Energy Efficiency: A Tool for Climate Change Adaptation

An Alliance to Save Energy White Paper

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ALLIANCE TO SAVE ENERGY

Using less. Doing more.

Abstract

Climate change is already making the United States hotter, and much greater temperature increases are expected in the coming decades. Along with increasing temperatures, precipitation patterns are shifting, extreme weather events such as storms and droughts are increasing, and sea levels are rising. These changes in weather patterns affect both energy demand, especially with increased peak electricity use for air conditioning, and energy supply, with reduced reliability and efficiency. They also have closely related effects on water demand and supply.

Energy efficiency is one of the most important tools for avoiding climate change by reducing use of fossil fuels. However, energy efficiency and related demand management measures also can address some of the energy sector's vulnerabilities to climate change impacts:

- Deploying energy efficient technologies in end-use facilities and in power generation, transmission and distribution can help counteract the increased demand on and decreased output of power plants due to higher temperatures;

- Demand response programs and efficiency programs aimed at peak loads can help counteract the increase in peak demand due to increased use of air conditioning and address the uncertainties in generation and consumption due to extreme weather, and thus help avoid the need for additional power plants;

- Builders can "future proof" buildings against predicted changes in weather patterns by ensuring long-lived characteristics such as orientation, insulation, and windows are appropriate for expected climate conditions;

- Cities can reduce ambient temperatures, and make buildings more efficient, with cool or green roofs;

- Constructing distributed generation, especially efficient combined heat and power (CHP) plants, can provide secure electricity for large energy consumers or microgrids that is less subject to grid outages due to extreme weather; and

- Water efficiency programs can address climate impacts on water resources and reduce energy use for pumping and treating water.

Contents

Introduction 1

From Mitigation to Adaptation 1

Impacts of Climate Change: A Broad View 2
- Warming Trends 2
- Changes in Precipitation Patterns 3
- Extreme Weather 3
- Climate Risk to the Energy Sector 3

Impacts on Energy Demand 4
- More Space Cooling, Less Heating 4
- More Electricity, More and Less Natural Gas Consumption 4
- More Energy Use for Water Resources 5

Impacts on Energy Supply 5
- Infrastructure Vulnerabilities 6
- Water Availability for Electricity Generation 7
- Efficiency of Thermal Power Generation 7
- Climate Change Impacts on Renewable Sources 7

Adapting to Energy Impacts 8
- Demand Response 8
- "Future Proofing" Buildings 10
- Cool and Green Roofs 11
- Distributed Generation/Combined Heat & Power 11
- Water-Energy Efficiency Programs 12
- Other Energy Efficiency Policies and Programs 12

Conclusion 13

Endnotes 14

About the Alliance to Save Energy 18

Acknowledgements 18

Introduction

Studies released in 2011 by both the National Research Council (National Academies) and the U.S. Global Climate Research Program (USGCRP) reinforce what climate scientists have been asserting for decades: that global temperatures are rising steadily, about 1.4˚F (0.8˚C) over the last 100 years overall, about 1˚F (0.6˚C) of which occurred during the last 30 years, observed particularly in the lower atmosphere and upper ocean.[1,2] The earth is getting warmer. These temperature increases vary by region and season. They also are contributing to more extreme weather events and rising sea levels.

As these climactic changes appear to be in large part the result of human (anthropogenic) greenhouse gas (GHG) emissions, especially carbon dioxide (CO_2) from burning fossil fuels, they are almost certain to get much worse in the coming decades. Warmer global temperatures and their impacts on weather patterns will require extensive planning and mobilization of energy resources in order to minimize property and environmental damage and loss of life, and ensure both continuity of services and our ability to respond swiftly to new, unexpected weather-related threats.

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While energy efficiency has frequently been referred to and used as a tool for carbon mitigation (i.e., reducing greenhouse gas emissions from energy production and consumption in order to avoid climate change), it also can serve an important role in climate adaptation: it can help address increased energy demand and constrained supply due to regional weather shifts and greater temperature volatility, such as increased building cooling needs and lowered efficiency of thermal generating plants.

Just as energy efficiency typically can meet general energy needs at a lower cost than building additional supply capacity, energy efficiency, and by extension energy conservation and demand response programs, can provide climate adaptation value[3] at low cost. As electricity demand increases and supply becomes less reliable due to climate change, energy efficiency savings and demand response ability will become more valuable to consumers and grid operators, while helping with climate mitigation as well.

From Mitigation to Adaptation

Climate policy has largely focused on greenhouse gas mitigation efforts, i.e., efforts to reduce GHG emissions to a point sufficient to keep the rise in global temperature from surpassing 3.6˚F (2˚C) by 2100,[4] and thereby forestall future severe climate changes beyond those already observed (i.e., extreme weather events, changes in precipitation patterns and greater temperature volatility). As burning fossil fuels is the principal driver of anthropogenic GHG emissions and climate change – energy-related CO_2 emissions constitute roughly 83% of total U.S. GHG emissions[5] – mitigation efforts have focused mostly on energy production and consumption. Attempts to mitigate worldwide greenhouse gas emissions continue with varying levels of success, through diverse efforts including federal/state regulation of greenhouse gases, international agreements on GHG emission limits like the Kyoto Protocol and Copenhagen Accord, voluntary goal and recognition programs, carbon trading markets, efficiency and renewables standards and incentives, reforestation efforts to create carbon sinks, and public and private sector sustainability programs.

