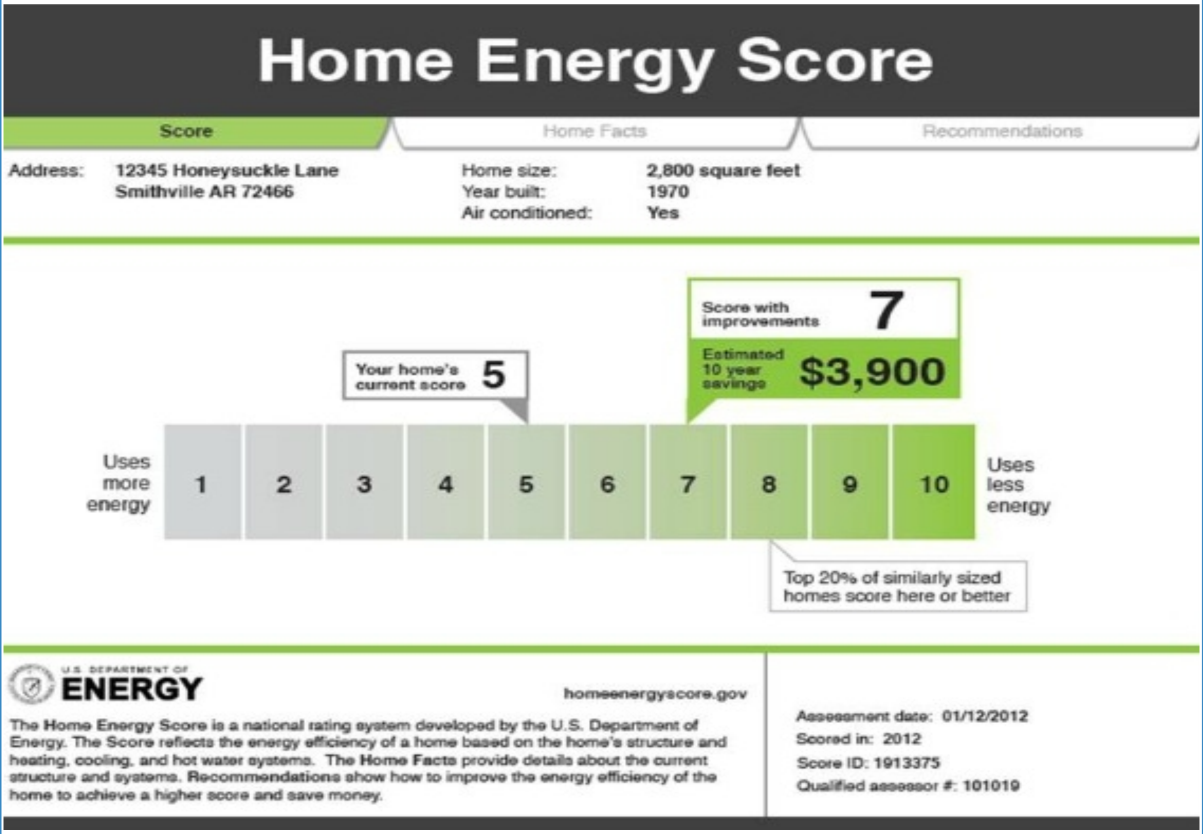
Dovetail Partners Consuming Responsibly Report No. 9

Reducing Home Energy Consumption



Jim L. Bowyer

Ed Pepke, Ph.D.   Harry Groot   Chuck Henderson

Gloria Erickson   Kathryn Fernholz   Mark Jacobs

Dovetail Partners, Inc.

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Reducing Home Energy Consumption

Executive Summary

Improving the energy efficiency of existing residential buildings and residential construction are key to reducing reliance on fossil fuels and lowering greenhouse gas emissions. Energy conservation measures on the part of homeowners, modest to deep energy retrofitting of existing buildings, and building new to high energy efficiency standards all hold considerable promise for reducing energy use and associated emissions, and for reducing energy bills of homeowners.

Because of the current large inventory of residential structures in the U.S., Canada, and throughout Europe, and the current slow rate of older building replacement, it is important that energy retrofits of existing buildings be given high priority. Because of this, the U.S. federal government and various states offer a range of financial and other incentives to those who wish to upgrade their home's energy performance. Similar programs operate in a number of other countries.

