS began inventorying the growth of Developed Land in 1982 as part of its National Resources Inventories (NRI's).

Despite both anti-sprawl initiatives (collectively known as "smart growth") and economic setbacks over the last decade that have somewhat slowed the pace of urban sprawl in the U.S., it continues to convert large areas of rural land and natural habitats into urbanized or developed land. In fact, from 2002 to 2010, over 8.3 million acres (approximately 13,000 square miles [mi^2] or 33,670 square kilometers [km^2]) – an area larger than Maryland – were developed (NRCS 2013b, Kolankiewicz et al. 2014).

From 1982 to 2010, 41.4 million acres (approximately 65,000 mi^2 or 168,350 km^2) – an area approximately equivalent to the state of Florida – of previously undeveloped non-federal rural land was built on to accommodate America's growing cities and towns. Of these 41 million acres lost – or "converted" as land managers and planners generally refer to it – over 17 million acres were forestland, 11 million acres cropland, and 12 million acres pasture and rangeland.

As the NRCS stated it in its 2007 summary report, reviewing the 1982-2007 quarter-century:

> The net change of rural land into developed land has averaged 1.6 million acres per year over the last 25 years, resulting in reduced agricultural land, rangeland, and forest land. Loss of prime farmland, which may consist of agriculture land or forest land, is of particular concern due to its potential effect on crop production and wildlife (NRCS 2013a).

Figure 3-3 shows the increase in developed land from 1982 to 2010, as estimated by the NRCS and the NRI initially in 5-year intervals, and later more frequently. The total area of developed land grew from 71.9 million acres (112,356 mi^2 or 291,000 km^2) in 1982 to 113.3 million acres (177,096 mi^2 or 458,678 km^2) in 2010. This latter area is about equal in size to the states of Maine, New Hampshire, Vermont, Massachusetts, Connecticut,

Rhode Island, Delaware, New York, and Pennsylvania, that is, the entirety of New England and then some. All of this land was originally developed from either agricultural land or natural habitat. As the NRCS observes: "more than one-third of all land that has ever been developed in the lower 48 states was developed during the last quarter-century" (NRCS 2013a).

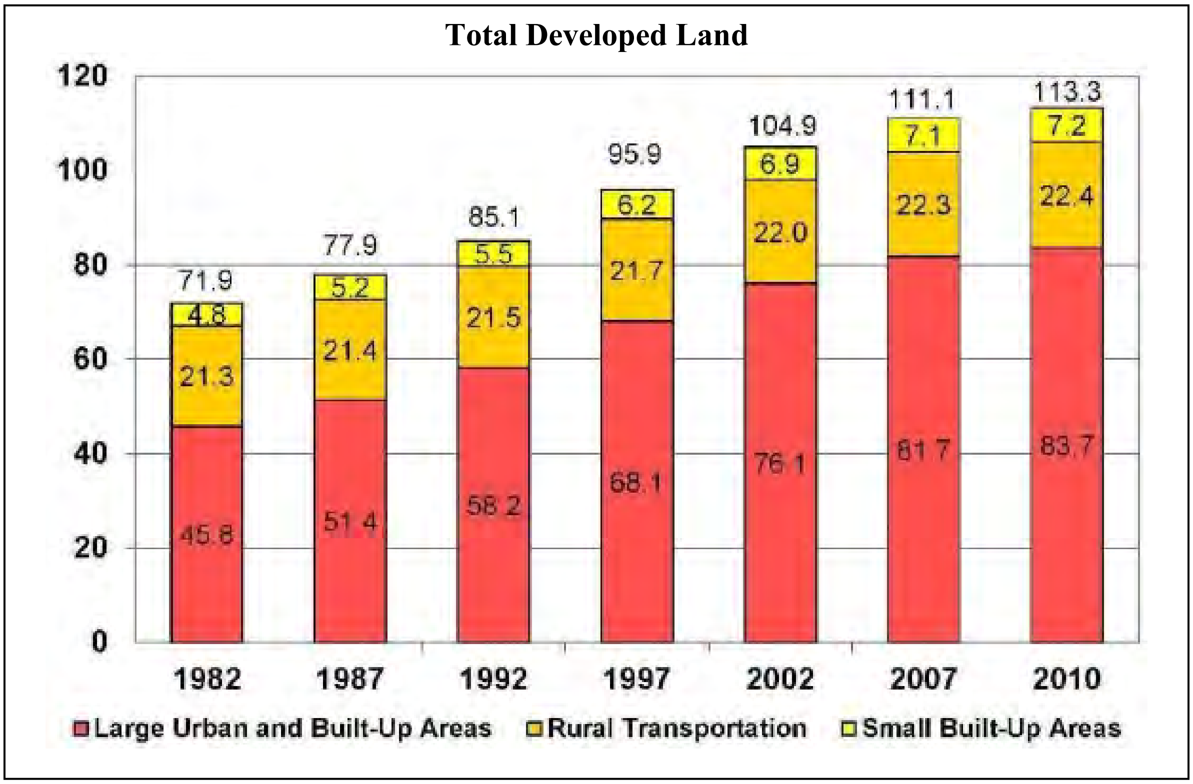


Figure 3-3. Growth in Developed Land, 1982-2010 (millions of acres)
Source: NRCS, 2013b. *Summary Report: 2010 National Resources Inventory*.

The annual increase in Developed Land over this 28-year period varied from 760,000 acres to 2,159,000 acres, and averaged 1.5 million acres/year. The low of 760,000 acres/year was the annual average for the 2007-2010 period, corresponding to the Great Recession.

The right column of Table 3-1 shows the average amount of open space that was developed to accommodate the addition of each extra person to the U.S. population during the designated period. The land developed for each additional resident in the United States ranged from a low of 0.3 acre during the 2007-2010 period to a high of 0.85 acre during the 1992-1997 period. The average was 0.53 acre for the entire 28-period of study. In essence, every additional person added to the United States population entails the development of about half an acre of farmland or natural habitat.

Table 3-1 dissects the data presented in Figure 3-2.

Table 3-1. Increase in Developed Land and Developed Land Per Capita, 1982-2010

Period	Period Growth in Developed Land (thousand acres)	Annual Growth in Developed Land (thousand acres)	Additional Developed Acreage for Each Person Added to Population During Period Shown	
1982-1987	6,025	1,205	1982-1987: 0.58	1982-1992: 0.58
1987-1992	7,205	1,441	1987-1992: 0.57	
1992-1997	10,796	2,159	1992-1997: 0.85	1992-2002: 0.65
1997-2002	9,007	1,801	1997-2002: 0.45	
2002-2007	6,121	1,224	2002-2007: 0.45	2002-2010: 0.39
2007-2010	2,281	760	2007-2010: 0.30	

The nation's 497 designated UA's sprawled by a total of 13,586 mi^2 (35,188 sq. km^2) from 2000 to 2010 (USCB 2013d). Table 3-2 lists the 10 cities (Urbanized Areas) with the most sprawl in the country from 2000-2010.

Table 3-2. Urbanized Areas with greatest sprawl in square miles (2000 to 2010)

Urbanized Area	Sprawl (sq. miles)
1. Atlanta, GA	683
2. Dallas-Fort Worth-Arlington, TX	372
3. Houston, TX	365
4. Phoenix-Mesa, AZ	348
5. Chicago, IL-IN	320
6. Charlotte, NC-SC	307
7. Austin, TX	205
8. Raleigh, NC	199
9. San Antonio, TX	190
10. Philadelphia, PA-NJ-DE-MD	182
Total sprawl from top 10 cities	**3,171**

Source: U.S. Census Bureau Urbanized Area data

America's population and cities have both grown many-fold since the country's origins in the 18th century. Yet after World War II, especially in the fifties and sixties, the juxtaposition of explosive population and economic growth – fueled by the Baby Boom, pent-up consumer demand, federal policies, and cheap gasoline – resulted in the new phenomenon of urban (or suburban) sprawl: the accelerated outward expansion of cities and their surrounding suburbs along the periphery (Figure 3-4). The suburbs were touted as combining the best of both country and city living. Lower residential densities and higher population growth interacted synergistically to increase the consumption and conversion rate of open space, countryside, and farmland. According to the NRI, by 2010, developed land comprised 7.6% of all non-federal land in the United States, up from 4.8% in 1982 (NRCS 2013b). A sense of relative proportion is provided visually by Figure 3-4, a recent composite satellite image of the U.S. at night, and Figure 3-5 from the USCB, which depicts all urbanized lands (UA's and UC's) in 2010.

Figure 3-4. Aerial view of suburban sprawl in San Jose, California

The brightly lit zones of Figure 3-5 correspond closely to the distribution of UA's and UC's of Figure 3-6, and are heavily concentrated along the East, West, and Gulf Coasts as well as portions of the South and margins of the Great Lakes. Similarly, Figure 3-5's bands of relative darkness that predominate over much of the West (approximately west of the 100th Meridian) in the High Plains, Rocky Mountains, and Southwestern deserts

match the location of Figure 3-6's more widely scattered Urbanized Areas and Urban Clusters. These darkish areas evince a much lower population density and the widespread presence of arid deserts, rugged mountains, and vast areas of both irrigated and dryland agricultural hinterlands that produce food for hundreds of millions of residents congregated in America's cities.

Figure 3-5. Composite satellite image of the United States at night

3.2.1.2 Farmland Loss

Conversion to developed land is not the only cause of the degradation and disappearance of high-quality agricultural land. Arable land is also vulnerable to other damaging natural and artificial forces such as soil erosion from wind and water, and salinization and waterlogging from irrigation, which can compromise the fertility, productivity, and depth of soils, and possibly even lead to their premature withdrawal from agriculture. Many of these adverse effects are due to over-exploitation by intensive agricultural practices needed to maintain and increase yield per acre and overall harvests to support: 1) a U.S. population growing by 25 million or more every decade, 2) diets heavy on meat and dairy products (which require much more land, water and other resources to produce a given amount of protein, calories, and other nutrients), and 3) exports of grain, meat, and other agricultural products.

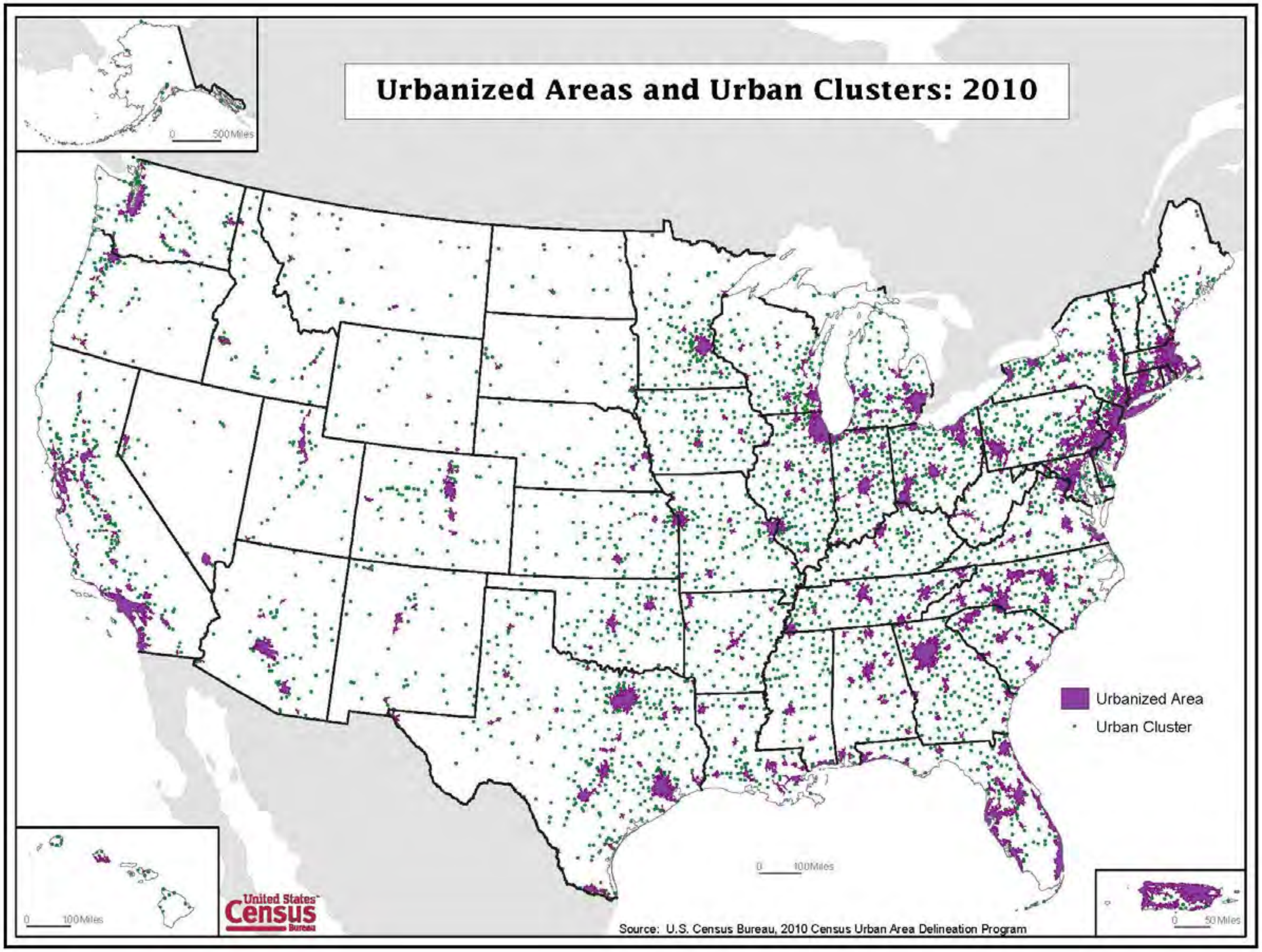


Figure 3-6. Nationwide spatial distribution and comparative size of Urbanized Areas and Urban Clusters in 2010

In essence, the potent juxtaposition of relentless development and land degradation from soil erosion and other factors is reducing the productive agricultural land base of the United States – even as the pressures on that same land base from a growing population and other causes are intensifying (Kolankiewicz et al. 2014). The NRI estimates that the acreage of cropland in the U.S. decreased from 420 million acres in 1982 to 361 million acres in 2010, a decline of nearly 60 million acres (14 percent) in less than three decades (Figure 3-7). Some of this cropland (cumulatively, 27 million acres in 2010) was withheld from active farming with federal government support and subsidies and placed into the Conservation Reserve Program (CRP), but these tend to be marginal, fragile, erosive, or environmentally sensitive sites on which cultivation is not deemed to be sustainable or environmentally appropriate.

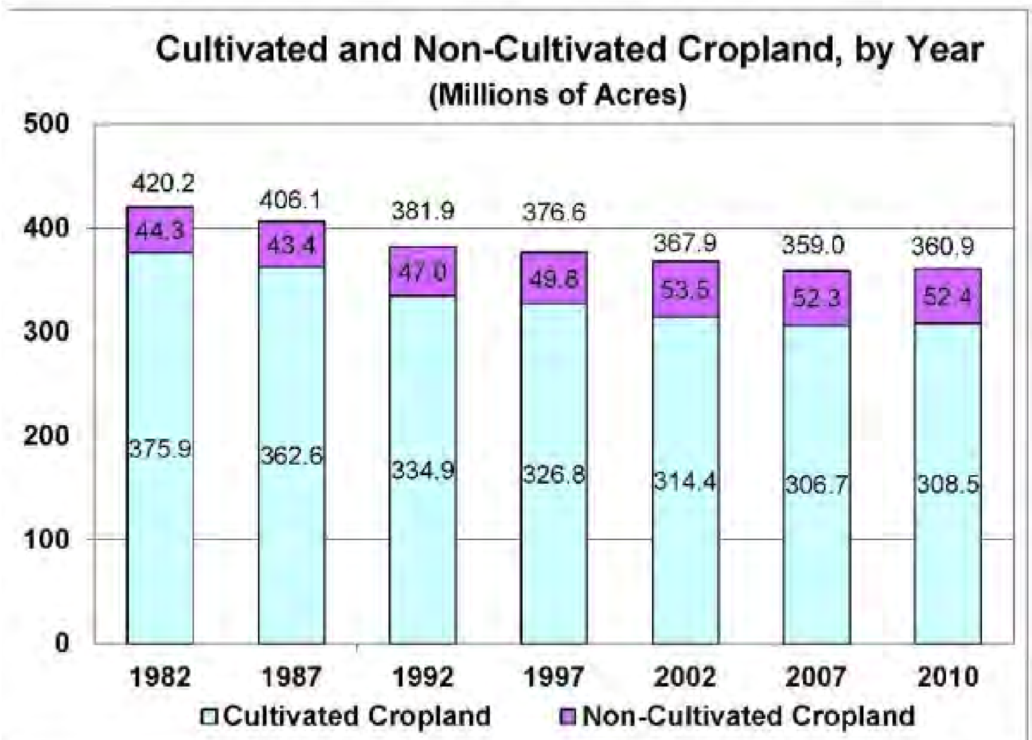


Figure 3-7. Area of cropland in the United States, 1982-2010
Source: NRCS 2013b

Even with the federal ethanol mandate and strong financial incentives over much of the last decade to grow corn in order to produce ethanol as a fuel for vehicles (blended with gasoline), the amount of cropland dropped by seven million acres in the eight years between 2002 and 2010, increasing slightly between 2007 and 2010. The land uses into which cropland was converted are depicted in Figure 3-8.

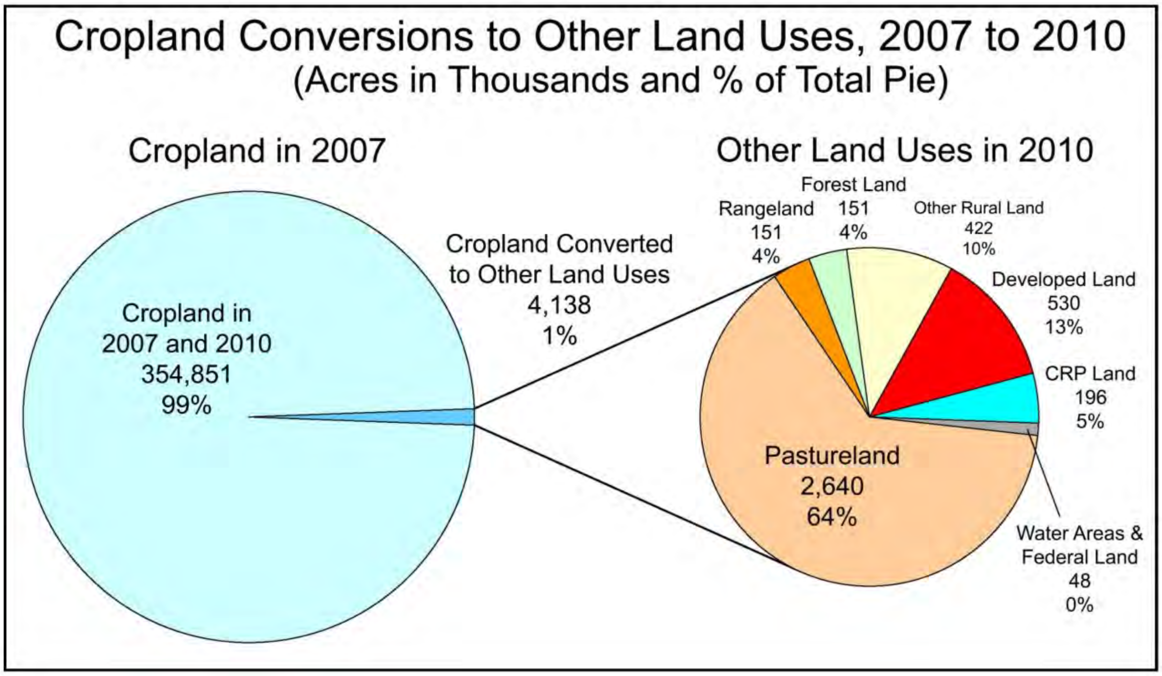


Figure 3-8. Cropland converted to other land uses from 2007 to 2010

If the 1982-2010 rate of cropland conversion and loss continues to the year 2100, the U.S. will lose an additional 193 million acres of its remaining 361 million acres of cropland, for a total cumulative loss of 253 million acres. Only 168 million acres would then remain – about 40 percent of the 1982 area – and none of this acreage would be in pristine condition after two centuries or so of intensive exploitation. Its soils and nutrients, while perhaps not depleted, would require even greater inputs of costly fertilizers. Two of the most critical fertilizers by mass – ammonium nitrate, manufactured from natural gas, and phosphorus, produced from phosphate mines – may be much more expensive in 2100 than at present, perhaps prohibitively so, because of the inexorable depletion of the highest-quality reserves of these non-renewable resources (Kolankiewicz et al. 2014).

Table 3-3 shows the area of cropland per capita in the United States in 1982, 2010, and projected to 2050 and 2100, assuming the same rate of cropland loss from 1982 to 2010 and using the most recent Census Bureau projections. Available cropland will have decreased from 1.9 acres per person in 1982 to 0.3 acre per person in 2100, an 84 percent drop. Figure 3-9 graphically depicts this significant loss in the form of a bar chart.

Table 3-3. Projected long-term decline in cropland per person

Year	Cropland in 48 contiguous states (millions of acres)	U.S. Population in Millions (48 states)	Acres of cropland per capita
1982	420	225	1.9
2010	361	306	1.2
2050	276[1]	400[2]	0.7
2100	168[1]	571[2]	0.3

[1]Projected using annual rate of cropland loss from 1982-2010 (2.1 million acres)
[2]Most recent projections from the United States Census Bureau
Source: Kolankiewicz et al. 2014

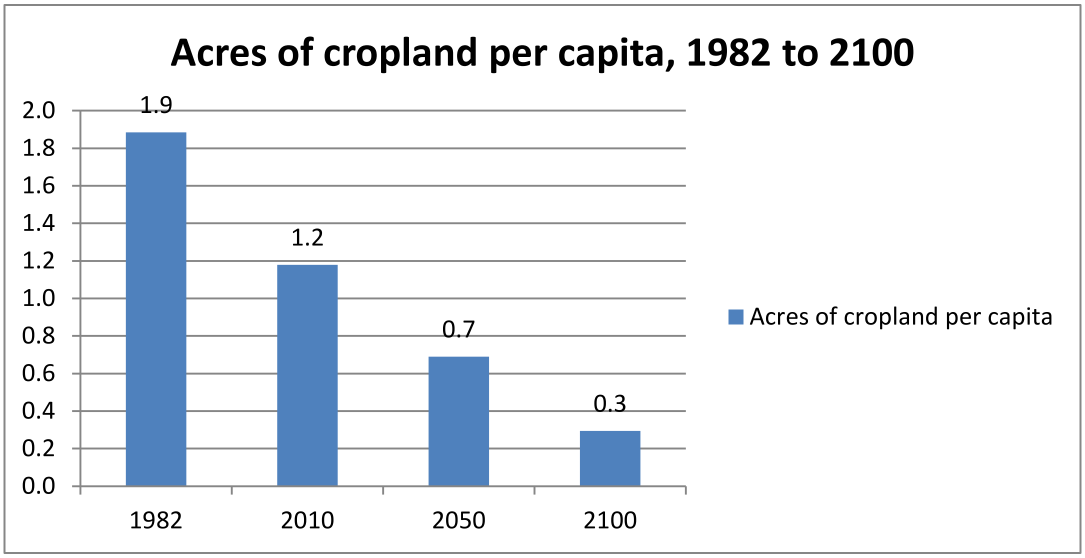


Figure 3-9. Projected long-term decline in cropland per person
Source: Kolankiewicz et al. 2014

3.2.1.3 Role of Population Growth in Sprawl

A series of studies conducted by NumbersUSA over the last decade have quantified the role of population growth in driving suburban sprawl. During the 1970 to 2000 period, while there was substantial variation from city to city and region to region, in the aggregate, population growth accounted for about half (approximately 50%) of all sprawl nationally, while declining population density (increasing per capita land consumption) accounted for the other half (Kolankiewicz and Beck 2001; Beck et al. 2003). In the more recent 2000-2010 period, population growth was related to approximately 70-90% of suburban sprawl on the national scale (Kolankiewicz et al. 2014).

The trend has been toward denser urban and suburban development patterns, and for the purposes of this EIS, it is assumed that this pattern of higher-density development will hold throughout the period of study (i.e., to the year 2100).

3.2.2 Environmental Consequences

3.2.2.1 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million from the 2010 population of 309 million It is also 47 million less than the 571 million projection for 2100 that the U.S. Census Bureau made in 2000 (Table 3-3, Figure 3-9, and Hollmann et al. 2000).

Urban Sprawl

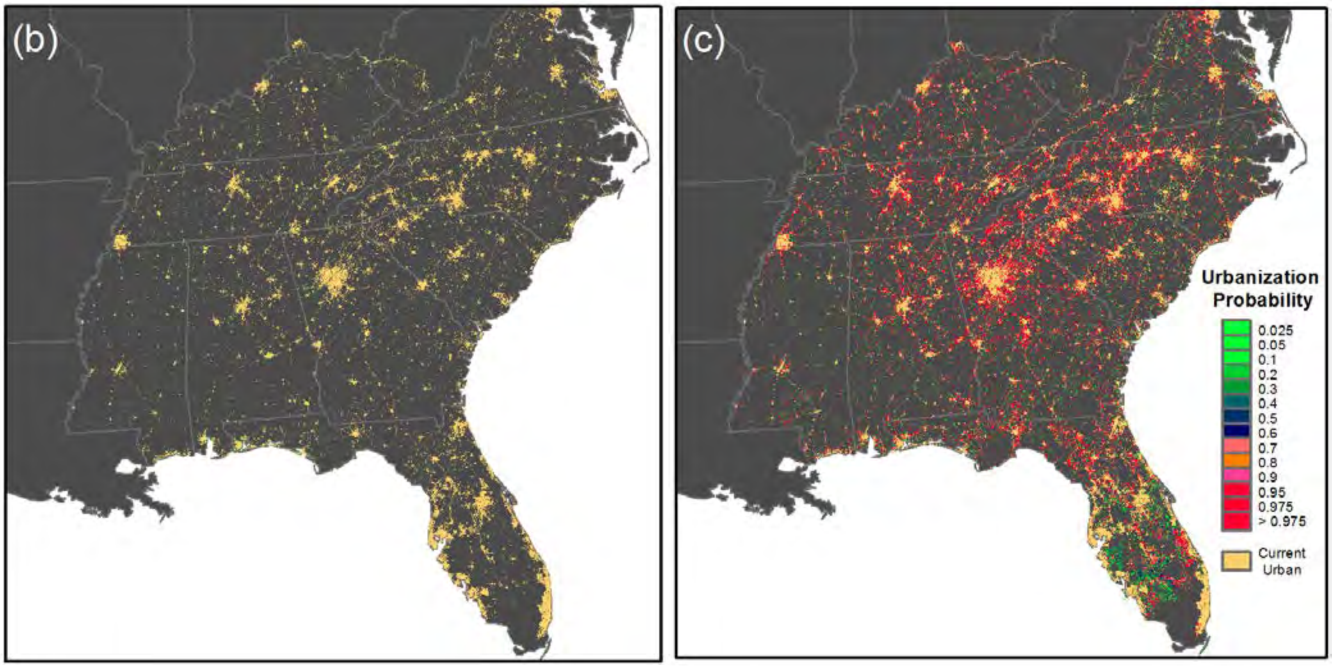
Table 3-1 indicates that during most recent decade for which data are available, each person added to the U.S. population was correlated with the development of approximately 0.4 acre of previously undeveloped land (all of it natural habitat, open space, or farmland). Cumulatively, there is about 0.37 acre of developed land per American. Assuming the same correlation holds throughout the period of study, the addition of 215 million new Americans under the No Action Alternative would entail the development of 79 million additional acres or 123,438 square miles of formerly rural land, an area larger than New Mexico, our 5th largest state. Alternatively, it approximates the combined size of Kentucky, Indiana, South Carolina and West Virginia.

About 90 percent of this sprawl would be due directly to population growth, while about 10 percent would be correlated with increasing per capita land consumption.

In 2010 there were 113 million acres of developed land in the United States. Thus, increasing this by 79 million acres would push the total amount of developed land to 192 million acres or 300,000 square miles in 2100, substantially larger than our second largest state (Texas, at 268,597 square miles). Large swaths of America would lose their rural character and "feel." The average American would be more isolated from authentic countryside than ever before in our history, and this countryside would take longer to reach than ever before; once accessed for sight-seeing, hiking, camping, or picnicking, open spaces such as state or national parks and forests would be more crowded than ever with fellow "urban refugees" seeking a green reprieve from artificial settings. Wild flora and fauna would decrease and threatened and endangered species would increase.

Figures 3-10 and 3-11 are maps showing predicted development in the Southeast and Piedmont regions in 2060 that give some sense of how these regions, once dominated by rural countryside consisting of woodlands, fields, and farms, will have been overtaken by sprawling development. Figure 3-12 shows projected development in Florida in 2060 if current trends persist.

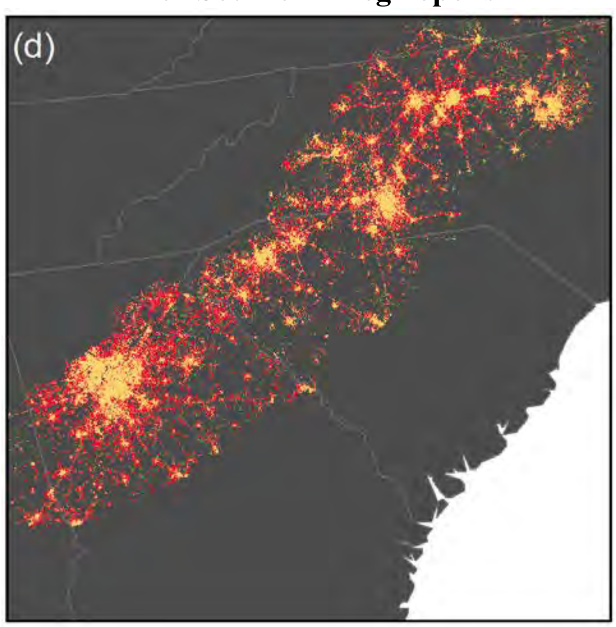
Figure 3-10. Projected increase in the extent of urbanized areas in the Southeastern United States



(b) Southeastern urban land cover in 2009 **(c) Projected Southeastern land cover in 2060**

Source: Terrando et al. 2014. "The Southern Megalopolis: Using the Past to Predict the Future of Urban Sprawl in the Southeast U.S."

Figure 3-11. Predicted 2060 extent of urbanization in the Piedmont – the "Southern Megalopolis"



Source: Terrando et al. 2014

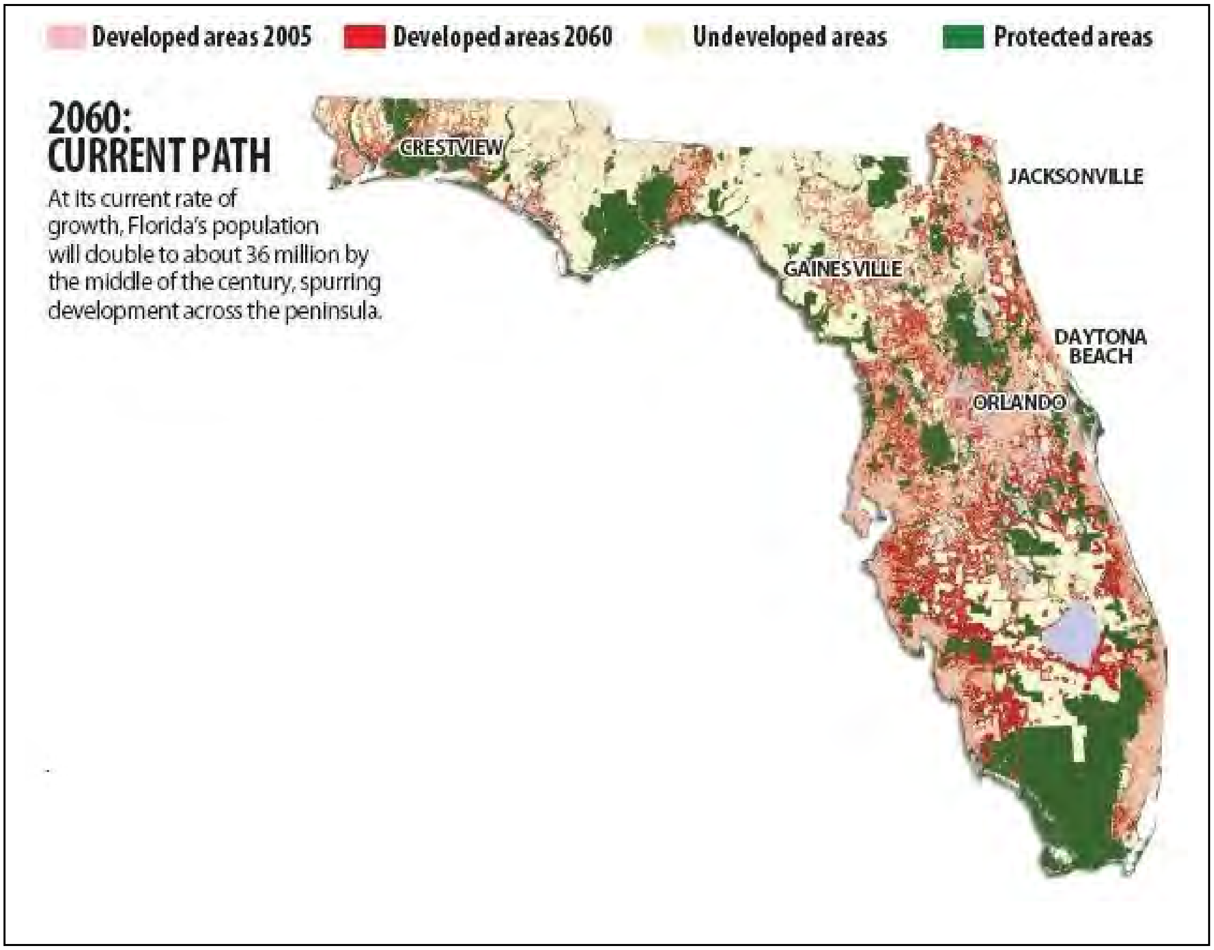


Figure 3-12. Projected development in Florida by 2060 if current trends persist

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would have indirect and cumulative impacts on sprawl as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on sprawl associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on sprawl associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on sprawl associated with the population growth under the No Action Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on sprawl associated with the population growth under the No Action Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher."

Overall, the effect of the No Action Alternative on suburban sprawl would be adverse, significant, and long-term. It would result in the permanent conversion of 79 million additional acres or 123,438 square miles of open space and natural habitat to urbanization – the essentially irreversible process of converting rural land into developed or urbanized land. Urbanized or developed land would increase from 7.6% of all non-federal lands in 2010 to 13.3% in 2100.

Figure 3-13 is a rough visual approximation of the approximate extent to which sprawl would likely have spread in the United States by 2100 under the No Action Alternative (1.25 million annual immigration) if the patterns of development and sprawl that have prevailed in recent decades were to remain unchanged throughout this century. Urbanized areas as of 2010 are shown in purple and additional areas expected to be urbanized by 2100 are in in red. This may be compared to Figure 3-6 from the U.S. Census Bureau.

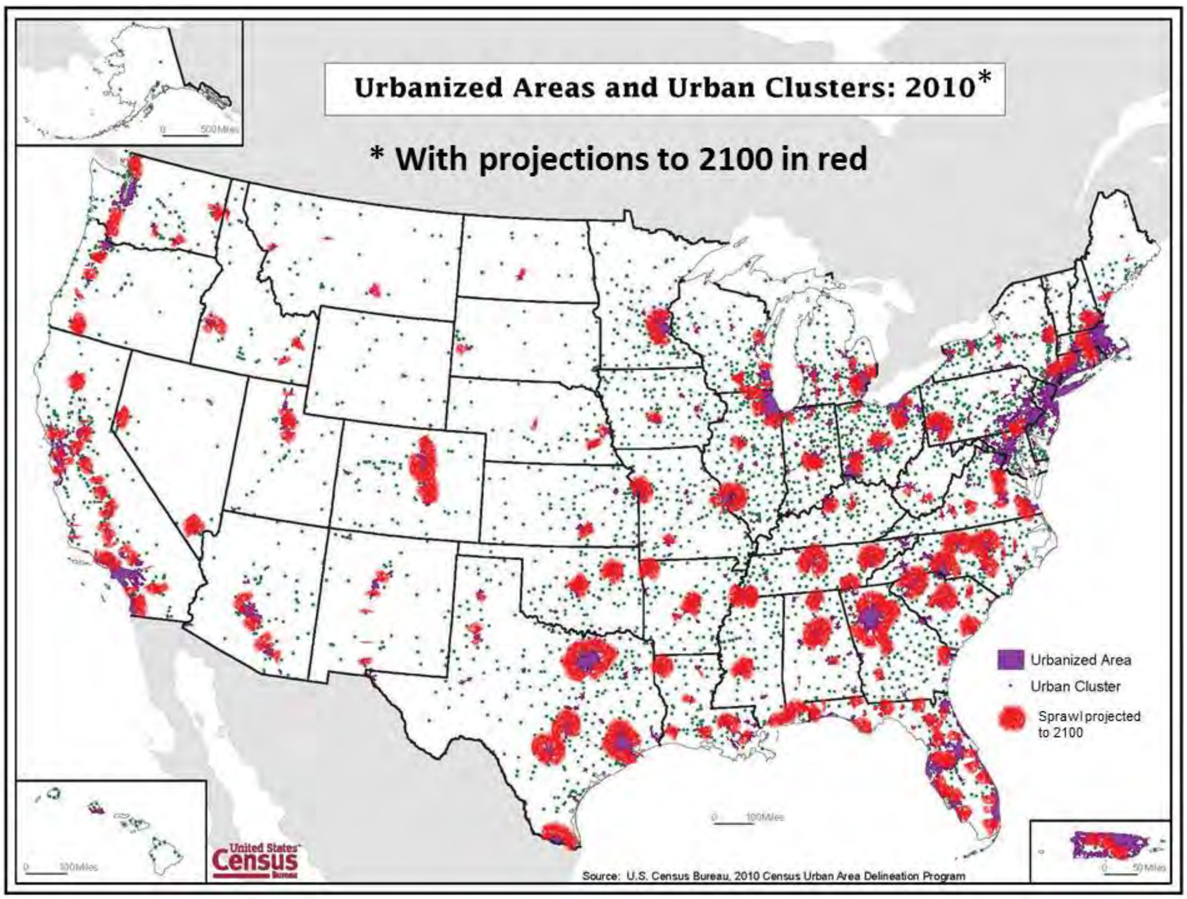


Figure 3-13. Extrapolated extent of sprawl in 2100 under the No Action Alternative

Loss of Farmland

Under the No Action Alternative, an annual immigration rate of 1.25 million into the United States would result in a U.S. population of 524 million in 2100, an increase of 215 million (70 percent) from the 2010 population of 309 million. Accommodating 215 million new Americans would require substantial space and land area – almost 80 million acres' worth. Because farmland tends to be flat, and flatlands are easier and cheaper to build on than hillsides, and because of the proximity of much farmland to urban areas, where it lies directly in the path of development (Figure 3-14), much of the acreage for the new development necessitated by 215 million more residents will likely come from the nation's agricultural land base.

Figure 3-14. Food-producing land vulnerable to urban sprawl
Credit: American Farmland Trust and Farmland Information Center

Interpolating and extrapolating from the average rates of cropland loss and population growth in Table 3-3, it can be inferred that under the No Action Alternative, cropland per capita would decrease from 1.18 acre/person in 2010 to 0.32 acre/person in 2100. At these rates, in 2100 each American would have only 27 percent of the cropland that he or she enjoyed in 2010. Another way of stating this is that agricultural yields (food

produced per acre) would have to increase almost four-fold just to maintain per capita food production.

In order to retain the moderate food prices and diverse diet to which Americans have become accustomed since World War II, there would have to be extraordinary advances in agricultural productivity through technological innovation and genetically modified organisms (GMOs) to offset these probable losses in the nation's productive land base. Simply increasing the use of fertilizers, pesticides, and irrigation, all of which worked in the 20th century to raise agricultural output enormously, will not be options. The extent to which output gains induced by future technological advances can cope with likely declines in the available productive land base is a subject of continuing lively discussion and debate among agricultural scientists, scholars, and policy makers.

The impact of farmland and cropland loss due to immigration-induced population growth could also be mitigated to some extent by sharpening America's commitment to implementing Smart Growth programs and farmland protection policies of the sort advocated by conservation groups like the American Farmland Trust (2013). Each of these policies, if successfully implemented at scale, would have the net effect of increasing population density on both existing and future developed land. Americans would have to be willing to accept relatively more apartments and condominiums and relatively fewer and smaller single detached homes with yards. Just how politically and culturally feasible this large shift in public attitudes would be remains to be seen.

Two other shifts could also potentially ameliorate the loss of cropland and farmland per capita that current demographic trends are forcing on the United States. First, America could import more agricultural products from places like Mexico, Chile, and Argentina, although if energy and transport prices increase substantially in the future with the ongoing depletion of conventional fossil fuels, this option could become costlier, less feasible, and ultimately prohibitive. Second, Americans could embrace less meat and dairy products and more vegetarianism and veganism. Well some might criticize this as a loss of dietary freedom, others might endorse it as a healthier diet less prone to cardiovascular disease. Nevertheless, it is well established in the scientific literature that low-meat diets (consuming plant protein and nutrients directly rather than feeding grains to livestock and poultry first) entail substantial environmental benefits via less energy, land and water consumption (Reijnders and Soret, 2003).

These are the profound and contentious issues raised by increasing population pressures on America's agricultural land base. As the 21st century proceeds, and if Americans acquiesce to the No Action Alternative on immigration rates, these questions will bear down ever harder on the collective American body politic.

Using the conversion rate (530,000 acres in three years) shown in Figure 3-8, some 16 million acres of cropland would be developed between 2010 and 2100. However, only 13 percent of the cropland conversions from 2007-2010 were to developed land (sprawl); 87 percent of the cropland converted was to other land uses, primarily another type of farmland – pastureland.

Another approach to predicting likely aggregate cropland loss from 2010 to 2100 that may be attributable to population growth uses the average rate of cropland lost specifically to development between 1982 and 2007, according to the NRCS's National Resources Inventory data. On average, 405,520 acres of cropland were developed annually during the 25-year period from 1982 to 2007 (NRCS 2013a). During that same time period, America's population grew by an average of 2.8 million per year. Dividing 405,520 acres by 2.8 million yields a rate of cropland loss of 0.145 acre per added resident; every seven people added to the population resulted in the development of one acre of cropland.

If we assume this relationship between population growth and cropland conversion (0.145 acre developed for each person added to population), and if the U.S. population were to grow by 215 million in 2100, as in the No Action Alternative, that would entail the direct loss of 31.2 million acres of the nation's cropland to population-growth-related development. Figure 3-15 graphically depicts these long-term, contrary trends: as population increases, cropland decreases, and this inverse relationship no mere coincidence. The added development needed to accommodate the needs of tens of millions more people – for residence, transportation, workplaces, schools, commercial districts, infrastructure, and so forth – inevitably uses land, and in many case, much of the most convenient land to build on at the urban periphery is cropland.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would have indirect and cumulative impacts on farmland as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on farmland associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on farmland associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on farmland associated with the population growth under the No Action Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on farmland associated with the population growth under the No Action Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on aggregate and per capita farmland acreage.

Overall, the effect of the No Action Alternative on farmland would be adverse, significant, and long-term. It would likely be associated with the permanent disappearance of many tens of millions of acres of farmland (cropland, pastureland, and rangeland) to urbanization. While the sustainability of many current agricultural practices is questionable, surviving farmland and soils remaining in cultivation or under grazing regimes would be subjected to even more intensive pressures and practices in order to maintain productivity at all costs. In itself, this is likely untenable and unsustainable over the long run.

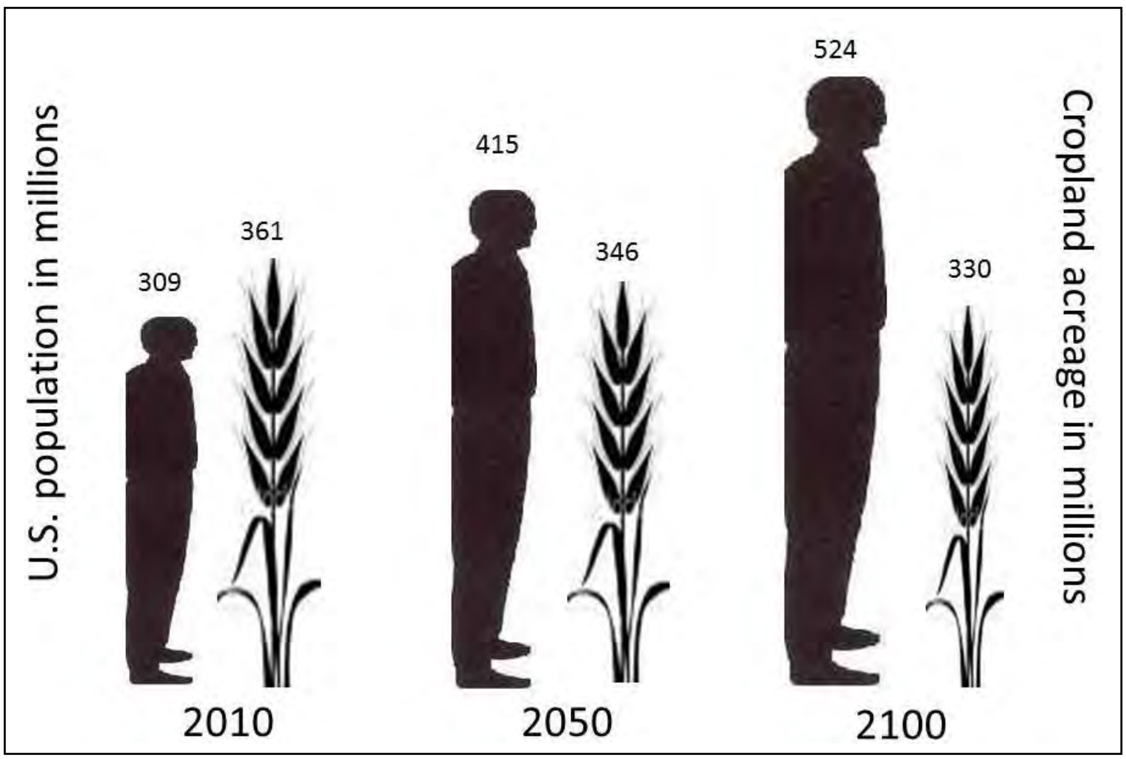


Figure 3-15. No Action Alternative – Rising population (silhouette of man) and falling cropland (silhouette of grain seedhead) in America in the 21st century

3.2.2.2 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would lead to a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million from the 2010 population of 309 million. It is also 98 million more than the "middle series" projection of 571 million for 2100 that the U.S. Census Bureau made in 2000 (Table 3-3, Figure 3-9, and Hollmann et al. 2000). But, it is worth pointing out, much less than the "highest series" projection of 1.2 billion Census made at the same time. The Expansion Alternative is thus within the realm of the plausible, and indeed, it may come to pass if proposals like those promoted by the Obama Administration and "comprehensive immigration reform" advocates in Congress – or future administrations or congresses – were ever to be signed into law.

Urban Sprawl

Under the Expansion Alternative, the 2100 U.S. population of 669 million would exceed the No Action Alternative population of 524 million by 145 million. In other words, the population would be 28 percent larger. For the purpose for of this basic analysis, it is assumed that each of these 145 million additional persons would utilize the same amount of urban land on average as in the No Action Alternative. That is, average per capita urban land consumption would remain the same. Thus, under the Expansion Alternative, the total Urbanized Land area (a.k.a. developed land or sprawl) in the United States would be 28 percent greater in this alternative than in the No Action Alternative.

Under the Expansion Alternative, 113 million acres of developed land in 2010 are therefore projected to increase to 245 million acres or 383,000 square miles by 2100. This would be about equal in area to Texas and New Mexico combined, that is, our second and fifth largest states. Still larger swaths of Rural America would forever be converted to Urbanized Areas and lose their rustic character and "feel" than in the No Action Alternative. Even extensive areas of the country that would still be officially designated "rural" under the classification systems of Census and the NRCS would nonetheless be under the influence of adjacent developed areas and would lose some of their rural feel. The delineated acreage of developed or urbanized land *per se* actually underrates its actual pervasiveness in the American landscape because built-up land affects environmental quality on the lands and waters adjacent rural areas by means of water demands, noise, views, odors, air and water pollution, transportation infrastructure, traffic levels, and crowding of parks and open space (Beck et al., 2003).

Examples abound of the widespread penetration of adverse urban influences into rural hinterlands:

- Coal-fired electricity generating stations in the Ohio River Valley that furnish electricity to tens of millions of consumers in large Eastern cities generate sulfur dioxide emissions that impair visibility in the countryside and then fall to earth as acid precipitation (rain and snow) hundreds of miles away in wilderness areas of the Adirondacks, Canada, and New England. By the 1970s, the once densely-forested summit of Mt. Mitchell in North Carolina's Great Smoky Mountains, at 6,683 ft. elevation, the highest point in eastern North America, had been stripped to skeletal tree remains from being bathed in acid-laced clouds.

Figure 3-16. Smog blights the Sierra Nevada Range of California

Likewise, prevailing winds transport smog originating in Southern California eastward toward the sparsely populated Joshua Tree National Park in the Mojave Desert and beyond to the Grand Canyon in northern Arizona. Smog from California's rapidly growing Central Valley often blights the beautiful blue-sky vistas in the Sierra Nevada mountain range just to the east (Figure 3-16). The largest trees in the world, the 2,500 year-old giant sequoias growing at 4,500-6,500 foot elevation on the flanks of the Sierra Nevada in Sequoia-Kings Canyon, are exposed to smog and elevated ozone concentrations (Wheelwright, 2014; Miller et al., 1994).

- Water quality in the East Coast's most important estuary, the Chesapeake Bay, is impaired by the sheer spread of pavement and other impervious surfaces within its 64,000-square-mile watershed. Already by 1990, some 11,480 square miles within the watershed had been developed, and analysis of satellite imagery and other ground-based data indicates that in the 1990s an additional acre was being developed every six to 10 minutes. Residential and related land development and other "non-point sources" degrades local streams and sends nutrients (primarily nitrogen and phosphorus compounds) and toxic pollutants into the bay, which threaten to overwhelm hard-won, costly reductions in these "loading" (Blankenship 2000, EPA 2014b).

- Urban growth demands water that, especially in the arid West, must be diverted from farmers and natural ecosystems. Suburban neighborhoods with lawns and pools are particularly water-intensive. Of California's 350 water basins, 40 are

seriously overdrafted, and by 2020 water planners predict a water supply deficit of two to eight million acre-feet ((Bank of America 1996). Recent droughts and climate change predictions of a drier future for the state paint an even more dire picture. Rising urban demands for water along over-allocated rivers such as the Platte River in Nebraska, the Rio Grande in New Mexico, and the Colorado River in Arizona have adversely impacted water quality and flows and terrestrial and aquatic wildlife habitat literally hundreds of river miles downstream from those urban areas withdrawing water for municipal use.

- One of the reasons farmers are often forced to quit farming as suburbia encroaches ever further into the countryside is that livestock and manure odors inevitably drift into adjacent subdivisions and cause complaints. Likewise, the acrid odor of factories, pulp mills, and smelters can diffuse across vast areas.

- Ever more frequently across the country, sightseers at local overlooks and viewpoints must gaze out across manmade clutter where once there had been mostly open landscapes. Hikers in California and Colorado reach summits only to be rewarded with vistas of new subdivisions under construction (Figure 3-17). Sprawl threatens the bucolic ambience of such national historic treasures as Mt. Vernon and the hallowed Civil War battlefields of Manassas- Bull Run, Antietam, Fredericksburg, and Gettysburg, among others.

Figure 3-17. Sprawl along Colorado's Front Range

- Noise from airports and highways propagates out across the empty spaces beyond. At Petroglyphs National Monument just west of Albuquerque, jets roaring overhead as they take off from the city's airport ("sunport") intrude upon the sense of tranquility and the timelessness of mute, centuries-old Native American rock carvings (Figures 3-18 and 3-19).

Figure 3-18. Sprawl on the edge of Albuquerque, New Mexico encroaches upon escarpment containing ancient petroglyphs

Figure 3-19. Sprawl butts up against centuries-old Native American petroglyphs next to Albuquerque, New Mexico

Figure 3-20 is a graphic depicting the estimated extent of sprawl by 2100 under the Expansion Alternative and a U.S. population of 669 million. This image is somewhat conjectural rather than definitive, but it is one reasonable scenario for the future based on extrapolating land development trends that have now persisted for the past 60 years or more.

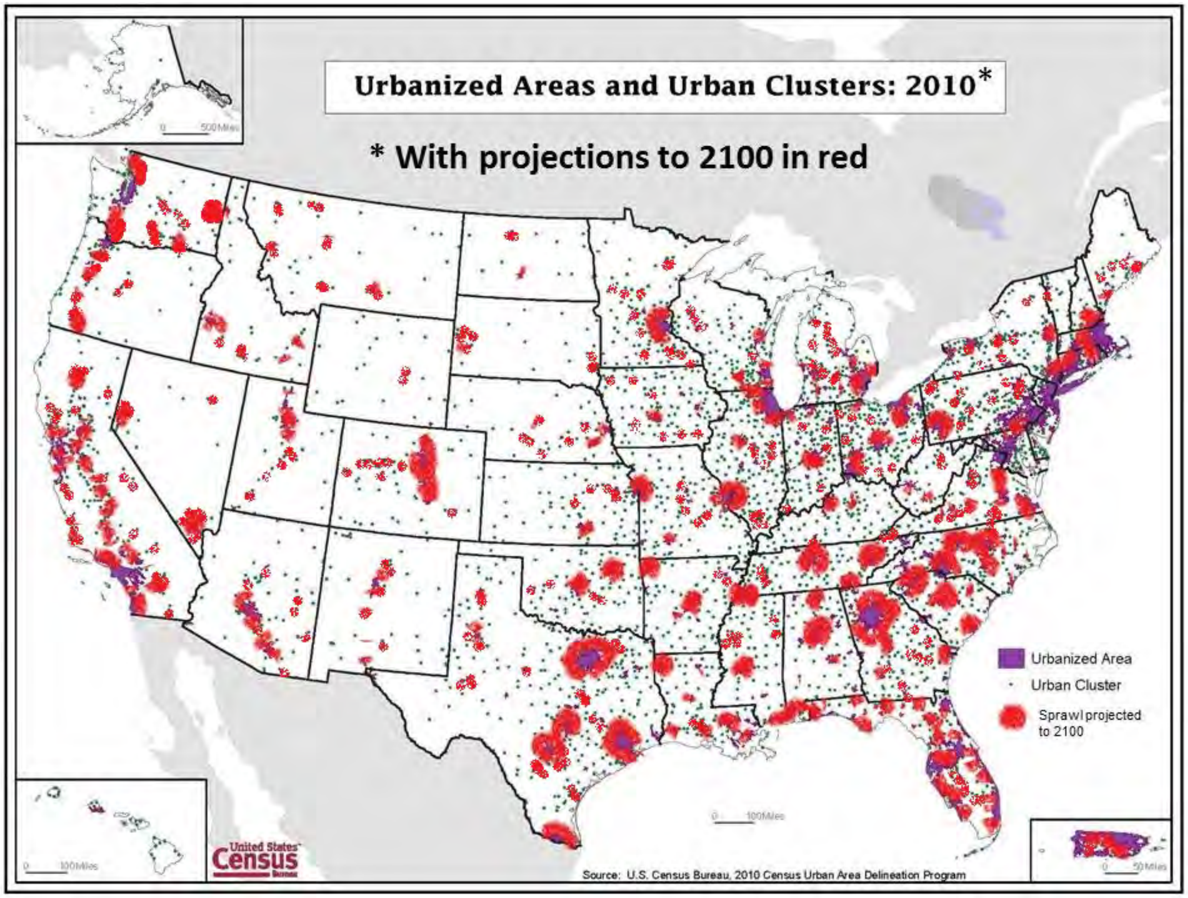


Figure 3-20. Extrapolated extent of sprawl in 2100 under the Expansion Alternative

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would have indirect and cumulative impacts on sprawl as follows:

- **Duration of Impact**: ***Long-term to permanent***. The duration of the impact on sprawl associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on sprawl associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on sprawl associated with the population growth under the Expansion Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on sprawl associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher."

Overall, the effect of the Expansion Alternative on suburban sprawl would be adverse, significant, and long-term. It would result in the permanent conversion of 132 million additional acres or 206,250 square miles of open space and natural habitat to urbanization – the essentially irreversible process of converting rural land into developed or urbanized land. Urbanized or developed land would increase from 7.6% of all non-federal lands in 2010 to 17 percent in 2100 (compared to 13 percent under the No Action Alternative).

Loss of Farmland

Under the Expansion Alternative, an annual immigration rate of 2.25 million into the United States would result in a U.S. population of 669 million in 2100, an increase of 360 million (70 percent) from the 2010 population of 309 million, more than a doubling. Accommodating 360 million new Americans would require significant space and land area – perhaps as many as 132 million acres' worth. As noted above, because farmland tends to be flat, and because flatlands are easier and cheaper to build on than hillsides, much of the acreage for the new development necessitated by 360 million more residents will likely come from the nation's agricultural land base.

Using the conversion rate (530,000 acres in three years) shown in Figure 3-8, some 16 million acres of cropland would be developed between 2010 and 2100. However, only 13 percent of the cropland conversions from 2007-2010 were to developed land (sprawl); 87 percent of the cropland converted was to other land uses, primarily another type of farmland – pastureland.

Another approach to predicting likely cropland loss from 2010 to 2100 that may be attributable to population growth uses the average rate of cropland lost specifically to development between 1982 and 2007, according to the NRCS's National Resources Inventory data. On average, 405,520 acres of cropland were developed annually during the 25-year period from 1982 to 2007 (NRCS 2013a). During that same time period, America's population grew by an average of 2.8 million per year. Dividing 405,520

acres by 2.8 million yields a rate of cropland loss of 0.145 acre per added resident; every seven people added to the population resulted in the development of one acre of cropland. Using this relationship established in the previous section between population growth and cropland conversion (0.145 acre of cropland developed to accommodate each new person in the population), if the population were to grow by 360 million in 2100, as under the Expansion Alternative, that would lead to the direct loss of 52.2 million acres of the nation's cropland to population-growth-related development.

Table 3-4 shows the projected cropland lost directly to population-related development alone under the three immigration and population growth scenarios (alternatives) considered in this EIS. Under the Expansion Alternative, cumulative cropland lost to development would be 22 million acres by 2050 and 52 million acres by 2100. If these acreages seem conservative, it must be remembered that development accounts for only relatively small percentage of cropland conversion, only 13 percent from 2007 to 2010 according to NRI data. In other words, total cropland conversion or loss by 2050 and 2100 will be much greater than the values shown in Table 3-4.

Table 3-4. Projected cumulative cropland loss by 2050 and 2100 under the three immigration scenarios (alternatives) used in this EIS

Alternative	Average annual net migration	U.S. cropland in 2010 (acres)	Cropland lost to development by 2050 (acres)	Cropland lost to development by 2100 (acres)
Reduction	250,000	361 million	8.7 million	10.2 million
No Action	1.25 million	361 million	15.4 million	31.2 million
Expansion	2.25 million	361 million	21.9 million	52.2 million

In addition, cropland is only one of the three categories of agricultural land or farmland designated by the NRCS and inventoried by the NRI. Pastureland and rangeland are the other two major categories of farmland, and these have also seen declines in recent decades because of development, though not as dramatically as cropland. The NRCS estimates that between 1982 and 2007, the nation's pastureland was developed ("paved over") at the rate of about 280,000 acres/year (compared to 400,000 + acres/year for cropland). Meanwhile, rangeland – which is more concentrated in the sparsely populated High Plains (the former shortgrass prairie province once dominated by vast herds of bison) and Rocky Mountain West, and therefore less vulnerable to development – was converted to developed land at the rate of 212,000 acres/year.

Under the Expansion Alternative, tens of millions of additional acres of pastureland and rangeland would also be developed by 2100 to accommodate the needs of 360 million more Americans.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would have indirect and cumulative impacts on farmland as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on farmland associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on farmland associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on farmland associated with the population growth under the Expansion Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on farmland associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on aggregate and per capita farmland acreage.

Overall, **the effect of the Expansion Alternative on America's farmland would be highly adverse, significant, and long-term**. It would likely be associated with the permanent disappearance of between tens of millions of acres of farmland (cropland, pastureland, and rangeland) to urbanization. While the sustainability of many current agricultural practices is questionable, surviving farmland and soils remaining in cultivation or under grazing regimes would be subjected to even more intensive pressures and practices in order to maintain productivity at all costs. In itself, this is likely untenable and unsustainable over the long run.

Figure 3-21 graphically depicts the same long-term, opposing trends for the Expansion Alternative (2.25 million annual immigration) as Figure 3-15 does for the No Action Alternative (1.25 million annual immigration): with a U.S. population increase of 360 million by 2100, cropland declines as development spreads across arable lands to make way for subdivisions, streets and highways, shopping centers, playgrounds, schools, government office buildings, wastewater treatment plants, electrical substations, and so forth – all of the structures and facilities needed to accommodate American consumers.

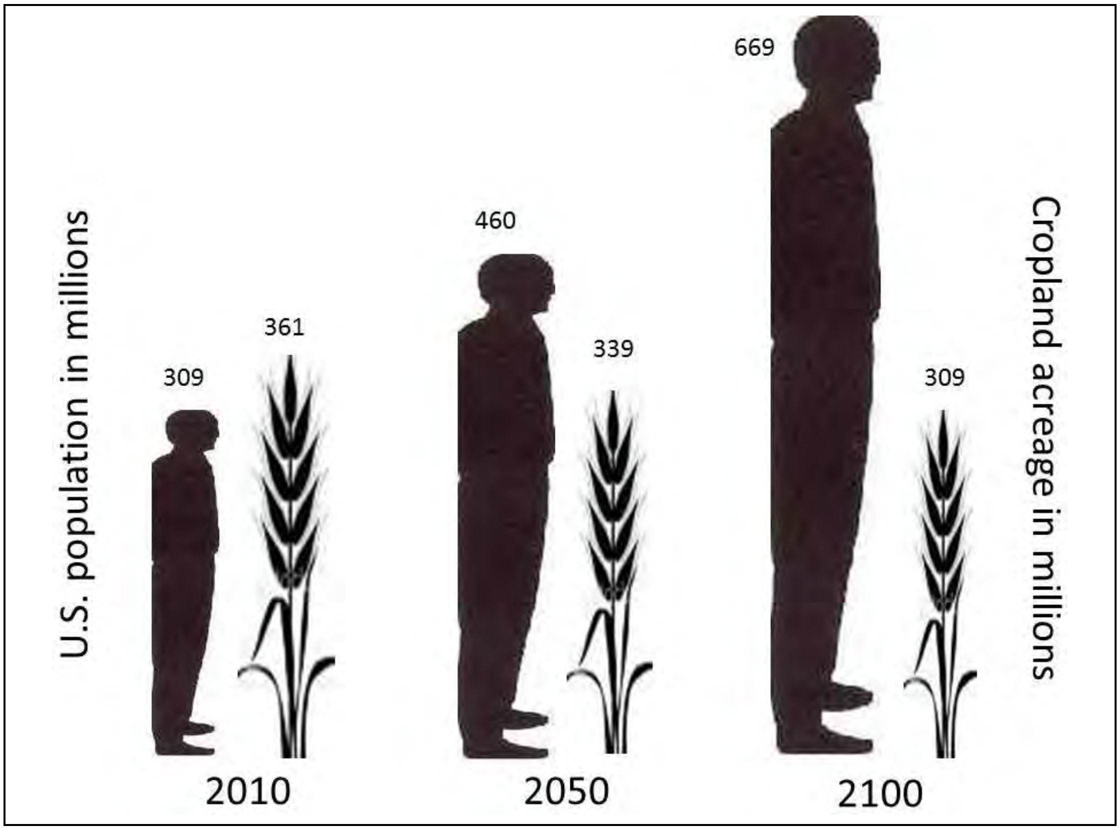


Figure 3-21. Expansion Alternative – Rising population (silhouette of man) and falling cropland (silhouette of grain seedhead) in America in the 21st century

It must be emphasized that the decline of cropland acreage shown in Figures 3-15 and 3-21 only represents the decrease due to development alone, almost all which would be related to population growth. As stated above, the ongoing cropland conversion leading to a long-term decline in the nation's cropland acreage is due to a number of other complex factors than just development pressure. The upshot is that actual cropland acreage by 2050 and 2100 may well be much less than that shown in these two graphics. In sum, in the face of tightening land constraints, the ability of U.S. agriculture to feed our own country much less produce enough surplus harvest to allow for exports of grains, meat, and other food products, will certainly be put to the test as the century progresses under the Expansion Alternative.

3.2.2.3 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This is an increase of 70 million from the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Urban Sprawl

Under the Reduction Alternative, the 2100 U.S. population of 379 million would exceed the 2010 population of 309 million by 70 million or 23 percent; it would be 145 million – or 28 percent – less than the 524 million of the No Action Alternative population.

As with the other alternatives, for the purpose for of this basic analysis, it is assumed that on average each of the 379 million Americans in 2100 would utilize the same amount of urban land for all purposes as at present. That is, average per capita urban land consumption would remain the same. Thus, under the Reduction Alternative, the total Urbanized Land area (a.k.a. developed land or sprawl) in the United States would be 28 percent less in this alternative than in the No Action Alternative.

As of 2010, there were 113.3 million acres (177,031 square miles) of developed land in the United States. With population growth of 70 million by 2100 under the Reduction Alternative, this built-up area would expand by 25.7 million acres to 139 million acres in aggregate at the end of this century. Table 3-5 compares the total area of all development acreage for all three alternatives in 2050 and 2100.

Table 3-5. Projected area of total developed land in 2050 and 2100 under the three immigration scenarios (alternatives) used in this EIS

Alternative	Average annual net migration	Developed land in 2010 (millions of acres)	Developed land in 2050 (millions of acres)	Developed land in 2100 (millions of acres)
Reduction	250,000	113.3	135.3	139.0
No Action	1.25 million	113.3	152.2	192.1
Expansion	2.25 million	113.3	168.7	245.3

Figure 3-22 is a map of the United States, which, like Figures 3-13 and 3-20, graphically portrays a visualization of the extrapolated extent of Urbanized Areas in 2100 if the U.S. population grows from 309 million to 379 million by the end of the century. In comparing these figures, it is evident that urban and suburban sprawl consume far less land under the Reduction Alternative than under either the No Action or Expansion alternatives.

Figure 3-23 is a bar chart that compares the growth of developed land in the United States under all three alternatives.

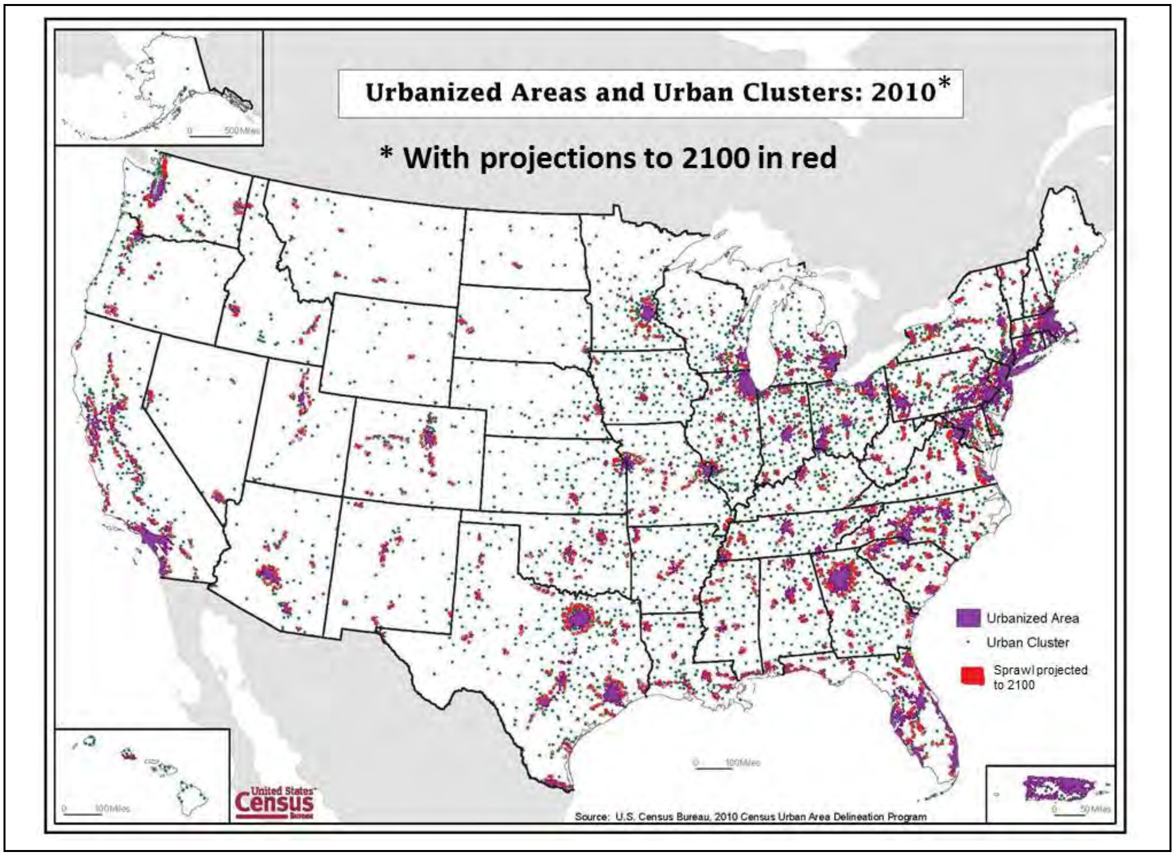


Figure 3-22. Extrapolated extent of sprawl in 2100 under the Reduction Alternative

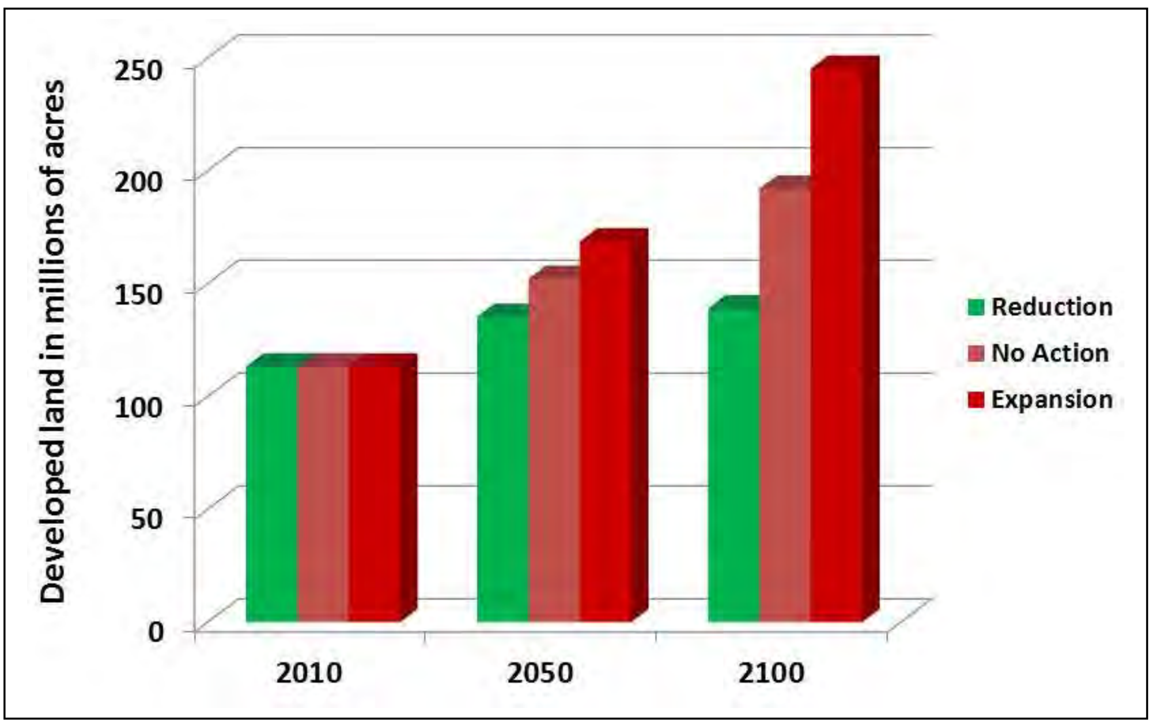


Figure 3-23. Estimated growth in amount of developed land in U.S. under three EIS immigration alternatives

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would have indirect and cumulative impacts on sprawl as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on sprawl associated with the projected population growth under the Reduction Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on sprawl associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Moderate***. The magnitude of the impact on sprawl associated with the population growth under the Expansion Alternative would be such that a, "noticeable change in a resource occurs, but the integrity of the resource remains intact." The Reduction Alternative is the only one of the three immigration-level alternatives that is rated "moderate" instead of "major," because it leads to substantially less sprawl than the No Action Alternative and the Expansion Alternative.

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on sprawl associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher."

Overall, the effect of the Reduction Alternative on suburban sprawl would be adverse, significant, and long-term. It would result in the permanent conversion of 26 million additional acres or 40,625 square miles (about the size of Kentucky) of open space and natural habitat to urbanization – the essentially irreversible process of converting rural land into developed or urbanized land. Urbanized or developed land would increase from 7.6% of all non-federal lands in 2010 to 9.3 percent in 2100 (compared to 13 percent under the No Action Alternative and 17 percent under the Expansion Alternative). Thus, even though all three alternatives are rated as adverse, significant, and long-term, the Reduction Alternative is quantitatively and qualitatively much less adverse than the No Action and Expansion alternatives.

<u>Loss of Farmland</u>

Under the Reduction Alternative, an annual immigration rate of 0.25 million (250,000) would result in a U.S. population of 379 million in 2100, an increase of 70 million (23 percent) from the 2010 population of 309 million. Accommodating 70 million new Americans – more than the current combined populations of our two most populous

states, California and Texas – would still require significant space and land area – but not nearly as much as in the No Action and Expansion alternatives. As shown in Table 3-4, barring major breakthroughs in the political acceptability of high density development and stringent Smart Growth measures, this alternative would directly cause the urban development of 10.2 million acres of cropland by 2100. Somewhat smaller, but still substantial areas – in the millions of acres – of pastureland and rangeland would also be developed because of the population growth induced by the Reduction Alternative.

Figure 3-24 is a schematic depicting the projected population growth and cropland loss to 2100 that are anticipated to take place under this alternative.

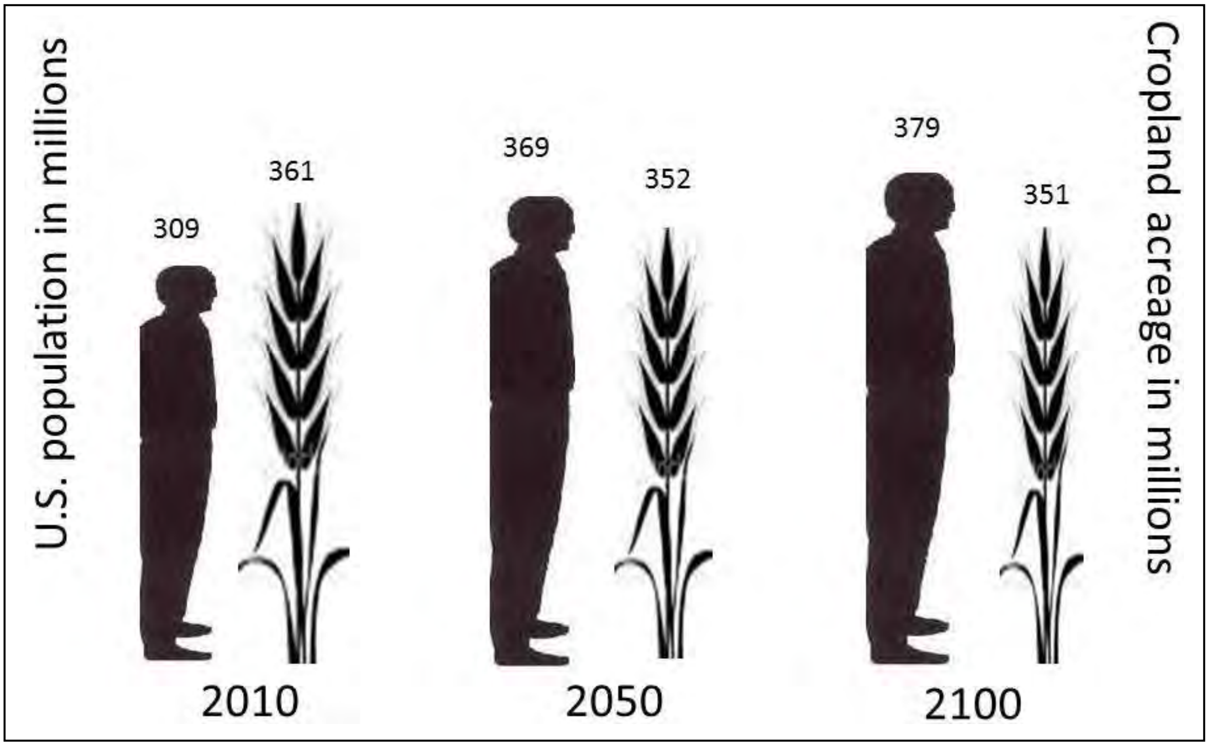


Figure 3-24. Reduction Alternative – Rising population (silhouette of man) and falling cropland (silhouette of grain seedhead) in America in the 21st century

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would have indirect and cumulative impacts on farmland as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on farmland associated with the projected population growth under the Reduction Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on farmland associated with the projected population growth under the Reduction Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact: *Moderate*.** The magnitude of the impact on farmland associated with the population growth under the Reduction Alternative would be such that a: "noticeable change in a resource occurs, but the integrity of the resource remains intact."

- **Likelihood of Impact: *Probable.*** – The likelihood of the impact on farmland associated with the population growth under the Reduction Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on aggregate and per capita farmland acreage.

Overall, the effect of the Reduction Alternative on America's farmland would be adverse, significant, and long-term. It would likely be associated with the permanent disappearance of about10-20 million acres of farmland (cropland, pastureland, and rangeland) to urbanization.

3.2.2.4 Conclusion

Each of the three alternatives would have significantly adverse, long-time impacts on the rate of sprawl, and this sprawl would result in the loss of tens of millions of acres of agricultural land and wildlife habitat by permanently converting it into urbanized land. However, there is wide variation in the magnitude of the impacts between the alternatives. Under the No Action Alternative, sprawl is predicted to cover an additional 79 million acres of countryside (to reach 192 million acres cumulatively). Under the Expansion Alternative, it would cover 132 million more acres (245 million acres cumulatively) and under the Reduction Alternative, 26 million acres (139 million acres cumulatively). See Table 3-6 and Figure 3-25.

Table 3-6. Anticipated additional sprawl by 2050 and 2100 under the three immigration scenarios (alternatives) used in this EIS

Alternative	Average annual net migration	Additional sprawl by 2050[1]	Additional sprawl by 2100[1]
Reduction	0.25 million	22	26
No Action	1.25 million	39	79
Expansion	2.25 million	55	132

[1] in millions of acres

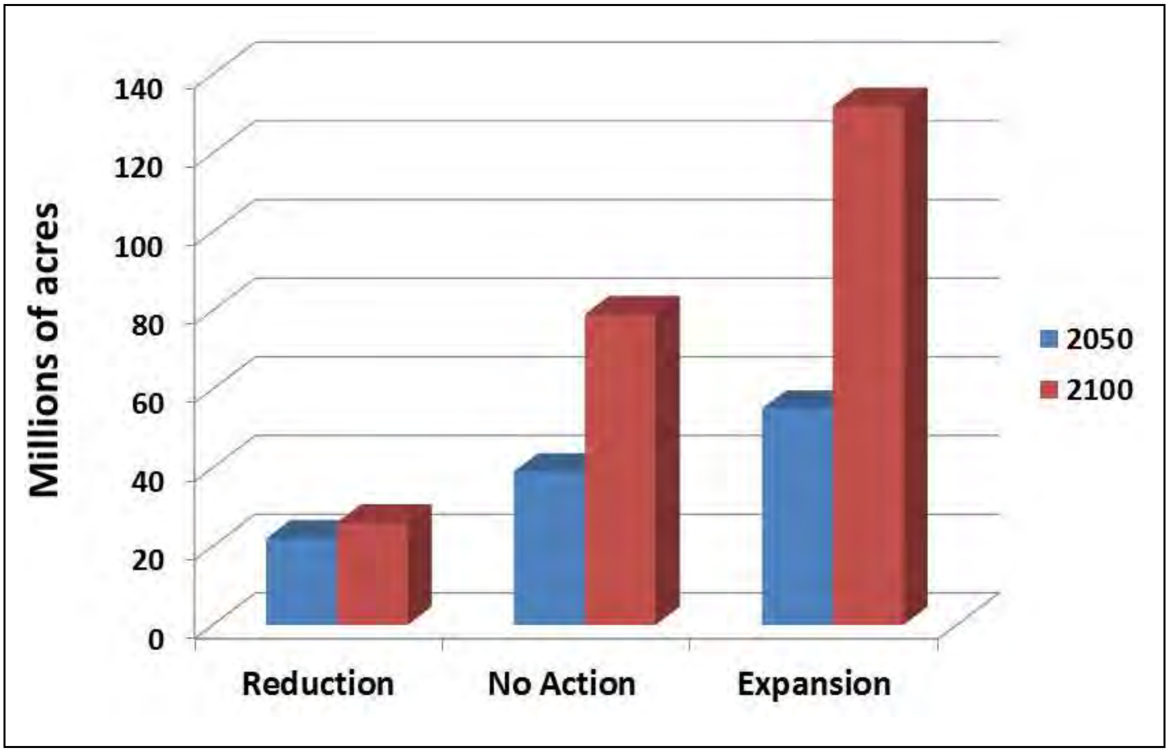


Figure 3-25. Anticipated additional sprawl by 2050 and 2100 in each of the three EIS alternatives

The magnitude of the adverse impact on sprawl of the Reduction Alternative is rated as Moderate, while both the No Action and Expansion alternatives are rated as Major. The impacts of all three alternatives on sprawl can be mitigated but not eliminated by “smart growth” policies that would encourage higher-density development. The faster the rate of population growth, the less successful smart growth will be in preventing sprawl.

Each of the three alternatives would also have significant adverse impacts on the nation’s supply of farmland as a result of the sprawl they would cause. Some of this sprawl would take place on farmland, permanently eliminating it from the inventory of productive agricultural land in the U.S. As with sprawl however, there is substantial variation among the three alternatives in the magnitude of their adverse impacts on farmland. The Expansion Alternative would likely cause by far the greatest loss of farmland, while the Reduction Alternative would result in the least loss of farmland.

The threat posed to America’s farmland by the business-as-usual (No Action) and Expansion alternatives and their implications for our country’s food security, national security, prosperity, diet, and physical health cannot be understated.

3.3 Habitat Loss and Impacts on Biodiversity

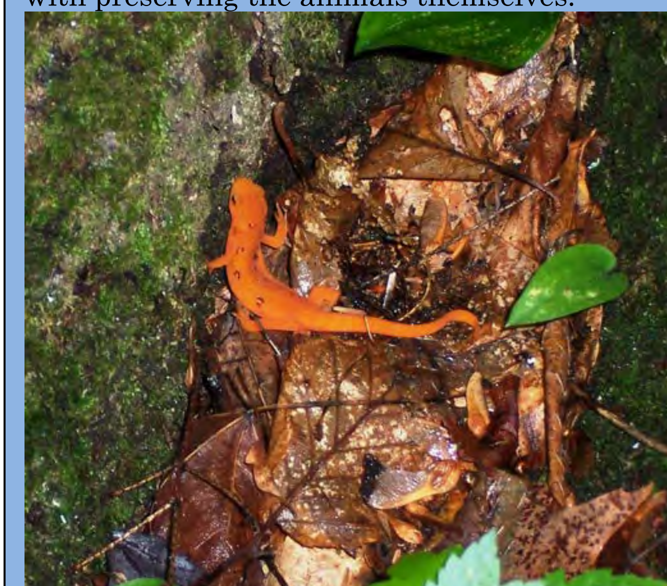
3.3.1 Affected Environment

3.3.1.1 Background

In the United States and around the world, human population growth is a direct cause of habitat loss. It is also a direct and indirect cause of adverse impacts on biodiversity, that is, on the number and variety of organisms and ecosystems that are found on Planet Earth, the only planet in our solar system and galaxy known at present to harbor life.

What is Habitat?

A plant or animal's habitat is its natural "home" on Earth, and this home includes particular biophysical attributes that meet the organism's needs. Physical factors may include soils, moisture, temperature range, and light availability. Biotic factors include food availability, vegetation composition and structure, and the presence or absence of predators.
If a species' habitat, its natural home, disappears or is destroyed, the species cannot survive in the wild and it will disappear as well. That is why wildlife biologists are just as concerned with conserving habitat as they are with preserving the animals themselves.



The habitat of the red eft phase of the eastern newt *(Notophthalmus viridescens)* consists of a moist forest floor with leaf litter in an eastern deciduous forest

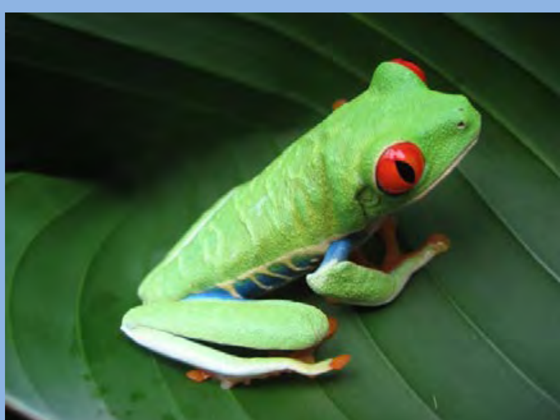
In the U.S., human populations directly contribute to loss of natural habitats because each person, and by extension populations of more than one person (e.g., settlements such as villages, towns, suburbs, cities, subdivisions, etc.), use land and water in a way that either completely eliminates or thoroughly modifies natural habitat features and functions, so as to constitute "loss" or degradation.

Converting a forest landscape into a subdivision by first cutting down and hauling away the trees, grading the surface topography, and then building streets, houses, and utility lines (water and sewer, telephone, electricity, cable) exemplifies the habitat loss that occurs with residential development. The ecosystem comprised of wild flora and fauna, that is, of ecologically interrelated populations and communities that formerly inhabited the site, is for all intents and purposes obliterated.

What is "Biodiversity?"

Biodiversity is the variety of living things, but it is much more than just a count of the number of species present in an area. Biodiversity occurs on multiple scales; species diversity is only one aspect of it. Biodiversity also refers to genetic diversity within species as well as the diversity of entire habitats and ecosystems.

Estimates of the total number of species on Earth range from three million all the way up to 100 million, many of which are difficult to detect and classify microbes. So far taxonomists have catalogued some 1.7 million species (NWF 2015). The most diverse group of organisms are the macroinvertebrates, animals visible (without the need of a microscope) lacking backbones, such as insects, spiders (arachnids), crustaceans, mollusks, and millipedes.



Over time, typically a period of decades, as the human community which replaced the natural community settles in and evolves, through the process of natural succession, some of the elements of the original natural landscape may return to the artificial, manmade landscape. That is, certain more adaptable or resilient native plants and animals may reappear. Some of these may even become abundant enough to acquire the status of pervasive and problematic "pests" – weeds in the lawn, raccoons tipping over garbage cans, foxes preying on house cats, or deer and groundhogs destroying ornamental or food gardens.

Nevertheless, the highly modified ecosystem of a suburb or city or even tree-filled city park does not replicate the natural ecosystem it displaced; it is far more simplified and contains much less species diversity. Moreover, many of the wild or feral species which do endure or even flourish in these artificial settings are themselves non-native, exotic or invasive. They arrived in North America by human agency, either accidentally (e.g., the chestnut blight, emerald ash borer, zebra mussel, English sparrow) or deliberately (e.g., starlings, nutria, tree-of-heaven, kudzu, feral swine or hogs). The Africanized honey bee (aka "killer bee") is a combination of both factors: it was brought to Brazil on purpose, escaped captivity, and has been spreading northward on its own ever since. Invasive exotic species of both plants and animals possess advantages that allow them to outcompete and displace native species, and they typically thrive in disturbed urban settings.

Residential land use – where we actually live – is only one type of developed land imposed by Americans upon the natural landscape, however. Each of us also requires land for transportation (e.g., streets, roads, interchanges, railroads, airports, ports, parking lots), retail commerce (e.g., shopping centers, malls, strip malls, stores), hospitality (e.g., restaurants, hotels), education (schools, universities, colleges), government services (e.g., police and fire buildings, municipal offices), infrastructure (e.g., wastewater treatment plants, power plants and substations, utilities), workplaces (e.g., factories, workshops, office buildings), recreation areas (e.g., soccer fields, golf courses, tennis courts, tot lots, playgrounds), and so forth. Residential land use is but a fraction of the entire land use each person accounts for.

Figure 3-26 depicts one the loss of one type of habitat in the United States – forestland – into developed land during the 25-year period from 1982 to 2007. In this brief period alone, nearly 18 million acres of forest alone succumbed to development in the 25 years from 1982 to 2007, at the rate of more than 700,000 acres annually. All of this forestland constituted natural habitat, and its conversion to pavement and rooftops represents a permanent loss of habitat for wild flora and fauna in the United States.

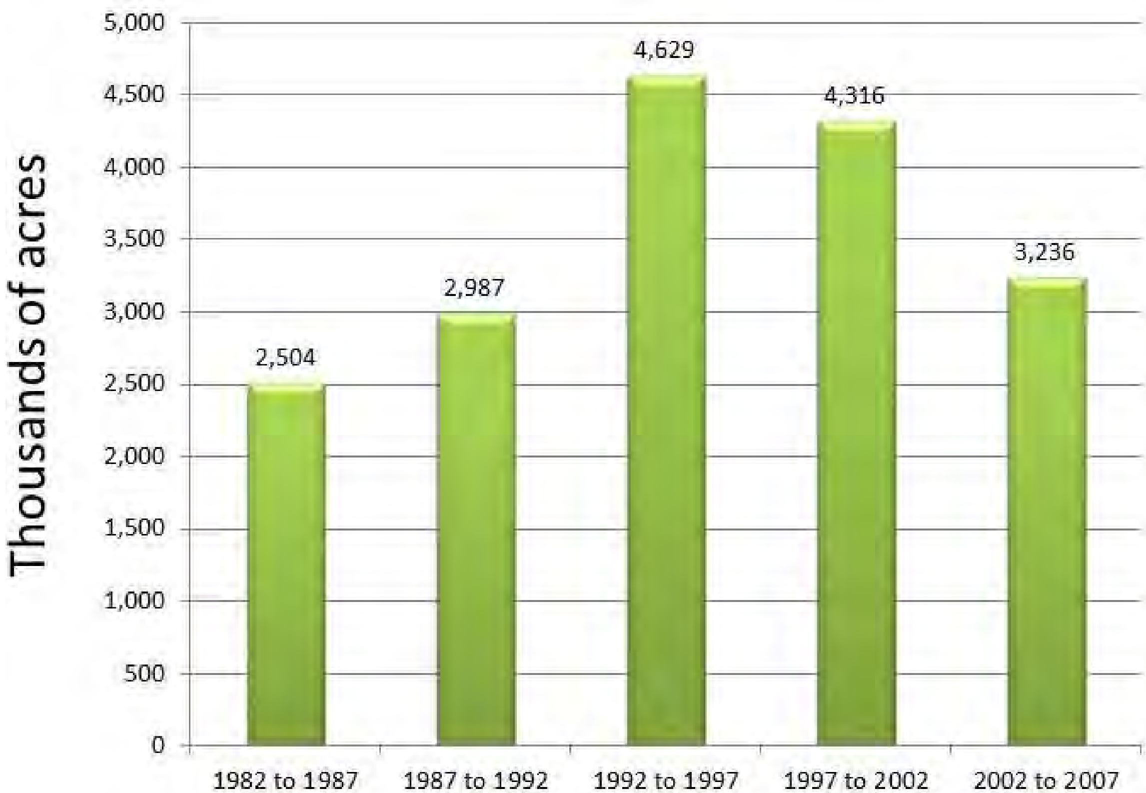


Figure 3-26. Permanent conversion of forestland to developed land in 5-year increments, 1982 to 2007
Source: NRCS 2013a

As explained in Section 3.2 above, in recent decades, on a nationwide level, about 70 percent or more of sprawl – defined as development of natural habitat and farmland via urbanization – is correlated with population growth. (The other 30 percent or less is due to increasing per capita land consumption – larger homes and lots, etc. – or declining residential population density within urbanized areas.) Thus, the preponderance of this habitat loss is a direct function of continued rapid U.S. population growth.

Additionally, every American, and therefore every added American, affects habitat and biodiversity above and beyond the developed or urbanized land he or she depends on. Most obviously, the food we eat is grown on farmland, consisting of the cropland, pastureland, and rangeland described in Section 3.2 above. Of these three types of farmland, the first two – cropland and pastureland – are not natural habitats. (Rangeland is typically a more natural habitat, although it may be affected by overgrazing.) They have to be converted from forests, woodlands, grasslands, and wetlands into cropland and pastureland. This entails substantial habitat loss and alteration – uprooting trees and understory, plowing up perennial grasses and sod, and so forth. Cultivated crops require fertilizers and pesticides, and often irrigation in the drier parts of the country. Maintaining ecological monocultures (i.e., cultivated crops) over time requires continuous exertion and disturbance (in the ecological sense of the term) to hold natural succession in check. Farmers also need to control wildlife, birds and mammals as well as insects, that threaten to eat or damage their crops, as well as predators that threaten their herds of livestock.

Agricultural lands are not devoid of value for wildlife. Indeed, they can be and frequently are managed to the benefit of certain wildlife regarded as beautiful, useful or economically valuable, such as deer and migratory birds. Huge flocks of geese and ducks, as well as sandhill cranes, have become dependent on grain crops (especially corn) provided by farmers and wildlife agencies as they overwinter in our southern states across the country (Figures 3-27 and 3-28). However, the point is that agricultural lands, while they may retain some habitat value, do not support the diverse native flora and fauna – the biodiversity, in a word – of the original, unaltered habitats they replace.

Figure 3-27. Snow geese at San Bernard National Wildlife Refuge in Texas

Figure 3-28. Every spring, over a half million sandhill cranes converge on the Platte River Valley in central Nebraska, where they feed on waste grains in surrounding farm fields, gaining weight and strength for the long journey northward to their breeding grounds in Canada and Alaska

Every resident of the United States – and American consumers in aggregate – use products daily that affect habitats and biodiversity. For example, we utilize paper products in multiple ways, from toilet paper to printer paper, newspapers and magazines and mail, to the cardboard in cereal boxes. Paper, of course, comes from pulp and pulp comes from wood fiber, that is, from trees and forests. We also use many other wood products, in furniture, pallets, and building construction. Harvesting forests does not usually mean clearing and destroying them (even if clearcutting is employed, because regeneration and replanting occur), but forest harvest, even if conducted sustainably, does entail substantial, non-trivial habitat modification and often damage. It has inevitable adverse effects on native biodiversity (Figure 3-29).