However, significant political opposition in the United States and elsewhere to policy measures explicitly focused on mitigation has significantly hampered mitigation efforts, as nations and corporations alike struggle to spur growth at low cost. With disaster-level weather events growing more frequent and sea level continuing to rise, this lack of significant momentum in mitigation efforts has caused both private-and public sector institutions worldwide to believe that major climate change is inevitable, and begin planning for climate adaptation in conjunction with existing GHG mitigation programs.

The purpose of this paper is to look briefly at the current and expected impacts of climate change on energy production and use, and discuss ways in which energy efficiency and related efforts can aid governments and companies in adapting to the impacts of climate change. Admittedly, energy efficiency's climate change mitigation effects are more direct, as reducing energy use reduces associated carbon emissions. However, energy efficiency also offers diverse adaptation effects:

- reducing the need for additional generation capacity due to increased peak electricity needs for air conditioning,
- insulating consumers from higher energy costs associated with shifting climate zones or extreme weather;
- making the national grid more resilient to extreme weather impacts on the electric power sector; and
- reducing energy supply needs for dwindling regional water resources.

Impacts of Climate Change: A Broad View

According to climate data gathered by the National Aeronautical and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA) and other U.S. governmental agencies, and by the Intergovernmental Panel on Climate Change (IPCC), the average temperature of the Earth's surface has risen 1.4˚F (0.8˚C) over the last 100 years[6] with sharper warming trends in the United States, where average air temperature has risen by more than 2˚F (1˚C) during the last 50 years.[7] This overall rise in temperature has contributed to changes in larger climactic cycles across the planet, resulting in shifts in precipitation patterns and greater temperature volatility, which in turn cause increased frequency and duration of extreme weather events such as storms, floods, uncharacteristic snowfall and droughts, often in areas that have not experienced them previously and are consequently ill-prepared for them. While we are already experiencing the first of these climate change impacts, all are forecast to become much stronger.

> Weather shifts resulting from climate change pose serious risks to the energy sector, including:
> - Warmer temperatures both decreasing generating efficiency and driving higher peak demand;
> - Extreme warm/cold causing plant shutdowns when customers most need power;
> - Changes in precipitation leading to either too little water or too much; and
> - Rising sea levels and greater frequency of storms threatening coastal facilities.

Warming Trends

Globally, 2010 was one of the two warmest years on record,[8] and 2000-2009 comprised the warmest decade on record, as were the 1990s before it and the 1980s before that.[9] The historical record over the last century shows a trend of continual warming. The USGCRP projects average warming in the United States of between 4 and 11˚F (2 – 6˚C) by the end of the century, a greater increase than is projected in most other countries. [10]

However, regional impacts may be more severe. For example, areas of the South currently experiencing 60 or more days per year over 90˚F – those resulting in peak demand for electricity – are predicted to experience 150 or more days above 90˚F by the end of the century.[11]

Prolonged exposure to very hot weather exacerbates many chronic health conditions, including respiratory and cardiovascular illnesses. In the United States, heat-related deaths (which may be undercounted in official statistics[12]) and deaths from storms usually outnumber deaths from cold, and would be expected to increase with a significant rise in surface temperature.[13] With warmer winters and heavier rain, diseases from insects, water and food are likely to increase in the United States.[14]

Changes in Precipitation Patterns

Precipitation in the contiguous United States has increased by about 6% over the last century[15], with the amount of rain falling in the heaviest downpours increasing by 20% during that period, even as serious droughts have affected the southern half of the country,[16] most recently in Texas and Oklahoma.[17] In northern regions lakes are freezing later and melting earlier, as is snowpack, and due to warmer conditions, more precipitation is falling as rain rather than snow.[18] These shifts are resulting in less recharging of water resources and are changing the timing of river runoff, leaving areas with either too little or too much water to manage.

These shifts in snowfall and rainfall have led to and will continue to drive significant water shortages in the Southwest and Southeast, where drinking water, wastewater and energy supply (e.g., mining, hydraulic fracturing, cooling towers) interests find themselves in intense competition for the same resources.[19] Conversely, other parts of the country have experienced unusually high levels of rainfall and resultant flooding, where local infrastructure is not equipped to accommodate higher-than-expected levels of stormwater.

While the country as a whole will see more precipitation as climate change continues, portions of the country will face increased incidences of drought, and precipitation will more frequently take the form of violent storms, driven by warmer ocean temperatures in the Atlantic.[20] Thus damage from heat, drought, flooding, and hurricanes is expected to increase.

Rising sea levels due to melting glaciers and ice sheets and to thermal expansion of the water also may overwhelm local infrastructure. Sea levels, after remaining relatively stable for the previous 2,000 years, have risen 8 inches over the last century, and the sea level rise rate has doubled over the last 15 years.[21] Coastal areas such as the Gulf Coast have already felt the effects over the last two decades, ranging from coastal erosion to increased vulnerability to storm surges and flooding. A 2007 estimate by the IPCC, which was not able to take into account melting ice sheets, predicted sea levels will rise an additional 8 inches to 2 feet by 2100. However, more recent estimates, under higher emissions scenarios and that included ice sheet loss, predict a 3 to 4 foot rise by the end of the century.[22]

Extreme Weather

The frequency of named North Atlantic tropical storms has increased dramatically over the last 15 years.[23] Extreme weather events (i.e., storms, floods) are taking a significant economic toll, one that is likely to escalate as the frequency of such events continues to rise. Over the past 30 years, the United States has contended with 107 weather-related disasters in which the overall damages and costs reached or exceeded $1 billion dollars or more. The National Climactic Data Center reports that the losses from those events exceed $800 billion, with the largest number of disaster events occurring in the South and Midwest, especially in states along the Gulf of Mexico and the Southern Atlantic coast.[24]

Although it is difficult to make long-term projections about unusual events, as climate change continues, the United States should expect these types of weather events to increase in frequency and intensity.