While energy related requirements of building codes are slowly evolving to require greater energy efficiency, current technology allows building to a far greater level of efficiency than attainable through code compliance. In the U.S. and Canada the ENERGY STAR program and various nongovernmental voluntary green building standards and organizations, including LEED, Green Globes, the Net Zero Project, and others provide resources to assist in achieving maximum efficiency.

Residential Energy Efficiency and Improvement Potential

There are approximately 139 million housing units in the U.S[1] of which about 122 million are occupied at any one time. The majority (70%) of occupied units are single family homes; the percentage rises to 76% when manufactured homes are included.[2]

In 2018 residential buildings accounted for 21% of the energy consumed in the United States, translating to consumption of over 21 trillion Btu (210 petajoules) of energy.[3] Residences also accounted for one-fifth of U.S. greenhouse (GHG) emissions. There is considerable potential for reducing these numbers through energy conservation, energy retrofits of existing homes, and building new for maximum energy efficiency.

The simplest and most cost effective approach to reducing energy consumption is energy conservation – taking simple steps to save energy. Things such as turning off lights when leaving a room, shutting off power to electronics when not in use, lowering thermostat settings in winter and raising them in summer, dialing back the heat setting on the water heater, and reducing use of hot water can result in significant energy savings. As indicated later in this report, change can be automated in many cases by installing readily available and inexpensive devices.

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[1] Federal Reserve Bank of St. Louis (2019)
[2] U.S. Census Bureau (2018)
[3] EIA (2019)

Another avenue for improving energy efficiency is through modification of existing homes. A recent study by the National Association of Home Builders found a rate of older home retirement of 0.6% annually, and as low as 0.1% annually when manufactured homes are taken out of the mix. Conversely, new homes are being built at an annual rate of 1.1 to 1.2 million annually, a number only modestly greater than the rate of housing unit retirement.[4] An obvious conclusion is that existing buildings will dominate the nation's housing inventory for many decades to come, and that attention must be given to the energy performance of existing homes if timely progress is to be achieved in reducing residential energy consumption and associated GHG emissions. A similar situation exists in Europe.

The most significant issues with older homes are inadequate insulation and leaky building envelopes. While it is obvious today that exterior walls need to be insulated, surprisingly, most homes built before 1960 in the U.S. (29% of the housing stock) have no wall insulation, unless done subsequent to construction (Table 1). Homes built in the following decade may or may not have insulation within the wall cavities, but if they do, insulation is likely to be minimal, again unless modified following construction. Since 1970, building codes across the U.S. have required insulation, with standards increasing modestly since then. However, throughout that period, up to the present, meeting of code requirements has resulted in a level of energy efficiency far short of what is achievable.

Table 1
U.S. Occupied Housing Statistics - 2017

Year of Construction	Percent of U.S. Housing Stock [a/]	Wall Insulation in Original Construction [b/]
1959 or earlier	28.9%	No
1960-1969	10.4%	About a 25% chance if built prior to 1965. Thereafter, likely 2", R-8 wall insulation
1970-1989	28.5%	Yes – R-11 most likely
1990-2017	45.8%	Yes- R-13 most likely

[a/] U.S. Census Bureau (2018)
[b/] Adams (2012)

Just as use of wall and attic insulation is recognized today as an obvious requirement in creating an energy-efficient building, so too is sealing of the building envelope to prevent both exfiltration of conditioned air and uncontrolled infiltration. Air leakage around improperly fitted and sealed window and door frames, corners, electrical outlets, water and gas connections, and other areas can result in substantial energy loss in buildings. The lack of attention to building tightness is especially common in older homes.

Because the older the home, the less likely that the building envelope will be adequately insulated, sealed, and ventilated, the oldest dwellings (those built prior to 1970) are the most logical targets for immediate attention.

[4] Emrath (2018)

Home energy performance improvement can take many forms, ranging from adding blown insulation to walls, ceilings, and basements, weather stripping door openings, and caulking to combat air leakage to what is known as a *deep energy retrofit*. The latter approach involves systematic assessment of all energy loads including space conditioning, heating of water, lighting, appliance efficiency, and outlet loads. Replacement of mechanical systems, windows, and even appliances may be part of such an effort. Incorporation of renewable energy systems (Figure 1) and passive solar design is also common in such projects. Reductions of energy consumption as great as 90% can be achieved, with total or near-total reduction of the need for energy from the electricity distribution grid.