Figure 3-29. Clearcut in Oregon

On a daily and annual basis, each American uses a vast array of products which originated as raw materials – primarily metals and non-metallic minerals – that had to be mined, refined, manufactured, and transported to market. Analyst Christopher Clugston emphasizes that industrialized existence, a.k.a. the "American way of life:"

> …is enabled almost exclusively by enormous and generally increasing quantities of NNRs (nonrenewable natural resources) — the finite and non-replenishing fossil fuels, metals, and nonmetallic minerals that serve as:
> • The raw material inputs to our economy;
> • The building blocks that comprise our infrastructure and societal support systems; and
> • The primary energy sources that power our society (Clugston 2015).

Clugston identifies 87 NNRs that are now indispensable, critical, or important to the American standard of living and quality of life. Each of these is mined, quarried, or scraped from the Earth, and the industrial operations that accomplish this extraction have pronounced impacts on habitat within the footprint of operations, and typically nearby.

Americans also consume huge quantities of nonrenewable fossil fuels – coal, oil, and natural gas – to provide energy and electricity to power our economy and maintain our standard of living. These fossil fuels must be drilled, dug, and pumped from the ground and transported to processing facilities (petrochemical plants). At the site of extraction habitats are impacted, and along transport routes – whether by pipeline, oil tanker, or rail – there is always the risk of an accidental and potentially devastating explosion or spill. The Deepwater Horizon explosion (Figure 3-30) and crude oil spill in the Gulf of Mexico on Earth Day in 2012 was a vivid and tragic reminder that marine habitats and wildlife are also vulnerable to excruciating damage.

Figure 3-30. BP's Deepwater Horizon offshore oil rig burns after the explosion which took the lives of 11 workers; the subsequent oil spill was the largest and most damaging in U.S. history.

Coal mining provides the bituminous and sub-bituminous coal which is burned in the boilers of thermoelectric power stations that generate electricity for transmission to hundreds of millions of Americans. At the present time, most of this coal is extracted by surface (or "strip") mining both in the West, in places like Wyoming's Powder River Basin, and in the East, in the southern Appalachian Mountains of Virginia, West Virginia, and Kentucky. In the East, to access deeper, less accessible coal seams buried under hundreds of feet of "overburden", enormous draglines (Figure 3-31) are used in mountaintop removal coal mining, which both disfigures ancient mountains even as it annihilates habitat (Figure 3-32).

Figure 3-31. Dragline used in mountaintop removal of coal

Figure 3-32. The late Larry Gibson (1946-2012) on Kayford Mountain, West Virginia, beside a mountaintop coal removal project he had fought long and hard

To reiterate, all human activities consume resources and create waste. As the magnitude of the U.S. – and global – populations and economies increase, there is a concomitant increase in the magnitude of our aggregate impacts on the environment, in a number of different respects and at all scales. In the last two decades, the Ecological Footprint (EF) has emerged as one of the world's leading measures of aggregate human demands on nature. Ecological Footprint (Figure 3-33) accounting addresses the ability of the biosphere to meet the growing demands of humanity (GFN 2014, WWF et al., 2014).

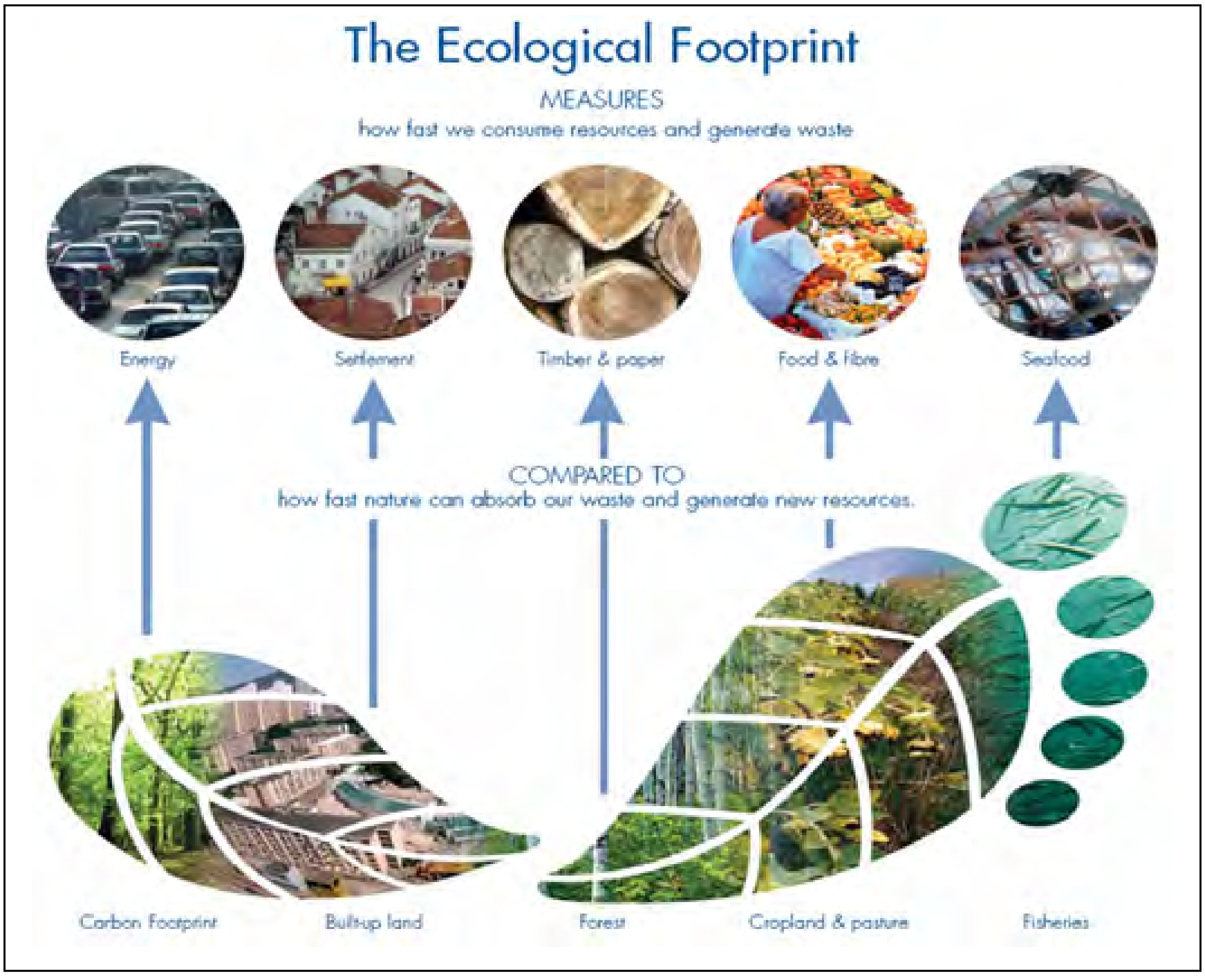


Figure 3-33. The Ecological Footprint showing Biocapacity at the bottom of the diagram

EF accounting represents both sides of a balance sheet. On the asset side, biocapacity stands for the area of Earth's biologically productive land, including forests, grasslands, rangelands, and pasture, cropland and fisheries. Particularly if they are left unharvested, these productive regions – through photosynthesis (nature's form of carbon sequestration) – can absorb a portion of the carbon dioxide emissions we release.

In EF analysis, biocapacity is compared with humanity's demands on nature, our Ecological Footprint. The EF represents the productive area required to supply the renewable resources humanity is using and to absorb its waste. The productive area currently occupied or usurped by urbanized land (developed areas whose surface is covered with pavement and rooftops) is also included in this calculation, since built-up land is not available for resource regeneration (GFN 2014).

Figure 3-34 shows that the United States has run an ecological deficit for more than the past half-century; that is, our Ecological Footprint has exceeded our Biocapacity, and over the long term, we are incurring an ever larger ecological and cumulative ecological debt. In ecological terms, the U.S. is in "ecological overshoot," as are most countries on Earth. Indeed, combining the Ecological Footprints of all countries, humanity as a whole is in ecological overshoot; it would take one and a half Earths to meet all of the demands we are placing on it. That is, the global Ecological Footprint is about 50 percent greater than the global Biocapacity (Figure 3-35). As the World Wildlife Fund says: "This continuing overshoot is making it more and more difficult to meet the needs of a growing global human population, as well as to leave space for other species" (WWF et al., 2014).

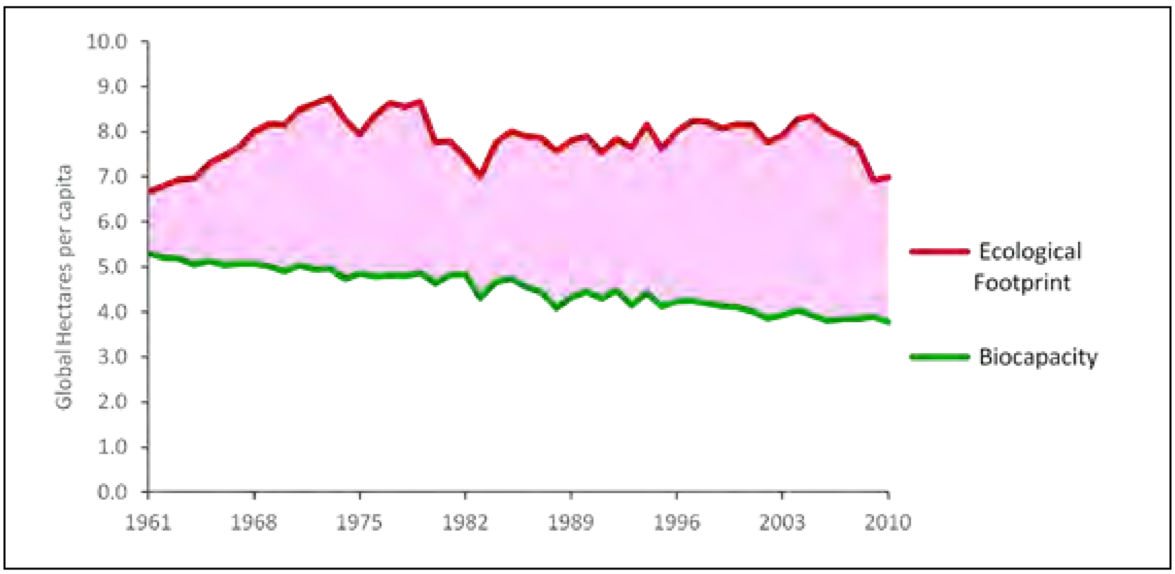


Figure 3-34. Per capita Ecological Footprint of the United States from 1961 to 2010

Source: GFN (2012)

Note from GFN: Biocapacity varies year to year with ecosystem management, agricultural practices (such as fertilizer use and irrigation), ecosystem degradation, and weather, and population size. Footprint varies with consumption and production efficiency.

The per capita footprint of the average American is approximately seven global hectares per capita. That is, on average, in order to provide for his/her resource and energy consumption patterns, each American is using – and impacting – about 17 acres of

ecologically productive land. This amount, of course, is far greater than the aggregate amounts of residential land or all urbanized land attributed to each American consumer. Our collective EF extends well beyond urban boundaries deep into the countryside and wildlands, adversely impacting habitats and biodiversity.

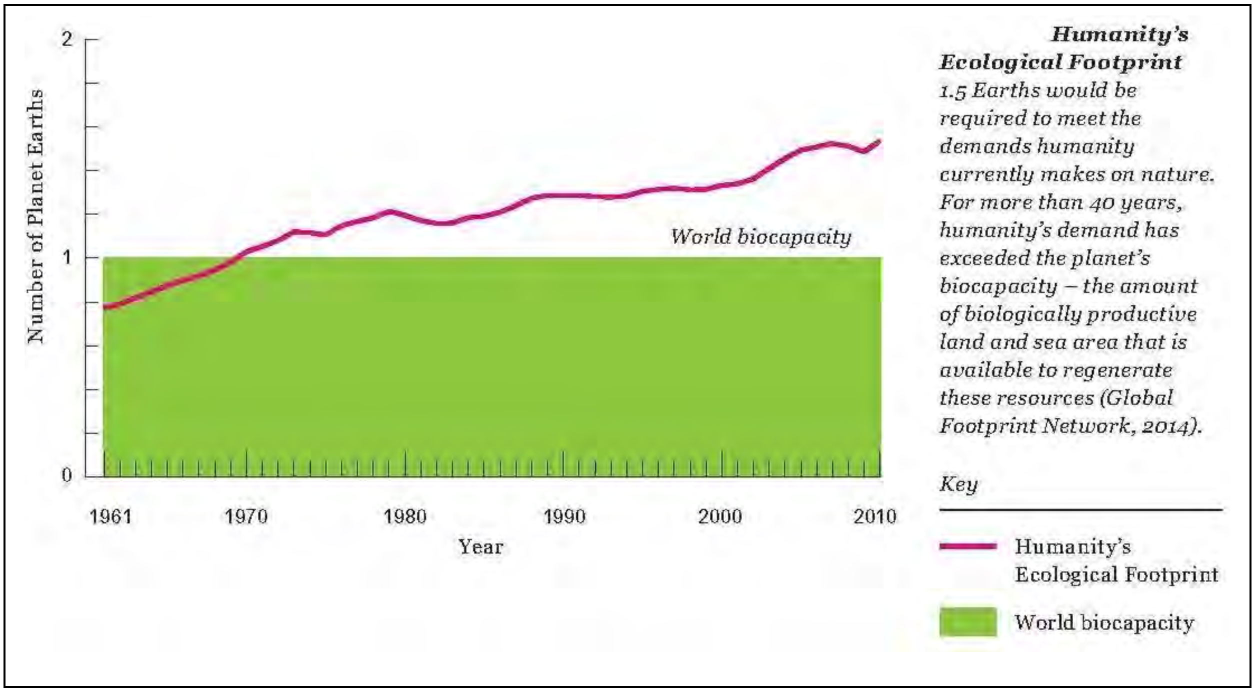


Figure 3-35. Humanity's Ecological Footprint surpasses Earth's Biocapacity
Source: WWF et al. (2014)

In 1970, global human population stood at 3.7 billion (PRB no date). In the 45 years since then, it has essentially doubled, growing to 7.3 billion. Over the same time period, global non-human vertebrate populations have been cut approximately in half (Figure 3-36). This inverse correlation is not merely coincidental, but causal.

Tens of centuries of slow growth and two centuries of vertiginous exponential growth of the human population have produced the extraordinary results shown in Figures 3-37 and 3-38. Biomass or "standing biomass" is the weight or mass of living tissue or matter. Ten to twenty thousand years ago the standing biomass of all human beings on Earth was a vanishingly small percentage of the aggregate biomass of all mammals and all vertebrates. This was an era, in the grip of the last Ice Age of the Pleistocene, in which megafauna dominated the planet. In North America, species such as mammoths, mastodons, giant sloths, dire wolves, giant beavers, a gigantic salmon species, giant tortoises, short-faced bears, *Amphicyonid* (bear dogs), stag moose, giant condors – some 33 genera of megafauna in total – went extinct after *Homo sapiens*, ancient Paleolithic hunter-gatherers from Asia, migrated onto the continent and began hunting them and disrupting the ecosystem in other ways.

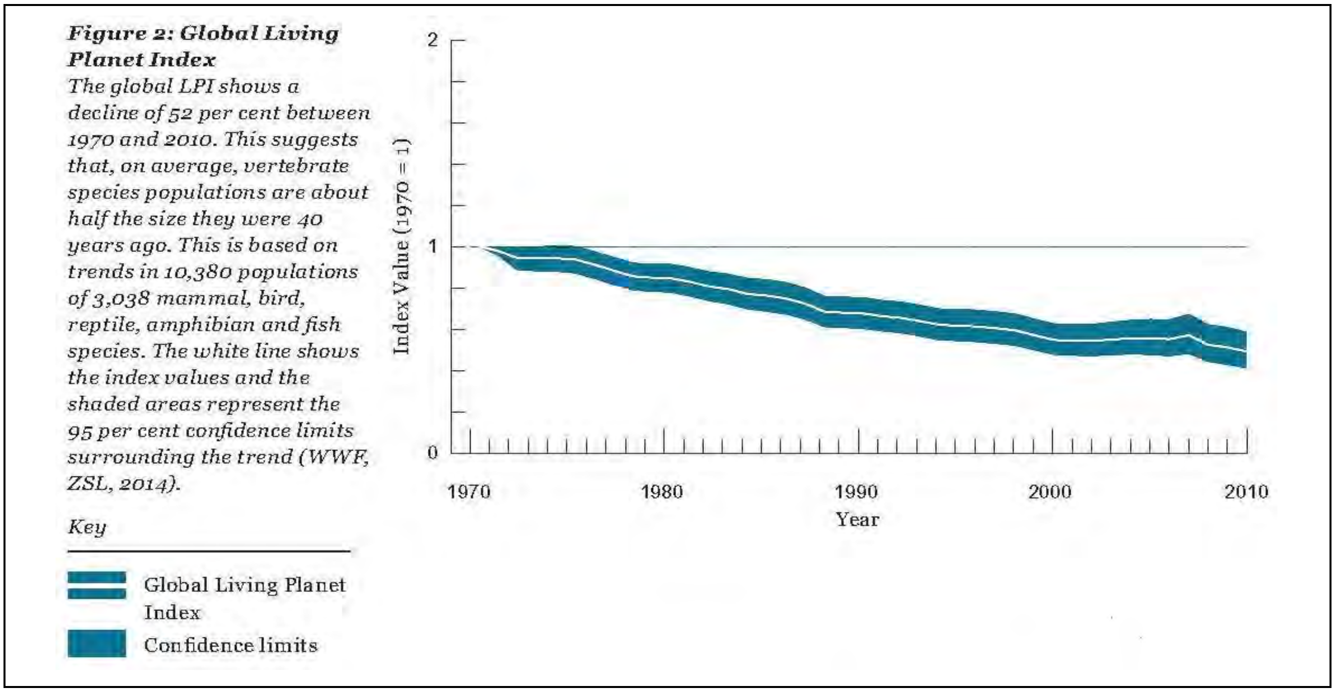


Figure 3-36. Living Planet Index of the World Wildlife Fund

Source: WWF et al. (2014)

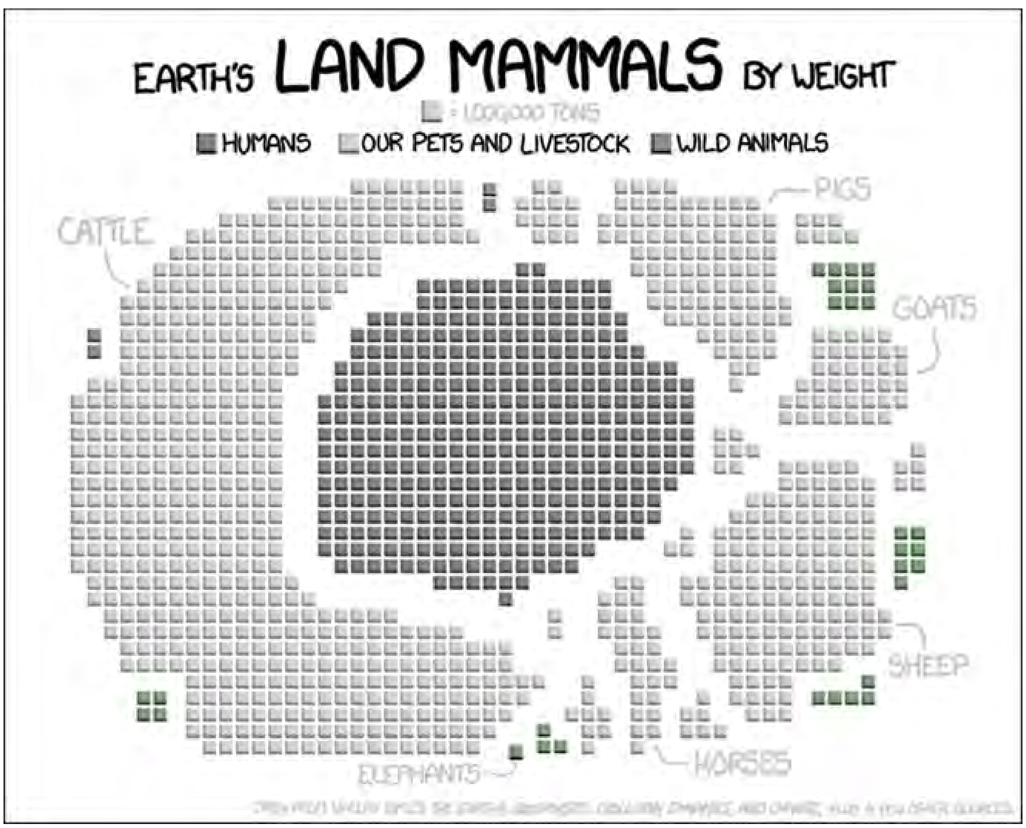


Figure 3-37. Weight of all humans and all domestic mammals compared to weight of all wild land mammals on earth

Source: Smil (2003), Munroe (2014)

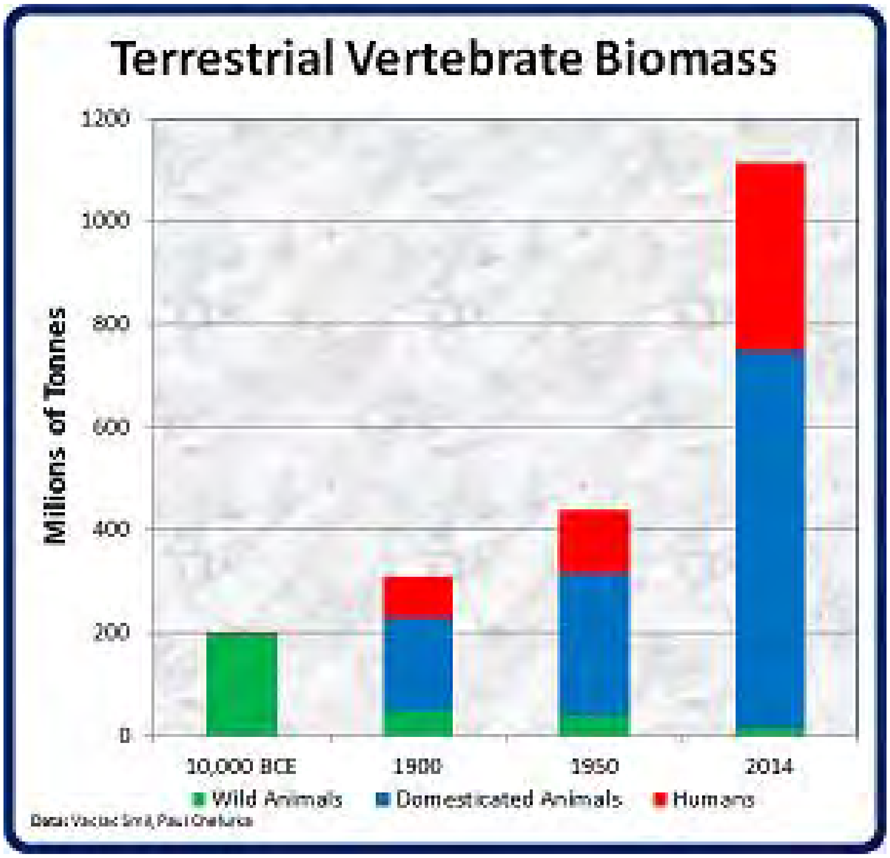


Figure 3-38. Human and domesticated animal biomass vs. total terrestrial biomass, 10,000 BCE to 2014
Source: Chefurka (2014)

Figure 3-39. The woolly mammoth and scores of other megafauna appear to have been driven extinct by early human settlers in North America, Paleolithic migrants from Asia who crossed the Bering Land Bridge at a time when sea level was lower.

Scientists now estimate that more than 90 percent of total vertebrate biomass on earth (that is, the total weight of all living organisms) is comprised of humans and a handful of our chosen domesticated animal species. Ten thousand years ago this figure was a mere 0.1% (Vince 2011).

In 2010, Charles Berger of the Australian Conservation Foundation (ACF) submitted a form to the Australian Government to nominate "Human population growth in Australia" as a "Key Threatening Process" under the Environment Protection and Biodiversity Conservation Act of 1999 (ACF 2010). ACF averred that, "Population growth is best viewed as an underlying process, which intensifies and exacerbates numerous other proximate threats to biodiversity…"

ACF continued:

> Population growth is the first driver in a complex chain of direct and indirect effects on Australia's biodiversity. It underpins and exacerbates nearly every other threat to our ecological life support systems.
> ……
>
> Population increase is, in turn, a driver of a numerous consequential biological and non-biological processes, including but not limited to the following:
>
> - Construction and operation of human infrastructure, such as roads, housing and other buildings, dams, transmission lines, and so forth;
> - Alteration of natural landscapes, such as clearance of habitat for agriculture and other purposes, dredging of marine environments for shipping access, and changed fire regimes to protect human infrastructure;
> - Increased intensity of use of natural resources, such as harvesting of forests for timber and extraction of water from rivers and aquifers;
> - Altered flow regimes for waterways and tidal zones;
> - Introduction of pollutants into natural systems, including nutrients, waste materials, oil spills, and other pollutants into riverine and coastal ecosystems;
> - Use of natural areas for recreational purposes, which may be accompanied by disturbance of organisms (such as nesting sea birds) and incidental destruction (as by boat propellers or trampling of sensitive areas);
> - Generation of greenhouse gases, with consequent alteration of climatic processes and sea levels; and

- Introduction of non-indigenous organisms, both intentionally (as for agricultural purposes) and unintentionally (as for a wide range of exotic pests) (ACF 2010).

In the United States, the Tucson-based Center for Biological Diversity (CBD no date) states that:

> The current mass extinction differs from all others in being driven by a single species rather than a planetary or galactic physical process. When the human race – *Homo sapiens sapiens* – migrated out of Africa to the Middle East 90,000 years ago, to Europe and Australia 40,000 years ago, to North America 12,500 years ago, and to the Caribbean 8,000 years ago, waves of extinction soon followed. The colonization-followed-by-extinction pattern can be seen as recently as 2,000 years ago, when humans colonized Madagascar and quickly drove elephant birds, hippos, and large lemurs extinct (CBD no date).

The first victims of extinction associated with the migration of *Homo sapiens* out of Africa and our conquest of every continent on Earth except Antarctica were large vertebrates felled by hunter-gatherers. A second, even larger wave of extinctions began roughly 10 millennia ago with the Agricultural Revolution: the discovery and spread of agriculture hastened human population growth and underwrote the ever-larger displacement of natural habitats and the wildlife that depended upon them. The third and largest extinction wave began in the early 1800s and continues to this day; it is associated with the exploitation of fossil fuels on a massive and ever-growing scale. With huge quantities of cheap energy at its disposal, the global human population grew rapidly from 1 billion in 1800 to 2 billion in 1930, 4 billion in 1975, and 7.3 billion today (CBD no date).

Figure 3-40 depicts parallel curves representing human population and the number of extinctions, growing in tandem.

McKee (2012) states that:

> There is now a growing body of academic literature…establishing a scientific link between human population density and growth and increased extinction threats for plants and animals, yet this key footprint remains on the outskirts of conservation dialogue.

In his study of a wide range of countries, McKee found that increasing human population density accounted for 90 percent or more of increasing numbers of threatened species (McKee 2012). Gross national production (GNP, or what environmentalists call "consumption") accounted for under 10 percent, and all other variables, such as agricultural land use practices, amounted to little more than "statistical noise."

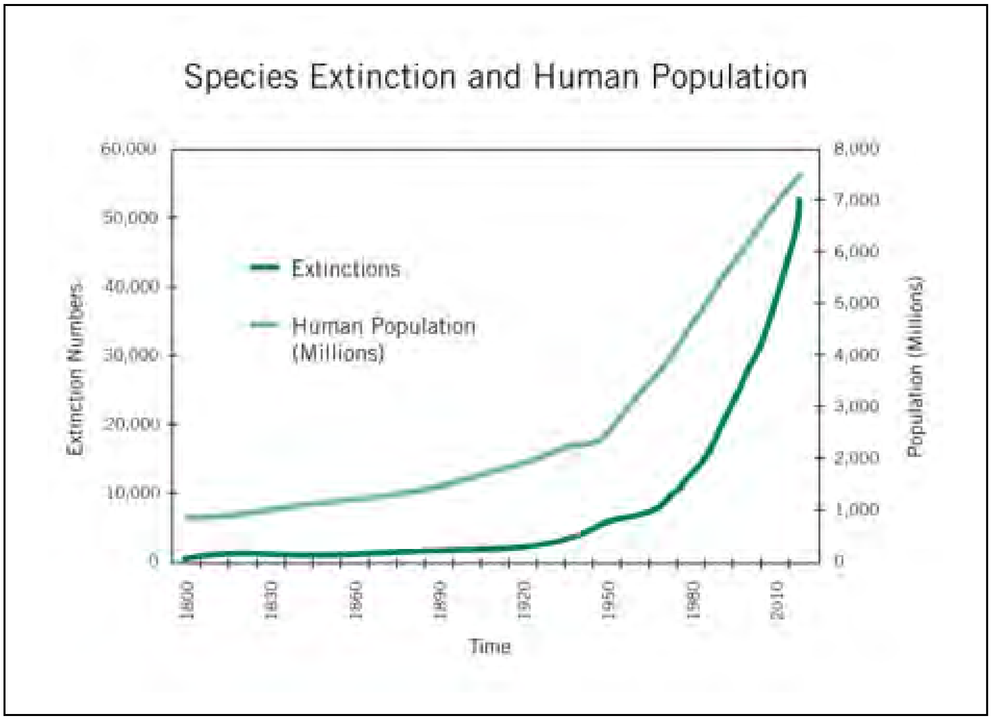


Figure 3-40. Increasing human population and increasing extinctions
Sources: Scott (2008), CBD (no date)

Prominent biologists such as Jared Diamond, E. O. Wilson, and Norman Myers concur that human population growth is devastating biodiversity. Diamond cites an "Evil Quartet" of habitat destruction, fragmentation, overharvesting, and introduced species (Sanderson and Moulton 1998). Wilson touts the acronym HIPPO: habitat destruction, invasive species, pollution, population, and overharvesting. He estimates that globally, at least 12,000 wild species are going extinct annually (Biello 2008). Other recent estimates are even higher, 30,000/year for instance, or three per hour (AIBS 2015).

The eminent paleontologist Niles Eldredge, curator-in-chief of the permanent exhibition "Hall of Biodiversity" at the American Museum of Natural History in New York City has written that:

> There is little doubt left in the minds of professional biologists that Earth is currently faced with a mounting loss of species that threatens to rival the five great mass extinctions of the geological past…
>
> The explosion of human population, especially in the post-Industrial Revolution years of the past two centuries, coupled with the unequal distribution and consumption of wealth on the planet, is the underlying cause of the Sixth Extinction (Eldredge 2001).

The Conservation Measures Partnership is a collaborative effort of major conservation organizations dedicated to improving international wildlife conservation. The partnership's "Threats Taxonomy" lists direct threats to biological diversity. The main categories of threats include:

1. residential and commercial development
2. agriculture and aquaculture
3. energy production and mining
4. transportation and service corridors
5. biological resource use
6. human intrusions and disturbance.

Clearly, each of these factors is a direct function of population size and, of course, affluence (Conservation Measures Partnership 2010).

The Southern Forest Resource Assessment was a massive, 3-year, cooperative research effort with many contributors from many agencies and organizations, including the U.S. Forest Service, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, state natural resource and forest agencies, the Southern Group of State Forests, and the Southeastern Association of Fish and Wildlife Agencies (Wear and Greis 2002).

The assessment was initiated in 1999 because of concerns raised by natural resource managers, the scientific community, and the public concerning the status and trends of Southern forests, which were increasingly being threatened by rapid population growth and urbanization, increasing timber demand, forest pests, and worsening air quality.

In spite of massive population growth over the last century, and equally massive deforestation of primary forests that began in earnest in the 1700s and 1800s, the South has once again become a heavily forested region. Forests now cover more than 60 percent of most states in the region. Agriculture is the dominant land use on the upper Atlantic Coastal Plain, the Mississippi Alluvial Valley, the Interior Plateau, and the Ridge and Valley regions of Tennessee and Virginia. Yet elsewhere, forests occupy a larger share of the landscape, giving biodiversity a chance to recover.

Yet irreparable damage has already been done. One of the most magnificent and iconic avian species of the Southeast, the ivory-billed woodpecker (Figures 3-41 and 3-42) (*Campephilus principalis*), was decimated by the destruction of old growth bottomland hardwood forests and cypress swamps in which it resided as an obligate dependent, as well as the uncontrolled hunting that accompanied the expansion of human population in the Southeast. Recent claims of sightings by hopeful ornithologists and experts notwithstanding (Cornell 2015), the species is probably extinct.

Figure 3-41. The ivory-billed woodpecker was a denizen of old growth Southern bottomland forests and swamps

Figure 3-42. An ivory-billed juvenile (nestling) on the Singer Tract in Louisiana, 1935. This particular specimen was the only one of its dying species that was ever banded. The Singer Tract, a large expanse of virgin timber on private land, was logged despite last-ditch efforts of the National Audubon Society to save it.

Similarly, the single most populous bird species in North America, the passenger pigeon (*Ectopistes migratorius*), was driven extinct by habitat loss and reckless overhunting as the number of Euro-American settlers and the size of their settlements grew rapidly.

3.3.1.2 Ecoregions in the United States

Ecoregions are large areas of similar climate where ecosystems are distributed in predictable patterns (USFS no date). Ecoregions are a hierarchical method of classifying the biosphere and its myriad habitats into units that share broad ecological characteristics. Domains are at the top of the hierarchy. The U.S. is divided into four domains – Polar, Dry, Humid Temperate, and Humid Tropical – based on very general climatic characteristics of temperature and precipitation. Domains are then broken down into divisions, which have more similar climatic conditions.

Divisions are subdivided into provinces; these not only have more similar climatic characteristics but also have similar geologic composition. Continuing down the hierarchy, provinces are further dissected into sections, which, in addition to the similarities of the higher units, also contain similar ecosystem types.

Thus, proceeding downward, the hierarchy is comprised of smaller areas with ever more uniform ecological characteristics. When considering large regions such as continents or the United States as a whole, the concept of ecoregions is useful for determining how well the current system of protection represents the range of natural conditions (PBI 2001). Bailey (1995) identified 52 ecoregion provinces in the United States, including 34 in the conterminous U.S. (Lower 48 states), 16 in Alaska, one for Hawaii, and one for Puerto Rico and the U.S. Virgin Islands (Figure 3-43).

The Pacific Biodiversity Institute and the Pew Wilderness Center inventoried each of the ecoregion provinces in the U.S. to measure the percentage of that province that was still roadless – that is, unfragmented by roads, a good measure or index of how intact biodiversity and habitat are in that ecosystem (PBI 2001). They also measured the percentage of the ecoregion province that was officially protected (Table 3-7).

It is worth noting in Table 3-7 that of the top ten ecoregion provinces with the highest percentages of remaining roadless areas, all but one are in the lower population density West. Of the bottom ten on the list – those with the lowest percentages that are still roadless (as well as the lowest percentages that are protected roadless areas) – all are in the higher population density East or densely populated California. There is an inverse relationship between human population density and prevalence of roadless areas, wilderness, biodiversity, and intact ecosystems; the higher human population density, the lower all of these measures of "naturalness."

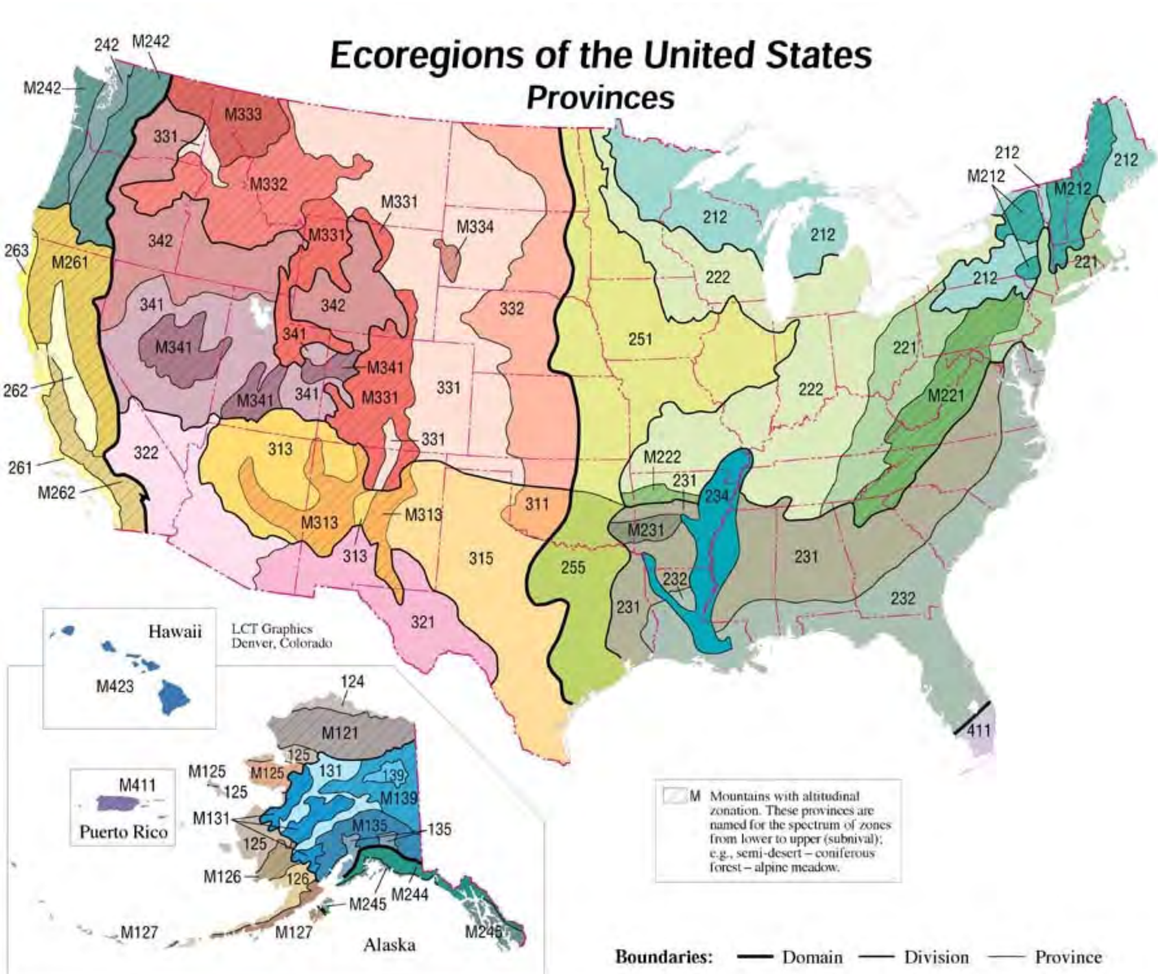


Figure 3-43. Ecoregion provinces of the United States after Bailey (1995)

Table 3-7. Percentages of each Bailey's Ecoregion Provinces which are roadless and officially protected outside of Alaska (Lower 48 states, Caribbean, and Hawaii)

Ecoregion Province	Percent roadless	Percent protected
American Semi-Desert and Desert	80.5%	17.5%
Nevada-Utah Mountains-Semi-Desert-Coniferous Forest-Alpine Meadow	75.0%	2.2%
S. Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow	65.2%	11.9%
Middle Rocky Mountain Steppe-Coniferous Forest-Alpine Meadow	61.4%	11.2%
Everglades	53.4%	17.0%
Sierran Steppe-Mixed Forest-Coniferous Forest-Alpine Meadow	53.0%	12.1%
Cascade Mixed Forest-Coniferous Forest-Alpine Meadow	52.7%	15.1%
Intermountain Semi-Desert	44.0%	0.9%
Northern Rocky Mountain Forest-Steppe-Coniferous Forest- Alpine Meadow	41.5%	4.2%

Ecoregion Province	Percent roadless	Percent protected
California Coastal Range Open Woodland-Shrub-Coniferous Forest-Meadow	37.9%	8.6%
Hawaiian Islands	37.4%	3.4%
Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow	35.17%	4.08%
Colorado Plateau Semi-Desert	34.2%	2.5%
Chihuahuan Semi-Desert	27.9%	0.9%
Intermountain Semi-Desert and Desert	25.1%	0.6%
Ouachita Mixed Forest - Meadow	18.5%	0.9%
California Coastal Chapparral Forest and Shrub	17.3%	3.2%
Adirondack-New England Mixed Forest-Coniferous Forest-Alpine Meadow	17.2%	0.6%
Laurentian Mixed Forest	17.1%	1.5%
Black Hills Coniferous Forest	17.0%	0.4%
Central Appalachian Broadleaf Forest-Coniferous Forest-Meadow	14.3%	1.2%
Ozark Broadleaf Forest - Meadow	12.7%	1.6%
Great Plains-Palouse Dry Steppe	9.4%	0.3%
Pacific Lowland Mixed Forest	6.1%	0.6%
Great Plains Steppe	5.5%	0.1%
Outer Coastal Plain Mixed Forest	5.4%	0.6%
Eastern Broadleaf Forest (Oceanic)	2.8%	0.1%
Lower Mississippi Riverine Forest	2.7%	0.0%
Puerto Rico	2.7%	0.0%
Southeastern Mixed Forest	2.0%	0.1%
Eastern Broadleaf Forest (Continental)	1.8%	0.1%
Southwest Plateau and Plains Dry Steppe and Shrub	1.3%	0.0%
Great Plains Steppe and Shrub	0.9%	0.1%
California Dry Steppe	0.7%	0.0%
Prairie Parkland (Subtropical)	0.5%	0.0%
Prairie Parkland (Temperate)	0.2%	0.0%

Source: PBI, 2001

The Pew Wilderness Center contracted with the Pacific Biodiversity Institute in 2001 to identify and analyze all roadless areas over 1,000 acres in size on federal and state land in the U.S. The subsequent study, "Wildlands of the United States," noted that:

> Our remaining wildlands now provide important refuges for animal and plant species that were once common, but have not faired well with the rapid development of our nation.

The PBI inventory identified 657 million acres (1.027 million square miles) of remaining wild and roadless land on federal and state land in the U.S. as of 2001. Areas protected as Congressionally-designated Wilderness accounted for 106 million acres – or only 16 percent of the total area of *de facto* roadless wildlands. Thus, most of our remaining wildlands exist without formal protection from road building, logging, mining, grazing, power line construction, and other development. Together, protected and unprotected

wildlands comprise about 29 percent of the land area of the entire United States. The single state of Alaska alone contains almost half (47 percent) of the unprotected roadless area in the United States and 55 percent of the designated Wilderness (PBI 2001).

Most of these wildlands are managed by four main federal agencies in the Departments of Agriculture and the Interior: the U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and National Park Service. More than 408 million acres of unprotected roadless wildlands are managed by these four agencies.

Figure 3-44. Alaska has almost half of the nation's roadless wildlands (wilderness)

Figure 3-45. Congressionally designated Chupadera Peak Wilderness Area on Bosque del Apache National Wildlife Refuge in New Mexico

3.3.1.3 Population, Habitat and Biodiversity

Two of the leading domestic and international wildlife conservation organizations – the National Wildlife Federation and the World Wildlife Fund – concur that habitat loss poses the greatest threat to wildlife and biodiversity generally. According to NWF (2015), there are three main types of habitat loss:

- **Habitat destruction**: A bulldozer knocking over trees is the classic image of habitat destruction. Other examples of direct habitat destruction are filling in wetlands, dredging rivers, mowing grasslands, and clear-cut logging.

Figure 3-46. Iconic image of habitat destruction

- **Habitat fragmentation**: Much of the remaining terrestrial wildlife habitat in the U.S. has been cut up into fragments by roads, pipeline and transmission lines rights-of-way, and development. The habitat of aquatic species has been fragmented by dams, canals, levees, and water diversions. These habitat fragments may not be large or connected enough to support species that need large territories in which to find mates, food, and support viable populations not subject to inbreeding. Loss and fragmentation of habitat make it difficult for migratory species to find places to rest and feed along their migration routes.

- **Habitat degradation**: Pollution, invasive species, and disruption of ecosystem processes (such as by changing the intensity of fires in an ecosystem) are some of the ways habitats can become so degraded that they no longer support native wildlife (NWF 2015).

Figure 3-47. Habitat fragmentation from oil and gas drilling activity on the Allegheny National Forest in Pennsylvania

Figure 3-48. Road construction is perhaps the most widespread means of habitat fragmentation.

Figure 3-49. Habitat destruction in terrestrial settings is depicted most vividly by forest clearcutting, but it is far from the only type.

Figure 3-50. Overgrazing can degrade or destroy grassland, steppe, and prairie habitats.

Figure 3-51. Bottom trawling is a type of net fishing that scrapes the ocean floor, damaging benthic habitats.

Figure 3-52. Since 1988, the invasive, exotic zebra mussel has spread rapidly through the Great Lakes and other aquatic ecosystems, clogging water pipes, smothering fish spawning grounds, and replacing native mussels.

NWF (2015) lists the main drivers of habitat loss as:

- Agriculture: Much of the habitat loss from agriculture was done long ago when settlers converted forests and prairies to cropland. Today, there is increasing pressure to redevelop conservation lands for high-priced food and biofuel crops like corn-derived ethanol.

- Land conversion for development: The conversion of lands that once provided wildlife habitat to housing developments, roads, office parks, strip malls, parking lots and industrial sites continues unabated in the United States.

- Water development: Dams and other water diversions siphon off and disconnect waters, changing hydrology and water chemistry (when nutrients are not able to flow downstream). For example, during the dry season, because of withdrawals, the Colorado River has little or no water in it by the time it reaches the Sea of Cortez.

- Pollution: Freshwater wildlife are most impacted by pollution. Pollutants such as sediments, untreated sewage, mining waste, acid rain, fertilizers and pesticides concentrate in rivers, lakes and wetlands and eventually end up in estuaries and the food web.

- Global warming: Climate change is the emerging driver of habitat loss. Species that need the cool temperatures of high elevations, such as the American pika (*Ochotona princeps*) in the Rocky Mountains, are running out of habitat. The habitats of coastal wildlife will disappear underwater as sea levels rise.

Figure 3-53. The American pika, a small relative of rabbits and hares, is vulnerable to rising temperatures, forcing it higher and higher up mountainsides, until there is nowhere to go.

In the view of the World Wildlife Fund (WWF), habitat loss poses the single greatest threat to wild species,

> The world's forests, swamps, plains, lakes, and other habitats continue to disappear as they are harvested for human consumption and cleared to make way for agriculture, housing, roads, pipelines and the other hallmarks of industrial development (WWF 2015).

According to WWF (2015), wild animals are: "losing their homes because of the growing needs of humans." Habitat loss is identified as the main threat to 85 percent of all species described in the *Red List* of the International Union for the Conservation of Nature (IUCN) as threatened or endangered. According to the Red List, the number of threatened species of vertebrates (mammals, birds, reptiles, amphibians, and fishes) increased from 3,314 in 1996 to 7,678 in 2014 (IUCN 2014).

Figure 3-54 shows that the area of developed land – from which natural wildlife habitats have been permanently erased – in the states of the United States is closely correlated with the population sizes of those states. The larger the state's population is, the larger the area of developed land in that state.

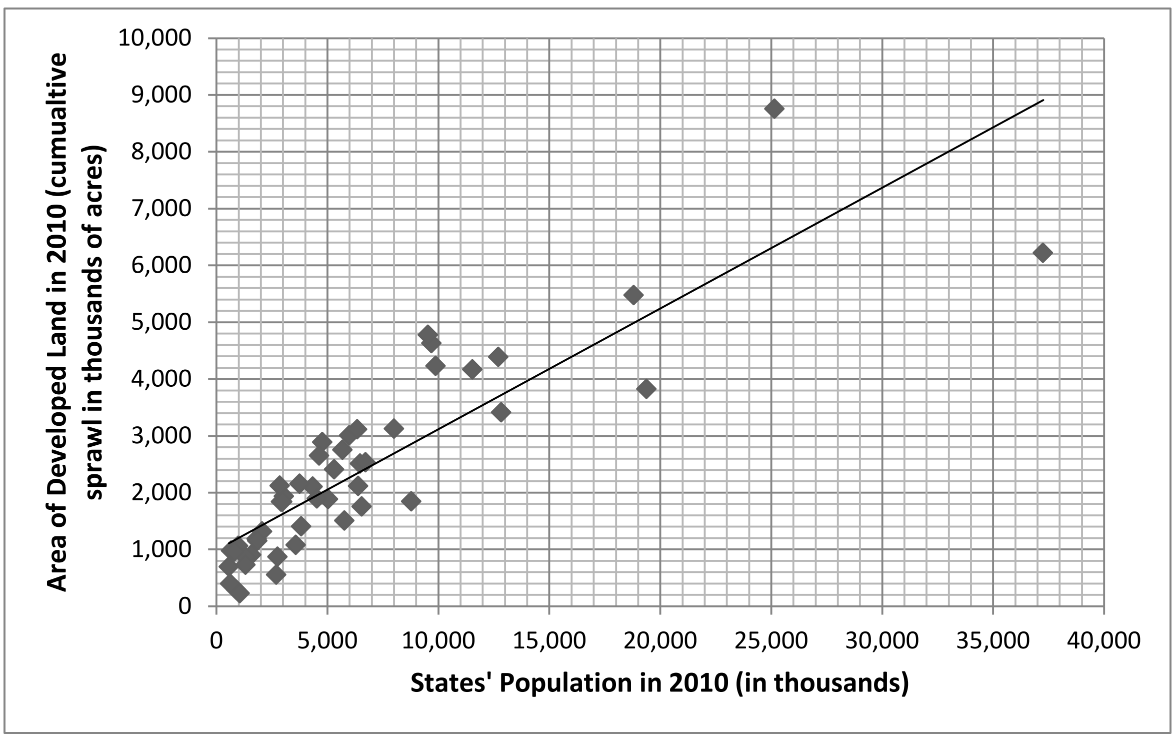


Figure 3-54. Cumulative Developed Land area (sprawl) is a function of population size

Source: U.S. Census Bureau; NRCS, 2013. *Summary Report: 2010 National Resources Inventory*

In the United States and elsewhere, population growth and rising material consumption per capita are the twin forces – the two sides of the same coin – behind "the growing needs of humans" that lead to wildlife "losing their homes." Each newcomer – whether through birth or immigration – imposes an added, incremental load on the environment and additional pressure on remaining wildlife, habitat, and biodiversity in the U.S.

However, predicting future specific impacts of U.S. population growth on habitat and biodiversity with any accuracy is not a simple matter because of so many mitigating and intervening factors and circumstances. By way of example, consider changes in the area of forest habitat in the United States over time.

It is estimated that in 1630, at the start of European colonization and settlement, the area of forest land that would later become the United States was 423 million hectares (1,045 million acres), or about 46 percent of the total U.S. land area (USFS 2001). Areas that were not then covered by forests were ecologically unsuited to them, such as deserts, prairies, tundra, marshes, or mountain ranges above timberline. By 1907, after two and a half centuries of accelerating growth, the U.S. population had surged to more than 75 million, and the area of forest land had shrunk by 116 million hectares (287 million acres, or 27 percent) to an estimated 307 million hectares (759 million acres), or 34 percent of the total land area in the U.S.

Deforestation occurred in conjunction with and because of this population growth, initially as a result of subsistence farming (clearing forests to make way for crops and livestock and to use wood as fuel for heating and cooking), and later because of commercial logging (cutting timber to provide wood products). Still later, more forest land was cleared on a large scale to make way for expanding towns, cities, suburbs, roads, and other development. Forests were eliminated to support an ever-growing and ever wealthier population's increasing aggregate consumption. Moreover, much of the remaining forested habitats consisted of lower-value, second-growth (or secondary) woodlands which grew back after higher-value, old-growth (or primary) forests were cut down or as abandoned, degraded farmlands gradually reverted to forest or brush because of natural ecological succession.

In the past century the U.S. population has doubled twice, expanding four-fold, from about 75-80 million to 320 million. Did the total acreage of U.S. forestland decrease significantly as a result of this population growth? No, it did not. And at least superficially, this is a surprising outcome. After all, a substantial continuing decline in forested area is what might have been predicted by an overly simplistic model postulating a direct decrease in forest lands because of the much higher needs and demands for wood

products, land, and space of a much wealthier (higher per capita consumption) human population four times greater.

In fact, total forest area in the U.S. has been relatively stable since 1907 (USFS 2001). In 1997, there were 302 million hectares (746 million acres) of forest in the United States, or 33 percent of the total land area of the United States (USFS 2001). See Figure 3-55. Today, forest land area represents approximately 70 percent of the area that was forested in 1630. Since 1630, about 120 million hectares of forest land have been converted to other uses – mostly agricultural. More than 75 percent of these net conversions to other land uses took place in the 19th century.

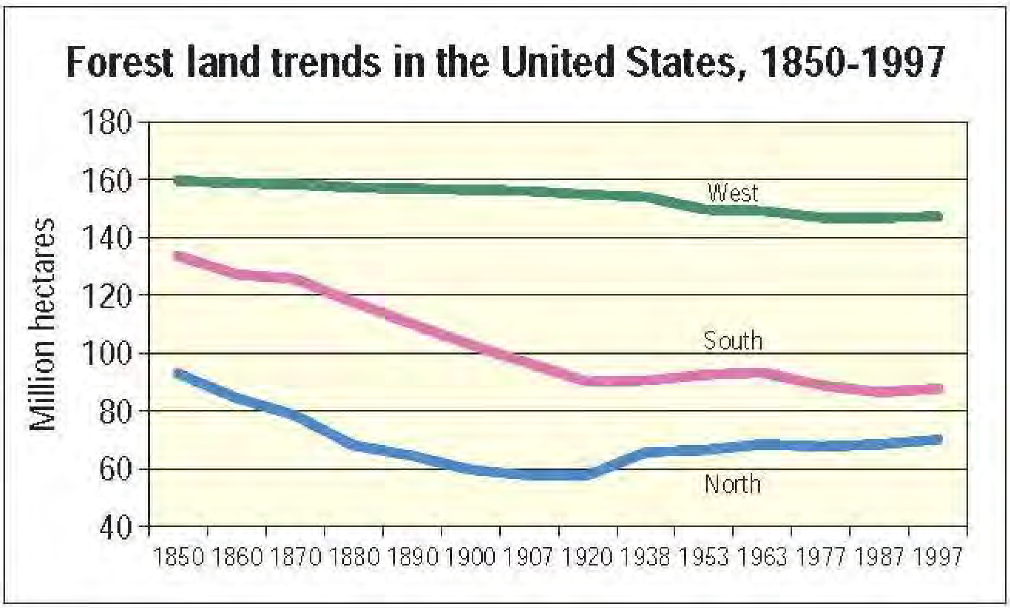


Figure 3-55. Change in area of U.S. forest land over time
Source: USFS 2001

On the face of it, this is remarkable. The land area that is now supporting 320 million high-consuming Americans has lost less than a third of its forested habitat. And in a century that saw the American population grow by four times – doubling in size twice – the proportion of the country that is forested has merely declined from 34 percent to 33 percent. If human population growth truly adversely affected the quantity and quality of habitats and biodiversity, one would have expected a greater impact than this. What could account for this counter-intuitive result?

As America grew more technologically sophisticated and economically complex in the 19th and 20th centuries, agriculture became more efficient and productive, so that an ever smaller share of the population was needed to grow the food to support an ever larger population. At the same time that less labor was needed “down on the farm,” there was a

growing demand for labor in industry – mines, smelters, factories, steel mills, manufacturing plants, retail, services, government, and so forth. The result was a long-term migration away from rural areas toward urban ones, a vast socioeconomic phenomenon (with massive social, cultural, economic, and environmental implications of its own) that continues throughout the entire world to the present day. This alleviated direct population pressures on many hinterlands. Marginal farmlands with depleted soils were able to begin to revert naturally back to forest (through natural process of ecological succession), although it would take centuries for returning second growth forests to fully acquire the habitat value and biodiversity that disappeared when old-growth forests and their associated communities of indigenous flora and fauna were obliterated.

Several points of clarification are in order. First, the same modern, industrialized, more productive agriculture that allowed for such a massive exodus to cities (thereby alleviating widespread pressures on forests) is highly dependent on fossil fuels at all stages and it is "mining" soils, so that it is itself unsustainable. Second, our consumption of the same fossil fuels (coal, oil, natural gas) in ever-growing quantities, which allowed society to move away from its traditional dependence on wood as a source of heat and energy, is also unsustainable. Third, the U.S. imports large volumes of wood products from other countries, primarily Canada but many other countries as well; this also eases logging pressures on our own forests. Imports in 2012 alone were valued at over $12 billion (USDA 2013). These are some of the reasons that account for how a four-fold growth in the U.S. population could avoid a commensurate increase in pressure on forest lands.

Given the long-term unsustainability and instability of these current conditions and circumstances, it may be premature and overly optimistic to conclude that the United States can continue to support even a population of 320 million – to say nothing of the still higher projections considered in this EIS – while still managing to retain 70 percent of its original forests. The United States might only have deferred an ecological debt that will inevitably and eventually come due. (Indeed, this is what is implied by the Ecological Footprint accounting discussed above, which indicates that the U.S. and most other countries on Earth are running deep ecological deficits and accumulating long-term ecological debts.)

Ceteris paribus, a human population that is 50 percent larger will have a 50 percent greater impact on wildlife, habitat, and biodiversity. As with other environmental impacts, with enlightened commitment it is possible to reduce the direct and indirect per capita impact or load on wildlife, habitat, and biodiversity by means of greater efficiency and conservation, but not infinitely so. People can live in well-insulated homes in higher-density, less-sprawling settlements, drive more fuel-efficient cars instead of gas guzzlers,

and so forth. But there are still limits to what is technically – and just as importantly, socially and politically – feasible. For the purpose of this analysis, it is assumed that the average American, including immigrants and their U.S.-born descendants, will utilize resources more efficiently in the future, as we have begun to in the recent past. In other words, for the remainder of the 21st century (the period of analysis), the average American will have a somewhat smaller ecological footprint and carbon footprint than at present.

3.3.2 Environmental Consequences

3.3.2.1 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million (70 percent) from the 2010 population of 309 million. It is also 47 million less than the 571 million projection for 2100 that the U.S. Census Bureau made in 2000 (Table 3-3, Figure 3-9, and Hollmann et al. 2000).

A U.S. population that is 70 percent larger than the present one would generally be expected to exert greater pressure on all natural resources and on all facets of the environment. However, due to long-term economic growth and improvements in the efficiency of resource use, the per capita direct, indirect, and cumulative impact on habitat and biodiversity of each American consumer in 2100 may not – probably will not – equal what it is at present. Economic growth would tend to increase per capita impact (because it has traditionally been linked with increased flows of matter and energy), while efficiency improvements would tend to decrease per capita impact. In other words, these influences tend to negate or offset one another, i.e., cancel each other out.

A phenomenon called the "Jevons Paradox" after its founder also has a bearing on this discussion. It was first identified and described in the 1865 book *The Coal Question* by the English economist William Stanley Jevons. Jevons put forth the counter-intuitive proposition that technological innovation that leads to an increase in the efficiency with which a resource is used tends over time to actually *increase*, not decrease, the aggregate rate of consumption of that resource (Alcott 2005). In his research into a wide range of industries, Jevons found that technological improvements which increased the efficiency of coal use ultimately led to increased consumption of coal. This outcome, running counter to intuition, means that we cannot automatically rely upon technological progress reduce the aggregate consumption of resources or aggregate environmental impacts. Modern economists have identified other examples of the Jevons Paradox. Improved energy efficiency can lower the relative cost of using a resource, which tends to increase

the aggregate quantity of the resource demanded, and this "rebound effect" can potentially offset any savings from increased efficiency.

Thus, in this EIS, we will present a range of possible interactions, from the "optimistic" to the "pessimistic," between economic growth, increased efficiency, and population growth. On the optimistic side, this EIS will assume a net 30 percent lower per capita impact from each American, so that if today's per capita impact is set at 1.0, by 2100 it would be reduced to 0.7. On the pessimistic side, per capita impact would be 30 percent higher, or 1.3 by 2100. This range from 0.7 to 1.3 may be too cautious, but it is also realistic and reasonable.

Applying these to the No Action Alternative, a 70 percent population increase by 2100, we get the following range of possible impacts on habitats and biodiversity:

(1) <u>Pessimistic scenario</u> 1.7 [increase in population] x 1.3 [per capita coefficient] = 2.2 times greater

(2) <u>Optimistic scenario</u> 1.7 [increase in population] x 0.7 [per capita coefficient] = 1.2 times greater

Thus, under the No Action Alternative – 1.25 million annual immigration into the United States leading to a U.S. population of 524 million in 2100 – the net, aggregate effect on habitats and biodiversity would range from approximately 1.2 to 2.2 times greater than it is today. This is not to say that 1.2 to 2.2 times the number of wildlife species would necessarily be threatened with extinction, or that habitats would be reduced by 1.2 to 2.2 times. Rather, a first-order approximation of the general impacts or demographic pressures on habitats and biodiversity of this immigration-induced population growth is that these impacts and pressures would range from 1.2 to 2.2 times greater than they are at present.

It should be stressed that even if U.S. population were to remain constant over the rest of the century and not increase at all, existing levels and patterns of land use and current rates of resource consumption and carbon dioxide emissions would still negatively impact habitats and biodiversity. Populations of many species of birds, for example, are in decline in the United States (Figure 3-56), and some of these declines would likely continue even without further habitat loss/degradation and other adverse effects from a growing human population.

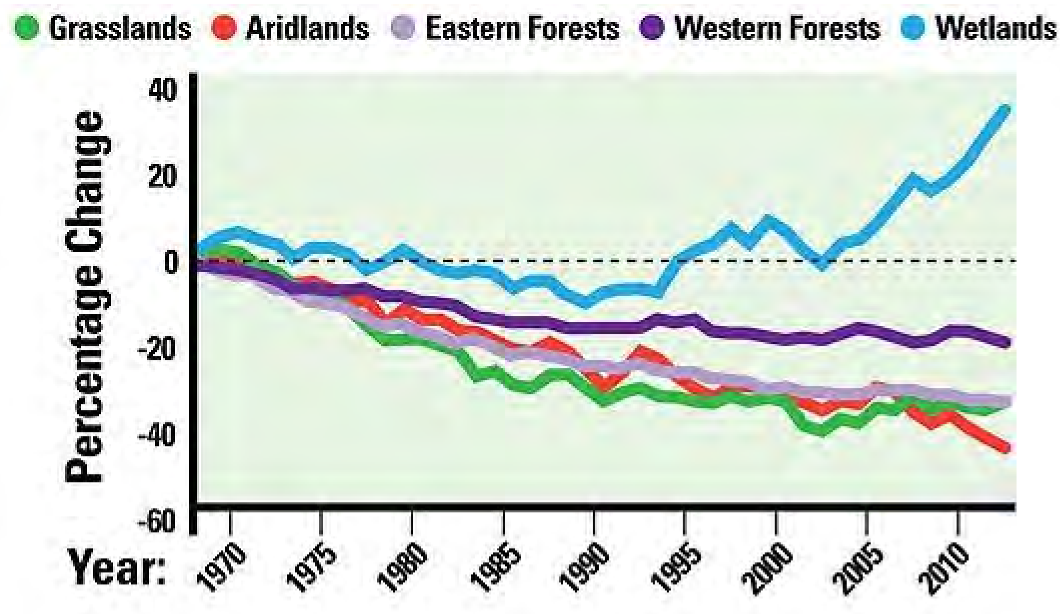


Figure 3-56. Bird population indicators in five inland U.S. habitats
Source: *The State of the Birds 2014*. North American Bird Conservation Initiative

In all three of the immigration-level scenarios addressed in this EIS, the great majority of the impacts from, 1) each American consumer, 2) each additional American consumer (from immigration and population growth), and 3) the aggregate, growing population of American consumers, on habitats and biodiversity are not direct, but rather indirect and cumulative, in the parlance of environmental planners (see Section 3.1.1). That is, the average native-born American, the average foreign-born American, and the average native-born American who is the offspring of foreign-born parents (i.e., second-generation immigrants), does not actually take an ax or chainsaw in hand to cut down trees to convert to lumber for use in building his or her home; neither does he or she clear a patch of forest on which to build that home and an access road to it. Similarly, the average American does not directly:

- Mine the coal used to generate the electricity he/she uses, in the process destroying and damaging natural habitats, disfiguring landscapes, filling in streams and valleys, and causing acid mine drainage, acid rain, mercury emissions (which accumulate in fish tissue), sulfur dioxide aerosol emissions (air pollution that blights scenic areas of the country like the Blue Ridge Mountains or the Grand Canyon); and carbon dioxide emissions (leading to global warming).

- Drill for the oil he/she uses to fill his/her SUV with gasoline and the natural gas to heat his/her home, office, and school every winter, in the process fragmenting terrestrial habitats from roads, drilling pads, and pipelines, while harming marine habitats from oil spills, and potentially damaging groundwater and surface waters all while causing noise, traffic congestion, local air pollution and development in formerly quiet, tranquil rural areas.

- Build dams and reservoirs on rivers to supply drinking and crop irrigation water, recreation sites, flood control, and hydro-electricity, while damaging or destroying salmon runs and those of other anadromous fish and freshwater aquatic biota, as well as blemishing or eliminating unique landscapes (like those along the Colorado River which disappeared under Lake Powell and the Glen Canyon Dam).

- Apply pesticides, herbicides, insecticides, and fertilizers to crops, damaging birds and beneficial insects as well as pests, or cause the runoff and soil erosion from those croplands that silt in our rivers, and the fertilizer runoff that leads to algal blooms in rivers, lakes and estuaries (like Chesapeake Bay) from excessive nutrients and ultimately causes a “dead zone” in the Gulf of Mexico at the mouth of the Mississippi River every summer.

This list could go on for quite some time. Suffice it to say that each and every American consumer, while he or she may not directly extract the resources and excrete the wastes or “residuals” that support his/her standard of living, quality of life, and level of consumption, is ultimately responsible or accountable for the indirect and cumulative impacts that take place in his or her name.

Figure 3-57 is a schematic which illustrates the broad types of effects that each American resident/consumer, and by extension all American consumers in aggregate, would have on habitats and biodiversity from the increased U.S. population size induced by immigration rates under the No Action Alternative. These “pathways to perdition” depict some of the more important routes by which increased aggregate American consumption from a population that is 70 percent larger would cause additional harm to natural habitats, wildlife, and biodiversity. This diagram is not meant to be thorough or exhaustive, merely suggestive. It divides impacts into two broad categories: 1) those flowing from consuming or using natural resources – including energy, water, raw materials such as minerals, and land – and 2), those flowing from residuals or wastes excreted back into the environment by economic processes. These wastes may be ejected into the environment at the point of extraction (such as mine tailings), manufacture and processing (such as air pollution from aluminum smelters or water pollution from petrochemical plants), or consumption (such as tailpipe emissions from an automobile).

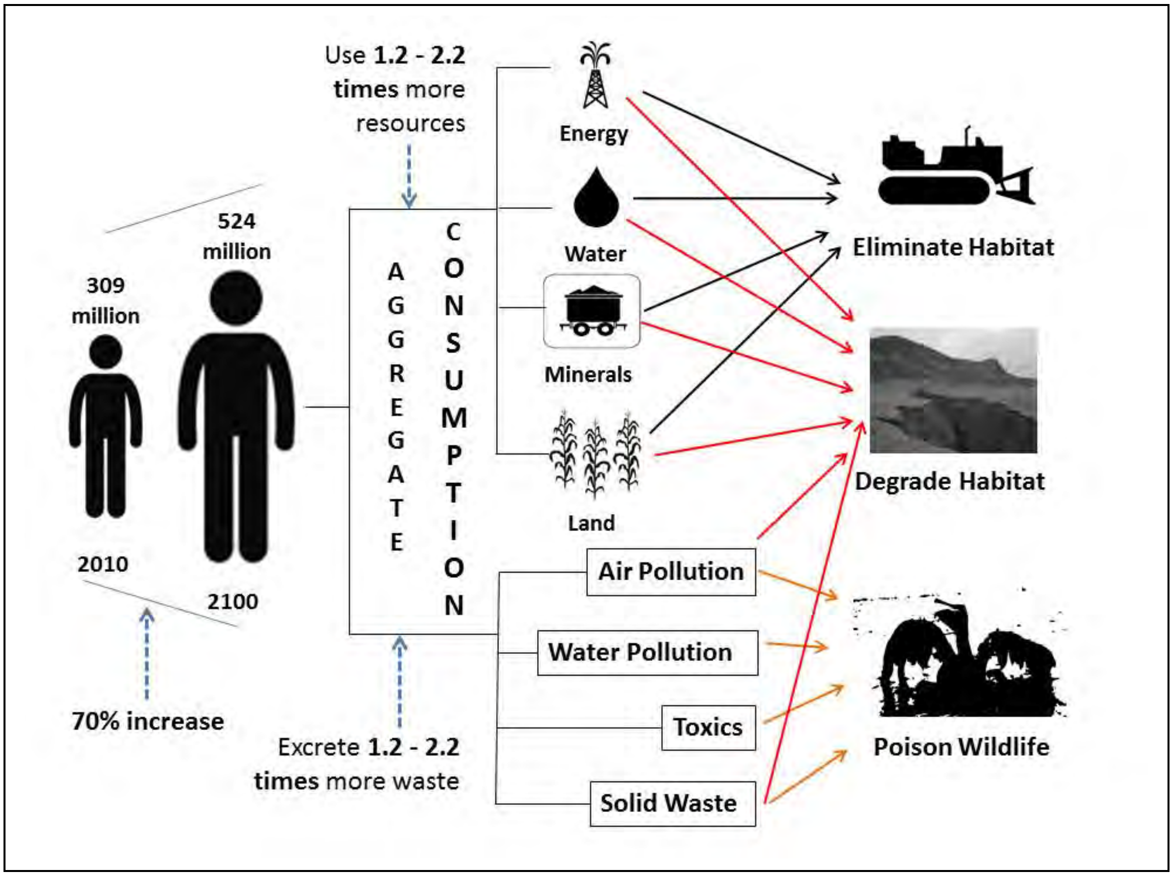


Figure 3-57. Pathways to perdition I: Illustration some of the routes by which the No Action Alternative would adversely affect habitats, wildlife, and biodiversity

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would have indirect and cumulative impacts on farmland as follows:

- **Duration of Impact**: ***Long-term to permanent***. The duration of the impact on habitats and biodiversity associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."
- **Extent of Impact**: ***Large***. The extent of the impact on habitats and biodiversity associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale."
- **Magnitude of Impact:** ***Major***. The magnitude of the impact on habitats and biodiversity associated with the population growth under the No Action Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on habitats and biodiversity associated with the population growth under the No Action Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on habitats and biodiversity.

Overall, the effect of the No Action Alternative on habitats and biodiversity would be adverse, significant, and long-term. It would likely be associated with the permanent loss of at least an additional 50-75 million acres (80,000 to 120,000 square miles) of wildlife habitat directly to development (sprawl and urbanization). A much larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 70 percent larger. These increasing pressures would stem from such stressors as:

- Air pollution including smog and ozone that damages leaves and growth of trees;
- Heavy metal contamination from toxic elements such as lead and mercury;
- Exposure of ecosystems and wild plants and animals to acute and chronic toxicity from pesticides;
- Acid precipitation damage of soils, plants, and aquatic ecosystems;
- Point and non-point sources of water pollution which damage aquatic environments;
- Noise pollution and other disturbances affecting wildlife in areas adjacent to developed zones;
- Increased demand for water for agriculture, municipalities, industry and recreation would place greater stress on aquatic habitats and biota;
- Habitat fragmentation due to road construction and right-of-ways for new pipelines and power lines (habitat fragmentation reduces the viability of wildlife species needing large areas of uninterrupted habitat to survive and thrive);
- Large-scale development of renewable energy (wind farms and concentrated solar facilities) in rural areas which both fragment and eliminate habitat and cause bird and bat mortality from collisions with spinning blades;

- Large-scale hydraulic fracturing for shale gas and tight oil, which entails an extensive network of roads, pipelines, and drilling pads that fragment, damage, and destroy wooded habitats;

- Spreading exotic invasive species of plants, animals, and microbes that aggressively outcompete and displace or infect native flora and fauna (e.g., kudzu, cogongrass, autumn olive, Brazilian pepper, giant reed, saltcedar, hydrilla, zebra mussel, red imported fire ant, Africanized honeybee, gypsy moth, hemlock wooly adelgid, emerald ash borer, West Nile virus, avian influenza, chestnut blight, dogwood anthracnose, Dutch elm disease, sudden oak death, white pine blister rust);

- Damaging logging practices which compromise forest composition and structure;

- The increasing area of wildland-urban interface around the country from suburban sprawl and exurban and vacation home development, which interferes with the use of prescribed fire and other fire management practices needed to maintain healthy habitats and control fuel loads;

- The myriad effects associated with global warming and climate change, including increasing soil moisture stress, extreme weather events (downpours, derecho winds, tornados, hurricanes, ice storms, heat waves, droughts), rapid migration northward and upward of species, perturbed phenology (disrupted timing of natural events that have traditionally coincided, such as the blooming of plants and the migration of birds), the drying out of much of the West, exposing forests over vast areas to moisture stress, mortality, and insect (particularly pine beetle) infestations.

Those wilderness and roadless areas – zones of great value for habitat and biodiversity – listed in Table 3-7 that are already protected or officially designated as wilderness would probably remain so for the duration of this century, although they would be subjected to greater levels of many of the stresses cited just above. However, Table 3-7 shows that there is a much greater area of unprotected roadless areas for each ecoregion province, and with the multiple demands exerted by an American population that is 70 percent larger, there is likely to be less political support for officially protecting these areas from resource exploitation (e.g., logging, mining, drilling, road-building) or development.

In sum, if Americans acquiesce to the No Action Alternative, maintaining immigration levels at 1.25 million per year, impacts on habitat and biodiversity would be significantly adverse.

3.3.2.2 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would result in a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million (117 percent) from the 2010 population of 309 million. It is also 98 million more than the "middle series" projection of 571 million for 2100 that the U.S. Census Bureau made in 2000 (Table 3-3, Figure 3-9, and Hollmann et al. 2000). But, it is worth emphasizing, much less than the "highest series" projection of 1.2 billion Census made at the same time. The Expansion Alternative is thus within the realm of the plausible or "reasonably foreseeable," and indeed, it may come to pass if proposals like those pushed by the Obama Administration and "comprehensive immigration reform" advocates in Congress – or future administrations or congresses – were ever to be signed into law.

A U.S. population that is more than twice as large as our current population would generally be expected to exert considerably greater pressure and stress on all natural resources and on all facets of the environment. However, as noted under the No Action Alternative, because of long-term economic growth and improvements in the efficiency of resource use, the per capita direct, indirect, and cumulative impact on habitat and biodiversity of each American consumer in 2100 may not – probably will not – equal what it is at present. Economic growth would tend to increase per capita impact (because it has traditionally been linked with increased flows of matter and energy), while efficiency improvements would tend to decrease per capita impact. In other words, these influences would tend to negate or offset one another, i.e., cancel each other out.

Using the same approach as in the No Action Alternative, this EIS presents a range of possible interactions under the Expansion scenario, from the "optimistic" to the "pessimistic," between economic growth, increased efficiency, and population growth. On the optimistic side, this EIS assumes a net 30 percent lower per capita impact from each American, so that if today's per capita impact is set at 1.0, by 2100 it would be reduced to 0.7. On the pessimistic side, per capita impact would be 30 percent higher, or 1.3 by 2100. This range – from 0.7 to 1.3 – is also realistic and reasonable, although it may err on the side of caution.

Applying these to the Expansion Alternative, a 117 percent population increase by 2100, the following range of possible impacts on habitats and biodiversity emerges:

(1) <u>Pessimistic scenario</u> 2.2 [increase in population] x 1.3 [per capita coefficient] = 2.9 times greater

(2) <u>Optimistic scenario</u> 2.2 [increase in population] x 0.7 [per capita coefficient]

= 1.5 times greater

Thus, under the Expansion Alternative – 2.25 million annual immigration into the United States leading to a U.S. population of 669 million in 2100 – the net, aggregate effect on habitats and biodiversity would range from approximately 1.5 - 3 times greater than it is today. This is not to say that 1.5 to 3 times the number of wildlife species would necessarily be threatened with extinction, or that habitats would be reduced by 1.5 - 3 times. Rather, a first-order approximation of the general impacts or demographic pressures on habitats and biodiversity of this immigration-induced population growth is that these impacts and pressures would range from about 1.5 - 3 times greater than they are at present. The same caveats discussed above for the No Action Alternative are also applicable for the Expansion Alternative.

Figure 3-58 is a schematic which illustrates the broad types of effects that each American resident/consumer, and by extension all American consumers in aggregate, would have on habitats and biodiversity from the increased U.S. population size induced by immigration rates under the Expansion Alternative.

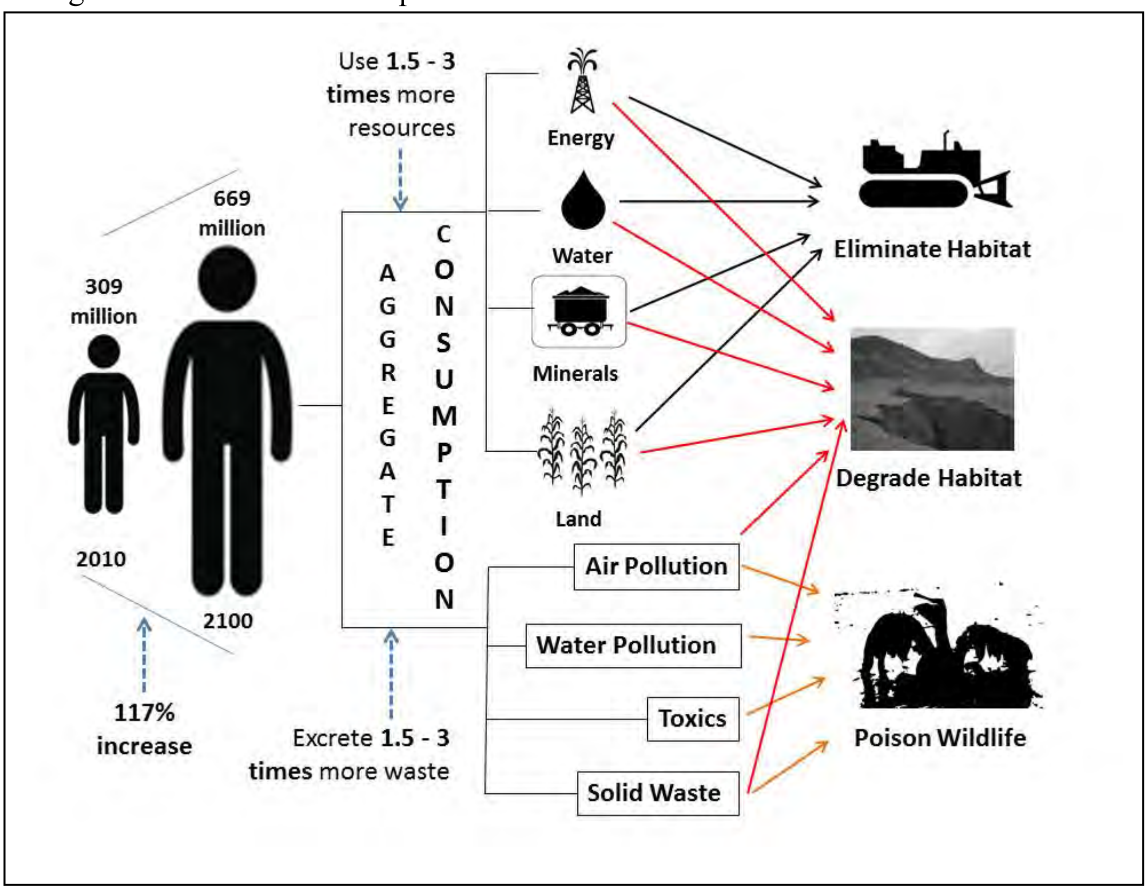


Figure 3-58. Pathways to perdition II: Illustration some of the routes by which the Expansion Alternative would adversely affect habitats, wildlife, and biodiversity

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would have indirect and cumulative impacts on habitat and biodiversity as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on habitats and biodiversity associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on habitats and biodiversity associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale." The extent of these impacts would be greater than under the No Action Alternative.

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on habitats and biodiversity associated with the population growth under the Expansion Alternative would represent a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard." The magnitude of the impact of the Expansion Alternative would substantially exceed that of the No Action Alternative.

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on habitats and biodiversity associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on habitats and biodiversity.

Overall, **the effect of the Expansion Alternative on habitats and biodiversity would be highly adverse, significant, and long-term**. It would likely be associated with the permanent loss of at least an additional 65-120 million acres (100,000 to 190,000 square miles) of wildlife habitat directly to development (sprawl and urbanization). A much larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 117 percent (2.2 times) larger.

Those wilderness and roadless areas – zones of great value for habitat and biodiversity – listed in Table 3-7 that are already protected or officially designated as wilderness would probably remain so for the duration of this century, although they would be subjected to much higher levels of many of the stresses cited just above. However, Table 3-7 shows that there is a much greater area of unprotected roadless areas for each ecoregion

province, and with the multiple demands exerted by an American population that is 117 percent (2.2 times) larger, there is likely to be much less political support for officially protecting these areas from resource exploitation (e.g., logging, mining, drilling, road-building) or development.

Increasingly, the more acute needs and demands of human beings are likely to be pitted against those of wilderness, wildlife, and biodiversity, and in these instances, when push comes to shove, wilderness, wildlife, and biodiversity tend to lose out, because they have no votes or political and economic clout of their own. An example of this is in occurring in California at the moment, where the survival of the endangered delta smelt (*Hypomesus transpacificus*) is in doubt as a result of the state's severe drought and waning political support for the freshwater flows in the Sacramento-San Joaquin Delta needed for this small fish to avoid extinction (Platte 2015). When thousands of farmers cannot grow crops and tens of millions of city dwellers watch lawns turn brown because of insufficient water, support for an inconspicuous, innocuous fish tends to dry up.

Figure 3-59. Endangered delta smelt (*Hypomesus transpacificus*) of California

In sum, if the United States Congress were to endorse the Expansion Alternative – opting to increase immigration levels up to 2.25 million per year – impacts on habitat and biodiversity would be significantly adverse. These impacts would be much greater than those of the No Action Alternative, which would also be significantly adverse.

3.3.2.3 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This is an increase of 70 million (23 percent) from the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

A U.S. population that is more than 23 percent larger than our present population would generally be expected to exert greater pressure and stress on all natural resources and on all facets of the environment. However, as noted both under the No Action Alternative and the Expansion Alternative, because of long-term economic growth and improvements in the efficiency of resource use, the per capita direct, indirect, and cumulative impact on habitat and biodiversity of each American consumer in 2100 may not – probably will not – equal what it is at present. Economic growth would tend to increase per capita impact (because it has traditionally been linked with increased flows of matter and energy), while efficiency improvements would tend to decrease per capita impact. In other words, these influences would tend to negate or offset one another, i.e., cancel each other out.

Using the same approach as in the No Action and Expansion Alternatives, this EIS presents a range of possible interactions under the Reduction scenario, from the "optimistic" to the "pessimistic," between economic growth, increased efficiency, and population growth. On the optimistic side, this EIS assumes a net 30 percent lower per capita impact from each American, so that if today's per capita impact is set at 1.0, by 2100 it would be reduced to 0.7. On the pessimistic side, per capita impact would be 30 percent higher, or 1.3 by 2100. This range – from 0.7 to 1.3 – is also realistic and reasonable, although it may err on the side of caution.

Applying these to the Reduction Alternative, a 23 percent population increase by 2100, the following range of possible impacts on habitats and biodiversity emerges:

(1) <u>Pessimistic scenario</u> 1.2 [increase in population] x 1.3 [per capita coefficient] = 1.6 times greater

(2) <u>Optimistic scenario</u> 1.2 [increase in population] x 0.7 [per capita coefficient] = 0.8 times (20 percent less overall environmental stress on habitat/biodiversity)

Thus, under the Reduction Alternative – 250,000 (0.25 million) annual immigration into the United States leading to a U.S. population of 379 million in 2100 – the net, aggregate effect on habitats and biodiversity would range from approximately 0.8 – 1.6 times what it is today. The "0.8" means that under optimistic assumptions as to the interaction of

economic growth and efficiency improvements, as well as the most optimistic population projection of this EIS (although one that still leads to population growth of 70 million people by 2100), overall aggregate human pressures on natural habitats and biodiversity would actually ease by about 20 percent between now and 2100.

As noted earlier, the same caveats are in order. This analysis does not conclude that 0.8 – 1.6 times the number of wildlife species would necessarily be threatened with extinction or driven extinct, or that habitat would be reduced by up to 1.6 times. Rather, a first-order approximation of the general impacts or demographic pressures on habitats and biodiversity of this immigration-induced population growth is that these impacts and pressures would range from about 0.8 – 1.6 times greater than they are at present.

Figure 3-60 is a schematic which illustrates the broad types of effects that each American resident/consumer, and by extension all American consumers in aggregate, would have on habitats and biodiversity from the increased U.S. population size induced by immigration rates under the Reduction Alternative.

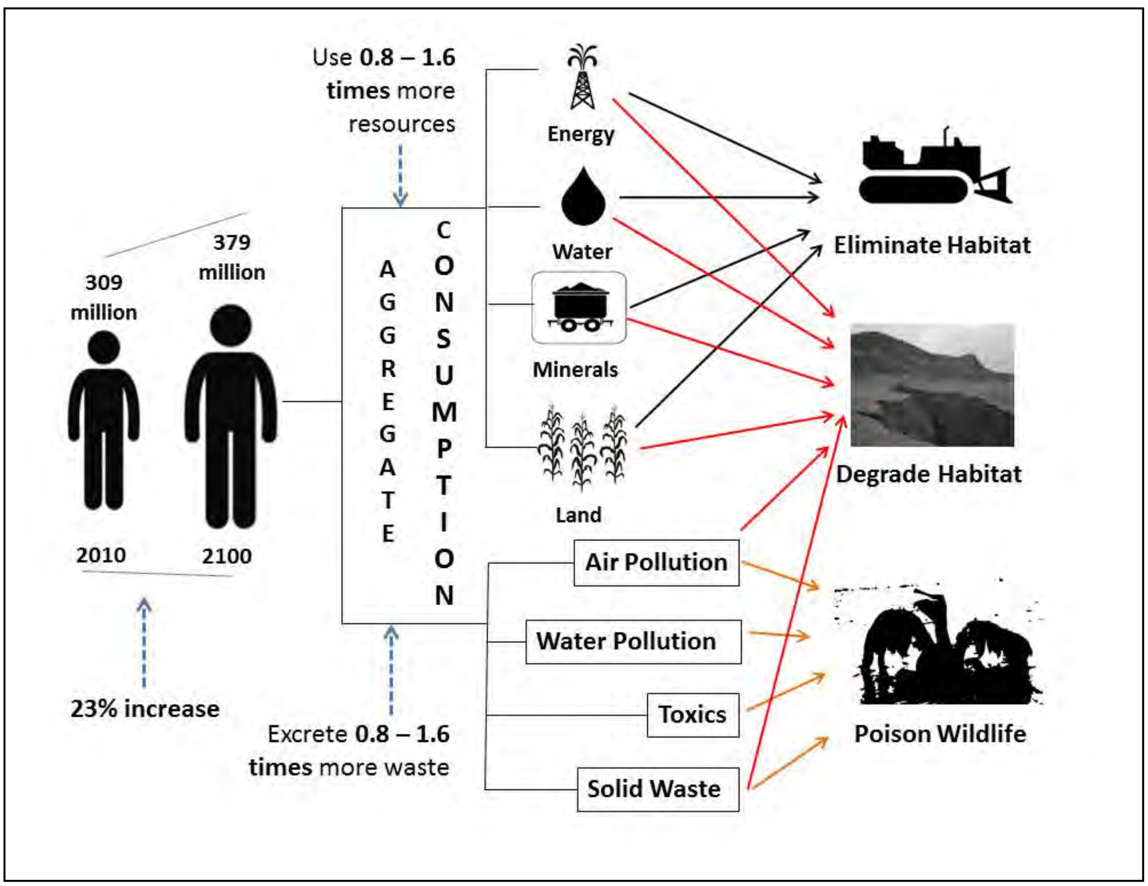


Figure 3-60. Pathways to (partial) perdition III: Illustration of routes by which the Expansion Alternative would adversely affect habitats, wildlife, and biodiversity

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would have indirect and cumulative impacts on habitat and biodiversity as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on habitats and biodiversity associated with the projected population growth under the Reduction Alternative would range from “would likely last for a decade or more” to “indefinite or everlasting and for all intents irreversible.”

- **Extent of Impact**: ***Large***. The extent of the impact on habitats and biodiversity associated with the projected population growth under the Expansion Alternative “would affect a resource on a regional, national, or global scale.” Nevertheless, the extent of these impacts would be much less than those of either the No Action Alternative or the Expansion Alternative.

- **Magnitude of Impact:** ***Moderate***. The magnitude of the impact on habitats and biodiversity associated with the population growth under the Reduction Alternative would be such that a, “noticeable change in a resource occurs, but the integrity of the resource remains intact.” The magnitude of the impact of the Expansion Alternative would substantially exceed that of the No Action Alternative.

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impact on habitats and biodiversity associated with the population growth under the Reduction Alternative is “more likely than not to occur, i.e., approximately 50% likelihood or higher.” While the impact may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on habitats and biodiversity.

Overall, **the effect of the Reduction Alternative on habitats and biodiversity would still be adverse, significant, and long-term**. It would likely be associated with the permanent loss of at least an additional 35-65 million acres (55,000 to 100,000 square miles) of wildlife habitat directly to development (sprawl and urbanization) – but this is much less than the predicted habitat losses of the No Action and Expansion alternatives. A still larger area of habitat – forestland, wetlands, desert, shrub-scrub, tundra, alpine, riparian, grasslands – would be vulnerable to degradation from increased environmental pressures and stresses associated with a human population that is 23 percent larger than our present population.

Those wilderness and roadless areas – zones of great value for habitat and biodiversity – listed in Table 3-7 that are already protected or officially designated as wilderness would

like remain so designated for the duration of this century, although they would be subjected to somewhat higher levels of many of the stresses cited earlier. Table 3-7 shows that there is a larger area of unprotected roadless areas for each ecoregion province than there is protected area – sometimes much larger. Under the Reduction Alternative, while human demands on the habitats and wildlife populations of these unprotected roadless ecoregion provinces would be greater than today, these demands and stresses would not be nearly as large as with the No Action and Expansion alternatives. Thus, under the Reduction Alternative, there would be a much higher probability of providing de facto or statutory protection for these biodiversity strongholds.

In sum, if the American people and the federal government were to endorse the Reduction Alternative – opting to decrease overall immigration levels to 0.25 million per year – impacts on habitat and biodiversity would still be significantly adverse and likely greater than they are at the present time. However, these impacts would be much less than those of the No Action Alternative or the Expansion Alternative. Furthermore, by 2100, the U.S. population would have stopped growing and stabilized under the Reduction Alternative, whereas under both the No Action and Expansion alternatives, it would still be growing rapidly with no end in sight. Thus, in the other two alternatives, the demographic component of increasing anthropogenic stresses on wildlands, wilderness, habitat and biodiversity would also still be growing with no end in sight.

Figure 3-61. "Where the Buffalo Roam"

American bison (*Bison bison*) grazing in the grassy hills of Wichita Mountains National Wildlife Refuge in Oklahoma. Under the Reduction Alternative, far more country-side would remain undeveloped as open space available to free-ranging wildlife than under either the No Action or Expansion alternatives.

3.4 Water Demands and Withdrawals From Natural Systems

"One thing is certain in the drinking water profession – the demand for water will continue to grow as our population grows." – Fairfax Water (2014)

3.4.1 Affected Environment

3.4.1.1 Water on Earth – A Global Perspective

Water is essential to all life – human and non-human, plant and animal, vertebrate and invertebrate, microscopic and macroscopic, prokaryotic and eukaryotic, terrestrial and aquatic alike. Water is found both inside and outside of the cellular membranes that demarcate the boundary between biotic (living) and abiotic (non-living) matter. Sixty to 70 percent or more of the weight of healthy, living plant and animal cells is water. The human body overall consists of more than 60 percent water, while our blood is 92 percent water and our brain and muscles are 75 percent water. Even bones are about 22 percent water (WIP 2015). Both economies and ecosystems wither without it. Where water in the liquid state is not plentiful, as in Antarctica or deserts, life itself is also not plentiful.

Fortunately for *Homo sapiens* and all other species, the Earth is blessed with an unfathomably enormous volume of water: 332,500,000 cubic miles (mi^3) to be exact (USGS 2014a). That's 250 million cubic yards for each of the 7.3 billion inhabitants of the planet, or about 70,000 Olympic-sized swimming pools. This quantity of water has remained essentially constant for billions of years, even as it circulates and recirculates through the endless loop called the hydrologic cycle. All that varies over geologic time are the relative proportions of water that are saline (in the oceans), fresh (in rivers, lakes, and aquifers on continents and islands), frozen (in Antarctica, Greenland, the world's glaciers, and the polar ice cap), and gaseous (as water vapor) in the atmosphere.

Indeed, the Earth has so much water that it has been called an "ocean planet," and 71 percent of its surface is covered with water. With so much of this substance, it seems paradoxical that, even with a global population of 7.3 billion thirsty human beings making ever greater claims on this liquid, that so many of them should be water-stressed, and destined to become even more so as the current century progresses.

Part of this seeming paradox is resolved by looking at Figures 3-62 and 3-63. To begin with, only three percent of the Earth's water is fresh, while 97 percent is saline, that is, in the oceans. While saltwater can be converted to potable freshwater, or desalinated, through reverse osmosis and other processes, these are costly economically, energetically, and environmentally, and thus are unlikely to be practicable or sustainable on a large scale. Of the three percent of the water on Earth that is fresh, nearly 70 percent is frozen as ice in Antarctica, Greenland and thousands of glaciers.

