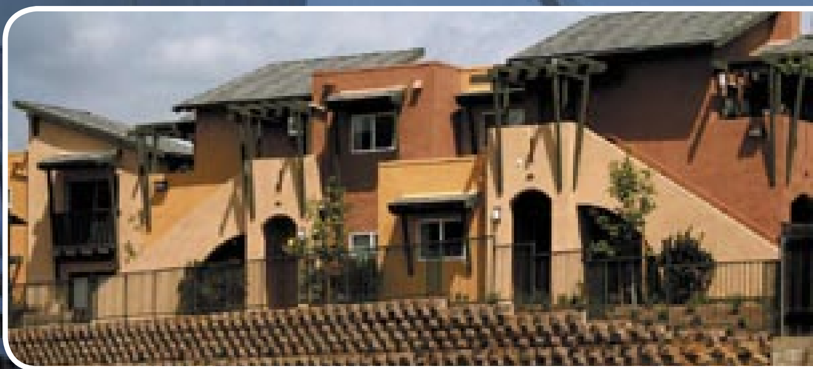
An Environment America Research and Policy Center white paper

Building an energy-efficient America:

Zero energy and high efficiency buildings



ENVIRONMENT AMERICA

Clean air. Clean water. Open space.

Building an energy-efficient America:
Zero energy and high efficiency buildings

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Environment America Research & Policy Center

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Cover: Top image, an energy-efficient house built in Washington, D.C. Center image: a green rooftop in Battery Park, New York City. Bottom, Solara, a solar-powered apartment community.

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Green roofing is one of many ways to boost the energy efficiency of homes and office buildings.

Solara is a zero energy affordable housing development in Poway, California, built in 2007. The buildings are extremely energy-efficient, and the energy for the community is offset by solar panels.[13]

Executive Summary

America is the largest consumer of energy in the world. Almost half of the energy we use—10 percent of the energy in the world—powers our buildings.[1] Most of this energy comes from burning fossil fuels. Our reliance on these fuels makes us vulnerable to supply disruptions, contributes to global warming and other environmental problems, and is becoming increasingly expensive.

We could be using far less energy in our buildings. Homes and businesses exist that use a fraction of the energy of typical buildings—some also generate 100 percent or more of the energy needed to power them on-site, using renewable sources such as wind and solar power.

Approximately 75 percent of our buildings will be new or renovated by the year 2035.[2] Although this situation represents huge potential for saving energy, market barriers are preventing the widespread adoption of energy-efficient building practices.

Those barriers include:

- Many construction and home building firms resist the marginally higher upfront costs of actions to improve building efficiency and therefore are slow to adopt measures that would benefit renters and home and building owners. [3, 4, 5]

- Buyers and renters lack the information needed to choose more energy-efficient properties.

Policies can be adopted to overcome these barriers and ensure that new buildings and renovations take advantage of energy-efficient practices, such as:[6]

- Building energy codes should be improved and enforced. National model codes should be 30 percent more efficient by 2010 and state codes should match or exceed the model codes.

- Federal, state, and local governments should adopt policies that encourage building far beyond code and retrofitting existing buildings for increased efficiency.

- Policies should be designed to encourage on-site renewable power.

- Political leaders should set the goal for all new buildings to be zero net energy by 2030.

These policy changes would have a huge impact on energy use and global warming emissions in the United States, at little cost.

- Adopting and enforcing strong building codes nationally could reduce our annual energy consumption by 2 percent from 2030 projected use.[7,8]

- Investments of $21.6 billion a year for five years through federal efficiency programs could reduce our energy use enough to replace more than 100 coal-fired power plants and lower annual carbon dioxide emissions by 433.5 MMT.[9]

- One quad of energy gained through building efficiency would cost $42.1 billion, 35 percent of the cost to gain the same amount of energy through new coal plants, and under 20 percent of the cost to gain the same amount of energy through new nuclear generation.

Half of the buildings constructed today will still be in use in the middle of this century.[10] The decisions we make today will have a lasting effect on our energy economy.

Genzyme, a biotechnology company, designed its corporate headquarters in Cambridge, Mass., to be extremely energy-efficient, with electricity costs about 42 percent less than a comparable building. Use of daylight allows 75 percent of employees to work with natural light alone.[12]

Introduction

A single day in a typical American's life requires quite a bit of energy, and much of that energy use is out of our control. You can turn the lights off in rooms you aren't using, and replace those lights with energy-efficient bulbs, but what about your office, the gym, your children's school, or the restaurant where you eat dinner?

Most of us spend the majority of our time indoors, but when we picture the energy we use, we tend to forget how much of it goes toward making the indoor environment comfortable. For instance, your water heater expends energy to keep your water hot all night, even though the morning shower is many hours away.

The amount of energy used in America's building is staggering—10 percent of the energy used in the entire world goes towards operating buildings in our country.[11]

A lot of that energy is wasted. Air that has been heated or cooled escapes from our buildings through cracks around doors, through attics, and through poorly insulated walls and single paned windows, taking with it the energy used to heat or cool the building. Water heaters, appliances, and light bulbs that use 10 to 75 percent less energy than the current models are easily available, but inefficient, energy-intensive models are still in widespread use.

America is on the brink of an energy crisis. Energy efficiency in our homes and offices is one relatively simple way to cut dependence on fossil fuels and reduce air and global warming pollution.

The resulting power that our buildings require is supplied mostly from natural gas, oil, nuclear power and coal. These energy sources are threatening our safety by contributing to global warming and other air pollution that will be with us for millions of years and making us dependent on unstable foreign countries.

A new vision for energy-efficient construction is emerging. Across the country, in all sorts of climates, more and more people are becoming committed to building homes, businesses, and factories that use significantly less energy—up to 70 percent less. More and more people are going further, coupling efficiency with on-site renewable energy sources, like solar or wind power, to create "zero energy buildings" that generate as much energy as they use.

Life in a world of zero energy buildings may seem far off. However, a future in which most Americans wake up in a well-insulated house or apartment that takes little energy to heat or cool, and go to work in high-performance, efficient buildings that generate as much renewable energy as they use, could be a reality within the next 50 years. The only thing holding us back is commitment and the political will.

This white paper will describe the different methods and technologies available to build highly efficient and zero energy buildings and to retrofit existing buildings to use much less energy than they do now, and the policies needed to make highly efficient and zero energy buildings the standard.

Problem

America is on the brink of an energy crisis. Our reliance on polluting energy sources contributes to global warming, unhealthy air quality, and mercury pollution in our lakes and rivers. For example, from 1990 to 2005, global warming pollution from electricity generation increased by more than 25 percent.[14]

We are importing more and more of our energy from abroad, leaving us vulnerable to supply disruptions and sending billions of dollars out of the local economy. Natural gas has become increasingly expensive as demand inches closer toward available supply—driven in part by the increased use of gas for electricity generation. Gas prices have roughly doubled since 2000, increasing the cost of heating our homes and fueling our industries.[15]

Since 1990, our consumption of energy has increased by 18 percent, and America is projected to use approximately 19 percent more energy in 2025 than we do today.[17,18]

Much of this energy is wasted. Per unit of economic output, America's economy is twice as energy-intensive as Germany's and nearly three times as energy-intensive as Japan's. We use more energy each year than China and Russia combined.[20]

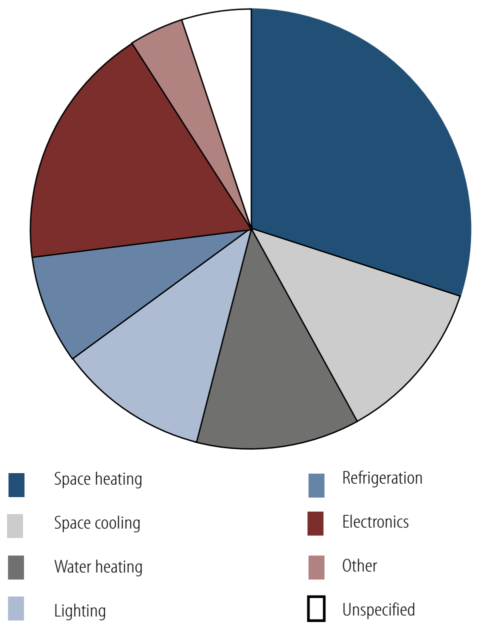
Buildings represent the biggest culprit in wasted energy. Forty-eight percent of our energy is used inside buildings, and 76 percent of our electricity.[21,22] Energy use in buildings is also responsible for 43 percent of America's carbon dioxide pollution, making our workplaces and our homes our nation's biggest global warming polluters.[23]

All of this waste, however, means that the building sector represents the largest opportunity to rescue ourselves from the impending crisis and re-create our energy economy to be efficient, clean, renewable and stable.