Figure 1
Solar Panels on New Homes

Source: U.S. Department of Energy

In a series of three articles with the provocative title *How to Destroy the Planet from the Comfort of Your Own Home,* the history of a 111 year-old home in Oakland, California, and its environmental impacts over time are chronicled.[5] When new, the structure had minimal insulation in the walls and attic, and no basement insulation, with the result that prodigious quantities of energy (~1,200 pounds of coal each month) were required for heating. Despite the high environmental (and energy) costs year after year, the building's original insulation remained unaltered for over a century. However, demonstrating both the need for attention to energy performance of existing buildings, and the possibilities for substantial improvement, a deep energy retrofit of this home resulted in the oldest net zero home in the United States.

A third approach to improving energy performance of the nation's housing stock is new construction, and it is this route which offers the potential for the most dramatic and long-lasting change. Today's technology allows construction of net zero buildings, even in the coldest and hottest climates. What this means is that it is possible – economically so – to create structures that require no energy to heat, cool, or otherwise operate beyond renewable energy created on site.[6] Net Zero represents the ultimate in energy performance.

Short of achieving a net zero standard in new construction, greater attention to construction details and systematic consideration of building dynamics can also yield considerable improvements in energy performance relative to traditional construction. High energy performance is promoted through the Department of Energy's ENERGY STAR Certified Homes program.[7] The ENERGY STAR program (Figure 2) is operated by the Environmental Protection Agency and provides a set of guidelines which typically result in 30% or greater energy efficiency than that obtainable through common practices and 15%

[5] Grocoff (n.d.)
[6] Zero Energy Project (2018a, b)
[7] ENERGY STAR (2019)

greater efficiency than compliance with state building energy codes.[8] Natural Resources Canada also operates an ENERGY STAR certified homes program.

Currently, less than 20% of new homes in the United States are built to ENERGY STAR standards, with only a small fraction to a net zero standard. Low consumer demand for ENERGY STAR homes has been attributed to a number of factors, including higher first costs of such buildings (and higher mortgage payments), a lack of consumer awareness of the ENERGY STAR for homes program, and failure of mortgage lenders to engage in promotion of energy-efficient mortgages which help to offset higher costs of efficient buildings.[9]

A number of non-governmental certification programs such as LEED for Homes, Green Globes, Greenbuild, Built Green, EarthCraft House, and the Net Zero Project also promote energy efficiency of residential buildings, with substantial market share of certified residences under these various programs in some regions. Such activity is increasing across the U.S.[10]

Figure 2
Energy Star Logo

energy
ASK ABOUT
ENERGY STAR
CERTIFIED HOMES

energystar.gov

Energy Codes – Their Importance and Evolution

The first energy efficiency standards for residences in the United States were developed in the 1950s by the Housing and Home Finance Agency (now HUD). It was not until the early 1970s oil crisis that the concept of a national building energy standard gained traction. The first published energy standard was released as a model code in 1975 by the American Society of Heating, Refrigeration and Air Conditioning as ASHRAE 90-75.