Climate Risk to the Energy Sector

Most of the discussion of climate change and the energy sector has focused on how to reduce energy-related CO_2 emissions in order to avoid the most extreme effects of climate change. However, both energy demand and supply in the United States are likely, in turn, to be significantly impacted by climate change directly and by its effects on the nation's water supply – in many ways, they already are. In particular, the energy sector faces acute risks from both individual extreme weather events (i.e., storms, flooding, droughts) and longer-term trends (i.e., sea level rise, low or depleted water resources). Increased temperature highs or lows increase energy demand and reduce electricity generation and transmission efficiency; in more severe cases extreme temperatures may force facilities to go offline or risk damaging equipment.

In order to continue to meet energy demand the energy sector must undertake proactive adaptation planning and implementation of measures that limit those impacts. The impacts of climate change on both energy demand and energy supply, and the wide variety of energy efficiency techniques and technologies available for adaptation, are discussed further below.

Impacts on Energy Demand

As discussed previously, some of the expected impacts of climate change include warmer surface/air temperatures, shifting precipitation patterns, and increasing frequency and intensity of strong storms. All of these impacts will affect domestic energy consumption patterns, in the form of increased space cooling demand causing greater reliance on electricity for cooling, especially at peak demand times; reduced heating, especially from natural gas; and regional water shortages requiring greater use of energy-intensive water transport and/or desalination.

Most of the United States experiences summer peaking, meaning electricity demand is highest on hot summer days, largely due to increased air conditioning loads.

More Space Cooling, Less Heating

In light of increasing surface temperatures, the most obvious shifts in energy consumption will be a decrease in demand for space heating and an accompanying increased demand for space cooling, refrigeration, and industrial process cooling. A review of several different climate models found that on average, nationwide space heating energy demand for buildings is projected to decline about 6-10% for every 1.8˚F (1˚C) increase in ambient air temperature, although this effect will vary widely by region.[25] Each 1.8˚F (1˚C) increase in temperature will have the opposite effect on the demand for space cooling in buildings, increasing it by roughly 5-20% in residential buildings and about 9-15% in commercial buildings nationwide, with regional variations.[26]

The increase in air conditioning demand may be relatively modest in cities accustomed to warm weather (i.e., ones that already have high air conditioning usage rates), but in cities with mild summers, like Buffalo, NY or San Francisco, CA, residential air conditioning penetration rates are very low, only about 20-25%.[27] To the extent that warmer temperatures render alternative cooling strategies like open windows and ceiling fans ineffective, residents will be driven to install air conditioners, dramatically increasing space cooling electricity consumption in those regions.

More Electricity, More and Less Natural Gas Consumption

Because a number of different fuels are used for space and water heating (natural gas, electricity, propane, heating oil, etc.), but electricity is used for almost all space cooling, higher ambient air temperatures will shift the nation's energy mix to a greater reliance on electricity.[28] Increased demand for space cooling and decreased demand for space heating will further a long-term trend towards electrification of the nation's energy portfolio. Electricity – spurred by greater penetration of large appliances, consumer electronics, and air conditioning – has represented an ever-growing percentage of total U.S. energy consumption, increasing from only 14% of the national energy consumption in 1949 to 40% in 2010.[29]

Much of the increased electricity use will be at periods of peak demand. Most of the United States experiences summer peaking, meaning electricity demand is highest on hot summer days, largely due to increased air conditioning loads. [30] As generation, transmission and distribution systems must be built to accommodate the rare periods of critical peak loads, an increase in demand during these peak periods is a much more acute problem than a general rise in overall energy consumption; wholesale prices can rise by several hundred times during periods of very high electricity demand. Since 1989, net summer peak electricity capacity has increased by 44%.[31] The Federal Energy Regulatory Commission estimated in 2009 that peak demand without any kind of demand response would grow at an average of 1.7% per year, reaching approximately 950GW in 2019, though existing demand response programs are expected to reduce peak demand by as much as 38GW.[32] The investment in new electricity generation and transmission facilities and other electricity-related infrastructure that this would necessitate would be extremely expensive, on the order of "many billions of dollars,"[33] if met wholly with the construction of additional generation resources. Increasing temperatures thus may be a major problem for the electricity industry even if they do not increase overall energy use.

The overall impact of climate change on natural gas use may be less clear. Direct natural gas use for space heating and water heating will be reduced. However, most new power plants are fueled by natural gas, and almost all new "peaking" plants designed specifically to meet periods of high demand. Generation capacity from natural gas has tripled since 1989. Thus, as peak electric demand rises, natural gas use for electricity generation is likely to increase. The reduced use for heating will mostly be in the winter in the north; the increased use for electricity will mostly be in the summer, especially in temperate regions. Of course climate change mitigation efforts will impact natural gas use at the same time. Expected Environmental Protection Administration greenhouse gas mitigation regulations could restrict coal-fired power plant emissions, with the capacity replaced in large part by natural gas-fired plants. But natural gas plants (especially older, inefficient peaking plants) also emit greenhouse gases, albeit in lower amounts, and could eventually be limited by greenhouse gas rules.