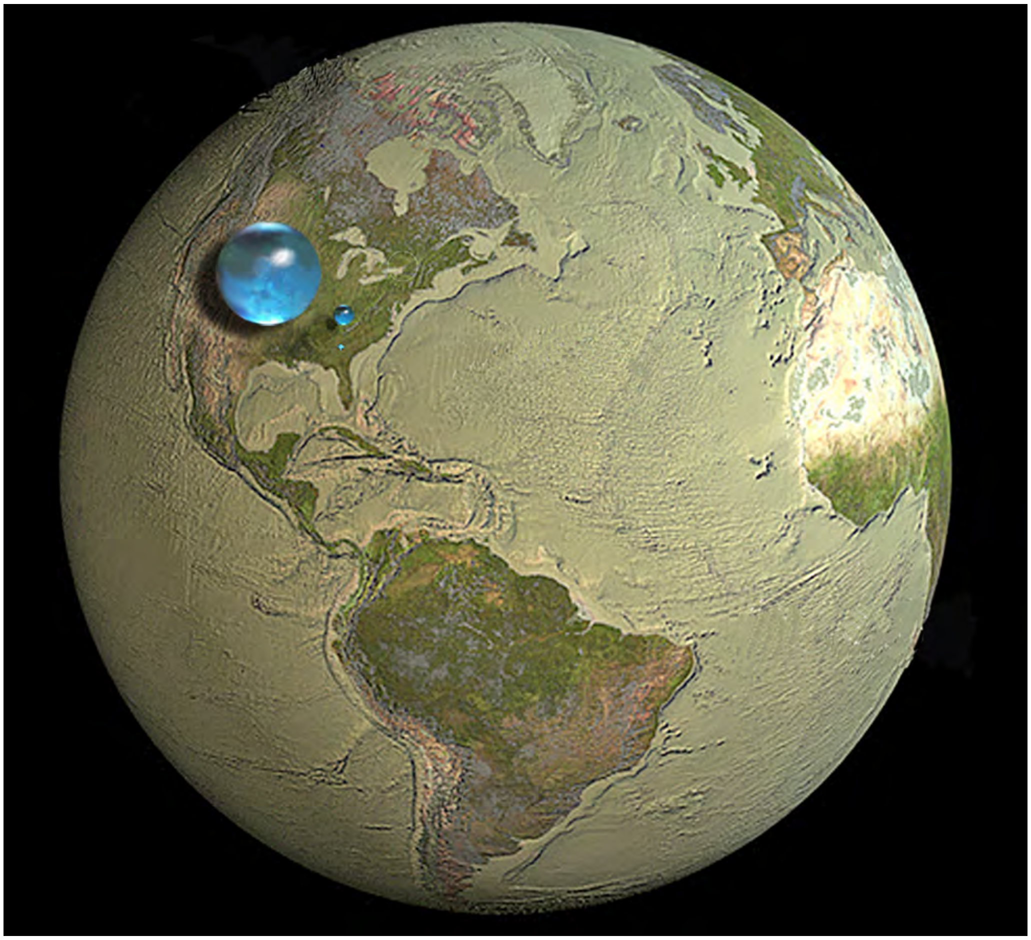


Figure 3-62. All of Earth's water combined and freshwater alone shown as a big sphere, a smaller sphere, and a small dot, respectively
Image: Jack Cook, Woods Hole Oceanographic Institution

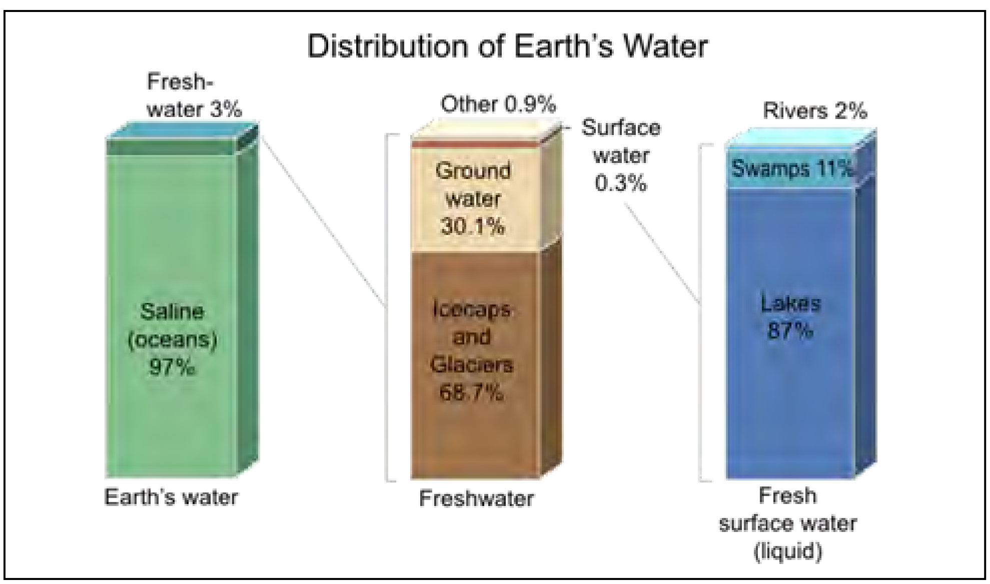


Figure 3-63. Distribution of the Earth's water resources

In Figure 3-62 of a globe sans seas, the larger sphere, 860 miles in diameter, includes all of the water on Earth: in the world's oceans, ice caps, lakes, rivers, aquifers (groundwater), atmospheric water, and even every living organism. This volume of water would cover the contiguous United States to a depth of 107 miles. The smaller sphere hovering above Kentucky represents the world's entire volume of freshwater, and it has a diameter of 170 miles.

The tiny, barely visible bubble or dot in Figure 3-62 poised above Atlanta, Georgia stands for all of the world's freshwater in all the lakes and rivers on the planet; most of the water people and other living things use on a daily basis comes from these surface-water sources. The volume of this sphere is about 22,339 mi^3 and it is about 35 miles in diameter (USGS 2014a).

Thirty percent of the Earth's freshwater is groundwater, while only 0.3 percent – a mere one-third of one percent, is surface water in rivers and streams, swamps, and lakes. Nearly 90 percent of the world's surface fresh water is in lakes, while only two percent is in rivers at any given time.

Table 3-8 shows how all water on Earth is distributed among various stocks or sources.

Table 3-8. Distribution of the Earth's water among various stocks

Water source	Water volume in cubic miles	Percent of fresh water	Percent of total water
Oceans, seas, and bays	321,000,000	--	96.54
Ice caps, glaciers, and permanent snow	5,773,000	68.7	1.74
Groundwater	5,614,000	--	1.69
Fresh	2,526,000	30.1	0.76
Saline	3,088,000	--	0.93
Soil moisture	3,959	0.05	0.001
Ground ice and permafrost	71,970	0.86	0.022
Lakes	42,320	--	0.013
Fresh	21,830	0.26	0.007
Saline	20,490	--	0.006
Atmosphere	3,095	0.04	0.001
Swamp water	2,752	0.03	0.0008
Rivers	509	0.006	0.0002
Biological water (within organisms)	269	0.003	0.0001

Source: Shiklomanov (1993)

About 3,100 cubic miles of water, mostly in the form of water vapor, is dispersed in the atmosphere at any one time. If it all fell as rain at once, the Earth would be covered with only about one inch of water. The 48 contiguous United States receive a total volume of about four cubic miles of precipitation each day. Each day, globally, 280 cubic miles of water evaporate or transpire into the atmosphere (USGS 2014a).

Worldwide, crop irrigation alone claims 70 percent of all water withdrawn from all sources, and of this, two-thirds is used up by the vegetation itself in what water managers call "consumptive water use" (Pimentel et al. 2010, Pimentel and Wilson 2004, Postel 1997), that is, it is non-recoverable and does not flow back into the water source it came from, unlike the return flows from cooling thermal power plants or the water that passes through penstocks and turbines to generate electrical power at hydroelectric facilities. A corn crop that yields about four tons/acre/year uses about 750,000 gallons of water per acre during the growing season (Pimentel and Pimentel 2008).

The worldwide distribution of water resources is extremely uneven. While the global hydrologic cycle provides enough freshwater in aggregate to meet minimum human requirements, the great bulk of this total water in circulation is concentrated in particular regions, leaving other regions with water shortages or deficits (Pimentel et al. 2010) . By 1993, water demands already exceeded supply in nearly 80 nations worldwide (Gleick 1993). Figure 3-64 shows the distribution of water scarcity around the globe according to the United Nations (U.N).

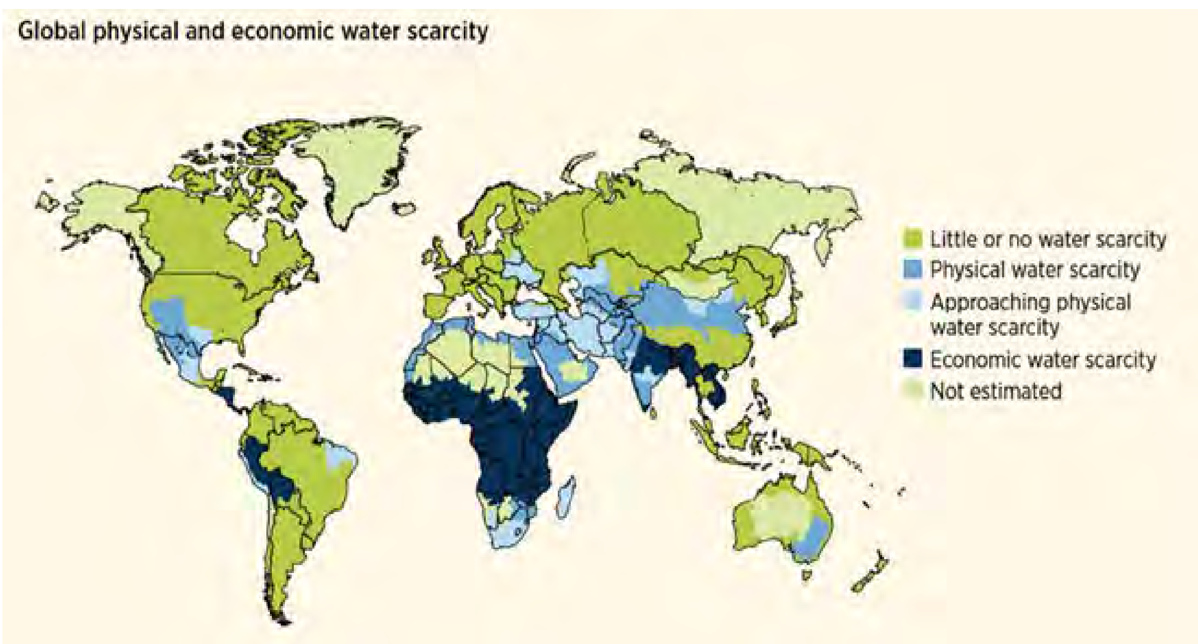


Figure 3-64. Distribution of water scarcity globally
Source: United Nations

The U.N. defines water scarcity as the point at which the combined impact of all water users "impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully." By 2025, the U.N. predicts that there will be 1.8 billion people in countries or regions with absolute water scarcity, and two-thirds of the world's

population could be living under water stressed conditions. By 2030, water scarcity in some arid and semi-arid regions could cause the displacement of between 24 million and 700 million people (U.N. 2014).

More than 300 cities in China suffer from inadequate water supplies (Berk and Rothenberg 2003), and the problem is worsening as population increase continues (albeit at a diminishing rate because of China's draconian one-child policy), aquifers are overdrawn, water is highly polluted, industrial and municipal demand for water intensifies, and climate change reduces snowmelt from the Himalayas.

In the world's arid regions, such as the Middle East and most of northern Africa, annual rainfall is low and irrigation is costly. Here, the prognosis for future water-dependent agricultural production is dismal and becoming ever more so as populations continue to grow unchecked (Pimentel et al., 2010).

In some water-stressed areas, tensions over access to water strain international relations. This has happened between India and Bangladesh over the Ganges River. It has occurred in the Middle East with Israel, Syria, Turkey, Jordan, and Iraq over the Tigris, Euphrates, and Jordan Rivers. There have been tensions between the U.S. and Mexico over diminished flow and impaired water quality in the Rio Grande and Colorado River. In 2013, before he was deposed by the Egyptian military, then President Mohammed Morsi told an Islamist audience that Egyptians must "stand united" in the face of potential threats to their water resources. These comments were in response to the potential for reduced flows in the Nile River and Egypt's water supply from the Grand Ethiopian Renaissance Dam project now under construction upstream in Ethiopia (Figure 3-65). This dam will divert the Blue Nile and almost certainly decrease Egypt's historic share of Nile water, impacting not only the amount of water available for irrigation but also hydroelectric generation at the Aswan High Dam.

Diversions from the Jordan River have led to a "dying" Dead Sea in Israel, into which the Jordan feeds, at the lowest spot on Earth, 1,400 ft. below sea level. The Aral Sea (Figure 3-66) in Central Asia was once the fourth-largest lake in the world, situated between the former Soviet republics of Kazakhstan and Uzbekistan, now independent states. Before the Soviets began diverting its tributary rivers into cotton irrigation projects, the Aral Sea had an area of 26,300 square miles (between Lake Michigan and Lake Superior in size) and supported a prosperous commercial fishery (Figure 3-67). By 2007, it had shrunk to 10 percent of its former area and split into four lakelets, one of which has since disappeared. The fate of the Aral Sea has been called one of the planet's worst environmental disasters. Residents of the region have been plunged into poverty and face

respiratory health problems from dust particles (particulate matter) kicked up off the dry lakebed by the wind. The dust is contaminated with pesticide residues and salt.

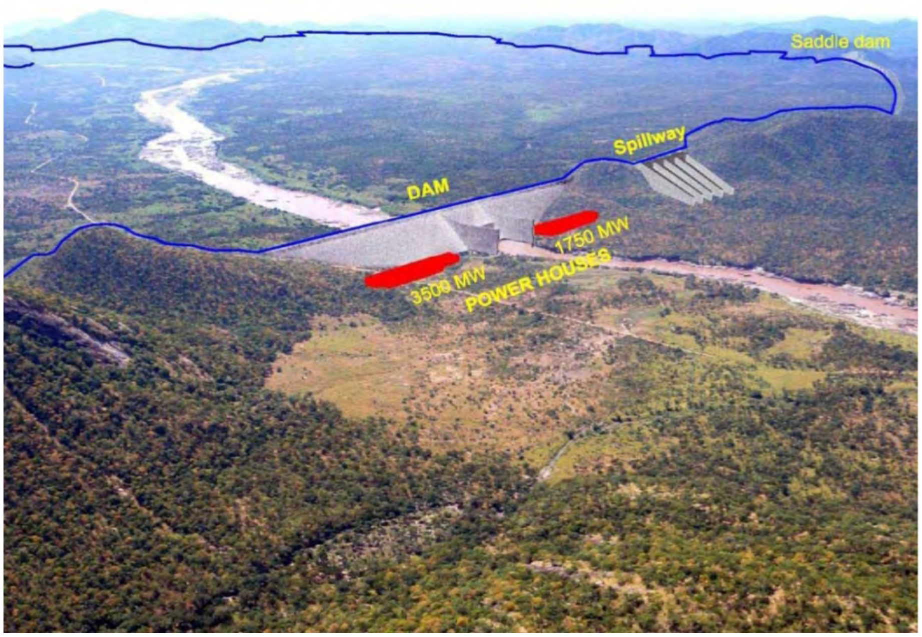


Figure 3-65. Grand Ethiopian Renaissance Dam project under construction on the Blue Nile River in Ethiopia

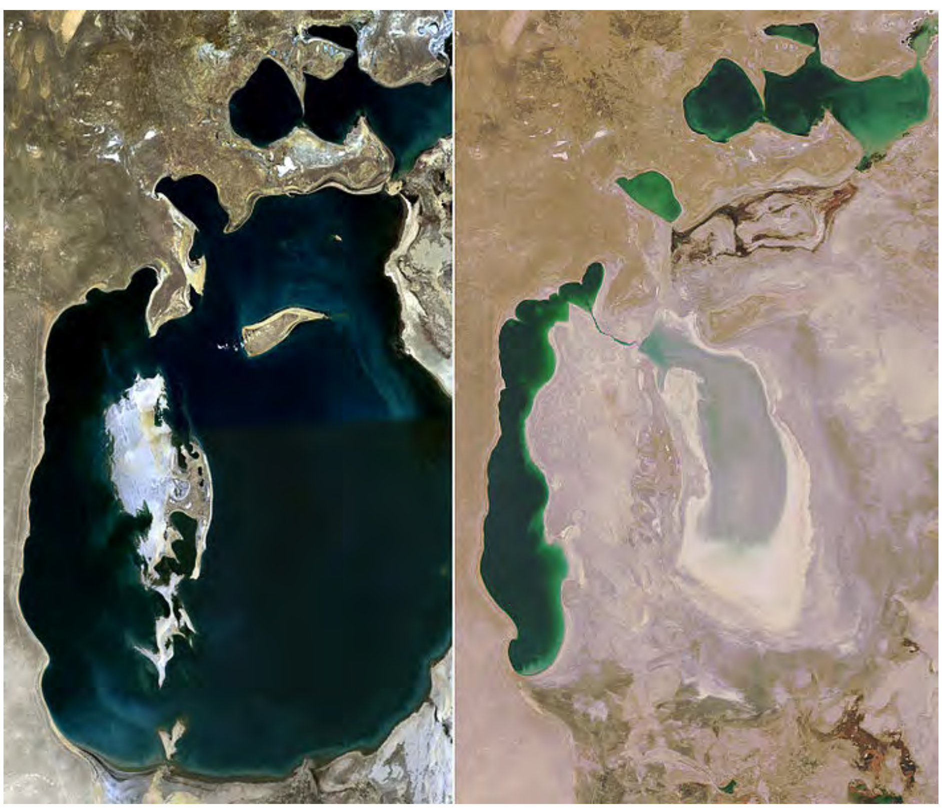


Figure 3-66. Aral Sea in 1989 (left) and 2008 (right)

Figure 3-67. Former fishing vessels on the dried up Aral Sea, now providing shade for livestock

Not only surface water is threatened from overuse and mismanagement related to human overshoot of the Earth's carrying capacity. Groundwater and aquifers are also in trouble and many critical ones are being pumped unsustainably or "mined." That is, the rate of recharge from precipitation is much lower than the rate of use, so the water table drops. It has been estimated that several hundred million of India's 1.3 billion inhabitants are being fed grains irrigated by aquifers that will be depleted in the coming decades. China, the world's largest grain producer, is in a similar situation (Brown 2003).

More groundwater is pumped or extracted from the ground than any other raw material in the world, an estimated 236 cubic miles every year, about 60 percent of which is used for agricultural irrigation (NGA 2013). Agricultural expert Lester Brown, founder of the Worldwatch Institute and the Earth Policy Institute, notes:

> Tapping underground water resources helped expand world food production, but as the demand for grain continued climbing, so too did the amount of water pumped. Eventually the extraction of water began to exceed the recharge of aquifers from precipitation, and water tables began to fall. And then wells begin to go dry. In effect, overpumping creates a water-based food bubble, one that will burst when the aquifer is depleted and the rate of pumping is necessarily reduced to the rate of recharge.

> Today some 18 countries, containing half the world's people, are overpumping their aquifers. Among these are the big three grain producers – China, India and the US – and several other populous countries, including Iran, Pakistan and Mexico.
>
> During the last couple of decades, several of these countries have overpumped to the point that aquifers are being depleted and wells are going dry. They have passed not only peak water, but also peak grain production. Among the countries whose use of water has peaked and begun to decline are Saudi Arabia, Syria, Iraq and Yemen. In these countries peak grain has followed peak water (Brown 2013).

Worldwide, crucial groundwater supplies are also threatened not just with overpumping but also with contamination by toxic pollutants. Because groundwater is relatively inaccessible and percolates so slowly, contamination of aquifers is almost irreversible, or at least is very persistent (Lee 2013).

3.4.1.2 Water Use in the United States

Except for the American Southwest, the United States is comparatively well endowed with water resources and uses prodigious quantities of both surface water (withdrawn from man-built reservoirs, natural lakes and rivers) and groundwater (pumped from subterranean aquifers) to supply agriculture, industry, and municipalities.

In 2005, about 410,000 million gallons of water every day (Figure 3-68) – more than a thousand gallons per person – was withdrawn for use in the United States – over four million swimming pools' worth or about 5,000 Rose Bowls filled to the rim. About 80 percent of our water supply is from surface water and the remaining 20 percent from groundwater (Barber 2009; USGS 2014a).

We use water to irrigate our crops, manufacture all manner of products ranging from steel to silicon chips to soft drinks, to water our lawns, fill our cooking pots, wash away our wastes, and even to cool our thermal (nuclear and coal) power plants. About 80 percent of water used in the U.S. is for agriculture (Pimentel et al. 2004), which is very water-intensive because crops (like all healthy plants) need it for photosynthesis and transpiration. All plants demand huge amounts of water during the growing season; much of this water is transpired, that is, evaporated back to the atmosphere through pores in leaves called stomata.

Since 1950, the U.S. Geological Survey (USGS) has estimated water use in the United States in total and state-by-state every five years. Estimates are provided both for groundwater and surface-water sources, for fresh and saline water quality, as well as by sector or category of use (USGS 2014b).

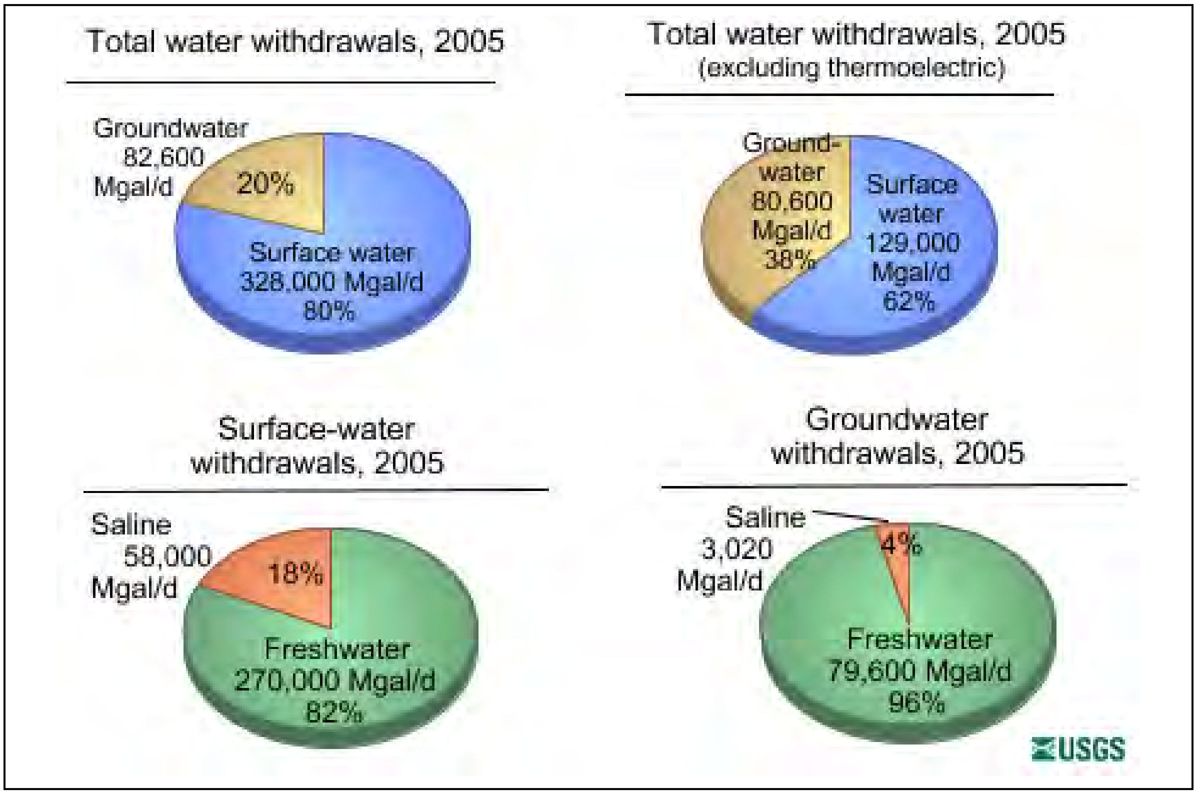


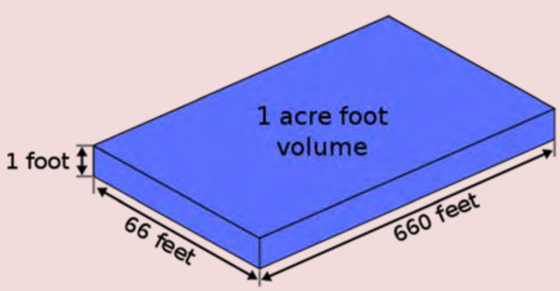
Figure 3-68. Daily water use in the United States in 2005

What is an Acre-Foot?

An acre-foot is a unit of volume commonly used in the United States when measuring or referring to large quantities of water such as the capacity of reservoirs, the annual flow of rivers or the annual consumption of cities.

One acre-foot equals 325,851 gallons. It is defined as the volume of water needed to cover one acre (43,560 square feet, or an area 660 ft. long and 66 ft. wide) to a depth of one foot.

A rough rule of thumb in water management is that a typical suburban American household or family of four annually consumes about one acre-foot of water for domestic purposes, including exterior landscape irrigation.



The USGS estimated total freshwater and saline-water withdrawals for 2010 at 355,000 million gallons per day (Mgal/d), or 397,000 thousand acre-feet per year (acre-ft/yr). This was 13 percent less than in 2005. Freshwater withdrawals comprised 86 percent of the total, while saline-water withdrawals made up the remaining 14 percent. Most saline-water withdrawals were of seawater and brackish coastal water for use in thermoelectric (coal and nuclear) power plants (Maupin et al. 2014; USGS 2014b).

Figure 3-69 is a map of the United States showing total 2010 water use in each state. Notably, the two states with the largest withdrawals are California and Texas, the two most populous states in the country. Figure 3-70 shows 2010 water withdrawals by sector or type of use. The three largest categories were thermoelectric power, irrigation, and public supply, cumulatively accounting for 90 percent of the national total (USGS 2014b).

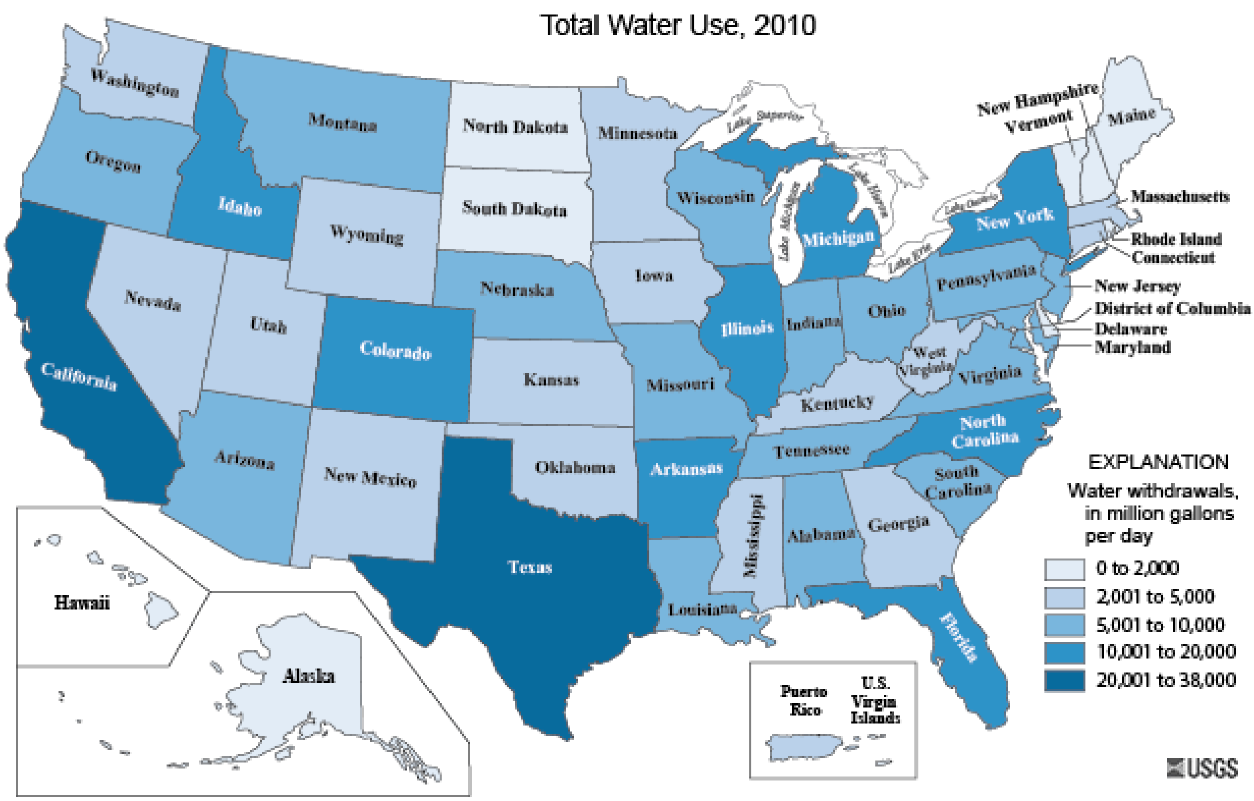


Figure 3-69. Total water use in the United States, 2010, state by state
Source: USGS, 2014b

Withdrawals for thermoelectric power and irrigation remained the two largest uses of water in 2010, and totals for both were less than in 2005: 20 percent less for thermoelectric power and nine percent less for irrigation. Similarly, other uses showed reductions compared to 2005, specifically public supply (–5%), self-supplied domestic (–3%), self-supplied industrial (–12%), and livestock (–7%). Only mining (39%) and aquaculture (7%) reported larger withdrawals in 2010 compared to 2005 (Maupin et al. 2014).

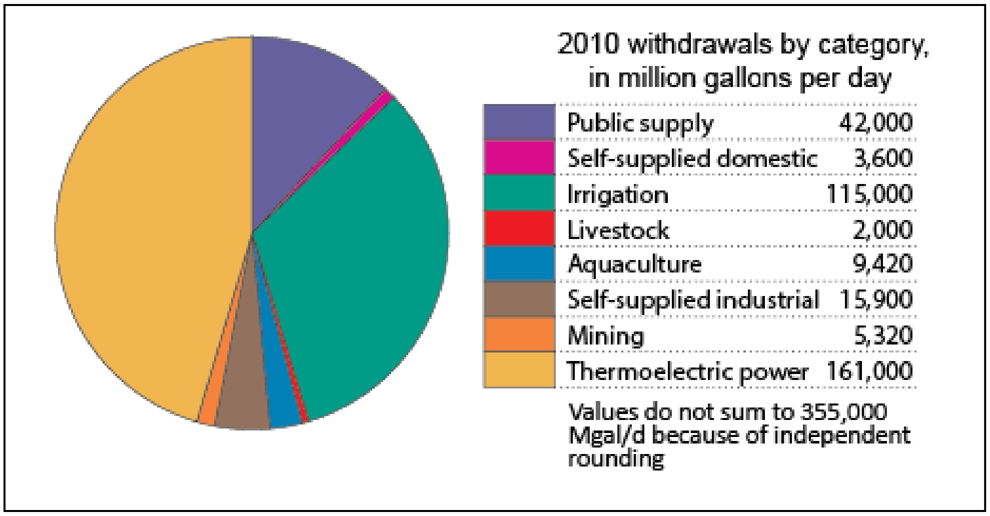


Figure 3-70. Withdrawals by water use category or sector in 2010 (million gallons per day)

Aggregate water use (withdrawals) in the U.S. actually decreased 13 percent from 2005 to 2010. During this same period, the U.S. population also increased by about 10 million inhabitants or three percent. This demonstrates that the relationship between population size and growth and aggregate water consumption is not a simple one. Every added increment of population does not necessarily guarantee an added increment of water consumption. 1 unit of population + 1 unit of population ≠ 2 units of water use.

In all likelihood, the decrease in aggregate water withdrawals between 2005 and 2010 was due mostly to the economic slowdown associated with the Great Recession of 2008.

Economic structure and level of activity, water conservation, reuse and efficiency measures all have a bearing as well as population size in determining total water consumption. To a point, for a period of time, under special conditions, and with strong public commitment and political support, total water use can be reduced – or at least held constant – even with a growing U.S. population, as it has been in recent years. However, the crucial point is that under these special circumstances, if the U.S. population were stable (non-growing), aggregate water use could be cut even more, were the same commitments made to water conservation, reuse and efficiency, allowing still more water to remain where nature intended it – in streams, rivers, and lakes.

In these natural settings, water performs valuable ecosystem services and functions. These functions not only include supporting aquatic biota (vertebrates and invertebrates, plants and animals), fisheries and wildlife (such as waterfowl and other water-dependent animals), but also commercial navigation, hydroelectric generation, recreation (e.g., boating, fishing, swimming), and even sight-seeing and tourism.

A prominent example of the latter is Niagara Falls (Figure 3-71). The Niagara River drains all of the Great Lakes (Superior, Michigan, Huron, and Erie), except for Lake Ontario, into which it flows. The water that courses down the Niagara River and over its mighty waterfall is part of the huge St. Lawrence River Basin or watershed, one of the largest in North America. Since 1961, up to 375,000 gallons of water every second have been diverted from the Niagara River upstream of the falls into gigantic conduits or penstocks (NYPA no date). The water flows downward by gravity and spins turbines and generators that convert its mechanical energy into clean, low-cost, renewable electric energy (hydroelectric power) (Figure 3-72).

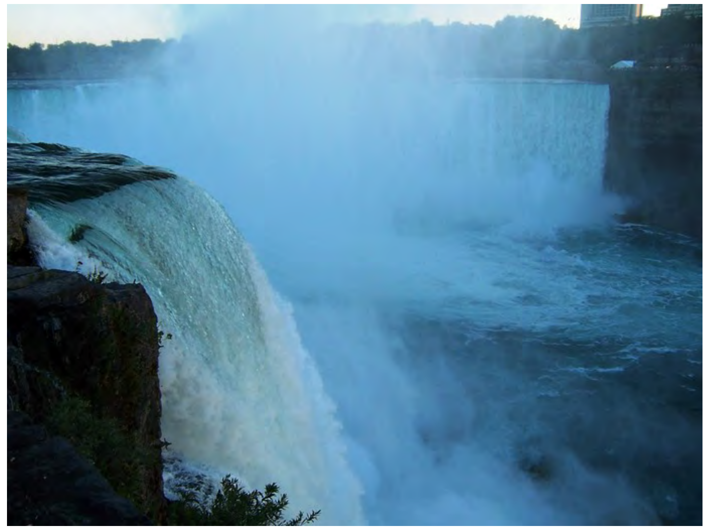


Figure 3-71. Niagara Falls from the New York side

Figure 3-72. Hydroelectric plant on the Niagara River

The Niagara generating station is the largest electricity producer in the entire State of New York, with a capacity of 2,400 megawatts – enough power to light 24 million 100-watt incandescent light bulbs simultaneously – or 96 million 25-watt compact fluorescent light bulbs. If hydro developers had received permission to divert the entire Niagara River into the hydroelectric plant, there would be none left to flow over the escarpment that constitutes Niagara Falls, and a spectacular wonder of nature and crucial tourism resource would be wiped out. What would be evident instead is a dry cliff or escarpment 167 feet high, surely not nearly as impressive as one of the world's great waterfalls, pounding and pouring as it has done for thousands of years.

Fortunately, Americans and Canadians were wiser than this (the U.S.-Canadian border cuts Niagara Falls roughly in half). To balance the potential for power generation with the imperative of preserving the beauty of Niagara Falls, the U.S. and Canadian governments signed a treaty in 1950 that limits the amount of water that can be diverted for hydroelectricity production. On average, more than 200,000 cubic feet per second (cfs), or 1.5 million gallons of water a second, pours from Lake Erie into the Niagara River. The 1950 treaty requires that at least half that amount of water – 100,000 cfs – spill over the Falls during the daylight hours in the tourist season, April through October (Figure 3-73). This flow may be cut in half (to 50,000 cfs) at night during the April-October tourism period and during the rest of the year with low tourist visitation (NYPA no date).

Figure 3-73. Tourists on the New York side of Niagara Falls

Figure 3-74 presents a series of bar graphs of USGS data on water withdrawals for the three largest water use sectors – public use (municipal), irrigation, and thermoelectric power – of the 50 states (plus Puerto Rico and the U.S. Virgin Islands) ordered geographically from west to east. The magnitude of the withdrawals cannot be compared in this graphic, since the scales of the graphs are not the same, but the different geographic distributions of categories of water use can be compared (USGS 2014b).

Irrigation withdrawals are predominantly in Western states on the left side of the graphs. Use of water in thermoelectric power – as a coolant – is larger in the Midwest and Eastern States.

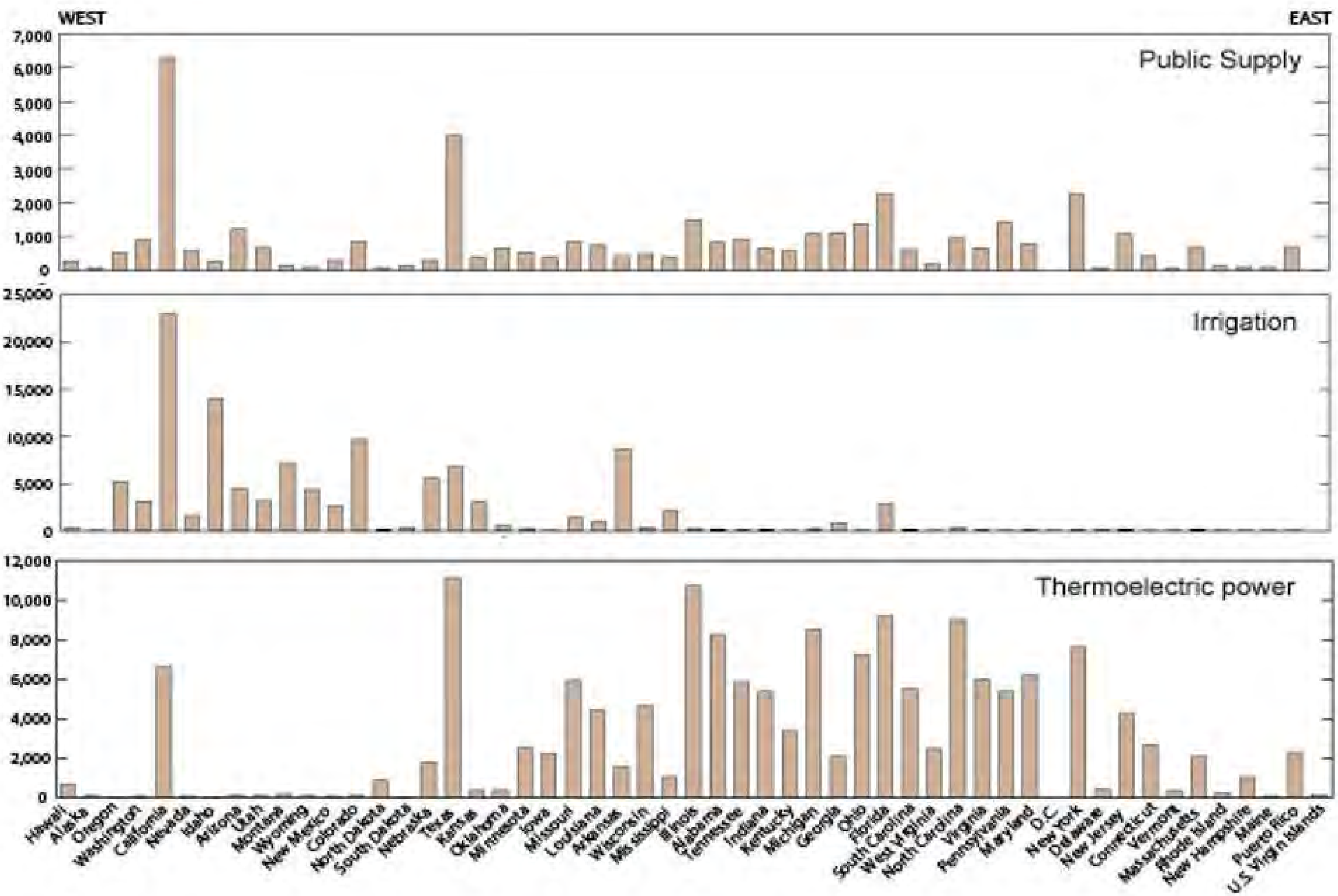


Figure 3-74. Water withdrawals in 2010 by state (west to east) for three largest water use sectors – irrigation, public use (municipal), and thermoelectric power (*Source*: Adapted from USGS 2014b)

Higher withdrawals for California (fifth bar from the left), our most populous state, are apparent on the public supply, irrigation, and thermoelectric power graphs. Tall bars are also evident for Texas, our second most populous state. It has large withdrawals in a number of categories, some of which are not shown in Figure 3-74, but are in the original USGS graphic at USGS (2014b) upon which it is based. Texas has large withdrawals for the public supply, self-supplied domestic, livestock, self-supplied industrial, mining, and thermoelectric power sectors.

Withdrawals for public supply, or municipal water uses, are closely correlated with a state's population size. Hence, the four tallest bars in the "Public Use" graph of Figure 3-74 are those for California, Texas, New York, and Florida, our four most populous states. In contrast, irrigation is a function less of a state's population size than of how arid the climate of the state is, whether its soils are suitable for large-scale irrigated agriculture and whether irrigation water is actually available, and ultimately, how large its agricultural sector is. In addition, a sizeable share of agricultural output from any given state is exported to other states or even overseas.

Thus, Idaho, with a population of only 1.6 million in 2010, less than 1/20th of California's 37.3 million, still used more than half the water California did in 2010 to irrigate crops. Idaho has a very extensive network of dams, reservoirs, canals and drainage ditches, which allow water to be used a number of times in many different ways. It has 3.2 million acres of irrigated land, on which it cultivates dozens of crops, including 70 percent of the hybrid temperate sweet corn seed produced in the world and more potatoes than any other state – 30 percent of the U.S. total (Agclassroom.org. 2013).

Figure 3-75. Center pivot irrigation system irrigates potato crop in Idaho

Thermoelectric Power

Generation of electricity is one of the largest uses of water in the United States and worldwide (USGS 2014c). Water for thermoelectric power is used to generate electricity with steam-driven turbine generators. In 2010, about 161,000 Mgal/d were used nationwide to produce electricity (excluding hydroelectric power). Surface water was the source of more than 99 percent of total thermoelectric-power withdrawals. In coastal areas, the use of saline water instead of freshwater expands the overall available water supply. Thermoelectric-power withdrawals accounted for almost half of total water use in the U.S., 41 percent of total freshwater withdrawals for all categories, and 53 percent of fresh surface-water withdrawals (USGS 2014c).

One of the main uses of water in the power industry is to cool the power-producing equipment. Water used for this purpose does cool the equipment, but at the same time, as dictated by the laws of thermodynamics and physics, the hot equipment transfers heat to the cooling water. Excessively hot water cannot be released back immediately into the aquatic environment, because of the harm it would cause, so the water coolant itself must first be cooled. The most common way of doing this is to build and operate very large cooling towers (Figure 3-76) and to spray the water inside the towers. Evaporation then occurs and in the process, water left behind in a liquid state is itself cooled. The essential need for water is why large generating stations are often located near rivers, lakes, and the ocean (USGS 2014c).

Figure 3-76. Evaporation from the large cooling towers at the Beaver Valley nuclear power plant next to the Ohio River, near Shippingport, Pennsylvania

Thermoelectric power has been the water use sector accounting for the largest withdrawals since 1965, and for 2005 comprised 49 percent of total withdrawals. The largest total and fresh and saline surface-water withdrawals were during 1980.

Withdrawals by thermoelectric-power plants increased from 40,000 Mgal/d during 1950 to 210,000 Mgal/d during 1980 (Figure 3-77). Withdrawals for thermoelectric power decreased and then have stabilized since 1980, despite the fact that total U.S. population has continued to increase; the total withdrawal of 201,000 Mgal/d for 2005 is slightly above that of 2000. In 2010, however, as noted above, thermoelectric-power withdrawals fell again, by 20 percent, to 161,000 Mgal/d.

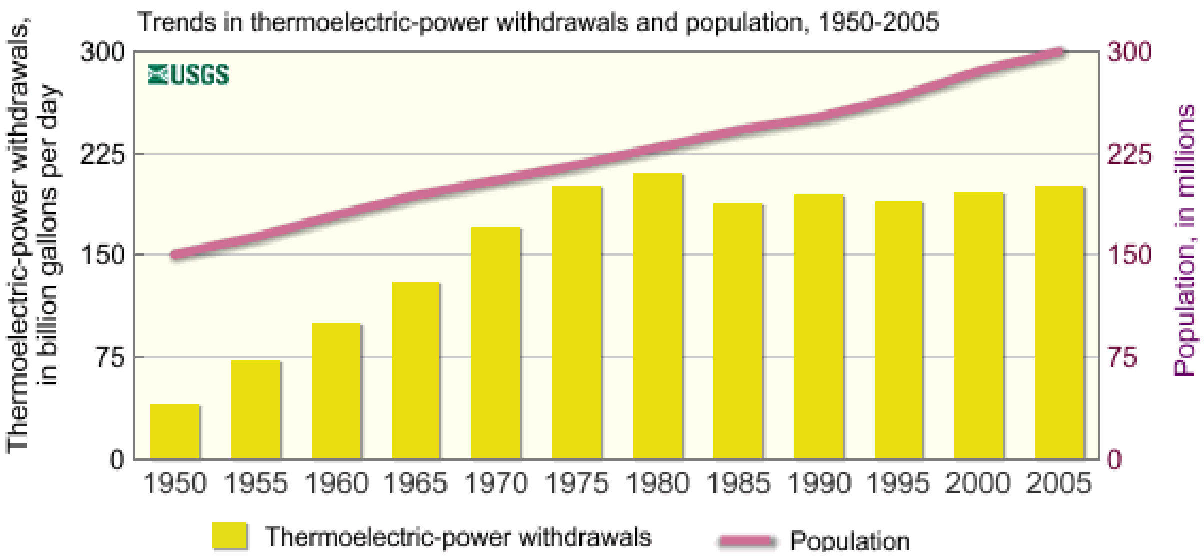


Figure 3-77. Trend in U.S. thermoelectric-power withdrawals from 1950 to 2010
Source: USGS (2014b)

What accounts for thermoelectric-power withdrawals having become "decoupled" from U.S. population growth in the last three decades? It is not that thermoelectric power production has not increased, for it has. Rather, technological and cultural innovation has occurred. Since the 1970s, an increasing number of generating stations were built with or converted to recirculating cooling systems or dry cooling systems, which use less cooling water than power plants with once-through cooling systems. Also, withdrawals at power plants have decreased in some states because of the implementation of new rules designed to minimize adverse effects to aquatic life at power plant intakes. A decline in the use of coal and a corresponding increase in use of natural gas (as a result of a sharp drop in natural gas prices from new supplies made available by hydro-fracking of shale gas), as well as new power plants coming online that use more water-efficient cooling technology also have helped to lessen withdrawals for thermoelectric power (Maupin et al. 2014).

Irrigation

Irrigation water is essential for keeping fruits, vegetables, and grains growing to feed the world's population. This has been true for thousands of years. The USGS estimates that almost 60 percent of all the world's freshwater withdrawals go towards irrigation uses. Irrigation represents an even larger share – 70 percent – of the world's "consumptive water use," that is, those uses that withdraw water from reservoirs, lakes, rivers or aquifers but do not return it in some fashion to these water bodies. That is because the water is incorporated into the crops themselves or is transpired back to the atmosphere as the crops photosynthesize and grow. Large-scale farming could not provide food for the world's large and growing population without the irrigation of crop fields by water taken from rivers, lakes, reservoirs, and wells. Without irrigation on a vast scale, high-value crops could never be grown in the deserts of California or Arizona or even the Western plains (USGS 2014d).

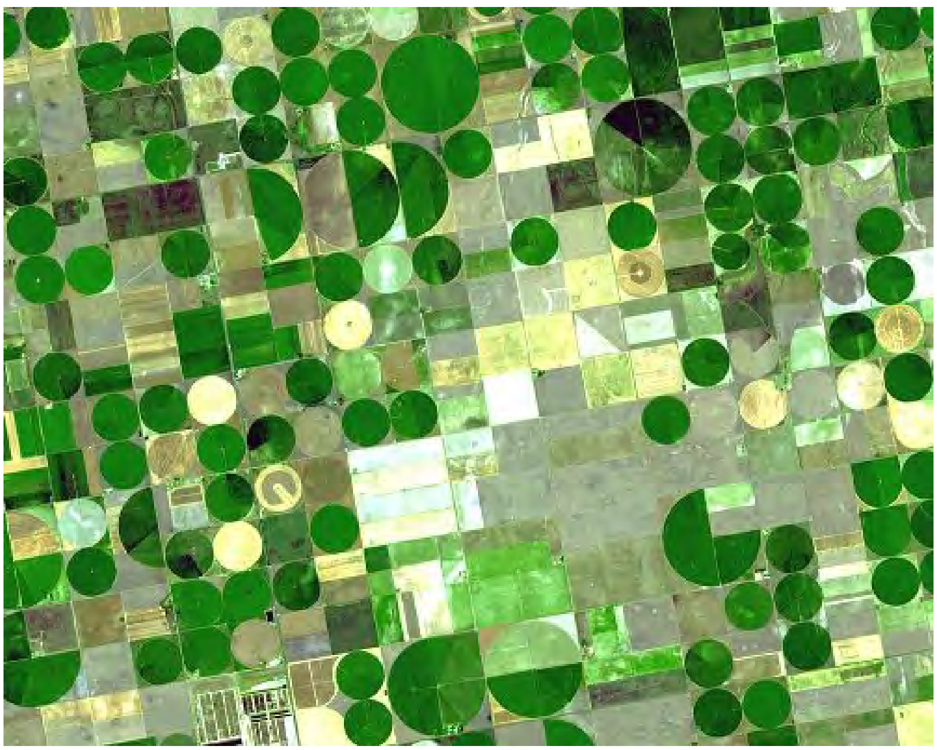


Figure 3-78. Irrigated crop circles in Finney County, Kansas

Sources: NASA, USGS

Note: Many passengers in cross-country flights may have noticed circles like these plastered across the landscape far below. They are center-pivot irrigation crop circles. In center-pivot irrigation systems, water is pumped from a well in the center of the circle from an underground aquifer and distributed through a giant, long sprinkler that pivots around a central point. In the past, large spray guns were used to spray water through the air onto the crops, but now more efficient low-pressure sprinklers hang from the pipes to aim water closer to the ground, a much more efficient method that saves water. This NASA satellite photo shows large crop circles that are between 0.5 mile and one mile in diameter. This particular area utilizes irrigation water from the Ogallala aquifer, which underlies an area stretching from Wyoming in the north to Texas in the south (USGS 2014d). The Ogallala is a fossil aquifer, one contains ancient water that is not being recharged; thus it is being "mined" and it is a non-renewable resource.

In general, when people use water at home, or when an industry uses water, about 90 percent of it used is eventually returned to the environment ("return flows") where it replenishes water sources. That is, water returns to a stream or lake, or it infiltrates down into the ground and returns to groundwater, and it can be used for other purposes, although it often requires treatment or cleaning first at a water treatment plant. However, of the water used for irrigation, only about one-half is reusable. The rest is lost by evaporation into the air, evapotranspiration from plants, or is lost in transit, by a leaky pipe, for example (USGS 2014d).

Irrigation withdrawals constitute about 37 percent of total freshwater withdrawals and 62 percent of total freshwater withdrawals for all categories, if thermoelectric power withdrawals are excluded. Surface water accounted for 58 percent of the total irrigation withdrawals. Sixty-seven percent of all groundwater withdrawals went to irrigation (Figure 3-79). Approximately 61.1 million acres were irrigated in the U.S. in 2005. About 26.6 million acres were irrigated with surface (flood) systems, 4.05 million acres with microirrigation systems, and 30.5 million acres with sprinkler systems. The national annual average application rate was 2.35 acre-feet per acre (USGS 2014d).

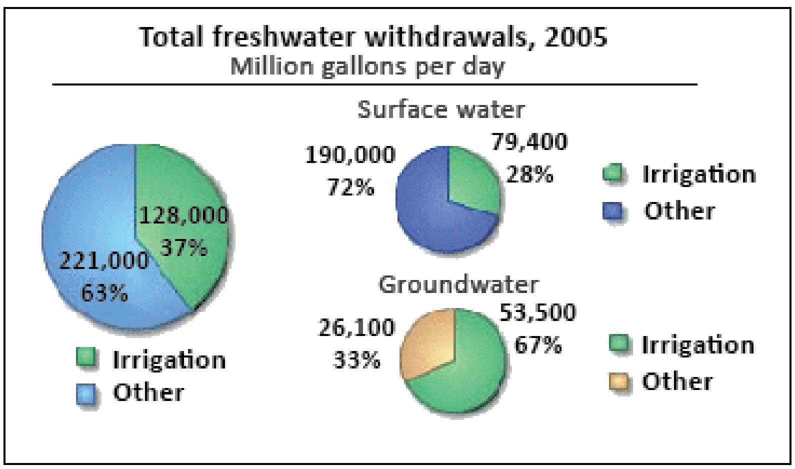
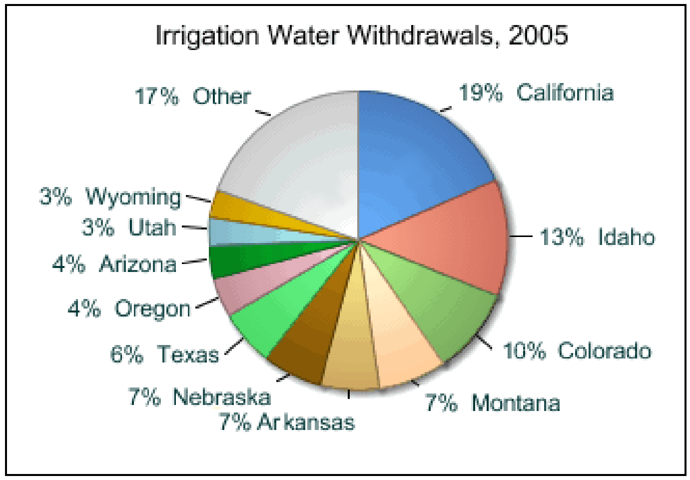


Figure 3-79. Total freshwater withdrawals for irrigation in 2005

The majority of irrigation withdrawals (85 percent) and irrigated acreage (74 percent) were in the 17 conterminous Western states. These are situated in areas west of the 100th Meridian, where average precipitation is typically less than 20 inches annually and is inadequate to sustain cultivated crops without supplemental water. Surface water was the primary source of irrigation water in the arid West and Rocky Mountain States. California, Idaho, Colorado, and Montana combined accounted for 49 percent of the total irrigation withdrawals and 64 percent of surface-water irrigation withdrawals (Figure 3-80). Nearly 90 percent of the groundwater used for irrigation was withdrawn in 13 states, and each of these states withdrew more than 1,000 Mgal/d (1,120 thousand acre-feet per year) of groundwater for irrigation in 2005. Among these 13 states, groundwater was the

primary source for irrigation in Nebraska, Arkansas, Texas, Kansas, Mississippi, and Missouri (USGS 2014d).

Figure 3-80. Irrigation water withdrawals in 2005, by state



Just five states – California, Nebraska, Texas, Arkansas, and Idaho – accounted for more than half (52 percent) of total irrigated acreage. Nebraska, Texas, and California represented 41 percent of the irrigated acreage using sprinkler and microirrigation systems. California alone comprised 65 percent of the irrigated acreage with micro-irrigation systems. Sprinkler and microirrigation systems combined were associated with more than 56 percent of total irrigated acreage.

Since 1950, irrigation has represented about 65 percent of aggregate withdrawals, excluding those for thermoelectric power. From 1950 to 1980, irrigation withdrawals increased by more than 68 percent (from 89,000 to 150,000 Mgal/d). Withdrawals have decreased since 1980 and have stabilized at between 134,000 and 137,000 Mgal/d between 1985 and 2000 (Figure 3-81). They were 128,000 in 2005 and 115,000 in 2010. Depending on the geographic area of the United States, this overall decrease, in spite of an increasing U.S. population, can be attributed to climate, crop type, advances in irrigation efficiency, and higher energy costs (USGS 2014d).

Surface water historically has been the primary source for irrigation, although data show an increasing usage of groundwater since 1950. During 1950, 77 percent of all irrigation withdrawals were surface water, most of which was used in the western states. By 2005, surface-water withdrawals comprised only 59 percent of the total. Groundwater withdrawals for irrigation during 2005 were more than three times larger than during 1950. Most of this increase occurred from 1965 through 1980.

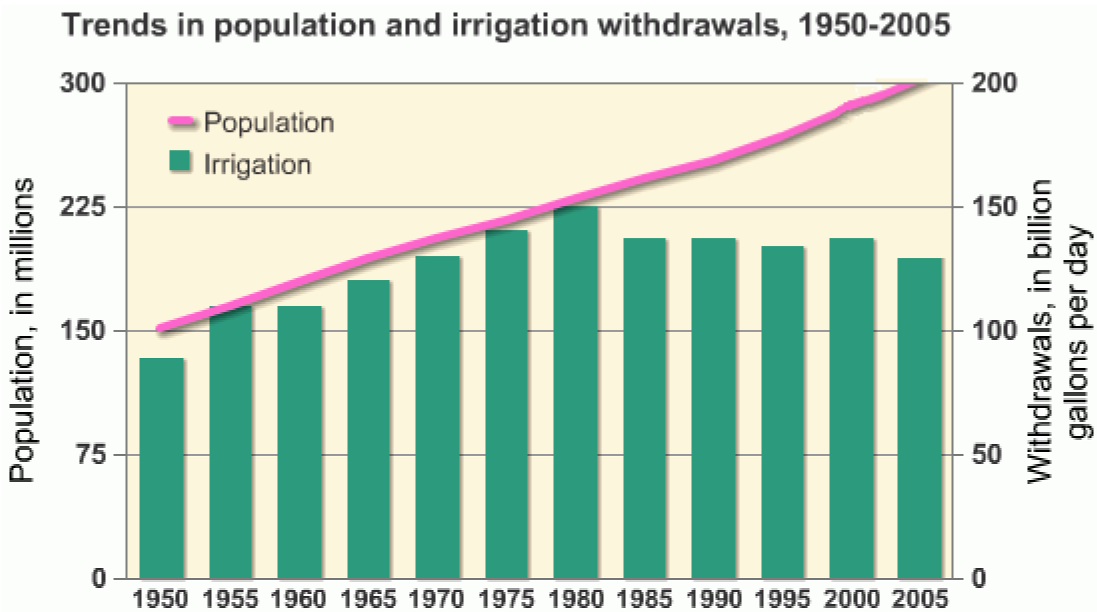


Figure 3-81. U.S. population and irrigation withdrawal trends from 1950 to 2005
Source: USGS 2014d

Public Supply (Municipal)

Public water-supply systems, also called county and city water departments, or municipal water districts, are vitally important to all urban, suburban and small town residents. These are government, quasi-government, or privately-run agencies with facilities that withdraw water from rivers, lakes, reservoirs, and wells and then treat and deliver it to America's homes, businesses, schools, and governments. At present, the lion's share of the U.S. population (about 86 percent) of the United States obtains its water from public-supply systems (USGS 2014e). In the past, when the American population was largely rural, most families used to have to dig their own wells and create storage tanks for their private, domestic water supply; water quality from those wells was not generally monitored or even known, and was sometimes substandard. Now the public water supply systems have taken over this role.

Figure 3-82. Lake Lanier, north of Atlanta, Georgia

Note: Lake Lanier was created by the impoundment of water behind Buford Dam on the Chattahoochee River in 1956; it is also supplied by the waters of the Chestatee River. It is the main water supply for millions of people downstream.

Figure 3-83. Portion of a municipal water treatment plant in Texas

An estimated 258 million people relied on public water supplies for their household use. States with the largest populations (California, Texas, New York, and Florida) withdrew the largest amounts of water for public supply. Two-thirds of water withdrawn for public supply in 2010 was from surface sources, such as lakes and streams; the other third was from groundwater. A total of 38 states (including the District of Columbia, which obtains its water from Maryland,) relied on surface water for more than half their public supplies. Only 15 states obtained more than half their public water supplies from groundwater. California, Texas, New York, Illinois, and Pennsylvania each withdrew more than 1,000 Mgal/d of surface water for public supply in 2005, and 45 percent of the total surface-water withdrawals for public supply occurred in these five populous states. Three states – Florida, California, and Texas – each withdrew more than 1,000 Mgal/d of groundwater for public supply in 2005 and together accounted for 32 percent of total groundwater withdrawals for this sector (USGS 2014e).

If only fresh water is considered, public supply represented about 13 percent of total withdrawals (Figure 3-84). Excluding thermoelectric-power supply, it comprised approximately 21 percent of all freshwater withdrawals.

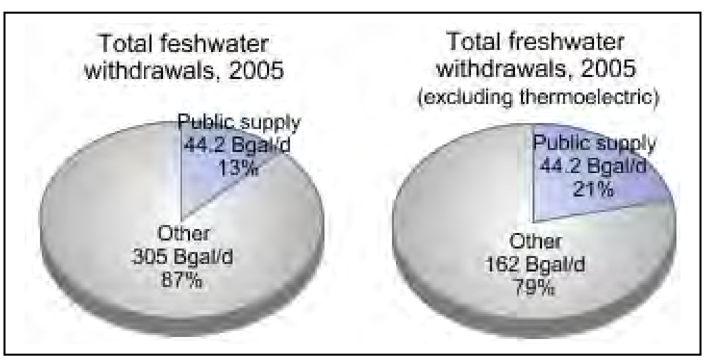


Figure 3-84. Public use withdrawals in 2005 as a percentage of total freshwater withdrawals

Estimated water withdrawals for public supply have increased continually since 1950 along with the population served by public suppliers of water (Figure 3-85). Public-supply withdrawals more than tripled during this half-century period; they also increased by about two percent from 2000 to 2005. The percentage of the U.S. population served by public water suppliers increased from 62 percent for 1950 to 86 percent for 2005. Public-supply withdrawals represented about eight percent of total withdrawals for 1950 and about 11 percent for 2005. The percentage of groundwater use for public supply increased from 26 percent for 1950 to 40 percent for 1985 and was about 33 percent in 2005 (USGS 2014e).

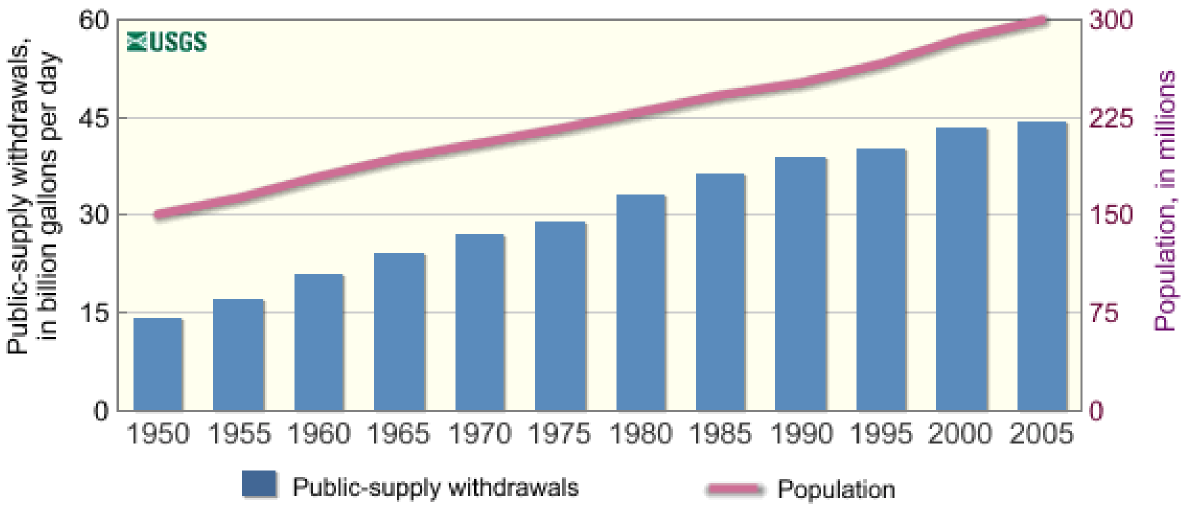
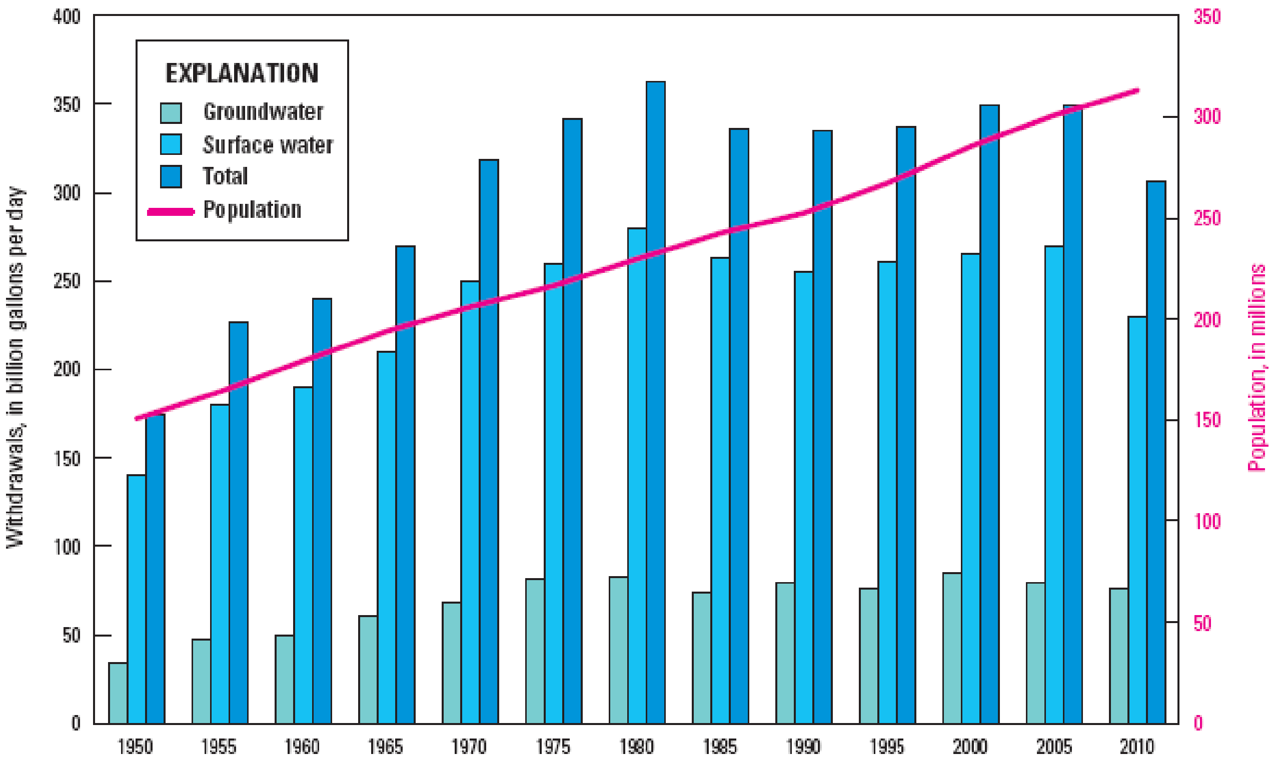


Figure 3-85. Growth of population and public-supply water withdrawals, 1950-2005

There has been a long-term trend, especially pronounced since the end of World War II, of people migrating from rural areas to the ever-expanding cities. This has important implications for water resources. Communities have had to start building large water-supply systems to deliver water to thirsty new populations and industries. Wastewater (sewage) systems have also had to be constructed, often by the same water/wastewater utilities.

<u>Water Use Trends in the United States, 1950-2010</u>

Figure 3-86 is a bar chart that shows the amount of water used for various categories of water use in the U.S. for the 60-year period from 1950 to 2010. This chart shows the trends in surface water, groundwater, and total-water withdrawals for the United States during this period. Against a background of steady growth during the first half of the period and relative stability in the second half, the relative amounts of surface- and groundwater withdrawals (in percentages) have remained fairly constant. About three-quarters of the water used in America is from surface water (USGS 2014f).



Trends in population and freshwater withdrawals by source, 1950–2010.

Figure 3-86. Long-term population and freshwater withdrawal trends by source

What is extraordinary about this graph is that it reveals that America's water use peaked 35 years ago in 1980 and has been relatively constant since then. Many of the pressures forcing greater water use have only increased since 1980, such as population (which grew by more than 80 million from 1980 to 2010), the need to grow more food (irrigation), more industry, more power plants, and so forth, yet in spite of these total water use has not risen. What this shows clearly is that water conservation and reuse efforts and greater efficiency in using water have made a difference in the last 35 years (USGS 2014f).

Figure 3-87 is another bar graph that shows trends in total water withdrawals by category from 1950 to 2010. The two bars that stand out are the yellow and green ones: the yellow bars represent freshwater withdrawals for thermoelectric power production and the green bars represent irrigation. Water use in electricity generation grew by almost 500 percent from 1950 to 2005, but fell about 19 percent from 2005 to 2010. Irrigation water use increased by about 29 percent from 1950 to 1980 – after all, more water is needed to grow food for our growing population. After 1980, however, water use started to ease, possibly due to water efficiency and conservation measures beginning to make inroads in consumption. In contrast to the stable, non-growing bars for water use in thermoelectric power generation and irrigation, the purple public-supply bars continue on an uptrend. These bars represent municipal water supplies withdrawn by county, city, and regional

water departments and districts, treated, and delivered to homes and businesses. Public-supply water is withdrawn to serve America's normal water uses, such as supplying industries, commercial districts, and residential areas with water. The ever-increasing population of the U.S. demands ever-increasing supplies of water (USGS 2014f).

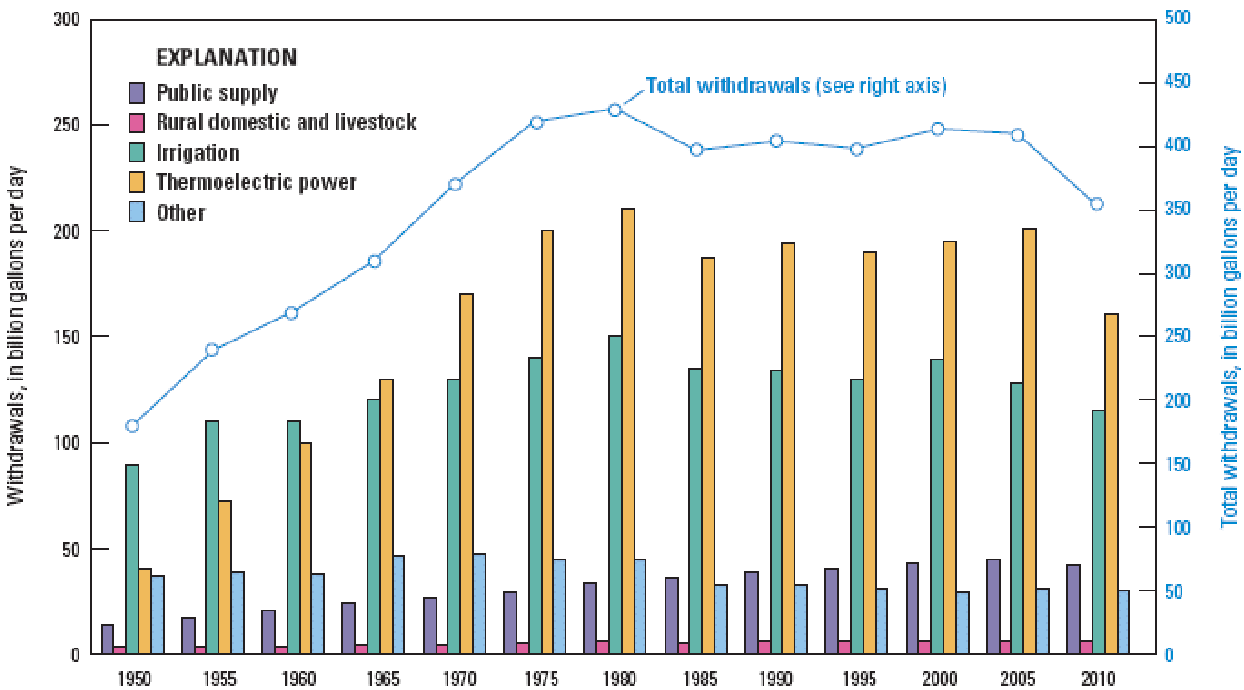


Figure 3-87. Trends in total water use by category, 1950 to 2010

<u>The Special Case of California</u>

California, as every Californian and indeed every American and many foreigners know, is a state of superlatives. At 39 million, California is far and away the most populous state in the country – 12 percent of the U.S. population, or one out of every eight Americans live here. It is also the nation's most lucrative agricultural state in terms of the monetary value of its agricultural production – over $30 billion annually – double that of its nearest rival, Texas.

To support its huge population and agricultural enterprises, California also consumes more water for all purposes than any other state. In 2010, California accounted for approximately 11 percent of total U.S. water withdrawals and 10 percent of freshwater withdrawals, predominantly for irrigation (see Figure 3-73). Once again, California's closest rival was Texas, which accounted for about seven percent of total withdrawals, predominantly for thermoelectric power, irrigation, and public supply (Maupin et al. 2014).

California withdrew more freshwater from the ground than any other state, accounting for 16 percent of the national total (Maupin et al. 2014). Crop irrigation accounted for 76 percent of California's total fresh surface-water withdrawals in 2010. There are nearly 82,000 farms in California, covering some 25 million acres. California produces more than 400 crops. For some of these, it is the only state in which they are cultivated commercially in the entire country; almonds, artichokes, dates, figs, raisins, kiwifruit, olives, clingstone peaches, pistachios, dried plums, pomegranates, sweet rice, and walnuts are grown in commercial quantities only in California. Overall, California grows nearly half of the nation's fruits, vegetables and nuts. Its leading agricultural commodity is milk and cream, accounting annually for nearly $6 billion in cash receipts; the second leading commodity, grapes, accounts for $3.2 billion in cash receipts every year (Agclassroom.org. 2012).

California was second among the states (after Florida) in saline surface water withdrawals, primarily to cool coastal nuclear power plants at places like Diablo Canyon, San Onofre, Bodega Bay, and Humboldt Bay.

California has one of most complex water capture, storage, and distribution systems in the entire country, consisting of reservoirs, aqueducts (Figure 3-88), pipelines, and even underground storage (in aquifers). (See Figure 3-89 for a statewide map of the entire water network). Rainfall and snowmelt in the Sierra Nevada and other mountain ranges are captured and stored in reservoirs and then distributed elsewhere in the state to

Figure 3-88. The Los Angeles Aqueduct runs from the Owens Valley to L.A.

California State Water Project (SWP) infrastructure
Central Valley Project (CVP) infrastructure
SWP–CVP shared infrastructure
Other federally owned/operated infrastructure
State and private infrastructure

Figure 3-89. Map of California's water capture, storage, and distribution system

agricultural and urban areas. California has ten major drainage basins or watersheds defined for the convenience of water management, each incorporating smaller watersheds. Precipitation usually falls in California only during the winter and spring months, from October through May. The northern half of the state has higher precipitation than the southern half. Summers are dry throughout the entire state. Precipitation falling as snow in the Sierra and other mountain ranges flows in the network of reservoirs and surface water canals, aqueducts, and ditches that supply the rest of state.

Groundwater is a crucial source of California's water supply (Figure 3-90). During a normal year, about 30 percent of the state's water supply comes from underground aquifers. In times of intense or prolonged drought, such as the one now in its fourth year, groundwater consumption can increase to 60 percent or more of the state's total freshwater consumption. Over 850 million acre-feet of water, enough to cover California to a depth of eight feet, is stored in California's 450 known groundwater reservoirs. However, not all groundwater is usable; over half is unavailable due to poor quality and the high cost of pumping the water from the ground. While surface water is concentrated mostly in the northern part of the state, groundwater is more evenly distributed (Carle 2004).

Figure 3-90. Groundwater pump in the Central Valley

The largest groundwater reserves in the state are located in the Central Valley, the large, flat valley that dominates the geographic center of California. The Central Valley, ranging from 40 to 60 miles wide and approximately 450 miles long, is perhaps the single most important agricultural area of its size anywhere in the entire world. The majority of the water supply here is in the form of runoff that seeps into the aquifer. The fresh water is usually found in deposits of gravel, silt, and sand. Below these deposits lies a layer of deep sediment, a relic of the distant time when the Pacific Ocean covered the valley floor.

Though California has laws governing surface water usage and quality, there are no statewide laws governing groundwater management. For all practical purposes, land ownership implicitly carries the right to essentially unlimited groundwater pumping. Here, as in many places around the world, the large stock of water beneath the ground surface has given rise to the delusion that groundwater is a renewable resource that can be tapped without limit. Calculations assuming that groundwater usage is sustainable if the rate of pumping equals the rate of recharge are often incorrect as a result of ignoring changes in water withdrawal and water recharge rates (Alley et al. 2002).

While the volume of groundwater in California is deceptively large, aquifers can readily be overdrafted when groundwater is pumped more rapidly than it is replenished. In 1999, it was estimated that the average, annual overdrafting was around 2.2 million acre-feet across the state, with 800,000 acre-feet in the Central Valley alone (Moores 1999). Since that time, overdrafting has increased considerably. Recent measurements by NASA's Gravity Recovery and Climate Experiment satellites found that in just the combined Sacramento and San Joaquin River basins, the northern and southern parts of the Central Valley, overdrafting between 2011 and 2014 was 12 million acre-feet of water per year (NASA-JPL 2014). This accelerated pumping occurred in order to support agricultural production in spite of the deepening drought, which was curtailing deliveries of surface water for irrigation. In Figure 3-91, colors progressing from green to orange to red signify accumulating water loss between June 2002 and June 2014.

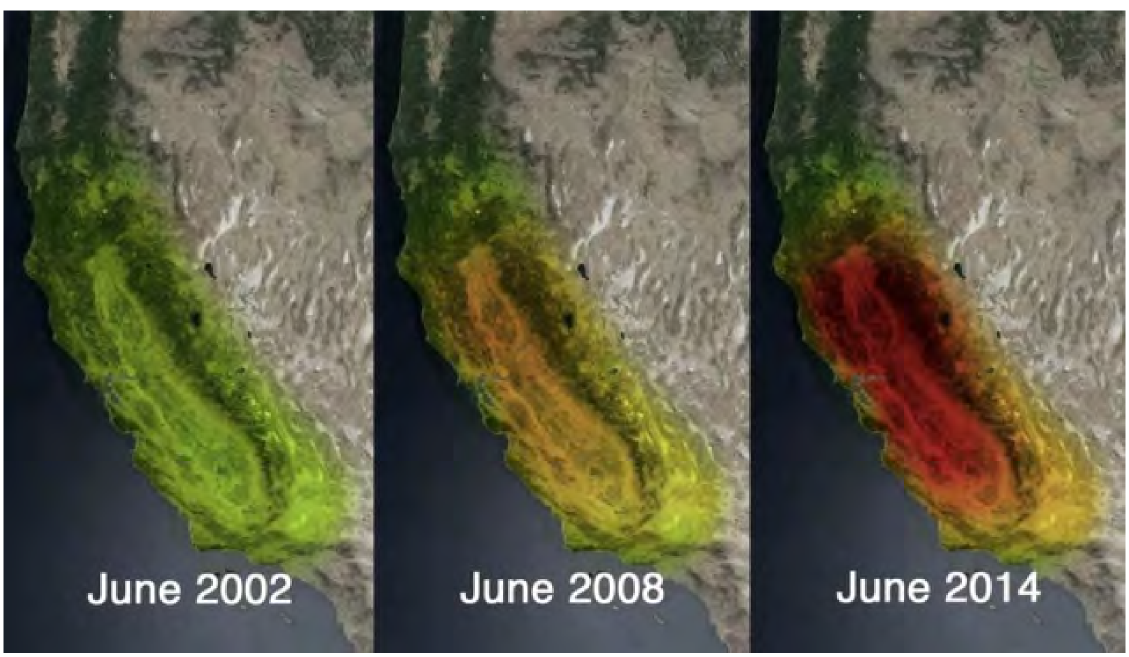


Figure 3-91. Accumulating groundwater loss in California's Central Valley as documented by satellite imagery

Figure 3-92. Land subsidence in the San Joaquin Valley (southern Central Valley)

California is currently suffering through the worst drought in its recorded history, which goes back more than a century. Because of low river flows, depleted reservoirs, reduced surface water deliveries, and dropping aquifers, farmers and landowners are drilling more and deeper wells in a frantic effort to continue supplying water.

In response, ground-water tables are dropping at an unprecedented rate. Water levels in many of the state's key aquifers – those tapped by municipalities in coastal Southern California and by Central Valley farmers – fell 50 feet or more between the spring of 2013 and the spring of 2014.

This widespread fall caused farmers and landowners to drill ever-deeper holes in the ground to access the receding water supply (LaFond 2014). Central Valley wells that used to hit water at 500 feet below ground surface must now be drilled down to 1,000 feet or more, at a cost than can exceed $300,000 for a single well (Dimick 2014).

As aquifers are depleted in the Central Valley, and sediments and rock strata drained of the water that helped give them structure, volume, and rigidity, the land surface begins to sink or subside (Figure 3-92).

Land subsidence occurs as a result of large quantities of groundwater being extracted from certain types of rocks, such as fine-grained sediments. The rock layers compact because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock collapses on itself and shrinks (USGS 2014g).

A 2013 USGS study found that land subsidence in the San Joaquin Valley reached nearly one foot per year at one site. This subsidence in turn is reducing the gradient and flow capacity of the Delta-Mendota Canal and the California Aqueduct, two major sources of water for the Central Valley and Southern California. Because canals are built with a small slope to help propel the water by gravity, differential land sinking can change that slope in random areas and thus impact flows. The USGS study reported that canals are not the only infrastructure at risk from subsidence. Railways, roads and pipelines – all linear structures that extend over a long distance – are also under threat (Dearen 2013).

Figure 3-93. Wasteful irrigation practices like this in California may soon become a thing of the past

As in many Western states, water and water rights are among California's most divisive political issues. With most of the state lacking rainfall in the dry season, water is limited in the most populous, and ever more overpopulated U.S. state. An ongoing debate is whether the state should increase the distribution of water to its large agricultural and urban sectors, or increase conservation and preserve the natural ecosystems of the water sources. With the prolongation of the most severe drought in the state's history, natural ecosystems and the species that reside in them are losing out to ever more anxious business, urban, and agricultural interests. Because of the threat to critical water supplies posed by California's drought, on January 17, 2014, Governor Jerry Brown declared a State of Emergency that suspended the California Environmental Quality Act (CEQA)

and state water quality plans with regard to actions to make water immediately available. According to the declaration, they "are suspended on the basis that strict compliance with them will prevent, hinder, or delay the mitigation of the effects of the emergency."

After another season of anemic precipitation during the 2014-2015 winter, the Sierra Nevada snowpack and the state's huge reservoirs are at unprecedented lows. At the same time, scientists are warning of the possibility of an incipient "megadrought" that could last decades. In March 2015, Governor Jerry Brown declared statewide mandatory water restrictions for the first time in California's history, ordering towns and cities to reduce their water use by 25 percent. This will be an enormous challenge, but if the severity of the drought continues, it may not be enough to stave off truly dire consequences for the state.

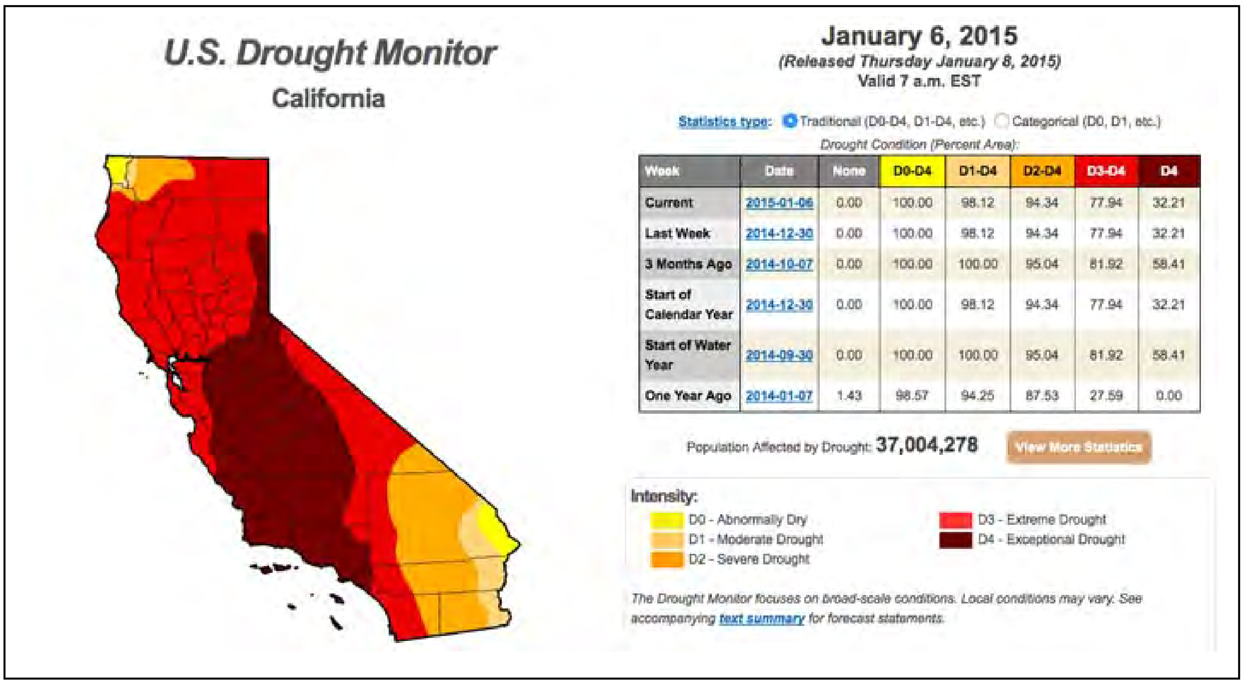


Figure 3-94. Drought map of California as of January 6, 2015

The severity and tenacity of the current drought has pushed a number of Californians to seriously consider or reconsider desalination as at least a partial solution to the state's water woes. A one billion dollar desalination plant is on the verge of completion at Carlsbad in San Diego County; when complete it will deliver about 50 Mgal/d of potable water to residents of San Diego County at a cost about twice that of conventional water supplies. The most commonly used desalination technology – reverse osmosis – entails forcing seawater through a membrane with tiny holes that allow the passage of water molecules but impede the flow of larger salt molecules. The pressure needed to accomplish this requires a large amount of electrical energy, although energy use has

been reduced through technological improvements. Still, if fossil fuel-derived electricity is used, desalination will emit carbon dioxide, exacerbating climate change. One future prospect is using wind or solar power to drive reverse osmosis, reducing or eliminating CO^2 emissions. Two other environmental problems associated with desalination are adverse effects on marine life from the intake of seawater, which can kill fish eggs and larvae, and the disposal of excess salt or brine back into the ocean (Gillis 2015).

In conclusion, California, with the largest population and the largest agricultural sector in the entire country – plus its particularly pressing water conflicts and challenges – represents a laboratory of sorts for the rest of the country and the world. One certainty is that continued population growth in California will only aggravate and intensify the state's water shortages (Figure 3-95).

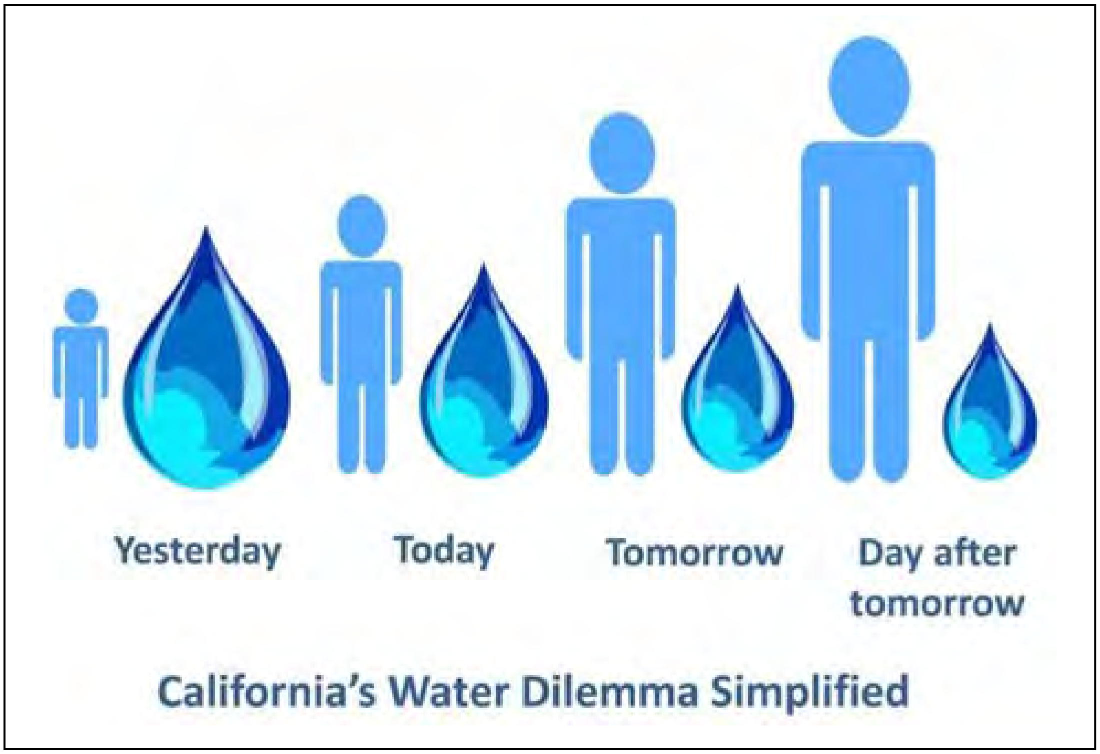


Figure 3-95. One view of California's water dilemma
Source: Kolankiewicz (2013)

3.4.1.3 Surface Water Resources, Wetlands, Watersheds, and Ecosystem Services

Up until now, the entire discussion in this section has focused on water supplies withdrawn from nature and put to some beneficial use by human beings. However, freshwater of course also plays an integral role in aquatic ecosystems: watercourses (streams and rivers), waterbodies (ponds and lakes), wetlands (marshes, swamps, bogs, etc.), springs, and estuaries (semi-enclosed brackish water bodies that are transition zones between land and sea, where fresh and saltwater mix). Indeed, these ecosystems and the

thousands of plant and animal species that live within them and depend upon them would not exist at all were it not for the availability of water. When water is taken from these ecosystems for use by human beings, there may be less or no water left behind to perform critical ecosystem services and functions. The integrity of these aquatic ecosystems is often adversely affected or even fundamentally altered.

Figure 3-96. Example of a small estuary. Two of the nation's largest estuaries are Chesapeake Bay on the East Coast and Puget Sound on the West Coast.

Aquatic ecosystems may also be modified and often damaged by human activity other than direct removal of water. This can occur from:

- flood control facilities (e.g., levees, channelization, dams)
- an increase in the amount of developed areas and impervious surfaces within a watershed, which increases the volume and rate of runoff during storm events
- land use practices within a watershed (e.g., crop cultivation, grazing, logging, deforestation) that cause erosion and lead to sedimentation within waterbodies
- construction within floodplains that impedes the flow of water
- navigation facilities within rivers, such as locks and dams on the Mississippi and Ohio rivers and many others
- dredging of rivers and bays to maintain navigation channels
- ports constructed and maintained in rivers, lakes, and bays
- construction of dams for hydroelectricity

As a result of the above activities, plus water pollution and water withdrawals, more than 123 species freshwater fauna species have been driven extinct in North America since the

year 1900. Hundreds of additional species of fishes, mollusks, crayfishes, and amphibians are considered imperiled today. Of North American freshwater species, nearly half of all mussel species, 23 percent of gastropods, 33 percent of crayfishes, 26 percent of amphibians, and 21 percent of fishes are listed as either endangered or threatened because of anthropogenic (manmade) influences. Recent extinction trends are due largely to extensive habitat deterioration from sedimentation and loading with organic compounds and nutrients, toxic contaminants, stream fragmentation and flow regulation by dams, channelization and dredging projects, and increasing numbers of invasive (introduced, non-native) species. Of 3.2 million miles of stream habitat in the U.S., less than two percent (< 62,000 miles) is of sufficiently pristine quality to be federally protected and only 40 rivers are still free-flowing after more than a century of intensive growth and development (Ricciardi and Rasmussen 1999).

There are three basic types of freshwater ecosystems (Vaccari 2005):

- Lentic: slow-moving or still water, including ponds, and lakes
- Lotic: faster-moving water such as streams and rivers
- Wetlands: areas where the soil is saturated or inundated for at least part of the time.

Limnologists typically divide **lentic ecosystems (ponds and lakes)** into three ecological zones. The shallow zone closest to the shore is called the littoral. This is where rooted wetland plants and emergent vegetation occur. The offshore is subdivided into two zones, an open water zone and a deep water zone. In the open water zone (or photic zone), sunlight penetrates the water and supports photosynthetic algae as well as the species that feed upon them. In the deep water zone, sunlight is unavailable and the food web is based on detritus descending from the littoral and photic zones above.

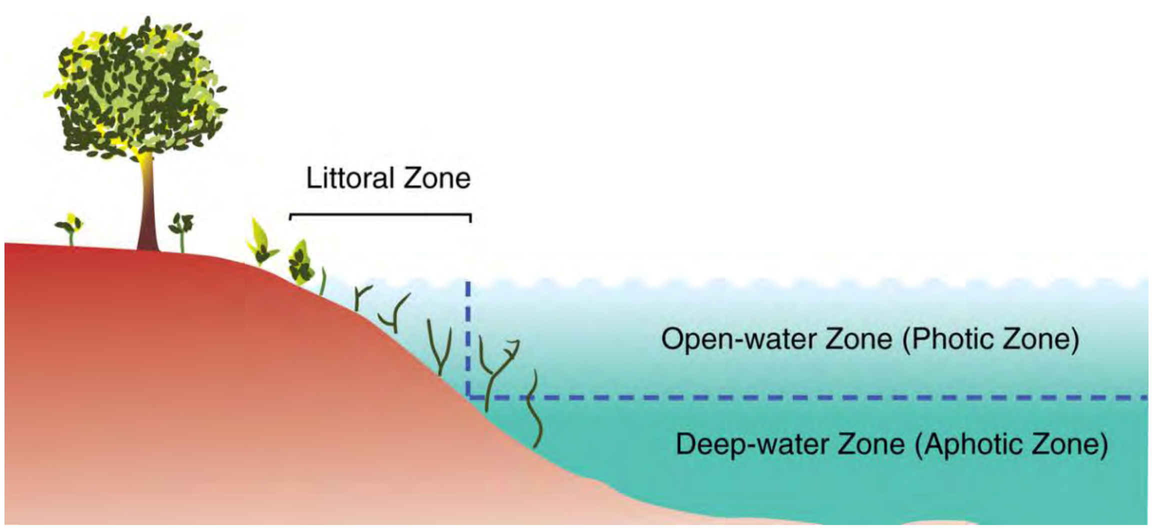


Figure 3-97. Three main zones of a lake ecosystem

The principal zones in **lotic (stream and river) ecosystems** are determined by the watercourse's gradient or by the velocity of the current. Faster-moving, turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow-moving water of pools. The food pyramid of streams within riparian forests is mostly derived from the leaf litter of trees, but wider streams and those that lack a canopy derive the majority of their food base from algae. Anadromous fish like salmon and shad are also an important source of nutrients, where they occur.

Environmental threats to rivers and adjacent riparian habitats such as bottomland hardwood forests in the East and cottonwood stands in the West include loss of water from diversions, dams and reservoirs, chemical pollution and invasive species (Alexander and Fairbridge 1999). A dam causes changes downstream, most of them adverse effects, which continue all the way to the river's mouth. The most important of these are reduction of spring flooding, which damages downstream wetlands and often interferes with fish reproduction; retention of sediment, which leads to increased bank and bed erosion downstream, loss of deltaic wetlands, and disappearance of sand on beaches along the seashore (Keddy 2010); and interference with the migration and reproduction of anadromous and catadromous fish.

Wild salmon runs – particularly those of the chinook or king salmon – on the Columbia River in the Pacific Northwest, were decimated by the construction of some 60 dams and reservoirs along the main river and its tributaries such as the Snake, Yakima, Pend Oreille, Clark, and Kootenay rivers. These dams and associated impoundments not only flooded spawning and rearing grounds, but blocked movement of adults swimming upstream to spawn as well as downstream migration of smolts (juveniles) attempting to enter the Pacific Ocean as part of their life cycle. To one extent or another, this experience was repeated on hundreds of rivers on the East and West Coasts.

Figure 3-98. King salmon smolts showing their vertical parr marks

Wetlands, in particular the "jurisdictional wetlands" under the regulatory authority of the U.S. Army Corps of Engineers, are characterized by three features: hydric (saturated) soils, wetland hydrology (partially, temporarily, or seasonally inundated), and hydrophytic ("water-loving") vegetation (USACE 1987). Wetlands are typically dominated by vascular plants that have adapted to saturated or hydric soils (Keddy 2010). There are four main types of wetlands: swamp, marsh, fen and bog.