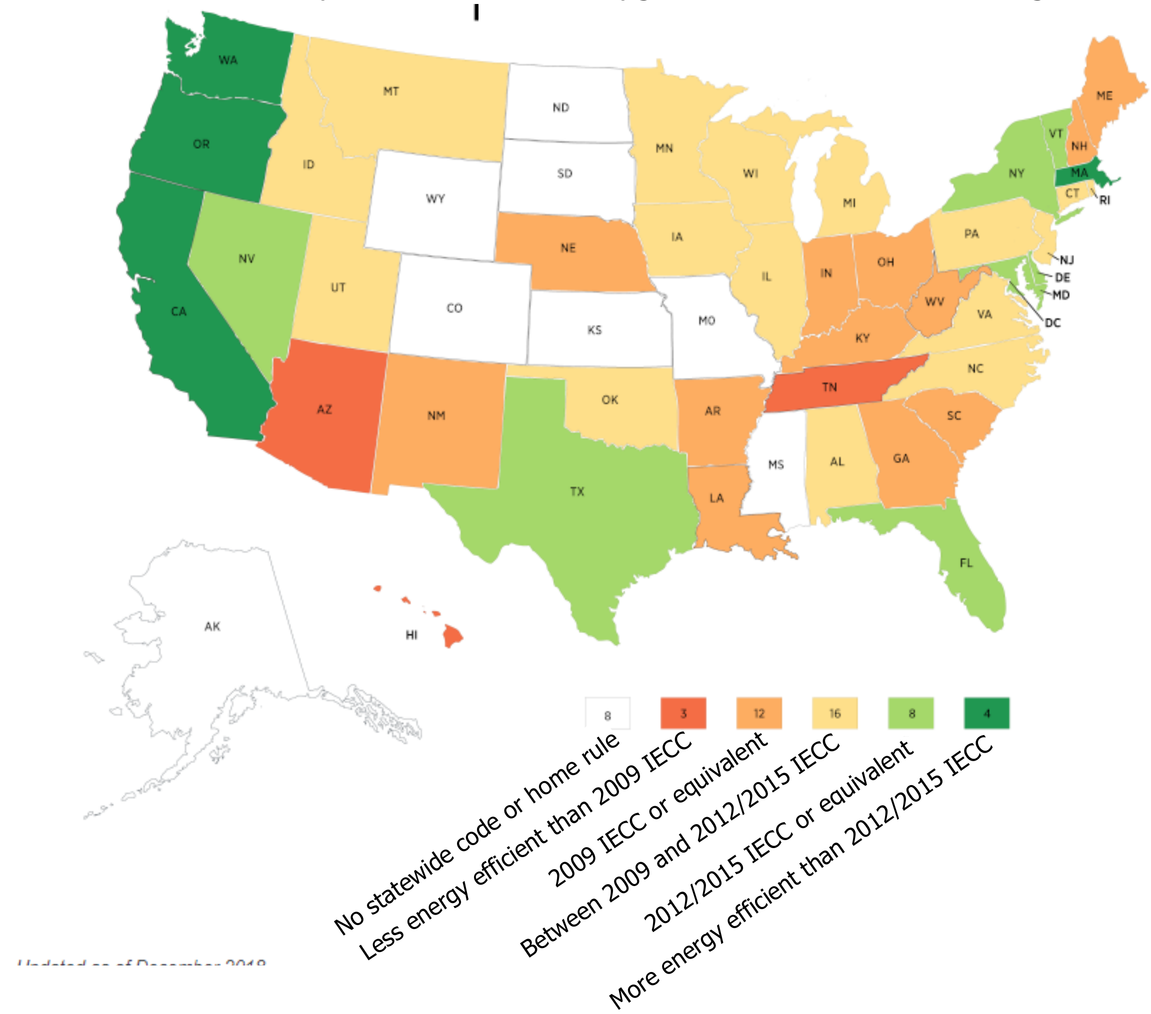
Congress also reacted to the early '70s oil crisis with passage in 1975 of the Energy Policy and Conservation Act (EPCA), which included a mandate to reduce energy demand and promote energy efficiency. By the mid-1970s, helped by the availability of newly developed and relatively low cost fiberglass insulating products, wall insulation in new homes became common across the U.S., with insulation thickness greater than in earlier years.

Today, the U.S.-based International Code Council has responsibility for maintaining a national model energy code for buildings (the International Energy Conservation Code – IECC). The model code is revised every 3 years through a national consensus process, each time triggering review by the Secretary of Energy and subsequent assessment of state code requirements by each of the states.[11] Analysis by the Department of Energy in 2016 determined that the three most recent editions of the IECC and ASHRAE 90.1 (2009, 2012, 2015) had the potential to reduce energy consumption by 30% compared to codes of just a decade earlier.[12]

8 Alliance Commission on National Energy and Efficiency Policy (2013)
9 McGlashen (2010)
10 Dodge Data and Analytics (2015)
11 U.S. Federal Register (2011), Alliance Commission on National Energy and Efficiency Policy (2013)
12 Athalye et al. (2016)

The approaches of different states to model code revisions have varied considerably (Figure 3). Whereas eight states have no statewide code, four – California, Oregon, Washington, and Massachusetts – have code requirements that exceed model code provisions of the latest (2015) IECC. California, for example, recently enacted legislation that requires solar panels on all new homes by 2020. Interestingly, Arizona, where state codes are less energy efficient than the 2009 IECC, had the highest ENERGY STAR market share in new home sales (59%) of any of the 50 states.