More Energy Use for Water Resources

Addressing water shortages may also add to regional energy demand. As water resources shift and become scarcer in some areas, water utilities may find themselves having to transport supplies further to serve residents' needs, a process that requires much more energy for pumping and distribution (and comes with significant new infrastructure costs). For example, in California, water systems account for 7% of the state's energy consumption and 5% of its summer peak demand, and the State Water Project, which provides water supplies for Northern California as well as urban areas in Southern California, consumes an average of 5 billion kWh per year, approximately 2% of all electricity consumed in California.[34] A West Basin Municipal Water District case study focused on Carson, California estimated importing water from elsewhere in the state or via the Colorado River Aqueduct consumes between 22 and 25 times more energy(155-175 million kWh/year) than utilizing naturally-recharging groundwater supplies (6.9 million kWh/year).[35]

Coastal areas also have the option of constructing desalination plants to convert seawater into potable water, but this type of plant is extremely expensive – more than ten times the cost of drawing and distributing water from local aquifers, according to the Texas Water Development Board[36] – has the potential to raise the salinity level of local water bodies via discharges, and is very energy-intensive. Electricity costs range from one-third to one-half of such a plant's operating expenses[37], and can require anywhere from 9,780 to 16,500 kWh per million gallons of water for desalination plus additional energy for distribution.[38]

In either scenario, should water utilities have to look beyond groundwater or surface water to satisfy local drinking or non-potable water needs, electricity consumption for water treatment and transport could add significantly to regional electricity demand. As discussed below, water shortages could also be exacerbated by increased water demand from power plants working to meet increased electricity demand.

Impacts on Energy Supply

As utilities build up capacity to meet increased demand, they will be expected to continue providing at least the same level of reliability of electricity delivery to which we are accustomed. However, the very phenomenon that will lead us to become more dependent on electricity will also render the electric grid – and, indeed, all energy supplies – more susceptible to system disruptions due to extreme weather, shifting climate zones, water availability and spikes in demand. Indeed, climate change confirms energy efficiency can be the most reliable of energy resources.

Direct weather impacts on energy supply could be quite diverse. Texas, for example, faced multiple weather-related emergencies during 2011. In February of 2011, unusually cold temperatures drove more than 50 Texas power plants with 7,000 MW capacity offline – with shutdowns stemming from frozen equipment and sensors, natural gas pipelines blocked by ice, low temperature cut-off limits, and a failure on some plants' part to "winterize" vulnerable facilities (i.e., leading to pipes bursting that would have delivered cooling water) – while the cold weather simultaneously drove up energy demand for heating. The combination of high demand and diminished supply resulted in the Electric Reliability Council of Texas (ERCOT), the state grid regulator, triggering rolling blackouts across the state for two days.[39,40] During the following summer Texas power plants saw water supplies used for cooling dwindle, the result of long droughts due to reduced precipitation and blazing summer temperatures evaporating standing reserves. In addition, surface water supplies that were available for cooling were warmer than before, reducing overall thermal plant efficiency and requiring longer cooling periods before water could be safely discharged into waterways.[41] As of January 2012, Texas' drought conditions continue[42], and Texas State Climatologist John Nielsen-Gammon projected that the current dry weather could continue into 2020 if weather patterns continue as they did under similar conditions in the 1950s.[43]

Types of **vulnerable energy infrastructure** include:

- Oil refineries and wells;
- Freight rail lines transporting coal;
- Hydroelectric dams;
- Liquid natural gas (LNG) and coal terminals; and
- Offshore wind turbines

Infrastructure Vulnerabilities

Much of the nation's energy infrastructure is located in coastal areas, where energy imports are received, processed and distributed throughout the country. Infrastructure as varied as oil refineries and oil wells, liquefied natural gas (LNG) terminals, power plants, coal import and export facilities, and offshore wind turbines are all commonly found on coastal sites and are thus vulnerable not only to storms – including hurricanes, which have disrupted energy production in facilities in Texas, Louisiana, Florida and Mississippi – but also to flooding and erosion, which could become more common or severe with climate change.[44]

Inland sites on rivers also are vulnerable. For example, In June and July 2011, two Nebraska nuclear power plants were in danger of being flooded with overflow from the Missouri River, leading to one of the plants, Fort Calhoun near Omaha, being shut down until floodwaters receded in the fall.[45] State authorities were forced to put additional measures in place to protect the Fort Calhoun plant, including water-filled barriers that held back the rising waters and overhead power lines that could deliver power to the plant in the event that flooding shorted out underground cables.[46]

Inland infrastructure used for fuel transport could be vulnerable to climate change as well. In Alaska and Canada, natural gas/oil pipelines and other energy infrastructure could be damaged by the melting of permafrost on which they were built.[47] Roughly two-thirds of the coal used in the United States is transported by rail tracks that are vulnerable to flooding, with most of the rest transported by inland waterways, which are susceptible to low water levels or silt deposition from floods or runoff, either of which could render them impassable. A significant disruption in coal supply could lead to widespread grid reliability issues, which would carry a very high economic cost:[48] power outages in the United States cost between $30 and $130 billion each year.[49]

When equipment or supply lines are knocked offline by extreme weather events, it can take months or years for capacity to return to 100% operating condition, as seen in the aftermath of Hurricanes Katrina and Rita in 2005. This damage not only reduces energy production capacity, it is also expensive: total energy industry damages in 2005 cost an estimated $15 billion.[50]

Water Availability for Electricity Generation

As noted previously, climate change could also impact water availability in several regions of the country, with widespread impacts on electricity generation.