Energy efficiency is also the cheapest and cleanest way to increase our energy productivity. A recent McKinsey report calculates that a $21.6 billion investment in simple, cost-effective building efficiency would save enough energy to eliminate the need for 22.3 conventional coal plants.[24,25] Based on that calculation, it would cost $42.1 billion to gain one quad of energy through residential and commercial building efficiency.[26] In comparison, it would cost $122 billion to deliver this much energy by building coal plants, and $222 billion by building nuclear power plants.[27]

Approximately 75 percent of our buildings will be new or renovated by the year 2035. Every building that is constructed without the highest levels of cost-effective efficiency technology available from now until then is truly a missed opportunity, the effects of which will stay with us for decades. We have to start seriously tackling the energy used in our buildings, today.

Home Energy Use



We can significantly reduce energy use in homes through common-sense practices such as reducing the amount of heat that escapes from our buildings and by using more efficient appliances and lighting systems.

Weatherization and proper insulation can prevent energy loss from air leakage

Solutions

Methods for reducing buildings' energy use fall into two categories: increasing efficiency and using on-site renewable sources of power in place of energy from the grid. Zero energy buildings use both.

Efficiency in homes

We can significantly reduce energy use in homes through common-sense practices such as reducing the amount of heat that escapes from our buildings and by using more efficient appliances and lighting systems.

Space heating and air conditioning

Space heating is the largest source of energy consumption in homes, accounting for nearly a third of residential energy use nationally.[28] Air conditioning accounts for an additional 12 percent of consumption. Despite dramatic improvements to the energy efficiency of the average American home since the energy crises of the 1970s, large opportunities remain to reduce energy consumption for both space heating and air conditioning.

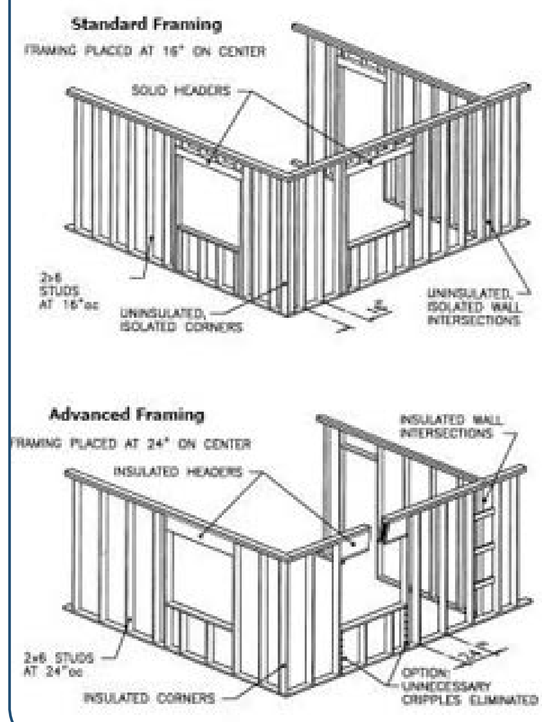
The appliances we use to heat and cool our homes can be much more energy-efficient. High-efficiency residential furnaces, such as those meeting the federal government's Energy Star standards, can reduce fuel use by about 20 percent compared to furnaces meeting the government's minimum furnace[30] efficiency standard, and by 40 percent or more compared to older furnaces. Because one quarter of all homes have furnaces that are 20 years old or older, the opportunity for energy savings is huge.[31] New federal standards for residential and commercial air conditioners will improve efficiency for new units by 30 percent and 26 percent, respectively.[32] However, air conditioners currently exist that exceed the new federal standard by 15 percent or more.

Energy consumption can be reduced even more through simple changes in building design and appropriate weatherization:

Weatherization—Air sealing, insulation and window replacements can reduce energy consumption by 20 percent.[33] Air escaping through cracks around doors, windows and other pathways increases the load on heating and air conditioning systems, wasting energy that could easily be saved by ensuring that the building envelope is completely sealed.

Better insulation—Insulation is available that is much more effective than the insulation commonly used. In addition, adding more insulation and ensuring that it is properly installed can save energy. It is easier to install good insulation in new buildings, but insulation can also be added to existing homes.[34]

Better windows—High efficiency windows can be six times more energy-efficient than more typical windows, through a "low-e" coating that increases the window's insulation power, sealing the window better and lowering heat conduction through the frame.[35] Windows are also one of the easiest parts of a building to replace, and most people who replace their windows replace them with more efficient models.[36]



Walls are made up of frames and open cavities filled with insulation. Traditionally, the framing portions are not insulated, which contributes to energy loss.

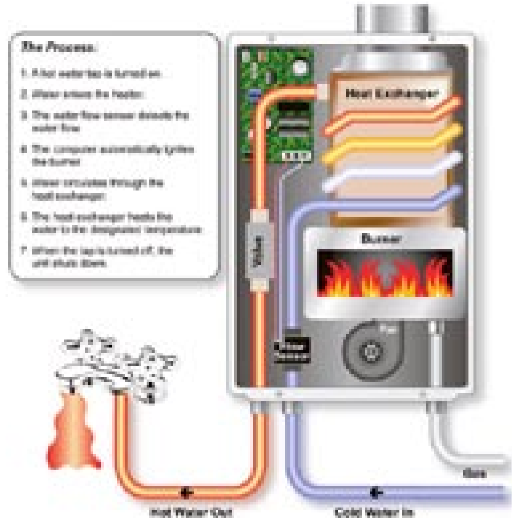
Wall design—Walls are made up of frames and open cavities filled with insulation. Traditionally, the framing portions are not insulated and make up a large portion of the total wall surface. However, walls can be built to minimize framing and reduce energy transfer. Framing insulation is starting to come into use, which can lower heat loss by as much as 50 percent.[37]

HVAC—Heating, ventilation, and air conditioning systems waste a lot of energy through duct work, losing 25 to 40 percent of the heating or cooling energy in a typical home.[38] Ducts leak 60 to 70 percent of the air that passes through them, but carefully sealing ducts can reduce that number to about 20 percent.[39] Duct work is also not very well insulated, and is often routed through the outside walls of a home where ducts are subject to extreme temperatures. In addition, HVAC systems are often oversized, which wastes energy by providing more heating or cooling than necessary, especially in otherwise efficient houses.[40] Large amounts of energy can be saved by sealing and insulating duct work, routing ducts through interior walls, and properly sizing the HVAC system to the house. Properly sizing the HVAC system also reduces the up-front cost of a building, which can offset increased costs from other efficiency and energy expenses.