Figure 3
State Adoption of Latest IECC Upgrades for Residential Buildings



Updated December 2018

Source: U.S. Department of Energy (2018)

Canada has a national building code similar to that of the U.S. The latest version (2015) contains robust energy efficiency provisions that only come into force upon adoption of laws and regulations by provinces and territories. Jurisdictions may also choose to adopt stricter energy requirements to promote greater energy savings.[13]

[13] Natural Resources Canada (2019)

The European Union has a comprehensive and mandatory code system.[14] Member countries are required to comply with the Electronic Energy Performance of Buildings Directive (2010/31/EU) and an Energy Efficiency Directive (2012/27/EU).[15] These directives contain, among other provisions, requirements for:

- Establishment of energy performance requirements for new buildings, the major renovation of buildings, and for the replacement or retrofit of buildings.
- Certificates that must be included in all advertisements for the sale or rental of buildings.
- Periodic inspection of HVAC systems.

In November 2016 the European Commission adopted a "Clean Energy for All Europeans" measure (also known as the "Winter Energy Package") that updates provisions of the 2010 directive, providing guidance for meeting 2030 energy and climate goals. A 2018 revision of Directive 2010/31/EU reflects requirements set forth in the clean energy measure, and established a 20-month deadline for adoption by all member countries.

EU energy efficiency initiatives are based in part on determination that about 35% of buildings within Europe are over 50 years old and that almost 75% of the building stock is energy inefficient. Similar to the U.S., only 0.4-1.2% (depending on the country) of the building stock is renovated or replaced each year, a finding that inspired regulation of energy efficiency upgrade at the time of building renovation or retrofit.[16]

Maximizing the Energy Efficiency of Your Home

Energy Conservation

The following energy conservation actions require little in the way of investment, but change home dynamics more or less automatically. Significant energy savings can be achieved.

- Installation of a programmable thermostat. These generally cost less than $40, are easy to install, and can reduce heating and cooling costs by as much as 10% per year.
- Installation of motion detector switches in bedrooms and bathrooms and other high use areas.
- Replacement of light bulbs with LED bulbs, replacing first in most-used fixtures.
- Use of power strips with personal computers and other electronic devices to allow complete shut down when devices not in use.
- Installation of low-flow showerheads and faucets to reduce hot water consumption.
- Installation of insulated shades and draperies to increase the effective R-value of windows.

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[14] Atanasiu et al. (2014)
[15] Young (2014), European Commission (2019)
[16] European Commission (2019)

Most of these things can be accomplished on a DIY basis, and materials and devices are readily available.

Home Energy Retrofit of an Existing Home

Retrofitting goes further than modification of family dynamics, to include improvements to the building envelope. There are a number of possibilities for improving the energy performance of almost any building. Deciding what to do first when seeking to improve energy efficiency can be daunting if making decisions independently. Obtaining an energy audit is a recommended first step in almost any project.

The Energy Audit

An energy audit involves a detailed assessment of a home, and typically involves a walk-through of every room, a blower door test to assess air leakage, a thermographic scan, and examination of past utility bills. Inspection of attic and crawl spaces may also be involved.[17]

A great deal can be learned through audits done on a do-it-yourself basis, and the Department of Energy has published instructions on how to go about this.[18] To gain the full advantage of an audit, including information obtained from blower door tests and thermographic scans, it is necessary to work with a professional. Most states and many utilities operate energy audit programs with inspections provided by staff or other professional energy auditors. Auditors can generally be easily located through a web-based search. Costs of an energy audit range from as low as $60-$70 to as high as $250-$300. Findings are often invaluable to guiding investment decisions.

Canada Energy Audit[19] offers in-home audits for a nominal fee. Rebates can be obtained following implementation of energy-saving recommendations.

Across Europe, home energy audits are in some cases available through power companies (for example, through Electricity France). Funds are also available through various governmental programs to support home audits when done in conjunction with energy efficiency improvement projects.

Common Areas of Needed Improvement

In existing homes common problem areas are lack of building tightness, which results in air leakage and drafts. Insulation is also often inadequate, as are windows. A priority list might, therefore, look something like the following:[20]