Most obviously, hydroelectric power – which is especially prevalent in the Pacific Northwest, but is also a major electricity generating fuel in Alaska and New England – is very vulnerable to variable or lower water flows. Recent annual hydroelectric generation has ranged from over 350 billion kWh in 1997 to less than 220 billion kWh in 2001.[51] This variation will only increase with changing precipitation and snow melt patterns that will come with climate change. To the extent that warming temperatures increase the evaporation rate from reservoirs, this could also limit hydroelectric generation potential.[52] In its report, the USGCRP noted that impacts of decreased precipitation tend to magnify, stating that "every 1 percent decrease in precipitation results in a 2 to 3 percent drop in stream flow; every 1 percent decrease in stream flow in the Colorado River Basin results in a 3 percent drop in power generation."[53]

Although hydropower is the energy source most obviously affected by water constraints, it is by no means unique. Power plants that generate electricity from fossil fuels and nuclear energy are also dependent on a readily available water supply, which they use for thermal cooling.[54] Power plants require nearly as much water as irrigation in the United States although over 97% of the water used in thermoelectric power generation is subsequently returned to the water source.[55] Power plants must secure sufficient water to accommodate both large draws and smaller consumption, depending on the type of cooling used, and release the water at a sufficiently safe temperature for aquatic life. Because an average draw of 25 gallons of water[56] is needed for each thermally-generated kWh of electricity, insufficient water supplies due to reduced precipitation combined with competition for water resources (i.e., drinking water, mining, agriculture) could make it difficult to site new power plants. Arizona, for example, has already rejected permitting for a proposed power plant due to lack of sufficient water resources,[57] and the Lower Colorado River Authority rejected a 40-year, multi-billion dollar water rights contract for a proposed coal-fired power plant near Bay City, Texas, which would have consumed at least 8.3 billion gallons of water a year.[58]

Efficiency of Thermal Power Generation

Electric generation facilities that use fossil fuels or nuclear energy as their primary fuel source would also be affected by warmer temperatures. Higher ambient air temperatures reduce generation cycle efficiency, and higher water temperatures make the process of water cooling in nuclear and fossil fuel plants more energy intensive. Further, spent water that is recycled back into the body of water after use in power plants is frequently subject to temperature requirements under Clean Water Act permitting that would become harder to meet with warmer water and air temperatures.

While changes to generation cycle efficiency are small effects on a plant-by-plant basis, they could have significant cumulative implications: if warming temperatures resulted in a net reduction in fossil fuel power plant generation of 1% on average, then 37 billion kWh would have to be replaced.[59] This is roughly the amount of electricity consumed by 3.2 million American households annually.[60] Warmer natural gas is less efficient to move through pipelines as well, making it more expensive to transport natural gas to utilities and end-users.[61]

Climate Change Impacts on Renewable Sources

In addition to hydroelectricity most other renewable energy sources also are susceptible to climate change's impacts. Because wind, solar, and biomass electric sources also depend directly on atmospheric resources, their generating potential will be more sensitive to the regional impacts of climate change than that of fossil fuels or nuclear energy. Wind patterns are expected to shift, with some areas that already have relatively large amounts of wind power becoming less windy, and other areas that have not yet exploited wind power becoming windier. Similarly, if certain regions experience more precipitation, they may be less able to exploit solar energy because of increased cloud cover. Equivalent effects are expected to impact some biomass production (i.e., changes in precipitation affecting crop yields, changes in temperature rendering some biofuels more or less viable for a particular area).[62] Increased rainfall or snowmelt could even increase hydropower generation at the expense of other renewables: for example, in the Pacific Northwest the Bonneville Power Administration has in the past ordered wind farm owners to power down turbines to avoid grid reliability problems.[63] Renewable energy technologies therefore have a complicated relationship with climate change, since they are frequently employed for their carbon mitigation potential, but the impacts of climate change could affect renewable energy's viability in certain areas.[64]

Adapting to Energy Impacts

Energy efficiency can be an important tool for climate adaptation because it preserves or extends resources in the face of a more constraining environment and usage patterns. Consequently, the approaches outlined below address adaptation from the perspective of reducing consumer energy demand, either peak demand or base loads, in ways that respond to changes in energy demand and production due to climate. Demand response programs and distributed generation such as combined heat & power (CHP) can help address reduced reliability of energy supplies due to climate change. Demand response and building efficiency programs can help reduce the peak electricity demand due to more air conditioning. Cool or green roofs can reduce warming across a city as well as in individual buildings.

Combining these tactics, many of which can be deployed over relatively short spans of time, can prove effective as a strategy for adapting to extreme weather trends. For example, California experienced a "perfect storm" of high natural gas prices and unseasonably hot summer and cold winter temperatures in 2000 and 2001. These uncharacteristic seasonal temperatures and high fuel prices, coupled with reduced hydroelectric generating capacity from dams in Oregon and Washington, required the purchase of large amounts of electricity on the spot market at prices that skyrocketed. Utilities were unable to cope with demand, leading to a series of rolling blackouts throughout the state, and were required by law to adhere to rate caps, leading to one utility filing for bankruptcy.[65] Facing the prospect of another excessively hot summer, California state agencies and utilities implemented a combination of programs to bring down both peak and baseload demand, including extensive consumer education through the media, utility load management programs, financial incentives for reduced electricity use, and energy efficiency programs (e.g. incentives for the purchase of efficient appliances and lighting). By the end of the summer of 2001, after less than a year, adjusted peak demand reductions averaged 4,200 MW, equal to a 10% reduction in peak demand.[66]

Energy efficiency can reduce the cost of adapting the energy sector to climate change. Saving energy is usually the least-cost way to meet increased energy demand. The cost to utilities of energy savings from efficiency programs has been estimated at an average of $0.025/kWh, equivalent to just over a fifth of the cost of new nuclear-fueled electricity generation, just over a quarter of the cost of new conventional coal-fueled electricity generation, and less than half of the cost of natural gas-fueled electricity generation.[67] Energy saved through energy efficiency represents supply capacity a utility will not have to build or purchase, the costs of which will not then be passed on to the consumer in the form of higher utility bills.