Figure 3-99. Flooded swamp or bottomland hardwood forest alongside the White River in White River National Wildlife Refuge, Arkansas

Figure 3-100. Nesting pair of trumpeter swans in wetlands (freshwater marsh) at Agassiz National Wildlife Refuge in northern Minnesota

Because of the availability of nutrients, water, and soil, wetlands are among the most productive natural ecosystems on Earth in terms of net primary productivity, that is, annual plant biomass production as measured in tons per acre. Thus, wetlands tend to support both abundance (high biomass) and biodiversity (species richness).

Due to the productivity of wetland soils, during the 20th century, wetlands were often converted into dry land with dykes, levees, and drains and used for agricultural purposes. The construction of dykes and dams can have negative impacts on both individual wetlands and entire watersheds. Their proximity to lakes and rivers means that they have often been developed with human settlements. Once settlements are constructed and protected by dykes or levees, the settlements then become vulnerable to land subsidence because they are no longer built up with sediments deposited during floods, and paradoxically, may face an ever-increasing risk of flooding.

The Louisiana coast south of New Orleans is a well-known example. Extensive levees – nearly 1,200 miles long – constructed for flood control along the Mississippi River prevent deposition of sediments onto the floodplain on either side of the river. Sediments carried by the river are now discharged far from the coast into the Gulf of Mexico, thereby depriving wetlands of vital sediment. Furthermore, throughout Louisiana's wetlands, an extensive network of dredged canals and flood-control structures (Figure 3-101), built to enable facilitate hydrocarbon exploration (drilling for oil and gas) and production as well as commercial and recreational boat traffic, has allowed salt water from the Gulf of Mexico to penetrate brackish and freshwater wetlands (USGS no date).

Figure 3-101. Canals dredged for navigation and energy exploration have damaged extensive areas of coastal wetlands in Louisiana

Large areas of the Mississippi Delta are subsiding and eroding even as the sea level is rising. Consequently, Louisiana has suffered a continuing loss of large areas of coastal wetlands decade after decade. By some measures, Louisiana's wetlands today represent about 40 percent of the wetlands of the contiguous United States, but about 80 percent of the total losses. The state's wetlands extend as much as 80 miles inland and along the coast for about 200 miles. Not all of Louisiana's wetlands are receding; some are stable, and others are growing. Overall, however at the present net rate of wetlands loss, Louisiana will have lost all of this important habitat in about 200 years (USGS no date).

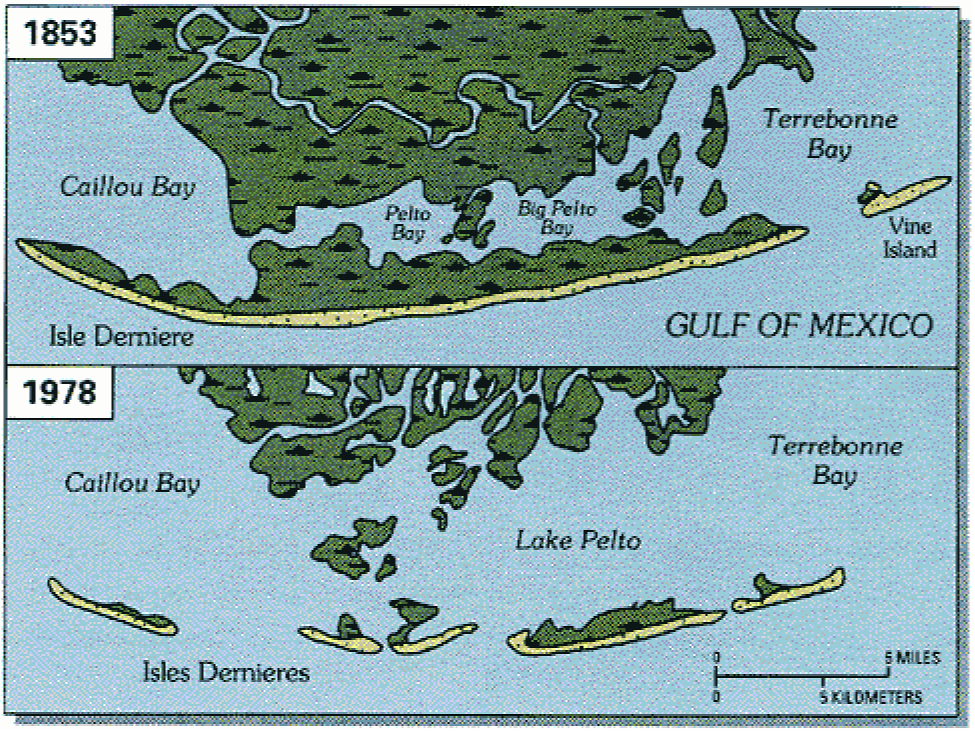


Figure 3-102. Coastal erosion and land loss of the Isles Dernieres on the Louisiana coast, 1853-1978

Approximately half America's original endowment of wetland habitats has been lost over the past 200 years. Human activities account for most of this, such as dredging wetlands for canals or draining and filling for agriculture, grazing, and development (USGS no date).

The lower 48 states held an estimated 110.1 million acres of wetlands in 2009 (Dahl 2011). This is an area equivalent in size to California. In 1994, an estimated 175 million acres of wetland existed in Alaska (Hall et al. 1994) – covering nearly half of the state – while Hawaii had 52,000 acres as of the 1980s (Dahl 1990). After Alaska, Florida (11.4 million acres), Minnesota (10.6 million), Louisiana (7.8 million), and Texas (7.6 million) have the largest wetland acreage (EPA 2013a).

In the 1600s, over 220 million acres of wetlands are believed to have existed in the contiguous (Lower 48) states (Dahl 1990). Since that time, extensive, widespread losses have occurred, and more than half of the original wetland acreage has been drained, dredged, or filled and converted to other uses. Some 22 states have lost more than 50 percent of their original wetlands, and seven states – California, Iowa, Indiana, Illinois, Kentucky, Missouri, and Ohio – have lost more than 80 percent. Both Ohio and California have lost 90 percent or more. The years from the mid-1950s to the mid- 1970s were particularly a time of massive wetland destruction, but since then the rate of loss has

diminished substantially (EPA 2013a). Since the 1970s, the largest losses of wetlands have been in Louisiana, Mississippi, Arkansas, Florida, South Carolina, and North Carolina (Mitsch and Gosselink 1993). For the last couple of decades, national policy has been that there should be “no net loss” of wetlands, which has slowed but not stopped the rate of wetlands loss. The net wetland loss nationwide was estimated to be 62,300 acres between 2004 and 2009 (DOI 2011). Figure 3-103 displays overall wetland losses state by state.

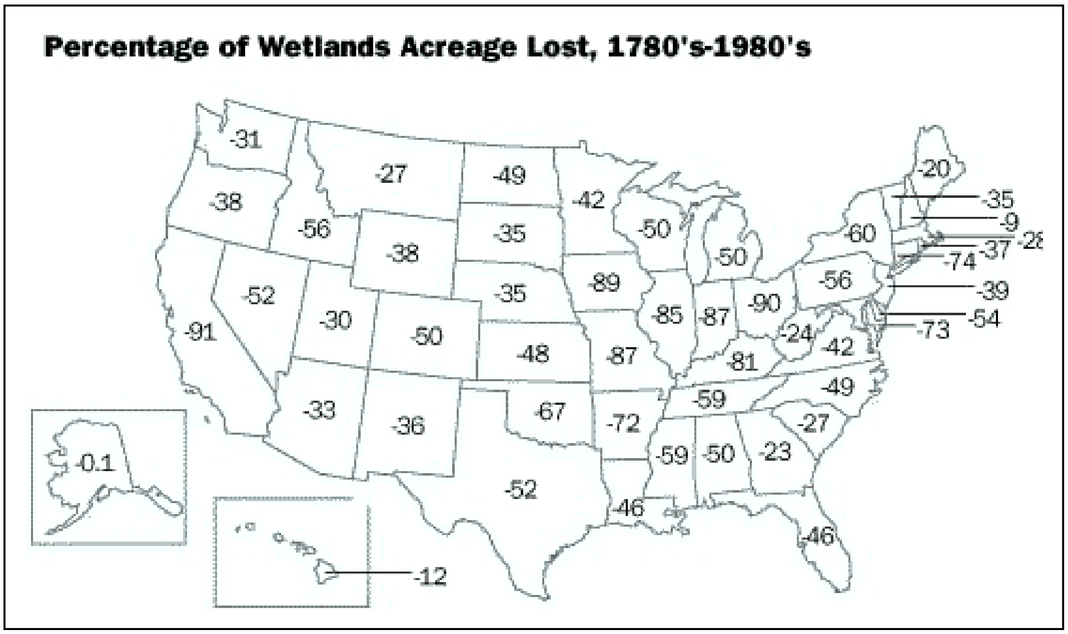


Figure 3-103. Total wetland losses by state, 1780s to 1980s

Sources: EPA (2013), Mitsch and Gosselink (1993)

Aquatic ecosystems perform many important ecological functions and services. They recycle nutrients, purify water, attenuate floods, recharge groundwater and provide habitats for wildlife (Loeb and Spacie 1994). Aquatic ecosystems are also used for human recreation, commercial fishing, and are extremely important to the tourism industry, especially in coastal regions (Daily 1997).

Wetlands in particular are also recognized for providing a host of environmental, economic and social benefits. They furnish habitat for fish, wildlife, and a variety of plants. Coastal wetlands are nurseries for many saltwater, freshwater, and anadromous fishes and shellfish of commercial and recreational importance; juvenile coho salmon (*Oncorhynchus kisutch*), for example, spend a year or two of their lives as juvenile fry and fingerlings in freshwater wetlands prior to migrating downstream to the ocean as smolts (Kolankiewicz 1993). Wetlands are also important landscape features because they hold and slowly release flood water and snow melt, recharge groundwater, act as

filters to cleanse water of impurities, recycle nutrients, and provide recreational opportunities for millions of people (DOI 2011).

The health of an aquatic ecosystem can be degraded when the ecosystem's ability to tolerate, absorb, or assimilate a stress has been exceeded. A stress on an aquatic ecosystem results from physical, chemical or biological modifications of the environment. Physical modifications include changes in water temperature, water flow patterns, bank and substrate structure, and light availability. Chemical modifications include changes in the loading rates of nutrients such as nitrogen and phosphorus, oxygen-consuming materials (measured by Biochemical Oxygen Demand or BOD), and toxic substances. Biological modifications include overharvesting of commercial species and the introduction of invasive, exotic species. Human populations can readily impose excessive stresses on aquatic ecosystems (Loeb and Spacie 1994).

There are many examples of excessive stresses with adverse impacts or negative consequences. The Great Lakes of North America have been subject to multiple stresses, such as water pollution, overharvesting and invasive species (Vallentyne 1974). Puget Sound, Chesapeake Bay, and North Carolina's Pamlico Sound are all estuaries under pressure from multiple human stressors, including chemical pollution, eutrophication from excessive nutrients, and overharvest of fish and shellfish. Lake Pontchartrain next to New Orleans along the Gulf of Mexico illustrates the negative effects of different stresses including levee construction, logging of swamps, invasive species and salt water intrusion (Keddy et al. 2007).

The mighty Mississippi River, including all of the major tributaries in its huge basin, such as the Missouri, Platte, Ohio, Illinois, Allegheny, Monongahela, Tennessee, and Cumberland rivers, have all suffered from some combination of serious water quality degradation, excessive water withdrawals, alteration of flow regimes to provide for navigation, and exotic species invasions (Figure 3-104) . These have sharply compromised the integrity of aquatic biota in and along these rivers.

California's San Joaquin and Sacramento rivers are overdrafted and overtaxed. The Columbia River system in the Pacific Northwest has been overregulated by 60 dams, devastating its once famous salmon runs. Flows in the Colorado River and Rio Grande in the Southwest have been highly altered and ecosystems in and alongside these rivers have been changed and impaired permanently. The integrity of the famous "river of grass" at the southern tip of Florida, the Everglades, has been badly compromised by invasive species but especially by diversions of water to support agriculture and population growth in Miami, Fort Lauderdale, and the rest of the Southern Florida megalopolis.

Zebra mussel **Saltcedar or tamarisk** **Hydrilla**

Figure 3-104. These exotic invasive species have had major adverse environmental consequences on American aquatic ecosystems.

In considering water resources in the United States, it is important to emphasize the role of watersheds, also known as drainage basins. A watershed is an area of land wherein all of the surface water and groundwater drains off or funnels into the same destination waterbody, and eventually an outlet to the sea. Watersheds occur in all sizes and shapes. In the continental U.S., there are some 2,110 designated watersheds (EPA 2012b). Drainage basins have not only been historically important for determining territorial boundaries, but serve as important ecological management units.

Figure 3-105. Major water resource regions in the United States, delineated by watersheds or drainage basins

Within any one watershed, waterbodies and watercourses are subject to changes in water quantity and quality upstream within the watershed, because the general direction of movement of water within the drainage basin is always downstream.

3.4.1.4 Water Quality and Water Pollution

Protecting water quality by avoiding and cleaning up water pollution is as important as managing and conserving water quantity.

Water quality is a measure of the suitability of water for a particular use based on selected physical, chemical, and biological properties. These uses include support of aquatic life, fisheries, contact recreation, irrigation, and drinking water. Water quality is determined by sampling and measuring, then analyzing characteristics of the water such as temperature, dissolved oxygen (DO), dissolved mineral content, suspended solids, and number of potentially harmful bacteria. These parameters are then compared to numeric standards and guidelines developed over the years by scientists and regulators at the EPA and state agencies to determine if the water is suitable for a given use (USGS 2014h).

Some aspects or *parameters* of water quality can be determined by technicians right at the stream sampling site or at the well. These include temperature, acidity (pH), DO, and electrical conductance (an indirect indicator of dissolved minerals and salts in the water). Analyses of individual chemicals are generally conducted in specialized laboratories.

Water quality varies naturally from setting to setting, as well as with the seasons, climate, and types of soils and rocks through which water flows or percolates. When water from rain or snowmelt moves over the land and through the ground, it often dissolves minerals in rocks and soil, percolates through organic material such as roots, leaf litter, and humus, and reacts with algae, bacteria, and other microbes. Some of these minerals may be naturally occurring toxic heavy metals like arsenic, while others like calcium and magnesium, present in limestone and dolomite, “harden” the water. Water may also carry plant debris and exposed sand, silt, and clay to downhill into waterbodies, making the water appear “muddy” or turbid. When water evaporates from lakes and streams, dissolved minerals become more concentrated in the water that remains behind. Each of these natural processes changes the water quality and potentially the use to which humans may put that water (USGS 2014h).

The most common dissolved substances in water are minerals or salts that, as a group, are referred to as dissolved solids. Dissolved solids include common constituents such as calcium (Ca), sodium (Na), bicarbonate (HCO_3-), iron (Fe), and chloride (Cl-); plant nutrients like nitrogen (N) and phosphorus (K); and trace elements such as selenium (Se), chromium (Cr), and arsenic (As).

In general, these common constituents – at the concentrations at which they typically occur – are not considered harmful to human or ecosystem health, although some of them can affect the taste, smell, or clarity of water. Plant nutrients and trace elements in water, on the other hand, can be harmful to human health and aquatic life if they exceed standards or guidelines (USGS 2014h).

Dissolved gases such as oxygen and radon are quite common in natural waters. Adequate oxygen levels (high DO) in water are critical for fish and other aquatic life; low DO or "hypoxic" conditions are a common cause of massive fish kills. Some species such as salmon and trout require higher DO levels than other species such as carp or catfish. Radon gas can threaten human health when it exceeds drinking-water standards.

A number of human activities can adversely affect water quality, and these activities are often, but not always, a reflection of high surrounding human population densities, or of damaging activities in rural areas (e.g., mining, drilling for hydrocarbons, logging, grazing, crop cultivation) that directly support high human populations elsewhere.

Urban and industrial development, sprawl, construction and earthmoving projects, farming, mining, fossil fuel combustion, stream channel modification, confined animal feeding operations, logging, off-road vehicle use, and other human activities can readily impact the quality of natural waters. For example, nitrogen and phosphorus fertilizers applied to crops and lawns are plant nutrients can dissolve easily in rainwater or snowmelt runoff. Excessive quantities or loadings of nutrients transported to streams, rivers, and lakes encourage explosive growth of algal populations, or "algal blooms," can coat the water surface and ultimately lead to crashing DO levels in the water and the subsequent fish kills (USGS 2014g).

Every summer, a massive, hypoxic (low DO, less than 2 parts per million of DO) or anoxic (no DO) "dead zone" develops at the mouth of the Mississippi River in the Gulf of Mexico as a result of all the nutrients carried downstream by the river due to fertilizer runoff from the tens of thousands of farms in the Mississippi drainage basin. The dead zone can increase to 7,000 square miles in area (Figure 3-106). The zone occurs between the inner and mid-continental shelf in the northern Gulf of Mexico, beginning at the Mississippi River delta and extending westward to the upper Texas coast.

The dead zone is caused by nutrient enrichment or eutrophication from the Mississippi basin, particularly by nitrogen and phosphorous. Watersheds within the Mississippi River Basin drain much of the central U.S., from Montana in the west to Pennsylvania in the east and extending southward along the Mississippi River itself. Most of the nitrogen loading originates in major farming states in the Mississippi River Valley, including Minnesota, Iowa, Illinois, Wisconsin, Missouri, Tennessee, Arkansas, Mississippi, and

Louisiana. Dissolved nitrogen and phosphorous flow into the river through upstream runoff of fertilizers, soil erosion, animal wastes, and sewage. In a natural, pristine system, these nutrients are not significant factors in algae growth because they are not found in artificially high concentrations and they are largely used in the soil by plants. However, with anthropogenically increased nitrogen and phosphorus input from fertilization to boost crop yields, algal growth is no longer constrained. Thus, algal blooms develop, the food pyramid is altered, and DO in the area is depleted. The size of the dead zone fluctuates seasonally and it is exacerbated by modern farming practices. It is also affected by weather events such as Mississippi River floods and Gulf of Mexico hurricanes (Bruckner 2012).

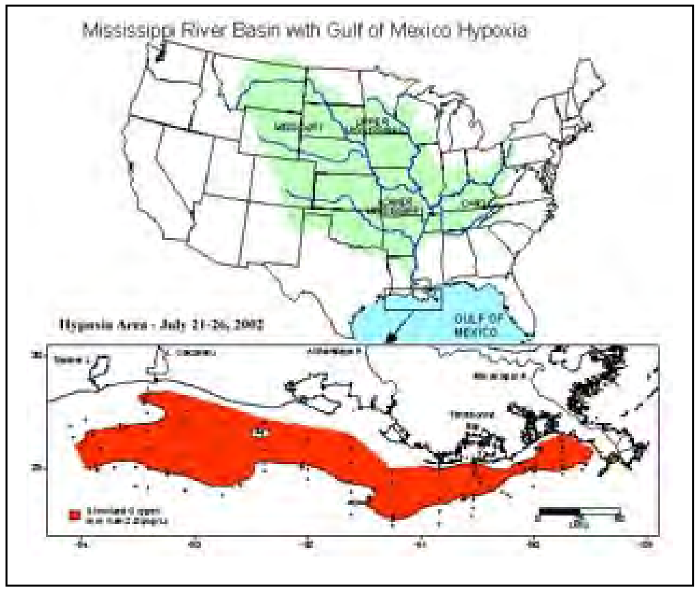


Figure 3-106. Dead zone at the mouth of the Mississippi River

When bacteria such as fecal coliforms, which are normally found in the intestinal tracts of humans and animals, also show up in water, this signals that disease-causing pathogens may be present. Giardia and cryptosporidium are pathogens that have been found occasionally in public-water supplies; they have caused illness in large numbers of people in several instances. Pathogens can enter our water from leaking septic tanks, wastewater-treatment discharge, and animal wastes.

Chemicals such as pharmaceutical drugs, dry-cleaning solvents, and gasoline that are used in urban settings have been found in both surface water and groundwater. After half a century of use, pesticides are now ubiquitous in streams and ground water, though they rarely exceed existing standards and guidelines established to protect human health. Some long-lived, or persistent pesticides, such as those in the organochlorine family like DDT (Dichlorodiphenyltrichlorethane), have not been used for 20 to 30 years, but they are still detected in fish and streambed sediment at levels that may represent a continuing risk to human health, aquatic life, and fish-eating wildlife such as bald eagles

and loons. So many chemicals in use today that determining the risk to human health and aquatic life is a highly complex task. In addition, mixtures of chemicals typically are found in water, but health-based standards and guidelines have not been established for chemical mixtures that may act synergistically when in combination.

Endocrine disruptors are synthetic chemicals that may interfere with the endocrine system in both humans and wildlife, potentially producing adverse developmental, reproductive, neurological, and immune effects. A wide range of substances, both natural and manmade, are believed to cause endocrine disruption, including pharmaceuticals, dioxin and dioxin-like compounds, polychlorinated biphenyls (PCBs), DDT and other pesticides, and plasticizers such as bisphenol A. Endocrine disruptors may also occur in many everyday products – including plastic bottles, metal food cans, detergents, flame retardants, food, toys, cosmetics, and pesticides. Research shows that endocrine disruptors may pose the greatest risk during prenatal and early postnatal development when organ and neural systems are forming (NIEHS 2015).

Endocrine disruptors have been correlated with declines in populations of certain wildlife species in certain places, such as American alligator in Lake Apopka, Florida (EPA 2015b). There are also many reported instances of "feminization" or "gender-bending" in wild fish populations that have been exposed to high levels of endocrine-disrupting chemicals; in such cases male fish have underdeveloped or improperly functioning gonads; studies are continuing into the population-level effects of these abnormalities (Jobling and Tyler 2003).

The EPA and state agencies collect, amass, and compile extensive quantities of data and information on the condition of waters in the United States (Table 3-9). The designated uses referred to in Table 3-9 are:

- Fish, shellfish, and wildlife protection and propagation
- Aquatic life harvesting
- Recreation
- Agricultural
- Aquatic life harvesting
- Public water supply
- Industrial
- Other
- Aesthetic value
- Exceptional recreational or ecological significance

Table 3-9. Assessed waters of the United States

	Rivers & Streams (miles)	**Lakes, Reservoirs and Ponds (acres)**	**Bays & Estuaries (square miles)**
Good waters[1]	476,351 / 45.6%*	5,686,264 / 31.6%*	7,296 / 21.8%*
Threatened waters[2]	7,559 / 0.7%*	145,290 / 0.8%*	
Impaired waters[3]	560,411 / 53.7%*	12,141,045 / 67.6%*	26,103 / 78.2%*
Total assessed waters	1,044,321	17,972,599	33,399
Total waters	3,533,205	41,666,049	87,791
% of waters assessed	29.6%	43.1%	38.0%

Source: Adapted from EPA (2015b)
*Of the waters assessed
[1] "A waterbody is considered "good" if it meets all the uses for which it was assessed.
[2] Waters rated by the states as "threatened" currently support all of their designated uses, but one or more of those uses may become impaired in the future (i.e., water quality may be exhibiting a deteriorating trend) if pollution control actions are not taken.
[3]A waterbody is considered "impaired" if any one of its uses is not met.

EPA lists the causes of impairment in the assessed rivers and streams; lakes, reservoirs and ponds; and bays and estuaries. Table 3-10 lists these causes for rivers and streams.

Table 3-10. Causes of impairment in assessed rivers and streams

Cause	**Miles threatened or impaired**
Pathogens	166,518
Sediment	119,412
Nutrients	106,305
Mercury	102,802
Organic enrichment/oxygen depletion	88,106
Polychlorinated biphenyls (PCBs)	80,255
Metals (other than mercury)	76,209
Temperature	69,322
Habitat alterations	64,089
Flow alterations	42,229
Turbidity	39,483
Cause unknown – impaired biota	38,635
Cause unknown	38,324
Salinity/Total Dissolved Solids/ Chlorides/Sulfates	34,051
pH/Acidity/Caustic conditions	28,745
Pesticides	19,032
Ammonia	12,143
Other cause	12,066
Total toxics	10,717
Fish consumption advisory	9,916

Cause	Miles threatened or impaired
Toxic inorganics	7,548
Algal growth	6,014
Dioxins	5,046
Toxic organics	4,993
Oil and grease	3,084
Biotoxins	2,150
Nuisance exotic species	1,448
Trash	1,415
Taste, color, and odor	854
Chlorine	754
Cause unknown – fish kills	678
Radiation	656
Noxious aquatic plants	354
Nuisance native species	127

In assessed lakes, reservoirs, and ponds, the top 10 causes of impairment, in order, are: mercury, nutrients, PCBs, organic enrichment/oxygen depletion, turbidity, metals (other than mercury), pH/acidity/caustic conditions, algal growth, nuisance exotic species, and sediments.

Table 3-11 lists the probable sources of impairments in assessed rivers and streams.

Table 3-11. Probable sources of impairments in assessed rivers and streams

Probable source	Miles threatened or impaired
Agriculture	131,149
Unknown	103,292
Atmospheric deposition	99,930
Hydromodification	61,088
Urban-related runoff/stormwater	60,849
Municipal discharges/sewage	58,558
Natural/wildlife	51,588
Unspecified nonpoint source	49,007
Habitat alterations (not directly related to hydromodification)	34,990
Resource extraction	29,289
Silviculture (forestry)	19,381
Industrial	17,920
Construction	12,903
Other	10,176
Land application/Waste sites/Tanks	9,409
Legacy/Historical pollutants	5,991

Probable source	Miles threatened or impaired
Spills/Dumping	3,351
Recreation and tourism (non-boating)	1,808
Aquaculture	317
Groundwater loadings/withdrawals	270
Recreational boating and marinas	142
Commercial harbor & port activities	52
Military bases	20

The ten leading probable sources of impairment in lakes, reservoirs, and ponds are, in order: atmospheric deposition, unknown, agriculture, other, legacy, historical pollutants, natural/wildlife, unspecified nonpoint source, municipal discharges/sewage, urban-related runoff/'stormwater, and hydromodification.

In conclusion, the occurrence and severity of water pollution or impairment of water quality is directly related to human population size and/or density. There is very little "natural" pollution in the absence of human populations and their contaminant-generating activities and consumption. Even where pollution or impairment occurs in rural areas with low surrounding population density, it is because of nearby human activities such as mining, farming, ranching, logging, or hydrological modifications (e.g., dams, impoundments, stream bank modifications, post-development erosion) that produce raw materials or products consumed by human populations elsewhere.

In the case of stream and lake acidification in natural areas from "acid rain," the largest single cause is sulfur dioxide (SO_2) emissions from coal fired power plants. SO_2 is converted to sulfuric acid (H_2SO_4) in the atmosphere and often transported long distances down-wind before falling out of the atmosphere as acidic precipitation (rain or snow). This is deposited onto land and water surfaces hundreds of miles away (Figure 3-107), where it alters soil and water chemistry and harms terrestrial plants and trees and aquatic life. For example, although the Adirondacks mountain range in Upstate New York has very low human population density and the 2.6-million acre Adirondack Forest Preserve is protected as wilderness managed in a "forever wild" condition by the New York State Department of Environmental Conservation, many lakes and streams have been severely damaged by acid rain. According to the Adirondack Council:

> More than 500 lakes and ponds (out of 2,800) in the Adirondack Park are already too acidic to support the plants and aquatic wildlife that once existed in them. Each spring, an entire winter's acidic snowpack melt into the Park's waters, jolting them with a huge jump in acidity known as "acid shock." It could not happen at a worse time. Many of the Park's plants, animals and insects are at their most vulnerable at the beginning of the growing season.

> Day after day, even when it doesn't even rain or snow, the pollution hangs in acid clouds that shroud the mountains in a caustic fog. Adding insult to a long list of injuries, Canadian studies show that the larvae of black flies – the bane of spring outdoor activities in the Northeast and southern Canada – seem to thrive in acidic waters. Consequently, their populations are exploding as pollution changes the chemistry of the waters from which they hatch.
>
> The Adirondack Park is suffering the worst damage in the nation from acid rain. And because nearly all of the utility plant pollution that causes acid rain in the Adirondacks comes from outside the state [e.g., Pennsylvania, Ohio, Indiana, Illinois], New Yorkers alone can do little to prevent the onslaught (Adirondack Council 2015).

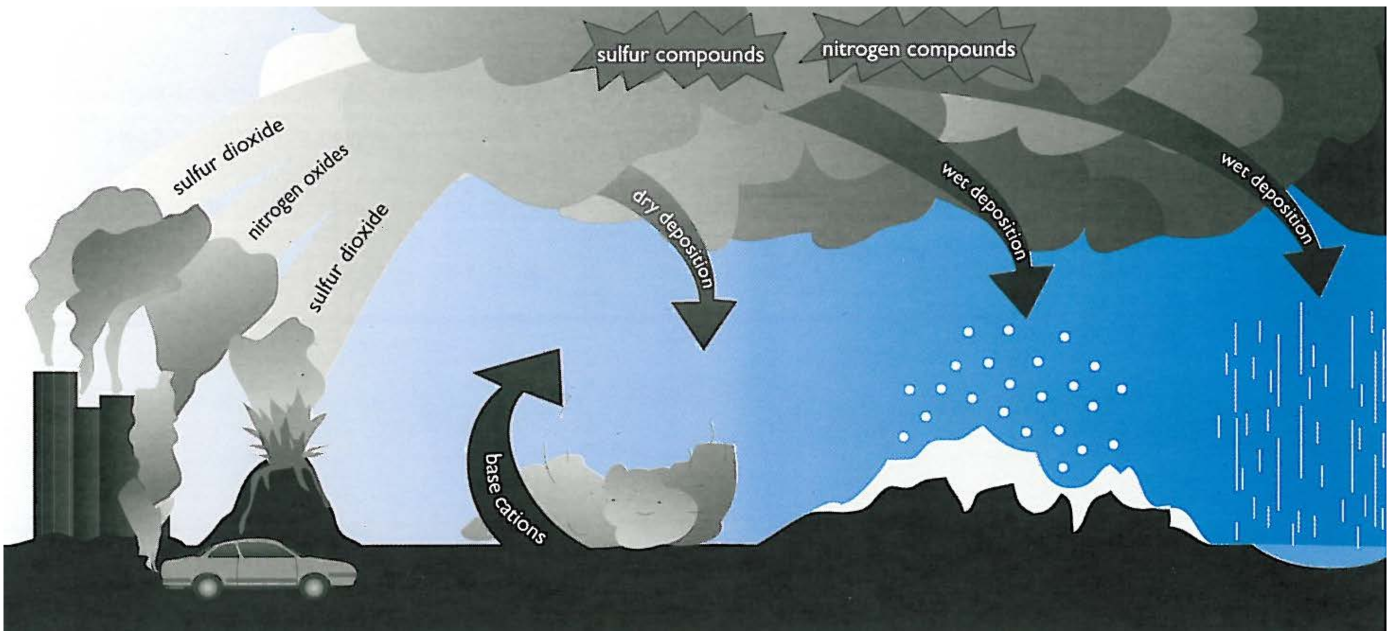


Figure 3-107. In the case of acid rain, air pollution is converted to water pollution

Rain, snow, sleet, hail, fog and mist falling on or enveloping the Adirondacks can have a pH of 3.3 or less (close to that of vinegar), more than 200 times as acidic as "untainted" rain. (7.0 is neutral on the pH scale, which is logarithmic, and "natural" rain is somewhat acidic, with a pH of 5.6.) (Adirondack Council no date). Even hardy brook trout populations cannot survive and thrive below a pH of 5.0.

Water pollution affects wildlife as well. In the case of acid rain effects on water quality in the Adirondack Mountains just mentioned, one of the prominent victims is the loon (Figure 3-108), a striking bird whose haunting call is one of the iconic symbols of the North Country. Loons live on lakes and eat fish; they have suffered elevated mortality from bioacccumulated mercury in the flesh of fish. The mercury is both emitted by coal-fired power plants, and leached out of soils and rocks by acidity.

Figure 3-108. The common loon has become less common as a result of acid rain and subsequent contamination of the waters it lives in and fish it lives on.

Water pollution affects wildlife and fisheries which in turn affect the economy. The Adirondack Council cites the case of Big Moose Lake, which in the mid-20th century was "teeming with life," human and non-human alike. For half a century, a steady stream of tourists converged on the lake to escape the hustle, bustle and pollution of city life and enjoy the tranquility and beauty of a lake 50 miles from the nearest urban center (Adirondack Council no date).

Figure 3-109. Big Moose Lake in the Adirondacks

The lake sported trophy-sized brook trout, white fish, and landlocked salmon. Lake trout abounded, luring anglers from around the world. Acid rain has since exterminated those fish species. Other native wildlife such as crayfish, freshwater shrimp, frogs, hooded mergansers and otters have become scarce as well. By 1980, the tourist hotel operators had given up on Big Moose Lake's fishing as a means of attracting tourists. Millions of dollars in potential revenues were lost.

One lakeside business also discovered to its dismay that acid rain can affect human health as well. The children of one lodge-owning couple started to complain about the taste of their drinking water, drawn from a well next to Big Moose Lake. When one of the young daughters developed stomach cramps and diarrhea, the owners had their water tested. Test results showed that it contained five times as much lead as is deemed safe for human consumption. The water contained excessive amounts of copper as well. Both metals were being leached out of the inside of pipes and plumbing fixtures because of the corrosive water. Lead is highly toxic to humans but copper also kills beneficial bacteria that allow septic systems to break down wastes and purify wastewater (Adirondack Council no date).

While the Adirondacks, Appalachians or even the Rocky Mountains – where acidified waters occur – have low human population densities themselves, to reiterate, the source of the acidity is from human activities elsewhere, in support of high human populations elsewhere. In the case of acid rain, the culprits are sulfur and nitrogen compounds emitted by the smokestacks of coal-burning power plants and the internal combustion engines and tailpipes of vehicles. The amount of these pollutants emitted from both these sources is directly linked to population size.

3.4.2 Environmental Consequences

3.4.2.1 IPAT and Impacts on Water Resources

As discussed in Section 3.1.3, IPAT is shorthand for I = P x A x T, which itself signifies Impact (I) = Population (P) x Affluence (A) x Technology (T). The case of water resources is an excellent illustration of IPAT, in particular, the potential of the Affluence and Technology factors to lessen per capita water consumption, in many instances achieving a reduction in overall, aggregate water consumption (I or Impact), even as population continues to increase, often quite rapidly (Figure 3-110).

Indeed, in many political and intellectual circles, those individuals and interests who are either indifferent to the environmental consequences of population growth or actively supportive of population growth as: 1) a sign of economic vitality and dynamism, and 2) necessary for continued perpetual economic growth, the proven ability of technology and

cultural/social/economic choices to substantially reduce per capita water consumption is considered both a godsend (because it is perceived as permitting future robust population growth *ad infinitum*), as well as a vindication of the view that innate human ingenuity and innovation will always avert any prospective shortages of natural resources that a growing population and dynamic economy might encounter (Simon 1980, Simon 1983, Simon 1998).

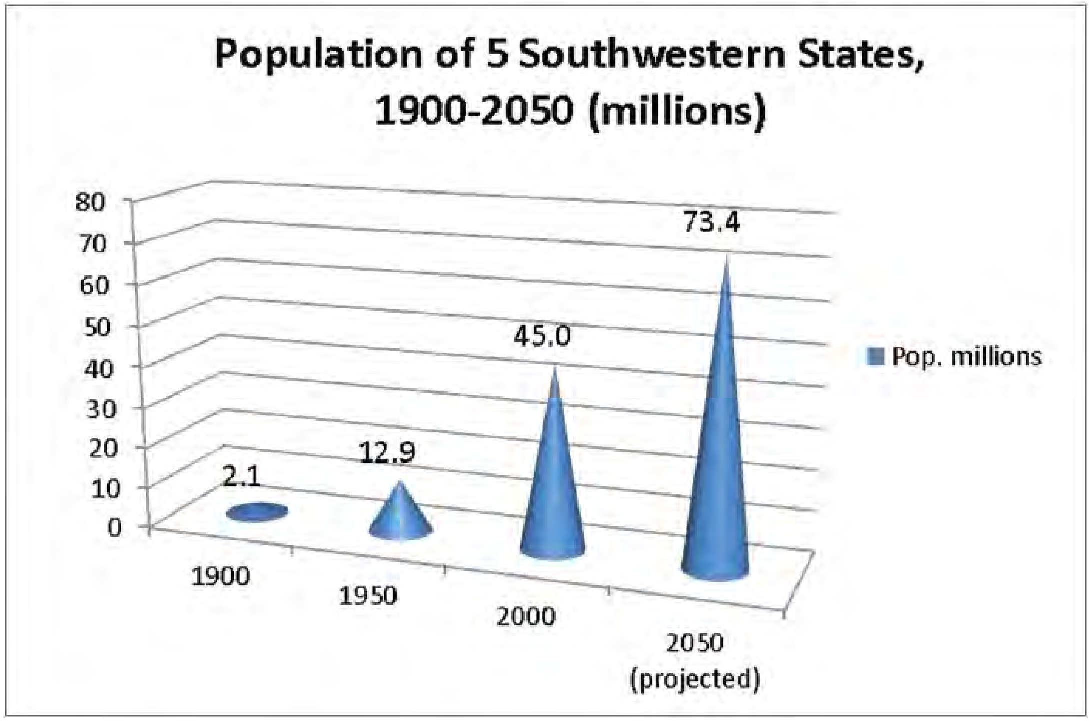


Figure 3-110. Population growth in five Southwestern states (California, Nevada, Utah, Arizona, and New Mexico) from 1900 with projections to 2050

Just what are these Affluence and Technology factors with respect to water resources? Affluence in this case refers to cultural/social/economic choices that either reduce water consumption or reallocate water to make it go further. In the arid Southwest, substituting expansive, inappropriate green lawns with xeriscaping (Figure 3-111) – landscaping with drought-tolerant, preferably native plants – can sharply reduce residential and institutional water consumption (Kolankiewicz 2014). Taking shorter showers helps too. Similarly, replacing or retiring agricultural crops requiring large amounts of irrigation water, such as many fruits and nuts and some crops like rice can save huge amounts of water. Growing one head of broccoli takes 5.4 gallons of water, one walnut 4.9 gallons, one head of lettuce 3.5 gallons, one tomato 3.3 gallons, one almond 1.1 gallons, and so forth. The water that is saved by fallowing or not growing these crops can then be

redirected toward urban areas and municipal uses. In theory, the food can be grown somewhere else with more abundant water.

Figure 3-111. Xeriscaping is an appropriate landscaping choice for the dry Southwest, and it need not be dull or unattractive

Water-saving technologies and water conservation, efficiency, and reuse offer tremendous scope for reducing water consumption both in agriculture and in municipal and residential uses.

A few examples of water-saving technologies and systems available even now for crop irrigation include the following (Big Picture Agriculture no date):

- <u>Pressurized water application methods (Drip or micro-irrigation)</u> – Drip irrigation delivers water (and fertilizer) either to the soil surface or directly to the roots of plants through networks of PVC tubing with small holes and other restrictive outlets. By calibrating these water inputs slowly and regularly, drip irrigation can conserve 50 to 70 percent more water than traditional methods while increasing crop production by 20 to 90 percent (Figure 3-112).

Figure 3-112. Drip irrigation

- Drought-tolerant crops and seeds – Dry regions which suffer perennial water shortages would be wise to plant crops which are more drought-tolerant to drought. Moreover, drought-tolerant crop seeds are now available both through biotechnology and from native seed varieties. Examples of drought-tolerant seeds available today include corn, rice, and cotton.

- System modernization – This can facilitate efficient water use at the farm level and increase water productivity by up to 20 percent through improved water releases in canals and rivers (Kulkarni 2011).

- Water saving rice irrigation – A number of newer methods and technologies have been developed and implemented in recent years to curtail water use associated with the traditional flooding methods and without compromising yield.

- Controlled drainage – This helps save freshwater by providing part of the consumptive use through capillary rise from shallow water tables. Capillary rise from the raised water table contributes moisture supply to the root zone; savings up to 40-50 percent are possible.

- Use of lower quality waters (water reuse and recycling) – Use of partially treated or untreated sewage water (sometimes called graywater) for growing vegetables and fodder for livestock "stretches" every gallon of water before returning it to waterbodies.

- GPS-based technology – Newly developed GPS-based technology allows farmers to more accurately target irrigation needs, reducing water consumption by an average of 15 percent. This, in combination with variable rate irrigation (VRI), permits farmers to selectively turn off specific nozzles as the center pivot moves over patches of crops that do not need additional water at the moment.

- Reducing wastage along the food chain – By minimizing loss and wastage of perishable food along the food chain, the need for additional food production, and thus irrigation water, can be curbed (Kulkarni 2011).

These are some of the innovations that are being invented and implemented at scale to reduce the aggregate amount of water needed to irrigate and grow crops as a result of increasing perceptions of scarcity. Similarly, a number of advances have been made in recent years that increase water efficiency and conservation in residential, commercial, and institutional settings.

Saving substantial volumes of water at home can be achieved with a mix of cultural practices, devices, and technologies, none of which involve going without:

1. Check faucets, toilets, and pipes regularly for leaks
2. Use your water meter to check for hidden water leaks
3. Install water-saving shower heads and low-flush toilets
4. Put plastic bottles or float booster in your toilet tank
5. Turn off the water after you wet your toothbrush
6. Use your dishwasher and clothes washer for only full loads
7. Minimize use of kitchen sink garbage disposal units
8. Water your lawn only when it needs it
9. Water during the early parts of the day; avoid watering when it's windy
10. Use a broom, not a hose, to clean driveways and sidewalks (Eartheasy.com 2014)

In California, the Orange County Water District has made big strides in recycling wastewater. About 2.4 million Orange County residents are supplied with water from a 350-square mile underground aquifer, which, since 2008, has been steadily recharged with billions of gallons of purified wastewater. Raw sewage is converted into drinking water through a variety of steps culminating with reverse osmosis, addition of peroxide and exposure to UV light, and then injected into the aquifer for storage (SCPC 2015).

Water efficiency, conservation, recycling, and reuse at home, in municipalities, and in irrigated agriculture can save large and stretch amounts of water, but they cannot work miracles or accommodate infinite or rapid, sustained population growth. This is illustrated by the case of one of the largest water utilities in the state of Texas, the North Texas Municipal Water District or NTMWD (USACE 2015). Chapter 1 of the Draft EIS (DEIS) on the Section 404 permit application to the U.S. Army Corps of Engineers for the proposed Lower Bois d'Arc Creek Reservoir identified the purpose and need for this 16,641-acre (26-square mile) water supply reservoir on a tributary of the Red River in northeast Texas: "State population projections show the… service area population increasing from 1.6 million to 3.3 million by 2060." Chapter 1 of the DEIS specifies that although advanced water conservation, efficiency, reuse, and recycling measures are able to offset a large share of the increase in municipal and residential water demand associated with a doubling of the service area population, they are unable to negate it entirely.

For the purposes of the present analysis in this EIS, it is assumed that the combination of Affluence and Technology factors – that is to say, water efficiency, conservation, recycling, and reuse – can reduce aggregate per capita consumption of water by 25 percent, the amount by which California cities are to reduce their consumption this year because of the drought. This will be assumed for each of the alternatives.

3.4.2.2 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million (70 percent) from the 2010 population of 309 million. Assuming an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 27 percent between 2010 and 2100 under the No Action Alternative (Figure 3-113). Demand is differentiated from actual consumption, because due to likely shortages, it may well not be possible to meet actual demand, or pressure to consume.

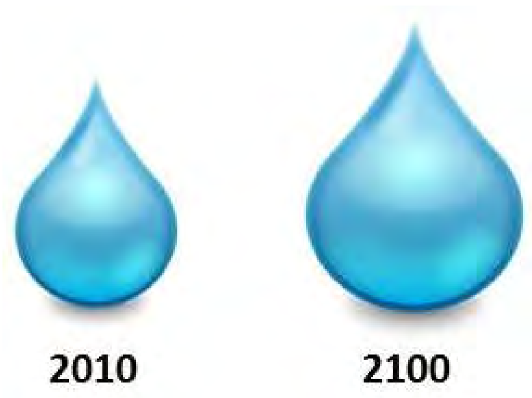
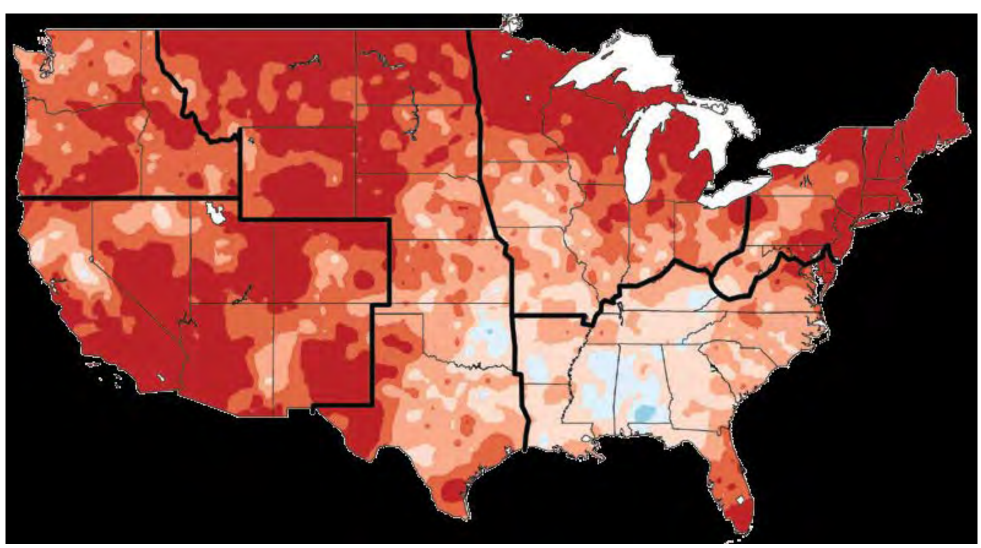


Figure 3-113. Total nationwide water demand would likely increase by 27 percent under the No Action Alternative

Effects on water resources from this growth would vary region by region. The 2014 U.S. National Climate Assessment divides the continental United States into six regions: Northeast, Southeast, Midwest, Great Plains, Southwest, and Northwest (Melillo et al. 2014) (Figure 3-114). Projected changes in precipitation due to anthropogenic climate change vary from region to region. Population projections also vary from region to region: in the contiguous 48 states, the fastest growing regions in recent decades, and

Figure 3-114. Regions delineated in the 2014 U.S. National Climate Assessment



also projected to grow the most rapidly in the foreseeable future, are the Southeast, Southwest, and Northwest, although portions of the so-called Great Plains states, especially Texas and Colorado, are also projected to add many millions of residents.

However, if water shortages predicted by current climate change models should come to pass, at least one of these demographic projections in particular may not be realistic – that for the Southwest. The 2014 National Climate Assessment states: "Snowpack and streamflow amounts are projected to decline in parts of the Southwest, decreasing surface water supply reliability for cities, agriculture, and ecosystems" (Garfin et al. 2014).

The Southeast Region is also anticipated to experience water problems. One of the three key messages for the region in the 2014 National Climate Assessment is: "Decreased water availability, exacerbated by population growth and land-use change, will continue to increase competition for water and affect the region's economy and unique ecosystems." While changes in projected precipitation for this region are highly uncertain, the reasonable expectation is that there will be reduced water availability due to the increased evaporative losses resulting from rising temperatures alone (Carter et al. 2014) (Figure 3-115).

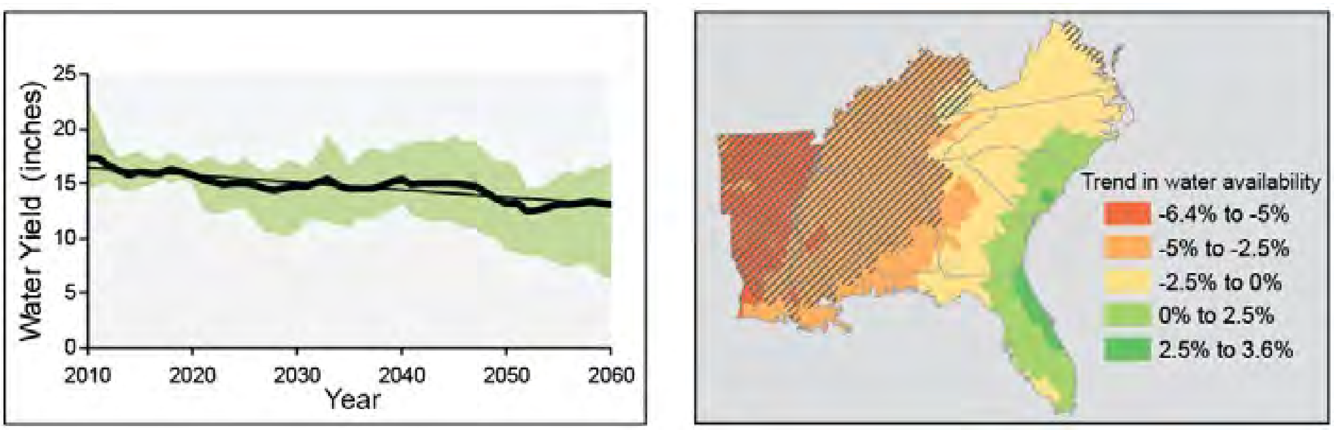


Figure 3-115. Downward trend in water availability in the Southeast Region

Overall, according to the 2014 National Climate Assessment, short-term (seasonal or shorter) droughts are expected to intensify in most U.S. regions. It may be advisable and necessary to build more water storage and flood control facilities in these regions as one form of adaptation and insurance to these emerging climatological circumstances. Longer-term droughts are expected to intensify in large areas of the Southwest, the southern Great Plains (i.e., Texas and Oklahoma), and the Southeast. Annual runoff and related river flows are projected to decline in the Southwest and the Southeast, and to increase in the Northeast, Alaska, Northwest, and upper Midwest regions, generally reflecting projected precipitation patterns (Melillo et al. 2014).

Combining these precipitation and water availability projections with regional demographic projections and the assumptions of the No Action Alternative, it is immediately apparent that under this alternative, two rapidly growing regions in the country – the Southwest and the Southeast – will experience very grave problems with water availability that will have significant adverse effects on urban areas, agriculture, and the already beleaguered aquatic ecosystems of these areas. Other regions of the country would face more manageable scenarios with regard to water resources. While demographic pressures on water quantity and quality would also increase in most of these other regions, the potential for increased water efficiency and conservation, as well as more stringent pollution control measures and improved technologies, offer real prospects for meeting human water demands while maintaining or perhaps enhancing the integrity of aquatic ecosystems.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would have indirect and cumulative impacts on water resources as follows:

- **Duration of Impact**: ***Long-term to permanent***. The duration of the impact on water resources associated with the projected population growth under the No Action Alternative would range from “would likely last for a decade or more” to “indefinite or everlasting and for all intents irreversible.”

- **Extent of Impact**: ***Large***. The extent of the impact on water resources associated with the projected population growth under the No Action Alternative “would affect a resource on a regional, national, or global scale.”

- **Magnitude of Impact:** ***Moderate to Major***. The magnitude of the impact on water resources associated with the population growth under the No Action Alternative would vary depending on the region in question. In the Northeast, Midwest, Great Plains, Northwest, Alaska, and Hawaii, it would have a Moderate impact, that is one in which there is a “noticeable change in a resource occurs, but the integrity of the resource remains intact.”

  However, in the Southeast and the Southwest, due to the especially high population growth projected for these two regions, as well as the projected water stress they are anticipated to undergo due to climate change, the magnitude of the impact would be Major, representing a “substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard.”

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on water resources associated with the population growth under the No Action Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While these impacts may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on water resources overall.

Overall, the net effect of the No Action Alternative on water demands and withdrawals from natural systems would be adverse, significant, and long-term. The degree of severity of this effect would vary from region to region, with impacts in the Southwest and Southeast being the most severe and other regions less so. While water-saving practices and technologies could to an appreciable extent ameliorate the adverse effects on water resources of adding 215 million more Americans, they would not entirely eliminate them. If population were not growing so robustly, then savings from widespread implementation of water conservation and efficiency would allow more water to be retained in rather than withdrawn from aquatic ecosystems. This in turn would benefit the flora and fauna of these natural systems as well as restoring and enhancing the diminished levels of ecosystem services they currently furnish to society.

3.4.2.3 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would result in a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million (117 percent) from the 2010 population of 309 million. Assuming an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total nationwide water demand (as opposed to actual consumption) would still increase by 62 percent between 2010 and 2100 under the Expansion Alternative (Figure 3-116). Demand is differentiated from actual consumption, because due to likely shortages, it may well not be possible to meet actual demand, or pressure to consume.

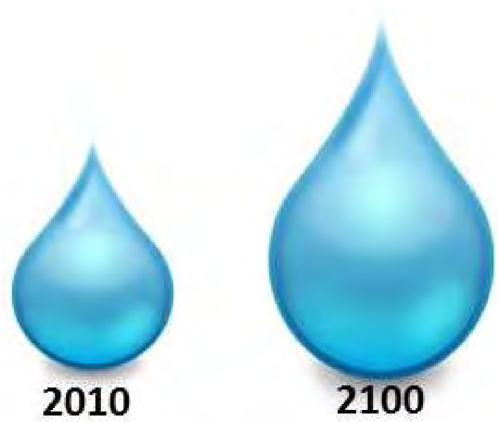


Figure 3-116. Total nationwide water demand would likely increase by 62 percent under the Expansion Alternative

Taking into account projected changes in regional water availability according to the 2014 National Climate Assessment, as was done with the No Action Alternative, the situation under the Immigration Expansion Alternative for the Southwest and Southeast would become even more precarious than under the No Action Alternative.

If: 1) the Expansion Alternative is chosen by the United States, and 2) regional demographic trends of the past half-century persist for the remainder of this century (to 2100), then both the Southwest and Southeast would undergo a tripling or more of their current populations at the same time that each region has less water available, and in the case of the Southwest, much less water available, than at present. Both of these regions are already experiencing severe water quantity and quality problems. In the future, these problems for the two most rapidly growing regions in the country would intensify enormously under the Expansion Alternative. While this is speculative, both regions may be forced to make politically unpalable or unpopular decisions, or it may be that what was once unthinkable will become acceptable or tolerable. It is impossible to be any more specific than this.

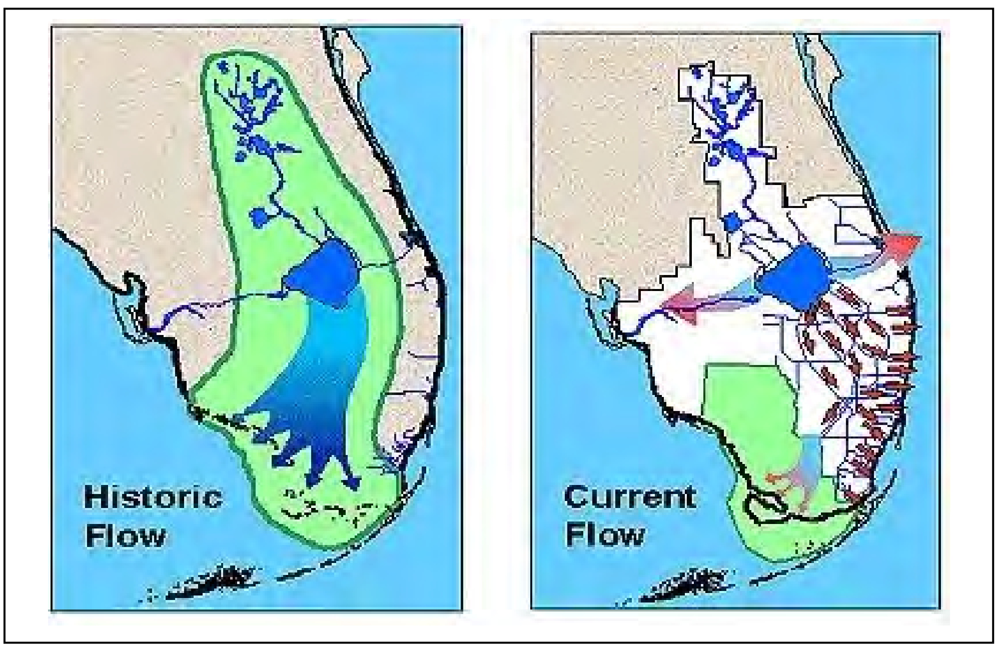


Figure 3-117. Natural historic (left) and current flows (right) of water from Lake Okeechobee into the Everglades in South Florida. Especially in the American Southwest and Southeast, in the future, under the Expansion Alternative pressures to divert natural flows to urban areas like the megalopolis around Miami would intensify enormously.

Figure 3-118. Water shortages would intensify under the Expansion Alternative, especially in the Southwest and Southeast, forcing diffcult decisions on how much water to leave in and take from natural sytems to supply agriculture and cities.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would have indirect and cumulative impacts on water resources as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on water resources associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on water resources associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on water resources associated with the population growth under the Expansion Alternative would vary depending on the region in question. In the Northeast, Midwest, Great Plains, and Northwest, it would have a Major impact, that is, one in which there is a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard." However, the magnitude of the Major impact in these regions would not be as great as for the Southwest and

the Southeast. Here the impact would also be Major, but it would also be extremely grave, because of the especially potent combination of projected demographic growth in these two regions (higher than the national average rate of growth) as well as projected reductions in available water. Pressure to divert water from natural systems would intensify, but even aquatic systems were left "high and dry," it is possible there would not be enough water to meet societal demands (agricultural, municipal, industrial, etc.).

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on water resources associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While these impacts may be mitigated by the factors discussed above, it is unlikely that these mitigation measures would be able to completely offset the adverse effects of population growth on water resources overall.

Overall, the net effect of the Expansion Alternative on water demands and withdrawals from natural systems would be highly adverse, significant, and long-term. The degree of severity of this effect would vary from region to region, with impacts in the Southwest and Southeast being the most severe and other regions less so. While water-saving practices and technologies could to some extent ameliorate the adverse effects on water resources of adding 360 million more Americans – more than a doubling of our current population – they would come nowhere near to eliminating them. If population were not growing so rapidly, then savings from widespread implementation of water conservation and efficiency technologies and practices would allow more water to be retained in rather than withdrawn from aquatic ecosystems. This in turn would benefit the flora and fauna of these natural systems as well as restoring and enhancing the now-diminished levels of ecosystem services they currently provide to American society.

In coastal areas, especially in Texas, California, and Florida – all of them experiencing population growth at much higher rates than the national average – pressure to build numerous desalination plants using reverse osmosis or some as-yet-unidentified-and-undeveloped technology, is likely to increase. The water emerging from these plants would likely be much costlier than water is at present, and whether or not future Texans, Californians, and Floridians would be rich enough to afford it is an open question. Concentrated salt (brine) that has been removed would require disposal in the least environmentally damaging fashion. Removing salt from seawater is inherently energy-intensive, and carbon dioxide would be emitted to the atmosphere, exacerbating the buildup of this gas, and resultant global warming, if fossil fuels were to be burned to provide the needed energy. The rapid population growth to the end of the century – and beyond – to which Americans would be committing their country under the Expansion Alternative, would force these hard choices, and others.

3.4.2.4 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This is an increase of 70 million (23 percent) from the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Assuming, as in the other two alternatives, an aggregate, across-the-country and across-the-board decline in per capita water demand of 25 percent due to implementation of improved water conservation and efficiency measures, total aggregate nationwide water demand (as opposed to actual consumption) would actually decrease by eight percent between 2010 and 2100 under the No Action Alternative (Figure 3-119). This is the only one of the three alternatives considered in this EIS that actually leads to a net reduction in the total aggregate nationwide water demand and perhaps consumption as well by the year 2100. In this alternative, aggregate nationwide water demand is more likely to equal actual aggregate nationwide water consumption because the U.S. would have a more realistic probability of actually supplying enough water to meet the demand, due to less overall pressure on water resources.

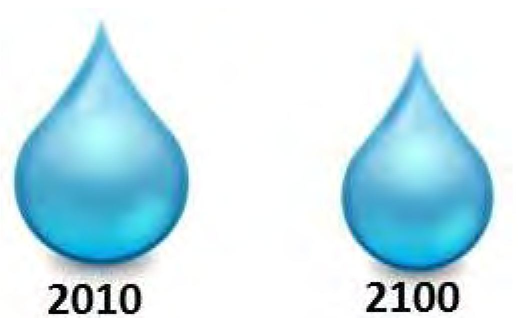


Figure 3-119. Total nationwide water demand would likely decrease by 8 percent under the Reduction Alternative

While the net reduction in nationwide demand for water in the Reduction Alternative would be a beneficial impact, two regions – the Southwest and the Southeast – would still encounter difficulties in meeting likely demand because they would have faster population growth than the national average and because, according to climate modeling, they would have less water availability than at present. However, these difficulties would be much more manageable than under either the No Action Alternative or the Expansion Alternative.

It is worth underscoring once more what a serious commitment to water conservation and efficiency makes in all three alternatives. Each alternative assumes that, on average, each American would consume 25 percent less water in 2100 than in 2090, due not to poverty or inability to pay for water, but entirely because of all-embracing implementation of

water-saving technologies and practices, as well as changes in land use and the economy (e.g., switching to less water-intensive crops, idling cropland as necessary to make water available to cities). Figure 3-120 illustrates what aggregate water demand would look like in 2100 if per capita water consumption were to remain the same as in 2010.

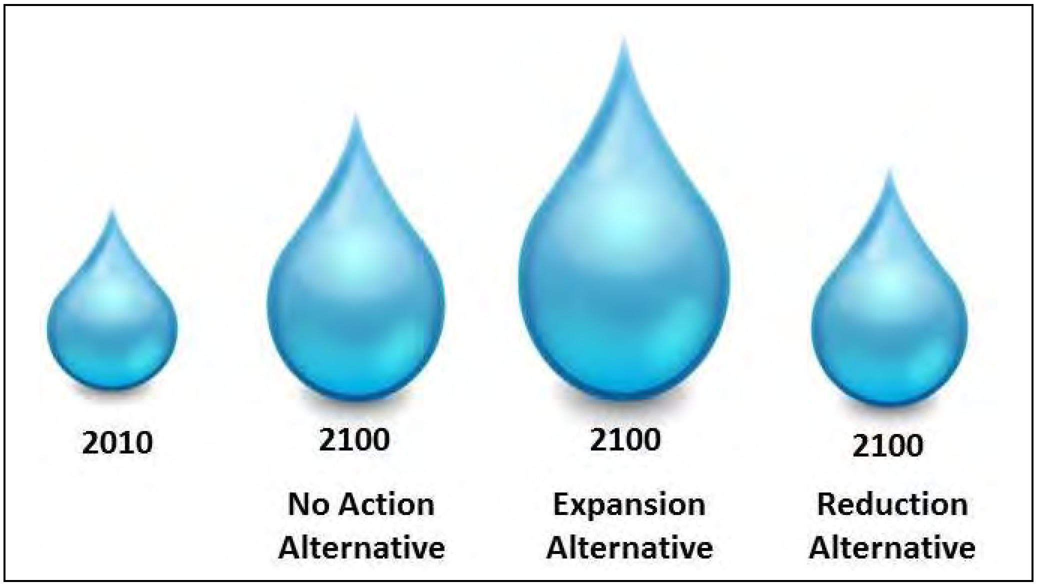


Figure 3-120. Comparison of water demand in 3 immigration alternatives in the year 2100 assuming per capita water consumption remains the same as in 2010

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would have indirect and cumulative impacts on water resources as follows:

- **Duration of Impact**: ***Long-term to permanent***. The duration of the impact on water resources associated with the projected population growth under the Reduction Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on water resources associated with the projected population growth under the Reduction Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact: *Minor, Moderate, and Major***. The magnitude of the impact on water resources associated with the population growth under the Reduction Alternative would vary depending on the region in question. In the Northeast, Midwest, Great Plains, and Northwest, it would have a Minor impact, that is, one in which a "change in a resource area occurs, but no substantial resource impact results." This is because under the Reduction Scenario, except for the Northwest, there would actually be reduced water demand and

consumption in these regions. While the Northwest would likely experience a net increase in its demands on the water resource due to more rapid population growth than the country on average, it is comparatively well-endowed with water resources, and is expected to remain so even with climate change.

The magnitude of the impact in the Southeast region would be Moderate, that is, a "noticeable change in a resource occurs, but the integrity of the resource remains intact." The Southeast is projected to have less water availability in 2100 than at present, and even under the Reduction Alternative, tens of millions more residents in the Southeast would likely be competing for this diminished quantity of water. Both human residents and natural ecosystems are likely to get by on less water, and both would be harmed as a consequence. There would also be increased pressure on freshwater quality from non-point pollution sources as well as from saltwater intrusion into aquifers from global warming-induced sea level rise. (These effects would be even more pronounced in the two previous alternatives.)

In the Southwest, the magnitude of predicted impact under the Reduction Alternative would range from Moderate to Major. Climate models project the Southwest to have starkly less water available by 2100; at the same time, even under the Reduction Alternative, the population of the states in this region would still increase by tens of millions, exerting greater demands and pressures on a shrinking water base. The political pressure to increase withdrawals from already stressed aquatic ecosystems would increase, though not nearly to the extent as with the No Action Alternative or the Expansion Alternative.

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on water resources associated with the population growth under the Reduction Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher."

Overall, the net effect of the Reduction Alternative on water demands and withdrawals from natural systems – provided that per capita water consumption were actually decreased by 25 percent as assumed – would be modestly but significantly beneficial. With the notable exception of two regions in particular, the Southwest and the Southeast, demands on the water resource, and subsequent withdrawals from aquatic ecosystems, would actually remain approximately constant or even decrease under the Reduction Alternative (or in the case of the Pacific Northwest, still be capable of being met even with projected population growth). This would allow more water to be retained "in-stream," increasing the flow not just of surface freshwater but also of ecosystems services provided to society by waters of the U.S., including wetlands.

3.5 Carbon Dioxide Emissions and Resultant Climate Change

"Recent warming coincides with rapid growth of human-made greenhouse gases. The observed rapid warming gives urgency to discussions about how to slow greenhouse gas emissions." – James E. Hansen, Ph.D., former head of NASA's Goddard Institute for Space Studies

3.5.1 Affected Environment

3.5.1.1 Key Concepts of Climate Science

This subsection is largely drawn from two documents from the Intergovernmental Panel on Climate Change (IPCC): 1) an overview of the climate system in the 2001 report prepared by Working Group (WG) I of the IPCC (Baede et al. 2001), and 2) another report prepared by WG I for the most recent (fifth) IPCC climate assessment, *Climate Change 2013: The Physical Science Basis* (IPCC 2013b). This latter 1,552-page report is part of the Fifth Assessment Report of the IPCC, released to the public in 2013 and 2014.

Weather and climate exert a profound influence over every living thing on Earth (Baede et al. 2001). Not only are they are part of the daily experience of the billions of human beings who step outside, but they are essential for health and well-being, from the level of biosphere writ large to that of the individual human going about her day-to-day routines.

It is important to distinguish between the meanings of weather and climate. Weather describes the fluctuating, variable conditions of the atmosphere at any given place and time. It refers to temperature, atmospheric pressure, humidity, wind speed, and other key parameters such as the presence or absence of clouds, precipitation, and the occurrence of special, more extreme phenomena, such as thunderstorms, dust storms, tornados, typhoons, or hurricanes (IPCC 2013). Weather has only limited predictability: beyond a week or two individual weather systems at any given site are inherently unpredictable.

In a narrow sense, climate is usually defined as the average weather. The most relevant quantities with respect to climate are most often surface variables such as temperature, precipitation and wind. In a wider sense, climate also includes not just the average or mean conditions, but also the associated statistics (e.g., frequency, magnitude, persistence, trends), and it often combines parameters to describe phenomena such as droughts.

"Climate change" then refers to a change in the state of the climate that can be identified through widespread, long-term observation and meticulous data collection. Statistical tests ascertain changes in the mean and/or the variability of climatic properties that persist for an extended period of time, typically decades or longer.

For billions of years, the sun has provided the energy source that powers Earth's climate system (Figure 3-121). About half of solar energy is furnished in the visible portion of the electromagnetic spectrum. Since the Earth's temperature has been relatively constant for many centuries, incoming solar energy must be nearly balanced with outgoing radiation. Of the incoming solar shortwave radiation (SWR), approximately half is absorbed by the Earth's surface. The fraction of SWR reflected back towards space by gases and aerosols, clouds, and the Earth's surface (called "albedo") is

What is the IPCC?

The IPCC is a scientific intergovernmental body under the auspices of the United Nations (U.N.). It was initially set up in 1988 at the behest of U.N. member governments by two U.N. agencies, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP), and was later endorsed by the U.N. General Assembly. Membership in the IPCC is open to all members of the WMO and UNEP. The IPCC produces reports that support the United Nations Framework Convention on Climate Change (UNFCCC), which is the main international treaty on climate change. The ultimate goal of this treaty is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (i.e., human-induced) interference with the climate system" (UNFCCC 2014).

The IPCC does not conduct its own original research. Neither does it monitor the climate system or related phenomena such as rising sea levels and shifting terrestrial ecosystems. Rather, the IPCC bases its five-year assessments on the published literature, including both scientific, peer-reviewed journals and non-peer-reviewed publications. Thousands of scientists and other experts from around the world contribute to writing and reviewing reports on a voluntary basis, without payment or other compensation from the IPCC. These reports are then reviewed by member governments. IPCC assessments issued every five years (most recently in 2013-2014) always contain a "Summary for Policymakers." This summary is subject to line-by-line approval by delegates from the governments of all participating countries, more than 120 of them.

The IPCC constitutes an internationally accepted authority on climate change, in that it generates reports representing the considered conclusions of leading climate scientists and the consensus of participating governments.

approximately 30 percent, and about 20 percent is absorbed in the atmosphere. Based on the temperature at the Earth's surface the majority of the outgoing energy flux from the Earth is in the infrared part of the electromagnetic spectrum (IPCC 2013).

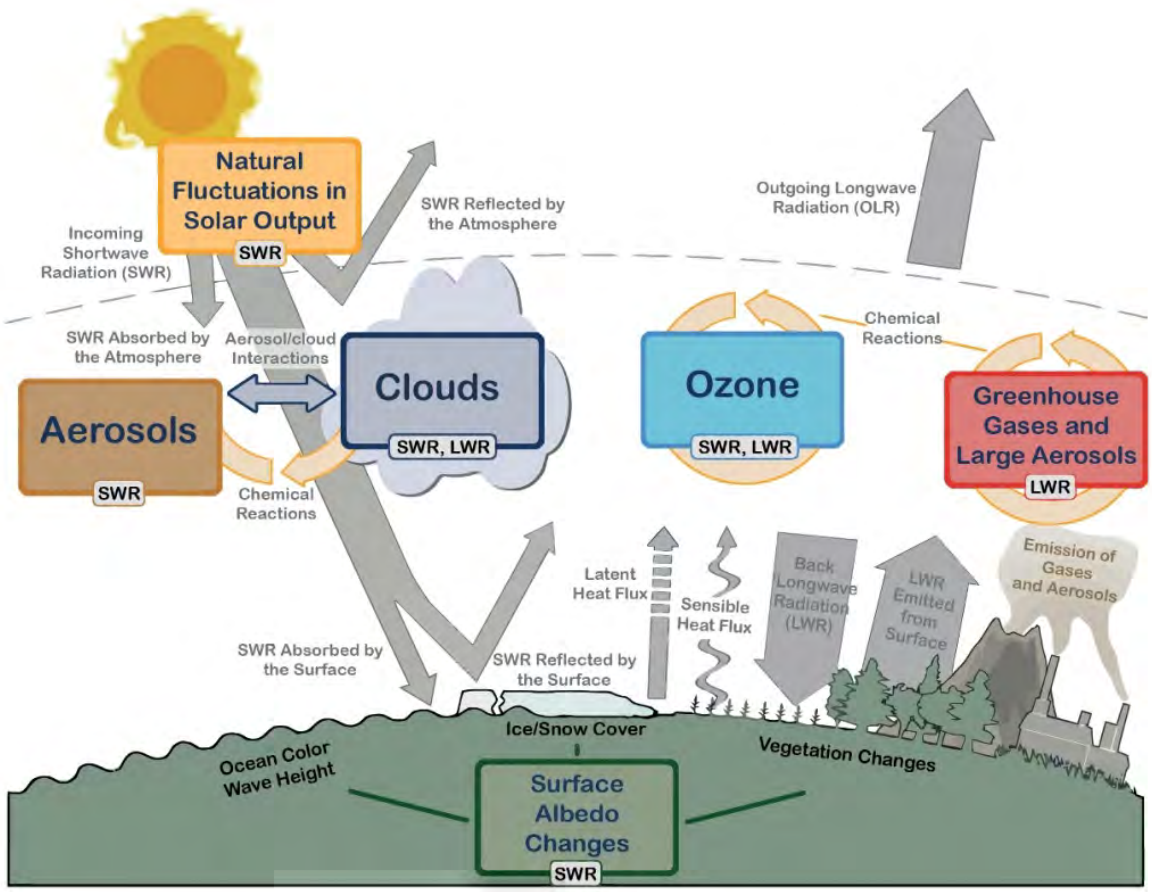


Figure 3-121. The greenhouse effect

Source: IPCC (2013)

This longwave radiation (or LWR, also known as infrared radiation) emitted from the Earth's surface is largely absorbed by certain atmospheric gases, including water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and other greenhouse gases (GHGs), as well as clouds, which themselves emit LWR in all directions. The downward directed component of this LWR adds heat to the lower layers of the atmosphere and to the Earth's surface itself. This is called the "greenhouse effect," because of its broad similarity to what occurs in greenhouse; in winter these are much warmer than the ambient air temperature outside because visible light passes through glass panes and is converted into heat (infrared radiation), which in turn warms the air within the greenhouse (IPCC 2013).

The dominant energy loss of the infrared radiation from the Earth is from higher layers of the troposphere (lowest layer of the atmosphere). The sun pours its radiant energy into the Earth, mainly in the tropics and the subtropics; this energy is then partially redistributed to temperate, polar, and sub-polar latitudes by atmospheric and oceanic transport processes.

The global climate system is an interactive one that consisting of five major components:

- Atmosphere (gaseous components)
- Hydrosphere (liquid components)
- Cryosphere (solid or frozen components)
- Land surface
- Biosphere

These five components are forced or influenced by various external forcing mechanisms, the most important of which is the sun (Figure 3-122). Human activities are also considered an external forcing mechanism on the climate system (Baede et al. 2001).

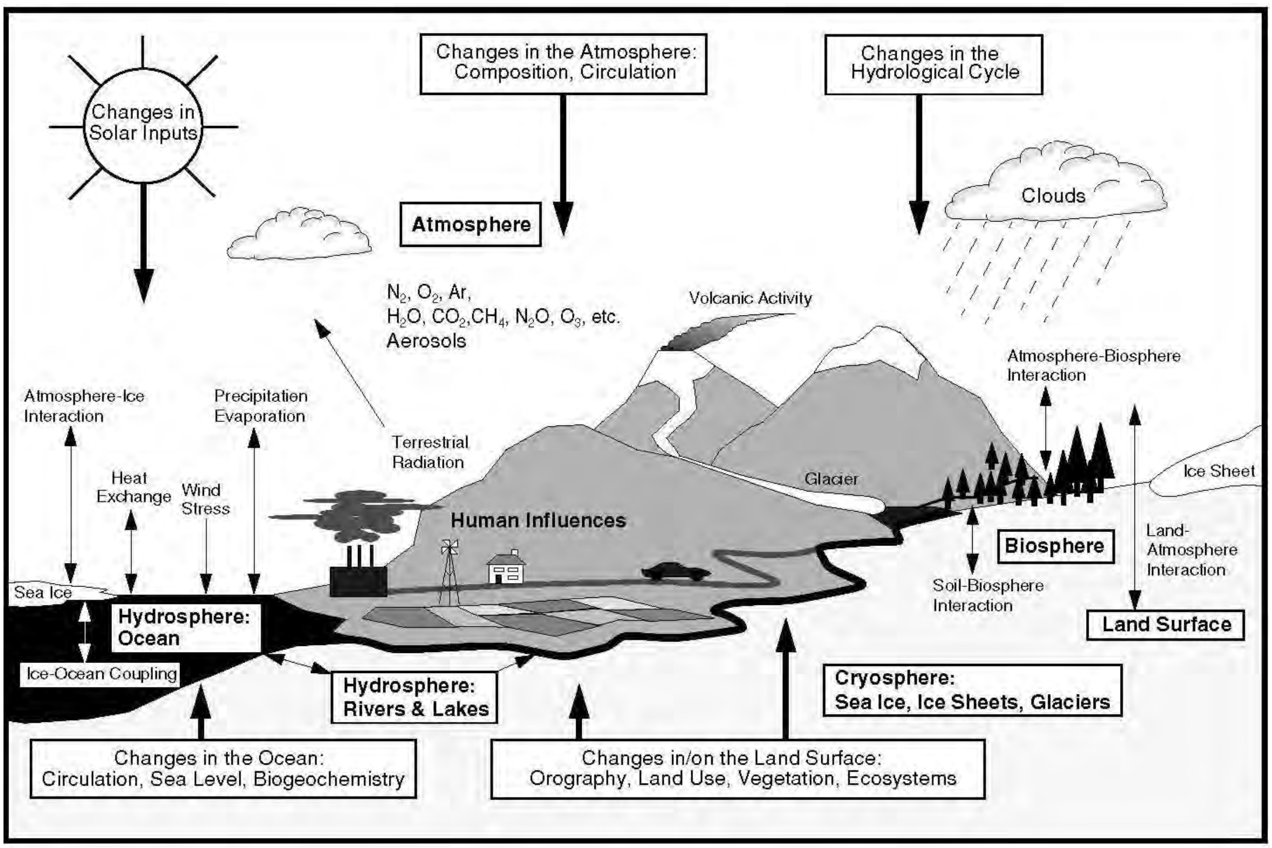


Figure 3-122. Schematic view of the main components of the global climate system
Note: Processes and interactions are represented by thin arrows and some aspects that may change by bold arrows.
Source: Baede et al. (2001)

Atmosphere

The atmosphere is the most dynamic, unstable and rapidly changing part of the climate system. Its composition, which has changed as the Earth has evolved over the geologic ages, is of central importance to the problem of anthropogenic climate forcing. The Earth's dry atmosphere is composed mainly of nitrogen (N_2, 78.1%), oxygen (O_2, 20.9%), and argon (Ar, 0.93%). These gases have only limited interaction with incoming solar radiation and they do not interact at all with outgoing infrared radiation emitted by the Earth. However, the three trace gases mentioned above, namely CO_2, CH_4, and N_2O, as well as a fourth, ozone (O_3), do absorb and emit infrared radiation. These so-called greenhouse gases, with a total volume mixing ratio in dry air of less than 0.1% by volume, play a vital role in the Earth's energy budget (Baede et al. 2001).

Furthermore, the atmosphere contains copious amounts of water vapor, that is, gaseous water (H_2O), which is also a natural greenhouse gas. (Clouds are condensed floating water vapor.) While its volume mixing ratio is highly variable, it is typically in the range of one percent. Because these greenhouse gases absorb the infrared radiation or LWR emitted by the Earth and emit this LWR both upward and downward, they tend to raise the temperature near the Earth's surface. Water vapor, CO_2 and O_3 also absorb solar short-wave radiation.

The distribution of O_3 in the atmosphere and its role in the Earth's energy budget is like no other gas. Ozone in the lower layers of the atmosphere, the troposphere and lower stratosphere, acts as a greenhouse gas, tending to trap LWR and warming the planet. Higher in the stratosphere is a natural layer of relatively high ozone concentration (about 10 parts per million or ppm O_3), the so-called "ozone layer," which absorbs inbound solar ultra-violet (UV) radiation. Thus, the ozone layer plays an essential role in the stratosphere's radiative balance, even as it filters out this damaging form of radiation.

In addition to gases, the atmosphere contains tiny floating solid and liquid particles called aerosols and clouds, which interact with incoming and outgoing radiation in a complex and spatially highly variable manner. The most variable component of the atmosphere is water in its various phases such as vapor, cloud droplets, and ice crystals. Overall, water vapor is the strongest greenhouse gas and is central to the climate and its variability and change (Baede et al. 2001).

Hydrosphere

The hydrosphere is the component of the climate system that comprises all surface and subterranean water in a liquid state, both freshwater, including rivers, lakes and aquifers, and saline water of the oceans and seas. Fresh water runoff from land surfaces returning to the oceans in rivers influences the ocean's composition and circulation. The oceans cover about 70 percent of the Earth's surface area. They store and transport a huge

amount of thermal energy and dissolve and store vast quantities of CO_2. Their circulation, driven by the wind and by contrasts in density from salinity and thermal gradients (the so-called thermohaline circulation), is much slower than the atmospheric circulation. Mainly because of the large thermal inertia of the oceans and the high specific heat of water, the seas functions as a moderator or regulator of the Earth's climate and as a source of natural climate variability, particularly on longer time scales (Baede et al. 2001).

Why Water's Specific Heat Matters

Water has a high specific heat index – it absorbs a substantial amount of heat before it starts to get hot. This is why it is valuable to thermal power plants and automobile radiator as a coolant. The high specific heat index of water also helps moderate the rate at which air changes temperature, which is why the temperature change between seasons is gradual rather than abrupt, especially closest to the oceans.

- USGS (2014i)

Cryosphere

The cryosphere consists of the parts of the Earth's surface where water exists in its frozen state, or ice. It includes the sprawling ice sheets of Antarctica and Greenland, as well continental glaciers and snow fields, sea ice and permafrost. The cryosphere is important to the climate system because of its high reflectivity (albedo) for solar radiation, its low thermal conductivity, its large thermal inertia and, especially, its critical role in driving deep ocean water circulation. Because the ice sheets can store such a large amount of water (more than two-thirds of the world's freshwater is frozen at the present time), variations in the volume of the cryosphere are a potential source of fluctuations in sea level over long periods of time (Baede et al. 2001).

Figure 3-123. Antarctica, part of the cryosphere, stores most of the Earth's freshwater as ice

Land Surface

Soils and vegetation on the land surface affect how incident solar energy is returned to the atmosphere. Some of it is returned as infrared LWR, heating the atmosphere as the land surface warms. Some functions to evaporate water, either in the soil or in the leaves of plants (transpiration or evapotranspiration), lifting water back into the atmosphere. Because the evaporation of soil moisture requires energy, soil moisture has a strong influence on the surface temperature. The land surface's texture (its roughness) affects the atmosphere dynamically as winds blow across it. Roughness is determined both by topography and vegetation. Wind also blows dust from exposed land surfaces into the atmosphere, where these fine particles or aerosols interact with atmospheric radiation (Baede et al. 2001).

Biosphere

Marine and terrestrial ecosystems, in their entirety called the biosphere or ecosphere, also have a big effect on the atmosphere's composition. The Earth's living organisms influence the uptake and release of greenhouse gases. Through the process of photosynthesis, both marine and terrestrial plants (especially forests) take up and store significant amounts of carbon from CO_2 in the air. Thus, the biosphere plays a central role in the carbon cycle, as well as in the budgets and fluxes of many other gases, such as CH_4 and N_2O. Other biospheric and anthropogenic emissions are the so-called volatile organic compounds (VOCs), which may have important effects on atmospheric chemistry and on aerosol formation, and thus on climate. Because the storage of carbon and the exchanges of trace gases are affected by climate, feedbacks between climate change and atmospheric concentrations of trace gases can occur. The influence of climate on the biosphere is preserved and can be studied in fossils, tree rings, pollen and other records. Indeed, much of what we have learned of the features of past climates is derived from the systematic, meticulous study such biotic indicators (Baede et al. 2001).

Interactions

Many physical, chemical and biological interactions between the various components of the climate system take place across a wide range of spatial and temporal scales. This makes the system exceedingly complex. Although components of the climate system differ markedly in their composition, physical and chemical properties, structure and behavior, they are all linked by fluxes of heat, mass, and momentum; all climatic subsystems are open and interrelated.

The atmosphere and the ocean, for instance, are tightly coupled and exchange water vapor and heat, among other things, through evaporation. This is part of the hydrologic cycle and it leads to condensation, cloud formation, precipitation over land and runoff from land back to the sea. It also furnishes energy to weather systems. On the other hand, precipitation affects salinity, its distribution and the thermohaline circulation. The ocean

and the atmosphere also exchange CO_2, among other gases, maintaining a balance by dissolving it in cold polar water, which because of its density, sinks into the deep ocean, and by "outgassing" from relatively warm water upwelling near the equator.

Some other examples of interaction between components of the climate system include (Baede et al. 2001):

- sea ice (cryosphere) hindering the exchanges between atmosphere and oceans;
- biosphere influencing the atmospheric CO_2 concentration by photosynthesis and respiration, which in turn is influenced by climate change;
- biosphere also affecting the input of water into the atmosphere through evapotranspiration and the atmosphere's radiative balance through the amount of sunlight reflected back to the sky (albedo).

Changes in the atmosphere, ocean, land, biosphere and cryosphere – whether natural or anthropogenic or both – can perturb the Earth's radiation budget, resulting in a radiative forcing (RF) with a net effect on climate (IPCC 2013). RF is a measure of the net change in the energy balance due to an external perturbation. The drivers of changes in climate may include, for example, changes in the solar irradiance (the sun's output) and changes in the concentrations of atmospheric trace gases and aerosols concentrations. The RF concept does not capture the interactions of anthropogenic aerosols and clouds. Thus in addition to the RF as used in previous IPCC assessments, the Fifth Assessment released in 2013 and 2014 introduced a new concept, effective radiative forcing (ERF). ERF accounts for rapid response in the climate system. It is defined as "the change in net downward flux at the top of the atmosphere after allowing for atmospheric temperatures, water vapor, clouds and land albedo to adjust, but with either sea surface temperatures (SSTs) and sea ice cover unchanged or with global mean surface temperature unchanged" (IPCC 2013b).

When a forcing is applied to the climate system, complex feedback mechanisms or loops determine its eventual response; usually this response will not be a simple linear one. Many feedback loops in the climate system can either amplify or diminish the effect of a change in forcing. The former are called "positive feedback" and the latter "negative feedback." Figure 3-124 is a schematic of some of the main feedbacks that have been identified in the climate system. One example of a positive feedback is the water vapor feedback, whereby an increase in surface temperature raises the evaporation rate, augmenting the amount of water vapor present in the atmosphere. Water vapor itself is a powerful GHG, so that increasing its atmospheric concentration enhances the greenhouse effect and results in even further surface warming.

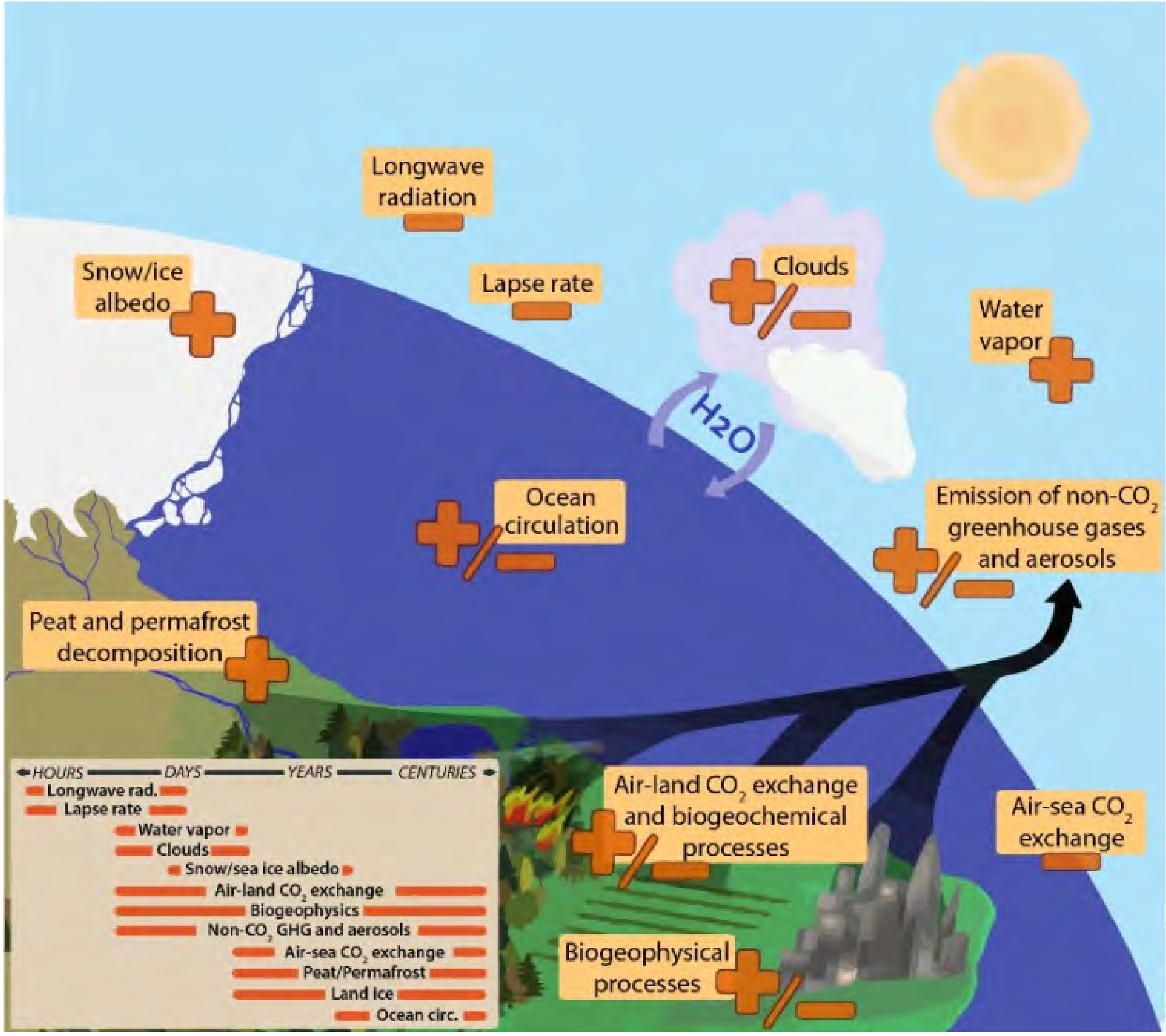


Figure 3-124. Positive and negative feedbacks (and timescales) in the climate system

Source: IPCC (2013b)

Another prominent and particularly troubling example of a positive feedback is the albedo effect from ice. Albedo decreases as highly reflective ice and snow surfaces melt, exposing the darker and more absorptive surfaces (ground, vegetation, or liquid water) below. This is one of the reasons why the documented summer melting of the polar ice cap around the North Pole and the earlier melting of snow in the higher latitudes of Alaska, Canada, and Russia (Siberia) in recent decades is so worrisome (Figure 3-125). In the ocean alone, hundreds of thousands of square miles of darker sea water that are now replacing lighter, brighter, reflective ice in summer months absorb 90 percent of the incident solar radiation, converting it into thermal energy or heat, whereas ice now lost reflected 90 percent of it back toward space. The disappearance of the ice and its replacement by open water contributes to even more warming. This is the essence of positive feedback.

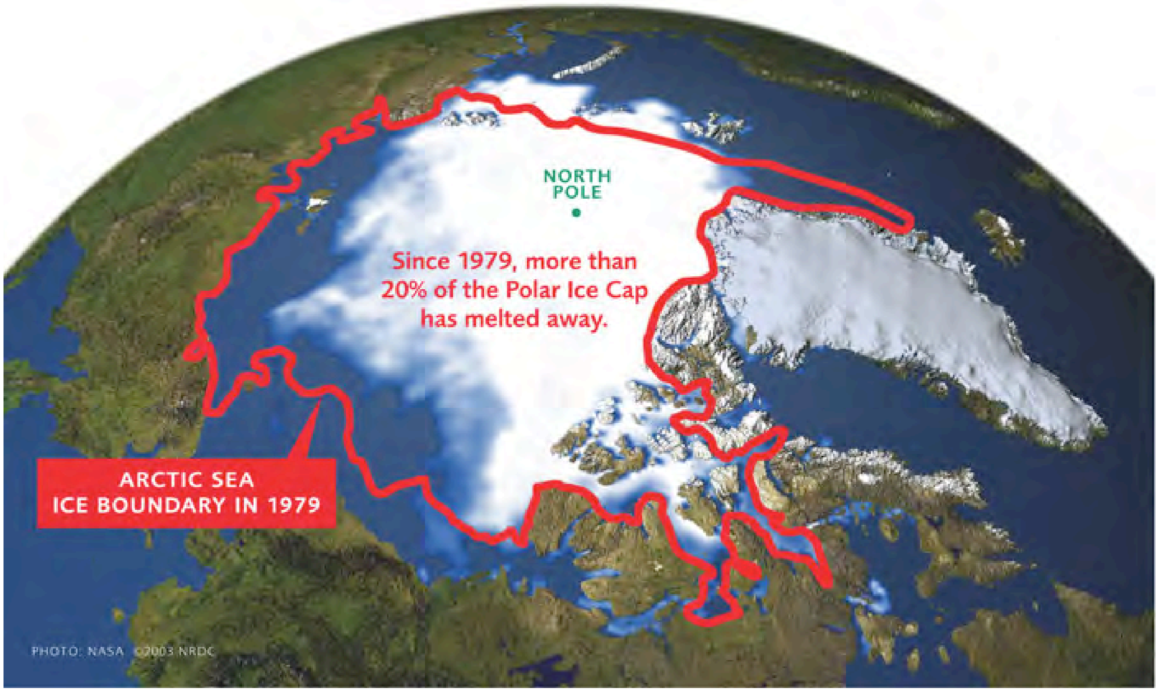


Figure 3-125. Artic sea ice extent from 1979 to 2005. Melting of the summertime polar ice cap in the Arctic Ocean means more open water, a lower albedo effect, and still more warming due to positive feedback

The dominant negative feedback in the Earth's climate system is the increased emission of energy through LWR as surface temperature increases. This is also sometimes called blackbody radiation feedback.

Some feedbacks operate quickly (on a timescale of hours), while others emerge and unfold over decades or even centuries. In order to grasp the full impact of a feedback mechanism, its timescale needs to be considered. The melting of land ice sheets can take place over a period of time ranging from days to millennia (IPCC 2013).

Figure 3-126 shows the relative strength of the various RF components, measured in terms of their net radiative forcing per square meter. On the left side are the various GHGs, which are entirely positive in their effect, and ozone, which has both negative and positive components, but a net positive overall. In the center are albedo and the aerosols. The albedo component has mixed effects while the aerosols are strongly negative – that is, tending to cool the atmosphere rather than warm it. On the right side of the graph is a bar showing the strongly positive net anthropogenic (human-caused) effect on the climate.