Cool roofs—In warm climates, a lot of heat is gained through the roof of a building, which increases the amount of energy used in air conditioning. Simply by changing roof materials, much of this energy can be saved. Light colored "cool roofs" that reflect rather than absorb the sun's heat have been shown to reduce cooling energy use by approximately 40 percent.[41] For cold and variable climates, "smart" roofing materials are being developed that would absorb heat from the sun in cold weather and reflect it in warm weather.[42]

Landscaping

Incorporating trees into the landscaping around a building can regulate temperatures by cooling the air around a home in the summer, and blocking wind in the winter. Deciduous trees provide shade



Tankless water heaters are much more efficient than traditional water heaters. Instead of keeping a tank of water constantly hot, it heat the water as it runs to pipes.

in the summer but let in light in the winter, although they are less efficient at blocking wind. Planting a green roof—a roof with plants growing in soil covering the entire surface—is a more aggressive use of landscaping, and can act as insulation and reduce the surface temperature of the roof.[43]

Water heating

Water heating accounts for about 12 percent of household energy use.[44] As with other sources of household energy demand, significant energy savings are possible from switching from less energy-efficient to more energy-efficient equipment. Better-insulated and more efficient water tanks can save a lot of energy. Heat pump water heaters work like refrigerators in reverse, moving heat from the surrounding air into the water tank instead of heating the water directly.[45] They use less than half as much electricity as traditional electric water heaters.[46] Tankless water heaters heat water instantly as it flows through the system, instead of keeping a large tank of water hot no matter how often it is used, and can use 24 to 34 percent less energy than conventional water heaters in homes that do not use large amounts of hot water.[47] In addition, some technologies that save water—such as front-loading clothes washers—can also reduce the amount of water needed, which reduces energy use.

Appliances

American homes are full of energy-consuming appliances—the vast majority of which can be made dramatically more energy-efficient. The biggest energy-consuming appliance in most American homes is the refrigerator, which consumes 8 percent of residential energy.[48] Federal efficiency standards for refrigerators have resulted in vast improvements in energy efficiency; the average refrigerator sold today uses one-third the electricity as the average unit from 1974, despite an increase in average size and performance.[49] Still, significant energy savings are possible by replacing older refrigerators with newer models. Refrigerators meeting Energy Star efficiency standards, for example, are 10 to 15 percent more efficient than average models.[50]

Similar gains are possible with other appliances—including appliances such as DVD players and other digital media. For example, many electrical appliances, including televisions, cable boxes and stereos consume power even when they are turned off. One study of 10 California homes found that consumption of standby or "vampire" power accounted for between 5 and 26 percent of the homes' annual electricity use.[51] Replacing existing appliances with those that minimize standby power use could reduce these losses by 68 percent.[52]

Lighting

Compact fluorescent light bulbs are becoming increasingly common in American homes and are vastly more efficient than traditional incandescent bulbs.[53] Lighting accounts for about 11 percent of household energy consumption. If every American household replaced its most highly used incandescent bulbs with compact fluorescents, America's total household lighting consumption could be cut in half.[54] Light-emitting diodes (LEDs) can be even more energy-efficient, and may replace compact fluorescent bulbs in the near future, especially in commercial applications.[55]

Embodied energy

Embodied energy is the energy used in production and distribution of the materials used in building construction. Currently, embodied energy accounts for 15 to 20 percent of the energy used by a building over a 50-year period. As building efficiency increases, embodied energy will become an even more significant part of a building's energy use.[56] Materials such as bamboo, recycled composites, straw bales, soil cement, and locally obtained materials take much less energy to produce and transport than traditional materials such as concrete and brick.[57]

Putting It All Together

There are many opportunities to reduce energy consumption in American homes using simple, common-sense practices and technologies. Aggressive weatherization of homes, combined with installation of high-efficiency furnaces and air conditioning, could reduce energy consumption for space heating and cooling by 20 to 40 percent or more. Similar energy savings are available for energy used in water heating, lighting, air conditioning, and many appliances. Combined, these simple practices can add up to huge reductions in energy use, and are the first step to achieving zero energy homes.

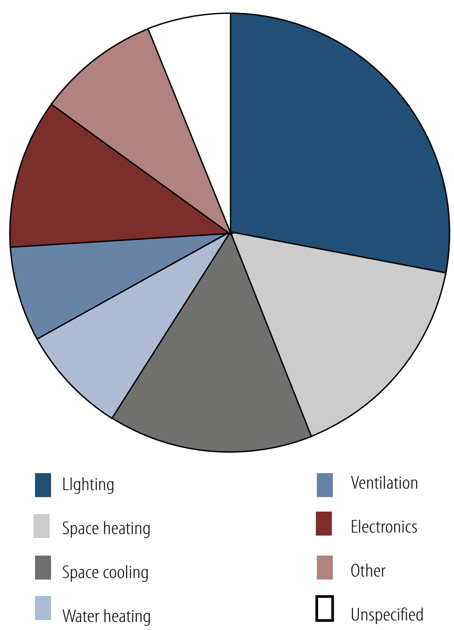
Energy efficiency in business and industry

Just as there is tremendous potential for improvements in the energy efficiency ofAmerican homes, so too is there great potential for energy savings in business and industry.

Commercial buildings such as shopping centers, office buildings and institutional buildings (such as schools and hospitals) are major consumers of energy, accounting for about 18 percent of total energy use in the United States.[58] Many of the same strategies that are available for reducing residential energy use also apply—on a much larger scale—to commercial buildings. For example, comprehensive energy-efficient retrofits of commercial buildings can achieve energy savings on the order of 11 to 26 percent.[59]

To give some idea of the potential, Wal-Mart, the nation's largest private electricity user, has pledged to reduce energy consumption at its stores by 20 percent and has committed to developing a prototype store that curbs energy consumption by 25 to 30 percent.[60]

Business Energy Use[61]



Just like homes, business have a huge potential to save energy.

Chicago's City Hall was retrofitted with a green roof in 2000.

Commercial energy end use

Lighting and air conditioning equipment used in commercial buildings can be made far more energy-efficient. State-of-the-art lighting systems in commercial establishments have the potential to reduce energy consumption for lighting by up to 40 percent nationally.[62] Wal-Mart has reduced its lighting expenses by approximately 66 percent in all new stores by installing motion sensor-activated LED case lighting.[63] As mentioned above, new federal standards for air conditioners will lead to dramatic improvements in energy efficiency, and air conditioners already on the market surpass those energy efficiency standards.

In addition, there are many opportunities for commercial facilities to use energy more intelligently. Variable-speed motors, automated lighting and climate controls, and even the simple act of turning off lights at the end of the workday can save large amounts of energy. For example, Adobe Corporation implemented a series of energy efficiency measures at its San Jose, Calif., headquarters—including installation of variable-speed motors, high-efficiency lighting systems and adjusting lighting and climate controls to the actual needs of the building. Over the past six years, Adobe has reduced per-employee electricity use at its headquarters by 35 percent and natural gas use by 41 percent.[64]

Combined heat-and-power (CHP)—CHP technologies represent yet another opportunity for energy savings in both commercial buildings and industrial facilities. Many large apartment buildings, commercial developments and industrial facilities could make greater use of CHP, in which heat produced to warm buildings or power industrial processes is also used to generate electricity. CHP systems can reach 70 to 90 percent thermal efficiency, compared to the 33 percent efficiency of today's power plants.[65]

Many industrial facilities already use CHP, but the potential for growth is enormous. Studies conducted for the U.S. Department of Energy found a market potential of 33,000 megawatts for industrial CHP systems (compared to current deployment of 11,000 megawatts), and as much as 77,000 megawatts in the commercial and institutional sector (compared to deployment of 5,000 megawatts as of 1999).[66] Building out this existing CHP potential would equal about 10 percent of America's current electric generation capacity, and technological improvements could allow CHP technologies to spread even farther in the years to come.[67]

Industrial facilities can also achieve much greater energy efficiency. In addition to increasing the use of combined heat and power, other measures that could save large amounts of energy include:

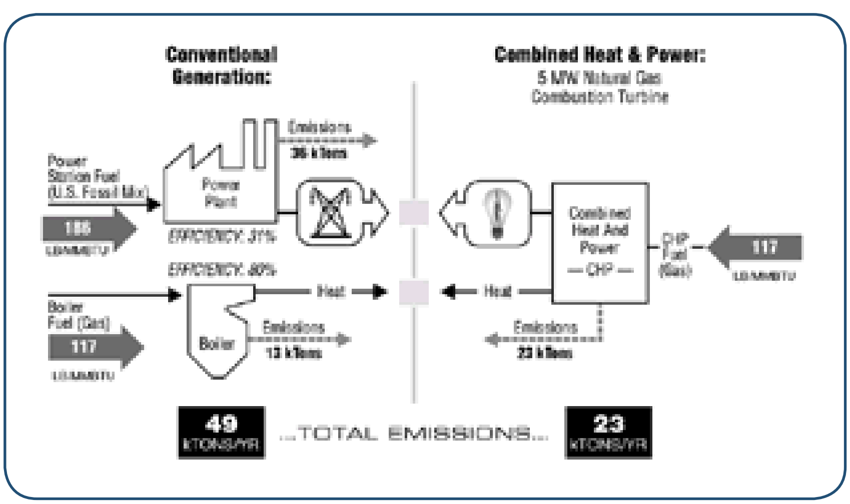
- Advanced motors—The use of high-efficiency motors and better controls in the industrial, electricity generation and commercial sectors could reduce total U.S. electricity demand by as much as 15 to 25 percent.[68]

- Efficient boilers—Industrial boilers produce steam and hot water for manufacturing processes. Significant improvements in efficiency—on the order of 15 to 19 percent—are possible for oil and natural gas boilers.[69]

- Thermal efficiency—Factories can achieve dramatic improvements in efficiency through techniques that seek to maximize the efficiency of the industrial process as a whole, rather than just the component parts. Using a technique called "pinch analysis," engineers can estimate the minimum amount of energy theoretically required at a given facility and make adjustments to processes in order to maximize energy efficiency. Such analyses can reduce energy costs by as much as 40 percent.[70]

Putting it All Together

As with residential buildings, there is a wide variety of technologies available to reduce energy use in businesses and industry. But in some key ways, commercial and industrial buildings may hold greater opportunities for efficiency improvements through the application of professional management and analytical techniques to reduce energy waste that may be hurting a company's bottom line. Many businesses have saved large amounts of energy by undertaking a thorough analysis of how energy is used in their facilities and applying appropriate technologies and practices to minimize energy consumption.



Combined heat and power systems save institutions money and cut energy waste.

Erecting a wind turbine in Harwich, Mass.

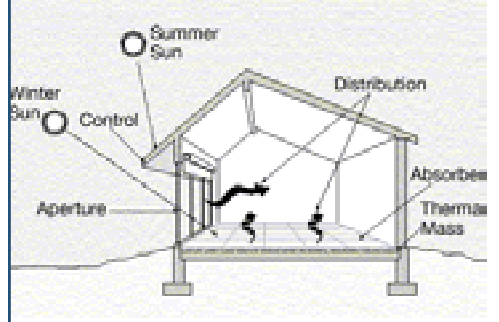
Renewable Energy

Beyond efficiency, buildings can be built to use even less polluting energy by taking advantage of the resources surrounding them, including solar panels and wind turbines, which actively harvest electricity. However, there are passive uses of renewable energy, such as designing the building to use the sun's light to replace some artificial sources of light. Humans have used passive renewable energy for thousands of years, before electricity was readily available and fuel was so cheap and convenient. As prices rise and energy from fossil fuels becomes less desirable, architects and developers have begun to build on the age-old methods to exploit the power of the sun and wind, using modern technology to maximize the energy gleaned.

We can best take advantage of these passive sources of renewable energy by approaching the design process as a whole from start to finish, instead of considering each step separately. By incorporating energy efficiency and passive renewable power into every part of construction, from site orientation to interior decoration, can decrease a building's electricity and fuel demand by 50 to 70 percent. The remaining demand can be easily met by active sources of renewable power such as solar panels and wind turbines.

Passive Renewable Energy

Passive solar heating—Buildings can be designed so that the heat from the sun is blocked in the summer and maximized in the winter, lowering heating and cooling costs. This can be as simple as designing roof overhangs so that the high summer sun is blocked and the low winter sun can penetrate, and maximizing south-facing windows. But it can also go a lot farther. Dark masonry surfaces that store heat can be incorporated into surfaces such as walls or floors in places where they can absorb heat from the sun in the winter, warming rooms at night by radiating the heat as the building cools.[72] The U.S. Department of Energy estimates that new office buildings using a combination of passive solar design and energy-efficient technologies can reduce energy costs by 30 to 50 percent versus the national average.[73] Similar savings are possible for homes.



Smart design allows winter sun in but blocks summer sun, minimizing the energy used for heating and cooling a home.

Daylighting—Passive solar goes hand in hand with daylighting—using light from the sun to replace electric lighting. Daylighting systems are designed to maximize daylight while minimizing glare. Windows can be placed so that the light distribution is even in a space. Light-colored surfaces which reflect and further distribute light and the use of glass instead of walls increases the penetration of light into a building. Combining these and other design techniques with electric lights that adjust to the amount of daylight can significantly reduce the energy used to light a building.[74]

Solar hot water—Solar water heating is another way to capture the sun's energy economically. Roof-mounted solar collectors allow solar energy to be captured and used to heat household water. Solar hot water systems generally can reduce fossil fuel use for water heating by about two-thirds.[75] Even if we assume that solar water heaters reduce energy consumption for water heating by only half, installing solar water heaters on 40 percent of America's homes would cut energy use by about 0.51 quads by 2025, saving enough energy to power 5.5 million houses[76]. Solar hot water heaters can also provide hot water for commercial and industrial use, thus producing further reductions in energy consumption.

Geothermal heat pumps—Unlike the air around us, the earth tends to maintain a fairly steady temperature over the course of the year—meaning the ground is warmer than the air outside in winter and cooler than the air outside in summer. Geothermal heat pumps use this stability in temperature to provide heating and cooling to homes and businesses. In winter, a geothermal heat pump exchanges the heat contained in the earth with the cool air inside a home, reducing the need for fossil fuels or electricity to provide heat. In summer, the process is reversed, with the warmth inside a home being exchanged with the cooler ground. Geothermal heat pumps can reduce energy consumption by 40 to 70 percent compared with other means of space heating.[77] Expanding the number of geothermal heat pumps in operation to account for 10 percent of the residential and commercial heating market could save 0.62 quads of energy by 2025.[78]

Natural ventilation—Natural ventilation takes advantage of natural wind currents and convection to cool buildings and reduce the amount of air conditioning needed. Even simple changes such as careful window and vent placement, using operable windows, and fans that distribute naturally cooler air into warmer spaces, can reduce the need for air conditioning. Ceiling and whole-building fans can drop the temperature of a building up to 9°F at 10 percent of the electricity consumption of a traditional air conditioning system. More intensive building design changes can further increase natural ventilation, such as wind towers that direct wind into a building during the day and let heat escape at night.[79]

Active Renewable Energy

Solar photovoltaic panels—Solar photovoltaic panels convert sunlight directly into electricity. They are the most commonly used renewable electricity source associated with zero energy buildings, because of their convenience. Every part of the United States receives enough sunlight to produce enough power to offset building energy use, especially in an efficient building. In addition, solar panels are low maintenance and unobtrusive.

WHAT'S A QUAD?

A British Thermal Unit (BTU) of energy is technically the amount of energy needed to raise the temperature of one pound of water by one degree Fahrenheit. Using a measure like the BTU allows us to compare fuels based on their energy value. For example, instead of having to explain the difference in energy content between a barrel of oil and a similar quantity of coal, we can use BTUs as a common means of measurement. This is particularly important in evaluating the New Energy Future target of replacing one quarter of America's total energy consumption with renewables.