At the same time, energy efficiency, energy conservation and demand reduction programs can help utilities avoid adding even more to the nation's carbon emissions load, breaking a positive feedback loop. Investment in new fossil fuel plant capacity due to climate impacts will lock in further GHG emissions for the life of a power plant, often 30-40 years or more. Energy efficiency, energy conservation and demand reduction programs and technologies offer consumers and utilities relatively inexpensive and expedient methods to extend supply and reduce demand while reducing the amount of greenhouse gases emitted.

Demand Response

As described above, increases in summer temperatures will increase critical peak electric loads, requiring utilities to add generation plants and transmission lines that are very expensive and difficult to site. Demand response programs reduce peak loads to help maintain grid stability and to mitigate price increases. These programs shift or curtail electric demand during times of high demand, reducing the strain placed on the electrical grid and reducing the need for high-cost generation resources.

During demand response events, a customer could postpone or curtail certain activities – for example, air conditioners can be cycled off for short periods. Energy consumers participating in demand response activities are normally compensated for this voluntary service. Demand response activities can be initiated by operators (*e.g.* a utility operator manually contacting an industrial facility's plant manager) or by automated systems (*e.g.* a utility's computer system determining that demand response is needed and sending a signal to a customer's building automation system that dims facility lighting slightly). It need not be proactively initiated by a utility: a (usually large) consumer whose electricity rates vary over the course of a day based on wholesale market prices may manually or automatically initiate demand response activities when electricity prices reach a certain level.

Examples of technologies used in **demand response** programs:

- Smart meters, allowing 2-way communication;
- Smart appliances and thermostats that can be cycled off by a utility; and
- Home energy management systems that let consumers switch off lights or appliances remotely.

Presently, demand response programs tend to be focused on large industrial customers taking manual action based on a proactive request by a utility. Increasingly, however, automated systems are allowing easier, faster use of demand response resources and allowing for aggregation of large numbers of smaller loads (residential and smaller commercial customers) for greater effect. Smart grid systems, smart appliances and thermostats, home energy management systems, and other advanced communications and control systems have made this feasible.

An Austin Energy demand response program, based on consumer thermostats able to receive signals from the utility, was effectively used in the 2011 Texas drought. That drought resulted in a temporary loss of generation capacity at the same time as cities across the state were struggling to keep up with high consumer demand from space cooling. As part of their demand management plan, Austin Energy implemented a coordinated cycling of thermostats in roughly 90,000 homes participating in their free programmable thermostat program – 22% of the utility's 411,000-subscriber base. This program enables the municipal utility to cycle off those homes' air conditioning units for 10 minutes out of every half hour during curtailment events. When deployed, this program has been demonstrated to reduce peak demand by 35-45 MW.[68]

Demand response can also be undertaken in response to price signals. Most consumers pay a flat rate for electricity based on an average cost of highly variable wholesale rates. As such, they pay *more* than actual costs during off-peak periods like night time and *much less* during peak periods like hot summer afternoons. If consumers were to pay variable prices for their electricity based on time of day or actual changes in price on the wholesale market, they could shift loads to take advantage of lower off-peak prices, which would in turn reduce wholesale prices for everyone during peak periods. Consumers could take such actions manually, or they could install smart appliances that could be programmed to take certain actions automatically: a refrigerator might defer a defrost cycle if the price were above a certain level, or a loaded clothes washer might wait for a nighttime price to drop below a certain point before beginning its wash. Smart appliances could access this information via a smart meter that connected to a utility or via Wi-Fi and a standard Internet connection to an automated web resource. Price signals can also lead to long-term load shifting: refrigerator defrost cycles and clothes washers can be programmed always to wait until nighttime.

Outside of peak demand situations, demand response capability can be an important tool in dealing with unexpected disruptions. If generation, transmission or distribution resources are lost due to extreme weather events, demand response can reduce the loads placed on surviving infrastructure; this could prevent grid instabilities that could cut power to consumers well beyond the damaged portions of the grid.[69]

While demand response and the shifting of peak loads can reduce overall energy use (*e.g.* dimming lights slightly at one time does not encourage people to set them even brighter at other times), it does not necessarily do so (*e.g.* turning down an air conditioner may mean it runs harder before or after a demand response event). If it includes greater consumer awareness of energy use, it may help broader demand side management activities, including energy efficiency and conservation programs.

"Future Proofing" Buildings

Despite the increasing efficiency of U.S. energy consumption, there are still significant energy savings to be realized in American buildings. The most recent residential and commercial model building energy codes are designed to achieve roughly 30% savings in covered energy use compared to a few years ago. A survey of energy efficiency potential studies found that on average, existing residential buildings could achieve 10-15% energy savings from energy efficiency below business as usual while 10-20% savings were achievable in commercial buildings.[70] Achieving even 10% savings, the low end of estimated potential, across the building fleet would yield annual savings of 1.76 quads of energy in residential buildings in 2035 and 1.98 quads in commercial buildings.[71]

"Future proofing" buildings for a changing climate may include:

- Adding additional insulation;
- Increasing use of daylighting, window shading and natural ventilation;
- Energy audits and recommissioning to ensure building performance.