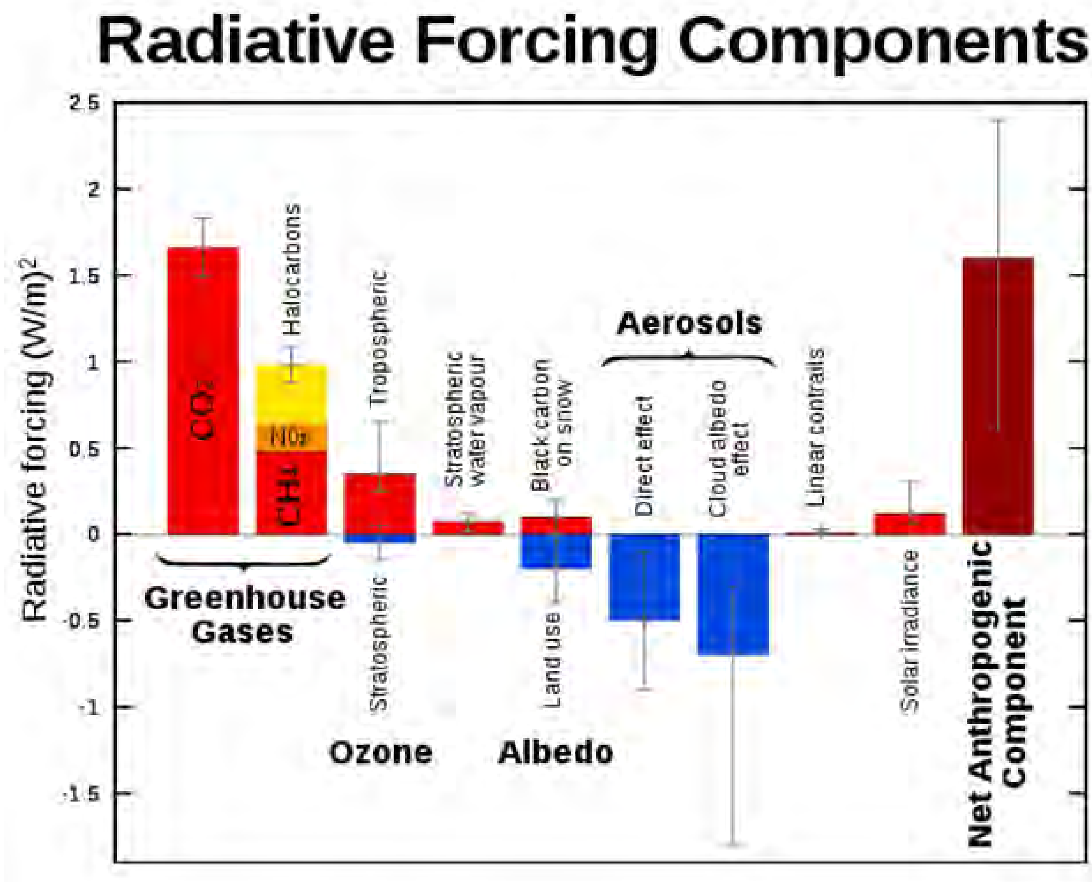


Figure 3-126. Relative strength and net effect of the various radiative forcing components

Recent research by Bjorn Stevens at the Max Planck Institute for Meteorology in Germany suggests that the aggregate negative forcing of aerosols does not exceed −1.0 W m^{-2} (one watt per square meter) (Stevens 2015). Tiny aerosol particles congregate in the highest levels of the atmosphere, where their net effect is to cool the planet. In the process, however, they somewhat counteract or disguise the positive forcing (potential warming) of the GHGs. Thus, climatologists have long been concerned that perhaps aerosols are cooling the planet so much, that in their absence, global temperatures would increase rapidly. It is possible that just such a future could unfold if countries curtail particulate pollution and sulfate aerosols from factories and power plants. However, if the maximum cooling ability of aerosols is only −1.0 W m^{-2}, as Stevens' research indicates, the particles would offset only a third of warming caused by GHGs. In contrast, at the IPCC's earlier maximum cooling value, aerosols would offset two-thirds of the warming (Vaidyanathan 2015).

3.5.1.2 Evidence and Indicators of a Changing Climate

Multiple lines of physical evidence – collected by diverse groups of scientists from many countries using different technologies and published in peer-reviewed scientific journals – all support the hypothesis that the climate is changing:

- *in situ* observations and ice core records that the atmospheric concentrations of GHGs like CO_2, CH_4, and N_2O have increased markedly over the last two centuries;
- instrumental observations show that land and sea surface temperatures have increased over the last century (supported by satellites measurements across a much broader spatial distribution over the last 30 years);
- observations indicate that the temperature of the upper ocean has increased at least since 1950;
- observations from satellites and *in situ* measurements suggest reductions in glaciers, Arctic sea ice and ice sheets;
- radiosonde measurements and satellite retrievals of atmospheric temperature show increases in tropospheric temperature and decreases in stratospheric temperatures, consistent with the increases in GHG effects found in climate model simulations;
- quantitative information on past regional to global climate and atmospheric composition variability provided by resources available prior to the instrumental period, including historical sources, natural archives, and proxies for key climate variables (e.g., tree rings, marine sediment cores, ice cores) (IPCC 2013b).

Table 3-12 summarizes the indicators of the anthropogenic climate change now underway. Warming of the climate system is unequivocal. Since the 1950s, many of the documented changes in the climate have been unprecedented over decades to millennia. The atmosphere and ocean have both warmed (Figure 3-127), amounts of snow and ice have diminished, and sea level has risen (Figure 3-128) (IPCC 2014).

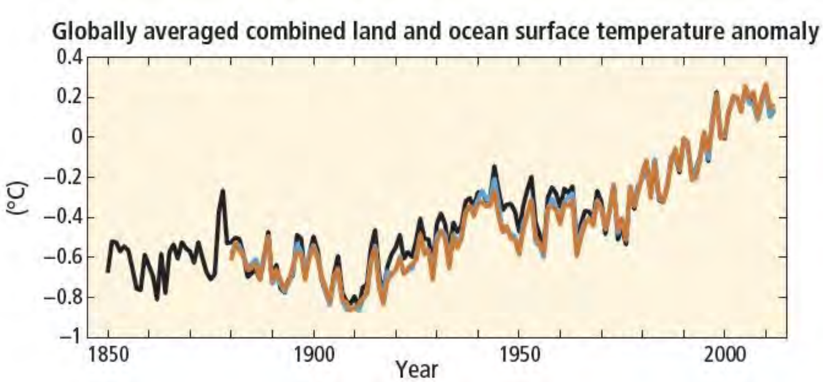


Figure 3-127. Warming of combined land and ocean surface since 1850

Table 3-12. Indicators of climate change

Atmosphere
Stratosphere • Cooling stratospheric temperature • Changes in winter polar vortex strength *Troposphere* • Warming from the surface through much of the troposphere • Long-term changes in large-scale atmospheric circulation, including a poleward shift of jet streams • Increasing concentration of CO_2 and other GHGs from human activities • Changes in cloud cover • Increasing tropospheric water vapor • Changes in aerosol burden and ozone concentrations
Near Surface
• Rising global average near surface temperature • Increasing surface humidity • Warming sea surface temperatures
Ocean
• Warming throughout much of the world's ocean • Increasing rates of global mean sea level rise • Changes in ocean salinity • Acidification of the oceans
Land
• More frequent warm days and nights; fewer cold days and nights • Reductions in the number of frost days • Decreasing snow cover in most regions • Degrading permafrost in areal extent and thickness • Large-scale precipitation changes • Increase in the number of heavy precipitation events
Ice
• Shrinking annual average Arctic sea ice extent • Widespread glacier retreat • Changes in ice sheets in Greenland and Antarctica

Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850 (Figure 3-129). The period from 1983 to 2012 was probably the warmest 30-year period in the last 1,400 years in the Northern Hemisphere, The globally averaged, combined land and ocean surface temperature data, as calculated by a linear trend, show a warming of 0.85°C (1.53°F) over the period 1880 to 2012 (IPCC 2014).

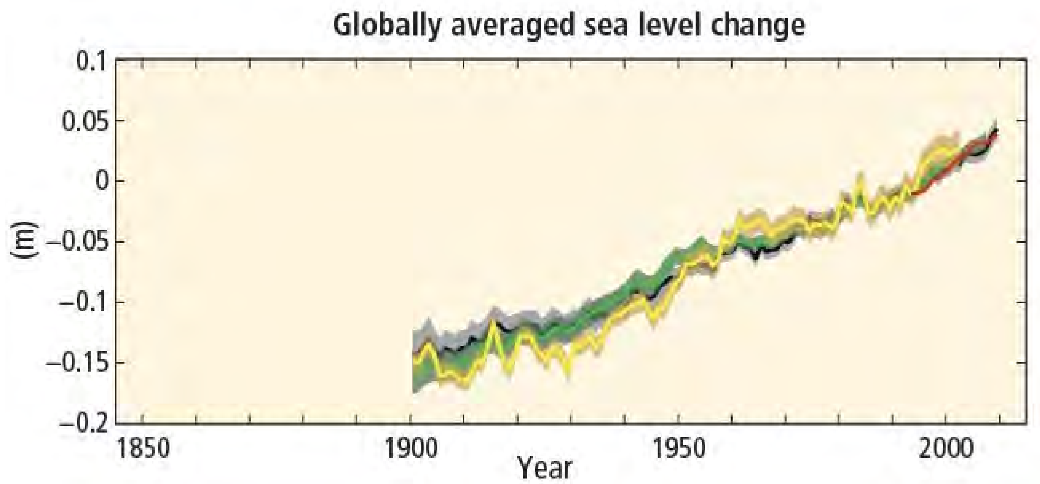


Figure 3-128. Global average sea level rise documented since 1900

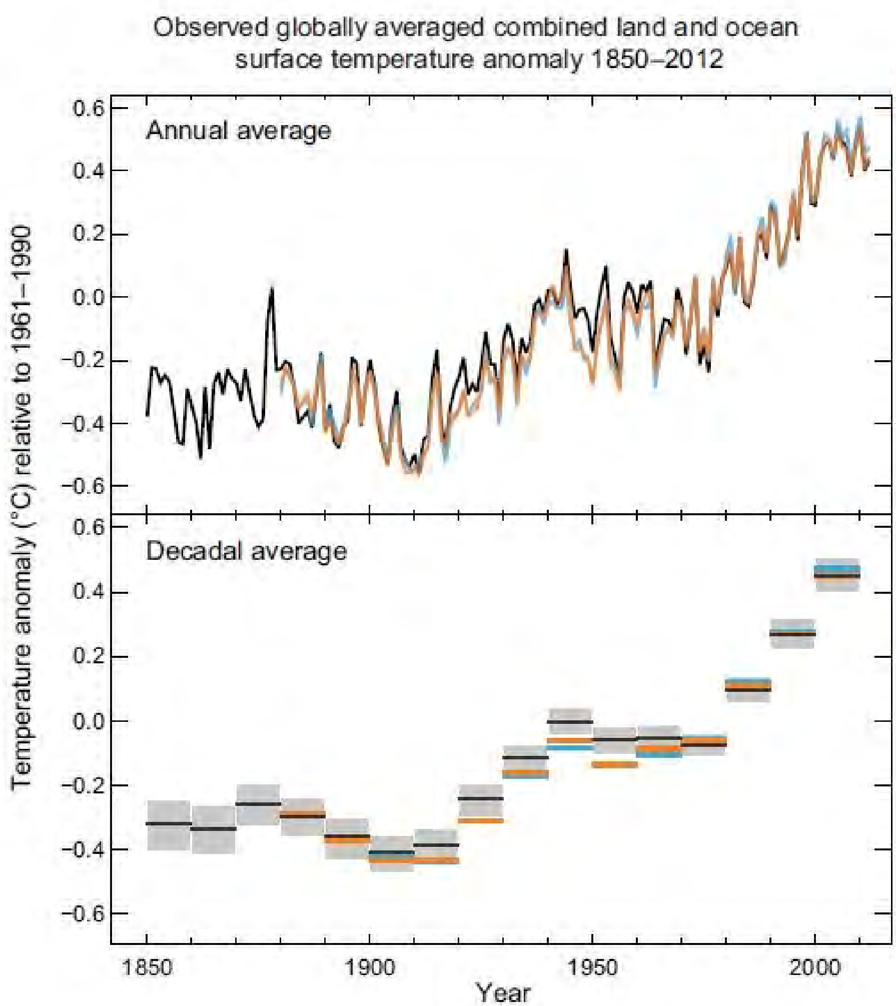


Figure 3-129. Annual average and decadal average changes in global temperature from 1850 to present. There is less random variation (noise) in the decadal averages

In addition to robust long-term warming, the globally averaged surface temperature exhibits substantial decadal and inter-annual (year-to-year) variability. Due to this natural variability, trends based on short periods are highly sensitive to beginning and end dates and do not in general reflect long-term climate trends. This fact has been exploited by "climate contrarians" to discredit global warming. In the case of one frequently cited example, the rate of warming over the 15-year period from 1998 to 2012 of 0.05°C per decade, which began with a strong El Niño year, is smaller than the long-term rate calculated since 1951 of 0.08°C per decade (IPCC 2014).

Ocean warming dominates the increase in total energy stored in the climate system. It accounts for more than 90 percent of the total thermal energy accumulated between 1971 and 2010, compared to only about one percent stored in the atmosphere. On a global scale, ocean warming is greater near the surface, and the upper 75 meters warmed by 0.11°C per decade over the period 1971 to 2010. It is virtually certain that the upper ocean (0−700 meters) warmed from 1971 to 2010, and it likely warmed between the 1870s and 1971 as well (IPCC 2014).

Total precipitation (combined rain and snowfall), averaged over the mid-latitude land areas of the Northern Hemisphere, has increased since 1901. Observations of changes in ocean surface salinity also provide indirect evidence for changes in the global hydrologic cycle over the ocean. Since the 1950s, it is very likely that regions of high salinity, where evaporation dominates, have become even more saline, while regions of low salinity, where precipitation dominates, have become still fresher since the 1950s (IPCC 2014).

Since the beginning of the industrial era, oceanic uptake of carbon dioxide and its conversion to carbonic acid (H_2CO_3) has resulted in acidification of the ocean; the pH of ocean surface water has decreased by 0.1, corresponding to a 26 percent increase in acidity, measured as the concentration of hydrogen ions (IPCC 2014).

Since the start of the industrial revolution, the ocean has absorbed approximately 30 percent of all CO_2 released into the atmosphere by human activity. The ocean continues to acidify at a rate virtually unprecedented in Earth's history. The most recent studies indicate that the rate of change in pH may be faster than at any time in the last 300 million years. Species-specific effects of ocean acidification have already been documented in laboratory and field studies on organisms from the tropics to the poles. Many organisms show adverse impacts (Figures 3-130 and 3-131), such as a reduced ability to create and maintain their shells and skeletons, as well as compromised survival, growth, abundance and larval development. Moreover, evidence suggests that some organisms are able to tolerate ocean acidification, while others, such as certain sea grasses, may even thrive. At current rates of acidification, within decades, large portions

of the polar oceans will become corrosive to the unprotected shells of calcareous marine organisms. The far-reaching effects of ocean acidification are predicted to have implications for marine food webs, biodiversity, aquaculture and hence societies (IGBP et al. 2013). Research has shown that a more acidic environment has dramatic effects on some calcifying species, including oysters, clams, sea urchins, shallow water corals, deep sea corals, and calcareous plankton. When shelled organisms like these are at risk, so is the entire food web (NOAA no date).

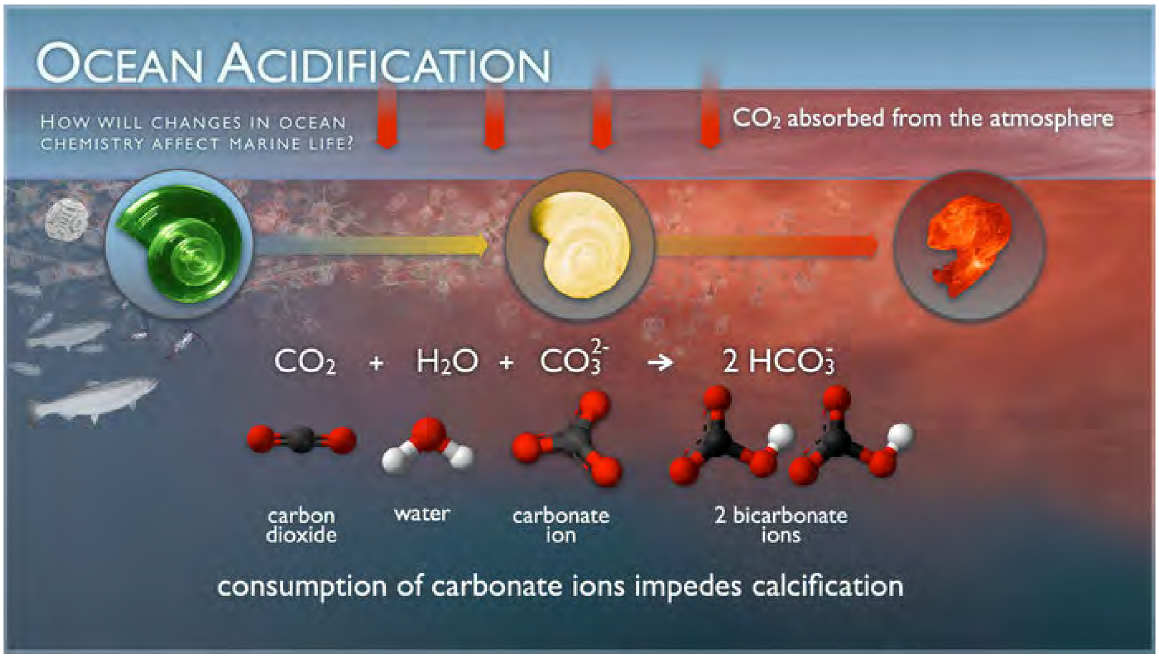


Figure 3-130. Mechanism by which ocean acidification impedes shell formation
Source: NOAA (no date)

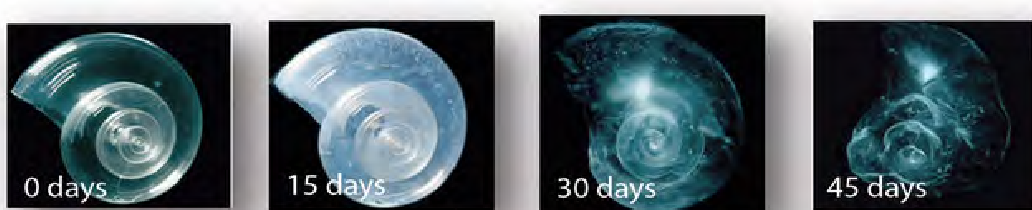


Figure 3-131. Corrosion of pteropod shell in laboratory experiment when exposed to pH and carbonate levels in sea water expected by 2100. Pteropods are an important food source in the marine food pyramid, providing sustenance to organisms ranging from tiny krill to juvenile Pacific salmon and giant baleen whales

Over the period from 1992 to 2011, the Greenland and Antarctic ice sheets have been losing mass, probably at a larger rate over 2002 to 2011. Glaciers have continued to shrivel and retreat almost worldwide and Northern Hemisphere spring snow cover has continued to decrease in extent. Permafrost temperatures have increased in most regions since the early 1980s in response to increased surface temperature and changing snow cover. The annual mean Arctic sea-ice extent decreased over the period 1979 to 2012 (Figure 3-124), at the rate of 3.5 to 4.1% per decade. Arctic sea-ice extent has also decreased in every season and in every successive decade since 1979 (IPCC 2014).

3.5.1.3 Causes of Changing Climate

The Fifth Assessment of the IPCC reports that anthropogenic GHG emissions have increased dramatically since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has resulted in atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are without precedent in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of the observed warming since the mid-20th century (IPCC 2014).

Figure 3-132 shows increasing anthropogenic GHG emissions (measured in terms of CO_2-equivalent warming potential) between 1970 and 2010. It is noteworthy that from 1970 to 2000, annual emissions increased on average by 1.3%; from 2000 to 2010, they increased by nearly twice that rate, 2.2% annually.

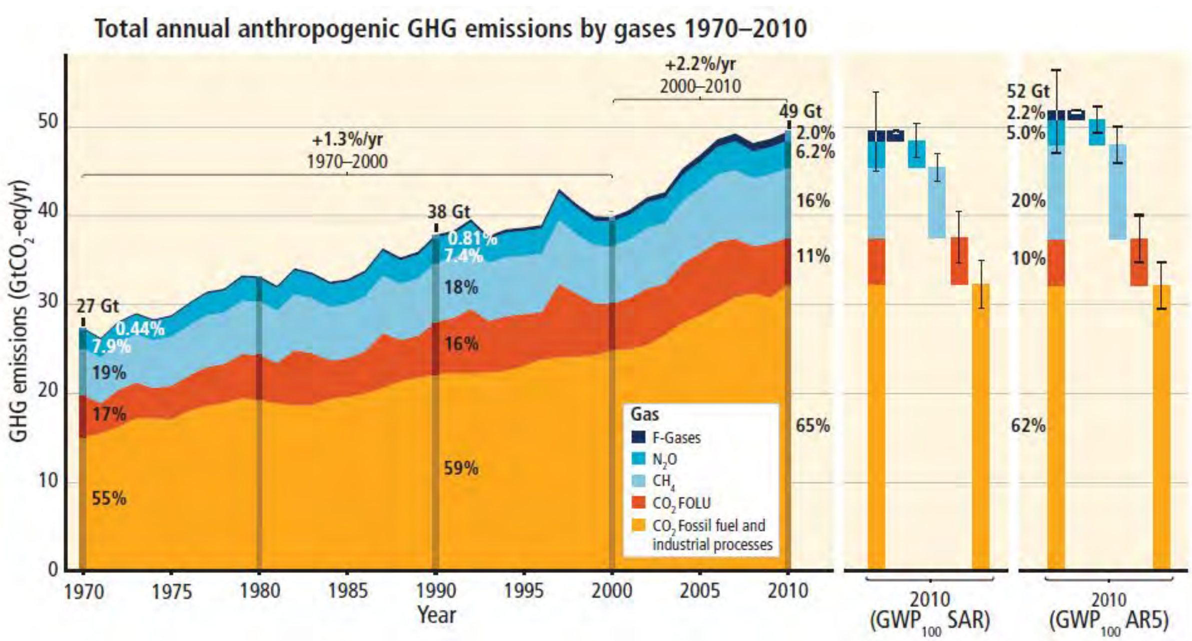


Figure 3-132. Anthropogenic GHG emissions from 1970 to 2010

GHG emissions since the pre-industrial era have driven large increases in the atmospheric concentrations CO_2, CH_4 and N_2O. Between 1750 and 2011, cumulative anthropogenic CO_2 emissions to the atmosphere were approximately 2,040 gigatons (Gt or billon tons). About 40 percent or 880 Gt of these emissions have remained in the atmosphere; the remainder was sequestered from the atmosphere and stored either on land (in plants and soils) or in the ocean. The ocean has absorbed about 30 percent of the emitted anthropogenic CO_2, causing the ocean acidification described above. Approximately half of the anthropogenic CO_2 emissions between 1750 and 2011 have occurred just in the most recent 40 years (IPCC 2014).

Total anthropogenic GHG emissions have continued to increase from 1970 to 2010, with larger absolute increases between 2000 and 2010. This has occurred in spite of growing political and social awareness of the problem and a growing number of climate change mitigation policies. Anthropogenic GHG emissions in 2010 have reached 49 Gt CO_2eq/year. Emissions of CO_2 from fossil fuel combustion and industrial processes contributed approximately 78 percent of the total GHG emissions increase from 1970 to 2010, with a similar percentage contribution for the increase during the period 2000 to 2010. Globally, population and economic growth continued to be the most important drivers of increases in CO_2 emissions from fossil fuel combustion. The contribution of population growth between 2000 and 2010 remained roughly identical to the previous three decades, while the contribution of economic growth has risen sharply. Increased use of coal to generate electricity has reversed the long-standing trend of gradual "decarbonization," that is, reducing the carbon intensity of energy (the amount of energy used to produce a dollar of GDP) (IPCC 2014).

The IPCC deems it *extremely likely* [emphasis theirs] that: "more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in GHG concentrations and other anthropogenic forcings together." The best estimate of the human-induced contribution to warming is similar to the warming actually observed over the 1951-2010 period (Figure 3-133).

Anthropogenic forcings have probably contributed substantially to surface temperature increases since the mid-20th century over every continent but Antarctica. Anthropogenic influences have also likely affected the global water cycle since 1960, contributed to the retreat of glaciers since the 1960s, and accelerated surface melting of the Greenland ice sheet since 1993. Human GHG emissions have "very likely" contributed to Arctic sea-ice loss since 1979 and have "very likely" made a substantial contribution to increases in global upper ocean heat content (IGCC 2014).

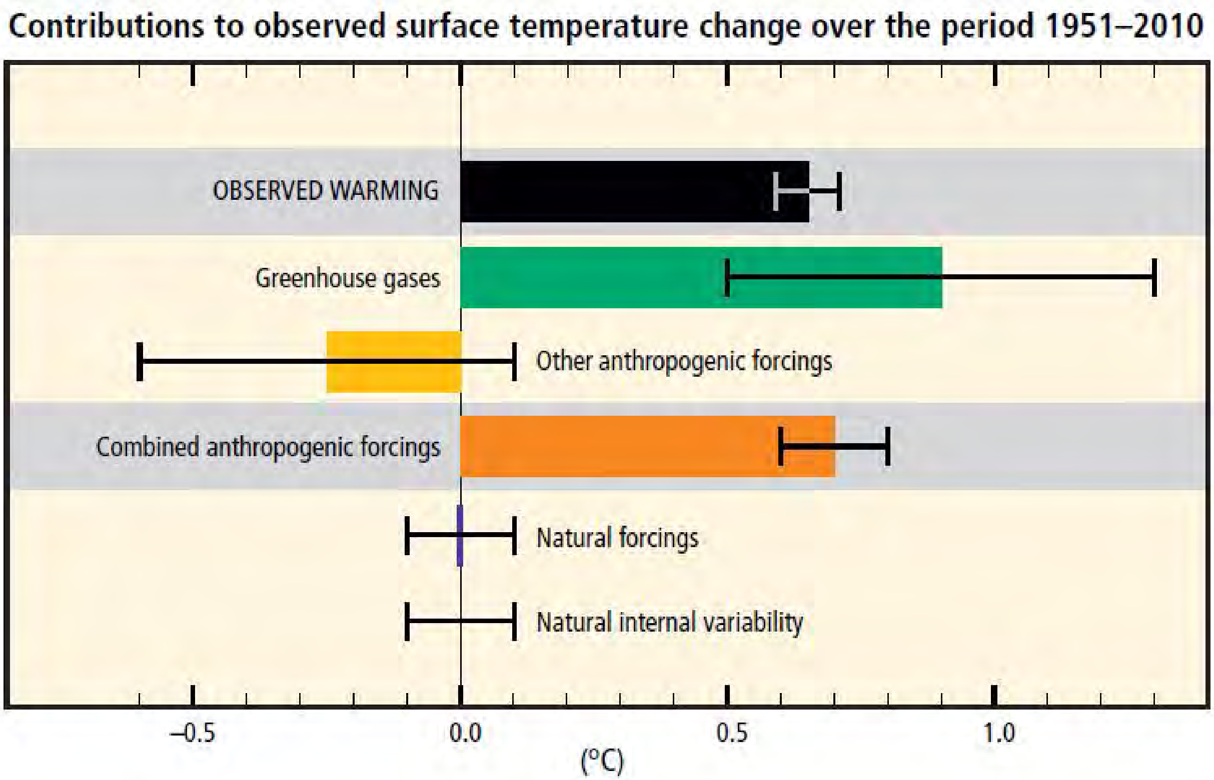


Figure 3-133. Contributing factors to observed surface temperature change, 1951-2010

3.5.1.4 Global Impacts of Climate Change

In recent decades, climatic changes have affected both natural and human systems on all continents as well as all oceans. These widespread impacts are due to observed climate change, regardless of its cause. They are a sign of the exquisite sensitivity of both natural and human systems to a changing climate.

The evidence of documented climate change impacts is most compelling and comprehensive for natural systems. In many regions, melting snow and ice and changing precipitation patterns are altering underlying hydrological systems, affecting the quantity, quality, and availability of water resources. Many terrestrial, freshwater and marine organisms have shifted their geographic ranges, seasonal activities, migration, abundance and interactions with other species in response to ongoing climate change (Figures 3-134 and 3-135). Some impacts on human systems have also been attributed to climate change, with a minor or major contribution of climate change discernable from other influences. Adverse effects of climate change on crop yields have been more common than positive effects. Some impacts of ocean acidification on marine organisms have already been attributed to human influence (IPCC 2014).

Figure 3-134. Polar bears dependent of disappearing ice have become the "poster children" of climate change's deleterious impacts on wildlife and natural ecosystems

Figure 3-135. Atlantic puffins nesting on the coast of Maine may already be adversely affected by changes in sea temperature, which may be responsible for the paucity of Atlantic herring, their main food source. On the opposite side of the Atlantic, in contrast, puffin populations may be benefiting from greater food availability, which is also an indirect function of climate change.

Extreme weather and climate events have been observed with greater frequency since about 1950. Some of these events have been linked to human influences, including a decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events in a number of regions (IPCC 2014).

The IPCC considers it "very likely" that, on a global scale, the number of cold days and nights has decreased and the number of warm days and nights has increased. It is also likely that the frequency of heat waves has increased in large parts of Europe, Asia and Australia. Peer-reviewed analysis places the death toll from the horrific summer 2003 European heat wave, centered in France, at 70,000 (Robine et al. 2008).

There are likely more land regions where the number of heavy precipitation events – storms and snowstorms – has increased than where it has decreased. Recent observation of increasing trends in extreme precipitation and discharge in some hydrologic basins implies greater risks of flooding at a regional scale. Flooding along the Mississippi River in 2011 was among the largest and most damaging in the past century, comparable to major floods in 1927 and 1993. Also in 2011, at least 360 people were killed, and some 5.3 million people displaced, by flooding from extreme monsoon rains in Pakistan.
It is likely that extreme sea levels such as those experienced from storm surges have increased since 1970; this is mainly a result of rising sea level (IPCC 2014).

The dramatic and sometimes catastrophic impacts from recent climate-related extremes, such as heat waves, droughts, floods, cyclones, hurricanes, and wildfires, reveal the vulnerability of some ecosystems, human settlements, and agriculture to extreme climate variability (Figures 3-136, 3-137, and 3-138).

Figure 3-136. Wildfires light up the night sky in Southern California

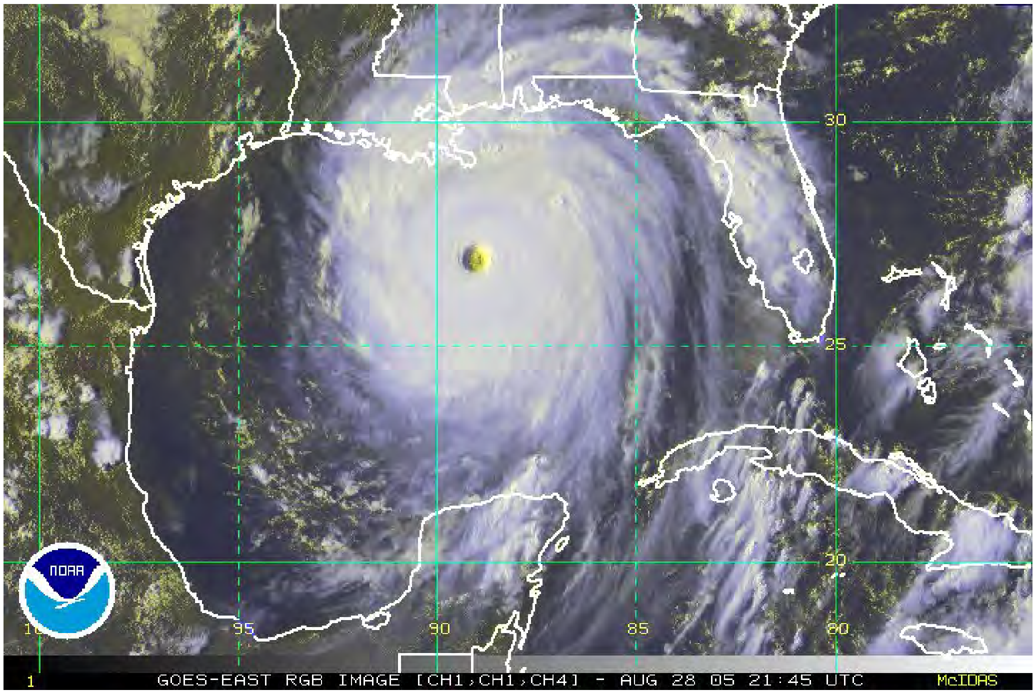


Figure 3-137. The eye of Hurricane Katrina in the Gulf of Mexico, 2005. At least 1,833 people died in this hurricane and subsequent flooding.

Figure 3-138. Destruction from Hurricane Katrina – US 90 between Ocean Springs and Biloxi, Mississippi

3.5.1.5 Projected Future Climate Change

The Earth's future climate will depend both on committed warming caused by past anthropogenic emissions, as well as additional warming from future anthropogenic emissions and natural climate variability. Under all emission scenarios, Earth's surface temperature is projected to rise over the 21st century. The IPCC considers it very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level will rise throughout the century and well beyond.

Continued emission of greenhouse gases will cause more warming and long-lasting changes in all components of the climate system. This in turn will increase the likelihood of severe, widespread, and irreversible impacts for both humanity and the biosphere. Limiting climate change would require substantial and sustained reductions in GHG emissions which, together with adaptation, can limit climate change risks (IPCC 2014).

Cumulative emissions of CO2 largely determine global mean surface warming by the late 21st century and beyond. Projections of greenhouse gas emissions vary over a wide range, depending on both socio-economic development and climate policy.

The main drivers of anthropogenic GHG emissions are population size, economic activity, energy use, land use patterns, lifestyle, technology, and climate policy. The IGG prepared Representative Concentration Pathways (RCPs), which they used to make projections based on these factors. The RCPs describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5) (IPCC 2014).

Scenarios without additional efforts to constrain emissions, or the so-called "baseline scenarios," lead to pathways ranging between RCP6.0 and RCP8.5 (Figures 3-139 and 3-140). RCP2.6 represents a scenario that aims to keep global warming below 2°C above pre-industrial temperatures. The RCPs are consistent with a wide range of scenarios published in the scientific literature in recent years. Many lines of evidence point to a consistent, nearly linear relationship between cumulative CO_2 emissions and projected global temperature change to the year 2100. Any given level of warming is associated with a range of cumulative CO_2 emissions, and therefore, e.g., higher emissions in earlier decades imply lower emissions later on (IPCC 2014).

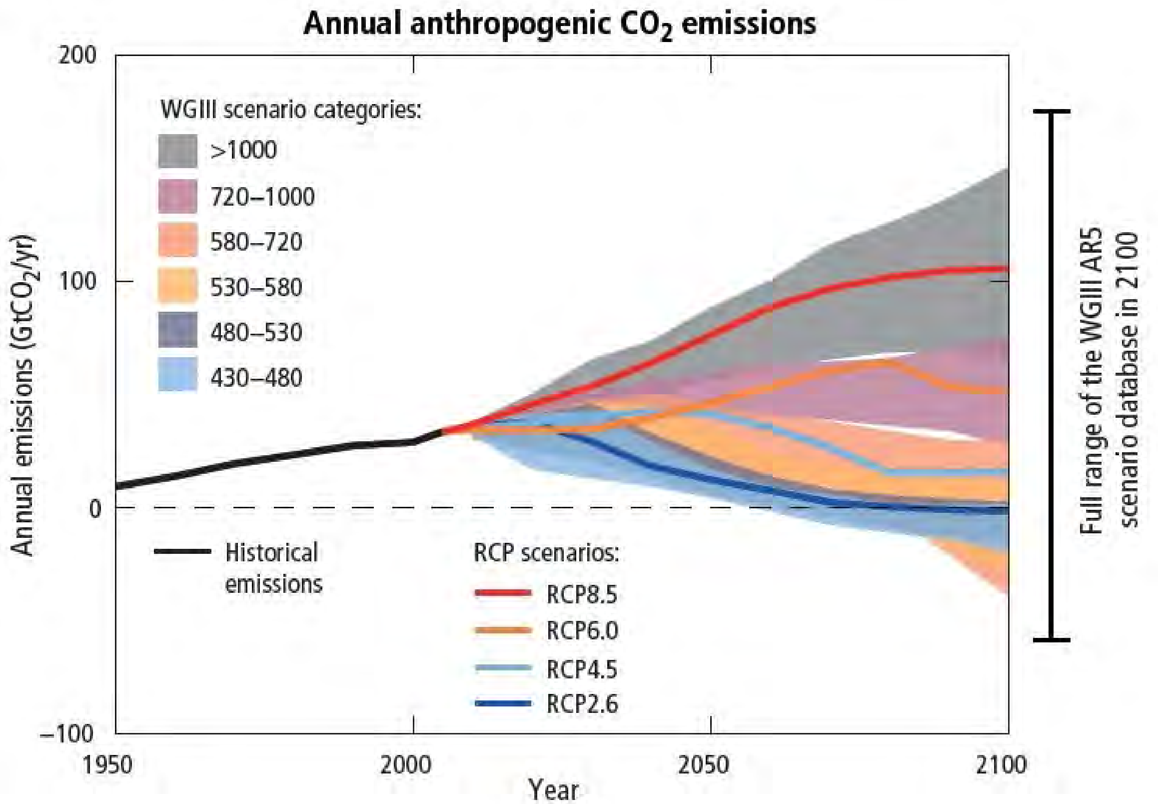


Figure 3-139. Annual anthropogenic CO_2 emissions under different scenarios and resulting atmospheric CO_2 concentrations (in parts per million)

Note: Emissions of CO_2 alone in the RCPs (lines) and the associated scenario categories (atmospheric CO_2 in ppm) used by IPCC's Working Group (WG) III (colored areas show 5 to 95% range). The WGIII scenario categories summarize the wide range of emission scenarios published in the scientific literature and are defined on the basis of CO_2-eq concentration levels (in ppm) in 2100.
Source: IPCC (2014)

The global mean surface temperature change for the 2016–2035 period relative to the 1986–2005 period is similar for the four RCPs, and will likely be in the range of 0.3°C to 0.7°C. This assumes that there will be no major volcanic eruptions or changes in some natural sources (e.g., CH_4 and N_2O), nor unanticipated changes in total solar output and irradiance. By the mid-21st century, the magnitude of projected climate change is substantially affected by the choice of emissions scenario (IPCC 2014).

Multi-model results show that limiting total human-induced warming to less than 2°C compared to the period 1861–1880 with a probability greater than 66 percent would require cumulative CO_2 emissions from all anthropogenic sources since 1870 to remain below the threshold of about 2900 $GtCO_2$ (with a range of 2550 to 3150 $GtCO_2$ depending on non-CO_2 drivers). Humanity's collective actions over the last century and a half had already emitted about 1900 $GtCO_2$ cumulatively by 2011 (IPCC 2014).

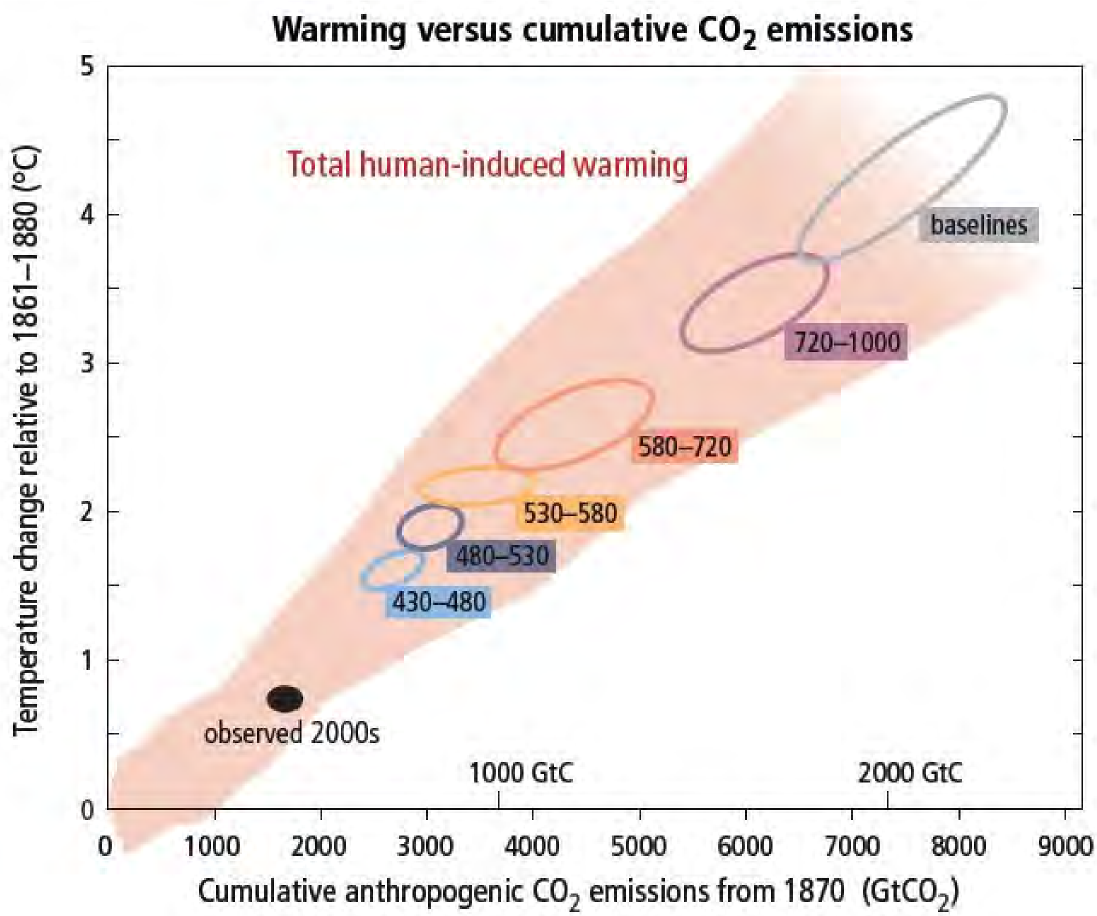


Figure 3-140. Cumulative anthropogenic CO_2 emissions and resultant warming

Note: Global mean surface temperature increase at the time global CO_2 emissions reach a given net cumulative total, plotted as a function of that total, from various lines of evidence. Colored plume shows the spread of past and future projections from a hierarchy of climate-carbon cycle models driven by historical emissions and the four RCPs over all times out to 2100, and fades with the decreasing number of available models. Ellipses show total anthropogenic warming in 2100 versus cumulative CO_2 emissions from 1870 to 2100 from a simple climate model (median climate response) under the scenario categories used in WGIII. The width of the ellipses in terms of temperature is caused by the impact of different scenarios for non-CO_2 climate drivers. The filled black ellipse shows observed emissions to 2005 and observed temperatures in the decade 2000–2009 with associated uncertainties.

Source: IPCC (2014)

Relative to the 1850–1900 period, global surface temperature change in the last two decades of 21st century (2081–2100) is expected to exceed 1.5°C for several scenarios (RCPs) and to surpass 2°C for a couple of scenarios. The Arctic region will continue to warm more rapidly than the global mean. As global mean surface temperature increases, it is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales. It is very likely that heat waves will occur with a higher frequency and longer duration, although occasional cold

winter extremes will continue to occur (IPCC 2014). Figures 3-141 and 3-142 show the ranges of projected warming and sea level rise under the various emissions scenarios.

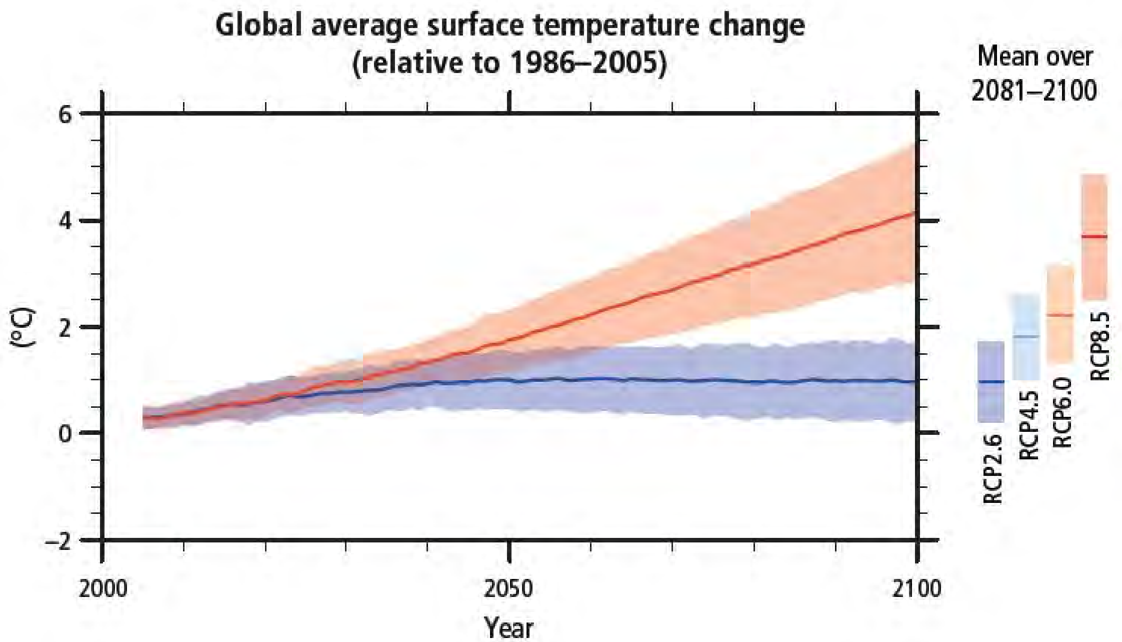


Figure 3-141. Range of projected warming

Note: All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as colored vertical bars at the right hand side of each panel.

Changes in precipitation will not be uniform across the globe. Higher latitudes and the equatorial Pacific are expected to experience an increase in annual mean precipitation under the RCP8.5 scenario. In many mid-latitude and subtropical dry regions, mean precipitation will likely decrease, while in many mid-latitude wet regions, mean precipitation will likely increase under the RCP8.5 scenario. Extreme precipitation events (storms and snowstorms) over most of the mid-latitude land masses and over wet tropical regions are very likely to become more intense and more frequent (IPCC 2014).

As stated above, the ocean will continue to warm throughout the 21st century and beyond, with the strongest warming projected for the surface in tropical and Northern Hemisphere subtropical regions. There will be a global increase in ocean acidification for all emissions scenarios by the end of the 21st century, with a slow recovery after mid-century under RCP2.6 (the stringent mitigation scenario). Under the most optimistic emissions scenarios, ocean surface acidity would increase 15-17%, while under the most pessimistic scenarios, acidity would increase from 100 to 109%.

Figure 3-141 shows projected changes in average surface temperature and average precipitation under two opposite emissions scenarios.

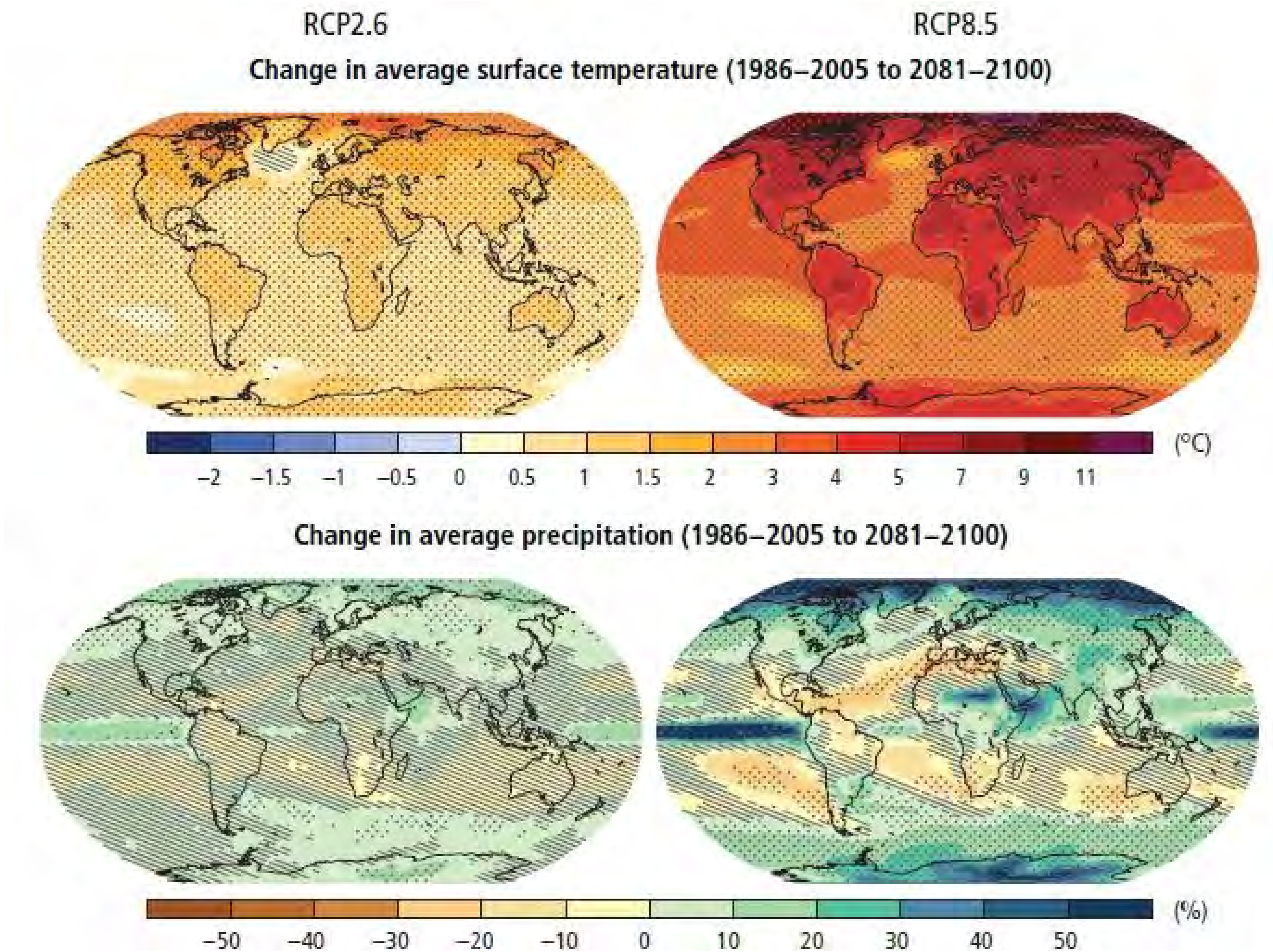


Figure 3-142. Projected changes in average global surface temperatures and average precipitation under two opposite emissions scenarios (RCPs)

The IPCC projects year-round reductions in Arctic sea ice for all emissions scenarios. A nearly ice-free Arctic Ocean in the summer before mid-century is likely for the highest emissions scenarios. It is virtually certain that near-surface permafrost extent at high northern latitudes will be reduced, with the area of permafrost near the surface projected to decrease by 37 percent even under mid-range emissions scenarios. The global volume of glaciers, excluding those on the periphery of Antarctica (and excluding the Greenland and Antarctic ice sheets), is projected to decrease by 15 to 85 percent, depending on the emissions scenario that comes to pass (IPCC 2014).

The IPCC emphasizes that climate change will amplify existing risks and create new ones for both natural and human systems. For human societies, such risks are not evenly distributed; in general, poorer countries are more vulnerable to the vagaries of climate change than richer ones, and within any given country, poorer people more at risk than richer people.

By way of example, the disadvantaged in developing (poorer) countries often live next to or on river banks or within floodplains, where they have ready access to (often contaminated) water for cooking and cleaning, but where they are also more exposed to flooding from the kinds of extreme weather events such as hurricanes and cyclones anticipated to occur with greater frequency and ferocity as the climate continues to warm (Figure 3-143).

Figure 3-143. Caving banks crumble into river water swirling around a char – an unstable island of shifting silt on which poor Bangladeshis live

For instance, millions of poverty-stricken Bangladeshis live on unstable, shifting islands of silt and sediment within river distributaries, known as "chars." Bangladesh is dominated by the low-lying deltas of the Ganges, Brahmaputra and Meghna rivers, collectively called the Gangetic Delta. Bangladesh is the size of Iowa – about 56,000 square miles – but against Iowa's population of 3 million, 157 million are crowded into Bangladesh at a density of 2,700 per square mile, by far the densest of any large country in the world. When a cyclone struck Bangladesh (then called East Bengal) in November 1970, an estimated half-million people perished.

At the time of this cyclone four decades ago, the population of Bangladesh was less than half of what it is today, yet it was already woefully overpopulated. That is why many of its vulnerable, underprivileged multitudes had, and have, little choice but to live at sea level on a floodplain exposed to regular inundation and the fury of tropical storms.

The risk of climate-related impacts results from the interaction between climate-related hazards and human and natural systems. These systems vary in their vulnerability and their capacity for adaptation. Increased warming and other changes in the climate system, including ocean acidification, raise the risk of severe, pervasive and in some cases permanent adverse impacts. Some risks are specific to certain regions while others are global. The overall magnitude of risk that future climate change presents can be reduced by limiting both the rate and ultimate magnitude of climate change. The precise levels of climate change sufficient to reach "tipping points" that may trigger abrupt and irreversible change remain uncertain, but the risk associated with crossing such thresholds increases with rising temperature (IPCC 2014).

Figure 3-144 is a graphic in which the IPCC rates the relative future risks associated with a changing climate for physical, biological, human, and managed systems (e.g., croplands, rangelands, forestry, fisheries) for different regions around the world. The risk levels are rated from very low through medium to very high for the present, near term (2030 to 2040), and long term (2080 to 2100) at two degrees Celsius warming and four degrees Celsius warming, respectively. The potential for additional adaptation to risk a given risk is also considered in the diagram.

A large number of species of plants and animals in the wild face a higher and rising risk of extinction because of climate change during and beyond the 21st century, especially as climate change interacts, perhaps synergistically, with other anthropogenic stressors, such as habitat destruction and fragmentation, invasive species, contamination, and overharvest/poaching. Most plant species cannot naturally shift their geographical ranges rapidly enough to keep up with current and high projected rates of climate change in most landscapes; most small mammals and freshwater mollusks will not be able to keep up at

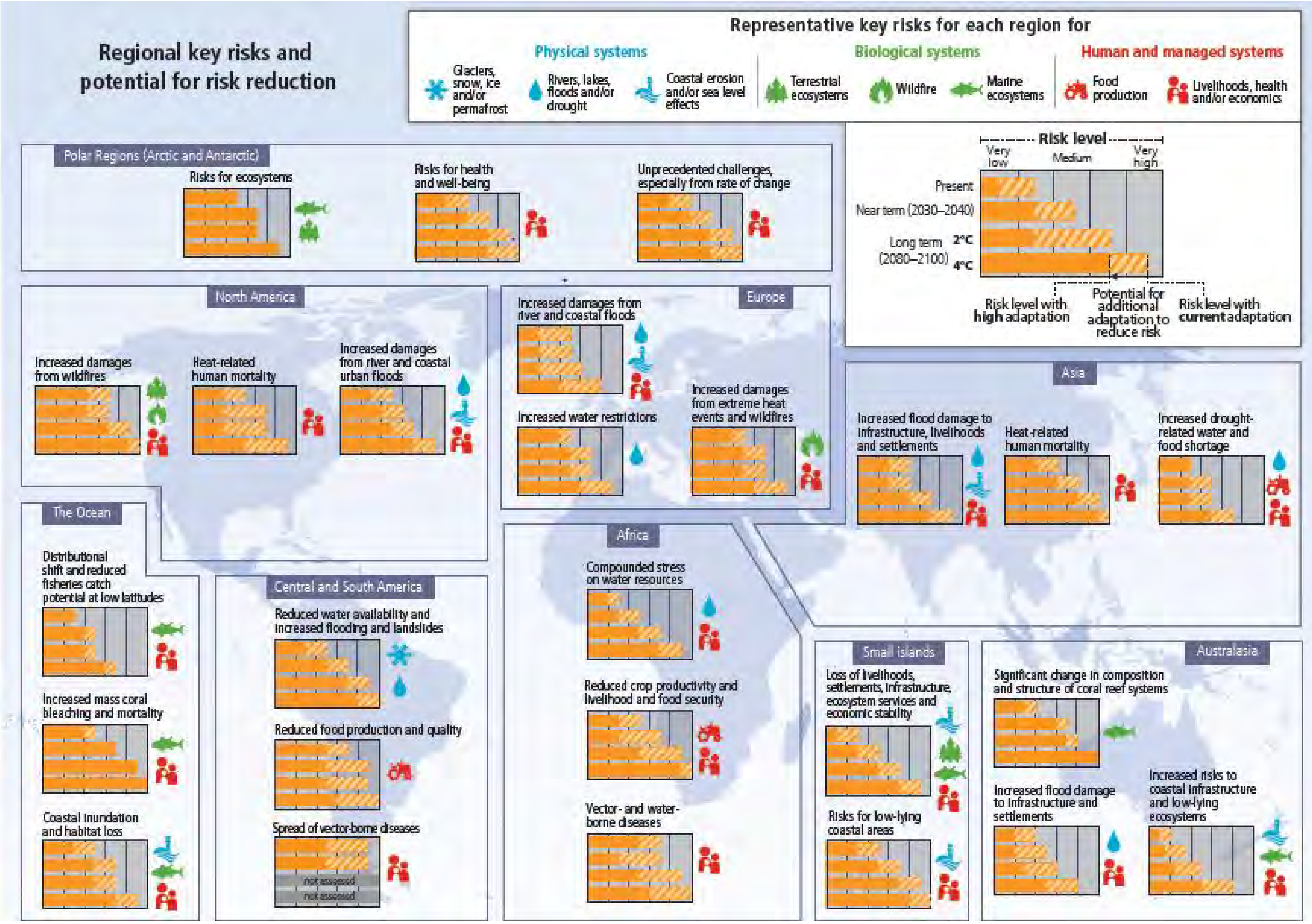


Figure 3-144. Future potential risks associated with climate change, by region

Source: IPCC (2014)

the rates projected under RCP4.5 and above in flat landscapes in this century. Future risk is indicated to be high by the observation that natural global climate change at rates lower than current anthropogenic climate change has caused significant ecosystem shifts and species extinctions during the geologic past. Marine organisms will confront progressively lower oxygen levels and high rates and magnitudes of ocean acidification, along with associated risks exacerbated by rising ocean temperature extremes. Coral reefs and polar ecosystems in particular are highly vulnerable. Coastal systems and low-lying areas such as mangroves, Louisiana's wetlands, and salt marshes are at risk from sea level rise, which will continue for centuries even if the global mean temperature is stabilized later in this century (IPCC 2014).

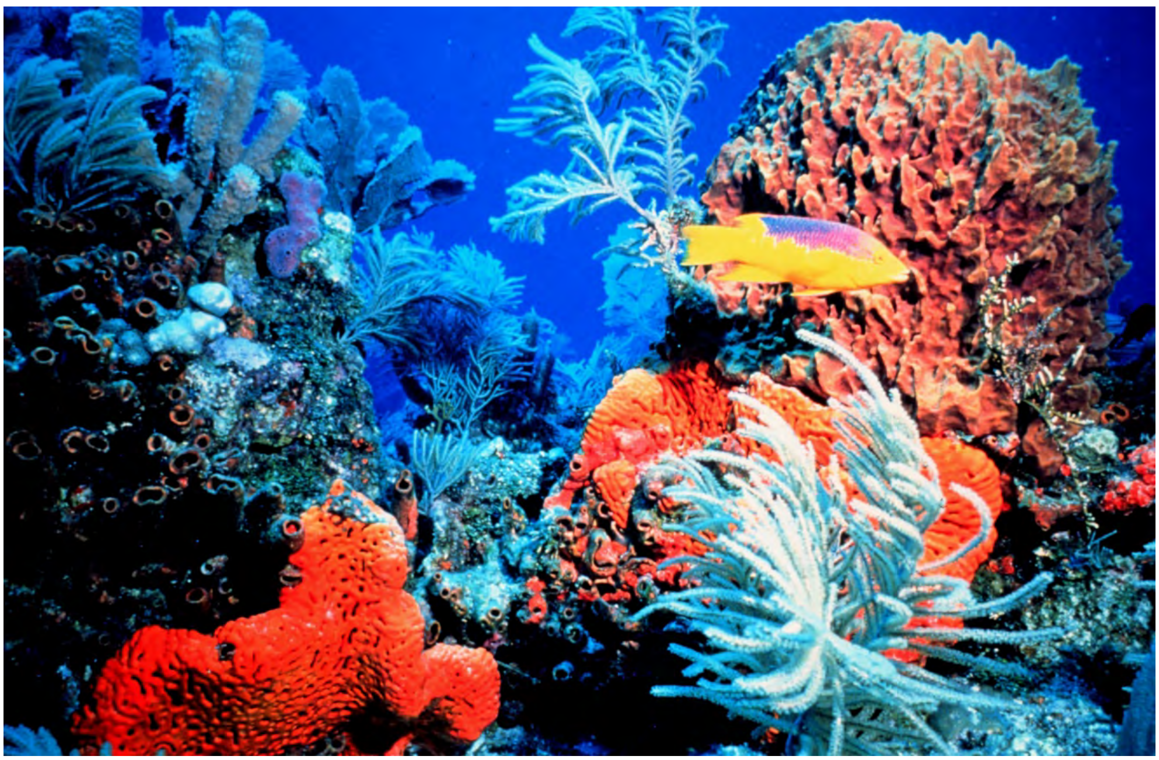


Figure 3-145. Highly biodiverse coral reefs are at risk worldwide from climate change and its resulting marine effects, including rising ocean temperatures and increasing acidification

Climate change is projected to increasingly undermine food security from both the sea and land as the current century progresses. At sea, due to projected climate change by the mid-21st century and beyond, redistribution of global marine species and reduction of marine biodiversity in the most sensitive regions will threatened the sustained yield of important commercial and subsistence fisheries. At land, for key grains such as wheat, rice and maize (corn) in both tropical and temperate regions, climate change without adaptation is projected to adversely affect production for local temperature increases of 2°C or more above late 20th century levels, although certain regions could benefit. Global temperature increases of approximately 4°C or more above late 20th century

levels, combined with increasing food demand, would pose large risks to food security on a global scale. Climate change is projected to reduce renewable surface water and groundwater resources in most dry subtropical regions; this in turn will intensify competition for water among agricultural, industrial, and municipal sectors (IPCC 2014).

Until the middle of the century, projected climate change will impact human health mainly by exacerbating already existing health problems. Throughout the 21st century, climate change is anticipated to lead to increases in ill health in many regions and especially in low-income developing countries. By 2100, under the highest emission scenarios, the combination of high temperature and humidity in some regions for parts of the year is expected to compromise everyday human activities, including growing food and working outside. In urban areas climate change is projected to increase risks for people, their assets, economies and ecosystems, including risks associated with heat stress, storms and extreme precipitation, both inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surges. These risks are exacerbated for those disadvantaged communities lacking essential infrastructure and services or living in exposed areas such as floodplains or steep hillsides (IPCC 2014). Tropical diseases like malaria, transmitted by mosquito vectors in the genus *Anopheles*, are likely to expand their reach because of global warming (Figure 3-146) (WHO no date).

Figure 3-146. The public health threat posed by malaria (*Plasmodium* spp.), carried by mosquito vectors in the genus *Anopheles*, is likely to expand geographically because of global warming

Figure 3-147. Residential barrio climbs a steep, deforested hillside in Tegucigalpa, Honduras. Exposed sites like these – and their residents – are highly vulnerable to dangerous landslides during heavy storms.

The IPCC anticipates that climate change will cause major adverse impacts for human populations in rural areas due to diminished water supply and food security, as well as negative effects on infrastructure and agricultural incomes, including shifts in the production areas of food and non-food crops around the world. Aggregate economic losses will accelerate with rising temperatures. From the perspective of the quest to reduce poverty globally, climate change impacts are projected to slow down economic growth, make poverty reduction more difficult, further compromise food security, and prolong existing and create new “poverty traps.”

Climate change is also projected to increase the displacement and migration of peoples. Those populations that lack the resources for planned migration will experience higher exposure to extreme weather events, particularly in low-income, developing countries. Climate change can also indirectly increase the risk of violent conflicts and wars within and between nations by amplifying well-documented drivers of these conflicts such as poverty, economic shock, and competition for scarce resources such as water, oil, and productive land (IPCC 2014). Chaotic, large-scale migration into cities and across borders can also lead to tensions and strife that sometimes degenerate into violence or armed conflict (Campbell et al. 2007).

While most climate change scenarios and projections stop arbitrarily at the year 2100, global warming will continue well beyond 2100 under all but the lowest GHG emission scenario. Surface temperatures will remain approximately constant at elevated levels for many centuries after a complete cessation of net anthropogenic CO_2 emissions. A large fraction of anthropogenic climate change resulting from CO_2 emissions is essentially irreversible on a multi-century to millennial timescale, except in the instance of widespread net removal of CO_2 from the atmosphere over a sustained period of time (IPCC 2014).

Figure 3-148. The Sahel region of Africa, on the southern edge of the Sahara Desert, is already experiencing damaging climate change, drying out and undergoing desertification.

Stabilization of global average surface temperature by no means implies that all aspects of the climate system will stabilize as well. Shifting biomes (large ecosystems), carbon in soils, ice sheets, ocean temperatures and associated sea level rise all have their own intrinsic long timescales. These ensure that changes induced by human activities and emissions will last hundreds to thousands of years even after global surface temperature is stabilized. Ocean acidification will increase for centuries if CO_2 emissions continue, and will powerfully influence marine ecosystems. It is virtually certain that global mean sea level will continue to rise for many centuries beyond 2100, with the magnitude of the rise dependent on future GHG emissions. The threshold for the loss of the Greenland ice sheet over a millennium or more, and an associated sea level rise of up to 7 meters (23 feet), is greater than about 1°C, but less than about 4°C of global warming with respect to pre-industrial temperatures. Abrupt and irreversible ice loss from the Antarctic ice sheet is possible, but current evidence and understanding is insufficient to make a quantitative assessment (IGCC 2014).

3.5.1.6 The Scientific Consensus on Climate Change

The international scientific community is almost unanimous that anthropogenic climate change is occurring and that it puts people, nations, and nature at risk. Thousands of scientists have published reams of reports, conducted innumerable conferences, spoken out at fora, and to the news media. Virtually every national scientific academy and relevant major scientific organization around the world – including the National Academy of Sciences (NAS), American Geophysical Union (AGU), and the American Association for the Advancement of Science (AAAS) in the United States – have issued statements and declarations on the reality of manmade climate change and the threats it poses. Based on the empirical evidence at hand, about 97 percent of climate scientists believe that human-caused climate change is occurring right now (AAAS no date). A 2013 paper published in the peer-reviewed journal *Environmental Research Letters* concluded: "Our analysis indicates that the number of papers rejecting the consensus on AGW [Anthropogenic Global Warming] is a vanishingly small proportion of the published research" (Cook et al. 2013).

In spite of all this, surveys still show that Americans are divided on climate change and that many believe scientists are as well. In a 2013 poll, only 42 percent of American adults understood that "most scientists think global warming is happening" and 33 percent said, "… there is a lot of disagreement among scientists about whether or not global warming is happening." Twenty percent said they, "don't know enough to say" (Cooke et al. 2013). More than six in ten Americans believe that "global warming is affecting weather in the U.S.," and this percentage has not changed appreciably in recent years (Leiserowitz et al. 2013).

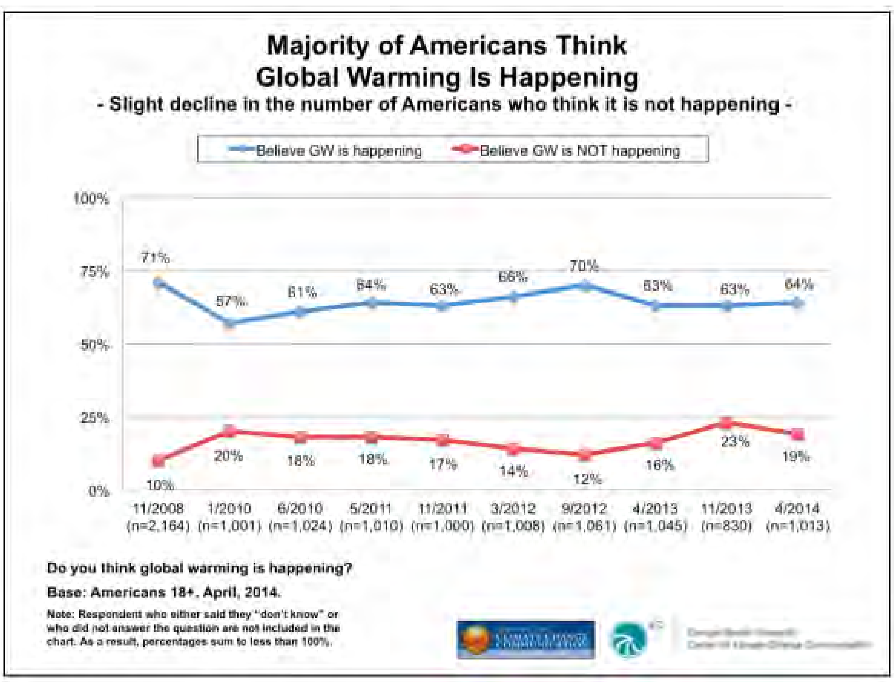


Figure 3-149. Percentage of Americans who believe in global warming has not changed much in recent years

3.5.1.7 Climate Change Effects on the United States

The U.S. National Climate Assessment of the U.S. Global Change Research Program was initiated at the request of the U.S. government and released to the public in 2014 (Melillo et al. 2014). The Assessment was prepared by a team of more than 300 experts guided by a 60-member National Climate Assessment and Development Advisory Committee. This was the largest and most diverse group ever assembled to produce a U.S. climate assessment. Stakeholders involved in its development included decision-makers from the public and private sectors, resource and environmental managers, researchers, business representatives, non-governmental organizations, and the public at large. More than 70 workshops and listening sessions were conducted, and thousands of public and expert comments on the draft report provided additional input to the process.

The 2014 Assessment draws on a large body of peer-reviewed scientific publications, technical reports, and other publicly available sources. The report was extensively reviewed by the public and experts, including a panel of the National Academy of Sciences, the 13 federal agencies of the U.S. Global Change Research Program, and the Federal Committee on Environment, Natural Resources, and Sustainability.

The Assessment emphasizes that climate change is not just some vague future threat but is already affecting Americans people at present in a number of tangible ways. Extreme weather events related to climate change have become more frequent and intense (or both); this “weird weather” includes prolonged heat waves, heavy downpours, floods and droughts. In addition, global warming is causing sea level to rise on the U.S. coastline; it is causing Arctic sea ice to melt, as well as glaciers in the Northern Rockies, Cascades, and Alaska. Oceans along our shores are becoming more acidic as they absorb CO_2. These and other results of climate change are disturbing Americans’ livelihoods, damaging some sectors of our economy, and stressing our natural environment. Figure 3-150 depicts documented U.S. temperature change over the past century

The Assessment’s key findings include the following (Melillo et al. 2014):

1. **Global climate is changing and this is apparent across the United States in a wide range of observations. The global warming of the past 50 years is primarily due to human activities, predominantly the burning of fossil fuels.**

   Many independent lines of evidence confirm that human activities are affecting climate in unprecedented ways. U.S. average temperature has increased by 1.3°F to 1.9°F since record keeping began in 1895; most of this increase has occurred since about 1970. The most recent decade was the warmest on record. Because human-induced warming is superimposed on a naturally varying climate, rising temperatures are not evenly distributed across the country or over time.

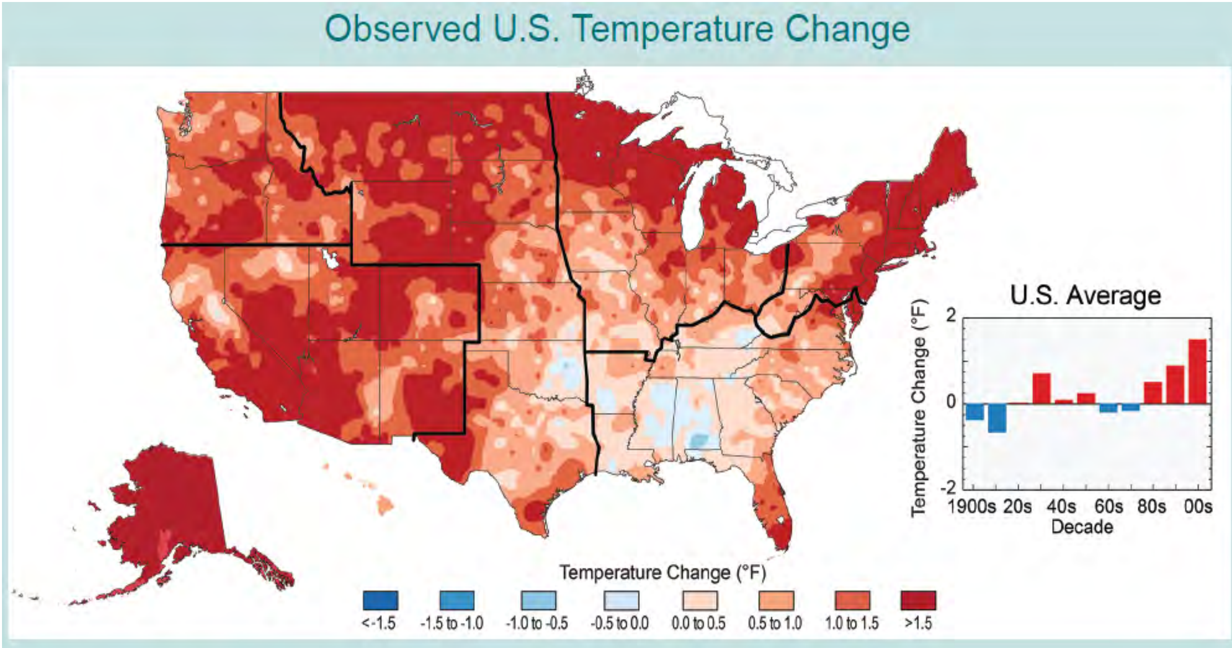


Figure 3-150. Observed U.S. temperature change: 1991-2012 average vs. 1901-1960 average

Note: The colors on the map denote temperature changes over the 22 years from 1991-2012 compared to the 1901-1960 average for the contiguous U.S., and to the 1951-1980 average for Alaska and Hawai'i. The bars on the graph show the average temperature changes for the U.S. by decade for 1901-2012 (relative to the 1901-1960 average). The far right bar (2000s decade) includes 2011 and 2012. The period from 2001 to 2012 was warmer than any previous decade in every region.

Source: Melillo et al. (2014)

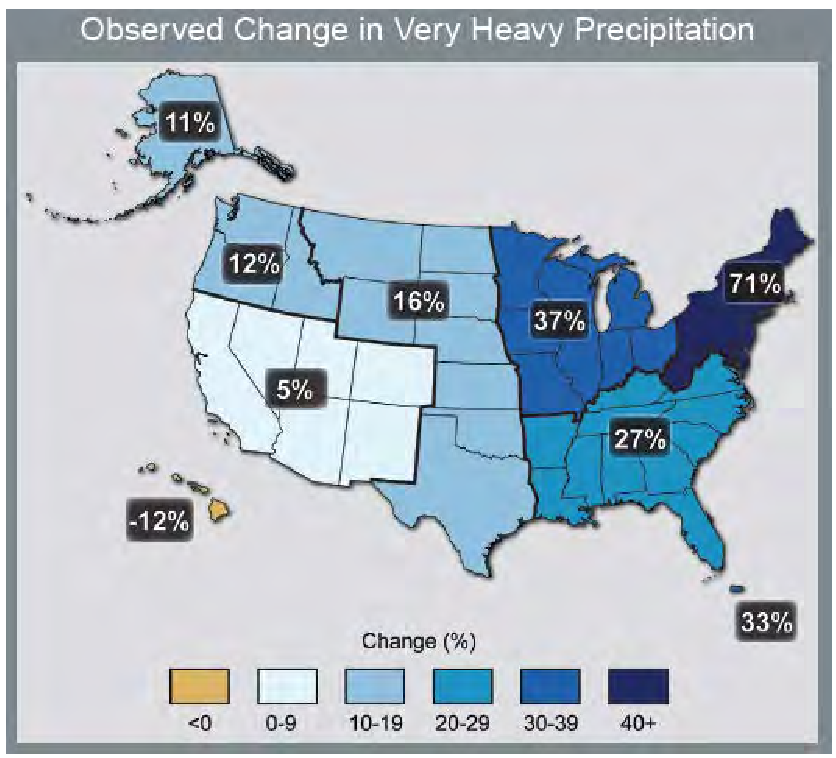


Figure 3-151. Observed changes in heavy precipitation

Note: Percent changes in the amount of precipitation falling in very heavy events (the heaviest 1%) from 1958 to 2012 for each region. There is a clear national trend toward a greater amount of precipitation being concentrated in very heavy events, particularly in the Northeast and Midwest.

Source: Melillo et al. (2014)

2. **Some extreme weather and climate events have increased in recent decades, and new and stronger evidence confirms that some of these increases are related to human activities.**

   Changes in extreme weather events are the primary way that most people experience climate change. Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, much of the U.S> has seen an increase in prolonged periods of excessively high temperatures, more heavy downpours (Figure 3-151), and in some regions, more severe droughts.

3. **Human-induced climate change is projected to continue, and it will accelerate significantly if global emissions of heat-trapping gases continue to increase.**

   Heat-trapping gases already in the atmosphere have committed us to a hotter future with more climate-related impacts over the next few decades. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases that human activities emit globally, now and in the future.

4. **Impacts related to climate change are already evident in many sectors and are expected to become increasingly disruptive across the nation throughout this century and beyond.**

   Climate change is already affecting societies and the natural world. Climate change interacts with other environmental and societal factors in ways that can either moderate or intensify these impacts. The types and magnitudes of impacts vary across the nation and through time. Children, the elderly, the sick, and the poor are especially vulnerable. There is mounting evidence that harm to the nation will increase substantially in the future unless global emissions of heat-trapping gases are greatly reduced.

5. **Climate change threatens human health and well-being in many ways, including through more extreme weather events and wildfire, decreased air quality, and diseases transmitted by insects, food, and water.**

   Climate change is increasing the risks of heat stress, respiratory stress from poor air quality, and the spread of waterborne diseases. Extreme weather events often lead to fatalities and a variety of health impacts on vulnerable populations, including impacts on mental health, such as anxiety and post-traumatic stress disorder. Large-scale changes in the environment due to climate change and extreme weather events are increasing the risk of the emergence or reemergence of health threats that are currently uncommon in the United States, such as dengue fever.

6. **Infrastructure is being damaged by sea level rise, heavy downpours, and extreme heat; damages are projected to increase with continued climate change.**

   Sea level rise, storm surge, and heavy downpours, in combination with the pattern of continued development in coastal areas, are increasing damage to U.S. infrastructure including roads, buildings, and industrial facilities, and are also increasing risks to ports and coastal military installations. Flooding along rivers, lakes, and in cities following heavy downpours, prolonged rains, and rapid melting of snowpack is exceeding the limits of flood protection infrastructure designed for historical conditions. Extreme heat is damaging transportation infrastructure such as roads, rail lines, and airport runways.

7. **Water quality and water supply reliability are jeopardized by climate change in a variety of ways that affect ecosystems and livelihoods.**

   Surface and groundwater supplies in some regions are already stressed by increasing demand for water as well as declining runoff and groundwater recharge. In some regions, particularly the southern part of the country and the Caribbean and Pacific Islands, climate change is increasing the likelihood of water shortages and competition for water among its many uses. Water quality is diminishing in many areas, particularly due to increasing sediment and contaminant concentrations after heavy downpours.

8. **Climate disruptions to agriculture have been increasing and are projected to become more severe over this century.**

   Some areas are already experiencing climate-related disruptions, particularly due to extreme weather events. While some U.S. regions and some types of agricultural production will be relatively resilient to climate change over the next 25 years or so, others will increasingly suffer from stresses due to extreme heat, drought, disease, and heavy downpours. From mid-century on, climate change is projected to have more negative impacts on crops and livestock across the country – a trend that could diminish the security of our food supply.

9. **Climate change poses particular threats to Indigenous Peoples' health, well-being, and ways of life.**

   Chronic stresses such as extreme poverty are being exacerbated by climate change impacts such as reduced access to traditional foods, decreased water quality, and increasing exposure to health and safety hazards. In parts of Alaska, Louisiana, the Pacific Islands, and other coastal locations, climate change impacts (through erosion and inundation) are so severe that some communities are already relocating from historical homelands to which their traditions and cultural identities are tied. Particularly in Alaska, the rapid pace of temperature rise, ice and snow melt, and permafrost thaw are significantly affecting critical infrastructure and traditional livelihoods.

10. **Ecosystems and the benefits they provide to society are being affected by climate change. The capacity of ecosystems to buffer the impacts of extreme events like fires, floods, and severe storms is being overwhelmed.**

    Climate change impacts on biodiversity are already being observed in alteration of the timing of critical biological events such as spring bud burst and substantial range shifts of many species. In the longer term, there is an increased risk of species extinction. These changes have social, cultural, and economic effects. Events such as droughts, floods, wildfires, and pest outbreaks associated with climate change (for example, bark beetles in the West) are already disrupting ecosystems. These changes limit the capacity of ecosystems, such as forests, barrier beaches, and wetlands, to continue to play important roles in reducing the impacts of these extreme events on infrastructure, human communities, and other valued resources.

11. **Ocean waters are becoming warmer and more acidic, broadly affecting ocean circulation, chemistry, ecosystems, and marine life.**

    More acidic waters inhibit the formation of shells, skeletons, and coral reefs. Warmer waters harm coral reefs and alter the distribution, abundance, and productivity of many marine species. The rising temperature and changing chemistry of ocean water combine with other stresses, such as overfishing and coastal and marine pollution, to alter marine-based food production and harm fishing communities.

12. **Planning for adaptation (to address and prepare for impacts) and mitigation (to reduce future climate change, for example by cutting emissions) is becoming more widespread, but current implementation efforts are insufficient to avoid increasingly negative social, environmental, and economic consequences.**

    Actions to reduce emissions, increase carbon uptake, adapt to a changing climate, and increase resilience to impacts that are unavoidable can improve public health, economic development, ecosystem protection, and quality of life (Melillo et al. 2014).

The 2014 Assessment emphasizes that both already observed and projected climate change impacts vary across the different regions of the U.S. Selected key regional impacts for different are listed in Table 3-13. The Assessment also stresses that as the impacts of climate change become ever more prevalent, Americans face choices. As a result of past emissions of long-lived, heat-trapping gases like CO_2, at a minimum, some additional climate change and related impacts are now unavoidable, or already "locked in." However, the magnitude of future impacts can be addressed and ameliorated through two broad groups of strategies called mitigation and adaptation. Mitigation embodies all efforts to limit (decrease) GHG emissions or increase the uptake (sequestration) or removal of CO_2 from the atmosphere. Adaptation refers to those actions that help prepare for and adjust to new conditions (Melillo et al. 2014). Both are important.

Table 3-13. Highlighted impacts of climate change in U.S. regions

.Region	Ongoing and Future Likely Impacts
Northeast	Communities are affected by heat waves, more extreme precipitation events, and coastal flooding due to sea level rise and storm surge.
Southeast and Caribbean	Decreased water availability, exacerbated by population growth and land-use change, causes increased competition for water. There are increased risks associated with extreme events such as hurricanes.
Midwest	Longer growing seasons and rising carbon dioxide levels increase yields of some crops, although these benefits have already been offset in some instances by occurrence of extreme events such as heat waves, droughts, and floods.
Great Plains	Rising temperatures lead to increased demand for water and energy and impacts on agricultural practices.
Southwest	Drought and increased warming foster wildfires and increased competition for scarce water resources for people and ecosystems.
Northwest	Changes in the timing of streamflow related to earlier snowmelt reduce the supply of water in summer, causing far-reaching ecological and socioeconomic consequences.
Alaska	Rapidly receding summer sea ice, shrinking glaciers, and thawing permafrost cause damage to infrastructure and major changes to ecosystems. Impacts to Alaska Native communities increase.
Hawai'i and Pacific Islands	Increasingly constrained freshwater supplies, coupled with increased temperatures, stress both people and ecosystems and decrease food and water security.
Coasts	Coastal lifelines, such as water supply infrastructure and evacuation routes, are increasingly vulnerable to higher sea levels and storm surges, inland flooding, and other climate-related changes.
Oceans	The oceans are currently absorbing about a quarter of human-caused carbon dioxide emissions to the atmosphere and over 90% of the heat associated with global warming, leading to ocean acidification and the alteration of marine ecosystems.

Source: Melillo et al. (2014)

3.5.1.8 Carbon Dioxide Emissions

As discussed above, carbon dioxide is the primary greenhouse gas emitted through human activities. In 2013, CO_2 accounted for about 82 percent of all anthropogenic U.S. GHG emissions (Figure 3-152). As described in Section 3.5.1.1, CO_2 occurs naturally in the atmosphere as part of the Earth's carbon cycle, which is the natural circulation of carbon among the atmosphere, oceans, lands (soil), and all living organisms. CO_2 is continually being exchanged among the ocean, atmosphere, and land surface as it is both produced and absorbed by countless microorganisms, plants, and animals. Emissions and removal of CO_2 by natural processes in equilibrium tend to balance each another. However, since the Industrial Revolution began around 1750, and accelerating quickly in the 19th and 20th centuries, human activities have contributed significantly to climate change by adding CO_2 and other heat-trapping gases (GHGs) to the atmosphere.

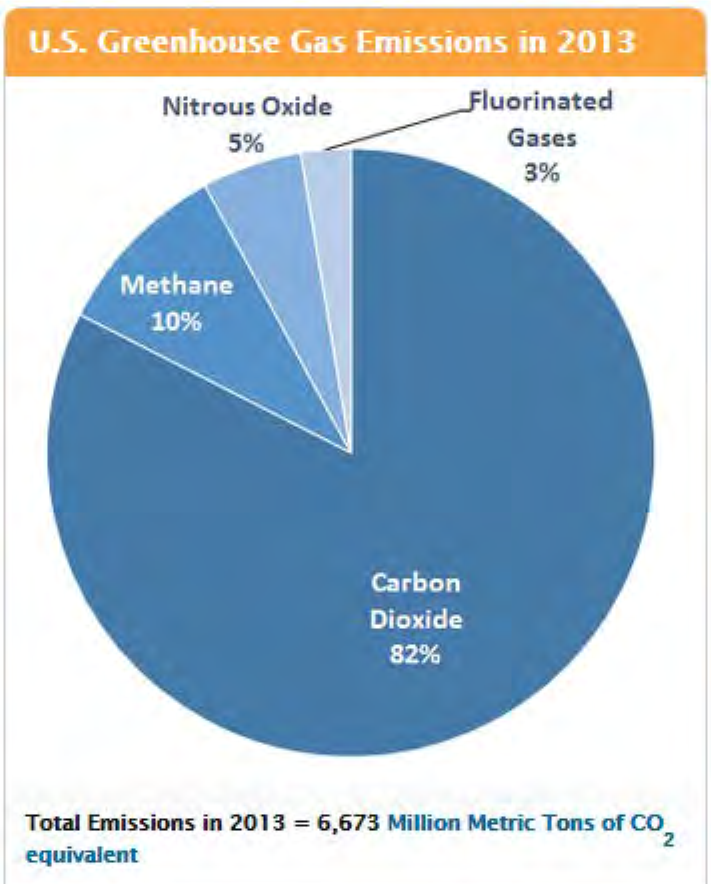


Figure 3-152. U.S. greenhouse gas emissions in 2013

Source: EPA (2015c)

<u>Note</u>: A metric ton or tonne is equal to 2,200 pounds, or 1.1 short (U.S.) tons. Thus, a million tonnes is equal to about 2.2 billion pounds, or 1.1 million tons. GHG emissions are often measured in CO_2 equivalent or CO_2e . To convert emissions of a gas into CO_2e, its emissions are multiplied by the gas's Global Warming Potential (GWP). The GWP takes into account the fact that many gases are more effective at warming Earth than CO_2, per unit mass, or molecule for molecule.

Human activities on the planet have now grown to such a scale that they are altering the global carbon cycle – both by emitting more CO_2 to the atmosphere and by reducing the ability of natural sinks, like forests, to remove CO_2 from the atmosphere. While CO_2 is emitted from a variety of natural sources, human-related or anthropogenic emissions are

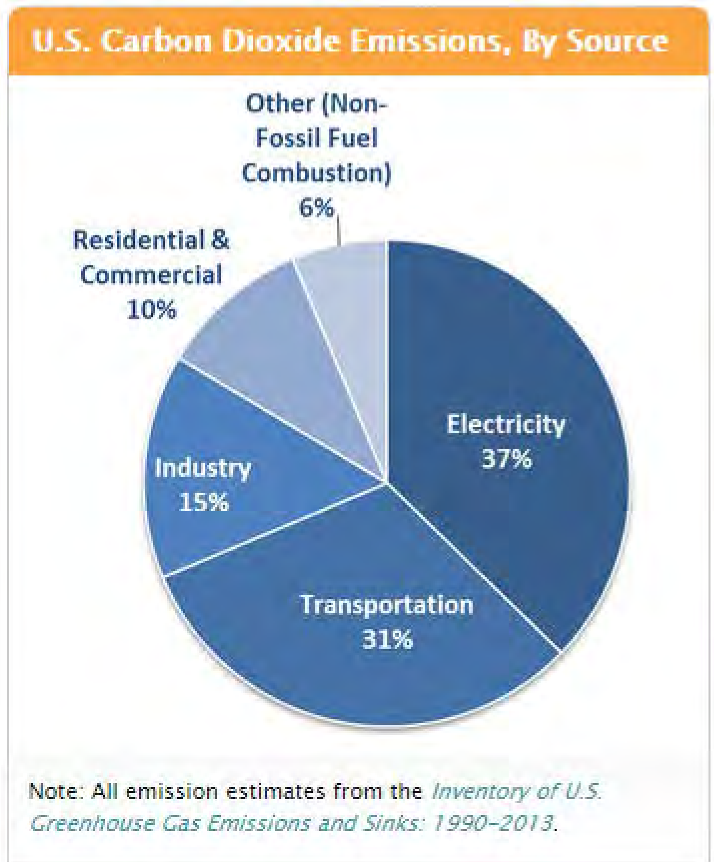
responsible for the increase in emissions and resultant CO_2 atmospheric concentrations that have occurred since the Industrial Revolution (EPA 2015c).

The main human activity in the United States (though not necessarily everywhere) that emits CO_2 is the burning or combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation. Certain industrial processes and land-use changes also release CO_2 into the air though on a much smaller scale (Figure 3-153).

Figure 3-153. U.S. carbon dioxide emissions by source in 2013

Source: EPA (2015c)

Note: Land use, land-use change, and forestry in the U.S. is a net carbon sink and offsets about 13% of total GHG emissions in any given year.



The main sources of CO_2 emissions in the United States are described briefly below.

- **Electricity –** Electricity is an important source of energy in the U.S. and is used to power residences, businesses, and industries. The combustion of fossil fuels – especially coal and natural gas – to generate electricity is the largest single source of CO_2 emissions in the nation, accounting for about 37 percent of total U.S. CO_2emissions and 31 percent of total U.S. greenhouse gas emissions in 2013. The type of fossil fuel burned to generate electricity will emit very different amounts of CO_2. To produce a given amount of electricity, measured as kilowatt-hours, burning coal will produce more CO_2 than either oil or natural gas, because coal is almost pure carbon.

- **Transportation** – The combustion of refined fossil fuels like gasoline in automobiles, diesel in trucks and trains, jet fuel in airplanes, and bunker fuel in ships to transport people, raw materials, and merchandise is the second largest source of CO_2 emissions, accounting for about 31 percent of total U.S. CO_2 emissions and 26 percent of total U.S. greenhouse gas emissions in 2013. This category includes transportation sources such as highway vehicles, air travel, marine transportation, and rail.

- **Industry** – Many industrial processes emit CO_2 through fossil fuel combustion. Several processes also produce CO_2 emissions through chemical reactions that do not involve combustion, for example, the production and consumption of mineral products such as cement, the production of metals such as iron and steel, and the manufacture of chemicals. Fossil fuel combustion from various industrial processes accounted for about 15 percent of total U.S. CO_2 emissions and 12 percent of total U.S. greenhouse gas emissions in 2013. Many industrial processes also use electricity and therefore indirectly cause the emissions from the electricity production (EPA 2015c).

Between 1990 and 2013, U.S. CO_2 emissions increased by about seven percent (Figure 3-154). Since fossil fuel combustion is the largest single source of greenhouse gas emissions in the U.S., changes in emissions from fossil fuel combustion have historically been the dominant factor in driving total U.S. emission trends. Changes in CO_2 emissions from fossil fuel combustion are influenced by many short- and long-term factors, including population growth, economic growth, changing energy prices, new technologies, changing behavior, and seasonal temperatures. Between 1990 and 2013, the increase in CO_2 emissions corresponded with increased energy use by an expanding population and economy, as well as overall growth in emissions from electricity generation. Transportation emissions also contributed to the seven percent increase, largely due to an increase in the number of miles traveled by motor vehicles. Looking ahead, CO_2 emissions in the United States are projected to grow by about 1.5% between 2005 and 2020 (EPA 2015c).

Throughout most of the 20th century, America was by far the largest emitter of CO_2 of any country on Earth. However, due to China's enormous population (largest in the world) and its historically unprecedented economic growth, China's CO_2 emissions surpassed those of the U.S. in about 2006 and are now about twice as great (Figure 3-155 and Table 3-14).