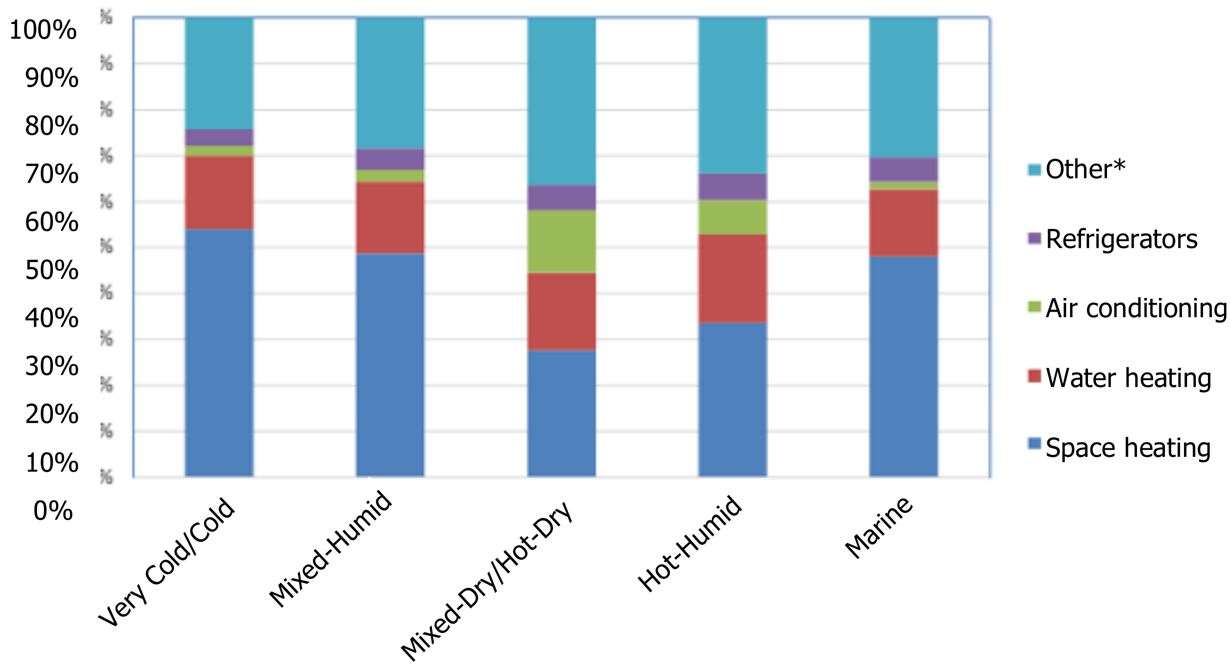
1. Caulk or weather strip penetrations into the building envelope including at sill plates and rim joists, window openings, doors, and walls (including electrical outlets).
2. Seal ceiling penetrations such as around recessed lights.
3. Add attic insulation.
4. Insulate basement walls.
5. Replace furnace and/or air conditioner with high efficiency models.

[17] U.S. Department of Energy (n.d.b)
[18] U.S. Department of Energy (n.d.a)
[19] http://www.canadaenergyaudit.ca/
[20] Efficiency Matrix (2018), Net Zero Project (2018b)

6. Add exterior or interior storm windows, or replace existing windows with high energy efficient products.
7. Provide for controlled fresh air ventilation through use of an air exchanger.
8. Look for opportunities for increase wall insulation, such as when replacing siding.

As illustrated in Figure 4, the climate zone in which you live also influences priorities. Focusing on heating energy is obviously a greater priority in northern regions, whereas greater attention to cooling is of greater importance in hot, dry regions.

Figure 4
End-Use Percentage of Total Home Energy Consumption by Climate Region



*Other includes appliances, lighting, electronics

Source: Cluett and Amann (2014), Rockefeller Foundation (2012)

A number of excellent resources regarding energy remodeling can help to guide decision-making.[21] And, working with an experienced professional is always a good idea.

Don't Overlook Aging Appliances

While the efficiency of the furnace and air conditioner are obvious things to consider when seeking to improve the energy performance of your home, the condition and age of appliances are a bit less obvious. Yet, the water heater alone can account for more than 15% of household energy consumption (see again Figure 4). Refrigerators, especially if very old, or if you have more than one in use, can also consume considerable energy. An earlier report in the Consuming Responsibly series explains the energy consequences of keeping a refrigerator for too many years or operating an old unit in the basement or garage.[22]

[21] HGTV (2019), Liaukus (2014), Kamel and Memari (2016)
[22] http://www.dovetailinc.org/report_pdfs/2019/DovetailConsumingResponsibly5Refrigerators.pdf

The Deep Energy Retrofit

Just as net zero is the ultimate in energy efficiency in new construction, remodeling toward zero is increasingly a goal in retrofit projects. A deep energy retrofit goes well beyond typical energy saving steps, and may include installation of ground source heat pumps for conditioning of air and heating water, as well as installation of solar arrays.