Buildings typically last for several decades. Basic design decisions such as building orientation and shape, framing and wall insulation, and type of windows are likely to determine the efficiency of new buildings over the next 30 to 100 years, the same timescale on which climate change is projected to be significant. Building design is heavily influenced by the local climate—both residential and commercial building energy codes generally are keyed to eight different climate regions in the United States. As average temperatures rise, seasonal temperatures in one region may come to resemble that of others; for example, the New York Times reported, "Climate scientists have told city planners that based on current trends, Chicago will feel more like Baton Rouge than a Northern metropolis before the end of this century."[72] That is a shift over three codes regions. In addition, the South may experience weather more similar to tropical zones than to any part of the United States today. But there is a high degree of uncertainty in current weather models as to what specific conditions will occur in which regions in the coming decades.

Both individual buildings and building energy codes should be more robustly designed to ensure that the buildings will be appropriate for future climate scenarios with temperatures and extreme weather events (and possible energy service interruptions) that in previous decades would have been unthinkable. This may mean, for example, better insulation, careful placement and shading of windows, and daylighting and natural ventilation.

As the exact shape and scope of new weather conditions in a region will be evolving but difficult to predict, for building characteristics that can be changed more easily, energy audits and recommissioning may be needed to ensure that buildings are responding appropriately to the changing climate. Improving air conditioner efficiency, combined with consumer-facing education, energy conservation and demand response programs, should be especially effective in countering the increased demand of existing buildings due to higher temperatures. The minimum required efficiency for new residential central air conditioners increased by 30% in 2006 and is scheduled to increase by another 8% in the South in 2015, with an added requirement in the Southwest to reduce peak demand. Efficiency of the best models has improved by at least as much, leaving significant room for further savings.

Cool and Green Roofs

Two novel building solutions to rising temperatures already in use across the United States are cool and green roofs, which serve to insulate buildings and, if implemented *en masse* in an urban area, could actually reduce the ambient temperature.

Urban heat islands – the name for the phenomenon of cities being a few degrees warmer than rural areas – contribute to global warming and make it worse for urban residents. One method that could help cool cities is by increasing the solar reflectance of urban surfaces via cool roofs and cool pavements – basically, by painting roofs and pavements white and with additional coatings to boost reflectivity. Every 100 m^2 painted white offsets the ambient warming from roughly 10 metric tons of CO_2 emissions per year.[73] Cool roofs also offer peak demand energy use reductions that in one survey of program areas ranged from 14-38%, depending on site and building features, such as climate, shading and insulation.[74] If the United States followed California's example and required all flat roofs to be painted white, and all sloped roofs to be cool-colored, it would make urban public outdoor spaces more comfortable, and offset some of the increased demand for space cooling due to climate change, and it would mitigate climate change as well, lowering the earth's "albedo" by reflecting sunlight back into space.[75] Lastly, cool roofs and pavements are both inexpensive – with coatings ranging from $0.75-$1.50 per square foot and single-ply membranes ranging from $1.50-3.00 per square foot[76] – and easy to implement.

Alternatively, building owners could install green roofs on their properties, in which the roof surface is partially or completely covered with vegetation and soil on top of a waterproof barrier. Green roofs provide shade and remove heat from the air through evapotranspiration, providing significant insulating benefits. Green roofs also reduce stormwater runoff, reducing stresses on local water systems, and can be designed to create usable green spaces on top of buildings. Studies modeling large-scale green roof implementation for Toronto (50% of the city's building stock) and New York City (100% of stock) estimated those implementations would cool the respective cities, on a 24-hour average temperature reduction basis for the entire city, 0.1-0.8˚C (0.2-1.4˚F) for Toronto and 0.2˚C (0.4˚F) for New York, with higher reductions projected for late afternoon (i.e., peak cooling demand times).[77] However, these types of installations require more maintenance and are costlier than cool roofs, with installation costs starting from $10 per square foot for extensive (lightweight) installations and $25 per square foot for intensive (harder, more diverse) installations.[78]

Distributed Generation/Combined Heat & Power

Given the potential for extreme weather or water shortages to interrupt electricity supply or cause demand to spike, one approach large energy consumers (i.e., industrial, institutional) could undertake to prevent such interruptions would be to pursue implementation of distributed generation projects, with combined heat and power (CHP) to increase system efficiency, wherever feasible.

Distributed generation technologies can help reduce large energy consumers' reliance on local grid resources and free up capacity to meet growing demand by others. **Combined heat and power (CHP)** techniques integrate electricity and thermal energy generation from a single source, producing additional energy that can be used for heating/cooling or for industrial processes.

Distributed power system (DPS) technologies provide small-scale power generation on the customer's site, including fossil fuel-powered turbines or engines, fuel cells and renewable systems (e.g., solar photovoltaic, wind microturbines, or even microhydropower), which may need to be paired with energy storage such as batteries to avoid intermittency issues. CHP, or cogeneration, is the integrated production of electricity and thermal energy from a single fuel source, including natural gas, biomass, biogas, coal or waste heat. Using CHP, heat left over from power generation is used for buildings or industrial processes (e.g., steam production, water or space heating, absorption cooling).