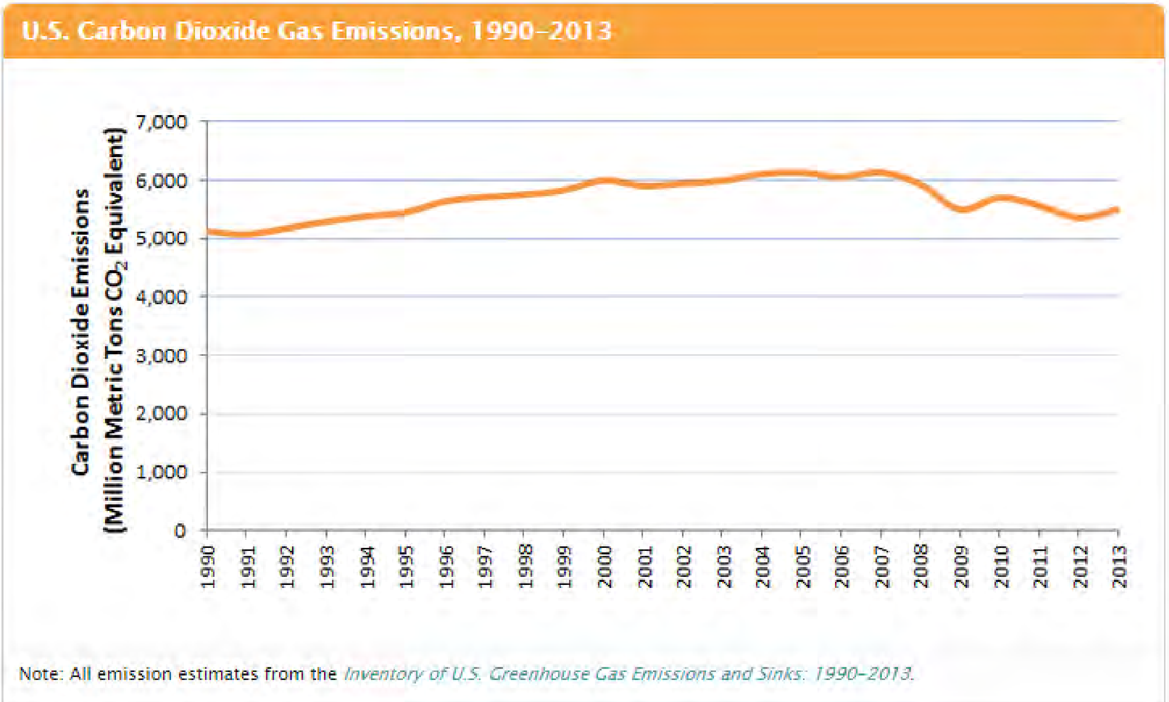


Figure 3-154. U.S. carbon dioxide emissions from 1990 to 2013

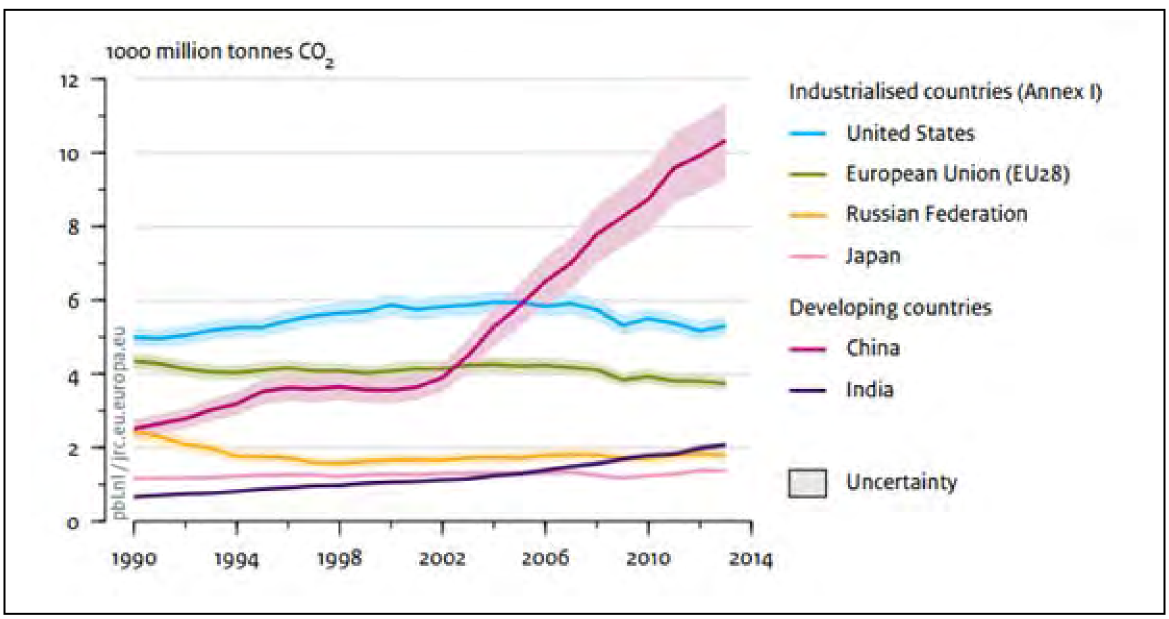


Figure 3-155. CO_2 emissions from fossil-fuel use and cement production in the top five emitting countries and the European Union (EU)

Source: Olivier (2014)

Table 3-14. Top 20 emitters of carbon dioxide in the world

Country	CO_2 emissions in gigatonnes[1]	CO_2 emissions per capita (tonnes)
World	35.27	5.0
China	10.33	7.4
United States	5.30	16.6
India	2.07	1.7
Russia	1.80	12.6
Japan	1.36	10.7
International transport	1.07	--
Germany	0.84	10.2
South Korea	0.63	12.7
Canada	0.55	15.7
Indonesia	0.51	2.6
Saudi Arabia	0.49	16.6
Brazil	0.48	2.0
United Kingdom	0.48	7.5
Mexico	0.47	3.9
Iran	0.41	5.3
Australia	0.39	16.9
Italy	0.39	6.4
France	0.37	5.7
South Africa	0.33	6.2
Poland	0.32	8.5

[1] One gigatonne equals one billon tonnes

Source: Olivier (2014)

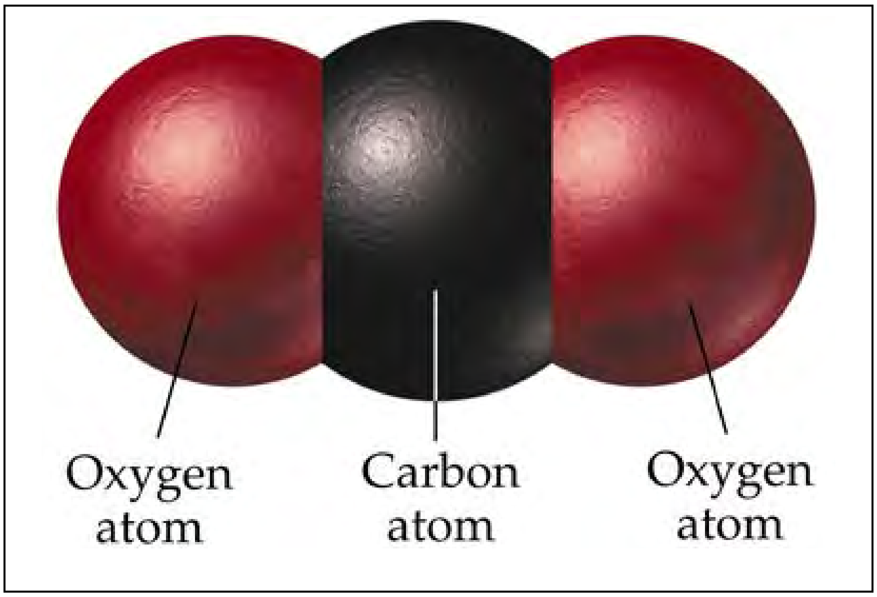
The role of a county's population size in determining its aggregate CO_2 emissions, and therefore the magnitude of its climate-change-forcing impact on the Earth, can be appreciated by comparing the two counties of China and the United Kingdom. They have nearly identical per capita CO_2 emissions – 7.4 tonnes/capita for China and 7.5 tonnes/capita for the U.K. – but because China's population is 1.4 billion compared to the U.K.'s 64 million, it has more than 20 times the aggregate effect on the climate with its emissions that the U.K. does.

All of the other developing countries that are among the top 20 aggregate CO_2 emitters – such as India, Brazil, and Mexico -- are not there because of their high per capita emissions (all below the global per capita average of 5.0 tonnes annually) but because of their relatively large populations – 1.3 billion for India, 196 million for Brazil, and 118 million for Mexico.

3.5.2 Environmental Consequences

3.5.2.1 U.S. Population Growth and Carbon Dioxide Emissions

As stated a number of times throughout Section 3.5.1, anthropogenic CO_2 emissions are the most important of the GHG emissions influencing the climate, hence the focus on them here and elsewhere. The CO_2 molecule or "chemical compound" consists of one carbon atom (represented by the black sphere in the model below) covalently double-bonded with two oxygen atoms on either side of it; chemically, this is represented as O=C=O, where the C denotes a carbon atom, the two O's two oxygen atoms, and the two equal signs (=) two covalent double chemical bonds.



The same CO_2 molecule is also frequently depicted as in Figure 3-156, which does not specify which atom is which; however, it should be obvious.

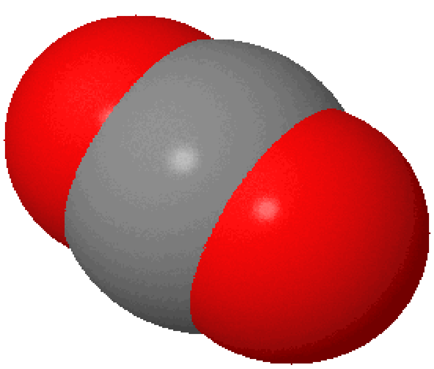


Figure 3-156. Another depiction of the CO_2 molecule (carbon atom gray; oxygen atoms red)

As discussed at length above in Section 3.5.1 of this EIS, "the global human enterprise," reflecting growing population, production, and consumption supported by rising fossil fuel consumption (and deforestation), has now reached such a scale or magnitude that it is tipping the balance or affecting the equilibrium of the global carbon cycle. As a consequence, the amount of CO_2 emitted to the atmosphere in any given year now exceeds, rather than approximately balances, the amount of CO_2 removed from the atmosphere by terrestrial and marine photosynthesis (converted into glucose and ultimately other plant matter) and by the oceans (dissolved and converted into carbonic acid).

This sub-section explores the relationship between 1) U.S. population size and growth, and 2) changing U.S. CO_2 emissions from fossil fuel consumption. As in the case of water (Section 3.4.2 of this EIS), this relationship can be characterized in terms of the IPAT equation. That is, in theory and in reality, CO_2 emissions are not just a simple function of population size; they are mediated both by Affluence (A) and Technology (T). In the particular case of carbon emissions, the IPAT equation indicates that population growth (P), per capita consumption (affluence or A), and the CO_2 emissions of a particular mix of technologies (T) that yield a given level of per capita consumption each contribute to environmental impact, in this case, aggregate CO_2 emissions and their impact on the atmosphere and climate. What IPAT does not tell us is the relative weight of each factor in any given situation.

Section 3.1.3 describes and Figure 3-2 illustrates the Kaya identity, which may be seen as a variation or extension of the IPAT equation to the question of carbon emissions by an economy. Named for Japanese energy economist Yoichi Kaya, who first proposed it, the Kaya identity states that aggregate climate-forcing CO_2 emissions to the atmosphere can be expressed as the product of four factors or inputs: population, Gross Domestic Product (GDP) per capita, energy use per unit of GDP, and CO_2 emissions per unit of energy consumed (Rosa and Dietz 2012). In the Kaya identity, population size serves as a multiplier of each of the other factors.

$$\text{Total emissions} = \text{population} \times (\text{GDP/population}) \times (\text{energy/GDP}) \times (\text{emissions/energy})$$

Or

$$\text{Total Emissions} = \cancel{\text{Population}} \times \frac{\cancel{\text{GDP}}}{\cancel{\text{Population}}} \times \frac{\cancel{\text{Energy}}}{\cancel{\text{GDP}}} \times \frac{\text{Emissions}}{\cancel{\text{Energy}}}$$

The common denominators and numerators cancel each other out so that we are left with an identity: total emissions equal emissions.

For the first several decades after World War II, aggregate U.S. energy consumption climbed steeply as a result of both a rapidly increasing population and rapidly increasing per capita energy consumption (Holdren 1991). Roughly 85 percent of primary energy consumption (i.e., measured as joules or BTUs used) was furnished by the fossil fuels – coal, oil, and natural gas – so that total national carbon dioxide emissions were rising rapidly as well. However, for the past four decades or so three of the four factors in the Kaya identify have not been increasing as rapidly as before or have actually fallen. GDP/population or GDP per capita, in real dollars, has roughly doubled over the past four decades. Energy/GDP or energy expended for each dollar of GDP produced has actually decreased substantially, falling almost by half from 1980 to 2010 (Figure 3-157).

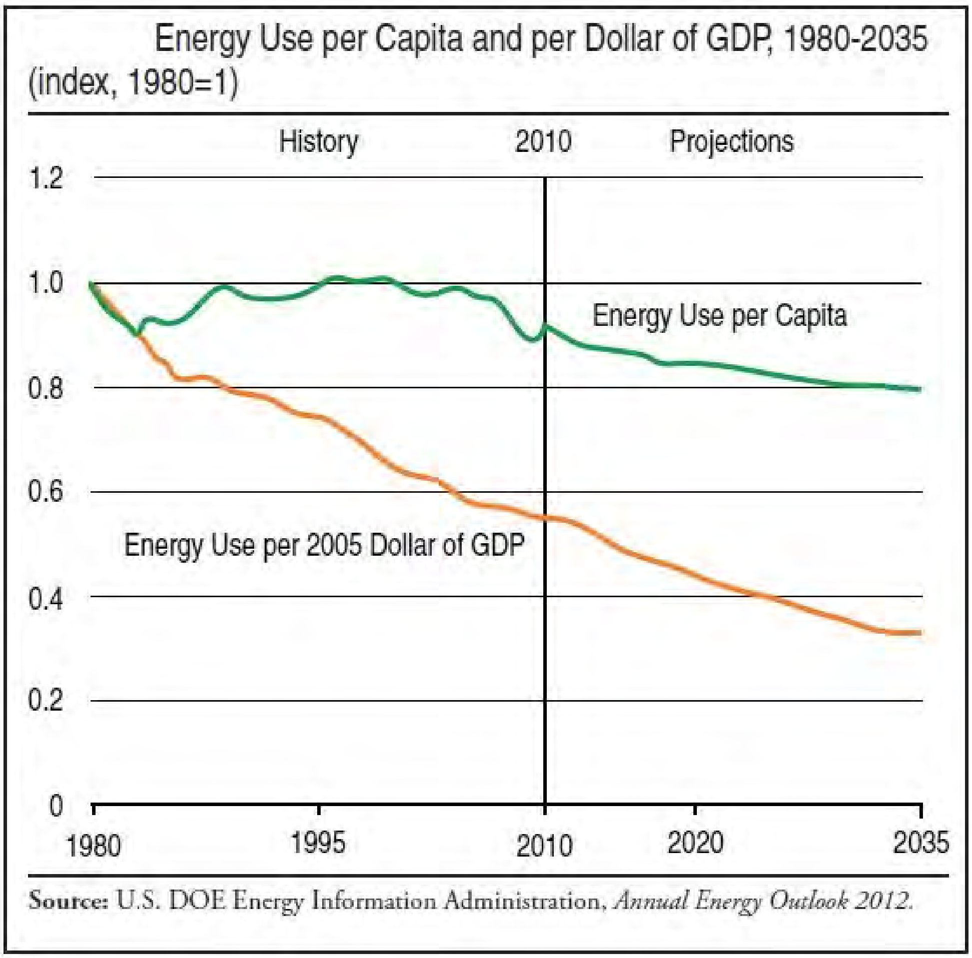


Figure 3-157. U.S. energy intensity – energy use per capita and energy use per dollar of GDP, 1980-2010 and project to 2035

Emissions/energy or CO_2 emissions per unit of energy used have remained about the same. The upshot is that per capita emissions of CO_2 have been roughly flat or falling for the last four decades. If U.S. population stabilized at a constant level then, aggregate U.S. CO_2 emissions would have been flat or falling over recent decades. But that is not

what has happened, because U.S. population has continued to climb steeply – growing by about 110 million from the early 1970s to the present. Figure 3-158 depicts U.S. population growth and total CO_2 emissions from 1975 to 2010.

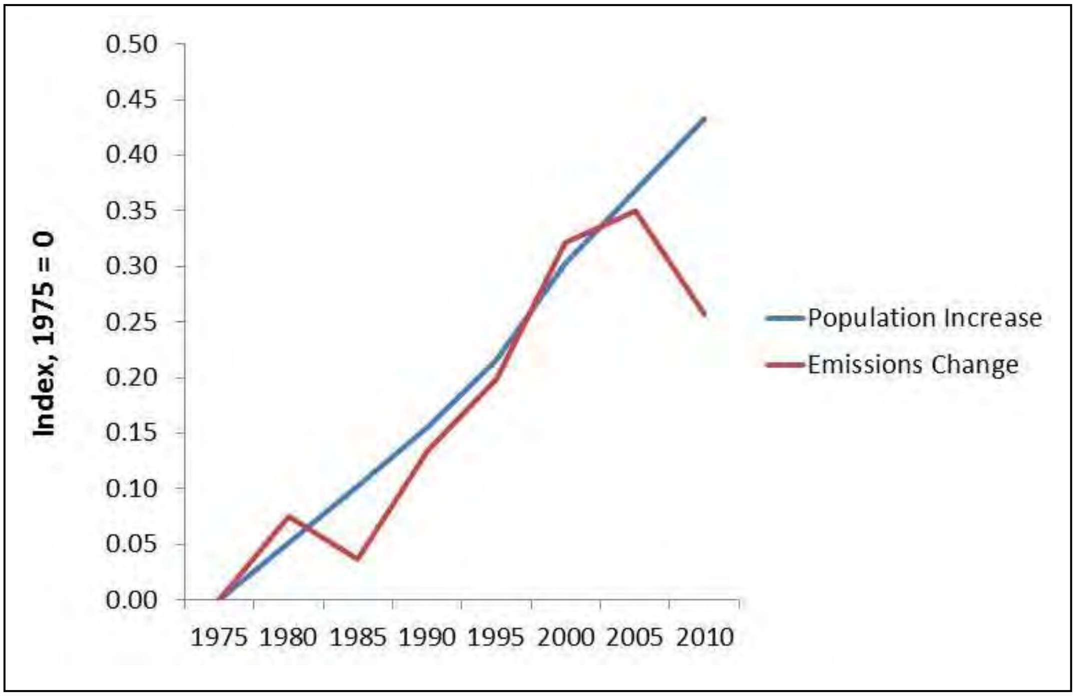


Figure 3-158. U.S. population growth and change in total CO_2 emissions, 1975 to 2010

U.S. population increased rather steadily from 1975 to 2010, and aggregate CO_2 emissions, which jumpier, more or less increased in tandem, until the last several years, when emissions fell as a result of the Great Recession of 2008 and its lingering effects. Table 3-15 compares the increase in U.S. population and total U.S. carbon dioxide emissions over the same time period, plus 2013 and 2014.

Table 3-15. Increase in population and increase in CO_2 emissions, 1975-2014

Year	U.S. population (millions)	CO_2 emissions (million metric tons)
1975	216.0	4,439
1980	227.2	4,771
1985	238.0	4,600
1990	249.5	5,039
1995	262.8	5,323
2000	281.4	5,868
2005	295.5	5,993
2010	309.4	5,582
2013	316.1	5,362
2014	318.4	5,415

Source: DOE Energy Information Administration (EIA)

The recent multi-year decrease in CO_2 emissions is likely an anomaly. In 2012, Eric Larson, Ph.D., Senior Scientist at Climate Central and research scientist at Princeton University's Energy Systems Analysis Group, wrote: "the decline is unlikely to continue" (Larson 2012). Larsen concluded:

> Recent declines in carbon emissions are the result of a combination of factors including the recession, increased natural gas production and the related decline in coal-fired electricity generation, continuing improvements in efficiencies of energy use, and growth in renewables, particularly wind power. The recession, however, appears to be the most significant factor in the decline. Consequently, as the economy rebounds the fall in emissions is likely to be neutralized or overtaken by growing population and incomes that will drive increased demand for energy-using appliances, air conditioners, TVs, personal electronic devices, cars, and other amenities. In the face of such growth and the 80 percent reliance of the U.S. on fossil fuels for energy today, modest improvements in energy efficiencies and expansions of lower carbon energy alternatives will not provide the level of change in the energy economy needed for carbon emissions to fall by 2050 to a level that most climate scientists believe is needed to avoid severe impacts of climate change (Larsen 2012).

Indeed, bearing out Larsen's 2012 prediction, emissions ticked modestly upward again in 2014 (Table 3-15). Larsen also found that assuming the economy recovers eventually and robustly from the Great Recession, an ever-growing number of increasingly affluent energy consumers demanding an ever-growing number of energy-using products and services will put upward pressure on the country's energy use. Since 80 percent of more of that energy is currently provided by fossil fuels, all of which emit CO_2 upon combustion, there will be concomitant upward pressure on CO_2 emissions.

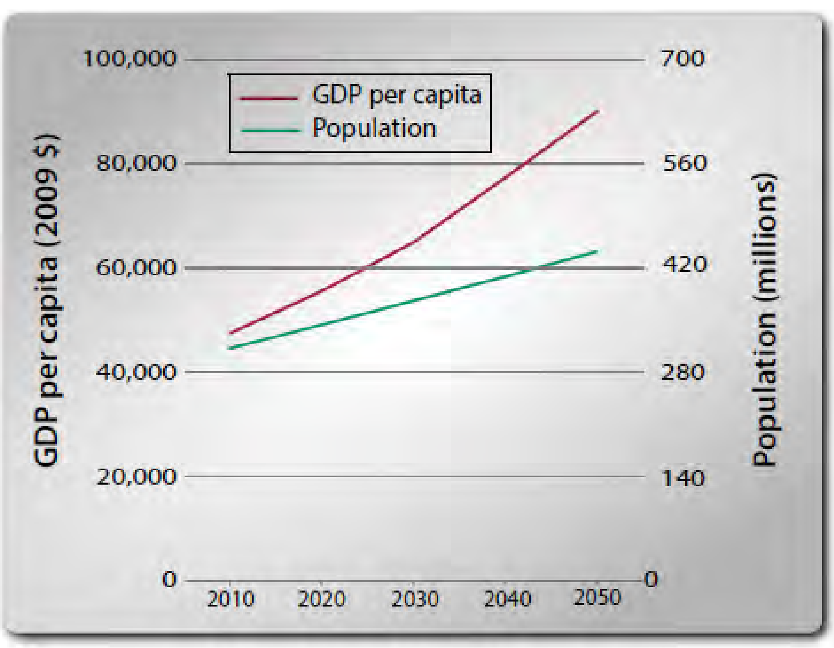


Figure 3-159. More people with more disposable income to spend on energy-using goods and services.

Source: Larsen 2012

Note: Projected U.S. population growth assuming low net international migration (U.S. Census Bureau, 2009). Also, per-capita GDP (in constant dollars), is projected to grow faster than population.

The tight correlation between U.S. population growth and CO_2 emissions was also borne out by an earlier study for NumbersUSA (Kolankiewicz 2002). CO_2 emissions in the U.S. from fossil fuel combustion grew by almost 13 percent from 1990 to 2000. U.S. population grew by almost an identical amount – slightly over 13 percent in the same decade. Thus, the increase in CO_2 emissions closely matched the increase in population. In other words, emission increases in the 1990s were very much correlated with domestic population growth, not increasing per capita emissions, because per capita emissions did not increase in that decade, nor have they subsequently.

The bearing of immigration levels on U.S. CO_2 emissions was analyzed in a 2008 paper (Kolankiewicz and Camarota 2008). Among this paper's findings were the following:

- The estimated CO_2 emissions of the average immigrant (legal or illegal) in the United States are 18 percent less than those of the average native-born American.
- Immigrants in the United States produce an estimated four times more CO_2 in the United States as they would have in their countries of origin.
- U.S. immigrants produce an estimated 637 million metric tons of CO_2 emissions annually – equal to the combined emissions of Great Britain and Sweden.
- The estimated 637 tons of CO_2 U.S. immigrants produce annually is 482 million tons more than they would have produced had they remained in their home countries.
- If the 482 million ton increase in global CO_2 emissions caused by immigration to the United States were a separate country, it would rank 10th in the world in emissions.
- The impact of immigration to the United States on global emissions is equal to approximately 5 percent of the increase in annual world-wide CO_2 emissions since 1980.
- Of the CO_2 emissions caused by immigrants, 83 percent is estimated to come from legal immigrants and 17 percent from illegal immigrants.
- Legal immigrants have a much larger impact because they have higher incomes and resulting emissions, and they are more numerous than illegal immigrants.
- The above figures do not include the impact of children born to immigrants in the United States. If they were included, the impact would be much higher.
- Assuming no change in U.S. immigration policy, 30 million new legal and illegal immigrants are expected to settle in the United States in the next 20 years.

- In recent years, increases in U.S. CO_2 emissions have been driven entirely by population increases, since per capita emissions have stabilized (Kolankiewicz and Camarota 2008).

The Kaya identity looks at a snapshot of CO_2 emissions at a given instant in time. In considering the long-term, multi-generational implications of reproductive decisions and population growth, the concept of the "carbon legacy" is useful. In evaluating what options individuals have in managing and minimizing their own contributions to climate change, a good deal of attention has been paid to the manner in which consumers' travel, home energy use, diet, and other daily activities affect their CO_2 emissions and, at the end of the day, their contributions to global warming (Murtaugh and Schlax 2009).

However, individual reproductive choices are rarely considered in measuring personal impact on the environment. To investigate this, two Oregon State University researchers estimated the extra emissions of fossil CO_2 that an average individual causes when he or she decides to have children. They found that the summed emissions of a person's descendants, weighted by their relatedness to him or her, may far exceed the lifetime emissions produced by the original parent. Under current conditions in the U.S., each additional child adds about 9,441 metric tons of CO_2 to the carbon legacy of an average female, which is nearly six times greater than her overall lifetime emissions (Murtaugh and Schlax 2009). In other words, in evaluating an individual's impact on the climate, how many children he or she choose to have is far more important than whether or not he or she recycles, bicycles to work, drives a fuel-efficient vehicles or a hybrid, places solar photovoltaic panels on the roof, or conserves energy at home with compact fluorescent light bulbs and setting the thermostat high in the summer and low in the winter.

In this sense, the act of immigrating is like the act of giving birth, because both add a new resource consumer/waste generator to the nation's population stock. Childbirth and immigration both have long-term or "downstream" environmental consequences. In a similar vein as with the carbon legacy of individual reproductive choices, the greater impact of contemporary and prospective future immigration levels on long-term U.S. CO_2 emissions are not the emissions of the immigrant him or herself, but the emissions of his or her U.S.-born descendants – children, grandchildren, great-grandchildren, etc.

3.5.2.2 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million (70 percent) over the 2010 population of 309 million. At the outset, it should be stressed that environmental consequences related to CO_2 emissions under the No Action Alternative would be indirect and cumulative, not direct.

Predicting what CO_2 emissions would be in the year 2100 under this alternative – 85 years into the future – is bedeviled by the impossibility of predicting what the other three principal factors in the Kaya identity will be in 2100: 1. *GDP/population*; 2. *energy/GDP*; and 3. *emissions/energy*. Each is considered in turn below.

- GDP/population, or its close proxy, per capita income, could range from a fraction of what it is today if the ecological collapse or economic malaise envisioned by some ecological economists, futurists, financial analysts, and scientists comes to pass, to more than a quadrupling (4x) if a mere 2% annual growth in real GDP/capita were to be maintained from now until 2100. This is roughly an order of magnitude (10-fold) variation, much greater than the roughly two-fold difference in population between the low and high population scenarios evaluated in this EIS.

- Energy/GDP is more predictable than the other two variables in the Kaya identity. Indeed, Figure 3-157 shows the EIA's projected continuing decline in energy/GDP to 2035. It is reasonable to expect this downward trend to continue, although it is likely to level off well before 2100 as further improvements in energy efficiency become more technically difficult and economically costly to achieve.

- Emissions/Energy is the true wildcard ratio in the Kaya identity. This is because it is related to the American economy's mix of energy sources and supplies. At present over 80 percent of primary energy in the U.S. is derived from the burning of fossil fuels, which releases CO_2 to the atmosphere upon combustion. Less than 20 percent is comprised of nuclear energy (nuclear fission to produce electricity) plus renewable sources (e.g., hydroelectricity, wind, solar, biomass).

  However, both because of the inevitable depletion of high-grade, lower-cost fossil fuels (e.g., conventional crude oil and natural gas, more accessible coal beds) and a growing recognition that America and the world must move away from carbon-intensive energy sources to avoid disruptive or catastrophic climate change, in the coming decades and certainly well before 2100, the percentage of the U.S. economy's primary energy furnished by fossil fuels will probably be much lower than at present. But any precise prediction of what the specific emissions/energy ratio is likely to be in 2100 is likely to be wrong and perhaps substantially so.

  The difficulty inherent in predicting what numerical value the emissions/energy factor will have more than half a century into the future is illustrated by the contradictions of President Barack Obama's own energy and environmental policies and priorities. On the one hand, President Obama has made addressing climate change the hallmark of his administration's environmental policy, has

encouraged breakthroughs in stalemated international diplomacy in this regard, has tightened regulations on high CO_2-emitting coal-fired power plants, and has supported and subsidized the development of low-carbon, renewable energy sources such as wind and solar. On the other hand, the Obama administration has lauded the hydraulic fracturing boom that has dramatically increased domestic production of natural gas and crude oil from shale formations in Texas, Pennsylvania, North Dakota, and elsewhere. The Obama administration has also supported opening new areas on the continental shelf and the Beaufort Sea north of Alaska to offshore oil drilling. These actions, of course, would tend to increase America's CO_2 emissions and offset or even reverse reductions in CO_2 emissions from Obama's other policy initiatives.

The aggregate American CO_2 emissions in 2100 that would result from the No Action Alternative would be a product of the four above factors: population, GDP/per capita, energy/GDP, and emissions/energy. Only one of these four factors is known with any certainty, because it is fixed, and a logical outcome of the demographic assumptions of the No Action Alternative. The widely ranging scenarios in Figure 3-160 for global CO_2 emissions to the year 2100 reflect how widely U.S. emissions could conceivably vary, even with the population factor being fixed and known.

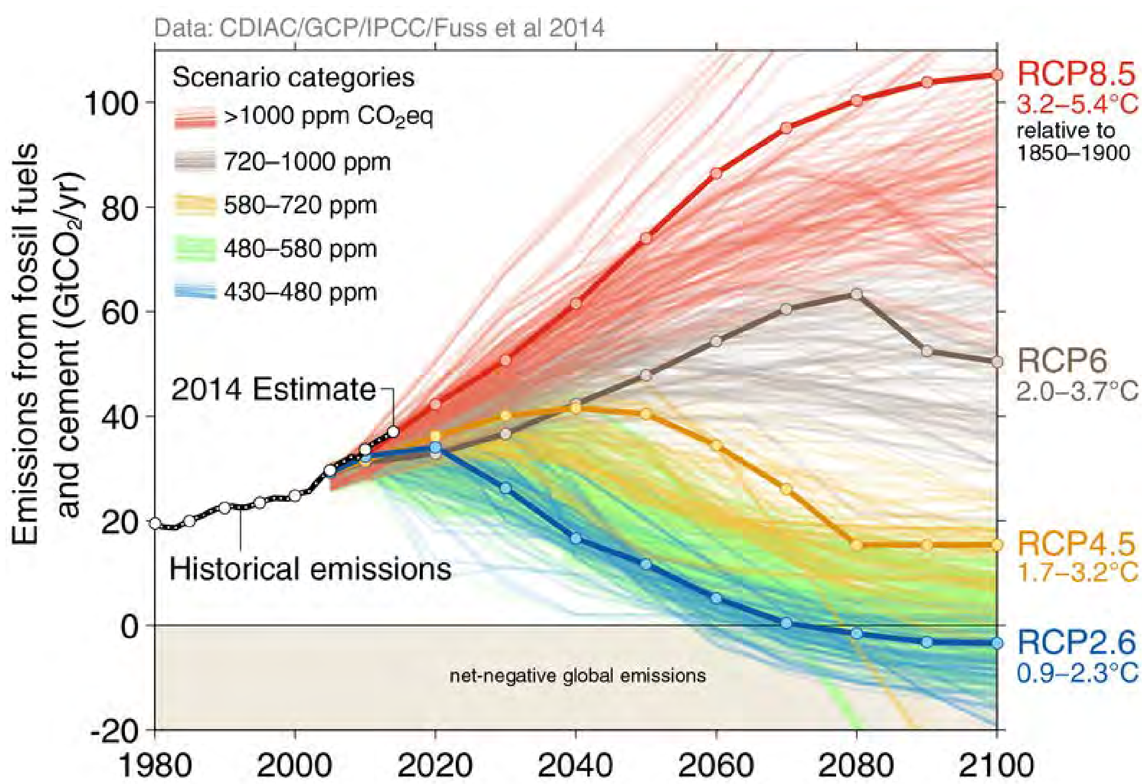


Figure 3-160. Wide-ranging global CO_2 emissions under different scenarios
Source: Global Carbon Project

What this EIS can predict and quantify with some confidence is the magnitude of upward pressure on CO_2 emissions exerted by the population growth that would occur under each of the three alternatives under consideration. As stated above, under the No Action Alternative, annual immigration of 1.25 million into the United States would result in a U.S. population of 524 million in 2100, an increase of 215 million or 70 percent above the 2010 population of 309 million. **Thus, there would be 70 percent greater upward pressure on CO_2 emissions under this alternative.** In other words, if there were no change at all in any of the other three factors, or these changes cancelled each other out, American CO_2 emissions would be 70 percent larger in 2100 (Figure 3-161). This should be compared with the call of climatologists for an 80 percent or more reduction in CO_2 emissions by 2050 – and eventually a complete elimination of all CO_2 emissions by 2100 if not beforehand – if our climate is to be stabilized at a temperature of, say, two degrees Celsius above preindustrial levels.

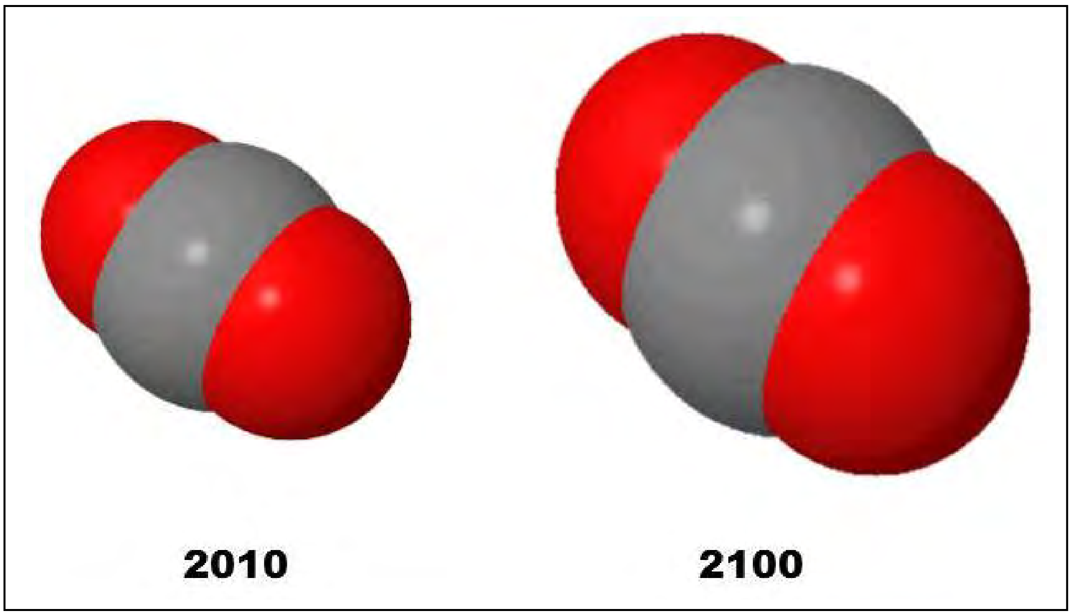


Figure 3-161. Graphic illustration representing magnitude of upward pressure exerted on American CO_2 emissions under the No Action Alternative – annual immigration of 1.25 million leading to a U.S. population in 2100 of 524 million

A crucial distinction needs to be emphasized between the magnitude of U.S. CO_2 emissions in any given year and the magnitude of the impact of climate change in 2100 on the American environment and economy. As stated at the top of this section, annual CO_2 and other GHG emissions from the United States do not cause a *direct* environmental impact; rather, they contribute *indirectly* and *cumulatively* in a tangible, non-trivial, quantifiable manner to what is without a doubt the ultimate long-term, cumulative environmental impact predicament on Earth, that of climate change. If U.S. CO_2 and other GHG emissions could somehow miraculously be eliminated entirely by

2100, but the growth in emissions in the rest of the world were to continue unchecked, the effects on the climate of the United States and the Earth as a whole in 2100 would be negligible to minimal. To make a substantial difference on global temperatures and the climate as a whole, every significant GHG emitting country on Earth would have to participate in a global program of moving away from fossil fuels and toward "decarbonization."

U.S. CO_2 and other GHG emissions are about 25 percent of the global total at present. Under the No Action Alternative, depending on what the rest of the world does and what the three other factors in the Kaya identity become, the U.S. share of aggregate global emissions in 2100 would range from a much lower percentage to a much higher percentage. The No Action Alternative in the U.S. would more or less correspond to the "Business As Usual" (BAU) scenario in terms of global CO_2 and other GHG emissions. The BAU scenario appears headed to push the planet towards an average warming of 4°C or more by 2100.

The potential implications of a world that is 4°C warmer have been sketched out by the World Bank (2012). The World Bank emphasizes that the effects of a 4°C warming would be asymmetrical (not be evenly distributed) around the world, and that neither would these effects merely be a simple extension of those experienced at a 2°C warming. The largest warming would occur over land areas and would range from 4°C to 10°C. Increases of 6°C (11°F) or more in the average monthly summer temperatures would be anticipated across enormous areas of the world, including the Mediterranean, North Africa, the Middle East, and the contiguous United States (World Bank 2012).

Furthermore, there would likely be a dramatic increase in the intensity and frequency of extreme temperatures. Extreme heat waves such as that which struck Russia in 2010 and Europe in 2003 will probably become "the new normal" summer in a 4°C warmer world. Tropical South America, central Africa, and all tropical islands in the Pacific are likely to regularly experience heat waves of unprecedented magnitude and duration. Over the past decade, such extreme heat waves have caused severe impacts, including many thousands of heat-related deaths, widespread forest fires, and large crop losses. The impacts of the extreme heat waves projected for a 4°C warmer world are anticipated to dwarf the consequences that have been felt to date. They could well exceed the adaptive capacities of many societies and ecosystems.

A warming of 4°C or higher by 2100 would correspond to an increase of about 150 percent in the acidity of the ocean. The observed and projected rates of change in ocean acidity over the next century appear to be unparalleled in the known history of the Earth. As described above in this EIS, evidence is already accumulating of the adverse effects of

acidification for marine organisms and ecosystems, combined with the adverse effects of ocean warming, overfishing, and habitat destruction. In particular, coral reefs are acutely sensitive to changes in water temperatures and pH, as well as the intensity and frequency of tropical cyclones. Coral reefs provide essential habitat for many species of fish and other marine organisms, in addition to providing protection against coastal floods, storm surges, and wave damage. Studies suggest that coral reef growth may stop altogether as the CO_2 concentration approaches 450 ppm over the coming decades (corresponding to a warming of about 1.4°C in the 2030s). By the time the concentration reaches around 550 ppm (corresponding to a warming of about 2.4°C in the 2060s), coral reefs in many parts of the ocean could actually start to dissolve. The combination of thermally induced coral bleaching episodes, ocean acidification, and sea-level rise threatens large areas of coral reefs even at 1.5°C global warming. The regional extinction of entire coral reef ecosystems, which could happen well before 4°C is reached, would have profoundly negative consequences for their dependent species as well as for the millions of people who depend on them for protein, income, tourism, and protection from waves and storms (World Bank 2012).

By 2100, warming of 4°C would likely signify a sea-level rise of 0.5 to 1 meter (20 to 39 inches), and possibly more; in addition, several additional meters of rise would occur in the coming centuries, already locked into place by past warming (an example of a lag effect which doesn't occur immediately). This compares to 20 cm (8 inches) of sea-level rise in 2100 if warming were limited to 2°C. (However, even if global warming were limited to 2°C, global mean sea level could continue to rise, with some estimates ranging between 1.5 and 4 meters above present-day levels by the year 2300.) Ultimate sea-level rise would likely be limited to below two meters (6.6 feet) only if warming were kept to well below 1.5°C (World Bank 2012).

The risks of a 4°C warmer world to agriculture and food production, freshwater availability, ecosystems and human health would be severe. Some estimates indicate that this degree of warming would substantially aggravate existing water scarcity in many regions, particularly northern and eastern Africa, the Middle East, and South Asia. Because of projected population growth combined with climate change in Africa, entire countries would be newly confronted with water scarcity on a national scale.

The risk of ecosystem disruption as a result of ecosystem shifts, wildfires, and forest dieback would be significantly higher under a 4°C warming regime. Increased exposure to heat and drought would stress entire forest ecosystems and likely lead to increased mortality and species extirpation and extinction. Ecosystems would be affected by more frequent weather extremes. In the Amazon basin, forest fires could as much as double by 2050 with warming of approximately 1.5°C to 2°C above preindustrial levels. Changes

would be expected to be far more severe in a 4°C warmer world. In fact, in a 4°C warmer world, climate change seems likely to become the dominant driver of ecosystem shifts. It would even exceed ongoing habitat destruction as the single greatest threat to biodiversity. Recent studies indicate that large-scale loss of biodiversity is likely to result in a 4°C world, with climate change and high CO_2 levels driving a transition of the Earth´s ecosystems to a condition "unknown in human experience." This degree of ecosystem damage would be expected to dramatically reduce the ecosystem services upon which societies depend (World Bank 2012).

The World Bank underscores that maintaining sufficient food and agricultural output in the face of increasing population and rising levels of income would be a challenge even without anthropogenic climate change. Food security would be imperiled in a 4°C warmer world.

Disruptive, large-scale changes to the Earth system are generally not included in climate modeling exercises, and rarely in impact assessments. However, as global warming approaches and then surpasses 2°C, the risk increases of crossing thresholds or nonlinear tipping points in the Earth system. Examples include the disintegration of the West Antarctic ice sheet, leading to more rapid sea-level rise than projected, or a large-scale die-off of the Amazon rainforest, drastically affecting ecosystems, rivers, agriculture, energy production, and livelihoods in an almost continental scale region, and potentially adding substantially to 21st-century global warming from the loss of this colossal carbon sink (World Bank 2012).

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would contribute to indirect and cumulative impacts on U.S. carbon dioxide emissions and global climate change as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on CO_2 emissions and climate change associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on CO_2 emissions and climate change associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on CO_2 emissions and climate change associated with the population growth under the No Action Alternative would be Major, representing a "substantial impact or change in a

resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on CO_2 emissions and associated with the population growth under the No Action Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While these impacts may be ameliorated partially by the other factors in the Kaya identity discussed above, it is unlikely that these factors (improved energy and carbon efficiency) would be able to completely offset the adverse, overall effects of population growth on CO_2 emissions and climate change.

Overall, the net effect of the No Action Alternative on CO_2 emissions and global climate change would be adverse, significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the No Action Alternative would be entirely responsible for U.S. CO_2 emissions in 2100, nor the cumulative increase of CO_2 in the atmosphere by that date, nor the cumulative impact of those elevated CO_2 and other GHG concentrations on global warming and the myriad, wide-ranging and long-term adverse environmental impacts linked to higher atmospheric temperatures and ocean acidification.

While U.S. and global population size and growth rates are a key, underlying factor in determining the magnitude of national and global CO_2 emissions, population is but one of several factors. Furthermore, while the U.S. is responsible for far more cumulative CO_2 emissions than any other single country on Earth, it is no longer the world's largest CO_2 emitter; the U.S. share of aggregate global CO_2 emissions is decreasing and is likely to be smaller still in 2100 than today. Even so, with a population of more than half a billion that would result under the No Action Alternative, it would be much more difficult for America to sharply reduce its CO_2 emissions, and thereby make a constructive contribution to the global partnership urgently needed to address the climate predicament.

3.5.2.3 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would result in a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million (117 percent) above the 2010 population of 309 million. The same conditions and caveats apply to this alternative as to the No Action Alternative discussed above.

Predicting the exact level, or even a reasonable range, of U.S. CO_2 emissions in the year 2100 under the Expansion Alternative – 85 years into the future – is all but impossible for the same reasons discussed under the No Action Alternative. However, it can be stated

with 100% certainty that under the Expansion Alternative, upward pressure on U.S. CO_2 emissions would be substantially higher than under the No Action Alternative, to wit, 117 percent greater versus 70 percent greater. That is, if each of the other three factors in the Kaya identity were to remain unchanged, U.S. CO_2 emissions in 2100 would be 117 percent higher than they are today. This outcome is depicted graphically in Figure 3-162 by the proportionally bigger CO_2 molecule.

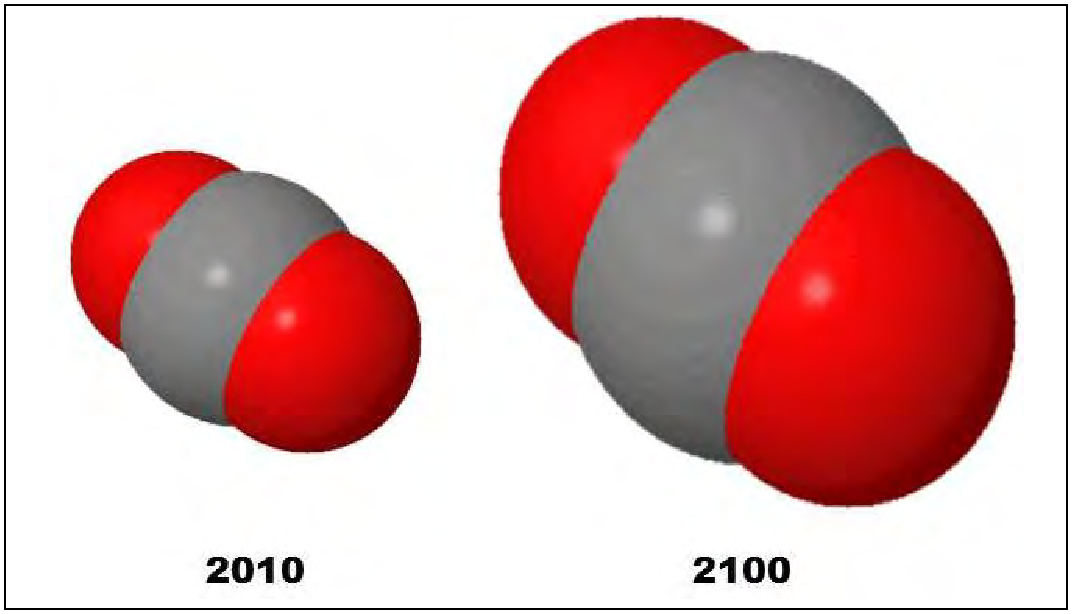


Figure 3-162. Graphic illustration representing magnitude of upward pressure exerted on American CO_2 emissions under the Expansion Alternative – annual immigration of 2.25 million leading to a U.S. population in 2100 of 669 million

Rating the probable effects of the Expansion Alternative on U.S. CO_2 emissions and resultant climate change according to the criteria and definitions in Section 3.1.1, this alternative would contribute to indirect and cumulative impacts on U.S. carbon dioxide emissions and global climate change as follows:

- **Duration of Impact**: ***Long-term to permanent***. The duration of the impact on CO_2 emissions and climate change associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on CO_2 emissions and climate change associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on CO_2 emissions and climate change associated with the population growth under the Expansion Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on CO_2 emissions and associated with the population growth under the Expansion Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While these impacts may be ameliorated partially by the other factors in the Kaya identity discussed above, it is unlikely that these factors (improved energy and carbon efficiency) would be able to completely offset the adverse, overall effects of population growth on CO_2 emissions and climate change.

Overall, the net effect of the Expansion Alternative on CO_2 emissions and global climate change would be adverse, significant, and long-term. To reiterate and underscore, neither the higher immigration rates nor the concomitant accelerated U.S. population growth associated with the Expansion Alternative would be entirely responsible for U.S. CO_2 emissions in 2100, nor the cumulative increase of CO_2 in the atmosphere by that date, nor the cumulative impact of those elevated CO_2 and other GHG concentrations on global warming and the myriad, wide-ranging and long-term adverse environmental impacts linked to higher atmospheric temperatures and ocean acidification.

While U.S. and global population size and growth rates are a key, underlying factor in determining the magnitude of national and global CO_2 emissions, population is but one of several factors. Furthermore, while the U.S. is responsible for far more cumulative CO_2 emissions than any other single country on Earth, it is no longer the world's largest CO_2 emitter; the U.S. share of aggregate global CO_2 emissions is decreasing and is likely to be smaller still in 2100 than today. Even so, with a population more than double that of today's (669 million vs. 320 million), which would result under the Expansion Alternative, it would be extremely difficult, if not impossible, for the United States to drastically reduce its CO_2 emissions, and thus make a constructive contribution to the global partnership urgently needed to address the climate predicament.

3.5.2.4 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This is an increase of 70 million (23 percent) above the 2010 population of 309 million. It is

145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Predicting the exact level, or even a reasonable range, of U.S. CO_2 emissions in the year 2100 under the Reduction Alternative – 85 years into the future – is all but impossible for the same reasons discussed above for the No Action and Expansion alternatives. However, it can be stated with 100% certainty that under the Reduction Alternative, upward pressure on U.S. CO_2 emissions would be substantially lower than under either the No Action Alternative or the Expansion Alternative, to wit: 23 percent greater for the Reduction Alternative, versus 70 percent greater for the No Action Alternative, and 117 percent greater for the Expansion Alternative. That is, if each of the other three factors in the Kaya identity were to remain unchanged, under the Reduction Alternative, U.S. CO_2 emissions in 2100 would be 23 percent higher than they are today. This outcome is depicted graphically in Figure 3-163 by the proportionally bigger CO_2 molecule.

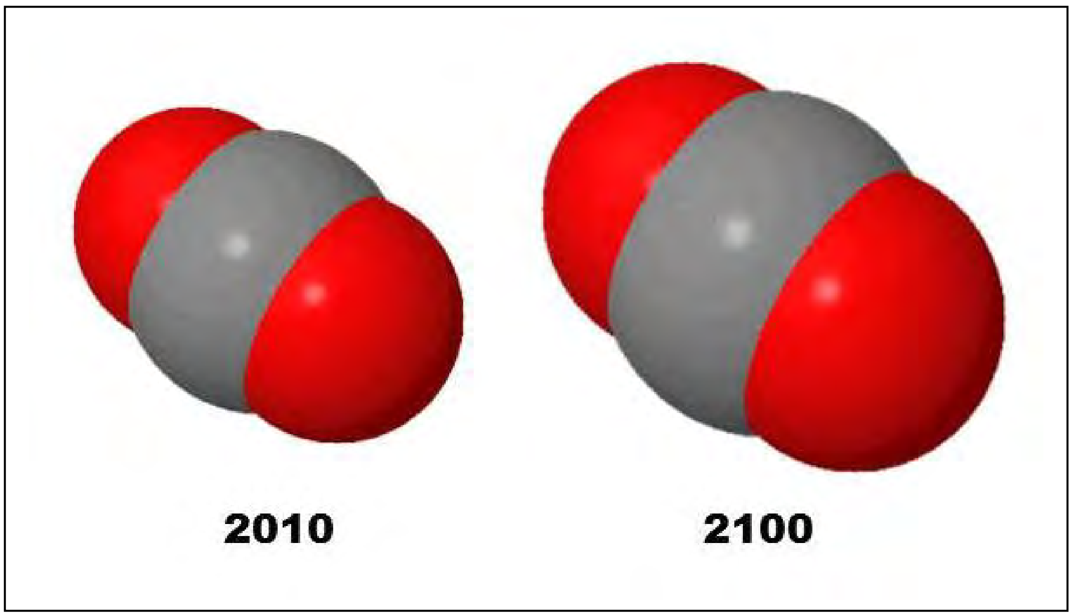


Figure 3-163. Graphic illustration representing magnitude of upward pressure exerted on American CO_2 emissions under the Reduction Alternative – annual immigration of 250,000 leading to a U.S. population in 2100 of 379 million

Rating the probable effects of the Reduction Alternative on U.S. CO_2 emissions and resultant climate change according to the criteria and definitions in Section 3.1.1, this alternative would contribute to indirect and cumulative impacts on U.S. carbon dioxide emissions and global climate change as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the impact on CO_2 emissions and climate change associated with the projected population

growth under the Reduction Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the impact on CO_2 emissions and climate change associated with the projected population growth under the Reduction Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the impact on CO_2 emissions and climate change associated with the population growth under the Reduction Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the impacts on CO_2 emissions and associated with the population growth under the Reduction Alternative is "more likely than not to occur, i.e., approximately 50% likelihood or higher." While these impacts may be ameliorated partially by the other factors in the Kaya identity discussed above, it is unlikely that these factors (improved energy and carbon efficiency) would be able to completely offset the adverse, overall effects of population growth on CO_2 emissions and climate change.

Overall, the net effect of the Reduction Alternative on CO_2 emissions and global climate change would be adverse, significant, and long-term. To reiterate and underscore, the lower immigration rates of this alternative would lead to a substantial slowdown in the rate of U.S. population growth. Nevertheless, population size would still increase by 70 million or 23 percent from 2010 to 2100 because of demographic momentum. Consequently, the Reduction Alternative would still produce upward demographic pressure on U.S. CO_2 emissions, although this upward pressure would be much less than with the No Action Alternative and the Expansion Alternative.

Continuing but slowing U.S. population growth (on the path to stabilization) that would occur under the Reduction Alternative would not be entirely responsible for U.S. CO_2 emissions in 2100, nor the cumulative increase of CO_2 in the atmosphere by that date, nor the cumulative impact of those elevated CO_2 and other GHG concentrations on global warming and the myriad, wide-ranging and long-term adverse environmental impacts linked to higher atmospheric temperatures and ocean acidification.

As stated previously, while U.S. and global population size and growth rates are a key, underlying factor in determining the magnitude of national and global CO_2 emissions, population is but one of several factors. Furthermore, while the U.S. is responsible for

far more cumulative CO_2 emissions than any other single country on Earth, it is no longer the world's largest CO_2 emitter; the U.S. share of aggregate global CO_2 emissions is decreasing and is likely to be smaller still in 2100 than today. With a 2100 U.S. population of 379 million, 70 million or 23 percent larger than the 2010 population of 308 million, it would be somewhat more difficult for the United States to drastically reduce its CO_2 emissions than with a stable, non-growing population. Nevertheless, under the Reduction Alternative, in contrast to the No Action and Expansion alternatives, it would be far more feasible for the United States to make a constructive contribution to the global partnership urgently needed to address the climate predicament.

Figure 3-164. Climate change is the greatest single global environmental challenge human civilization has ever faced

3.6 Energy Demands and National Security Implications

3.6.1 Affected Environment

3.6.1.1 Introduction to Energy

Energy, matter, space, and time are four of the fundamental features of the cosmos. In the simplest terms, physicists define energy as the ability to do work. However, this pedestrian definition scarcely conveys the profound significance of energy to our very existence. It falls short much as the definition of sound (a particular type of energy) as merely "vibratory disturbance through a medium" misses the phenomenal variety and richness of sounds and the language, music, communication, social behavior, human civilization, and emotional responses that sound enables (Kolankiewicz 2002).

Figure 3-165. Energy underlies all human and natural activity, as depicted in this image representing three forms of renewable energy: solar, wind, and biomass

Energy animates both natural ecosystems and the human economy. Solar energy activates virtually all life, both terrestrial and aquatic, at the surface of the Earth. It energizes the biosphere, that thin film of living organisms and their inorganic medium that envelops the planetary surface. Hundreds of millions of years ago, cyanobacteria, prokaryotic precursors to eukaryotic green plants, evolved the ability to tap into this reliable source of energy through the complex biochemical process of photosynthesis. Using water and

carbon dioxide as primary raw materials, the tiny factories called chloroplasts, present in the cells of every green leaf, and containing the green pigment chlorophyll, manufacture glucose (a simple sugar or carbohydrate) as a main product and oxygen as a byproduct.

The net result is that low-energy (higher entropy) inorganic matter is converted to high-energy (lower entropy) organic matter. Organic compounds are characterized by their covalent chemical bonds linking carbon atoms into long chains. Ecologists call green plants "primary producers," because they furnish the fundamental organic foodstuffs upon which all animals in the great chain of life nourish themselves, directly or indirectly. Without green plants to harvest the energy of the sun, quite simply there would be no sheep, dolphins, humans, or any other animal. Ecology classifies all animals as "consumers," because we consume the products of photosynthesis carried out by green plants. Even the formerly vast stocks of fossil fuels found on our planet – coal, oil, and natural gas – originated as plant matter that was converted by geologic processes (e.g., heat, compression, chemical reactions) into a form of concentrated, congealed solar energy.

Solar energy also drives the hydrologic cycle (without which there would be no rain or rivers), winds, large-scale atmospheric circulation patterns, and ocean currents. It provides the heat without which earth's surface would be frigid and sterile. Deep within the earth's mantle, another kind of energy – nuclear fission, or the splitting of uranium atoms – releases the prodigal quantities of thermal energy or heat that impel the geologic processes of our restless planet, including plate tectonics ("continental drift") and the mountain-building forces of volcanism, earthquakes, and folding/faulting (Kolankiewicz 2002).

The human economy is equally dependent on energy. This should not be surprising, since the human economy is but a subset, albeit an ever-larger one, of the biosphere, or "nature's economy" (Worster 1994, Ehrlich 1986, Daly 1987). From the era of ancient bands of hunter-gatherers to the satellite-enabled Information Age, Internet, and World Wide Web of the 21st century, human beings have always relied on solar energy for all the food we eat and for many other resources that furnish indispensable commodities. Until the Industrial Revolution two centuries ago, essentially all of our energy was derived from renewable, that is to say solar, sources. Firewood used to cook food and heat living spaces during winter – allowing *Homo sapiens* to expand its range to the far reaches of every continent except Antarctica – was an indirect form of solar energy, as was the muscle power of draft animals and human laborers.

The kinetic energy of moving water (hydropower) had been exploited for many centuries. With the discovery of electricity and its many applications in the eighteenth and

nineteenth centuries, by the late 1800's, inventors and engineers were moving swiftly to develop hydroelectricity: impounding water behind a dam, allowing gravity to pull it down through a tube or penstock to spin the blades of a turbine, and turning a generator to induce the flow of electrons, that is, produce an electric current or electricity.

Also beginning in the 1800's, man began to exploit the vast deposits of Earth's fossil fuels on a significant scale – first coal, then oil, and finally natural gas. According to accepted geologic theory, these fossil fuels originated hundreds of millions of years ago when complex organic compounds from partially decomposed plants and animals were subjected to millions of years of heat and pressure (Steinhart and Steinhart 1974). These plants and animals lived and died in swampy settings and aquatic and shallow marine environments and their remains were deposited as sediments, accreting in ever-thicker layers on the anaerobic (oxygen-starved) bottom (Deffeyes 2003, 2006). Thus, in a very real sense, the fossil fuels amount to a form of indirect or secondary solar energy – concentrated, "cooked," accumulated, and enriched over many millions of years. At present rates of consumption however, industrial civilization will exhaust in mere centuries (Figure 3-166) the treasure-trove of fossil fuels that took nature tens of millions of years to fabricate (Hubbert 1976, Bartlett 1978). While this by itself is extraordinary, it is perhaps even more astounding that by and large, most of humanity acts oblivious to this impending depletion, squandering the fossil fuels as profligately as if they were expected to last – and even meet ever-growing demands – forever (Kolankiewicz 2002).

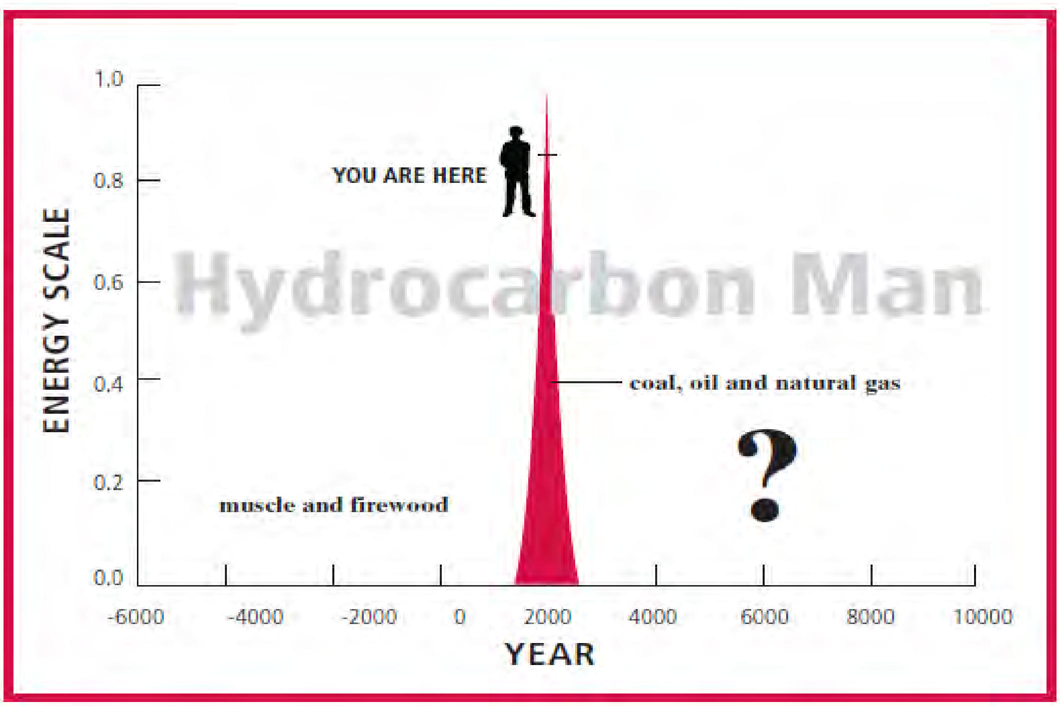


Figure 3-166. The short-lived Age of "Hydrocarbon Man"

Two of the more ironclad laws of physics – the first and second laws of thermodynamics – pertain to energy and mass. The First Law of Thermodynamics, sometimes called the Conservation Law, states that the total amount of matter-energy in the universe is constant and unchanging; while energy can be converted into mass and vice versa, the total amount of matter-energy after any such transformation remains unchanged, i.e. is conserved. The Second Law of Thermodynamics is sometimes called the Entropy Law. It states that in every conversion of energy, there are inefficiencies: some energy is invariably lost or dissipated into unusable forms, typically low-grade or "waste" heat. These laws pertain at all scales – from the prodigious energy output of distant galaxies and quasars to the comparatively tiny power produced by a wristwatch battery. The first and second laws of thermodynamics also prevent the development of that classic will-o'-wisp, the perpetual motion machine, which once set into motion, will continue operating in perpetuity without any input from an external energy source.

Until those economists and technophiles who fantasize about the human brain as the "ultimate resource" (Simon 1980, 1993, 1998) are able concoct a way to repeal or amend these most fundamental laws of nature, human destiny, like that of every other living organism on earth, will be in large part dictated by what these laws allow, and what they relegate to the realm of science fiction. One thing they most certainly will not permit is perpetual growth in raw energy consumption of the magnitude the world has experienced over the past century, whether these gigajoules and "quads" (quadrillion British Thermal Units or Btu's) are supplied by the fossil fuels, hydropower, renewable energy (e.g., solar, wind, biomass, tidal, wave), nuclear fission or fusion. Growth may hypothetically be possible for a century or two yet, by drawing down and depleting the Earth's natural capital and running up its ecological debt, including the atmospheric accumulation of GHGs and subsequent global warming discussed in the previous section. Ultimately, however, this growth is unsustainable, and will involve unprecedented and potentially devastating interruption of the cycles, flows, stocks, sinks, and processes of the biosphere that sustain all life on earth, including that of *H. sapiens* (Kolankiewicz 2002).

3.6.1.2 A Primer on Energy Production and Consumption in the United States

In the United States, total primary energy consumption more than tripled over the past six decades, jumping from 31 quadrillion Btu's (31 quads) in 1949 to 97 quads in 2011 (EIA 2012b). (The Btu is the traditional English unit for measuring energy content. It is the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit. One quadrillion or 1,000,000,000,000,000 or 10^{15} Btu's is sometimes referred to as a "quad," a convention that will be followed here.) The great majority of our energy produced and consumed domestically is from burning the fossil fuels – oil, natural gas and coal – and fossil fuel consumption nearly tripled over the same 1949-2011 period, from 29 to 80 quads (Table 3-16)

Table 3-16. U.S. primary energy overview, 1949 to 2011 (in quads)

	Production				Trade					Stock Change and Other [8]	Consumption			
					Imports		Exports		Net Imports [1]					
Year	Fossil Fuels [2]	Nuclear Electric Power [3]	Renewable Energy [4]	Total	Petroleum [5]	Total [6]	Coal	Total [7]	Total		Fossil Fuels [9]	Nuclear Electric Power [3]	Renewable Energy [4]	Total [10]
1949	28.748	0.000	2.974	31.722	1.427	1.448	0.877	1.592	-0.144	0.403	29.002	0.000	2.974	31.982
1950	32.563	.000	2.978	35.540	1.886	1.913	.786	1.465	.448	-1.372	31.632	.000	2.978	34.616
1955	37.364	.000	2.784	40.148	2.752	2.790	1.465	2.286	.504	-.444	37.410	.000	2.784	40.208
1960	39.869	.006	2.928	42.803	3.999	4.188	1.023	1.477	2.710	-.427	42.137	.006	2.928	45.086
1965	47.235	.043	3.396	50.674	5.402	5.892	1.376	1.829	4.063	-.722	50.577	.043	3.396	54.015
1970	59.186	.239	4.070	63.495	7.470	8.342	1.936	2.632	5.709	-1.367	63.522	.239	4.070	67.838
1975	54.733	1.900	4.687	61.320	12.948	14.032	1.761	2.323	11.709	-1.065	65.357	1.900	4.687	71.965
1976	54.723	2.111	4.727	61.561	15.672	16.760	1.597	2.172	14.588	-.175	69.107	2.111	4.727	75.975
1977	55.101	2.702	4.209	62.012	18.756	19.948	1.442	2.052	17.896	-1.946	70.991	2.702	4.209	77.961
1978	55.074	3.024	5.005	63.104	17.824	19.106	1.078	1.920	17.186	-.339	71.854	3.024	5.005	79.950
1979	58.006	2.776	5.123	65.904	17.933	19.460	1.753	2.855	16.605	-1.650	72.891	2.776	5.123	80.859
1980	59.008	2.739	5.428	67.175	14.658	15.796	2.421	3.695	12.101	-1.210	69.828	2.739	5.428	78.067
1981	58.529	3.008	5.414	66.951	12.639	13.719	2.944	4.307	9.412	-.257	67.571	3.008	5.414	76.106
1982	57.458	3.131	5.980	66.569	10.777	11.861	2.787	4.608	7.253	-.723	63.888	3.131	5.980	73.099
1983	54.416	3.203	6.496	64.114	10.647	11.752	2.045	3.693	8.059	.798	63.152	3.203	6.496	72.971
1984	58.849	3.553	6.438	68.840	11.433	12.471	2.151	3.786	8.685	-.892	66.506	3.553	6.438	76.632
1985	57.539	4.076	6.084	67.698	10.609	11.781	2.438	4.196	7.584	1.110	66.093	4.076	6.084	76.392
1986	56.575	4.380	6.111	67.066	13.201	14.151	2.248	4.021	10.130	-.549	66.033	4.380	6.111	76.647
1987	57.167	4.754	5.622	67.542	14.162	15.398	2.093	3.812	11.586	-.074	68.521	4.754	5.622	79.054
1988	57.875	5.587	5.457	68.919	15.747	17.296	2.499	4.366	12.929	.861	71.557	5.587	5.457	82.709
1989	57.483	5.602	6.235	69.320	17.162	18.766	2.637	4.661	14.105	1.361	72.911	5.602	6.235	84.786
1990	58.560	6.104	6.041	70.705	17.117	18.817	2.772	4.752	14.065	-.284	72.332	6.104	6.041	84.485
1991	57.872	6.422	6.069	70.362	16.348	18.335	2.854	5.141	13.194	.882	71.880	6.422	6.069	84.438
1992	57.655	6.479	5.821	R69.958	16.968	19.372	2.682	4.937	14.435	1.392	73.396	6.479	5.821	85.783
1993	55.822	6.410	6.083	68.315	18.510	21.273	1.962	4.258	17.014	2.094	74.836	6.410	6.083	87.424
1994	58.044	6.694	5.988	70.726	19.243	22.390	1.879	4.061	18.329	.037	76.256	6.694	5.988	89.091
1995	57.540	7.075	6.558	71.174	18.881	22.260	2.318	4.511	17.750	2.105	77.259	7.075	6.560	91.029
1996	58.387	7.087	7.012	72.486	20.284	23.702	2.368	4.633	19.069	2.468	79.785	7.087	7.014	94.022
1997	58.857	6.597	7.018	72.472	21.740	25.215	2.193	4.514	20.701	1.429	80.873	6.597	7.016	94.602
1998	59.314	7.068	6.494	72.876	22.908	26.581	2.092	4.299	22.281	-.140	81.369	7.068	6.493	95.018
1999	57.614	7.610	6.517	71.742	23.133	27.252	1.525	3.715	23.537	1.373	82.427	7.610	6.516	96.652
2000	57.366	7.862	6.104	71.332	24.531	28.973	1.528	4.006	24.967	R2.515	84.731	7.862	6.106	R98.814
2001	58.541	8.029	5.164	71.735	25.398	30.157	1.265	3.771	26.386	-1.953	82.902	8.029	5.163	96.168
2002	R56.837	8.145	5.734	R70.716	24.674	29.408	1.032	3.669	25.739	R1.190	R83.899	8.145	5.729	R97.645
2003	56.099	7.959	5.982	70.040	26.219	31.061	1.117	4.054	27.007	.931	84.014	7.959	5.983	97.978
2004	55.895	8.222	6.070	70.188	28.197	33.544	1.253	4.434	29.110	R.864	R85.819	8.222	6.082	R100.162
2005	55.038	8.161	6.229	R69.428	29.248	34.709	1.273	4.560	30.149	R.705	R85.794	8.161	6.242	R100.282
2006	55.968	8.215	R6.599	R70.782	29.169	34.679	1.264	4.872	29.806	R-.959	R84.702	8.215	R6.649	R99.629
2007	R56.409	8.455	R6.509	R71.373	28.781	34.703	1.507	5.482	29.221	R.702	R86.211	8.455	R6.523	R101.298
2008	57.482	8.427	R7.202	R73.111	27.685	32.992	2.071	7.060	25.932	R.231	R83.549	8.427	R7.186	R99.275
2009	R56.685	8.356	R7.616	R72.657	25.082	29.706	1.515	6.965	22.741	R-.839	R78.488	8.356	R7.600	R94.559
2010	R58.235	R8.434	R8.136	R74.806	R25.371	R29.877	2.101	R8.234	R21.643	R1.273	R81.109	R8.434	R8.090	R97.722
2011P	60.601	8.259	9.236	78.096	24.491	28.587	2.751	10.356	18.232	.974	79.779	8.259	9.135	97.301

[1] Net imports equal imports minus exports. A minus sign indicates exports are greater than imports.
[2] Coal, natural gas (dry), crude oil, and natural gas plant liquids.
[3] Nuclear electricity net generation (converted to Btu using the nuclear heat rate—see Table A6).
[4] See Tables 10.1–10.2c for notes on series components and estimation; and see Note, "Renewable Energy Production and Consumption," at end of Section 10.
[5] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[6] Also includes natural gas, coal, coal coke, fuel ethanol, biodiesel, and electricity.
[7] Also includes natural gas, petroleum, coal coke, biodiesel, and electricity.
[8] Calculated as consumption and exports minus production and imports. Includes petroleum stock change and adjustments; natural gas net storage withdrawals and balancing item; coal stock change, losses, and unaccounted for; fuel ethanol stock change; and biodiesel stock change and balancing item.
[9] Coal, coal coke net imports, natural gas, and petroleum. For petroleum, product supplied is used as an approximation of petroleum consumption. See Note 1, "Petroleum Products Supplied and Petroleum Consumption," at end of Section 5.
[10] Also includes electricity net imports.
R=Revised. P=Preliminary.
Notes: • See "Primary Energy," "Primary Energy Production," and "Primary Energy Consumption" in Glossary. • Totals may not equal sum of components due to independent rounding.
Web Pages: • See http://www.eia.gov/totalenergy/data/monthly/#summary for updated monthly and annual data. • See http://www.eia.gov/totalenergy/data/annual/#summary for all annual data beginning in 1949.
Sources: Tables 1.2, 1.3, and 1.4.

Source: Table 1-1, EIA (2012b)

During the 1949-2011 period, total U.S. primary energy consumption actually peaked at 101 quads in 2007, the year before the Great Recession began. By 2014, consumption had still not regained the 2007 peak. Figures 3-167 through 3-170 provide an overview of U.S. production, consumption, and flows in 2011.

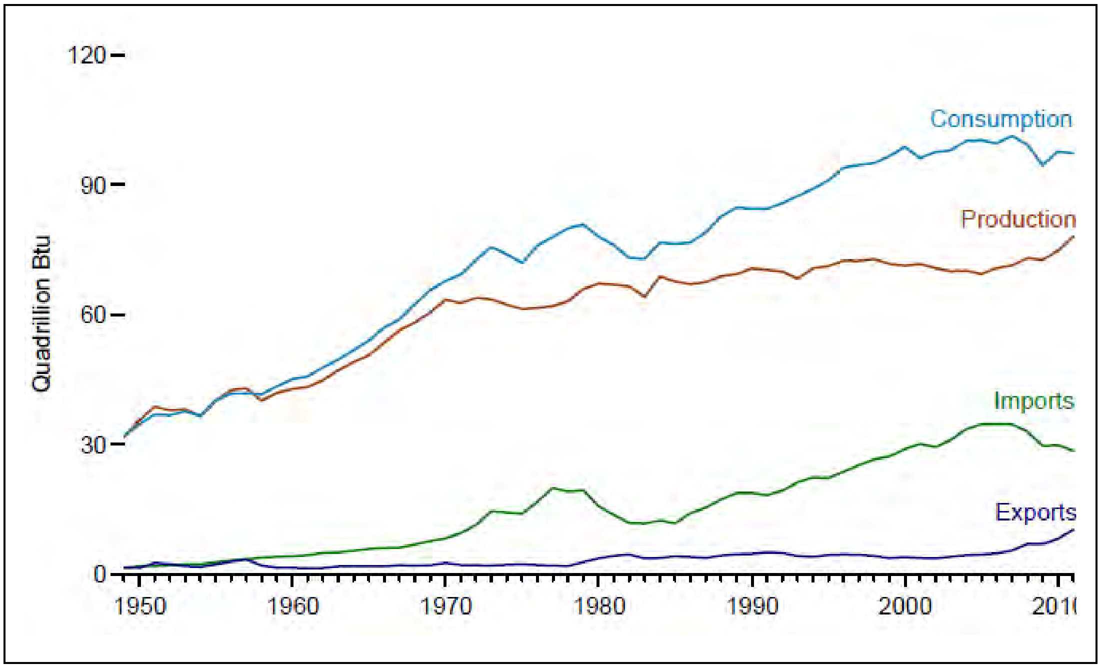


Figure 3-167. U.S. primary energy overview, 1949-2011
Source: Figure 1-1, EIA (2012b)

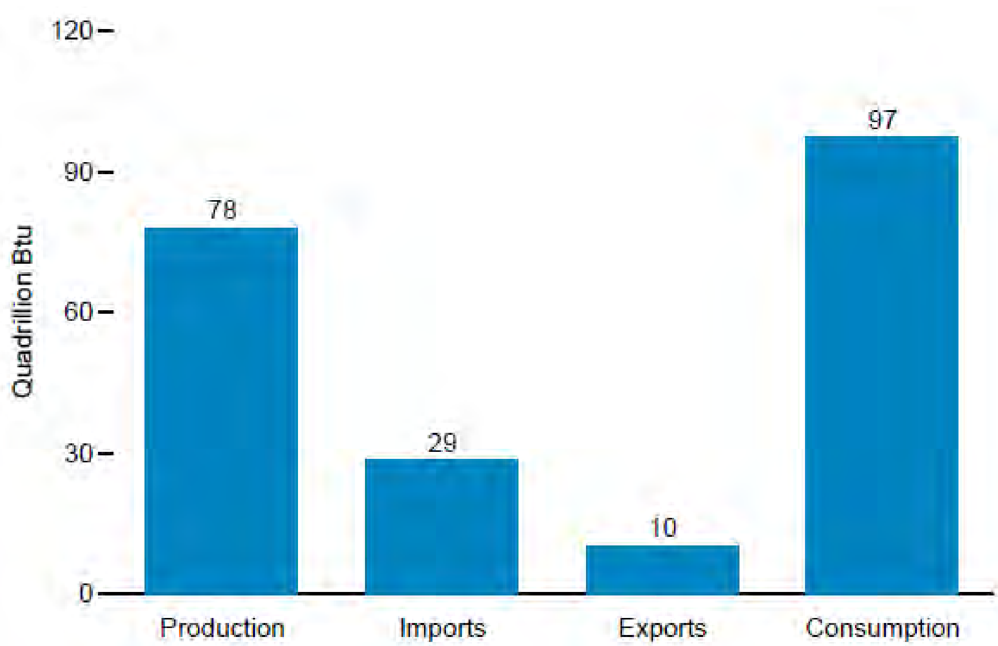


Figure 3-168. Bar chart of U.S. primary energy overview in 2011
Source: Figure 1-1, EIA (2012b)

As can be seen in Figures 3-167, the gap between domestic energy production and consumption began to widen after about 1970. Not coincidentally, domestic crude oil production peaked in 1970, so increasing U.S. consumption of oil products such as gasoline, diesel, and jet fuel to support population and economic growth (U.S. population has grown by more than 110 million since 1970) was facilitated by rising oil imports, which peaked at 29 quads in 2005. Our oil imports came from places like Canada, Mexico, the Middle East, and Venezuela.

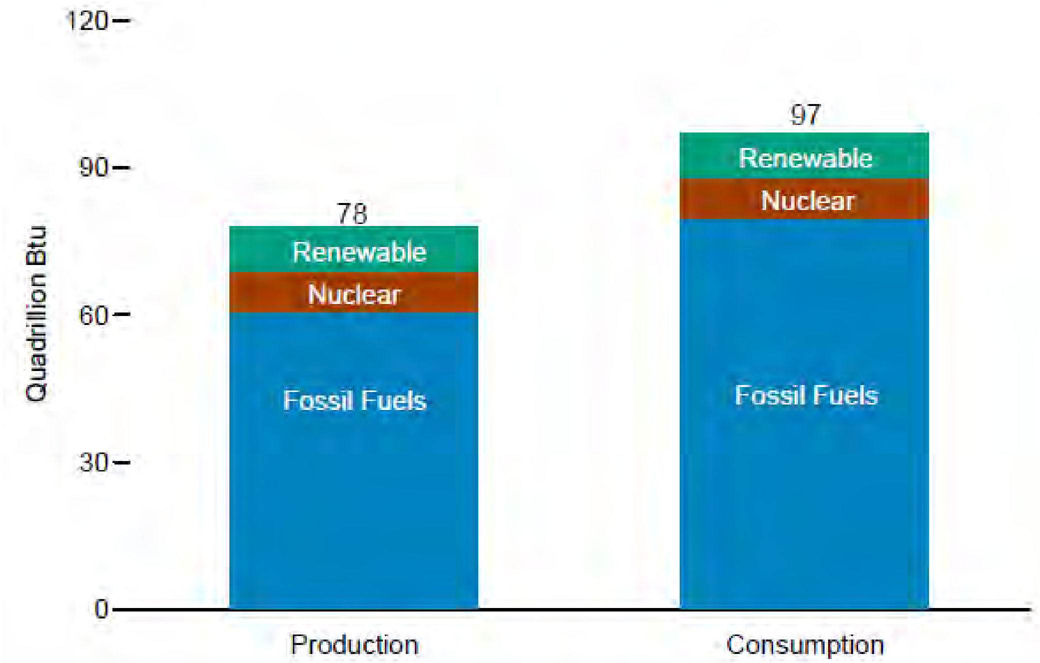


Figure 3-169. Energy sources in U.S. primary energy production/consumption, 2011

Source: Figure 1-1, EIA (2012b)

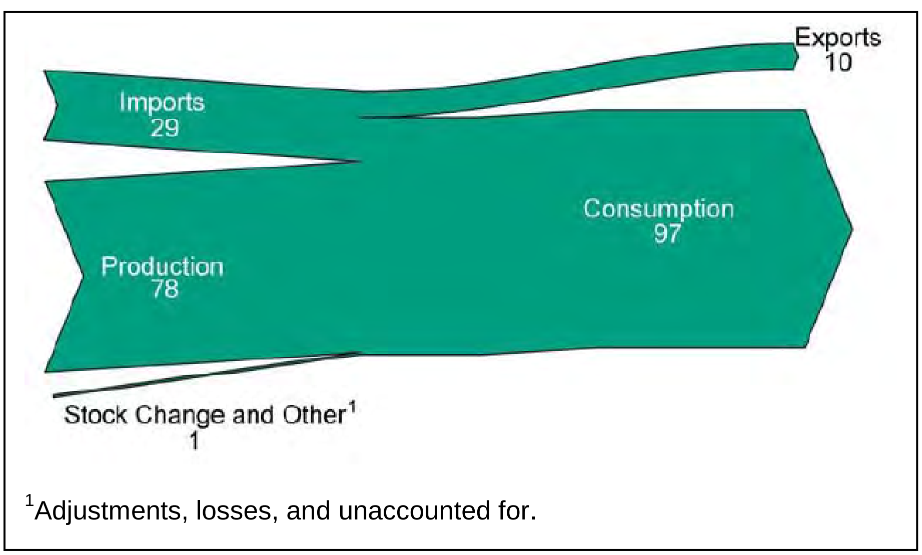
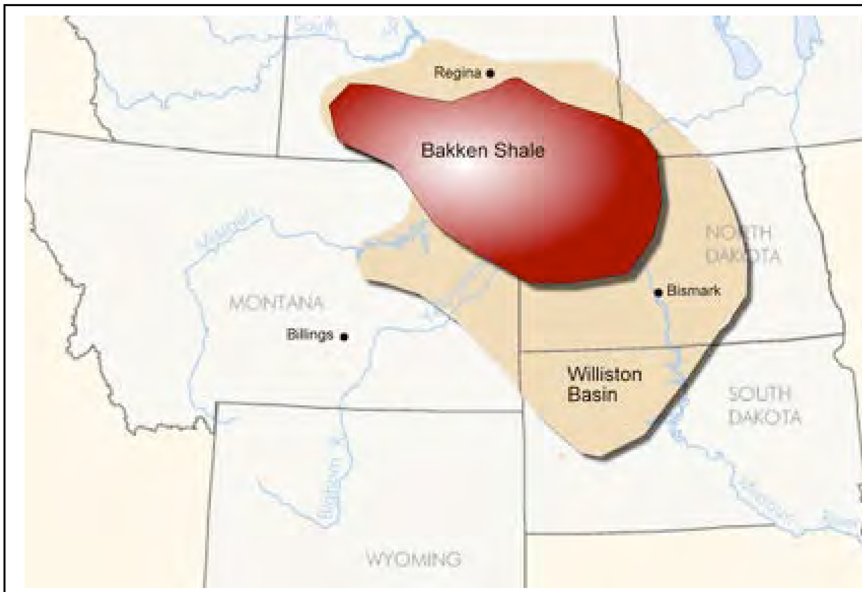


Figure 3-170. U.S. primary energy flow (quads) in 2011

Source: Figure 1-1, EIA (2012b)

The import-export gap began to close after about 2005 because of the increase in domestic petroleum (oil and natural gas) production brought on by the boom in hydraulic fracturing (hydrofracking). Production of so-called shale gas and tight oil from places like the Barnett and Eagle Ford Formations in Texas, Bakken Formation in North Dakota and eastern Montana (Figure 3-171), and Marcellus Formation in Pennsylvania was only made possible by high oil and gas prices, because hydrofracking is a costly procedure and well depletion rates are high. Nevertheless, as of 2011, imports of primary energy still exceeded exports by 19 quads, or 20 percent of our total national energy consumption. We consumed 20 percent more energy than we produced, and were thus rather far from "living within our means" or achieving "energy independence." The gap between domestic production and consumption gives rise to energy insecurity, because of our dependence on oil imports from countries or regions that are politically and socially unstable (the Middle East), politically and/or culturally hostile to the United States (e.g., Saudi Arabia, Venezuela), at war (e.g., Libya, Iraq), or deeply corrupt (e.g., Nigeria, Russia).

Figure 3-171. Location map of the Bakken Shale Formation



As shown by Table 3-16 and Figure 3-169, in 2011, fossil fuels comprised 60 of 78 quads (or 77 percent) of U.S. primary energy production, and 80 of 97 quads (or 82 percent) of our energy consumption. Since precise EIA record-keeping began in 1949, fossil fuels have always comprised more than 80 percent of our national primary energy consumption, sometimes more than 90 percent. Of course, this was not always the case, and historically, it is only a very recent phenomenon. Throughout thousands of years of human history, and up until the 19th century, renewable energy – primarily biomass in the form of wood – was predominant. However, the high energy density, versatility, and abundance of the fossil fuels facilitated their rise to dominance of U.S. and then global

energy markets in the 19th and 20th centuries and allowed for spectacular population, industrial and economic growth in America and the world (Heinberg 2005). Figure 3-172 shows how the fossil fuels enabled an accelerating global human population boom beginning in the 1800's (19th century) by increasing food production and other indirect means.

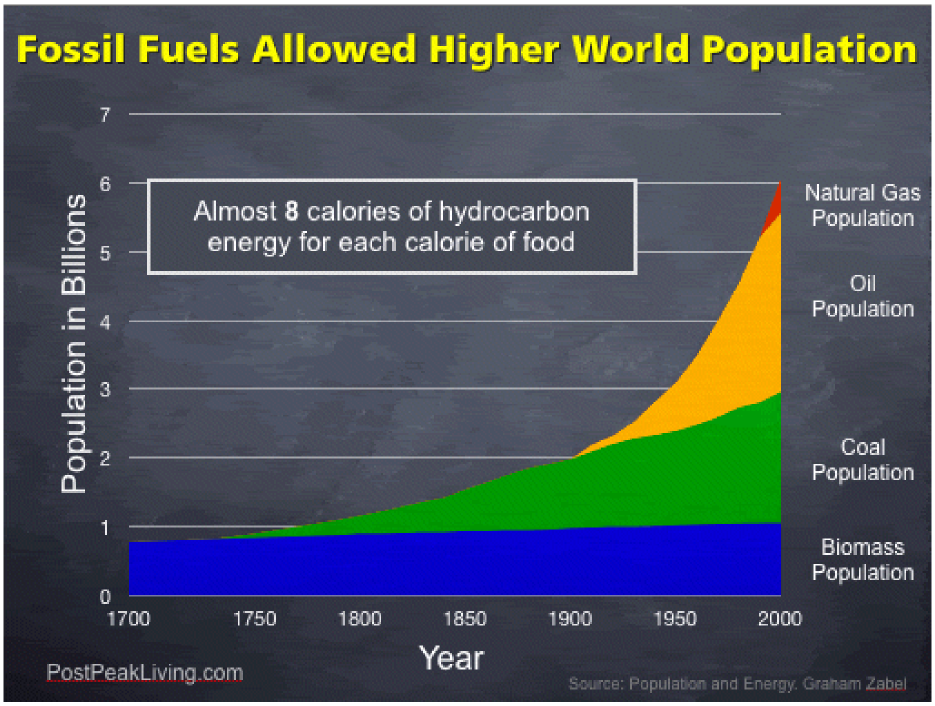


Figure 3-172. Explosive, exponential growth in the human population was aided and abetted by exponential growth in the exploitation of fossil fuels on a massive scale beginning in the late 1700s and accelerating in the 1800s and 1900s.

U.S. Energy Production

Figure 3-173 is a graph showing the trends in U.S. primary energy production by major source (measured in quads) – fossil fuels, nuclear electric power, and renewable energy – from 1949 to 2011. The overall growth and fluctuations of all three sources across these six decades and the dominant position of the fossil fuels can be appreciated. Also noteworthy is that U.S. fossil fuel production grew rapidly in the 1950s and 1960s to about 1970, more than doubling in size, but has been almost stagnant or stable since that time, with fluctuations from year to year. Nuclear power began to make an appreciable contribution to the nation's energy production in about 1970 and grew steadily for several decades, but has been stable for about the last decade. Renewable energy – originally almost entirely hydropower with some biomass at the start of the period, and now including wind and solar – has grown more or less steadily over the past six decades, except for a dip in the late 1990s and early 2000s.

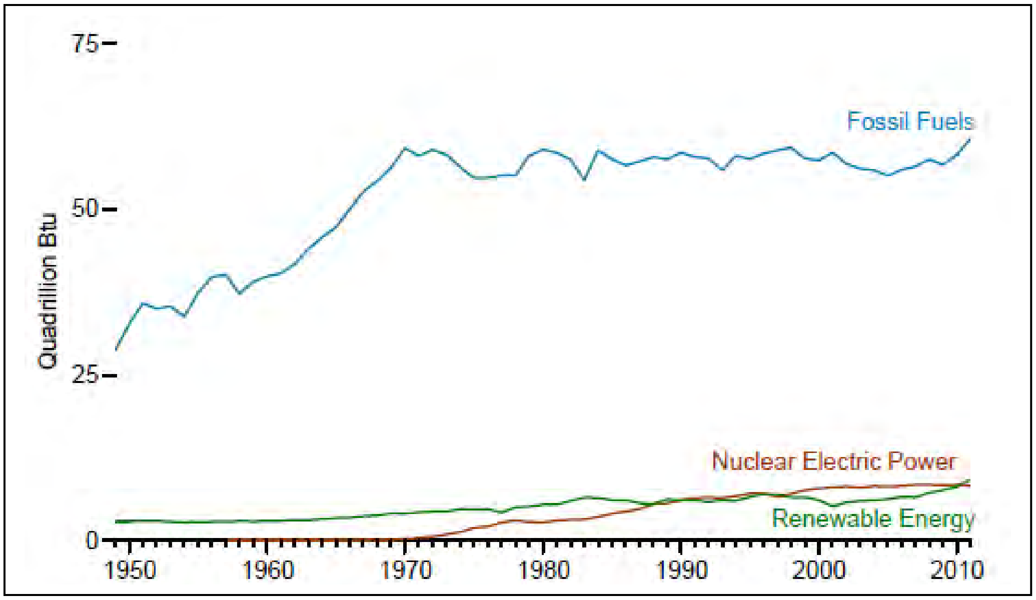


Figure 3-173. U.S. primary energy production by source category, 1949-2011
Source: Figure 1.2, EIA (2012b)

Figure 3-174 is a bar chart that disaggregates U.S. primary energy production by source in 2011. At 24 quads, there was more production of natural gas than any other single energy source in the U.S. Coal was a close second with 22 quads. Then came crude oil at 12 quads, nuclear power at eight quads, biomass at five quads, hydroelectric power and natural gas plant liquids (NGPLs) each at three quads, and all other renewable energy sources combined (including geothermal, solar/photovoltaic, and wind) at two quads. Table 3-17 presents the same information, and adds the percentage that each source comprises of total U.S. energy production in 2011.

Table 3-17. U.S. primary energy production in quads by source in 2011

Source	Quads	% of total U.S. primary energy production
Natural gas	24	31%
Coal	22	28%
Crude Oil[1]	12	15%
Nuclear electric power	8	10%
Biomass	5	6%
Hydroelectric power[2]	3	4%
NGPL[3]	3	4%
Other renewable energy[4]	2	3%

[1]Includes lease condensate
[2]Conventional hydroelectric power
[3]Natural gas plant liquids
[4]Geothermal, solar/photovoltaic, wind

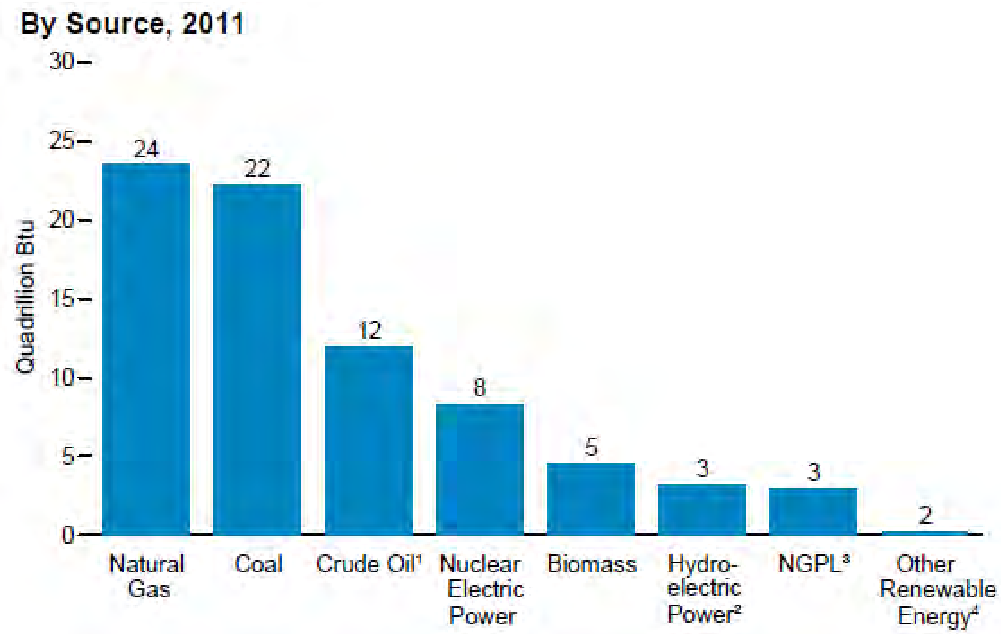


Figure 3-174. U.S. primary energy production in quads by source in 2011
Source: Figure 1.2, EIA (2012b)

Figure 3-176 (next page) shows the dramatic changes in primary energy production by source from 1949 to 2011. The sharpest swings in output are for crude oil, production of which peaked in 1970 at 3.5 billion barrels annually, after which it fell sharply, with one notable bump caused when crude from Alaska's Prudhoe Bay field was brought online in the late 1970s. However, in the last several years, domestic crude oil production has increased sharply because of the hydrofracking boom, principally from the Eagle Ford Formation in Texas and the Bakken Formation in North Dakota. This can be appreciated by the sharp bump upward on the right side of the production curve in Figure 3-175. In 2014, annual crude oil production reached 3.1 billion barrels, a level it had not been at in four decades (EIA 2015a).

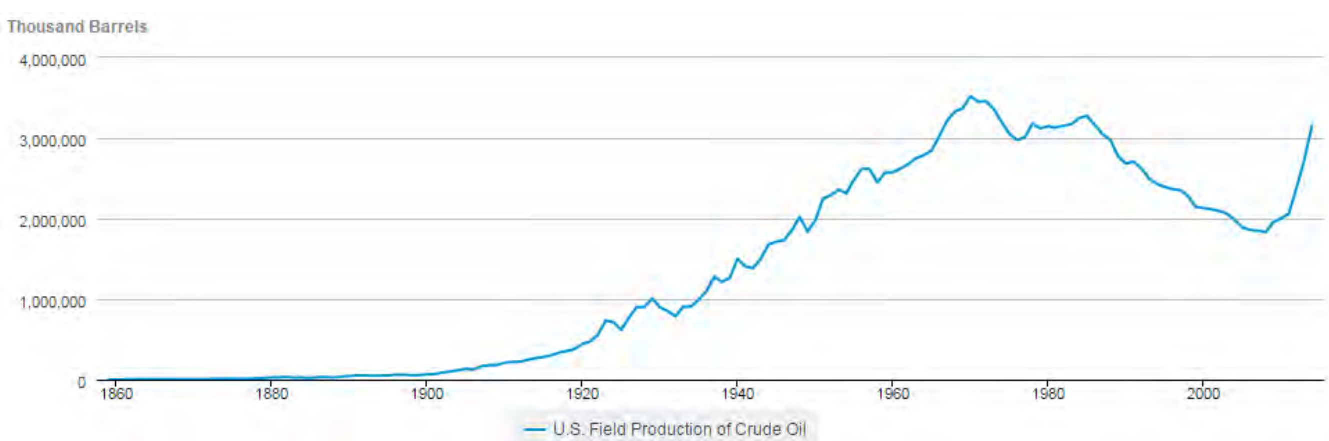


Figure 3-175. Trend in annual production of U.S. crude oil, 1859 to 2014
Source: EIA (2015a)

Just how high this boom will reach or how long it will last is uncertain, but production has already slipped in 2014 because of the glut of crude oil on global markets and the prolonged slump in the price of crude. Most disinterested analysts do not expect costly, so-called "tight oil" – oil contained within impermeable, imporous (low-porosity) shale rock formations – to be a long-term "game changer" or substantially shift the date of "peak oil," i.e., the year at which global crude oil production peaks.