On a national scale, the amount of energy we use is so large that it is described in terms of quadrillion (or "quad") BTUs. In 2005, the United States consumed just under 100 quads of all forms of energy. So, one can picture a quad as roughly equal to 1 percent of the amount of energy currently used in America every year, or enough energy to power the entire country for three and a half days. Achieving a target that would reduce our fossil fuel use by 0.5 quads would, therefore, cut our energy use by about 0.5 percent compared to today's levels of consumption.

Solar panels generate energy that powers this zero energy home in Seattle.

As solar power has become more popular, the cost of photovoltaic systems has dropped. There have also been more technological advances in solar technology that give consumers more options. Photovoltaic cells can now be integrated into the roof of a building, installed as shingles or as "thin film" photovoltaics, which can be glued directly to metal roofs.[80] Research has also shown that while photovoltaic panels are most efficient when facing due south and tilted at a specific angle, panels oriented towards the east or west at the same angle as most roofs can still produce almost as much power.[81]

Wind power—Wind turbines can be cheaper than solar panels for the same amount of electricity gained, but there are a number of disadvantages that have led to a preference for solar panels in zero energy buildings. Wind turbines cannot be connected directly to a building, and are prohibitively difficult to install in urban or high-density suburban areas. They must be placed high on towers to capture the most wind, and smaller models make a low humming noise. Moreover, sufficient wind to power a turbine is not available in every part of the United States.

Still, many parts of the United States have huge wind resources, and for consumers in very windy areas such as the Great Plains or New England, wind power often is a better option than solar power. Since wind power benefits from economies of scale(large wind turbines are much cheaper per kW than smaller models), wind can be a better option for larger buildings, especially in rural areas. Many farms and schools have already built wind turbines to offset their energy costs, and there is huge potential for large businesses to do the same, especially when combined with measures to first make the building highly energy efficient.

Wind power could become much more widespread on the residential side as well by combining a larger wind turbine with an energy efficient housing development. Community wind development has been very successful in a number of places. Most notable of these is Denmark, where a wind development model of turbines collectively owned by a community helped the country's wind industry grow to prominence.[82] The town of Hull, Mass., gets about 12 percent of its electricity from two wind turbines on town land, through the town-owned utility, and is looking to develop enough offshore wind turbines to supply the rest of the town's electricity demand. The proposal has met with little opposition, in stark contrast to the nearby Cape Wind project proposed by a private developer.[83]

Many near zero energy homes are built as part of large zero energy developments powered by solar photovoltaics, mostly in California and Arizona. As zero energy housing developments spread to areas with more wind resources than sun, developers may use the Denmark and Hull models to build developments of energy-efficient houses grouped around a wind turbine sized to provide all the energy for the community.

Case Studies

Zero energy buildings are not a fantasy; hundreds have been built, and though they cost more to build than similar houses, savings on energy bills can more than make up for higher mortgage payments.[84] While zero energy use is more difficult to achieve in buildings in cold climates, many have been built. And while some may picture zero energy buildings to be extravagant and complicated, many are in fact modest and practical. The following three case studies defy both misconceptions.

Habitat for Humanity

Habitat for Humanity is an organization that recruits teams of volunteers to build houses for low-income families. The group typically builds energy-efficient houses to keep utility costs down for the homeowners they serve. In 2005, Habitat for Humanity of Metro Denver partnered with Department of Energy's (DOE) Building America Program to build a model zero net energy house.

The resulting1,200 square foot, 3-bedroom home had to be built in a way that balanced the goal of zero net energy use with practical considerations. The project needed to be easily replicable by Habitat For Humanity, and user-friendly for the future owners. The design team made sure that the building would be just as simple to operate as a typical home, that all technologies used were readily available and replaceable by any technician, and that there were no complicated mechanical systems.[85]

Usually, Habitat for Humanity homes are 20 to 30 percent more efficient than code requires, through better insulation, efficient appliances, compact fluorescent light bulbs and passive solar orientation when possible.[86] To get this already efficient home to zero net energy use, Habitat ramped up efficiency measures even further. They maximized passive solar energy by placing many windows on the south side of the house, with roof overhangs to block the sun in the summer, and by using energy-efficient windows that minimize heat transfer on windows on the other sides of the house.

Designers placed the natural gas heater to feed directly into the living and dining rooms, making ducts unnecessary. They also designed the ventilation system so that instead of releasing warm exhaust air, the system cycles the exhaust air back to heat incoming fresh air. Solar water heating further reduced the home's use of energy. A 4-kilowatt photovoltaic system was sized to offset the rest of the house's expected energy needs.[87]

Habitat For Humanity built this zero energy home in North Carolina. Solar offsets the little energy that the home uses, which keeps heating and cooling prices very low for the owners.

This zero-energy home takes advantage of constant temperatures underground to cool and heat its rooms. When power is required, it draws from energy generated by solar panels.

The house produced 2,347 kWh more electricity than it used, far surpassing the 560 kWh needed to compensate for the cost of the natural gas used in the home.[88]

Ideal Design

Ideal Design is a private building company in Oklahoma that specializes in highly efficient homes. In 2005, Ideal Design built the country's first zero energy home priced under $200,000. The building is 1,650 square feet and has three bedrooms and two bathrooms, and is based on one of Ideal Design's stock floor plans.

In order to increase the efficiency of the home, Ideal Design used better insulation and air sealing, energy-efficient windows, more efficient appliances, a tankless heater, more efficient ducts, compact fluorescent lighting, and an efficient ventilation system. In addition, they used a geothermal heat pump to reduce energy costs even more. Some measures considered, such as a solar hot water heater and ducts routed through conditioned spaces, were rejected due to price considerations. To reach net zero energy use, the house was fitted with a 5.3kW photovoltaic system.

Ferreira Construction Zero Net Energy Office

In 2006 Ferreira Construction, a New Jersey construction company, built what they claim is the first zero electricity commercial building. The building is a 41,500 square foot shop and office building. Ferreira used technologies such as a solar hot water system, daylighting, compact fluorescent lights paired with light sensors, and a high efficiency Energy Star HVAC system to reduce the load on their 223kW photovoltaic system. Ferreira also estimates that they've reduced at least 5% of their energy use through occupant participation – employees and visitors see the real-time energy monitor display in the lobby of the building and voluntarily contribute by turning off computers at night and not using the elevator.[89] In their first year of operation, the solar panels generated enough electricity to provide 13 months of operation.[90] Some of the cost was offset by state grants, and they expect the payback period to be between five and seven years, lower than expected because of rising energy prices and refinements to their system.[91]

Ferreira still uses natural gas for heating, but uses 77 percent less gas than a base model for the project.[92] Most of the savings were achieved by using radiant flooring to heat the building – hot water pumped through tubes installed in the floors – paired with an extremely efficient boiler. The building is also makes some use of extra insulation and passive solar heating. The building managers have found that not only does the radiant flooring provide very efficient heat, it also creates a more comfortable environment. When the large bay doors in the shop area are opened, the radiant flooring keeps the area at a much more constant temperature than a typical hot air system would. The company is looking at replacing the natural gas fuel source with a geothermal heat pump or solar thermal panels, to make the building 100 percent zero energy and eliminate its carbon emissions entirely.[93]

The Ferreira Construction building in New Jersey is the first zero electricity commercial building.