A 2011 joint report by the Brookings and Hoover Institutions estimates that certain DPS/CHP technologies – integrated cycle engines and gas turbines with CHP, medium- and community-scale wind – could be considered cost-competitive on a per-MWh basis with central-station generation under higher-cost fuel price scenarios (e.g., natural gas at up to $7.50/MMBtu). Other technologies considered near cost-competitive include medium-sized solar PV (2-5 MW), microturbine CHP and fuel cells.[79] A Oak Ridge National Laboratory study found that CHP accounted for 85 GW or 9% of generating capacity in 2008 and could provide 20% of U.S. electric capacity by 2030, saving an estimated 5.3 quadrillion Btu of energy annually.[80]

Implementing efficient DPS/CHP projects could serve multiple adaptive purposes. DPS/CHP projects reduce large energy consumers' reliance on local grid resources, including both central generation and the transmission and distribution lines that would be needed to deliver the electricity, thus freeing up centralized capacity to meet growing demand by others and providing the large consumers electricity with fewer vulnerabilities to disruption due to extreme weather.

Water-Energy Efficiency Programs

Lack of investment in water infrastructure continues to exacerbate water resources issues, as significant amounts of water supplies are lost to leaks. The U.S. EPA estimates that in the roughly 880,000 miles of water infrastructure across the country, water utilities experience nearly 237,600 breaks per year, requiring the pumping and treatment of more water to satisfy demand, which in turn requires additional energy and chemical usage; water worth an estimated $2.8 billion is lost each year.[81] As precipitation patterns shift and temperatures increase, ensuring steady water supplies will become – and in some cases, already is – critical in parts of the Southwestern and Southeastern United States.

Communities' best options for water adaptation planning, as with energy, address both demand and supply issues:

- Policy options such as consumer-facing water conservation programs (e.g., incentive programs for low-flow appliances, native landscaping/xeriscaping, green infrastructure, restrictions on irrigation, and rainwater harvesting);

- Leak detection and repair (both in homes and businesses and in utility systems);

- Improving operational and maintenance procedures within water utilities to maximize efficiency; and

- Upgrading equipment within water distribution networks (i.e., pumps, variable drive motors, energy management software).

Combined water/energy efficiency efforts – which seek to identify leaks and improve water infrastructure to minimize water losses, improve pump operating efficiency, and in some cases, generate hydropower from treatment plant outfalls – have been embraced by some U.S. municipalities, but have yet to see widespread implementation.

Other Energy Efficiency Policies and Programs

Besides the specific efficiency and demand side management measures discussed above, energy efficiency more broadly can be used for climate adaptation. Almost any energy efficiency will reduce summer peak loads (as well as base loads) and reduce water usage by fossil fuel power plants. Many energy efficiency measures can be implemented more quickly than power plants can be built, and at different scales, making the efficiency resource more quickly adaptable to changing energy demand and changing energy supply due to weather.

The potential of energy efficiency as a resource is enormous. The Alliance to Save Energy estimates that energy efficiency measures taken since 1973 already save about 50 quadrillion Btu each year—about half as much as the total energy used in the United States each year. The McKinsey Global Institute has estimated that with an investment of $500 billion the nation could economically save 23% of energy use in the residential, commercial, and industrial sectors, and save $1.2 trillion, by 2020.[82] But many economic barriers prevent cost-effective energy efficiency from being used, from lack of information that makes it difficult and expensive to figure out what to do to split agency (landlord-tenant, builder-buyer) in which the person who decides whether to invest in efficiency does not pay the energy bills. The leverage afforded through government policies and programs frequently is necessary to overcome those barriers.

On the decadal time scale of climate change, energy efficiency policies and programs work best when they work in concert to address many stages of commercialization. Research and development (R&D) support, such as funding for various Department of Energy programs, helps develop the technologies and practices needed to improve energy efficiency, especially in fractured industries in which one company will see little of the benefit of R&D. Financial incentives, such as utility rebate programs and income tax credits, help overcome the high costs of initial introduction of technologies into the marketplace. Consumer education programs such as Energy Star and convenient financing can help make use of the technologies widespread. And building energy codes, appliance efficiency standards, and fuel economy standards can ensure that all consumers receive the benefit of cost-effective efficiency levels regardless of the economic barriers.

Some of these policies build savings over many years. But even the more rapidly deployed efficiency behavioral programs that one might use to address unexpected changes (as in California in 2001) rely on the base of technologies, infrastructure, and expertise built up through the combination of policy levers.

Conclusion

Energy efficiency is an important tool for adaptation to climate change. As described in this paper, some of the key impacts of climate change are on energy production and demand, as well as related water usage. Energy efficiency measures and broader management of energy demand can help address rising demand for cooling, reduced electricity generation, unexpected changes in energy production and demand, urban heat islands, service interruptions and water shortages.

As noted earlier, most of these same energy efficiency measures also will reduce carbon dioxide emissions from energy production; they will help avoid climate change as well as deal with the consequences. Almost every analysis of how we can reduce greenhouse gas emissions finds energy efficiency must be a key part of the solution, especially in the early decades.[83] For example, McKinsey & Company finds that energy efficiency measures account for more than a third of the potential low-cost GHG abatement in the United States and worldwide, and most of the cheapest options.[84][85] Because they reduce energy costs, energy efficiency measures also can save money while achieving climate benefits. Thus while energy efficiency is only one tool in the climate adaptation toolbox, it is one of very few that can claim to reduce climate change and save money while helping with adaptation.

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About the Alliance to Save Energy

The Alliance to Save Energy is celebrating its 35th year as a nonprofit organization that promotes energy efficiency worldwide through research, education and advocacy. The Alliance advances energy efficiency policies, conducts research on various energy-related topics, and increases awareness and knowledge about the many ways that energy consumption can be reduced in the United States and throughout the world. For more information about the Alliance and its activities, please visit www.ase.org, follow us on Twitter and like us on Facebook.

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