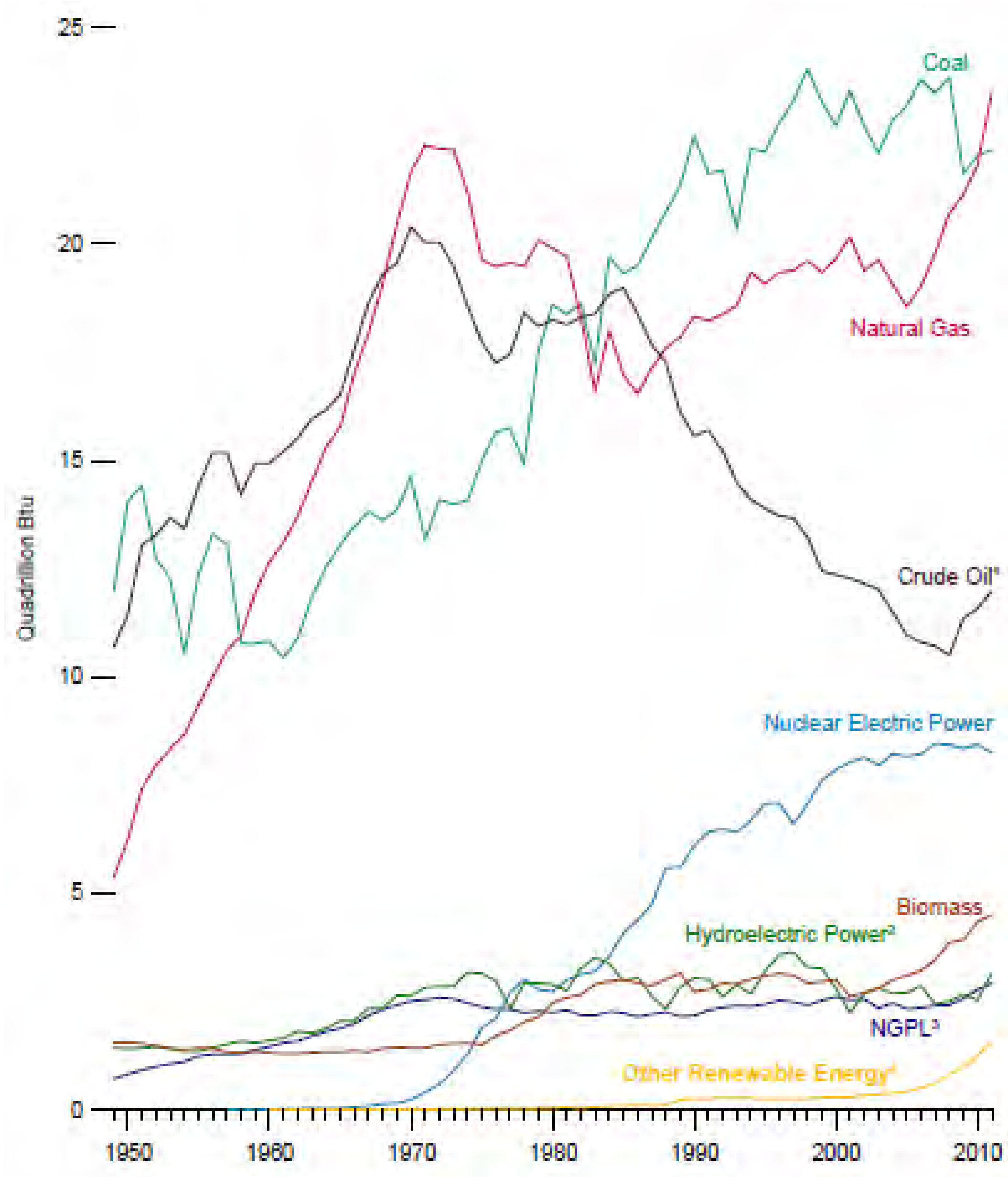


Figure 3-176. Trends in U.S. primary production by source from 1949 to 2011

Source: Figure 1.2, EIA (2012b)

U.S. Energy Consumption

When considering energy in the United States, it is important to distinguish between energy produced here and energy consumed here, because they are not always the same thing. This is particularly true of oil and petroleum, as discussed above. Figures 3-177 to 3-179 graphically depict energy consumption trends in the United States by major source. U.S. primary energy consumption roughly tripled in the five decades from 1949 to about 2000, but has not increased since then.

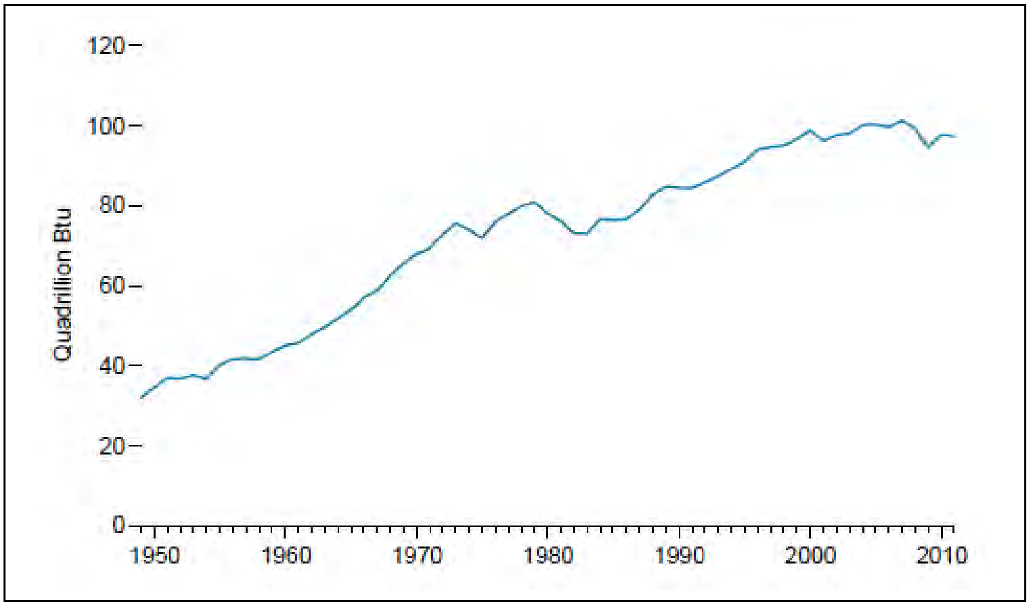


Figure 3-177. Total U.S. primary energy consumption, 1949-2011

Source: Figure1.3, EIA (2012b)

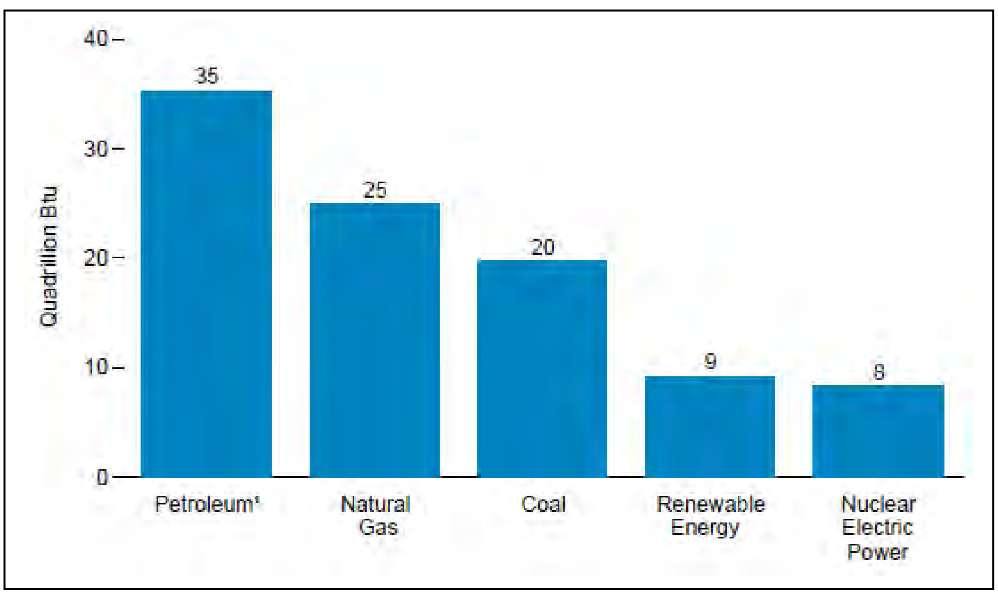


Figure 3-178. Total U.S. primary energy consumption by major source, 2011

Source: Figure1.3, EIA (2012b)

Comparing the bar chart in Figure 3-178 (U.S. energy consumption in 2011) with the bar chart in Figure 3-174 (U.S. energy production in 2011), what is immediately apparent is the striking gap between production of crude oil/petroleum and consumption of the same. In 2011, only 12 quads of crude oil were produced in the United States, but 35 quads of petroleum products were consumed. This included natural gas plant liquids and crude oil burned as fuel. (It did not include biofuels like ethanol that were blended with petroleum, which were included in "renewable energy.") The difference between production and consumption was bridged by crude oil imports.

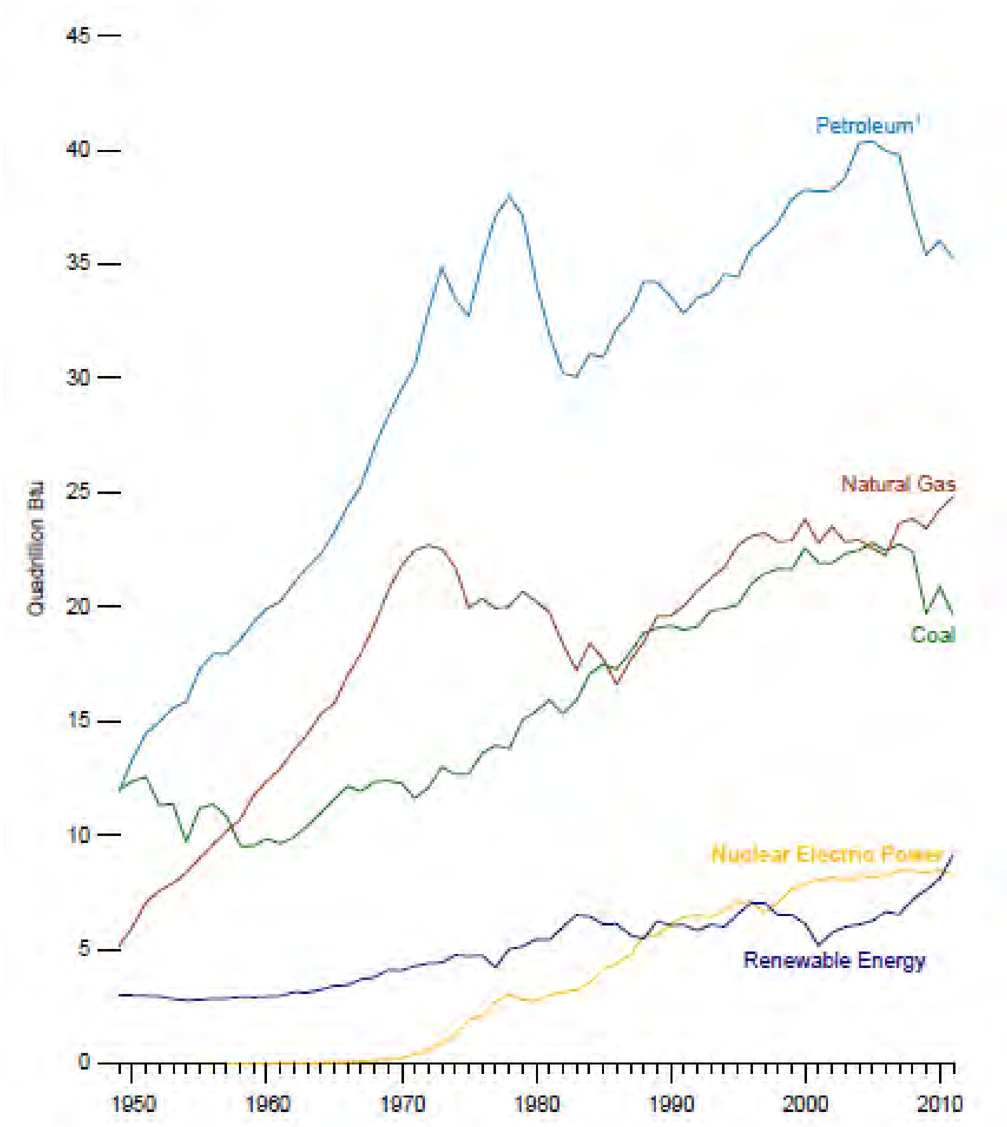


Figure 3-179. Total U.S. primary energy consumption by major source, 1949-2011

Source: Figure1.3, EIA (2012b)

Energy Imports and National Security

Historically, the United States was essentially self-sufficient in energy (or "energy independent") until the 1960s (Figure 3-180). Although we imported a small amount of energy supplies, we also exported them, and imports more or less equaled exports, so that net imports were zero. This changed beginning in the late 1950s, when imports of petroleum (mostly crude oil) began to rise rapidly (Figure 3-181).

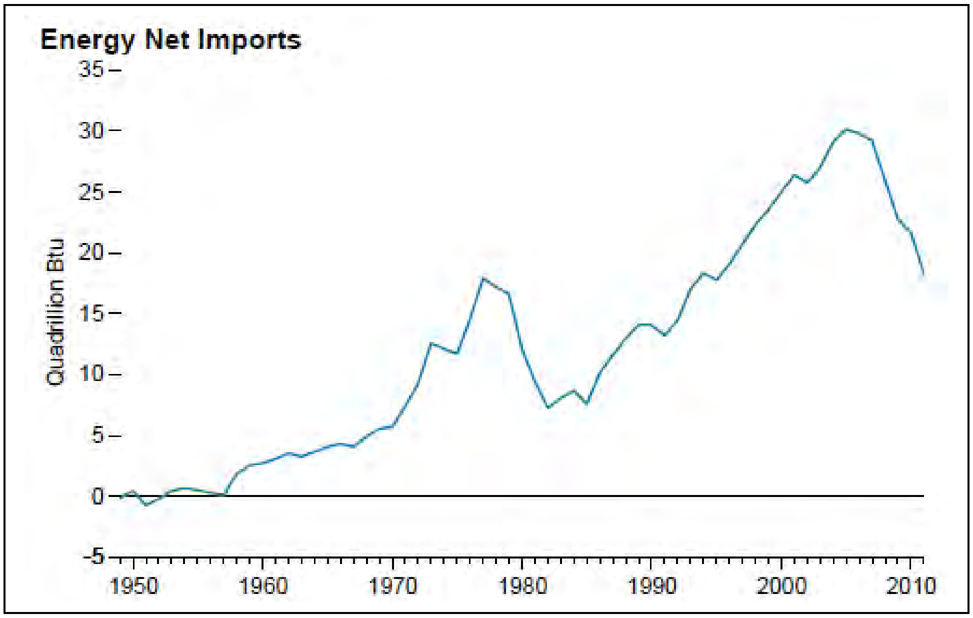


Figure 3-180. Primary energy net imports, 1949-2011

Source: Figure1.4, EIA (2012b)

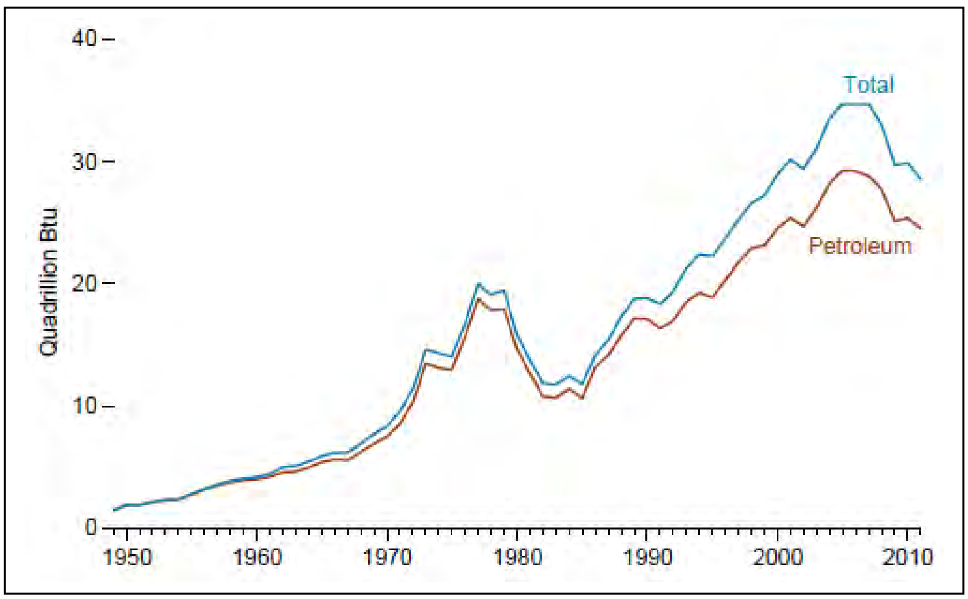


Figure 3-181. Total primary energy and petroleum imports, 1949-2011

Source: Figure1.4, EIA (2012b)

Imports of petroleum surged in the 1970s after U.S. domestic crude oil production peaked in 1970. However the Arab oil embargo of 1973-1974 (in retaliation for American support of Israel in the Yom Kippur War of 1973) and the Iranian Revolution of 1979 disrupted oil exports/imports, and net U.S. imports fell as crude oil prices skyrocketed. These two events shook American confidence and complacency that meeting our rapidly growing energy demands could be taken for granted. Americans old enough to remember the Arab oil embargo will recall long lines and waits at gasoline pumps, gas stations running out of gasoline, and exorbitant prices. Every U.S. president since Nixon has called for U.S. energy independence, so that American industry and consumers would not be at the mercy of hostile powers, capricious foreign governments, or the outbreak of war in volatile regions. Not a single president has been able to deliver on his promise and vision of halting the potentially dangerous U.S. dependency on foreign oil.

On January 23, 1980 President Jimmy Carter proclaimed a policy that came to be known as the Carter Doctrine. It stated that the United States would use military force, if necessary, to defend its national interests in the Persian Gulf. Many of the world's leading oil-exporting nation states and members of the Organization of Petroleum Exporting Countries (OPEC) are located around the Persian Gulf (Saudi Arabia, Kuwait, United Arab Emirates, Iran, Iraq, Qatar) and much of the world's exported oil is carried by oil tankers that pass through the chokepoint of the Strait of Hormuz at the mouth of the Persian Gulf (Figure 3-182).

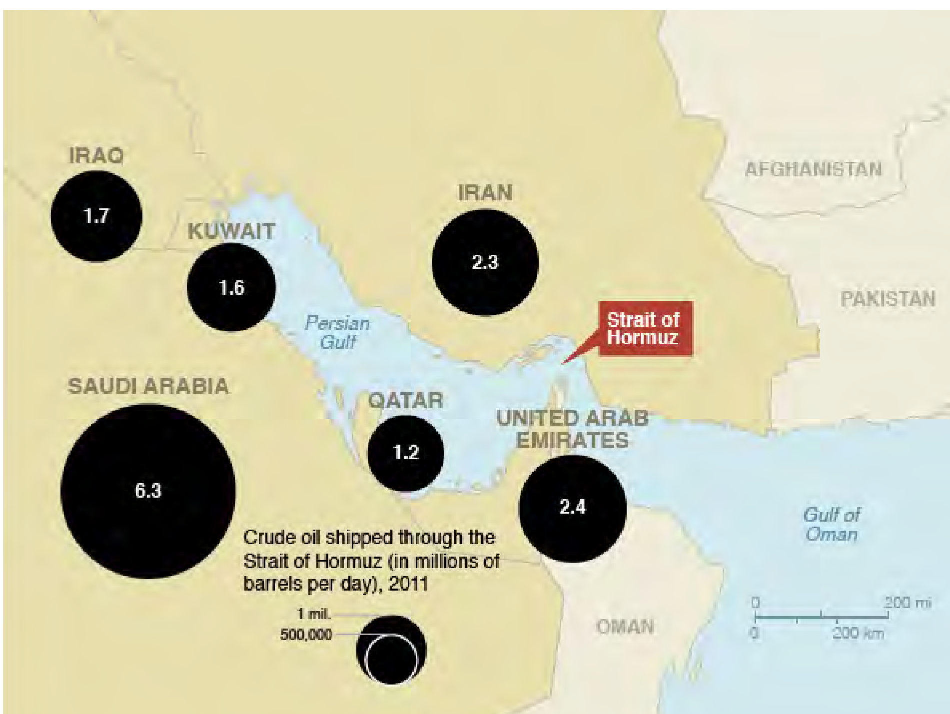


Figure 3-182. Daily crude oil shipments through the Strait of Hormuz, 2011

This is a vital, vulnerable strategic bottleneck, and is regularly patrolled by navies and warships of several countries, including the United States. During times of tension in the Middle East, all parties are on high alert.

The U.S. has recognized the strategic significance of the Middle East, generally, because of its vast petroleum reserves and resources, and of the Persian Gulf and Strait of Hormuz in particular, going back as far as World War II. On February 14, 1945, while returning from the Yalta Conference, and just two months before his death, President Franklin D. Roosevelt met with Saudi Arabia's King Ibn Saud on the Great Bitter Lake in the Suez Canal; it was the first time a U.S. president had ever visited the Persian Gulf region. Two days later, Roosevelt said: "the defense of Saudi Arabia is vital to the defense of the United States" (Klare 2004).

Figure 3-183 shows U.S. primary energy imports and exports in 2011. There were net imports of 18.6 quads of crude oil and petroleum products in that year. From a peak of 12 million barrels a day in 2005, by 2014 net imports of crude oil and petroleum products had fallen to five million barrels a day, the lowest in three decades (Figure 3-184). This is due to a combination of high prices (until 2014), the Great Recession and slow recovery, and the hydrofracking boom (EIA 2015b).

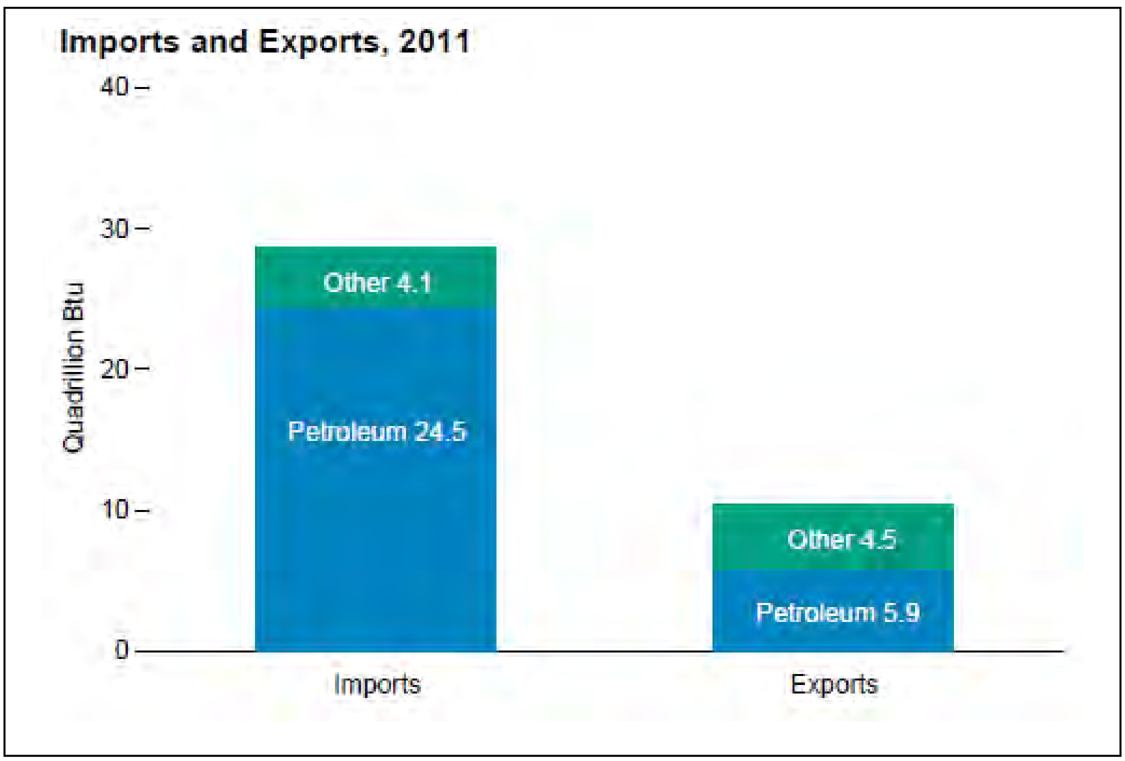


Figure 3-183. U.S. primary energy imports and exports, 2011
Source: Figure1.4, EIA (2012b)

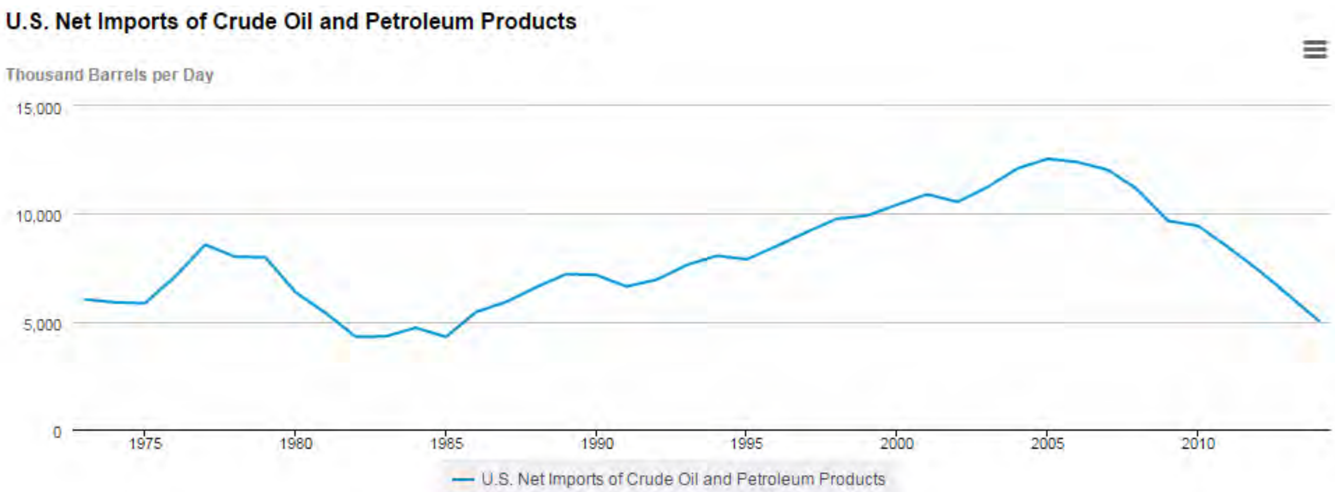


Figure 3-184. U.S. net imports of crude oil and petroleum products, 1973-2014
Source: Figure1.4, EIA (2015b)

Notwithstanding a good deal of hype about America truly achieving long-lasting energy independence this time around and becoming the world's leading energy producer (Anon. 2012), due to the fracking boom and the Athabasca tar sands in the Canadian province of Alberta, due to a variety of factors, the recent decline in net crude oil imports is likely a relatively temporary phenomenon when viewed from a long-term perspective. Fracking is costly, well depletion rates are extremely high, and there continue to be vast amounts of much cheaper oil in the Middle East.

3.6.1.3 Energy and the Environment – An Overview

The manner in which we produce and consume energy has many profound implications for the environment. This section summarizes the more salient effects of the major types of energy.

<u>Oil</u>

Virtually all phases of obtaining and using petroleum resources entail some type of environmental impact(s), including exploration, extraction, transport of crude oil, refining, transport of petroleum products, and ultimate consumption.

The 1989 *Exxon Valdez* oil spill in pristine Prince William Sound, Alaska, was a vivid reminder for Americans of the dark side to the extraordinary substance that has propelled global industrial civilization for more than a century. Spread by tides and currents, the black slick consisting of 11 million gallons of thick Prudhoe Bay crude eventually extended across an area of 10,000 square miles, coating formerly pristine wilderness beaches more than a hundred miles away from where the oil tanker struck a reef while its skipper slept off one too many drinks. In the first days and weeks it killed thousands of

salmon, seabirds, otters, seals, whales and eagles; its long-term effects are still being studied and evaluated a quarter-century later. Litigation continues in federal courts. This was the kind of worst case scenario that opponents of the 800-mile Trans-Alaska (Prudhoe Bay to Valdez) Pipeline System (TAPS) worried about and warned against in the debate over the construction of TAPS in the early 1970's. More than five years after the accident at Prince William Sound, an ocean kayaker could still report smelling petrochemicals whenever he stepped ashore (Atkinson 1996).

Figure 3-185. Oil slick spreads across the water surface from the Exxon Valdez

Figure 3-186. Oil-coated sea otters in Prince William Sound, Alaska. The toll on wildlife of the *Exxon Valdez* oil spill was staggering.

The *Exxon Valdez* disaster was bad enough: at that time the worst oil spill in U.S. history. But British Petroleum's *Deepwater Horizon* Macondo well drilling platform explosion and blowout in the Gulf of Mexico on April 20, 2010 off the coast of Louisiana was far more tragic and damaging (NOAA 2015a). The initial explosion took the lives of 11 oil workers and the concurrent blowout released nearly five millions barrels of oil (over 200 million gallons, roughly 20 times the *Exxon Valdez*) into the Gulf from a ruptured pipe at the ocean bottom before it was finally capped after three months.

Figure 3-187. Deepwater Horizon drilling platform goes up in flames

In spite of multi-billion dollar cleanup efforts undertaken by BP and federal and state agencies, the impacts of this spill on the Gulf ecosystem will likely last for decades. In 2015, the National Oceanic and Atmospheric Administration (NOAA) released a study that tied the Deepwater Horizon oil spill to an abnormal spike in bottlenose dolphin deaths (NOAA 2015b). An excessive number of dead Gulf dolphins had rare lesions on their lungs and hormone-producing adrenal glands. Of dead dolphins examined from Louisiana, Mississippi and Alabama, one third had lesions affecting their adrenal glands, resulting in a serious condition known as "adrenal insufficiency." The adrenal gland makes hormones such that regulate metabolism, blood pressure and other bodily functions. The deaths of more than 1,200 dolphins have been linked to the oil spill (Akpan 2015).

Figure 3-188. Dead dolphin that washed ashore along Louisiana coast in 2012

These two epic disasters (*Exxon Valdez* and *Deepwater Horizon* oil spills) should not be taken as typical for the oil industry. They are outliers, but they do represent the risks that oil exploration, drilling, and transport entail for ecosystems and the public. A single mistake, a single disaster can cost a number of lives and impose ecological and economic damages that last decades. The Gulf of Mexico area, both onshore and offshore, is one of the most important regions for energy resources and infrastructure in the world (Figure 3-189).

Gulf of Mexico offshore oil production in federal waters accounts for 17 percent of all U.S. crude oil production and over 45 percent of total U.S. petroleum refining capacity is located along the Gulf coast (EIA no date). There are several thousand active offshore thousand production platforms on the Outer Continental Shelf currently operating in the Gulf of Mexico. The Associated Press reported in 2010 that there are more than 27,000 abandoned oil and gas well in the Gulf (AP 2010). If only one in 27,000 ever blew up and leaked like the *Deepwater Horizon*, that is a low rate of risk per well, but the scope and scale of that disaster demonstrate that even one disaster has huge consequences for a region. Moreover, low-volume, chronic leaks of oil and gas from active and abandoned wells whose seals may be failing are a serious long-term issue in the Gulf of Mexico.

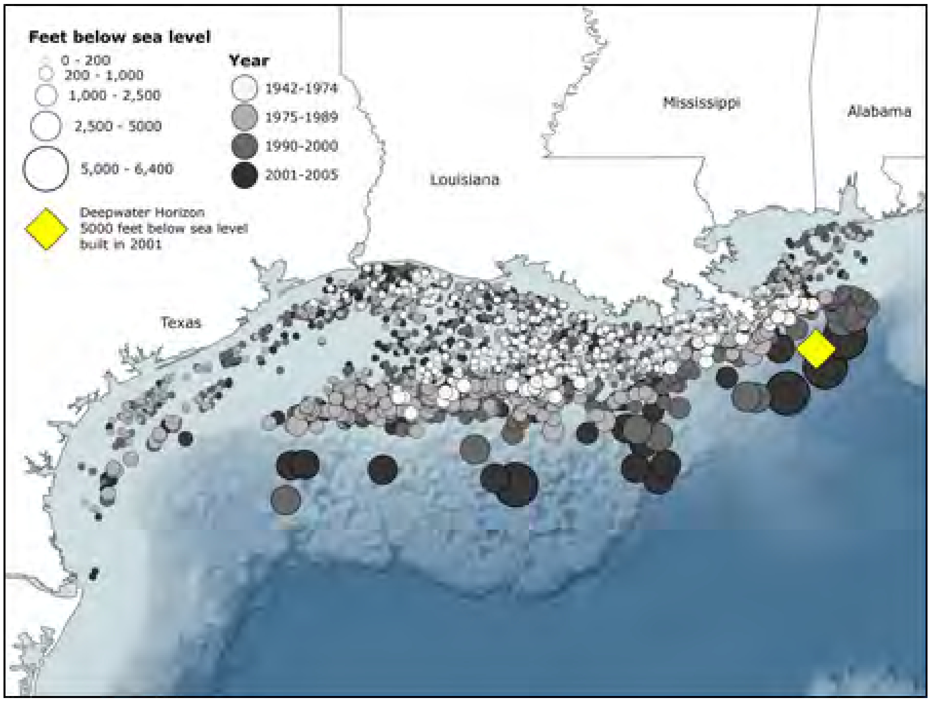


Figure 3-189. Offshore oil production wells in the Gulf of Mexico

Onshore, in general, oil exploration and development in wildland or wilderness areas damages the environment and destroys wilderness character through the building of roads and industrial infrastructure, fragmentation of wildlife habitat, the release of contaminants to air and water, and the introduction of large numbers of workers, vehicles and noise into formerly rural or even wild settings (Figures 3-190 and 3-191). Still, oil extraction would have to be judged significantly less damaging to the environment than extraction of that solid fossil fuel known as coal. And in recent years, technological innovations have greatly reduced the "footprint" of developed surface area on wild country. Directional drilling, for instance, associated with hydrofracking, allows exploratory wells to bend up to ninety degrees underground in different directions and look for oil reservoirs miles away from directly beneath the platform and pad.

Transport of crude oil via oil tankers, pipelines, and freight trains involves the risk of sabotage and accidents that can result in spills, into the marine environment in the case of the former and onto land and into rivers and lakes in the latter two cases. In 2001, a vandal fired shots into the Trans-Alaska Pipeline 107 miles north of Fairbanks, rupturing the pipe and spewing 70,000 gallons of crude oil into the surrounding scrub and spruce forest (Spiess 2001). In recent years, there have been a number of high-profile accidents involving derailment and explosion of tanker trains (i.e., with tank cars carrying crude oil or petroleum products) because of insufficient pipeline infrastructure. The worst such incident, the 2013 Lac-Mégantic rail disaster, occurred in the Eastern Townships of Quebec, Canada. A train transporting Bakken Formation crude oil derailed and burst into flames; at least 42 residents lost their lives in the explosion and fire (Anon. 2015a).

Figure 3-190. Oil drilling equipment inside a national forest

Figure 3-191. Habitat fragmentation from oil and gas exploration and development

Naturally occurring oil seeps have existed for millions of years, and crude oil is, after all, a natural organic substance for which nature has devised physical, chemical and biological means of decomposing. Nonetheless, crude oil and refined petroleum are toxic, and human-caused spills typically release such strong concentrations and large volumes that they cause devastating, if generally temporary and localized, effects on plants, animals, soils and water quality. More oil is dispersed into the marine environment when ballast water is released from oil tankers, but since it is far less concentrated, its effects, if any, would be more subtle and chronic.

Figure 3-192. Temporary storage of wastewater from an oil and gas drilling operation inside a national forest

There are vast quantities of "unconventional oil" (and natural gas) resources still extant in the world. Figure 3-193 shows the "resource pyramid" of all petroleum resources. This graphic depicts the relationship between *in situ* resource volumes and the distribution of conventional and unconventional accumulations of petroleum with the generally declining net energy and increasing difficulty of extraction as volumes increase lower on the pyramid (Hughes 2013).

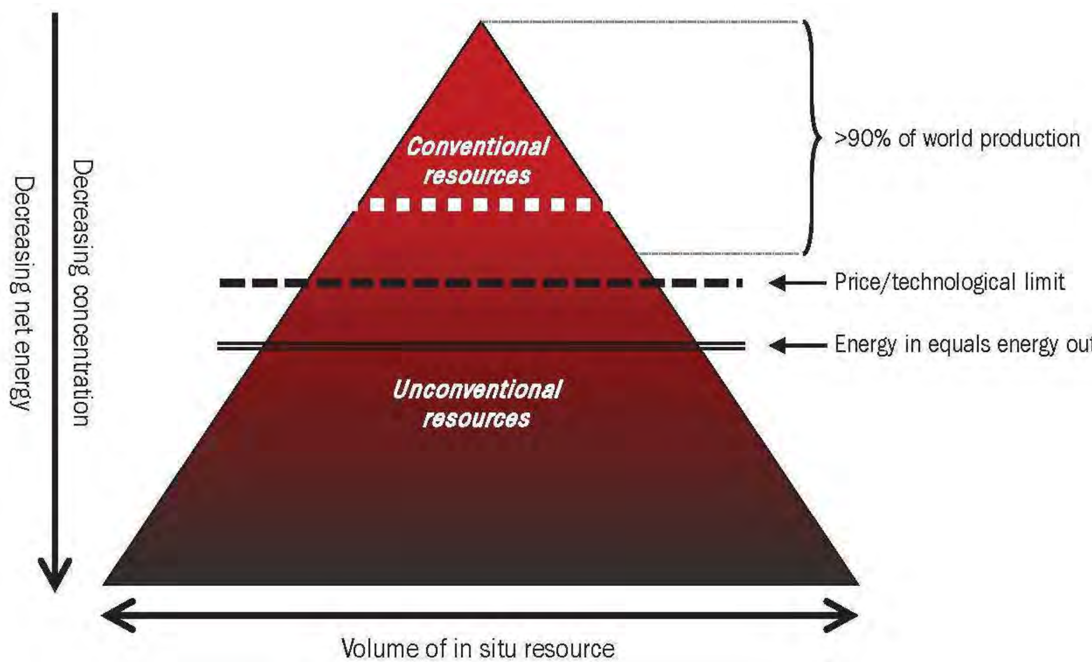


Figure 3-193. Pyramid of petroleum (oil and gas) resource volume versus resource quality

North American examples of these unconventional hydrocarbon resources are the Athabasca “tar sands” of Alberta, Canada, and the “oil shale” of the Green River Formation in the American Southwest. Tar sands (also called oil sands) are a combination of clay, sand, water, and bitumen, which is black, viscous oil. Tar sands can be mined – and today are being mined in Canada – and then processed to extract the oil-rich bitumen. The recovered bitumen is then refined into oil. Bitumen in tar sands is too thick, like asphalt or tar, to be pumped from the ground in its natural state, like conventional oil is. Rather, tar sand deposits are typically mined, usually using surface mining techniques. Extracting oil from tar sands is more complex than conventional oil recovery. Oil sands recovery processes include extraction and separation systems to separate the bitumen from the clay, sand, and water that comprise the tar sands. Bitumen also requires additional upgrading even before it can be refined. Because it is so viscous (thick), it also requires dilution with lighter hydrocarbons so that it can be transported by pipeline (BLM and ANL 2012).

Figure 3-194. Strip mining the Athabasca tar sands in Alberta, Canada

“Oil shale” is not conventional shale. Rather, the term oil shale generally describes any sedimentary rock containing solid bituminous materials (called kerogen) that are released as petroleum-like liquids when the rock is heated in the chemical process of pyrolysis. Oil shale formed millions of years ago by deposition of silt and organic debris on the bottoms of lakes and seas. Over the eons, heat and pressure transformed these organic materials into oil shale in a process much like the geologic processes that form oil; however, the heat and pressure were insufficient to create oil itself. Kerogen generally contains enough oil that it will burn without any additional processing, and for that reason it is called "the rock that burns" (BLM and ANL 2012).

Environmental concerns about developing both tar sands and oil shale are both localized and global. The localized concern relates to the severe environmental impacts of large-scale surface mining on habitats, landforms, water resources (quantity and quality), wildlife, air quality, and nearby indigenous and rural populations. Global concerns are related principally to climate change. Because there are very large quantities of both of these resources, in North America and globally, and because of their comparatively low energy return on energy invested (EROEI or net energy), were they to be exploited to a significant extent, concomitant CO_2 emissions and climate impacts would be enormous.

Figure 3-195. "The rock that burns" – kerogen or oil shale on fire

So far only the Athabasca tar sands have seen development on a commercial scale. But just as there is considerable political pressure now from the oil industry and the Canadian government to construct the Keystone XL pipeline to carrying syncrude from the Athabasca tar sands to refineries in Port Arthur, Texas, there may also eventually be a concerted push to exploit in earnest the hypothetically vast quantities of Green River Formation oil shale in Utah, Colorado, and Wyoming. An estimated three trillion barrels of oil resources are found here (GAO 2012), more than the entire quantity of conventional oil left on Earth. However, the operative word is "hypothetical," for while these resources have been known for well over a century, they have always been and may always be a resource of the "future". Their time may never come. Their EROEI appears to be very low. That is, producing a barrel of oil from kerogen may take almost an equivalent amount of energy in some form. Furthermore, processing would require large amounts of water in an arid region, and land surface reclamation would be difficult (Youngquist 1997).

Refining oil at petrochemical plants produces great volumes of toxic and hazardous organic chemicals that in the past were dumped willy-nilly into the air and water, creating such noxious zones as "Cancer Alley" along the Mississippi River in Louisiana and the notorious industrial barrens of northern New Jersey and Long Beach, California. As a result of the federal Clean Water Act and Clean Air Act, pollution control technology has made major strides in cleaning up the petrochemical industry over the last four decades. Nevertheless, oil refineries and petrochemical plants are still major producers of smog-generating compounds (nitrogen oxides and volatile organic compounds or VOC's) and toxic wastes that must be regulated.

Figure 3-196. Oil refinery in Louisiana

Burning petroleum products like gasoline, diesel, jet fuel, and home-heating oil generates carbon dioxide (CO_2), carbon monoxide (CO), volatile organic compounds (VOCs or hydrocarbons), and nitrogen oxides (NO_x), as well as other unwanted waste byproducts. In the presence of sunlight, VOCs and nitrogen oxides react to form ozone, which is valuable in the stratospheric ozone layer that protects life from damaging ultraviolet-B radiation, but a potent pollutant in the troposphere or near the ground. Ozone is often measured as an index of smog severity. Tailpipe emissions of some of these substances for automobiles have been improved dramatically in recent decades, but one of the gases released, carbon dioxide, cannot readily be captured, controlled, or converted into anything else because it is simply one of the fundamental products of the exothermic chemical reaction that releases energy. As noted in Section 3.5, CO_2 is the main greenhouse gas, implicated in global climate change and global warming.

NO_x emissions contribute not only to smog, but to acid rain and to the degradation of water bodies like the Chesapeake Bay. NO_x can be converted into nitric acid in the atmosphere; falling to earth, it acidifies unbuffered soils and waters, with consequent adverse effects on trees, plants and aquatic life. Water quality and aquatic organisms in Chesapeake Bay and other coastal estuaries are being harmed by an excess of nutrients like nitrogen, which falls out of the air and can be carried into the bay by its tributaries. These excess nutrients contribute to algal blooms which eventually deplete dissolved oxygen from water bodies, creating hypoxic or anoxic conditions which are harmful or lethal to aquatic life and can result in “dead zones.”

Natural Gas

Natural gas is the cleanest-burning of the fossil fuels, emitting fewer conventional or “criteria” pollutants (e.g., CO, SO_2, NO_x, particulate matter, VOCs) per Btu delivered. Natural gas combustion also emits substantially less CO_2 than either oil or coal (Table 3-

18; EIA 2014c); it emits less than 60 percent of the CO_2 per Btu than coal. However, natural gas exploration and production entail many of the same impacts on natural or rural habitats as oil drilling and development, including the potential for a degree of localized air and water pollution, habitat fragmentation (from seismic surveys, road and pipeline building, and well pad construction), soil erosion, and impacts on scenery (USFS 2001, USGS 2015). While the impact of any one natural gas well may be relatively small, when this is multiplied by tens of thousands around the country, these widespread, additive, cumulative impacts become significant. Nevertheless, at both the point of extraction and the point of consumption, natural gas is the least environmentally damaging of the three main fossil fuels.

Table 3-18. Pounds of CO_2 emitted per million Btu of energy for various fuels

Fuel	Pounds of CO_2 per million Btu
Coal (anthracite)	228.6
Coal (bituminous)	205.7
Coal (lignite)	215.4
Coal (subbituminous)	214.3
Diesel fuel & heating oil	161.3
Gasoline	157.2
Propane	139
Natural gas	117

U.S. natural gas production had peaked four and a half decades ago at approximately 22.6 trillion cubic feet (Tcf), about the same time as domestic crude oil production (Figure 3-176 and Figure 3-197), but then began to climb steeply in the latter part of the 2000s as a result of high gas prices and the spread of hydraulic fracturing combined with horizontal drilling, which enable the industry to exploit the large quantities of gas found in impermeable, low-porosity source rocks, namely shale. There are a number of potentially economically viable shale plays around the country (Figure 3-198).

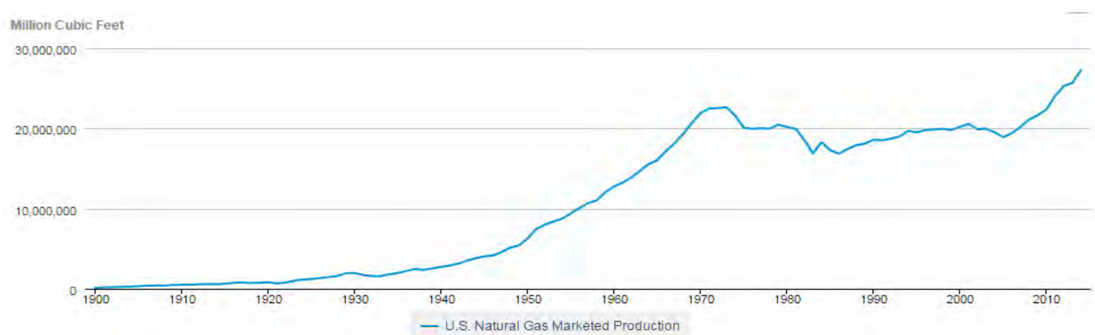


Figure 3-197. U.S. natural gas production, 1900-2014
Source: EIA (2015c)

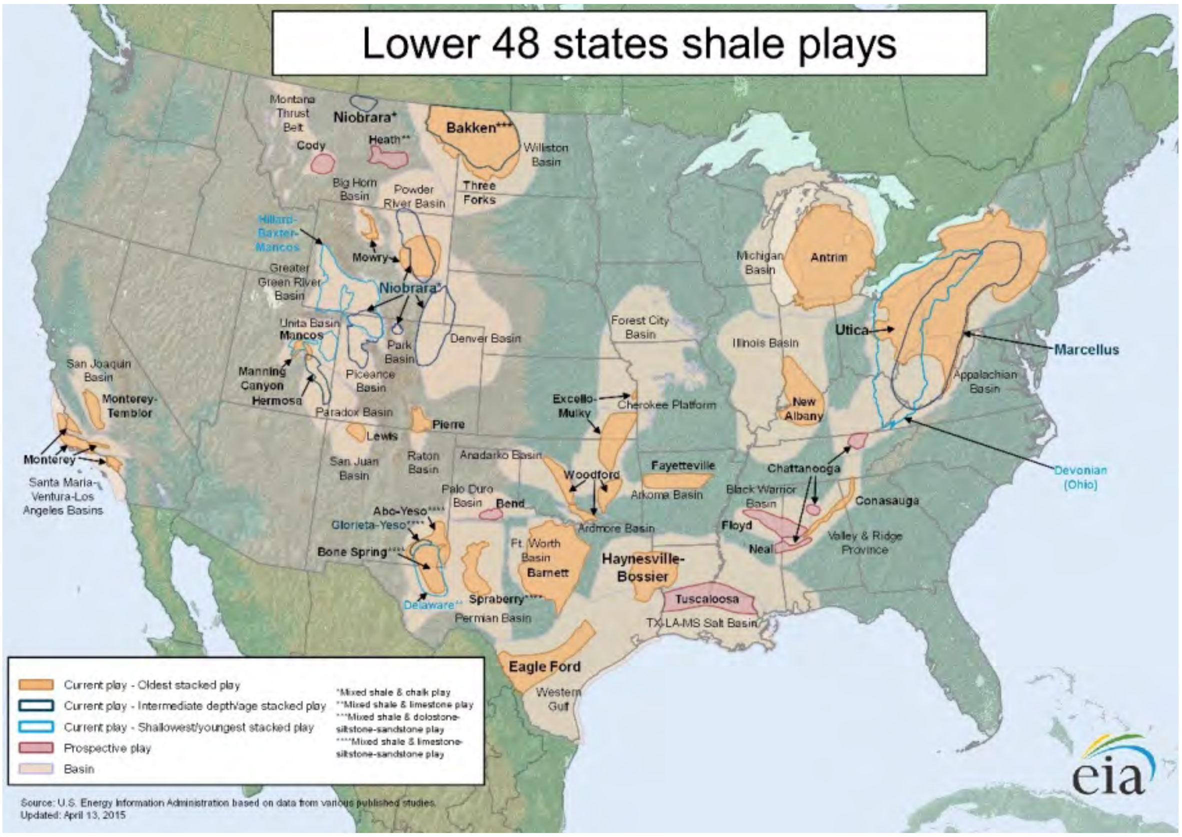


Figure 3-198. Shale plays in the United States (Lower 48 states)
Source: EIA, 2015d

Virtually all of the recent increase in U.S. natural gas production is due to hydrofracking. In 2011 alone, about 27,000 new gas wells were completed in the U.S. (EIA 2015e). The pace of new well completion plummeted after that as a result of a glut of gas on the market.

In fracking, rock layers or strata, typically shale formations, are fractured by a hydraulically pressurized liquid, usually water with suspended sand and chemicals. Under high pressure, this fluid is injected into a wellbore to create cracks, fractures, or fissures in the shale formations through which natural gas, crude oil, and brine can flow more freely. After the hydraulic pressure is removed, small grains called proppants (sand or aluminum oxide) keep the fractures open and allow fluid hydrocarbons to flow. As of 2012, over one million wells had been fracked in the United States alone, and 2.5 million globally (King 2012). Figures 3-199 and 3-200 depict a hydrofracked and the hydrofracking process, respectively.

Hydrofracking consumes and contaminates large quantities of freshwater, perhaps an average of 2-4 million gallons of water per well (EPA 2011). While this sounds like a lot, it still represents perhaps only about 0.1% of total water withdrawals and 0.3% of

total water consumption (consumptive water use) in the United States (Jenkins 2013). Nonetheless, in certain areas where water scarcity is increasing, this level of consumption can potentially become problematic.

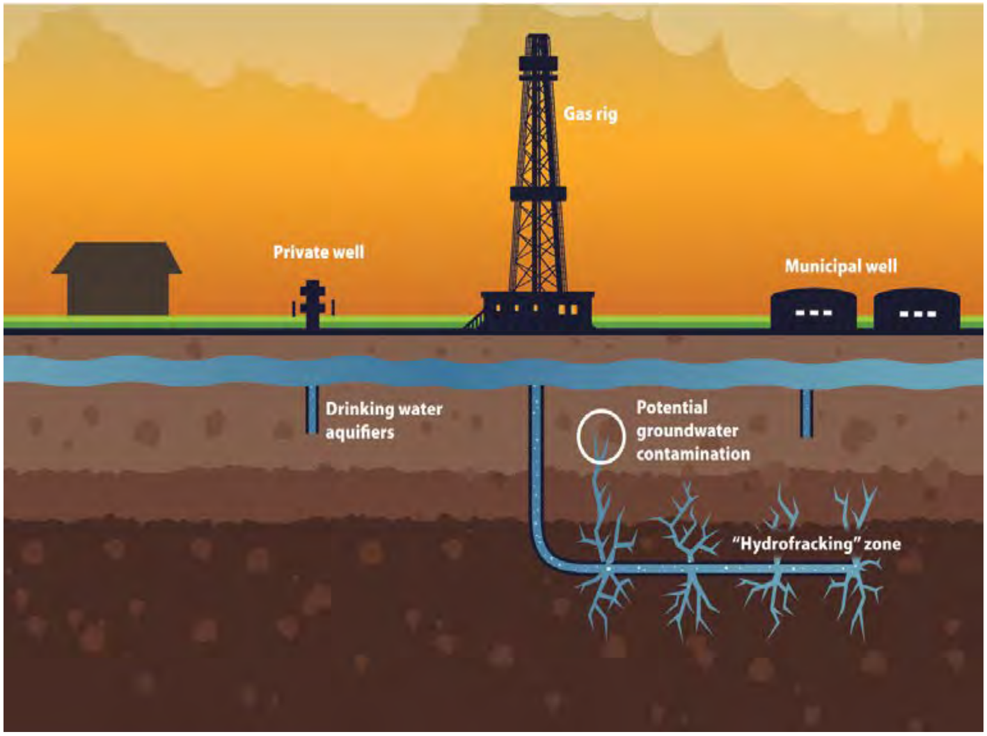


Figure 3-199. Schematic of hydraulic fracturing ("hydrofracking")

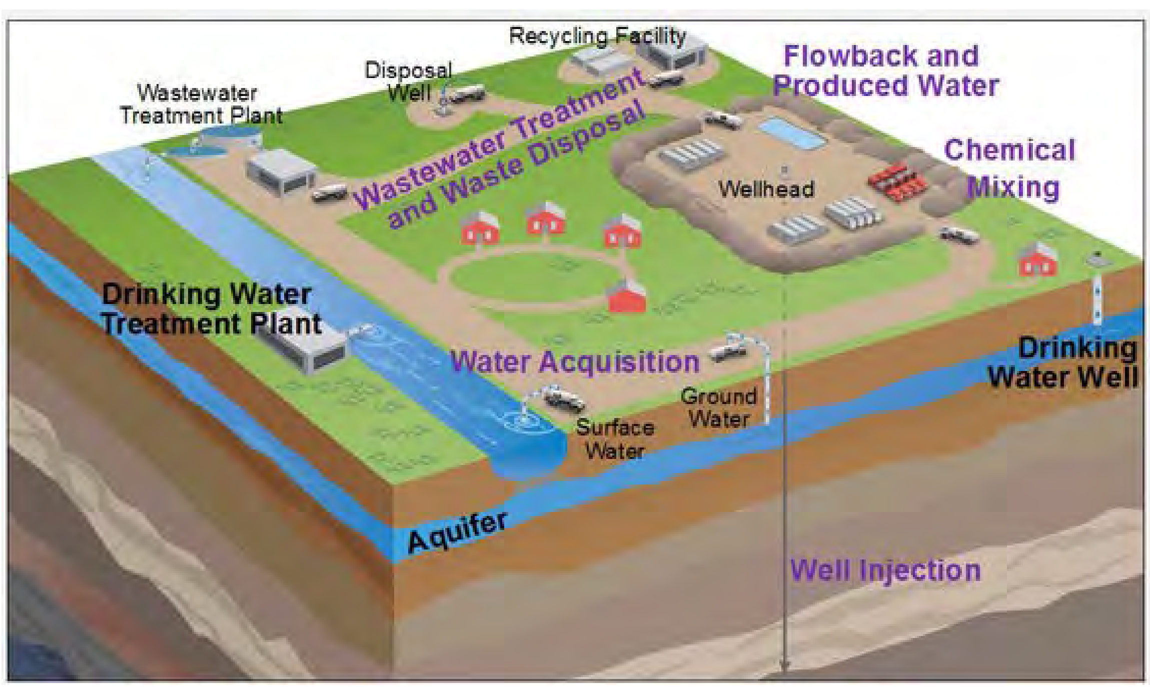


Figure 3-200. Hydraulic fracturing water cycle
Source: EPA

Figure 3-201 shows the water lifecycle of hydraulic fracturing in greater detail.

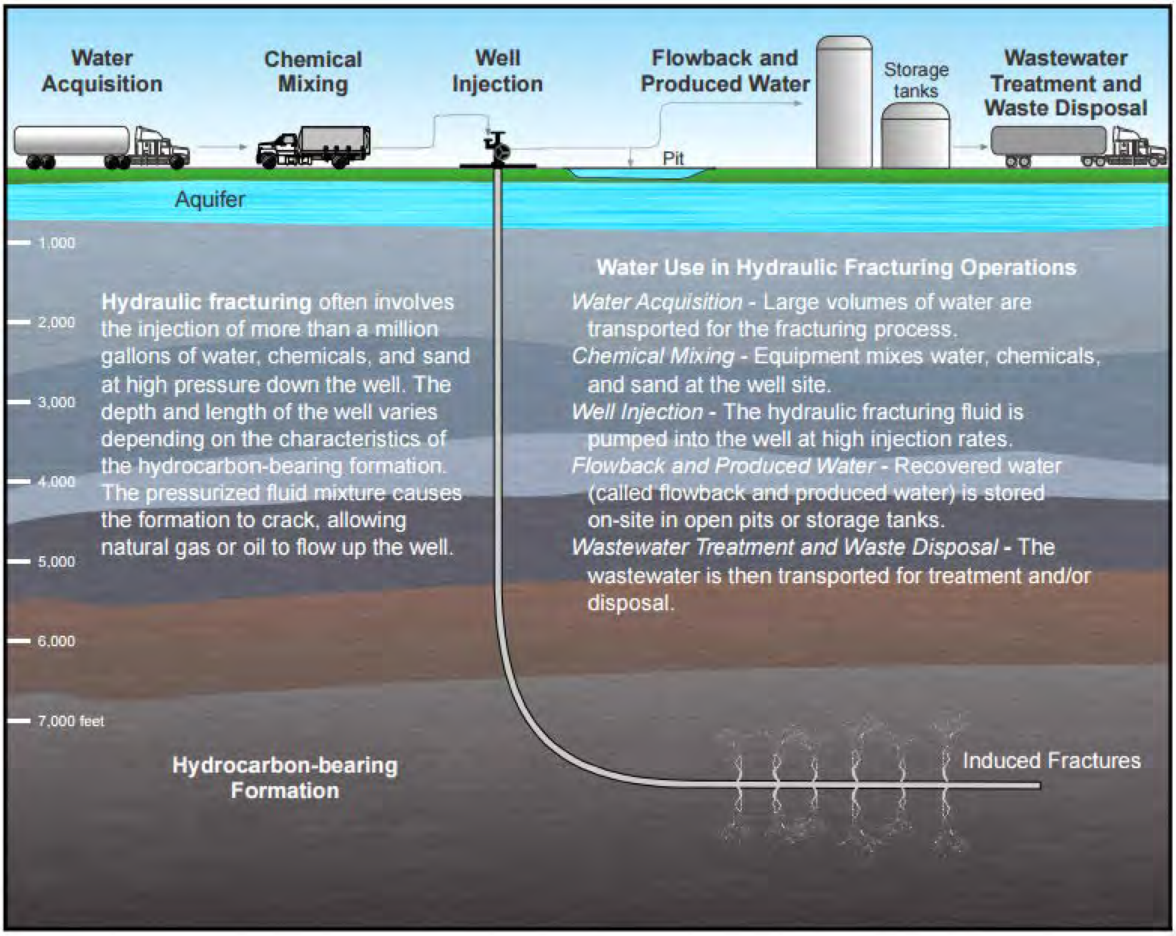


Figure 3-201. Water lifecycle in horizontal well subjected to hydrofracking
Source: EPA (2011)

Fracking involves the use of toxic chemicals during the fracking process and the subsequent release of additional toxic chemicals and radioactive materials during well production. Fracking fluid flowback – the fluid pumped out of the well and separated from oil and gas – not only includes the chemical additives employed in the drilling process but also includes heavy metals, radioactive materials, VOCs, and hazardous air pollutants (HAPs) such as benzene, toluene, ethylbenzene and xylene (BTEX). Furthermore, numerous pathways occur throughout the fracking process for the inadvertent or accidental release of these toxic substances. As a result, proper handling of toxic (and radioactive) materials is crucial throughout the lifecycle of a hydrofracked well to avoid environmental contamination (Network no date).

Figure 3-202 shows the different stages of water use in hydrofracking and the potential for drinking water issues in each.

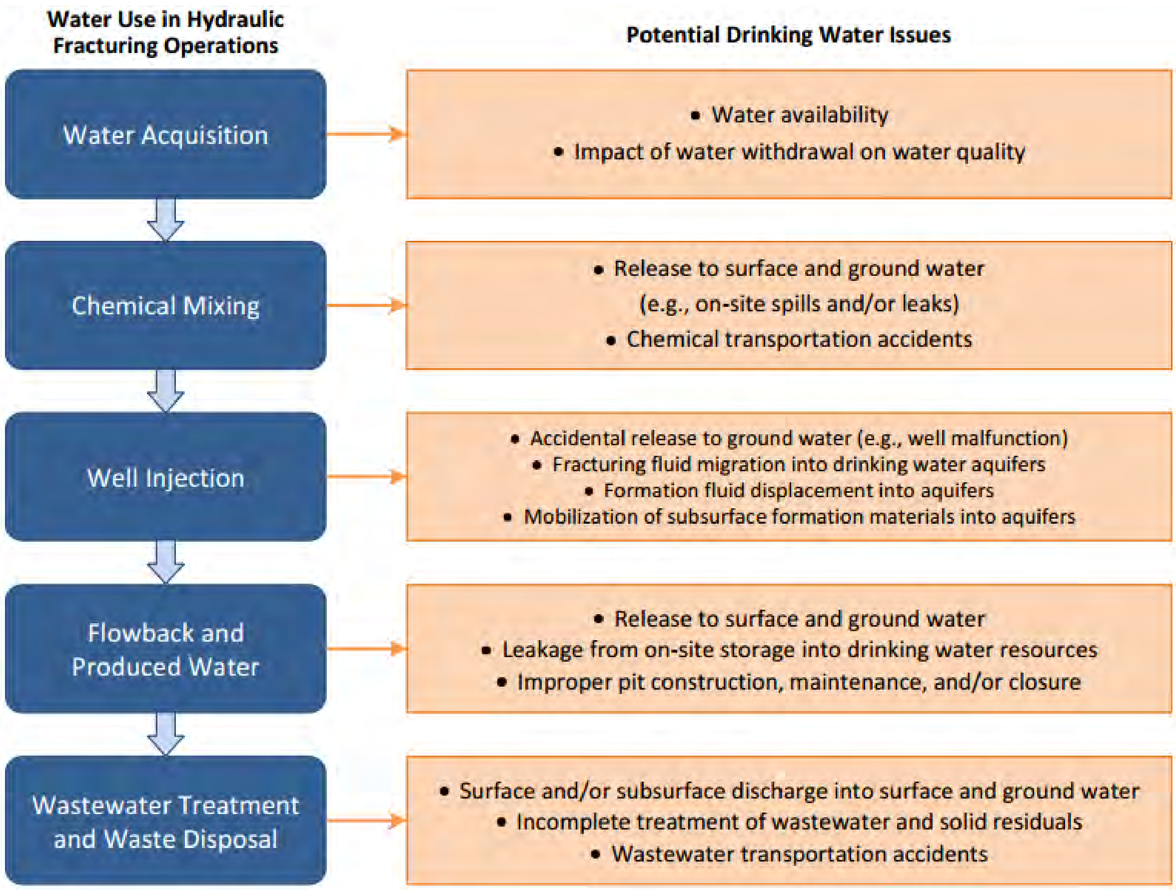


Figure 3-202. Water use in hydrofracking stages showing potential issues posed by each stage for drinking water
Source: EPA (2011)

Another potentially serious problem for water quality from hydrofracking involves methane contamination of well water supplies. A 2011 study across five counties in northeastern Pennsylvania by researchers affiliated with Duke University's Nicholas School of the Environment found high levels of leaked methane in groundwater collected from 68 private wells close to hydrofracking drilling sites for shale gas. At the same time, the study found no evidence of well contamination by the chemicals present in fracking fluids, or from "produced water," that is, the wastewater that is extracted back out of the wells after the shale has been fractured (Lucas 2011).

Still another 2011 study highlighted the potential for another form of methane leakage, this time to the air rather than to groundwater, which calls into question the conventional wisdom that natural gas has a lower carbon footprint than competing fossil fuels (oil and coal). Researchers from Cornell University published a study in the scientific journal *Climatic Change Letters* which concluded that leaking methane from hydraulic fracturing outweighs any benefits of natural gas enjoyed as a transition fuel to greener technologies.

The Cornell researchers estimated that as much as eight percent of the methane in shale gas leaks to the atmosphere during the lifetime of unconventional natural gas extraction -- 40 percent to 60 percent higher than for conventional gas wells. Due to this leakage, they also contended that over a 20-year span, hydrofracked shale gas is worse even than burning coal in terms of climate change. However, other Cornell researchers have challenged this finding and related assertions and the matter is probably not yet settled (Ju 2012).

As noted above, hydrofracking, and to some extent, all natural gas exploration and development, also entails localized impacts on air quality. The main sources of air pollution are from:

- Venting and flaring – After the initial fracking process, a mixture of gas and flowback fluid rises to the well surface for several weeks. During this time, it is not cost-effective to separate the gas and liquid. Thus, the gas may be either vented – released directly into the atmosphere – or flared – burned upon its release. The Environmental Protection Agency indicates that these methods account for one of the largest sources of air emissions prior to actual well production (Network no date, EPA 2011).

- Dehydration units – Tri-ethylene glycol dehydrators are used to remove water during natural gas production. These units release the VOCs and HAPs contained in the gas.

- Condensate tanks – A condensate tank is utilized if wells produce a semi-liquid condensate (liquid hydrocarbons) along with the gas. These are designed to vent chemical vapors directly to the atmosphere.

- Evaporation pits – Pits are used to evaporate fracking flowback and dehydration unit wastewater. Both the original fracking chemicals as well as any of the chemical compounds naturally present in the gas (e.g., lighter molecular weight hydrocarbons, benzene, toluene, hydrogen sulfide) that combined with the fluid during the fracking process are then evaporated into the atmosphere.

- Fugitive emissions – Fugitive emissions are unintentional emissions that occur from leaks in pipelines, storage tanks, or other equipment, facilities, or infrastructure. These emissions contain HAPs and VOCs.

- Motors – Motors are used to run gas compressors to increase the pressure of the gas for pipelines. These motors release NO_x, CO, and VOCs.

- Emissions from truck traffic – Truck trips are a major source of air emissions with hydrofracking. Due to the volume of water and chemicals required in fracking, each well entails an estimated 300 to 1,300 truck trips. Diesel engine trucks are large emitters of nitrogen oxides (NO_x), carbon monoxide (CO), and hydrocarbons or VOCs. In addition, operating trucks on dry dirt roads produces fugitive dust, which also adversely impacts air quality (Network no date).

Coal

If natural gas is the most benign of the fossil fuels, coal is clearly the most problematic, both in the production and consumption phases of its utilization. While there have undoubtedly been many safety and health improvements in recent decades, at least in the United States and other developed countries with coal industries, underground coal mines in particular (as opposed to surface or strip mines) have traditionally been dangerous and unhealthy workplaces. The history of the industry is marred by deadly cave-ins and explosions triggered by high concentrations of methane and suspended coal dust. Many long-time workers exposed to years of coal dust, inadequate ventilation and lack of proper breathing apparatus have succumbed to black lung disease. In 2001, the American Lung Association (ALA) stated that an estimated 4.5 percent of miners were so afflicted, and over 14,000 deaths in the USA from 1979-1996 were attributable to it (ALA 2001). More recently, with improved mine ventilation and other reforms, ALA has indicated that an estimated three percent of coal miners are affected with black lung disease and about 0.2 percent have lung scarring, its most advanced form. Between 1999 and 2004, according to the ALA (2008) an average of 355 people died annually of black lung disease.

Underground mines can also generate acid mine drainage (AMD) from the oxidation of iron pyrite (FES_2) or fool's gold, which is often found in the presence of coal seams. If it reaches surface waters, AMD damages aquatic ecosystems, much as acid rain does, by reducing the pH to levels that many fish, aquatic invertebrates and other organisms cannot tolerate (EPA 2013b).

Surface or "strip" mines for coal have permanently altered landforms and disfigured landscapes in the heart of Appalachia, especially in eastern Kentucky and West Virginia but in many other states as well. Since the late 1970's, federal law (the Surface Mining Control and Reclamation Act) has mandated that landscapes be revegetated and restored to "original contours," but implementation and enforcement have been uneven at best. Furthermore, in recent years, as technology has improved and as thicker coal seams near the surface have been exhausted, in order to reach deeper-lying, high-quality coal beds, the coal industry has resorted to a practice called mountaintop removal. Up to several hundred feet of mountain summits and ridgetops are stripped away with explosives and massive earth-moving machinery such as bucket wheel and dragline excavators (Figure 3-203), which can be 20 stories high and scoop up to 120 tons of dirt and rock ("overburden") in a single bucket-load (Meadows 1998).

With mountaintop removal, since the volumes of earth are so great, no attempt is made to restore the original landscape; rather, valleys and streams are filled in with this "overburden," and artificial new landscapes are constructed. If the use of coal were to

Figure 3-203. Traffic is stopped as a huge bucket wheel excavator crosses a rural highway

continue to expand, as conventional energy analysts, electrical utilities, previous presidential administrations, and of course the coal industry itself all assumed just a few years ago, this highly damaging practice, if allowed to continue, would have enormous effects on many southern Appalachian landscapes and remaining natural habitat (Figures 3-204 and 3-205). In addition, nearby communities, while the beneficiaries of employment and other economic stimulus from the mining – at least until the coal runs out – would also bear the brunt of environmental impacts. These effects will last for much longer than the coal does. Colorado and other Western states are still paying for pollution from hard rock mines that closed a century ago and the scars will afflict Appalachia for generations.

Figure 3-204. Mountaintop removal in West Virginia

Figure 3-205. Mountaintop removal is a significant and often permanent disturbance on the Appalachian landscape

The Office of Surface Mining, EPA and the Army Corps of Engineers regulate mountaintop removal mining under both the Surface Mining Control and Reclamation Act and the Clean Water Act (EPA 2013c, EPA et al. 2003, EPA et al. 2005). The Obama administration has been attempting to tighten these regulations so as to reduce environmental impacts, which the industry and politicians in states coal-dependent states like West Virginia have been fighting vigorously.

Much of the coal surface now mined in the United States and burned in power plants to generate electricity is subbituminous coal from the Power River Basin in northeastern Wyoming and southeastern Montana (Figure 3-206). The Power River Basin is now the largest coal-producing region in the U.S. This is lower-sulfur coal with fewer landscape and AMD impacts (Kolankiewicz 1982); it also has higher potential for reclamation to land uses and landforms resembling those of pre-mining conditions. It should also be emphasized that even in Appalachian landscapes and coalfields, in 50 or 500 years, the landscape, wildlife habitat, and stream quality will be very different than they are when mining is in progress or immediately afterwards in the initial stages of reclamation. Figures 3-207 through 3-209 show sites subjected to surface mining in various stages of reclamation.

Figure 3-206. Surface coal mining in the Power River Basin

Figure 3-207. Mountaintop removal reclamation site in West Virginia struggling to re-establish trees on steep slope (note gullies)

Figure 3-208. Reclaiming mined lands can often be carried out successfully if done right. Before (left) and after (right).

Figure 3-209. The Powell River Project in southwestern Virginia is a reclaimed mine landscape with productive soils that support cattle grazing and other economically valuable land uses.

Most coal mined (80 percent) in the U.S. is used in thermal power plants to generate electricity. Two pollutants released at power plants cause serious environmental problems; a third is also a source of concern. The first is sulfur dioxide (SO_2), emission rates of which can vary substantially depending on the concentration of sulfur in the coal formations (in general, western coal is lower-sulfur than eastern coal). Sulfur dioxide is related to two grave environmental problems: acid rain (more properly known as acid precipitation or deposition, and discussed in Section 3.4.1.4 of this EIS), and reduction of visibility across various areas of the country. The first problem has received more attention from scientists, policy-makers and the public, and has damaged lakes, streams and to some extent forests in parts of the country, particularly the Adirondacks and the Northeast. The poorly buffered rocks and soils of the vast Canadian Shield, the oldest bedrock on the North American continent, which underlies much of Canada east of the Canadian Rockies, are especially vulnerable to acid deposition.

Sulfur dioxide's second problem, visibility reduction, has compromised the beauty of vast areas of the rural American landscape, especially in the East (NPS 1997, Malm 1999). In Shenandoah National Park for example, located in Virginia's picturesque Blue Ridge Mountains, scientists estimated that the average visibility within the park had decreased from about 65 miles in 1900 to 15 miles in the late 20th century (Connors 1988). Expansive views of ridge after ridge receding to the horizon have largely disappeared; the ridges disappear instead into a shroud of smog. Sulfur dioxide particles or aerosols aren't the only cause of this, but they are the main one, at least in the East, where SO_2 is estimated to cause some 60-90 percent of visibility reduction (Malm 1999). Most SO_2 can be removed from power plant smokestacks with "scrubbers," but these are expensive and imperfect. Nevertheless, they work well enough that the 1990 Clean Air Act amendments relied on them as well as an emissions trading program to reduce the

nation's overall sulfur emissions, and this is gradually occurring. Whether the SO_2 emissions can be cut back to a level low enough to avoid or reverse the damage they are causing remains to be seen.

Then there's CO_2. As shown in Table 3-18, coal emits more carbon dioxide per Btu generated than either oil or natural gas, although none of the fossil fuels is exempt from releasing CO_2 upon combustion. As discussed at length in Section 3.5 of this EIS, there is a broad consensus among climatologists that the earth's atmosphere is gradually warming and that anthropogenic emissions (both industrial and agricultural) of the so-called greenhouse gases, principally CO_2 and methane (CH_4), are responsible.

The potential ecological ramifications of climate change are far-reaching. A 2001 workshop of scientists and natural resource specialists on vegetation management at Voyageurs National Park in northern Minnesota considered some of these ramifications. Certain workshop participants worried that plans to restore the park's majestic stands of red and white pines and other elements of the "transitional boreal forest" to some semblance of their former condition (before decades of logging and fire suppression radically altered forest composition, structure and quality) would be undermined by this type of forest community shifting northward beyond the park boundaries in response to rising temperatures.

Yet another concern of workshop participants related to the more frequent, violent weather events that are also a predicted consequence of an unstable, warming climate. On July 4, 1999, a massive storm known as a "derecho," with heavy rains and winds exceeding 90 miles per hour, blew down almost half a million acres of forest in northeastern Minnesota, most of it within the renowned Boundary Waters Canoe Area Wilderness (USFS 2000). Such storms would especially threaten large, tall trees that protrude high and exposed above the forest canopy. No one can predict for certain, but it is within the realm of possibility that old growth groves of the tallest, most ancient forest giants could largely vanish from American forests if for no reason other than the higher frequency of more fierce storms and gales that knock them down.

As if all this were not enough, thermal power plants burning coal are the dominant source of mercury emissions in the U.S. (NCAR 2001, EPA 2014c). On average, unless controlled with specialized and costly technology, each 1,000 megawatt coal-fired plant emits approximately 2,200 pounds of mercury annually to the air, which eventually falls out and is deposited onto the land and into water bodies and sediments (Glass et al. 1986). The toxic form of mercury is called methyl mercury. It "bioaccumulates," that is, it becomes more concentrated – and thus more toxic – as it moves up the food chain and

into animals that eat other animals that eat other animals (known to ecologists as tertiary consumers or carnivores), such as walleye pike, bald eagles, and human beings.
Thus, with all these problems associated with mining and burning coal, it is a decidedly mixed blessing that the United States is so richly endowed with this particular fossil fuel. At more than 200 billion metric tons, the U.S. has more proved reserves of coal than any other country in the world (WRI et al. 1994). In 2014, recoverable reserves at producing mines totaled 19,745 million short tons. This represents the quantity of coal that can be recovered (i.e., mined) from existing coal reserves at active mines. These reserves essentially reflect the working inventory at producing mines. Estimated recoverable reserves were 256,709 million short tons. "Estimated recoverable reserves" counts coal in the demonstrated reserve base considered recoverable after excluding coal estimated to be unavailable because of land use restrictions, and after applying assumed mining recovery rates. This estimate does not include specific economic feasibility criteria. The demonstrated reserve base is much larger still, estimated to contain 479,914 million short tons. "Demonstrated reserve base" is comprised of coal resources that have been identified to specified levels of accuracy and may support economic mining under current technologies. It includes publicly-available data on coal that has been mapped and verified to be technologically minable (EIA 2014d).

Oil Shale, Oilsands and Tarsands

As mentioned above in the discussion under oil, known resources of these low-grade fossil fuels are massive. The U.S. has the world's largest oil shale deposits, concentrated chiefly in Wyoming, Colorado and Utah (Youngquist 1997). "Oil shale" is a promotional term. Oil shale contains no oil and is not shale. The hydrocarbon it contains is called kerogen and rock in which it occurs is called organic marlstone. Petroleum geologist Walter Youngquist observes that "enthusiastic reports on the potential of oil shale abound." The U.S. Geological Survey, for instance, estimated that total U.S. deposits (as opposed to recoverable reserves) contain several trillion barrels of oil – which embody more hypothetical primary energy than global conventional crude oil reserves. However, this promise has proved elusive, as oil shale deposits have proven prohibitively expensive to develop, which to date has stymied efforts to extract and market them over the past 90 years.

Moreover, when the energy costs of mining, transporting, refining and waste disposal are tallied up and included in the energy budget for this energy source, the *net* amount of energy recovered (net energy or EROEI) from oil shale is likely to be small. What this does is increase the amount of shale that must be mined and processed for each unit of net energy obtained, which in turn increases the amount of ground that must be dug up, and the area of landscape that must be disturbed. Youngquist estimates that each Btu of net energy obtained from oil shale may disturb up to five times the amount of land as

each Btu of net energy from coal. Another major impediment to developing oil shale is that it is a water-intensive process in an inherently water-scarce region – the American Southwest. Finally, if oil shale ever were used en masse, it would have many of the same pollution problems as petroleum and coal, including emissions of VOC's, nitrogen oxides, and carbon dioxide.

Oilsands and tarsands are ancient oil fields that have been exposed by erosion and from which the lighter, more volatile chemical compounds have escaped. Alberta, Canada contains the largest reserves of tarsands in the world -- the Athabasca deposit north of Fort McMurray (described above). As with oil sands, the energy profit ratio or net energy is less than for conventional oil. Three barrels of oil extracted and refined from tarsands yield, in effect, one net barrel of oil. Two of the three barrels are used up in extracting the oil from oilsands or tarsands (Youngquist 1997). As with conventional fossil fuels, both the processing and consumption of oils derived from tarsands generates air and water pollution.

Hydroelectricity

Hydropower furnishes about four percent of the nation's primary energy production (EIA 2012b) and eight percent of the nation's electricity generation by electric utilities (EIA 2001). Its two environmental advantages are that it is "clean" – during its operational phase, it does not release significant amounts of carbon dioxide, sulfur dioxide, particulates, or mercury to the air – and somewhat renewable.

Figure 3-210. Mitsubishi pump turbine at Southern California Edison's Big Creek hydro-electric project in the Sierra Nevada Mountains of central California. In its generating mode, this massive but high-precision device converts the kinetic energy in flowing water into the rotational motion of the coupled pump/turbine and generator shaft.

It is "somewhat" renewable rather than entirely renewable in perpetuity because over a period of time ranging from decades to centuries, hydroelectric reservoirs (as in the case of all reservoirs and indeed all natural lakes as well) inevitably fill in with sediments.

This reduces the water storage capacity, and therefore the potential electrical energy generating capacity of the facility, that is, its ability to produce "dispatchable" electricity, or power on demand, when the electrical grid needs it to respond to consumers' aggregate demands. Thus, while water will continue to flow over a dam or through penstocks into turbines and generators – and generate electricity – as long as the earth's grand hydrologic cycle of evaporation, rainfall, and runoff continues to function – presumably for millions of years to come – over the long term, hydroelectric power plants at dam sites will inexorably suffer a decline in generating capacity. Ultimately, this will match the marked daily and seasonal fluctuations in streamflow. Hydroelectric plants will not necessarily be able to generate power when people actually need it.

Another advantage of hydropower is that to some extent, it can be combined with facilities that also provide for flood control, navigation, water supply, and lake-based recreation (fishing, boating, water-skiing, swimming, etc.) (USACE 2001). These ancillary benefits are very valuable to society.

Hydroelectricity's disadvantages are many, severe, far-reaching, and well-documented (Krutilla and Fisher 1975, McCully 1996, WCD 2000, EPA 2013d, NREL 2014a, UCS no date). The floodplain directly inundated by a dam and reservoir (i.e., the "footprint") contains wetlands or nature's most productive forests or farmlands and their fertile soils, which are permanently drowned. The valley or canyon flooded by the reservoir may contain exceptional scenic or landscape values which are permanently lost or marred, such as Glen Canyon on the Colorado River (upstream of the Grand Canyon) and Hetch Hetchy Valley in California's Yosemite National Park, both of which disappeared under the rising waters impounded by dams.

Figure 3-211. Glen Canyon on the Colorado River, before inundation by the Glen Canyon Dam and Lake Powell. According to the Glen Canyon Institute, "before its inundation, Glen Canyon was a wonderland of gorges, spires, cliffs and grottoes. After the dam, it became 'the place no one knew.'"

In the past, dam and reservoir construction displaced thousands of residents in the United States. In this country, these days are over, but in densely-populated, developing countries like China, India, and Egypt, recent and ongoing large-scale dam projects entail the permanent uprooting and relocation of hundreds of thousands or even millions of farmers and rural inhabitants. In the case of the Nile River, the Aswan Dam in Egypt flooded irreplaceable archaeological treasures thousands of years old.

Hydropower's impacts are not confined to the area inundated itself, but continue downstream all the way to a river's mouth or confluence with a larger river to which it is tributary. Since suspended sediments in transport are intercepted, settle out, and are deposited in the bottom of the reservoir, "hungry" waters released downstream will strip away sediments from banks, shorelines and shallows; for example, since the construction of the Glen Canyon Dam, many beaches have disappeared or been drastically reduced in the Grand Canyon downstream. In some instances, this effect extends all the way to the ocean – beaches can gradually erode away if they are not replenished with sand and sediments, some of which is furnished by rivers. The clearer, colder water released from dams tends to favor certain fishes and aquatic invertebrates over others. That some water, if obtained from the bottom of the reservoir, may be much colder and oxygen-starved than waters used to be in downstream segments prior to dam construction; once again, this change in the medium, if substantial enough, has significant effects on the aquatic community.

One of the most egregious effects of dams and reservoirs is on anadromous fish, in particular the Atlantic and Pacific salmon, which return from the ocean to their home streams to spawn in the latter or final stages of their life cycle. Not only do dams interfere with upstream migration, an impact only partially mitigated by fish ladders, but they have an even more pronounced adverse effect on the survival of salmon smolts migrating downstream by the millions to the sea. Finger-length smolts have difficulty negotiating the long miles of slack water in reservoirs upstream of dams – for which they were never genetically programmed. They succumb to lake-based predators like trout and they are sometimes sucked into penstocks and ground up in turbines. The Pacific salmon runs (particularly the Chinook or king salmon, largest of them all) of the Columbia River and its tributaries in the Pacific Northwest were devastated when the lion's share of that river system was converted from a free-flowing fish factory into a hydroelectric factory with the construction of some 60 dams and reservoirs. It was a tradeoff that engendered the spectacular growth of the Pacific Northwest by providing cheap, clean, partially renewable electricity.

The geographical and political reality facing hydroelectricity is that, outside of Alaska, very few untapped dam sites with large hydroelectric potential can be developed, because

many of the best sites have already been exploited, and the political opposition to damming remaining free-flowing segments of rivers would be intense. The U.S. already has over 100,000 large and small dams (McCully 1996); the construction of new ones has slowed considerably and all but stopped, leading some in the environmental community and government to proclaim that America has moved beyond the great dam-building era. There is, however, noteworthy potential in retro-fitting existing dams, especially smaller ones, to generate hydropower, but this additional generation is not likely to substantially boost the nation's overall electric generating capacity.

Figure 3-212. Grand Coulee Dam on the Columbia River. Built between 1933 and 1942, it is the single largest electric power-generating facility in the U.S. (hydroelectric or thermal), at nearly 7,000 megawatts (MW) of total capacity.

Figure 3-213. Fish ladder on the John Day Dam on the Columbia River in Oregon

Wind Energy

Winds originate from the uneven heating of the Earth's surface by solar radiation, so in a sense they are another indirect form of solar energy (BLM 2005). Human exploitation of wind to generate power has occurred for centuries. In the early 1900s, windmills were commonly used in the U.S. to pump groundwater; in the Great Plains, many are still visible today, though no longer in use (Brower 1992a). Until the last decade or two, almost all of America's wind electricity-generating capacity was found at just three major sites in California – San Gorgonio Pass (Figure 3-214) near Desert Palm Springs east of Los Angeles, in the Tehachapi Mountains north of L.A., and at Altamont Pass on the way to Livermore east of San Francisco Bay. Each of these was developed under the visionary leadership of California Governor Jerry Brown (in his first stint as governor of California) and his innovative California Energy Commission after the oil price hikes of 1973 and 1979. However, in the late 1990s and early 2000s, wind development on a large scale began to spread with wind farms being built and beginning to operate at a number of other sites in a wide variety of states, including Colorado, Iowa, Minnesota, Oregon, Pennsylvania, New York, Texas and Wyoming (Brown 2001a).

Figure 3-214. Wind farm at San Gorgonio Pass, California

Windmill technology has advanced tremendously in the last thirty years (AWEA 2015). Wind turbines and the "farms" of windmill networks are now sophisticated, high-tech apparatuses. This technical progress has led to a marked decline in generating costs, making wind energy competitive with conventional sources of electricity generation. The

two major technical disadvantages of wind are that it is intermittent (not constant, and therefore not dispatchable), and dispersed (not concentrated), so that it takes a large land area to generate a given amount of electrical energy. However, as with hydroelectric reservoirs providing multiple benefits (i.e., recreation, water supply, flood control), areas with wind farms can still continue to provide for certain other rural land uses, such as agriculture, pasture, and rangeland. As the modern wind boom was beginning to get underway, Lester Brown, founder of the Worldwatch Institute and Earth Policy Institute, insisted that in parts of the country like the northern Midwest and certain Western states like Wyoming, many farmers and ranchers would be happy to receive a second income from utilities placing windmills on their property (Brown 2001b). This has since been borne out by experience in a number of states, where rural landowners tend to be some of wind power's biggest supporters (but also some of its biggest critics and opponents).

One problem, wind power's intermittent nature, is not a major issue provided wind is a relatively small part of the mix of generating sources on the electric grid. Once it attains a sizeable share of the system generating capacity, the need to develop a means of storing and integrating the energy it produces so it can be released when needed by consumers will become crucial. If this problem is not solved, wind's ultimate contribution to the nation's electricity supply will be constrained. Fortunately, several possible long-term solutions do appear to be available and under development: one is electrolyzing water to produce hydrogen. Hydrogen can be then be stored, transported, and burned as a fuel in various manners. Several other storage technologies are also being studied.

Wind energy has rapidly emerged as a mainstream source of electricity in the U.S., supplying 4.5% of the nation's electricity demand as of 2013 (DOE 2015a). With more than 61 gigawatts (GW) installed across 39 states at the end of 2013, utility-scale wind power has proven a cost-effective source of low-emissions power generation. Wind power installations have expanded in geographic deployment and cumulative capacity (Figure 3-215). Wind power costs have also declined by more than one-third since 2008, and the U.S. manufacturing base has expanded further to support annual deployment level growth – from 2 GW/year in 2006, to 8 GW/year in 2008, to peak installations of 13 GW/year in 2012. New U.S. investments in wind plants averaged $13 billion/year from 2008 through 2013. Global investment in wind power grew from $14 billion in 2004 to $80 billion in 2013, a compound annual growth rate of 21 percent (DOE 2015a).

The three main environmental concerns raised by wind energy development are noise, visual impacts, and avian and bat mortality (BLM 2005). As wind energy has expanded exponentially in recent years, these impacts and related concerns have grown in tandem. Anticipated future growth of the industry will incur greater pressures on these limited environmental resources and spur greater opposition to this promising energy source.

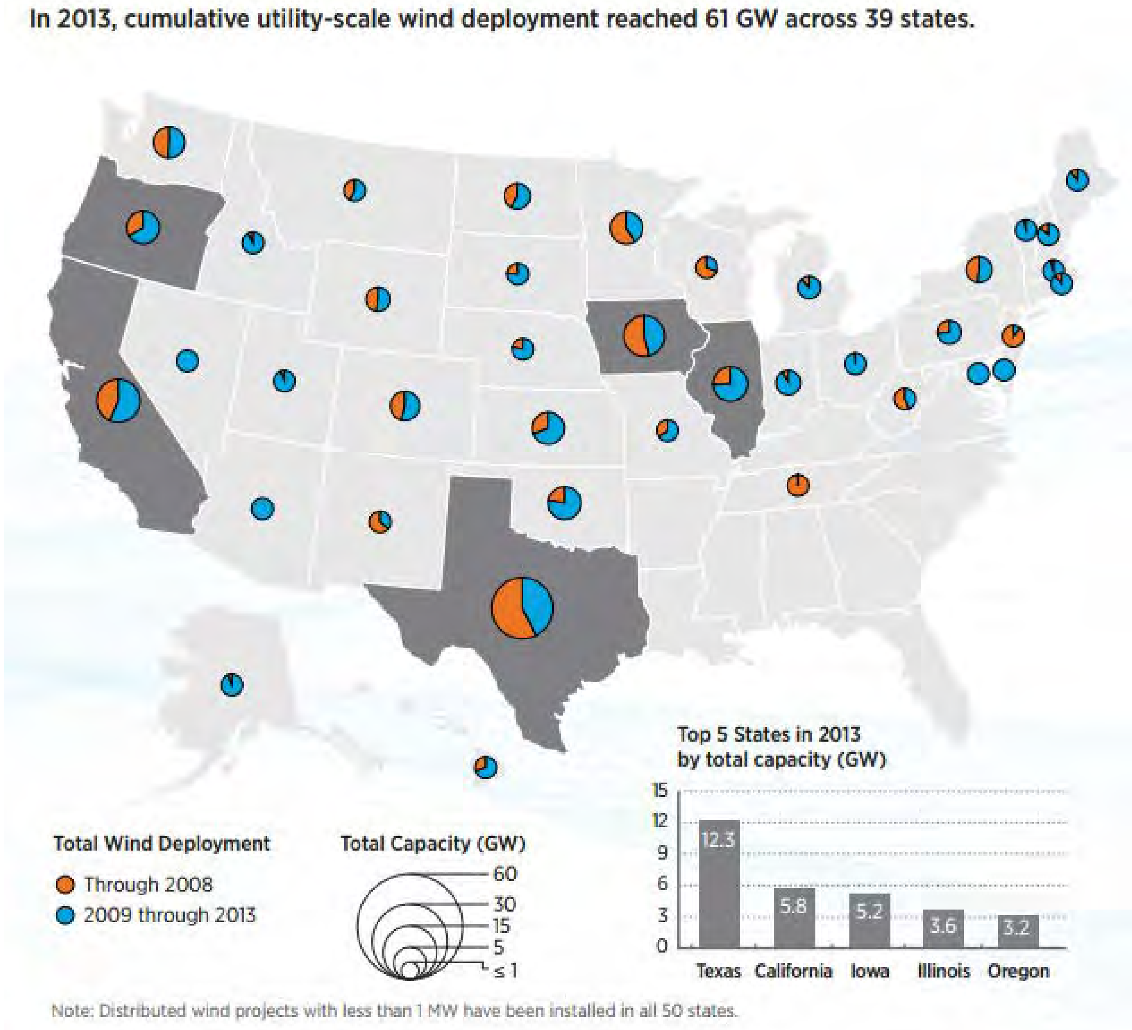


Figure 3-215. Growth in utility-scale wind deployment through 2013

Source: DOE (2015)

- Noise – Like all mechanical systems, wind turbines produce some sound when they operate, which can be interpreted as noise (i.e., unwanted sound) if there are people nearby. However, most of the turbine noise is masked by the sound of the wind itself, and the turbines run only when the wind blows. In recent years, engineers have made design changes to reduce the level of noise from wind turbines. Early model turbines are generally noisier than most new and larger models. As wind turbines have become more and more efficient, a greater share of the wind is converted into rotational torque and less into acoustic noise. Moreover, proper siting of wind turbines and wind farms and the use of insulating materials can reduce noise impacts (BLM 2005).

- Visual Impacts – Because they must generally be located in exposed sites that get the most wind, ever-larger wind turbines are often highly visible (Figure 3-216) (NRC 2007). However, visibility is not necessarily the same as intrusiveness. Aesthetic issues are by their nature inherently and highly subjective and dependent on the values and interests of the observer(s) in question. Proper siting decisions can help to avoid or minimize aesthetic impacts to the landscape. One strategy now being used to partially offset visual impacts is to site fewer turbines in any one location by using multiple locations and by using today's larger and more efficient models of wind turbines, so that fewer overall number of facilities are necessary to generate the same amount of power (BLM 2005).

Figure 3-216. Wind farms can have prominent adverse aesthetic impacts on the surrounding rural or natural landscape, adding to the rapidly growing number of manmade objects "cluttering" the natural world (Laurel Mountain in West Virginia)

- Bird and Bat Mortality –
  Wind facilities can have adverse effects on wildlife populations at the local or regional level, both by damaging or eliminating habitat and by killing birds and bats that fly into spinning turbine blades (NRC 2007). Among birds, the most frequent turbine fatalities are nocturnal, migrating songbirds (passerines), probably because of their sheer abundance. However, a 2007 study and review by the National Research Council of the National Academy of Sciences found no evidence, at that time at least, that fatalities from then-existing wind facilities were causing measurable reductions in bird populations in the United States.

  A possible exception is mortality among birds of prey (raptors), such as golden eagles and hawks, at the wind farm near Altamont Pass, California (Figure 3-217). This is a facility, dating back to the early 1980s, has older, smaller turbines with faster-spinning blades that appear more likely to kill birds than are newer turbine models.

Figure 3-217. Wind farm near Altamont Pass in California

The small turbines used at Altamont Pass are hazardous to the various species raptors that hunt California ground squirrels that are abundant in the area. An estimated 1,300 raptors (and 4,700 birds in total) are killed annually, among them 70 federally protected golden eagles (Figure 3-218). Overall there has been an 80 percent decline in golden eagles in Northern California, with no golden eagles nesting near the Altamont Pass wind farm, although it is a prime habitat.

Figure 3-218. The majestic golden eagle is a resident of the American West and is federally protected by the Bald and Gold Eagle Protection Act

A 2014 study and review of data compiled from 116 studies estimated annual fatalities from collision of small passerines with wind turbines in the U.S. and Canada at approximately 134,000 to 230,000, or 2.10 to 3.35 small birds/MW of installed capacity. When adjusted for species composition, these results indicate that about 368,000 fatalities for all bird species are caused annually by collisions with wind turbines. Other human-related sources of bird deaths, (e.g., communication towers, buildings and their windows, and domestic cats) have been estimated to kill millions to billions of birds each year. Compared to continent-wide population estimates, the cumulative mortality rate per year by species was highest for the black-throated blue warbler and tree swallow; 0.043% of the entire population of each species was estimated to annually suffer mortality from collisions with wind turbines (Erickson et al. 2014).

Another study estimated total U.S. fatalities of 573,000 for birds (including 83,000 raptor fatalities) and 888,000 for bats in 2012 (Smallwood 2013).

Concerning bats, turbines located on Appalachian Mountain ridgetops – as many are in the mid-Atlantic region – appear more likely to kill bats than turbines sited elsewhere. In fact, preliminary data suggest that in the mid-Atlantic highlands more bats are killed than expected based on experience with other regions. Although scarce data thwart a determination of whether this mortality affects overall bat populations, the possibility of overall population effects is substantial, especially if more turbines are added, given a general decline in several species of bats in the eastern United States (NRC 2007) due to the widespread and lethal white-nose fungus epidemic.

The prospect of large numbers of deaths of birds and bats deaths is probably the most single most controversial issue related to the rapid growth of the wind industry. Fish and wildlife agencies and conservation groups have raised serious concerns about bird and bat mortality at wind farms (USFWS 2007, USFWS 2009, USFWS 2012). As noted, one of the nation's original utility-scale wind farms at Altamont Pass east of San Francisco Bay has killed thousands of raptors due to collisions with spinning blades. On the other hand, several large wind facilities have operated for years with only minor adverse impacts on wildlife (BLM 2005).