Policy Options

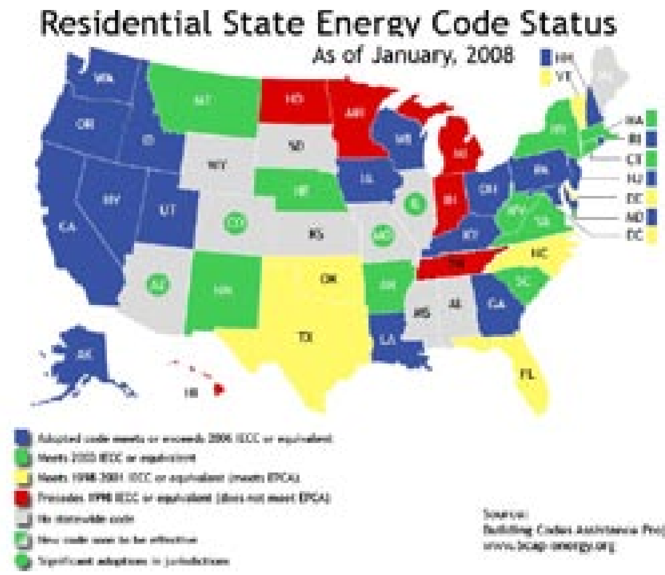
With all these technologies available, it's clear that we can and should be building and renovating homes and businesses to be much more energy-efficient, and setting ourselves on the path toward zero energy buildings as the standard. However, there are a number of barriers that will prevent progress unless we implement strong policies to overcome them.

Despite higher upfront costs, high efficiency buildings are ultimately cheaper for home and business owners. But "split" incentives often stand in the way of realizing these benefits: a builder or landlord doesn't want to pay upfront costs that will save money for buyers or renters.[94] This especially affects multi-family homes. In addition, many building firms are small and therefore unwilling to take risks by using practices and technologies they aren't used to.[95,96]

Compounding this problem is a general lack of awareness about the potential for energy savings in buildings, and the benefits that often come with higher efficiency, beyond their societal importance. When buying or renting, consumers often don't have the information they need to choose more energy-efficient properties. On the commercial side, energy expenses are often a small share of total expenses and therefore overlooked.

Moreover, "green" buildings are perceived as expensive, an optional added luxury, when in fact choosing energy efficient and zero energy techniques can be a way to save money over the long term; as we've seen, some techniques, such as orienting a building differently to maximize sunlight or reducing the size of the HVAC system, have no added upfront cost and can even lower the upfront cost of a building or renovation.

Public policy should be designed to eliminate these market barriers and to push new technologies into the marketplace so that they can become mainstream.



Most states have not yet adopted the most recent commercial and residential building codes.

The experience of California shows how aggressive public policies can eliminate barriers to energy-efficient building. California has long been a leader in energy efficiency. It was the first state to adopt energy efficiency standards for home appliances, has the nation's most stringent building energy codes, and has long had well-funded, aggressive programs for promoting energy efficiency. While homes have become more efficient across the United States, California has truly excelled. On a per capita basis, the country used 16 percent less energy in homes in 2002 than it did in 1975. But in California, residential energy use declined by more than 40 percent per capita between the mid-1970s and 2002.[97]

If the United States had achieved the same per capita percentage reduction in residential energy use between 1975 and 2002 as California did, the nation would have consumed more than 3 percent less energy in 2002. Moreover, residential energy consumption in the United States would have been 17 percent lower in absolute terms than it was in 1975, rather than 12 percent higher.[98]

These changes can, and should, be replicated in other states and on a national level. We need both policies that establish a minimum standard for building energy efficiency, and those that encourage building far beyond those standards to put us on the path towards zero energy building.

Building energy codes

Building energy codes regulate energy use in new buildings and major renovations, and strengthening the codes is the best way to affect the bottom line standard for building efficiency.

In general, building energy codes are adopted at the state or local level and based on national model codes. These model codes and standards are updated every few years and states and localities have the option of adopting them once the updated version is published.

Though many states have adopted the latest model codes, most have not, and some do not have any statewide code. In addition, in many states enforcement of the codes is severely lacking—compliance is estimated to be 40 to 60 percent for new buildings, depending on the state, and this number is even probably lower for renovations.[99] Building code agencies tend to be understaffed and understandably prioritize health and safety code enforcement while energy code enforcement falls by the wayside. A lack of training in energy code enforcement among officials and builders and designers compounds the problem.[100]

The potential for saving energy through building codes is huge. If all states adopted building energy codes that are 30% more efficient by 2015 and 50% more efficient by 2025, and enforced them with 90 percent compliance, we would use 2.6 fewer quads of energy in 2030 – almost 3 percent of our current annual energy use. This would also reduce our carbon dioxide emissions by 41 MMT and save consumers $25.5 billion annually. Under this scenario, cumulative savings through the year 2050 would be 111 quads of energy and 1,757 MMT of carbon dioxide emissions.[101]

There is a wide array of policies that could improve building energy codes across the country and ensure that they are better enforced.

Strengthening building codes

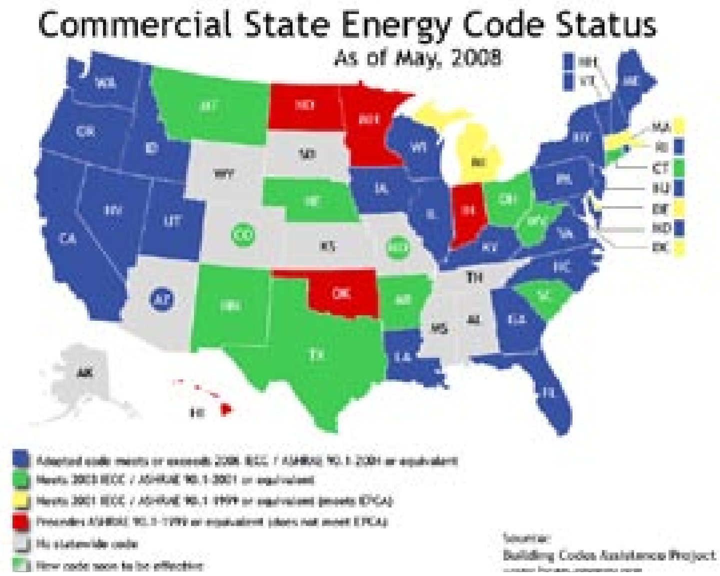
Increasing the efficiency required by the model codes is the best way to affect the bottom line standard for building efficiency. Almost every state has standard energy codes for new residential and commercial buildings. Most of these are based on national model codes: the International Energy Conservation Code (IECC) for residential buildings, and the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) Standard 90.1 for commercial buildings. Both of these codes are updated every few years, and states are required by federal law to either adopt the new version, or explain why they chose not to.

Increases in the efficiency mandated by these codes have been small and incremental in the past. However, in the current cycle the ASHRAE board has set a goal to make the 2010 commercial standard 30 percent more efficient than the 2004 version. The Energy Efficient Codes Council (EECC), made up of a number of energy efficiency organizations, proposed changes to the 2009 IECC residential code that would increase its efficiency by 30 percent; enough of these changes passed the first round of decision-making to significantly increase energy efficiency. In the second round of voting, the full 30 percent could be reinstated for the published version if enough code officials turn out to vote for energy efficiency. Either way, it is likely that the energy efficiency required by the 2009 IECC model code will be significantly improved compared to the 2006 version.

In the near future it will be important to ensure that the model codes are published with these efficiency increases, and that all states adopt the new codes. This is a critical strategy to improve the majority of buildings, but it is also vital that we set our sights much higher and put the country on a track towards net zero energy homes. The California Public Utility Commission has set a goal of net zero energy codes for all new residences by 2020, and all new commercial buildings by 2030.[102]

Once model energy codes are improved, states must adopt them in order for them to have any effect. Only 18 states have adopted the

Residential building codes, in enforced, could save money for new homebuyers.



More states have adopted up-to-date commercial codes than residential codes, but code adoption is still inconsistent across the country. Requiring all states to have up-to-date codes for both commercial and residential buildings would save a huge amount of energy.

most recent residential model codes or equivalents, and only 24 states have adopted the most recent commercial energy codes. Sixteen states currently have building energy codes that date to 1998 or prior, or no statewide code, despite significant increases in the strength of building energy codes since then.

So although it looks likely that the model code will be updated to reflect some of today's potential for building energy efficiency, it is much less certain that they will be adopted and enforced on a short timeline across the country. Eliciting strong leadership from governors and mayors in the form of executive orders to meet specific goals will help both in ensuring that the model codes are strong and that they're quickly adopted and enforced.