As explained by the Net Zero Project, a 'toward zero remodeling plan' involves implementing the lowest cost measures first and then estimating the lifetime of appliances, heating and cooling systems, roofs, siding, windows, and doors, and putting those estimated lifetimes into a replacement timeline to be done gradually as time, budget, and circumstances allow."[23]

The same basic approach is used in retrofitting toward Net Zero as employed in creating new Net Zero buildings (see following section). The difference is that retrofitting is more difficult and often more costly than when a new building is involved. That is why development of a stepwise plan is recommended when seeking to move an existing building toward net zero performance.

As with any retrofit activity, an energy audit is recommended as the first step. Results of the audit identify problem areas and can help in prioritizing remediation investments.

Resources that are helpful for planning a net zero project include the following:

- Zero Energy Project. 2018b. Renovate to Zero. (http://zeroenergyproject.org/renovate/remodeling-path-zero-homeowners/)
- U.S. Department of Energy. n.d. Where to Insulate in a Home. (https://www.energy.gov/energysaver/weatherize/insulation/where-insulate-home)
- Roberts, S. and Stephenson, R. 2012. Measure Guideline: Wall Air Sealing and Insulation Methods in Existing Homes. U.S. Department of Energy, Building Technologies Program. (https://www.nrel.gov/docs/fy12osti/55480.pdf)
- Wendt, 2007. The Challenge of Existing Homes: Retrofitting for Dramatic Energy Savings. Building Green, July 10. (https://www.buildinggreen.com/feature/challenge-existing-homes-retrofitting-dramatic-energy-savings)

If Building or Buying New

When considering desired features of a new home, energy efficiency should be near the top of the list. A home built today may be in existence into the 22nd Century or beyond. What is done at the outset of construction will have a major impact on the legacy of the building throughout its life. Moreover, building to high energy efficiency will yield immediate benefits to the owners.

Consider Net Zero First

Creating a building that is completely independent of the national or regional energy grid is now realistically possible. As outlined by the Zero Energy Project there are 12 steps to

[23] Net Zero Project (2018b)

realization of zero energy structures.[24] A listing of these 12 steps (plus one that we have added) effectively serves to illustrate the essence of a net zero building**:**

1. Start with informed, smart design
2. Use energy modeling
3. Super-seal the building envelope
4. Super-insulate the building envelope
5. Heat water wisely
6. Use highly insulated windows and doors
7. Design for passive solar
8. Create an energy efficient fresh air supply
9. Select a highly energy efficient heating and cooling system
10. Install energy efficient lighting
11. Select highly energy efficient appliances and electronics
12. Capture solar energy
13. Provide battery storage for storage of solar energy

Although initial costs will be higher than when building a more conventional structure, elimination of energy utility payments and, in some cases net returns from selling energy back to the regional grid, can markedly reduce real costs. In addition, tax credits and other incentives in many states and localities can slash initial costs. Key sources of information include the Database of State Incentives for Renewable Energy and Efficiency,[25] State Residential Energy Efficiency Programs[26], Home Improvements and Residential Energy Tax Credits,[27] and State Tax Breaks for Energy.[28]

Not Quite Zero, But Going Beyond Code

If living in a state with residential energy efficiency standards you are assured that your home will at least comply with energy provisions of the state or local code. However, state code requirements seldom reflect recommended best practices, so if you wish to maximize energy efficiency it is necessary to look beyond code. The ENERGY STAR Certified Homes program or one of the many green building programs provide a pathway to improved energy performance.

The ENERGY STAR Certified Homes program operates in all 50 states. In addition to publishing step-by-step guidelines on how to build highly energy efficient homes, the program also provides links to builders, state and federal incentive programs for efficient building, and building rating companies who can certify compliance to ENERGY STAR. Certification can be important when selling a home as it provides proof to prospective buyers of high energy performance.

Summary

There are a number of approaches to improving the energy efficiency of residences and of the existing housing stock overall. Energy conservation measures, modest to deep energy

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[24] Net Zero Energy Project (2018a)
[25] DSIRE (2019)
[26] NASEO (2019)
[27] Perez (2018)
[28] Moreno (2018)

retrofitting of existing buildings, and building new to high energy efficiency standards all hold considerable promise for reducing energy use and associated emissions, and for reducing energy bills of homeowners.

Because of the enormous inventory of existing residential structures and the relatively slow rate of older building replacement, existing building energy retrofits are of considerable importance going forward. The availability of relatively low cost energy audits, a wealth of freely available information, and a range of government and utility incentive programs make it easy to get started toward a better energy future.

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