To try to address this issue, the wind industry and government agencies have funded research into collisions, surveys, relevant bird and bat behavior, mitigation measures, and appropriate study design protocols. Also, wind project developers are required to collect data through monitoring efforts at existing and proposed

> wind energy sites. Careful site selection is needed to minimize fatalities and in some cases additional research may be needed to address bird and bat impact issues (BLM 2005).
>
> While structures such as smokestacks, lighthouses, tall buildings, and radio, cell, and television towers are also associated with bird and bat fatalities, bird and bat mortality is a serious concern for the wind industry and the public.

Unlike most other electricity generation technologies and energy sources, wind turbines do not use combustion to generate electricity, and thus do not produce so-called criteria air pollutants (e.g., NO_x, SO_2, CO, VOCs, O_2, PM_{10} and $PM_{2.5}$). The only potentially toxic substance or hazardous materials are relatively small amounts of lubricating oils and hydraulic and insulating fluids. Therefore, contamination of surface or groundwater or soils at wind farms is highly improbable. The primary health and safety considerations are related to blade movement and the presence of industrial equipment in areas potentially accessible to the public. An additional concern associated with wind turbines is potential interference with radar and telecommunication facilities. Like all electrical generating and transmission facilities, wind generation produces electric and magnetic fields (BLM 2005).

A further primary benefit of wind-generated electricity is that it produces no CO_2, a major greenhouse gas, or any other air pollutant. Based on DOE projections for wind-energy development in the United States, the NRC estimated in 2007 that by 2020, wind energy will offset approximately nearly five percent of the CO_2 that would otherwise be emitted by other electricity sources (NRC 2007).

Figure 3-219. These two images symbolize the promise and peril of exploiting and expanding wind power in the U.S.

Figure 3-220. Small-scale wind turbine on the beach near Juneau, Alaska, for use by a single-family home. Wind power can be exploited at a wide range of scales.

Biomass

Biomass takes a number of different forms, including the burning of firewood in residential woodstoves (Figure 3-221) for home heating and cooking, the use of hog fuel or wood waste in sawmills and pulp mills to generate process heat or electricity, and the conversion of crops such as corn, sugar cane, or soybeans into biofuels like ethanol (ethyl alcohol), methanol, or biodiesel for uses as fuel additives or substitutes. Ethanol in particular has been used on a large scale as an additive to gasoline because of lower emissions of most air pollutants.

Figure 3-221. Modern woodstoves can be a clean and efficient tool for using a renewable, sustainable energy resource

Figure 3-222. Ethanol production plant

One of the serious long-term issues confronting biomass energy sources is their generally low EROEI, in other words, whether some of the products, for instance ethanol and methanol, actually generate any net energy for society. That is, the cultivation, production, and chemical distillation of the crops from which they are derived are so energy-intensive that these processes may actually consume as much or more energy than they yield as surplus for the economy (Pimentel 1998, Hammerschlag 2006, Philpott 2006). For example, in one 1990s-era study critical of ethanol's prospects, the energy expended to produce one liter of ethanol from corn with an energy content of 5,130 kilocalories (kcal) was 10,200 kcal – a net energy loss (Pimentel et al. 1994). If ethanol were used as a substitute for oil in the U.S., 250-430 million hectares (625 to 1,075 million acres) of land would have to be appropriated to supply the raw material input, an area far greater than that devoted to cropland. While other more recent research using different assumptions or studying different processes have shown that ethanol from corn or cellulose does have a positive EROEI, net energy or the energy profit ration is still low enough that it is unlikely ethanol could ever provide adequate liquid fuels at scale (i.e., to replace fossil fuels) for society. In view of unfavorable chemical and physical realities like these, it is doubtful that ethanol and methanol are practical, sustainable or renewable energy sources at scale.

With regard to GHG and CO_2 emissions, a 2007 study by DOE's Argonne National Laboratory found that when entire fuel life cycles are considered, using corn-based ethanol instead of gasoline reduces life cycle GHG emissions by 19-52 percent, depending on the source of energy used during ethanol production (Figure 3-223). Using cellulosic ethanol yields an even greater benefit – reducing GHG emissions by up to 86 percent (DOE 2014a).

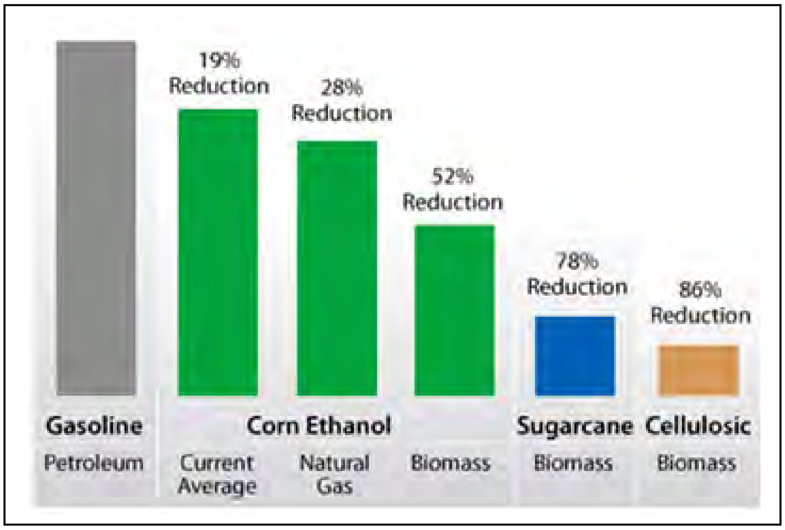


Figure 3-223. GHG emissions of transportation fuels by type of energy used in processing
Source: DOE (2014)

Where biomass is a waste product or byproduct of some agricultural or industrial activity, or when crops, such as trees, can be harvested in a truly sustainable manner, then biomass may make environmental sense. But this also establishes a fairly restrictive limit in terms of the amount of biomass energy available to society. Harvesting crop residues as a fuel can expose agricultural soils to wind and water erosion, as well as remove organic materials that add soil structure and essential nutrients from the land that must be replaced by fossil fuel-based fertilizers. Biomass energy can also compete with other critical land uses for high-quality land and soils (Kolankiewicz 2002).

The amount of land that could be devoted to energy biomass is limited, since most suitable land is in used by agriculture, human settlement, covered by forests, or protected as parks or wildlife refuges (FAO 2003). A University of Florida study suggests that to substitute biofuels for the entire U.S. gasoline supply would require 60 percent of all available cropland in the U.S. (Moreira, 2005). Therefore, energy biomass plantations would compete with the existing agricultural land uses or could lead to the conversion of remaining natural areas that should be kept under conservation (Convention on Biological Diversity no date).

One consequence of energy biomass plantations expanding into remaining natural landscapes would be biodiversity loss from habitat destruction and fragmentation. Additional adverse effects on biodiversity would occur if unsustainable agricultural practices – such as overuse of chemical inputs (e.g., fertilizers, pesticides) that may lead to eutrophication and water pollution, or tillage that can result in soil erosion or compaction – are used when establishing and managing the planted biomass. Given limited amounts of suitable land, energy biomass may also expand into riparian areas, set-aside land, or tree lines which all play an important ecological role. Wetlands biodiversity could also be at risk being drained to plant energy crops. However, planting

energy biomass could rehabilitate marginal and degraded lands (Convention on Biological Diversity no date).

In addition to the potential loss of forest due to land clearing for agriculture, the growing interest in cellulosic biomass (second generation feedstock) may increase existing pressures on forests from fuelwood harvesting (particularly in developing countries) and exacerbate the already disturbing loss of biodiversity in these ecosystems. Furthermore, harvesting forests to produce biofuel can counteract greenhouse gas reduction efforts, given that some 25-30 percent of the greenhouse gases released into the atmosphere each year (1.6 billion metric tonnes) is caused by deforestation (Convention on Biological Diversity no date).

With rising global demand for food, converting croplands and pasture to biomass energy production may force farmers to clear additional natural or marginal lands for food cultivation and grazing, as well as result in food price increases. This in turn could force indigenous or rural peoples to rely more intensively on food from the wild (bush meat), negatively impacting biodiversity (Convention on Biological Diversity no date).

Potential environmental drawbacks to biomass include usurping land to produce it – so that a biomass-dedicated unit of land is not available to support other types of plant communities that may have more value for, say, forest products or biodiversity, using polluting or unsustainable inputs like pesticides and fertilizers to assist improve yield, and causing some level of pollution at the point of end use. When woodstoves became very popular in the 1970's and 1980's, their improper use contributed to a good deal of smoke air pollution (especially particulate matter), particularly in confined valleys with limited air circulation. Generally, the combustion of biomass generates more air pollutants than gas, but less than coal.

In conclusion, while biomass does play an important role in today's and tomorrow's energy mix, its potential for any significant expansion is severely constrained and its sustainability in many instances is questionable.

Solar Energy

Solar energy comes in many different forms, some of which are centralized and some of which are decentralized or "distributed." Centralized forms include several kinds of concentrating solar thermal electricity-generating plants and photovoltaic (PV) facilities, which can produce electricity for the electric grid. California in particular has been building projects for several decades. Examples of decentralized solar technologies are passive solar space heating, rooftop solar hot water heaters, and photovoltaic panels for rooftops and dispersed applications (road signs, telephones, buoys, etc.). Most analysts

agree that solar has a bright future, as concerns about pollution, global climate change, and environmental sustainability spread and deepen, and the last decade has seen rapid expansion of solar energy nationally and globally. During operation, solar energy has little or no emissions of greenhouse gases, sulfur dioxide, nitrogen oxides, volatile organic carbons (hydrocarbons); it does not generate significant quantities of solid waste or water pollutants. On the other hand, solar thermal plants use fairly large amounts of water, comparable to the quantities of similarly-sized coal or nuclear plants (Anon. 2000). Solar manufacture is also heavily dependent on rare earth minerals – critical materials that are subject to depletion. Solar photovoltaics and solar cells, for example, use cobalt, gallium, germanium, manganese, tellurium, titanium, and zinc (Heinberg, no date, Clugston 2015).

Figure 3-224. Solar photovoltaic cells in the California desert

Solar energy is renewable, and the generation or conversion of the sun's rays into electricity or heat is non-polluting, although production of solar panels does entail the use of certain toxic substances (principally heavy metals). Solar is about as "green" as it gets, but as with wind energy, it is no environmental silver bullet. The main reasons are that solar energy is relatively diffuse or dispersed compared to other energy sources, particularly the fossil fuels and nuclear energy, and like wind, it is intermittent. Unlike wind, no direct solar energy at all is available once the sun sets until it rises again.

It is estimated that five acres of land are needed for each megawatt of capacity (Anon. 2000), or about 5,000 acres (almost eight square miles) for a typical 1,000-megawatt power plant. This means that it takes comparatively large areas to capture a given amount of solar energy. If U.S. energy supply were to be met entirely by solar energy, a sizeable percentage of the country's land area would have to be expropriated for this purpose. One estimate thrown around over the years is ten percent or so. On the other

hand, another estimate is that only 60,000 square kilometers, or about 20 percent of Arizona would need to be covered by photovoltaic cells to meet the USA's entire electricity demand (EPA 2001).

This is still an enormous amount of land and whether the country could accommodate or accept this degree of appropriation is open to question. Unlike placing wind turbines on a site, the solar panels associated with a centralized generation facility completely alter its ecology and appearance every bit as much as a hydroelectric dam and reservoir transform a river. The native flora and fauna of the site, if not completely displaced, are radically transformed and biodiversity is reduced or eliminated (Figure 3-224). If America's Southwestern deserts were on the path to being allocated or sacrificed entirely to solar energy production, it is likely that large elements of the conservation community would strenuously oppose conversion of vast areas of wild desert landscapes and ecosystems to energy factories as strenuously as they oppose any new dams now. This has already begun to happen in California (Figure 3-225) (Maloney 2008).

Figure 3-225. Planned solar thermal plant in the Mojave Desert at Kramer Junction, California

A 2008 *New York Times* article described the planned setting of solar projects in the California desert in this manner:

> "…home to the Mojave ground squirrel, the desert tortoise and the burrowing owl, and to human residents who describe themselves as desert survivors and who are unhappy about the proliferation of solar projects planned for their home turf.
>
> "'We're tired of everyone looking at the desert like a wasteland,' [said one resident].

The above discussion applies to solar-generated electricity when constructed as central station systems connected to the electric grid. One advantage of PV is that it can be developed in a widespread, dispersed pattern as distributed systems that use little or no additional land, since the panels can be installed on the rooftops of existing homes, commercial buildings, parking lots, or other structures (Anon. 2000) (Figure 3-226).

Figure 3-226. Rooftop solar photovoltaic has a good deal of promise and requires no additional land for electricity generation, though its manufacture is not free of environmental impacts.

Life cycle GHG emissions from all renewable energy technologies, including solar, are generally much less than those powered by fossil fuel-based resources. In recent decades, thousands of Life Cycle Assessments (LCAs) have been published for a variety of electricity generation technologies. These LCAs have shown widely variable results, due to the technologies evaluated (e.g., differing system designs, commercial versus conceptual systems, system operating assumptions, technology improvements over time) as well as LCA methods and assumptions. Recently, analysts at DOE's National Renewable Energy Laboratory (NREL) developed and applied a systematic approach to review the LCA literature, identify primary sources of variability and, where possible, reduce variability in GHG emissions estimates through a procedure called "harmonization." This harmonization methodology is based on a two-step meta-analytical approach (NREL 2013, NREL 2014b). Results for the electricity generation technologies and primary energy sources analyzed are shown in Figure 3-227.

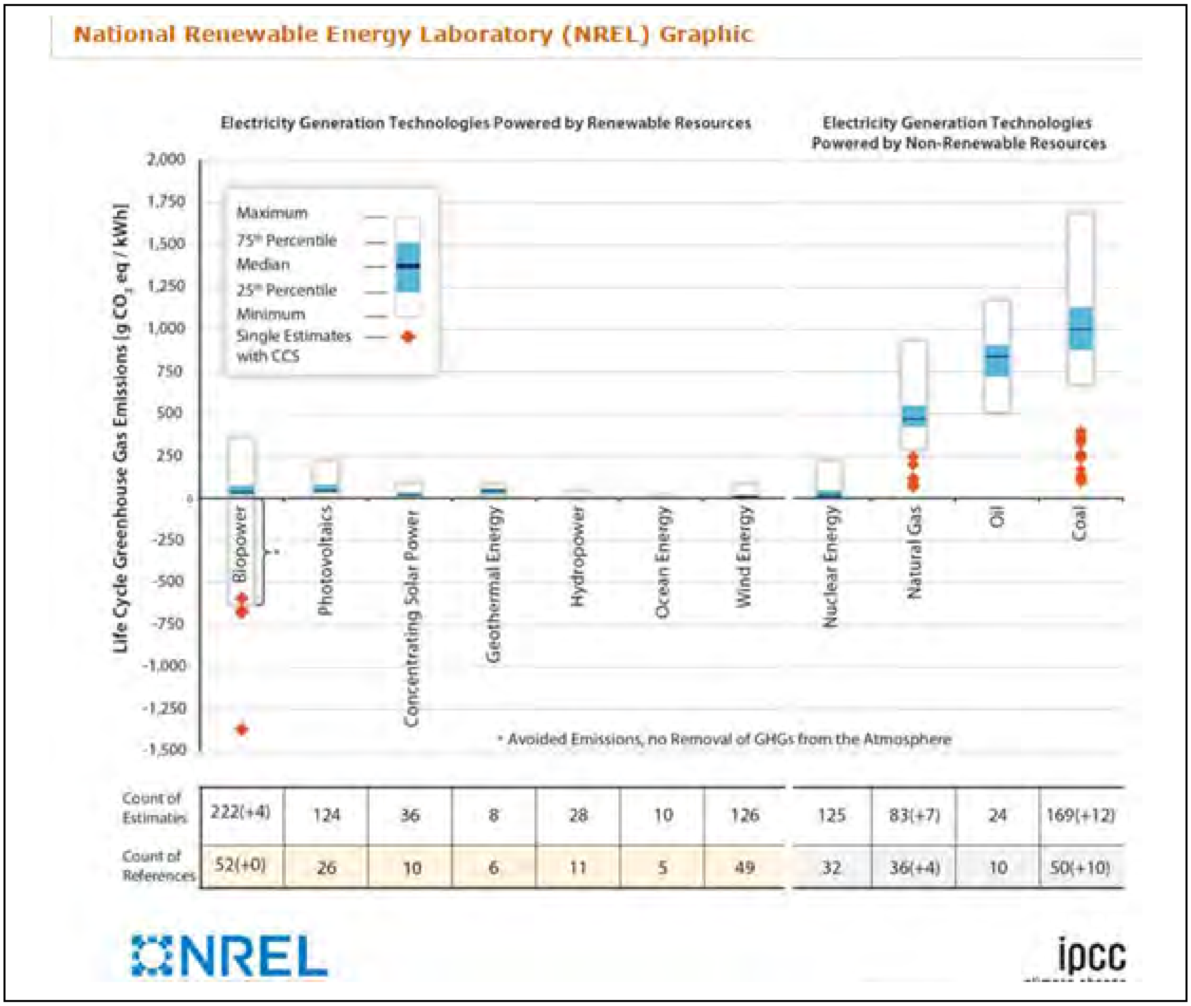


Figure 3-227. Comparison of GHG life cycle emissions from renewable and fossil-fuel electricity generation technologies and energy sources

In conclusion, the potential environmental impacts of solar energy include habitat loss, water use, and the use of hazardous materials in manufacturing. These can vary greatly depending on the technology – PV solar cells or concentrating solar thermal plants – as well as the scale, pattern (concentrated or dispersed) and location of development. Solar energy has environmental advantages, but it is not unlimited and it is not free of environmental impacts, contrary to the impression of some solar enthusiasts. A complete commitment to solar energy would not obviate the need to stabilize population, because a larger population would need more solar energy, which as shown, has its environmental shortcomings, even if they are fewer than fossil energy sources.

Geothermal Energy

Geothermal energy is derived from heat contained in certain geologic formations beneath the ground surface within the earth's crust. Geothermal resources can be exploited for both electrical power generation and direct heat applications. In comparison with other

energy sources, geothermal energy has some significant environmental benefits: greenhouse gas emissions are quite low (Figure 3-227); ozone-depleting chemicals from both direct and indirect sources are also negligible; sulfur oxide emissions are virtually zero because, by design, geothermal's modern closed-cycle systems reinject almost everything but the extracted heat; and geothermal facilities demand relatively little land surface area. Within their footprint, they resemble most light industrial facilities (DOE 1997) (Figure 3-228).

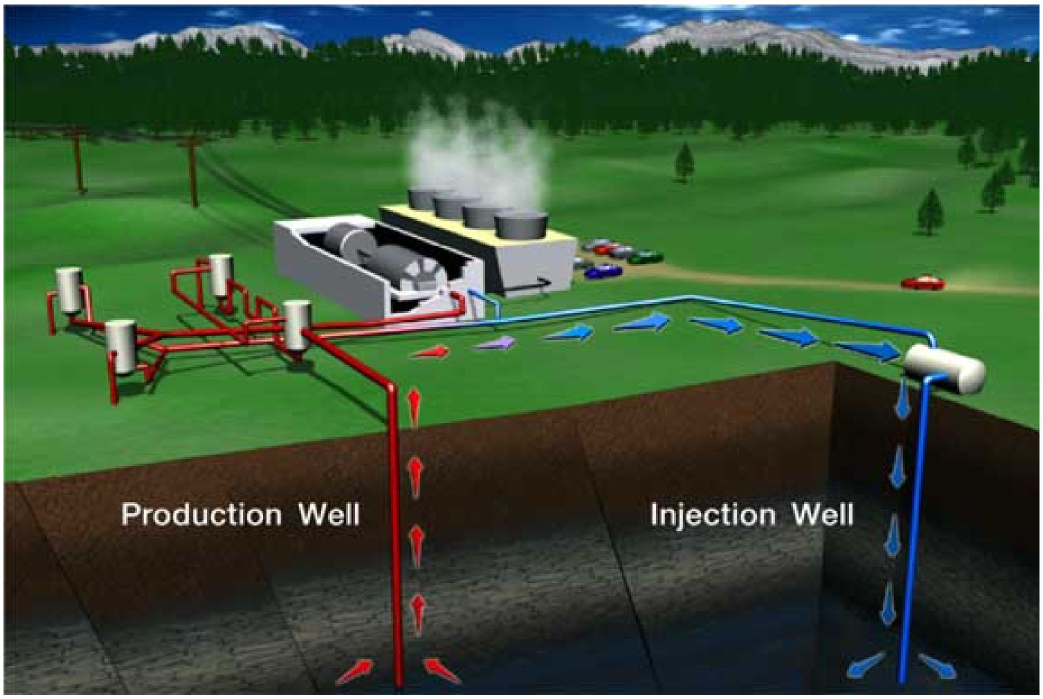


Figure 3-228. Illustration of geothermal power plant

Geothermal resources differ in many respects, but all involve similar environmental concerns, including air and water pollution, the safe disposal of hazardous waste, siting and construction of industrial facilities in natural habitats (habitat destruction and fragmentation), land subsidence, and potential adverse effects on rare hydrogeological formations, like geysers and hot springs (Brower 1992b).

For example, at The Geysers (Figure 3-229) in Northern California's Mayacamas Mountains, which is the USA's and world's largest geothermal facility, steam vented at the surface by the complex of 22 power plants contains hydrogen sulfide (H_2S), with its attendant "rotten egg" smell, as well as other pollutants, including ammonia (NH_3), methane (CH_4), and carbon dioxide (Brower 1992b). Nevertheless, for each kilowatt-hour of electricity or quad of energy generated, the amount of carbon dioxide released is still only a tiny fraction of the amount emitted by a coal- or oil-fired power plant.

Figure 3-229. The Sonoma Calpine 3 power plant is one of 22 power plants at The Geysers geothermal complex in Northern California.

Scrubbers can reduce air emissions but result in a watery sludge with elevated levels of sulfur and vanadium, the latter a potentially toxic heavy metal. Still more sludge is produced when hydrothermal steam is condensed, and dissolved solids precipitate out. This sludge is usually high in silica compounds, chlorides, arsenic, mercury, nickel, and other toxic heavy metals (Brower 1992b). Many of these wastes can be reinjected back into a porous stratum of a geothermal well, taking care that they are injected well below freshwater aquifers to avoid groundwater contamination. Such reinjection may also help avert land subsidence. Most geothermal power plants will require a large volume of water for cooling. Where water is scarce, this demand could conflict with other water consumers like agriculture, industry, municipalities, and residences.

As with several other energy sources, one drawback of geothermal energy is that many hydrothermal reservoirs are located in or near outstanding natural areas like Yellowstone National Park (home of the world's most famous geyser, "Old Faithful") and the Cascade Mountains. Proposed developments in such areas have been intensely opposed by environmentalists and wilderness advocates (Brower 1992b). Not only can such facilities compromise wilderness character, but they can also disrupt the "plumbing" that geysers and other surface hydrothermal features depend on. Thus, the potential for substantial future expansion of this renewable energy resource is limited not only by geographic considerations but political ones as well (conflicts with other resource values). If hydrothermal-electric development is to expand much further in the United States, reasonable compromises will have to be reached between environmental groups and industry.

Nonetheless, the U.S. Department of Energy and many other analysts regard geothermal energy as environmentally superior to conventional fossil energy sources (DOE 1997, Grassley 2011).

Renewable Ocean Energy: Wave, Tidal, Current and Offshore Wind

Waves, tides and currents are rhythmic natural flows and phenomena that abound around the planet, and offer certain promise of being harnessed as renewable, sustainable, clean energy sources. However, their contribution to the world's commercial energy supply to date has been miniscule and the scope for expanding this contribution highly uncertain. Whether they can make a difference at scale is unknown and perhaps unlikely.

Offshore wind, on the other hand, is already providing a substantial contribution to European electricity production. However, not a single commercial facility has yet been built or operated in the United States, in part because of environmental objections.

Energy from Ocean Waves

Around the Earth, winds blowing across the ocean's surface generate waves. In most parts of the world, the wind blows with enough consistency and force to provide continuous waves along the shoreline. These ocean waves have tremendous energy potential. Wave power devices extract energy from the surface motion of ocean waves or from pressure fluctuations below the surface (Figure 3-230). Ocean wave energy is captured directly from surface waves or from pressure fluctuations below the surface (BOEM no date-a).

Figure 3-230. Artist's conception of an array of attenuator wave energy devices

Ocean waves consist of rotating water molecules moving in an orbiting pattern. Most of the wave energy – about 95 percent – occurs between the surface and a depth equal to one quarter of the wavelength. These waves can travel for thousands of miles with little loss of their kinetic energy until they approach a shoreline where they begin to interact

with the seafloor at depths of approximately 600 feet. Wave energy system technologies aim to harness this kinetic energy as waves roll toward the shore, and convert it into useable power for communities (ACEP 2012). Wave action and wave energy are clean and renewable, and will last as long as the sun shines.

Data collected by NREL show that in high wave energy-dense areas such as the Pacific Northwest, energy production rates can reach about 1.5 MW for every 100 feet of shoreline occupied by generators. By comparison, a large fossil fuel plant of 1,000 MW capacity would occupy about two hundred acres. Installing a comparable capacity using on shore wave power would occupy 12-13 miles of shoreline. This estimate is for places like the Pacific Northwest where conditions are favorable for this technology.

While renewable, clean, and sustainable, wave energy is not without environmental concerns. Among these are potential impacts on fish and other marine life, marine benthic habitat, sediment transport, commercial shipping, archeological sites, marine navigation, fishing, onshore impacts (from ancillary facilities), outdoor recreation, and aesthetics. Many of these potential adverse impacts could be avoided or minimized through proper planning and siting (BOEM 2007).

Energy from Ocean Tides

Tidal energy is a phenomenon powered by the semi-diurnal (approximately twice a day) natural rise and fall of the sea, which occurs due to the rotation of the Earth and the relative positions of the moon (and to a smaller extent, the sun), which exert gravitational force on ocean waters. Any given shoreline experiences two high and two low tides a day.

Ocean tides, unlike many other forms of intermittent renewable energy (wind and solar in particular, but also wave), are a reliable source of kinetic energy caused by regular, highly predictable tidal cycles caused by the phases of the moon. Intermittency is a serious drawback for wind, wave and solar power, since the sun isn't always shining and the wind isn't always blowing. These sources of renewable energy often require backup from traditional (e.g., fossil fuel, often gas turbines) dispatchable forms of power generation that can be turned on and off quickly. However, the intrinsic predictability of tidal power is very attractive for management of the electrical grid, as it obviates the need for back-up thermal plants powered by fossil fuels. Tidal turbines are installed on the seabed at locations with high tidal current velocities (MCT no date). These high tidal current velocities are found at entrances to bays or narrow straits along ocean channels.

Tidal turbines are very similar to underwater windmills, except that the rotors are driven by consistent, rapid currents rather than flowing air (winds). The submerged rotors

harness the power of the marine currents to drive generators, which in turn produce electricity. Water is more than 800 times denser than air and therefore tidal turbine rotors can be much smaller than wind turbine rotors. They can also be arranged much closer together and still generate equivalent amounts of electricity (MCT no date).

Production of electricity from tidal energy to date has been very small. There are very few commercial-sized tidal power plants operating in the world. The first was located in France and the largest existing facility is in South Korea. The U.S. does not yet and may never have a single tidal plant, as there only a handful of sites where tidal energy could be produced at a reasonable price. In terms of environmental impacts, while there would be no GHG or criteria pollutant emissions while in operation, there could be localized adverse effects on marine habitats, fish populations, and navigation during construction and operational phases. In general, the scope is small both for tidal energy to help meet the nation's need for sustainable, clean energy and for it to produce significant environmental impacts.

Energy from Ocean Currents

Ocean currents are a physical manifestation of the Earth's rotation and other factors. The continuous and relatively steady flow of ocean currents transports huge amounts of water through the earth's oceans. Technologies are now under development so that usable energy that can be extracted from ocean currents (BOEM no date-b).

Ocean waters are constantly moving. They flow in complex patterns influenced by wind, water salinity, temperature, topography of the ocean floor, as well as the Earth's rotation. Most are driven by wind and by solar heating of surface waters near the equator, while some result from density and salinity variations of the water column. Ocean currents display relatively constant velocity, and flow only in one direction, in contrast to tidal currents running along shores. Tidal currents (discussed in the subsection just above) flow one direction for six-plus hours, then reverse course and flow in the opposite direction; not so ocean currents like the Gulf Stream. Along the East Coast of the United States, the Gulf Stream constantly flows north and north-east. At any one place, it does not change direction.

While ocean currents flow quite slowly compared to typical wind speeds, they contain a great deal of energy because of the much higher density of water – more than 800 times denser than air. Thus, across the same surface area, water moving at a velocity of 12 miles per hour (mph) exerts the same amount of force as a constant 110-mph wind. Because of this physical property, ocean currents contain an enormous amount of energy that humans can harness and convert to usable forms. For example, it has been estimated

that using just one-tenth of one percent of the available energy from the Gulf Stream could supply Florida with 35 percent of its electrical needs (BOEM no date-b).

America and other countries are conducting research into ocean current energy; however, it is at an early stage of development. Relative to wave, tidal, and offshore wind resources, ocean currents' energy potential is the least understood, and the technology for harvesting it most in its infancy. There is not a single commercial grid-connected ocean current turbine operating anywhere in the world, and only a small number of prototypes and pilot-project units have even been tested. More advanced technologies have been developed for use with tidal currents in near-shore environments, such as at the Bay of Fundy in Canada's province of Nova Scotia (BOEM no date-b).

Because not a single project is in operation, analysis of impacts of ocean current development and utilization is necessarily somewhat speculative. The largest impacts from ocean current energy facility construction activities would likely be due to installation of the turbine anchors or foundations, and the submarine electric cable from each ocean current device to a collection hub and from that hub to an onshore substation. There could be potential moderate noise impacts on fish, sea turtles, and marine mammals from pile-driving during installation of any anchors or foundations. Without proper mitigation, disturbance of the seafloor could result in moderate to major impacts on seafloor habitat. Construction activities could also entail moderate, if temporary, air quality impacts, mainly from fugitive dust emissions, and moderate impacts to coastal habitats such as wetlands and barrier beaches. Construction activities could also interfere with nesting and foraging habitats for seabirds. Once operational, impacts to marine mammals, sea turtles, and fish from the operating underwater turbines (with spinning or rotating blades) could conceivably occur. A U.S. Bureau of Ocean Energy Management (BOEM) EIS concluded that these impacts "could be major for some threatened and endangered species" (BOEM 2007).

Figure 3-231. Artistic rendering of ocean current turbines

Energy from Offshore Wind

Unlike the three forms of ocean-related energy described above, offshore wind is no longer mostly hypothetical. It has already been demonstrated and developed at scale as a viable, affordable, renewable energy source, at least in Europe, if not the United States. The first offshore wind project was built off the coast of Denmark in 1991. Since then, many other commercial-scale offshore wind facilities have been built and are operating in shallow waters around the world, mostly in Europe.

At present, Europe has at least 70 complete, operational wind farms and 2,300 turbines in its waters (Leber 2015). However, to date, not a single commercial offshore wind electricity generating facility has been built or operated in the U.S., although there have been several proposals, the most advanced of which until recently was the 130-turbine, $2.5-billion Cape Wind in Nantucket Sound, Massachusetts. But after withstanding a decade and a half of scrutiny, studies (including two Environmental Impact Statements) (DOE 2012), regulatory hurdles, and lawsuits launched because of tenacious local opposition from wealthy, politically connected residents of Martha's Vineyard (worried about their ocean views from prime real estate), fishermen, and some Native Americans, in early 2015 it was announced that the Cape Wind project is on hold (Abel 2015). It appears to have lost its financial backing (perhaps in part because of investors made nervous by such sustained opposition) and two utilities have cancelled their contracts to purchase electricity from it. Efforts to develop wind off the shores of Delaware and Maryland have also stalled.

Figure 3-232. Offshore wind farm in Denmark

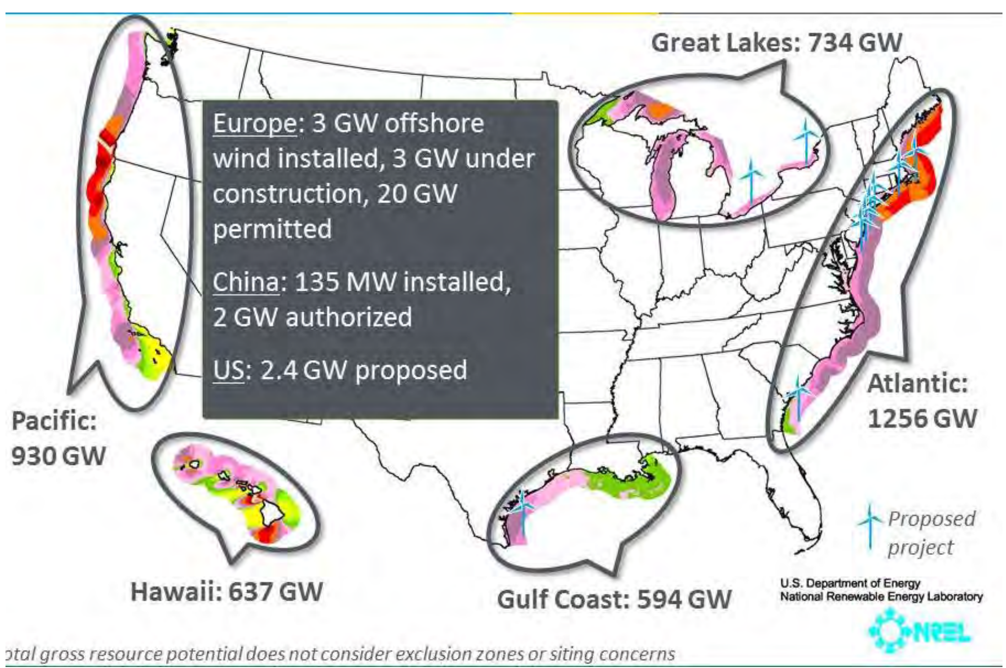
On the other hand, developer Deepwater Wind has received all needed approvals and permits to begin construction in mid-2015 on a much more modest proposal: five offshore wind turbines located 18 miles off the coast of Rhode Island (Leber 2015). Furthermore, the U.S. government under the Obama administration remains committed to promoting the development of offshore wind potential (BOEM no date-c). In 2010, the U.S. Department of the Interior's launched its "Smart from the Start" initiative to facilitate siting, leasing and construction of new offshore wind projects on the outer continental shelf (DOI 2010). Innovative turbine and foundation technologies are being developed so that wind power projects can be built in deeper waters further away from the shoreline, so their visibility is reduced and aesthetic impacts incite fewer objections.

Offshore winds tend to be strong and consistent – blowing harder and more uniformly than on land. The potential energy produced from wind increases in direct proportion to the cube of the wind speed. Thus, increasing wind speed by just a few miles per hour can produce a substantially larger amount of electricity. For example, a turbine at a site with an average wind speed of 16 mph would produce 50 percent more electricity than at a site with the same turbine and average wind speeds of 14 mph. This is a key reason that wind developers are keen on harnessing offshore wind resources (BOEM no date-c).

Average wind speeds off the Atlantic Coast and in the Gulf of Mexico are lower than those off the Pacific Coast. However, the presence of shallower waters in the Atlantic coastal shelf makes development more attractive and economical for the time being. Of all states, Hawaii has the highest estimated potential, accounting for roughly 17 percent of the entire estimated U.S. offshore wind resource.

Figure 3-233. Huge U.S. offshore wind potential

Source: Gilman (2011)



In many ways, commercial-scale offshore wind facilities are quite similar to onshore wind facilities. Wind turbine generators installed in offshore environments include special modifications to prevent corrosion in the salty air and water, and their foundations must be designed to withstand the rigorous chemical and physical environment of the sea, including storm waves, hurricane-force winds, and even ice flows in some places. About 90 percent of the U.S. outer continental shelf wind energy resource is found in waters that are too deep for current turbine technology. Engineers are investigating and devising newer technologies, such as innovative foundations and even floating wind turbines, that may eventually permit expansion of offshore wind power development into the even harsher conditions associated with deeper waters (BOEM no date-c).

In general, most environmental impacts from offshore wind would be negligible to moderate for all phases of wind energy development, assuming that proper siting and mitigation measures are followed. Potential impacts during the construction phase would be the highest, because this phase involves the highest amount of vessel traffic, noise generation, and air emissions. There is a potential for major impacts to certain threatened and endangered species of marine mammals, birds, or sea turtles from vessel or turbine collisions, nesting area disturbance of nesting areas, alteration of crucial habitat, or low-probability large spills of fuel, lubricating oil, or other fluids. Moderate impacts to fish and fisheries could occur due to the establishment of exclusion zones within wind energy facilities. Potential visual impacts can be mitigated through several means, most importantly siting facilities further away from sensitive areas with many viewers (BOEM 2007).

Wildlife biologists have expressed concerns on repeated occasions about the potential impacts of offshore wind development on seabirds and marine life (Welch no date, Jarvis 2005, Gilman 2011). Both baseline studies and measurements of actual effects on wildlife are difficult and costly to study in these inaccessible environments. Concerns relate to collision; displacement from breeding, feeding or nesting areas; the energetic costs of avoidance (flight time and energetic cost); displacement of prey base; noise/vibration that may interfere with communication, foraging, or predator detection; benthic (bottom-dwelling) communities; and electromagnetic field (EMF) effects. Actual empirical evidence on any of these possible effects is scanty.

In view of these concerns, which necessitate additional research, investigation, study, and monitoring, it is worth noting the European experience and the following comment from the Final Report of the Danish Monitoring Program in 2006 (Gilman 2011):

> …offshore wind power is indeed possible to engineer in an environmentally sustainable manner that does not lead to significant damage to nature.…the prospects for future expansion of offshore wind farms look bright.

Nuclear Fission

In nuclear fission reactors, the nuclei of heavy uranium (atomic symbol U, atomic number 92; atomic mass 235) atoms are split into smaller nuclei after being bombarded by neutrons. The fission process releases free neutrons and photons (in the form of gamma rays), as well as a prodigious amount of thermal energy (heat). Nuclear fission has been used to produce both highly lethal weapons, such as the atomic bombs dropped on Hiroshima and Nagasaki that ended World War II, as well as commercial electrical energy from nuclear power plants. The world's first full-scale nuclear electric power plant devoted exclusively to peacetime uses was the Shippingport Atomic Power Station near Pittsburgh, Pennsylvania, commissioned in 1958. In a 1954 speech to the National Association of Science Writers, prominent nuclear advocate Lewis L. Strauss, a commissioner on the Atomic Energy Commission (AEC), famously predicted that atomic power might someday produce "electrical energy too cheap to meter." This proved unduly optimistic.

Instead, for several decades, the beleaguered nuclear power industry has been mired in a quagmire of economic, political and environment problems that slowed the domestic advance of this once-promising energy form to a crawl. Still, in 2011 nuclear fission supplied 11 percent of the primary energy produced and 8.5 percent of the primary energy consumed in the United States (Table 3-16 and EIA 2012b). Nuclear represents about one-fifth of the nation's power generated by the nation's electric utilities.

The environmental advantages of nuclear power are worth noting: when nuclear fission is underway in thermal power plants, producing heat that boils water which spins turbines and generators, it produces no conventional ("criteria") air pollutants like SO_2, CO, VOCs, and particulates as well as no HAPs like mercury. Neither does it entail the permanent flooding of untamed rivers and productive or scenic valleys and the ruinous effects on salmon runs. Nor does it release CO_2, the main greenhouse gas, into the atmosphere while generating electricity. Moreover, uranium mines do not mutilate the landscape like surface coal mines often do. These are important advantages, frequently touted by nuclear power's supporters to nuclear critics and a skeptical public that all too often tends to see it as an environmental villain.

Against these advantages must be weighed a number of disadvantages. Hundreds of underground uranium mines in the U.S. active from the 1940s to the 1980s affected the health and lives of thousands of miners, many of them Native Americans (especially Navajos) in the Southwest (Boice et al., 2010, Pasternak 2010, USFS 2013). Still other American Indians have protested the desecration of sacred lands in addition to the residual radioactivity in uranium tailings piles left behind after mining and milling (Kolankiewicz 1988, USFS 2013). Altogether, these persistent problems and concerns

are called “legacy issues,” and they have resulted in a deep and widespread residue of mistrusts, even hostility, toward the uranium mining that is needed to furnish the uranium oxide (U_3O_8) ore and processed “yellowcake” that are converted into enriched uranium used in fuel rods in a nuclear reactor.

Uranium supplies are not unlimited. The isotope used in American light-water reactors, U-235, comprises only 0.7% of naturally-occurring uranium. Thus, nuclear fission itself cannot be seen as a sustainable or renewable technology. So-called breeder reactors, which can utilize U-238 (by far the most abundant isotope of uranium) to produce or “breed” plutonium, the atoms of which can later themselves be split to produce energy. The use of breeder reactors would significantly extend the lifetime of uranium reserves. However, the few experimental breeders to date, in the United States and France, have proved highly complex, tricky to operate, and expensive. President Jimmy Carter canceled the only U.S. breeder reactor at a DOE research facility near Savannah, Georgia more than 30 years ago. Breeders also raise significant concerns about the “plutonium economy,” running on one of the deadliest substances known to man (with a half-life of 250,000 years and problematic more for its chemical toxicity than for its radioactive properties), in addition to one that raises global security, terrorism, and nuclear proliferation concerns.

Figure 3-234. Three Mile Island nuclear power plant (with its four cooling towers) on the Susquehanna River downstream of Harrisburg, Pennsylvania

For a number of years, physicists, engineers and policy-makers debated the operational safety of civilian nuclear power reactors. In 1975, the Rasmussen Report, commissioned by the AEC, precursor agency to the Nuclear Regulatory Commission (NRC), and prepared by a team of experts headed by a distinguished MIT professor of nuclear

physics (Dr. Norman Rasmussen), concluded that the probability of a nuclear incident with significant loss of life was vanishingly small (NRC 1975). Then came the serious accidents at Three Mile Island (USA) in 1979 and Chernobyl (Soviet Union) in 1986, and now more recently Fukushima Daiichi (Japan) in 2011, and the book on safety has had to be rewritten. Incident scenarios that had not been accounted for and whose probability had not been quantified actually occurred.

In addition, nuclear energy produces low and high-level radioactive wastes that must be properly disposed of or reprocessed. At present, each nuclear power plant in the U.S. has been storing these wastes in temporary repositories on-site. This is considered a stop-gap measure, and for decades, the federal government has been investigating a centralized permanent underground storage site in a stable, dry geologic formation.

In 1982, Congress passed the Nuclear Waste Policy Act, which directed the Department of Energy to construct and operate a repository for spent nuclear fuel and other high-level radioactive waste (NEI 2015). DOE eventually selected Yucca Mountain, at a remote location on the former Nevada Test Site, 100 miles northwest of Las Vegas, where wastes would be entombed in a permanent geologic repository deep underground. The objective of this $58 billion project was to bury 77,000 tons of highly radioactive nuclear wastes from civilian nuclear reactors, and effectively isolate them from the environment for the next 10,000 years – an unprecedented endeavor (Llanos 2002). Yucca Mountain underwent testing for a number of years, and DOE officials estimated it could be ready to open by 2010. In 2008, after two decades of site studies, the federal government filed a construction license application for the Yucca Mountain repository.

Figure 3-235. Yucca Mountain, Nevada: planned site for a permanent geologic repository or storage site for high-level radioactive waste from commercial nuclear reactors

However, in a case of "NIMBYISM" at a state level, the State of Nevada fiercely opposed being made the nation's nuclear waste disposal site. While the Bush Administration and the U.S. Senate gave the green light to this project, Nevada officials and environmentalists threatened court action. Environmentalists spent years trying to persuade the American public that thousands of shipments of high-level radioactive waste would pass near almost every American's backyard en route to Yucca Mountain.

In 2010, they succeeded, when President Obama stopped the Yucca Mountain license review, in what was widely interpreted as a political favor to then-Senate Majority Leader Harry Reid, a fellow Democrat representing Nevada. Obama established a yet another task force to recommend a new policy for the long-term management of used fuel and high-level radioactive waste. In January 2012, the so-called Blue Ribbon Commission on America's Nuclear Future published its final recommendations, most of which are supported by the nuclear power industry (NEI 2015). In its report to then-U.S. Secretary of Energy Stephen Chu, the Blue Ribbon Commission declared:

> America's nuclear waste management program is at an impasse. The Obama Administration's decision to halt work on a repository at Yucca Mountain in Nevada is but the latest indicator of a policy that has been troubled for decades and has now all but completely broken down (BRC 2012).

The Commission went on to state:

> Continued stalemate is also costly—to utility ratepayers, to communities that have become unwilling hosts of long-term nuclear waste storage facilities, and to U.S. taxpayers who face mounting liabilities, already running into billions of dollars, as a result of the failure by both the executive and legislative branches to meet federal waste management commitments.

DOE's used fuel management strategy to implement this commission's recommendations was released in January 2013 (NEI 2015).

The nexus between peaceful nuclear power and the proliferation of military or terrorist uses of nuclear materials and technology is another concern. With the spread of peaceful nuclear reactors comes the spread not only of materials that can be used to make bombs, but also some of the technical wherewithal for the same (Lovins 1976, 1977). It was this fear that led Israeli warplanes to destroy an ostensibly civilian nuclear power plant under construction in Iraq back in 1981. It is also the concern that has inspired so much international angst about Iran's "civilian" nuclear program in recent years. Although reactor-grade uranium fuel is not sufficient for bombs, by-products of nuclear fission such as plutonium can be diverted into weapons of mass destruction and "dirty bombs".

The September 11, 2001 terrorist attacks on the Pentagon and the World Trade Center renewed concerns that nuclear power plants are inviting targets for sabotage or outright attack by terrorists hostile to the United States (Long 2001, Behr 2001, Grundwald and

Behr 2001, Finn 2001). Nuclear reactors themselves are not the only or even most vulnerable target – even nuclear waste is apparently being sought by terrorists looking to assemble a dirty bomb – that is, a conventional explosive packed with radioactive waste that would be ejected and spread out in the blast. In the wake of the 9-11 attacks, it came to light that the presumed hijackers looked into using crop-dusters to disperse chemical or biological agents and/or obtaining access to hazardous/toxic materials. The shocking audacity of the attacks in New York, Virginia, and Pennsylvania, carried out precisely to wreak the greatest possible carnage, loss of American lives, and destruction of American symbols, leaves no doubt that certain organizations such Al Qaeda or the Islamic State would stop at nothing to damage the U.S. economy and prestige and to take as many American "infidel" lives as possible.

In sum, in the near and medium term, commercial nuclear fission power is characterized both by promise and peril. It is a low-carbon source of electricity. In the long term, however, because it is not renewable and depends on high-grade uranium resources subject to scarcity and depletion, as well as a declining energy return on investment (EROEI), or energy profit ratio, nuclear fission's prospects are dubious at best.

<u>Exotic Nuclear – Hot and Cold Fusion</u>

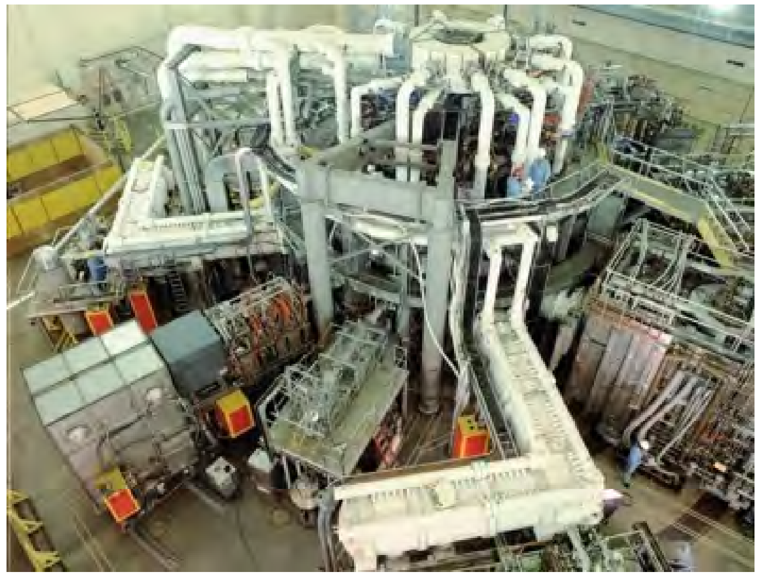
Nuclear fusion is the opposite of nuclear fission. The latter splits an atom of uranium, the largest and heaviest naturally occurring element on Earth. The former fuses or combines atoms of the lightest element – hydrogen (H), to produce the next lightest element, helium (He). Nuclear fusion is occurring at this very moment in our Sun, as it has for billions of years, and every other star as well, emitting colossal amounts of energy according to the famous formula from the special theory of relativity, $E=Mc^2$ (energy is equal to mass times the speed of light squared). Humanity already has a dedicated hot fusion nuclear reactor at its service, and it is located at a safe distance of 93 million miles. Each second, the core of the Sun, at a temperature of 14 million degrees Kelvin, fuses 620 million metric tons of H into He.

Physicists have been studying hot nuclear fusion as a potential source of commercial-scale electricity for more than 60 years. During most of that time, fusion's emergence as a viable energy source has been described as "several decades away." According to the Word Nuclear Association (WNA), "fusion power offers the prospect of an almost inexhaustible source of energy for future generations." However, fusion has presented enormous scientific and engineering challenges that, to date at least, have been insurmountable (WNA 2014).

In theory, heat from the fusion reaction could be utilized to operate a steam turbine that drives electrical generators, the same thermal-electric process that occurs in existing fossil fuel and nuclear fission generating stations. A number of different fusion

concepts have been studied over the years. The current leading designs are the tokamak (Figure 2-237) and inertial confinement fusion (laser) approaches. These technologies are not yet, and may never be, commercially viable. While nuclear fusion has been obtained on small scales and for very brief periods, currently, as for many years, it takes more energy to initiate and contain a fusion reaction, than the energy it produces. In other words, the EROEI or net energy is negative.

Figure 2-236. Tokamak fusion test reactor at the Princeton Plasma Physics Laboratory in Princeton, New Jersey, in 1989



Unlike modern fission reactors, in a nuclear fusion reactor, there would be no possibility of a catastrophic accident involving a substantial release of radioactivity to the environment posing significant threats to human health and safety. Another hypothetical advantage of fusion over fission is that fusion power would produce no high-level radioactive waste (though irradiated plant structural materials would still require disposal). Furthermore, fusion would not lend itself to nuclear proliferation to nearly the same extent that nuclear fission does. Finally, supplies of two of the main raw materials used in fusion, deuterium (an isotope of hydrogen) and the chemical element lithium (Li), are vast (though not inexhaustible). It has been observed, though all too infrequently, that any “inexhaustible” supply of energy, even if it were entirely clean and renewable, which permitted essentially unlimited growth in the human enterprise (size of the population and the economy) on Earth, would over time yield tremendous, significantly adverse indirect and cumulative environmental impacts (Bartlett 1989).

“Cold fusion” is a hypothetical kind of nuclear reaction claimed to occur at, or near, room temperature, in stark contrast to the “hot fusion” that takes place naturally in our Sun and other stars, under extraordinary extremes of temperature (millions of degrees Kelvin) and pressure. At present, there is no accepted theoretical physical/chemical model that would allow cold fusion to occur. In 1989, Martin Fleischmann and Stanley Pons, in a small,

tabletop and self-funded experiment at the University of Utah, reported that their apparatus had produced anomalous quantities of heat, or "excess heat," that defied explanation unless nuclear processes were invoked. At a hastily arranged news conference, they also reported measuring small quantities of nuclear reaction byproducts, principally neutrons and tritium (an isotope of hydrogen with two neutrons in the nucleus) (Fleischmann and Pons 1989).

The Fleischmann and Pons experiment involved electrolysis of heavy water on the surface of a palladium electrode; its claims of a nuclear reaction at room temperature generated a worldwide media firestorm, and raised hopes, if only briefly, of an abundant and cheap source of energy (Voss 1999). According to a CBS *60 Minutes* broadcast, cold fusion promised to be "cheap, limitless, and clean. Cold fusion would end our dependence on the Middle East, and stop those greenhouse gasses blamed for global warming. It would change everything" (CBS 2009).

Back in 1989, numerous scientists at prestigious universities and institutes immediately tried to replicate the Fleischmann-Pons experiment. However, hopes quickly faded due to the large number of negative replications and results, as well as the discovery of errors in the original experiment, and that Fleischmann and Pons had not actually detected nuclear reaction byproducts (Huizenga 1993). As early as late 1989, most physicists considered cold fusion claims utterly debunked, and unfairly or not, cold fusion subsequently gained a reputation as "pathological science," a term coined by Nobel Prize-winning chemist Irving Langmuir in 1953 referring to areas of research that will just not go away, and "the science of things that aren't so" (Park 2000).

In 1989, a review panel organized by DOE found that evidence for the discovery of a new nuclear process was not convincing enough to start a special program, but was "sympathetic toward modest support" for experiments "within the present funding system." A second DOE review, convened in 2004 by the DOE Office of Science to look at new research, reached conclusions similar to the first (DOE 2004). Support within the then-present funding system did not occur.

However, a small, widely dispersed community of researchers continues to investigate cold fusion; researchers now prefer to use the less loaded term "low-energy nuclear reaction" (LENR) rather than the discredited "cold fusion." Experiments have continued in a number of laboratories in several countries, supported by Toyota and other entities including the U.S. Department of Defense, but since LENR papers are rarely published in peer-reviewed mainstream scientific journals, they do not attract the level of scrutiny and interest normally expected of "serious" science. LENR appears to be a real and

intriguing, though a poorly understood, phenomenon. While it certainly warrants further research and an open mind, its potential as a game-changer in the energy field is entirely too speculative at this point.

3.6.2 Environmental Consequences

3.6.2.1 U.S. Population Growth and Energy Consumption

The amount of energy used by the United States in 2050 and 2100 will be a function of the size of the population and the economy, as well as "energy intensity," that is, the amount of energy use per capita and per dollar of GDP. In its "reference case," DOE's Energy Information Administration (EIA) projects that from 2013 to 2040, there will be an average annual reduction in per capita energy use per capita of 0.4%/year and an average annual decline in energy use per 2009 dollar of GDP of 2.0%/year (EIA 2015f) (Figure 2-237). However, because both the population and the economy are projected to grow faster than the rates of decline in their respective energy intensities, there will be an absolute increase in the amount of annual energy consumption over this time period.

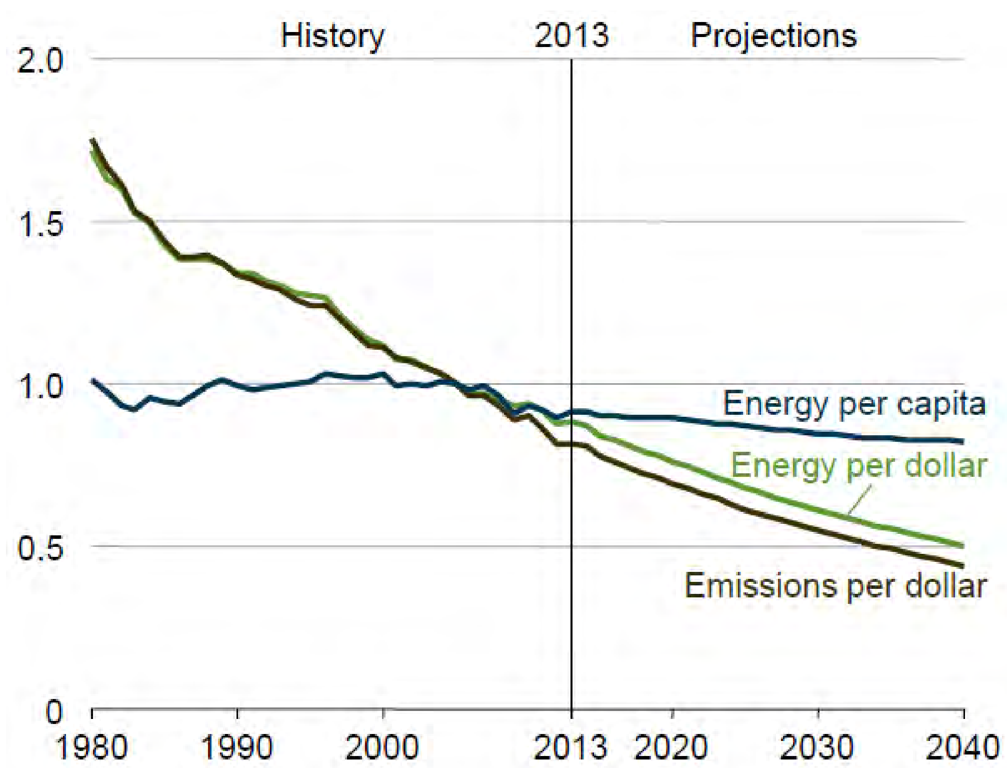


Figure 2-237. Energy intensity per capita, energy intensity per dollar of GDP, and CO_2 emissions per dollar, 1980-2040
Source: EIA, 2015f; note: index 2005 = 1.0)

For the purposes of this EIS analysis, it is assumed that EIA's reference case for decreasing energy intensity per capita continues through 2050 and all the way to the year 2100. This being the case, per capita energy consumption in 2100 would be approximately 70 percent of what it was in 2010. In other words, as a result of continually increasing energy efficiency, structural changes in the economy and changing lifestyles, the average American in 2100 would consume 30 percent less primary energy every year than in 2010, in spite of economic growth, which tends to increase the production and consumption of goods and services that use energy.

It should be emphasized that this assumption, while reasonable, and while well-supported by recent experience (indeed, an extrapolation of it), is conditional. For the last several decades, the energy field has been in a state of great flux. In the 1960's and 1970's, for example, based on then-recent and current trends, reputable and official forecasts by oil companies, electrical utilities, think tanks, and governments of energy production and consumption, especially for end-use electricity, were on the order of seven percent increases per annum, with doubling times in production/consumption of a mere decade or so. By the 1980's, these annual rates of increase had begun to taper off for several reasons. Thus, any forecast, prediction, projection, or extrapolation should be considered provisional at best, but they can still be potential useful intellectual exercises.

For years, energy policy innovator and iconoclast Amory Lovins and his Rocky Mountain Institute (RMI) in Snowmass, Colorado have been conducting analyses and preparing reports arguing that far more aggressive pursuit of energy efficiency and renewables is economically and technically feasible and would yield substantial environmental benefits, including much lower primary energy consumption and drastically reduced dependence on fossil fuels (RMI 2015). If that is indeed the case, then, as with water consumption and greenhouse gas emissions considered earlier in this chapter, a smaller population in conjunction with these innovations would yield even greater environmental dividends than would be possible under a larger population.

It is also important to emphasize that by the year 2100, even assuming business-as-usual optimism, namely that economic and demographic growth as well as technological advances have managed to continue (as they did in the 20th century) relatively uninterrupted for nearly another century – without the systemic stasis, stagnation, or collapse forecast by a number of futurists – that there will be noteworthy changes in the nation's energy supply. The most salient of these is that the fossil fuels – oil, natural gas, and coal – which now dominate the U.S. energy mix, comprising about 80 percent (78 percent of production and 83 percent of consumption) in 2010, will have diminished substantially due to some combination of depletion and substitution by other lower-cost and less carbon-intensive renewable alternatives.

3.6.2.2 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million (70 percent) over the 2010 population of 309 million. At the outset, it should be stressed that environmental consequences related to energy production, consumption, and national security implications under the No Action Alternative would be indirect and cumulative, not direct.

Total U.S. primary energy consumption in 2010 was approximately 98 quads (Table 3-16). If energy intensity (per capita energy use) were the same in 2100, there would be a corresponding 70 percent increase in consumption, with all the attendant impacts associated with both production and consumption of energy, due to projected population growth under the No Action Alternative. Primary energy consumption would be 167 quads. However, due to the assumed reduction in overall national energy intensity (energy consumption per capita) because of ongoing future efficiency improvements, conservation, structural economic changes, and the like, consumption would rise to 117 quads by 2100, an increase of "only" 19 percent. It is highly doubtful whether this level of aggregate national energy consumption is sustainable. While with technical advances and breakthroughs, as well as sustained political and public commitment, the nation could perhaps conceivably meet this level of energy consumption entirely with renewables, this would occur at great cost to land and visual resources, habitat, and wildlife. In addition, components of renewables such as wind, solar, and advanced batteries are made of scarce, non-renewable and exhaustible raw materials (rare earth elements and other rare and costly metals). Their own long-term durability has yet to be persuasively established.

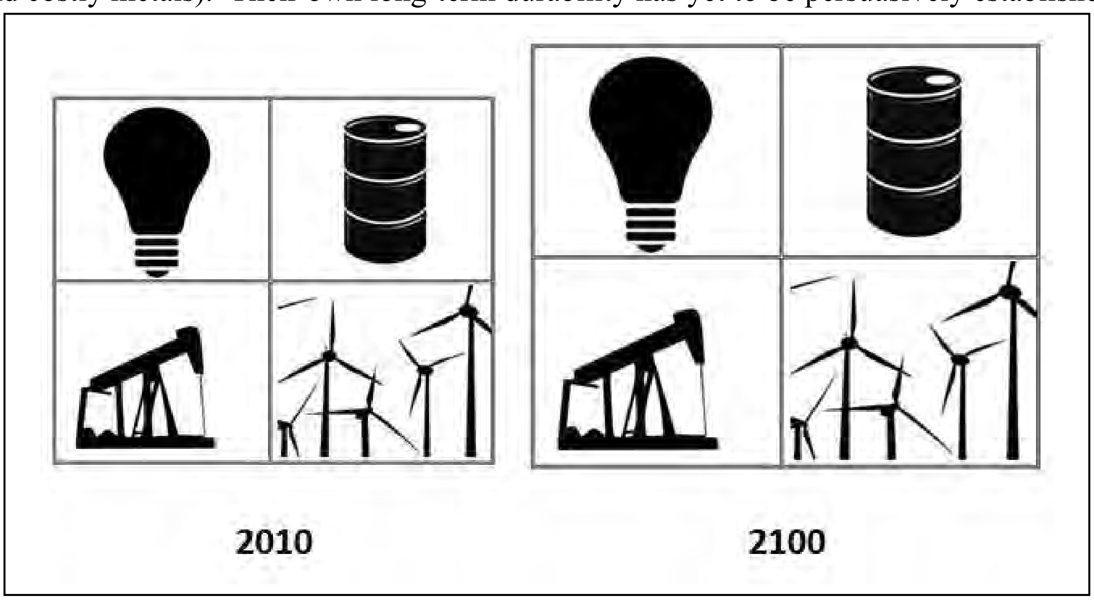


Figure 3-238. Approximate relative scales of U.S. energy consumption in 2010 versus 2100 under the No Action Alternative

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would contribute to indirect and cumulative impacts related to U.S. energy production and consumption as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the effects related to energy production and consumption associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the effects related to energy production and consumption associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the effects related to energy production and consumption associated with the population growth under the No Action Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Possible to Probable.*** – The likelihood of the effects related to energy production and consumption associated with population growth under the No Action Alternative occurring would range somewhere between "some chance of occurring, but probably below 50%" (possible) to "more likely than not to occur, i.e., approximately 50% likelihood or higher" (probable). Likelihood is very hard to predict with regard to population growth's impact on energy production and consumption because the energy field is in such a state of tremendous flux and uncertainty at present, with a complex host of unpredictable and interacting economic, technical, and environmental factors all potentially influencing future production and consumption patterns. All that can be stated with certainty is that a U.S. population of 524 million in 2100, 70 percent larger than the 2010 population of 309 million, would exert much greater pressure on energy resources and the impact on the environment of exploiting those energy resources.

Overall, the net effect of the No Action Alternative on energy would be adverse, significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the No Action Alternative would be entirely responsible for levels of energy production and consumption – and their attendant environmental impacts – in the year 2100.

3.6.2.3 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would result in a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million (117 percent) above the 2010 population of 309 million. The same conditions and caveats apply to this alternative as to the No Action Alternative discussed above.

As stated earlier, total U.S. primary energy consumption in 2010 was approximately 98 quads (Table 3-16). If energy intensity (per capita energy use) were the same in 2100, there would be a corresponding 117 percent increase in aggregate U.S. consumption – more than a doubling – with all the attendant impacts associated with both production and consumption of energy, due to the accelerated population growth anticipated under the Expansion Alternative. Primary energy consumption would be 213 quads. However, due to the assumed 30 percent reduction in overall national energy intensity (energy consumption per capita) due to ongoing and future efficiency improvements, conservation, structural economic changes, and the like, consumption would rise to 149 quads by 2100, an increase of 52 percent over 2010 energy consumption.

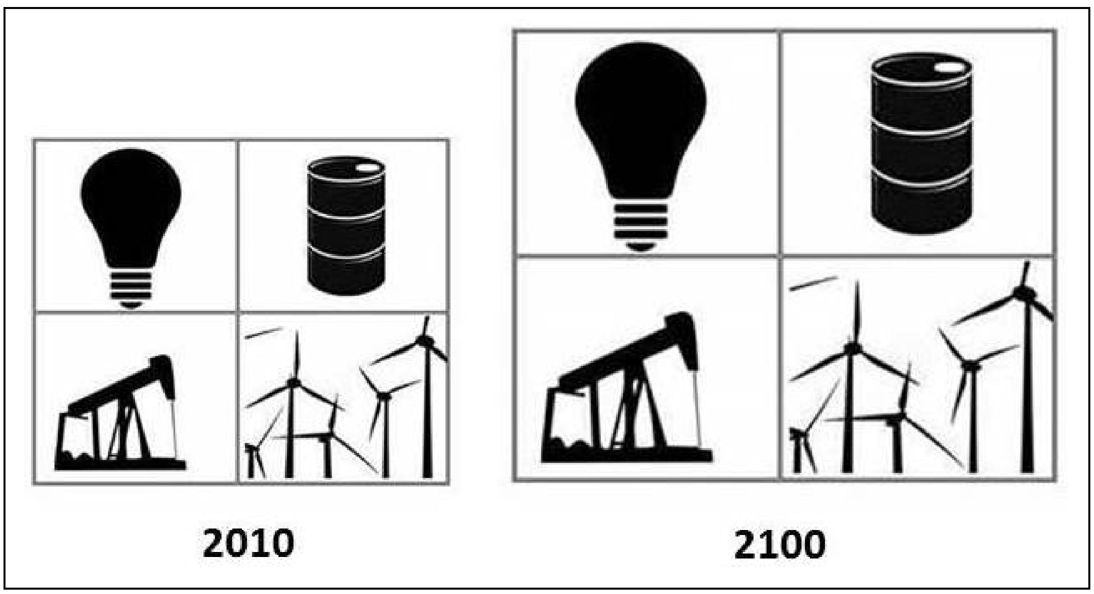


Figure 3-239. Approximate relative scales of U.S. energy consumption in 2010 versus 2100 under the Expansion Alternative

It is highly implausible that this level of aggregate national energy consumption will be attainable or sustainable. For one thing, while 149 quads represent a 52 percent increase in aggregate consumption from 2010, it would require a doubling of domestic energy production (from about 75 quads to 149 quads). By 2100, the oil imports that now cover the deficit between domestic energy production and consumption will have essentially ceased, so that all energy consumed in the United States will have to be produced here.

In 85 years, economic reserves of the non-renewable fossil fuels that now comprise about 80 percent of U.S. energy production and consumption will be largely if not entirely exhausted. Thus, if 149 quads of primary energy are to be produced, it would have to be from some combination of nuclear power, biofuels, and non-hydroelectric renewable energy sources. (There is very little scope for increasing largescale hydroelectric capacity; hydroelectricity generated in 2100 will probably decline as reservoirs gradually lose water storage due to sedimentation.) Nuclear power and biofuels are tightly constrained for different reasons, as discussed earlier in Section 3.6.1. In 2010, non-hydroelectric renewables accounted for about *two quads* (Figure 3-174). To suggest that energy production from solar, wind, and other sources could increase on the order of ***50-75 times*** over the coming 85 years to reach a total of 149 quads strains credulity.

Even more so than in the case of the No Action Alternative, while through the miracle of innovation the U.S. might possibly be able to attain this level of energy production entirely with renewables, this would happen only by converting a large fraction of the American landscape into a colossal electricity generator harnessing clean and renewable wind and photons. That is, much of the countryside would have to be covered with solar panels, wind turbines, and transmission lines. As previously noted, components of wind turbines, solar panels, and advanced batteries are built from scarce, unevenly distributed, non-renewable raw materials subject to depletion such as europium, terbium, neodymium, and lithium. The multi-generational longevity and sustainability of these devices has yet to be demonstrated. Indeed, two geochemists refer to photovoltaic solar as "semi-renewable," because "the energy collected is renewable, but the materials in the technology are not" (Sverdrup and Ragnarsdóttir 2014).

One likely casualty, among many wildlife species, of renewable energy development on this colossal scale is the golden eagle, which was discussed previously. Spinning wind turbine blades and power line electrocutions are even now, at current scale, major sources of mortality for this magnificent raptor. An order of magnitude or more increase in the presence of these artificial structures on the Western landscape would surely have a pronounced harmful effect on the golden eagle population.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would contribute to indirect and cumulative impacts related to U.S. energy production and consumption as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the effects related to energy production and consumption associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the effects related to energy production and consumption associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact: *Major***. The magnitude of the effects related to energy production and consumption associated with the population growth under the Expansion Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact: *Possible to Probable.*** – The likelihood of the effects related to energy production and consumption associated with the accelerated population growth under the Expansion Alternative occurring would range somewhere between "some chance of occurring, but probably below 50%" (possible) to "more likely than not to occur, i.e., approximately 50% likelihood or higher" (probable). Likelihood is very hard to predict with regard to population growth's impact on energy production and consumption because the energy field is in such a state of tremendous flux and uncertainty at present, with a complex host of unpredictable and interacting economic, technical, and environmental factors all potentially influencing future production and consumption patterns. What can be stated with certainty is that a U.S. population of 669 million in 2100, 117 percent higher than the 2010 population of 309 million, would exert enormously greater pressure on energy resources and the impact on the environment of exploiting those energy resources.

Overall, the net effect of the Expansion Alternative on energy would be highly adverse, significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the Expansion Alternative would be entirely responsible for levels of energy production and consumption – and their attendant environmental impacts – in the year 2100. That said, an alternative that more the doubles the number of energy consumers in the United States would exert much greater stress on our energy resources and generate far greater impact on the American environment from the intensified exploitation of those resources that would be necessary to meet the expectations of consumers and the economy.

3.6.2.4 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This

is an increase of 70 million (23 percent) above the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

As stated earlier, total U.S. primary energy consumption in 2010 was approximately 98 quads (Table 3-16). If energy intensity (energy use per capita) were the same in 2100, there would be a corresponding 23 percent increase in aggregate U.S. consumption – more than a doubling – with all the attendant impacts associated with both production and consumption of energy, due to the accelerated population growth anticipated under the Expansion Alternative. Primary energy consumption would be 121 quads. However, due to the assumed 30 percent reduction in overall national energy intensity (energy consumption per capita) because of ongoing and future efficiency improvements, conservation, structural economic changes, and so forth, consumption under the No Action Alternative would actually fall to 85 quads by 2100, a decrease of 13 quads or about 13 percent from 2010 energy consumption.

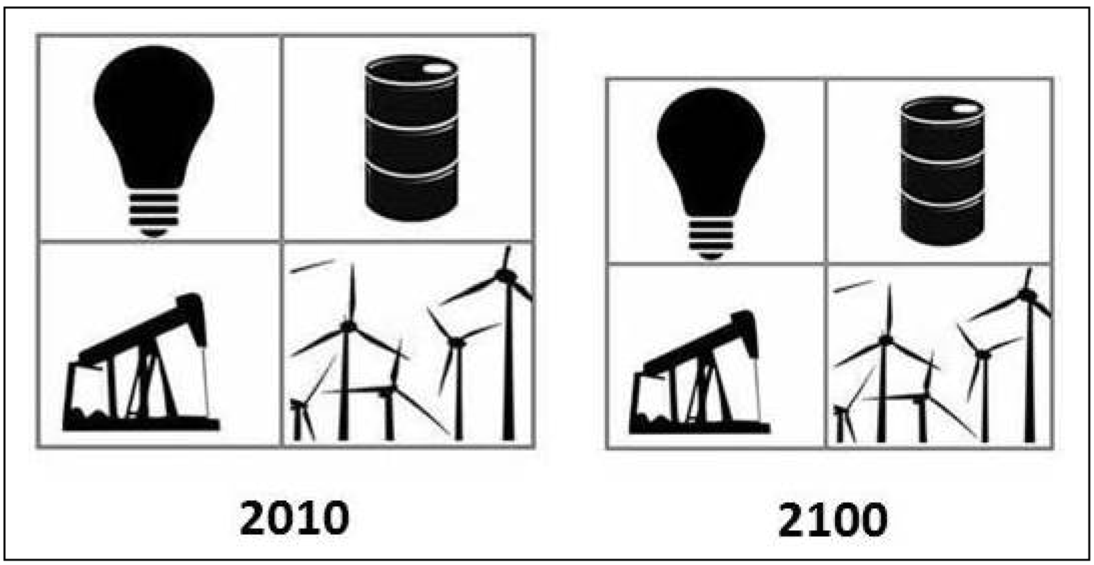


Figure 3-240. Approximate relative scales of U.S. energy consumption in 2010 versus 2100 under the Reduction Alternative

Annual energy consumption of 85 quads in 2100 is a much more favorable and manageable situation – and one with much lower environmental impact – than under the No Action Alternative (117 quads) or the Expansion Alternative (149 quads). However, even this level of energy consumption may not be realistic over the long term when one considers that more than four out of every five quads of our energy consumption today come from fossil fuels, which will have to have been largely replaced by 2100.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would contribute to indirect and cumulative impacts related to U.S. energy production and consumption as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the effects related to energy production and consumption associated with the projected population growth under the Reduction Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the effects related to energy production and consumption associated with the projected population growth under the Reduction Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Moderate***. The magnitude of the effects related to energy production and consumption associated with the population growth under the Reduction Alternative would be Moderate, representing a "noticeable change in a resource occurs, but the integrity of the resource remains intact."

- **Likelihood of Impact:** ***Possible to Probable.*** – The likelihood of the effects related to energy production and consumption associated with the accelerated population growth under the Reduction Alternative occurring would range somewhere between "some chance of occurring, but probably below 50%" (possible) to "more likely than not to occur, i.e., approximately 50% likelihood or higher" (probable). Likelihood is very hard to predict with regard to population growth's impact on energy production and consumption because the energy field is in such a state of tremendous flux and uncertainty at present, with a complex host of unpredictable and interacting economic, technical, and environmental factors all potentially influencing future production and consumption patterns.

  What can be stated with certainty is that a U.S. population of 379 million in 2100, 23 percent higher than the 2010 population of 309 million, would exert proportionately greater demands on energy resources than the 2010 population but much less than the demands and stresses exerted by the higher populations that would result from the No Action and Expansion Alternatives. While these demands may be offset, or even more than offset, by projected continuing improvements (reductions) in per capita energy intensity, the net adverse effects would be much lower still were 70 million additional people not added to the U.S. population in the first place.

Overall, the net effect of the Reduction Alternative on energy would be adverse, moderately significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the Reduction Alternative would be entirely responsible for levels of energy production and consumption – and their attendant environmental impacts – in the year 2100. Of the three alternatives considered, this one would entail by far the fewest adverse impacts related to energy resources and their development. It would also have the most favorable implications for national and energy security, reducing demand for and dependence on foreign oil in the coming decades, although by the year 2100, there will be little or no foreign oil left to import at affordable prices.

Figure 3-241. Environmental effects of energy development will be much less under the Reduction Alternative than the No Action or Expansion Alternatives

3.7 International Ecological Impacts of U.S. Immigration Policies

3.7.1 Affected Environment

As described in Section 1.8.6, U.S. consumption and population growth impact the natural resources and environment not just of U.S. territory itself but of the lands, natural resources, environments and (often indigenous or tribal) residents of other countries and continents. Many of the raw materials, resources, and manufactured products used directly or indirectly by American consumers originate overseas and are imported into the U.S. as part of international trade.

For example, the United States imports large quantities of raw materials such as wood products, metals and minerals, and energy (e.g., natural gas, oil, hydroelectricity) from our more thinly-populated northern neighbor Canada, which has about one-tenth the U.S. population in an area roughly equal in size. Imports of lumber and wood products like pulp, paper, newsprint, and packaging encourage logging operations and the destruction of old-growth forest and loss of wilderness and wildlife in British Columbia and elsewhere (Kolankiewicz 1981).

Figure 3-242. Mountainside scalped in coastal British Columbia, Canada

Likewise, enlarging the U.S. market for "renewable" Canadian hydroelectricity serve to induce the construction of dams and reservoirs that flood vast areas of forest, wildlife habitat, fisheries, and indigenous homelands in Canadian provinces like Quebec and Manitoba (DOE 2014b, 2015b).

Figure 3-243. Part of the James Bay Project in the northern part of the Canadian province of Quebec, this spillway at the 5,616 MW Robert-Bourassa generating station can accommodate twice the flow volume of the Saint Lawrence River.

The mirror image or flip side of these adverse environmental impacts are the beneficial impacts these U.S. imports (Canadian exports) generate for the Canadian economy. Exports accounted for more than one-quarter (28 percent) of Canada's GDP in 2014 (Anon. 2015b). This gets at the heart of a long-running schism between ecologists and economists: the former focus on the negative environmental impacts of increased international trade while the latter focus on the positive economic benefits to the economies of both the exporting and importing nations. Ecologists tend to be critical of increased "free trade" while economists are highly supportive of it as a manifestation of "comparative advantage" theory, developed by pioneering British economist David Ricardo in the early 1800s.

Another example of a major U.S. natural resource import is crude oil: the United States is the largest importer of crude oil in the world. In the late 2000s imports averaged over 400 million barrels every month (EIA 2013d). By 2013 this had dropped to about 300 million barrels/month from reduced domestic demand due to the recession and improved fuel efficiency, as well as a result of increased crude oil production domestically from hydraulic fracking and horizontal drilling. Transporting crude oil via enormous oil tankers poses well-known, well-documented environmental impacts and risks.

Figure 3-244. Oil tankers are the largest oceangoing ships on Earth, exceeding even bulk container ships and aircraft carriers in length, reaching 1,500 feet (five football fields) and a draft of 80 feet or more.

The United States also imports many other raw materials as well as processed and manufactured goods that originate in other countries. For about a decade until 2013, when Molycorps's mine reopened in California, the U.S. was importing nearly all 17 rare earth metals, critical to a variety of new and renewable energy technologies, especially wind and solar, as well as in electronics and national security applications (Humphries 2013; Steadman 2012). Extracting and refining these ores can be a very polluting process unless carried out with stringent environmental controls and state-of-the-art pollution control technology and methods. Many communities in China now confront toxic legacies of substantial environmental contamination left behind by two decades of almost unregulated mining and processing of rare earth ores. The Chinese government has begun spending the billions of dollars it will cost to remediate this contamination (Bradsher 2013).

Table 3-19 shows U.S. import dependency on a number of non-renewable resources (NNRs) for which we import at least 40 percent of our annual domestic consumption.

Nearly all of the bauxite ore consumed in the U.S. to make aluminum is imported (Kelly 2002), 11 million tons of it in 2012; 90 percent of these imports come Jamaica, Guinea, Brazil and Guyana (USGS 2013).

Table 3-19. U.S. import dependency on select nonrenewable natural resources (NNRs) and metals

U.S. import %	NNRs imported by the U.S.
41%-60%	Chromium, Lithium, Magnesium Compounds, Nickel, Oil (All Liquids), Silver, Tungsten
61%-80%	Abrasives, Barite, Cobalt, Garnet, Peat, Stone (Dimension), Tin, Titanium Mineral Concentrates, Titanium Metal, Zinc
81%-99%	Antimony, Bismuth, Gallium, Germanium, Iodine, Platinum Group Metals (PGMs), Potash, Rare Earth Minerals (REMs), Rhenium, Uranium, Vanadium
100%	Arsenic, Asbestos, Bauxite, Cesium, Fluorspar, Graphite, Indium, Manganese, Mica, Niobium, Quartz Crystal, Rubidium, Strontium, Tantalum, Thallium, Thorium

Source: Clugston 2015

Figure 3-245. Rare earth mineral mine in China

While these raw materials and commodities help meet U.S. demand and provide jobs, income, and tax revenue to exporting nations, many of which are developing countries with high unemployment, there are associated environmental impacts and these must be accounted for. American industry and consumers are "outsourcing" the pollution, GHG emissions, environmental damage, and human health effects associated with an enormous amount of drilling, digging, blasting, mining, manufacture, and harvesting – often under primitive conditions with little environmental oversight – that provides goods and services for our domestic consumption (EarthTalk 2009, IPCC 2014, Shiva 2012). More Americans will raise demand for imports and trigger more associated impacts in those countries that export to us.

Figure 3-246. Massive container ships stacked high with containers ply the world's oceans and have become powerful symbols of the explosion of international trade and commerce in recent decades.

Similarly, U.S. consumption itself, primarily of the fossil fuels, releases large amounts of carbon dioxide that are contributing to climate change and concomitant widespread ecological effects around the biosphere. Many of these effects are being experienced most acutely in the developing world and by poorer, marginalized populations (IPCC 2014).

Overall, an ever larger number of American consumers will generate ever larger international ecological effects from both production and consumption, although these

effects need not be proportional if Americans can continue to improve resource and energy efficiency and intensity, as is assumed elsewhere in this EIS. One means of measuring the overall ecological impacts of a given population of consumers that has gained widespread acceptance and application over the last two decades is the Ecological Footprint (EF), which was described in the section of this chapter on biological diversity (Section 3.3.1).

To reiterate briefly, EF is a measure of the load that aggregate human demands impose on the biosphere, or "ecosphere." EF accounting compares the demands of the human economy, or subsets of it, with the Earth's (or a given country's) ecological capacity for regeneration and renewal, that is, its "biocapacity." EF represents the amount of biologically productive land and water area needed to regenerate the renewable resources a given human population consumes and to absorb and render harmless, or assimilate, the corresponding waste or residuals it generates. The global EF now exceeds global biocapacity by some 50 percent (GFN 2011), which is not a sustainable situation over the long run; it means the United States is drawing down "natural capital" and running up an "ecological debt" (Kolankiewicz 2010).

Immigration is increasing the U.S. population size and thus raising our national EF, forcing the United States deeper into ecological debt. If global per capita consumption of resources equaled American per capita consumption, humanity would need 4.05 earths to provide adequate biocapacity; in other words, the aggregate ecological footprint would be 4.05 earths (GFN 2012). Some share of the "global hectares" U.S. consumers use comes from outside the United States; that is, part of our ecological footprint is being imposed on non-U.S. parts of the ecosphere.

Figure 3-247. The problem of "digital dumping grounds" or e-waste disposal in developing countries has come to light in recent years.

Importing Resources/Exporting Waste
In sum, as a wealthy developed nation, the United States has comparatively high levels of natural resource consumption (e.g., energy; raw and processed materials such as forest products, metals, and other minerals; water; agricultural products) and waste generation (e.g., GHG emissions; residuals, solid waste, or pollutants discharged into the air, water, and land). U.S. population growth over the coming decades will be determined largely by immigration levels. According to demographers at the Pew Research Center, 88 percent of projected U.S. growth over the next half century (to 2065) will be from immigration (Jordan 2015).

Just to maintain its standard of living, this larger population size, in turn, will tend to have a greater “throughput” from “source” to “sink” (in the jargon of ecological economics). That is, it will consume more resources and generate more waste, although these increases can be offset to some extent by conservation, efficiency, reuse and recycling. Furthermore, the U.S. is philosophically committed to “free trade,” and fully engaged in international trade and commerce, with substantial volumes of exports and imports annually. An undetermined and unquantifiable – but nontrivial – portion of the ecological effects associated with these patterns of resource consumption and waste generation will occur not in the United States, but in other countries, in other continents and other parts of the biosphere.

3.7.2 Environmental Consequences

3.7.2.1 No Action Alternative – 1.25 million annual immigration

Under the No Action Alternative, 1.25 million annual immigration into the United States would lead to a U.S. population of 524 million in 2100 (Figure 2-2). This is an increase of 215 million (70 percent) over the 2010 population of 309 million. At the outset, it should be stressed that international ecological impacts under the No Action Alternative would be indirect and cumulative, not direct.

Under this alternative, *ceteris paribus* (if resource consumption and waste generation per capita were to remain constant), the potential for international ecological impacts from aggregate U.S. consumption in 2100 would be up to 70 percent greater than in 2010. The U.S. economy would likely import more raw materials, food, and manufactured goods, the production of which would entail substantial adverse environmental effects in the countries of origin. These range from the impacts of mining and forestry activities on the landscape, wildlife habitat, water quality, human health and the wellbeing of indigenous peoples (where traditional tribal lands are exploited for their resources without express consent of their longtime inhabitants) to the impacts on air quality and human health from pollutants emitted by factories producing goods for export to the United States.

There would likely be a comparable increase in U.S. carbon dioxide and other GHG emissions, as well as upward pressure on our ecological footprint, both of which have international or global ramifications.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the No Action Alternative would contribute to indirect and cumulative international ecological impacts as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the international ecological effects associated with the projected population growth under the No Action Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the international ecological effects associated with the projected population growth under the No Action Alternative "would affect a resource on a regional, national, or global scale." Effects on the climate from U.S. GHG emissions would be widespread, indeed global.

- **Magnitude of Impact:** ***Major***. The magnitude of the international ecological effects related to population growth under the No Action Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Possible to Probable.*** – The likelihood of the effects related to energy production and consumption associated with population growth under the No Action Alternative occurring would "probable," that is, "more likely than not to occur, i.e., approximately 50% likelihood or higher" (probable).

Overall, the international ecological effects of the No Action Alternative would be adverse, significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the No Action Alternative would account for all of the international environmental impacts of the United States in the year 2100.

3.7.2.2 Expansion Alternative – 2.25 million annual immigration

Under the Expansion Alternative, 2.25 million annual immigration into the United States would result in a U.S. population of 669 million in 2100 (Figure 2-2). This is an increase of 360 million (117 percent) above the 2010 population of 309 million. The same conditions and caveats apply to this alternative as to the No Action Alternative discussed above.

Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be more than twice (approximately 117 percent) as great as in 2010. Under a much larger population, all of the effects mentioned in Section 3.7.1 (Affected Environment) and under the No Action Alternative would be magnified even further in order to just maintain U.S. consumption and living standards, to say nothing of increasing them. While as noted above, there would likely be positive economic effects in exporting countries from supplying much larger U.S. imports, there would be correspondingly larger environmental impacts as well.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Expansion Alternative would contribute to indirect and cumulative international ecological impacts as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the international ecological effects associated with the projected population growth under the Expansion Alternative would range from "would likely last for a decade or more" to "indefinite or everlasting and for all intents irreversible."

- **Extent of Impact**: ***Large***. The extent of the international ecological effects associated with the projected population growth under the Expansion Alternative "would affect a resource on a regional, national, or global scale."

- **Magnitude of Impact:** ***Major***. The magnitude of the international ecological effects associated with the population growth under the Expansion Alternative would be Major, representing a "substantial impact or change in a resource area that is easily defined, noticeable, and measurable, or exceeds a standard."

- **Likelihood of Impact:** ***Possible to Probable.*** – The likelihood of the international ecological effects associated with the accelerated population growth under the Expansion Alternative occurring would be "probable," that is, "more likely than not to occur, i.e., approximately 50% likelihood or higher" (probable). There is little or no doubt that a U.S. population that has more than doubled in size will vastly increase the indirect and cumulative environmental effects it exerts beyond our borders.

Overall, the international ecological effects of the Expansion Alternative would be highly adverse, significant, and long-term. To reiterate and underscore, neither the immigration rates nor the concomitant U.S. population growth associated with the Expansion Alternative would be entirely responsible for international ecological impacts of the United States in the year 2100. That said, an alternative that more than doubles the number of resource consumers and waste emitters in the United States would exert much

greater stresses and generate far greater widespread impacts that extend well beyond U.S. borders into the rest of the biosphere.

3.7.2.3 Reduction Alternative – 250,000 (0.25 million) annual immigration

Under the Reduction Alternative, 250,000 (0.25 million) annual immigration into the United States would lead to a U.S. population of 379 million in 2100 (Figure 2-2). This is an increase of 70 million (23 percent) above the 2010 population of 309 million. It is 145 million less than the 524 million projection for 2100 of the No Action Alternative, and 290 million less than the 669 million projection of the Expansion Alternative.

Under this alternative, international ecological impacts of aggregate U.S. consumption in 2100 would be about a quarter (approximately 23 percent) larger than in 2010. Nonetheless, these effects would be substantially smaller than for the No Action Alternative and the Expansion Alternative.

Rating these impacts according to the criteria and definitions in Section 3.1.1, the Reduction Alternative would contribute to indirect and cumulative impacts related to U.S. energy production and consumption as follows:

- **Duration of Impact***:* ***Long-term to permanent***. The duration of the international ecological effects associated with the projected population growth under the Reduction Alternative would range from “would likely last for a decade or more” to “indefinite or everlasting and for all intents irreversible.”

- **Extent of Impact**: ***Large***. The extent of the international ecological effects associated with the projected population growth under the Reduction Alternative “would affect a resource on a regional, national, or global scale.”

- **Magnitude of Impact:** ***Moderate***. The magnitude of the international ecological effects associated with the population growth under the Reduction Alternative would be Moderate, representing a “noticeable change in a resource occurs, but the integrity of the resource remains intact.”

- **Likelihood of Impact:** ***Probable.*** – The likelihood of the international ecological effects associated with the accelerated population growth under the Reduction Alternative would be Probable, that is, “more likely than not to occur, i.e., approximately 50% likelihood or higher” (probable).

Overall, the international ecological effects of the Reduction Alternative would be adverse, moderately significant, and long-term. To reiterate and underscore, neither

the immigration rates nor the concomitant U.S. population growth associated with the Reduction Alternative would be entirely responsible for international ecological impacts emanating from the United States in the year 2100. Of the three alternatives considered, this one would entail by far the lowest level of adverse international ecological impacts. Figure 3-248 is a schematic that graphically compares the approximate relative magnitudes of these impacts.

2010

No Action Alternative (1.25 million annual immigration; population 524 million in 2100)

Expansion Alternative (2.25 million annual immigration; population 669 million in 2100)

Reduction Alternative (0.25 million annual immigration; population 379 million in 2100)

Figure 3-248. Schematic comparing approximate relative magnitude of international ecological impacts of aggregate U.S. consumption in 2010 with magnitudes of the three EIS alternatives – No Action, Expansion, and Reduction – in 2100

Chapter 4
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Appendix A
ACRONYMS AND ABBREVIATIONS

AAAS	American Association for the Advancement of Science
ACF	Australian Conservation Foundation
AEC	Atomic Energy Commission
AF	Acre-foot
AGL	Argonne National Laboratory (U.S. Department of Energy)
AGW	Anthropogenic Global Warming
ALA	American Lung Association
AMD	Acid Mine Drainage
AP	Associated Press
As	Arsenic
AWEA	American Wind Energy Association
BLM	Bureau of Land Management, U.S. Department of the Interior
BOEM	Bureau of Ocean Energy Management (formerly the Minerals Management Service, or MMS), U.S. Department of the Interior
BPA	Bonneville Power Administration
BTEX	Benzene, Toluene, Ethylbenzene and Xylene
Ca	Calcium
CBD	Center for Biological Diversity
CEQ	Council on Environmental Quality, Office of the White House
CFCs	Chlorofluorocarbons
CFR	Code of Federal Regulations
Cfs	Cubic feet per second (unit of water flow volume)
CH_4	Methane
CIS	Center for Immigration Studies
Cl-	Chloride
Cr	Chromium
CO_2	Carbon dioxide
DD	Decision Demographics
DDT	Dichlorodiphenyltrichloroethane
DEIS	Draft Environmental Impact Statement
DO	Dissolved oxygen
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EA	Environmental Assessment
EF	Ecological Footprint

EIA	Energy Information Administration (in the U.S. Department of Energy)
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
ERF	Effective radiative forcing
EROEI	Energy Return On Energy Investment or Invested (net energy)
FAO	Food and Agricultural Organization (of the United Nations)
Fe	Iron
FEIS	Final Environmental Impact Statement
FERC	U.S. Federal Energy Regulatory Commission
FES_2	Iron pyrite or fool's gold
FHWA	Federal Highway Administration, U.S. Department of Transportation
FONSI	Finding of No Significant Impact
GAO	U.S. Government Accountability Office
GDP	Gross Domestic Product
GFN	Global Footprint Network
GHG	Greenhouse gas
H	Hydrogen atom
H_2	Hydrogen molecule
H_2O	Water
H_2SO_4	Sulfuric acid
HAP	Hazardous air pollutant
HCO_3-	Bicarbonate
HIPPO	Habitat destruction, invasive species, pollution, population, overharvesting
He	Helium
IPAT	Impact (I) = Population (P) x Affluence (A) x Technology (T)
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for the Conservation of Nature and Natural Resources
K	Phosphorus
Li	Lithium
LENR	low-energy nuclear reaction
LWR	Longwave radiation
pH	measure of hydrogen ions in solution, or acidity
PRB	Population Reference Bureau
PSA	Public Service Announcement
MDEQ	Montana Department of Environmental Quality
Mgal/d	Million gallons per day (unit of water flow volume)
MIT	Massachusetts Institute of Technology
MW	Megawatt
N	Nitrogen
N_2O	Nitrous oxide

Na	Sodium
NAS	National Academy of Sciences
NASA	National Aeronautic and Space Administration
NCAR	National Center for Atmospheric Research
NGA	National Groundwater Association
NGPL	Natural gas plant liquid
NIEHS	National Institute of Environmental Health Sciences
NNR	Nonrenewable natural resource
NPS	National Park Service
NEPA	National Environmental Protection Act
NGO	Non-Governmental Organization
NOA	Notice of Availability
NOAA	National Oceanic and Atmospheric Administration
NOI	Notice of Intent
NO_x	Nitrous Oxides
NRC	National Research Council
NRC	Nuclear Regulatory Commission
NRCS	Natural Resources Conservation Service
NRI	National Resources Inventory
NTMWD	North Texas Municipal Water District
NWF	National Wildlife Federation
O_3	Ozone
PBI	Pacific Biodiversity Institute
PCB	Polychlorinated biphenyl
PM	Particulate Matter
PM_{10}	Particulate Matter smaller than 10 microns in diameter
$PM_{2.5}$	Particulate Matter smaller than 10 microns in diameter
RCP	Representative Concentration Pathway
RF	Radiative Forcing
RMI	Rocky Mountain Institute
ROD	Record of Decision
RUS	Rural Utilities Service, U.S. Department of Agriculture
SCS	Soil Conservation Service
Se	Selenium
SO_2	Sulfur dioxide
SST	Sea surface temperature
SUV	Sport Utility Vehicle
Tcf	Trillion cubic feet (unit of measure of natural gas volume)
TFR	Total Fertility Rate
UA	Urbanized Area

UC	Urban Cluster
UCS	Union of Concerned Scientists
U.N.	United Nations
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
U.S.	United States
US	United States
USA	United States of America
USACE	U.S. Army Corps of Engineers
USCB	U.S. Census Bureau
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UV	Ultraviolet
VOC	Volatile Organic Compound
WCD	World Commission on Dams
WHO	World Health Organization
WIP	Water Information Program
WNA	World Nuclear Association
WRI	World Resources Institute
WWF	World Wildlife Fund or Worldwide Fund for Nature
ZPG	Zero Population Growth, or the NGO formerly named Zero Population Growth, Inc. (now Population Connection)

Appendix B
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