Colorado State University
Extension

The Whole-House Approach to Energy Efficiency

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The whole-house (or systems) approach to energy efficiency is a way of thinking about how the passive and active energy systems in a home are interconnected. By becoming more efficient in one aspect of home energy use, consumers can gain opportunities to become more efficient in others. One example of this approach is using enough insulation to reduce the heating needs–and thereby the size of the furnace–of a home. This fact sheet is intended to help Colorado residents understand how to apply the whole-house approach when considering energy use in the home.

How Energy is Used

As shown in Figure 1 below, the average single family home in the U.S. spends the majority of its energy budget on heating and cooling. In Colorado, the percentage of energy used for heating is even greater than what is shown for the average home in the U.S., and the percentage used for cooling is lower. But because Colorado's climate can vary significantly from one region and elevation to another, it is important to identify the major energy users in your home specifically.

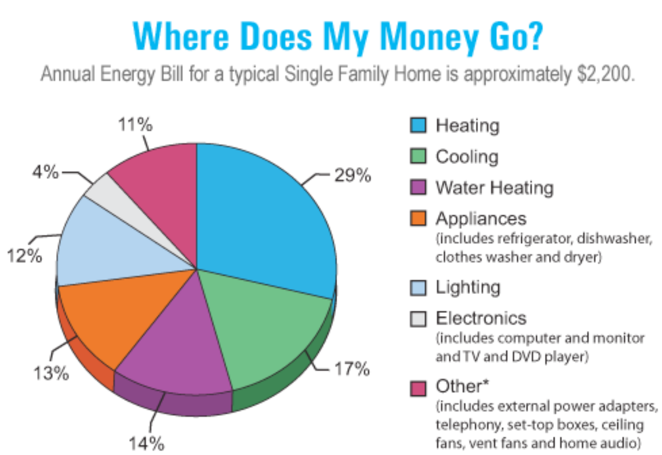
Determining a Baseload

There are a number of ways to determine where your home tends to use the most energy. One good way to start this investigation is by taking a close look at your energy bills. If you can gather all of your bills from the previous 12 months, you will have all you need to determine a baseload of your home's energy use (see Table 1).

Without plotting a graph, one can see that electric use is dramatically higher in the summer months than in the winter months and the opposite is true for use of natural gas. This indicates that a lot of electricity is used for cooling, and a lot of gas is used for heating this particular home.

Our 'baseload' is the amount of energy used under the least demanding set of conditions. For electricity in this example, this happens when no cooling is required in the summer, when no fans are needed to blow hot air in the winter, and when natural lighting can be maximized: October. Electricity use is restricted to appliances, lighting, electronics, and other small loads. For natural gas in this example, this happens when no space heating is needed: June, July, and August. Natural gas use is restricted to the water heater and stove/oven.

Figure 1. Average U.S. household energy expenses by type.



Source: U.S. EPA

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Quick Facts

- There are a number of ways to determine where your home tends to use the most energy. One good way to start this investigation is by taking a close look at your energy bills.
- Energy demand is the amount of power we need to achieve certain functions, such as maintaining a comfortable temperature or level of light, drying clothes, and freezing food.
- By minimizing our demand on active heating and cooling systems we can reduce the size of the heating and cooling equipment we need to keep ourselves comfortable.

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Table 1. Sample home's monthly energy use.

Month	Electric (kWh)	Gas (therms)
January	620	125
February	590	140
March	570	100
April	565	70
May	710	25
June	840	15
July	900	10
August	885	10
September	655	20
October	550	45
November	565	70
December	605	120

To understand how much electricity is needed to cool this home, we can multiply our baseload of 550 kWh (October) times four for the four warm months in which we see a spike in electricity use. Then we subtract that number (2,200) from the total kWh used in those warm months (3,335) to arrive at 1,135 kWh used for cooling. At $0.10 per kWh, we could also determine that this home spends over $110 per year on electricity for cooling.

To understand how much natural gas is needed to heat this home, we multiply our lowest monthly use (10 therms) times 12 for an annual baseload of 120 therms. We can then subtract that number from our actual annual total (750 therms) to arrive at 630 therms used for heating. At $0.80 per therm, this translates into just over $500 per year.

Determining a baseload can help to focus our priorities for making energy efficiency improvements. When such large swings in energy are correlated with changes in the seasons, for instance, we can decide to invest in strategies that will lower our overall heating and/or cooling bills.

Reducing Energy Demand

The whole-house approach dictates:

1. Reduce the need to use energy in our home in the first place (demand); then
2. Use energy efficiently when energy is required.

Our energy 'demand' is the amount of power we need to achieve certain functions, such as maintaining a comfortable temperature or level of light, drying clothes, and freezing food. When most people talk about 'conserving' energy, they are really talking about reducing energy demand. For heating and cooling, our energy demand depends on how we choose to counteract the extreme temperatures that make us uncomfortable. In Figure 2 below, ways in which the home loses heat are represented by the arrows pointing right, while ways we make up for this heat loss are represented by the arrows pointing left.

As you can see, in the cold months warm air in the home is lost to the cold outdoors through the ceiling, walls, windows, and the home's foundation as well as through air leaks in the building envelope. That lost warm air needs to be regained through some combination of internal heat (i.e. body heat, lights, etc.), heat from the sun, and heat supplied by one's active heating system such as a furnace or boiler.

In warm weather (Figure 3), hot air enters the home as direct radiation from the sun, through leaks in the building envelope, as internal heat, and by transmission through the building envelope as warm air naturally moves to colder indoor spaces. That excess warm air needs to be removed until we are comfortable through some sort of cooling system or process.