In the longer term, it will be important to ensure that states continually update their energy codes to match the increasing efficiency of the model codes. Some states, such as Pennsylvania, have language built into their code legislation that requires them to update their energy codes to the latest model codes. The Northeast Energy Efficiency Partnership (NEEP) is developing model state energy code legislation that would provide for the adoption of the latest version of the national model codes within one year of any revisions, with no amendments that would increase energy consumption in buildings. Even more effective would be a national requirement that states adopt codes that match or exceed the efficiency of the latest model codes.

Enforcing codes

Enforcement of building energy codes is often lax; depending on the state, compliance can be as low as 40 percent for residential energy codes, and some jurisdictions don't enforce the energy codes at all.[103] NEEP's model legislation includes provisions that would increase compliance with energy codes by requiring specific energy code training for all officials and inspectors, and requiring that all new construction and major renovations pass inspection by third party certified inspectors.[104] On the national level, legislation requiring state adoption of the model codes could also require states to achieve 90 percent compliance with their updated codes within a certain time period.

"Commissioning" refers to a process through which third-party evaluators ensure that buildings perform as designed with respect to system operations. Some state legislation requires that all buildings over a certain size undergo commissioning, which improves energy code compliance and building performance.

Going beyond code

Establishing a baseline standard for efficiency through building energy codes is important in order to ensure that all new buildings at least meet the minimum of what is possible for energy efficiency. With so much potential for energy efficiency, however, policies that encourage building far beyond code can have a huge impact.

A recent McKinsey report calculated that annual energy consumption in residential and commercial buildings could be reduced by 11.1 quads in 2020 through cost effective changes such as lighting and appliance replacements for a cost of $21.6 billion per quad.[105] That is, if we invested $21.6 billion a year for five years on building efficiency through federal programs—a small portion of the recent $168 billion economic stimulus package—we would use 5 fewer quads of energy a year and emit 433.6 MMT less carbon dioxide.[106]

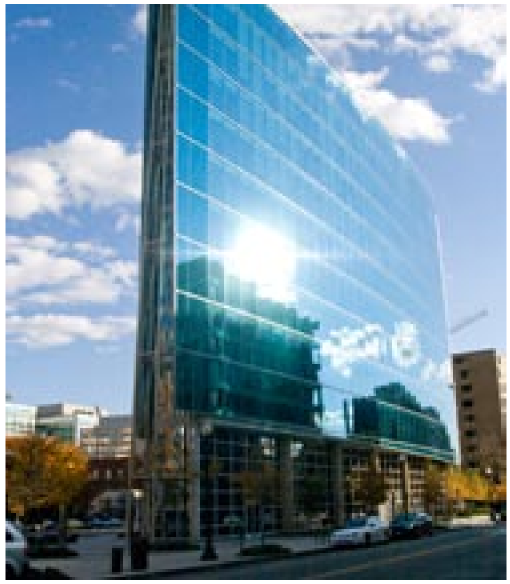
Many of these policies are especially suited to encourage higher efficiency through retrofits and renovations. These policies are also necessary to gain wider acceptance of new building methods and technologies, so that we can keep raising the minimum energy efficiency called for in the codes.

Time-of-sale energy audit—A time-of-sale energy audit requirement would establish a scoring system for building energy use. Massachusetts has introduced legislation which, if passed, would mandate the development of a home energy scoring program, and require that licensed personnel score any house with less than five units at the time of sale. The legislation would also require home sellers to provide potential buyers with copies of utility bills. This would give consumers the information they need to consider efficiency when buying a home, and provide an incentive to increase energy efficiency in both new buildings and renovations and through retrofits.

Stretch codes—"Stretch codes," standards that may be adopted by jurisdictions that want energy codes that are more stringent than the state code, can be included in state building energy codes in an "Informative Appendix," which provides information without requiring adoption. In NEEP's proposal, these standards would reduce energy use by a minimum of 20 percent and ideally 30 percent, above the state code.[107] Including stretch codes makes it much easier for cities and counties to improve the efficiency of their building codes.

Incentives—Incentives encourage building beyond code by lowering the upfront cost of building efficiently. Many local and state jurisdictions have tax incentives, tax deductions and/or rebates for energy efficient building. These are also the policies most often used to encourage retrofits.

In 2005 the federal government established the first comprehensive set of tax incentives for new buildings that use 50 percent less energy than typical building, through the Energy Policy Act of 2005



The National Association of Realtors building in Washington, D.C., was the first LEED certified building in that city in 2004. It achieved this certification partly due to being 30 percent more efficient than ASHRAE standards require.

(EPACT 2005). EPACT 2005 also set up incentives for highly efficient heating and cooling equipment and appliances. However, some of these tax incentives expired at the end of 2007 and others will expire at the end of 2008, too short a time for most taxpayers to use them. These incentives were not renewed in the latest energy bill, and should be extended and increased to encourage efficient building in the next bill.[108]

Tax incentives are also highly effective at the state level. In 2007, New Mexico enacted a "Green Building Tax Credit," which extends some of the federal credits and also enacts stronger ones of its own, based on square footage, a green building rating and energy efficiency.[109] Oregon also enacted tax credits for energy-efficient building practices in 2007, with separate programs for residential and commercial buildings.[110] These tax credits can amount to thousands of dollars and large percentages of the incremental costs, making a significant difference in the ability of homeowners to save energy.

Utilities can also provide incentives for builders to build green. Some utilities have goals for efficiency that they must reach, and it is therefore in their best interest to provide incentives for consumers to increase their buildings' efficiency. These incentives are often funded by a systems benefit charge, whereby a fee on utility consumers' bills is used to fund incentive programs for consumers to reduce their energy consumption.

Funding for research and technology development—There is huge potential to improve energy-efficient technology, and to find ways to make it available and affordable on a wider scale. Building America is a program sponsored by the DOE that conducts research with the long-term goal of developing cost-effective net zero energy use homes. The program is a private/public partnership and works to develop energy-efficient techniques to improve both new and existing homes.[111] Funding for programs such as this helps bring even higher levels of energy efficiency within our grasp.

Weatherization assistance program—For three decades, the federal government has been providing grants to state agencies that help low-income households improve their energy efficiency through the Weatherization Assistance Program. A recent evaluation of the program in 19 states found that the program reduced natural gas consumption for space heating in affected homes by approximately 32 percent.[112] Recently, this program has been threatened; instead it should be expanded to provide even further to reach more homes and provide even greater energy efficiency improvements.

Energy star—Energy Star is a rating program for homes, businesses, appliances and efficiency techniques, jointly administered by the U.S. Environmental Protection Agency and the U.S. Department of Energy. Appliances that are Energy Star rated are also at least 15 percent more efficient than standard appliances, and the label allows consumers to choose energy-efficient products.

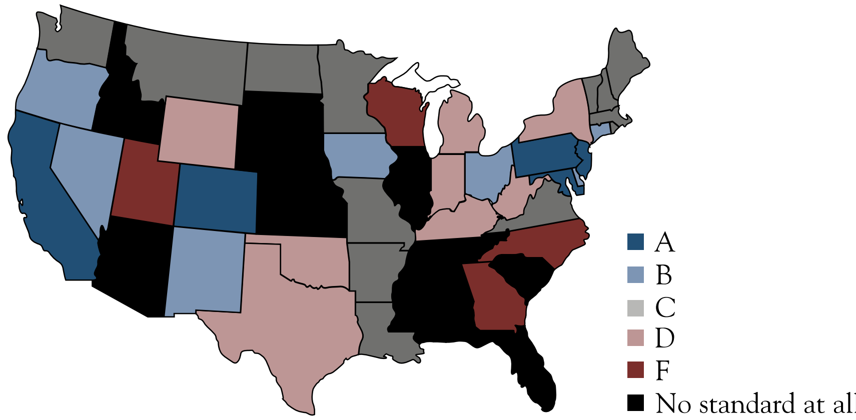
For homes, Energy Star uses a Home Energy Rating System (HERS) to score a building from zero to 100, with a building that meets minimum codes rated at 100 and a net zero energy use building rated at zero. Energy Star certified buildings are at least 15 percent more efficient than code, and often as much as 30 percent more efficient.[113] Though this is small compared to the energy savings possible in buildings, as codes improve, by definition the Energy Star program also improves. Energy Star is a great resource for builders and renovators who want to exceed the code and for homebuyers who can use the Energy Star rating to find a house that will save them money on utility bills.

LEED—LEED (Leadership in Energy & Environmental Design) is a popular green building rating system that provides certification for green building, awarding points for meeting specific performance criteria. It was first developed by the United States Green Building Council (USGBC) in 1999, and has since become an internationally recognized standard. LEED-certified buildings are rated at one of four progressively stringent levels: certified, silver, gold, and platinum. Energy efficiency and on-site renewables are covered by the "Energy and Atmosphere" credits, which requires commissioning and energy efficiency above code, and rewards more points for higher efficiency and onsite renewable energy. The average LEED Home in USGBC's pilot program uses 40 percent less energy than a typical home.[114]

Energy efficiency and on-site renewables are only one part of LEED certification, which also looks at a building's effect on water use, runoff, transportation, and inhabitants' health, among other criteria. While these diverse stresses that buildings put on the environment are not the focus of this paper, they certainly should be minimized when possible. Moreover, minimizing these effects often saves money, through lower utility bills beyond energy savings, and for workspaces, through higher worker productivity.

Some state and local governments are beginning to look to LEED as a comprehensive standard for green building. Connecticut has legislated that new commercial buildings projected to cost more than $5 million must achieve a silver rating from LEED starting in 2009, and all major renovations over $2 million must do the same starting in 2010.[115] Oregon's Business Energy Tax Credit provides a 35 percent rebate for LEED certified commercial buildings, based on the square footage of the building being renovated or built.[116]

Net metering allows homes that generate power to sell it back to utility companies.



States with net-metering laws. Not all net-metering laws are the same. Some programs allow full net-metering, while others limit the amount of energy that consumers can sell back to the utility company. States here graded by the quality of their net-metering policies.[118]

Getting to zero

Zero energy buildings require small-scale renewable power to cancel out the small amount of energy they use. While solar power and small wind turbines are becoming more common, there are a number of barriers to their widespread use. Policies in many states make it difficult to connect a small system to the grid, or limit the amount of electricity a household or business will be compensated for. And while solar panels can ultimately save money over time, the up-front cost of adding any of these systems is prohibitive for many.

Currently, electricity in the United States is supplied from large, centralized power plants. Distributed generation is a new model in which electricity is supplied by small, usually renewable generators owned by individuals and businesses to offset their power needs. This model better serves consumers by making prices more stable, reducing the amount of electricity lost in transmission, and making our power supply less vulnerable to large-scale failures, in addition to the environmental and national security benefits of local, renewable power.[117] Distributed generation also serves utilities by reducing the need to find new sources of power, and, in the case of small solar systems, supplying extra power at the times when demand is highest.

However, utilities inexperienced with distributed generation worry that it will make the grid unstable or pose a safety hazard and reduce their revenue.[118] In many states current policies cater to utility fears and discourage small generators; instead, states should design policies to empower home and business owners to add renewable systems to their buildings.

Net metering and interconnection standards—Net metering requires utilities to buy energy from small, grid-connected generators such as solar panels by running the electric meter backwards when a building is producing more energy than it is using, or by crediting the electricity bill for excess electricity. This allows homes and businesses to use energy from the grid when on-site generation isn't sufficient, and sell energy back to the grid when it's generating a surplus.[119]

Thirty-nine states currently have net metering laws, but not all net metering policies are equally strong. Some state policies restrict eligibility for net metering, usually so that commercial and industrial buildings cannot connect, or limit the size of generators eligible for net metering. Some limit the amount of energy that can be sold back to the utility, or don't allow excess generation to roll over from month to month. Others limit the total amount of energy in the grid that can be supplied by distributed generation.[120]

Interconnection standards regulate the process that a customer must go through in order to connect a generator to the grid. In some states, this process is lengthy and expensive, complicating the installation and adding to the cost of installing a system through fees and additional labor expenses.[121]

State policies should attempt to increase distributed generation and make it easier for home and business owners to install small renewable systems. A good example of a state net metering policy is New Jersey. In 2004 the New Jersey Board of Public Utilities (BPU) changed the state's policy with a goal of encouraging renewable energy, partly to help meet the state's Renewable Portfolio Standard (RPS). The BPU expanded the types of systems that are eligible, established credits for excess generation, simplified and accelerated the interconnection process, and increased the limit on the size of individual systems to be one of the highest in the country. Because of these changes, New Jersey now has the highest rate of net metering enrollment of any state.[122,123]

Incentives—Incentives can have a huge impact in reducing barriers to the wider use of on-site renewables. In addition to reducing the upfront costs to consumers in the short term, by increasing the market for renewable systems incentives can lower the cost of the systems over time, eventually eliminating the need for incentives. In California the price of retrofitted residential solar energy systems dropped by 36 percent from 1998 to 2004 because of a strong incentive program.[124]

Renewables in new buildings—Rewiring a home or business for on-site generation adds to the cost of installing solar panels or other renewable power. In states with a large potential for solar power, requiring that all new homes have hook-ups for photovoltaic and solar hot water systems would remove a significant barrier to new installation. California, as part of its ground-breaking Million Solar Roofs legislation, mandates that solar panels become a standard option for all new houses by 2011.[125]

Recommendations

We need to put America on the path toward zero energy buildings, and start taking advantage of all the energy efficiency techniques that are available and cost-effective today. Every new building or renovation that does not improve energy efficiency locks in pollution for decades. Quick action will require strong leadership from policy-makers to make energy-efficient buildings the standard.

1. Government leaders should commit to a goal of zero energy buildings for all new construction starting in 2030.

2. Building energy codes should be improved and enforced:

a. The ICC and ASHRAE should update the next versions

State programs, such as the Million Solar Roofs program in California, provide the kind of incentives needed to push energy efficiency and renewable energy in the states.

of the model codes to require a 30 percent increase in energy efficiency of buildings;

b. The federal government should exercise their authority to require all states to adopt model codes or equally energy efficient codes soon after any updates, and to enforce the codes much more stringently

c. State and local governments should pass legislation requiring adoption of model codes soon after they are updated and set high goals for enforcement;

d. Federal and state policy should provide for increased training of relevant officials and require commissioning of large buildings that are newly built or renovated

3. Federal, state, and local governments should pass policy packages that encourage building far beyond code and retrofitting existing buildings for increased efficiency:

a. Federal and state officials should work to mandate uniform home energy rating systems and require disclosure of a building's energy rating at the point of sale;

b. Federal and state policy should include "stretch codes" that can be adopted by jurisdictions that want to go farther than the code;

c. Incentives that encourage energy efficient retrofitting and building beyond the model code should be ramped up at all levels, including the federal government, state governments, and utilities;

d. Funding should be increased for other government programs that increase the reach of energy efficient building technologies, such as the Weatherization Assistance Program and Building America;

4. Policies should be designed to encourage on-site renewable power:

a. States should improve net metering and interconnection laws to encourage distributed generation;

b. Federal and state incentives for renewable technologies should be established or increased;

c. Where appropriate, state governments should require all new houses to have solar power as a standard feature.

As this paper demonstrates, we have the technology to save ourselves from the impending energy crisis, through new and traditional techniques that increase building efficiency and allow us to provide any remaining building energy needs with clean, renewable fuels. Strong policies can put these building methods and technologies into widespread use so that inefficient, wasteful buildings are a thing of the past. All we need is the commitment to make this vision a reality.

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