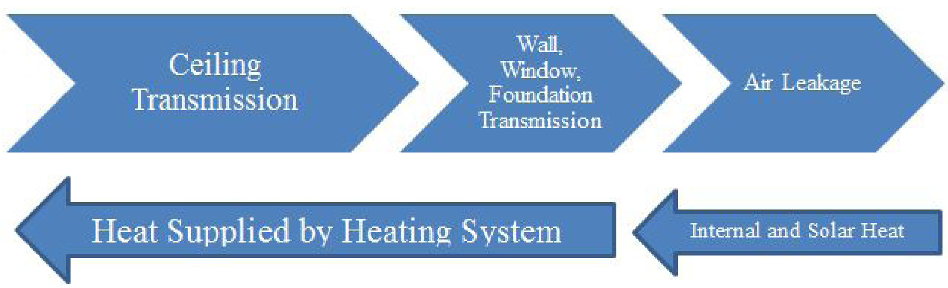
While one way of thinking would dictate the building of larger, high powered active heating and cooling systems to ensure our comfort, the whole-house approach to energy efficiency takes the opposite view: Instead of growing the energy intensity of our heating and cooling systems, practitioners of the whole-house approach first try to decrease the forces that make us uncomfortable in the first place.

Based on the graphics, it is clear that: 1) reducing air leakage; 2) slowing the transmission of heat; and 3) making solar heat work to our advantage depending on the season are the most effective means of reducing our heating and cooling loads. How do we accomplish this?

Air sealing techniques can vary quite a bit but it is not the intention of this fact sheet to provide these details. What is important to remember for now is that air sealing should be done before adding insulation because it may be difficult to seal an attic, for example, under new insulation and because many types of insulation are ineffective at preventing air leaks.

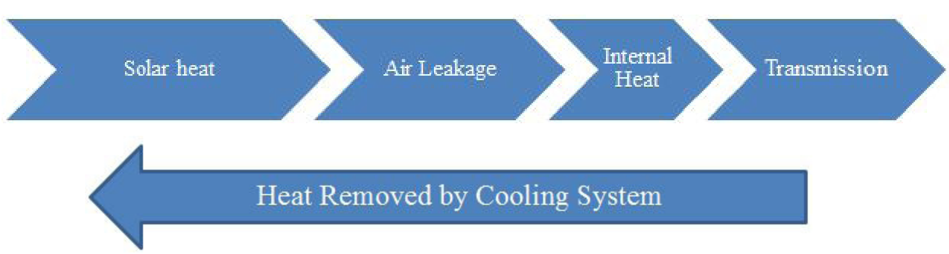
It is also important to understand that building codes set minimum rates of air exchange. If a home is sealed so tightly to be beyond this minimum, indoor air quality can suffer. For this reason, it is recommended that one arrange for a home energy audit with blower door test to measure ventilation levels and identify actions that will achieve desired levels of ventilation (generally .35 air changes/hour) before sealing major air leaks. Homes can also be sealed as much as possible and

Figure 2. Factors influencing heat loss and energy use.



Adapted from J. Krigger and C. Dorsi. Residential Energy, 5th edition (2009)

Figure 3. Factors influencing heat gain and energy use.



Adapted from Residential Energy, 5th edition

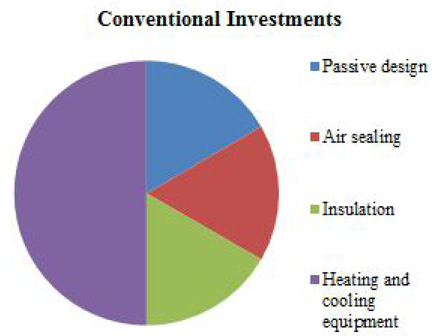
ventilated to recommended levels through use of mechanical ventilation such as a heat recovery ventilator. In addition to introducing a proper, controlled amount of fresh air into the home, with mechanical ventilation systems we also know that our supply of fresh air comes from one filtered, central point in the home and not just a random set of cracks and gaps.

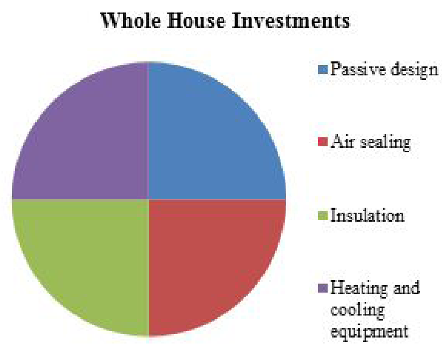
After a home is properly air sealed, adding insulation to recommended levels (depending on your climate zone within Colorado) can slow the transmission of heat from indoors to outdoors in winter and from outdoors to indoors in summer. This reduces the need to add heat or cold to a space through mechanical, energy-intensive equipment. Because windows are also a major source of unwanted heat transmission, making them more efficient is a reasonable priority in most cases. It is important to keep in mind, however, that simply installing brand new windows is a very expensive way of reducing energy demand in a home and typically has a poor return on investment. Other techniques for slowing heat transmission both into and out of the home through windows–such as use of insulating drapes and storm windows–should be investigated first.

Making solar heat work to our advantage means letting direct sunlight inside when it's cold out and keeping direct sunlight out of our home when it's hot out. Proper use of window treatments and landscaping for energy conservation are two common techniques for managing solar heat. Proper orientation of new homes to face south with appropriate overhangs and other passive solar features is another way to take advantage of solar radiation.

By minimizing our demand on active heating and cooling systems we can reduce the size of the heating and cooling equipment we need to keep ourselves comfortable. Since smaller equipment costs less than larger equipment, we can save ourselves money when installing new or replacement equipment. Also note that oversized equipment will not run as efficiently as right-sized equipment. In essence, the whole-house approach to energy efficiency means we shift where we make our energy investments from 'reactive equipment' to 'proactive systems' (Figure 4).

Figure 4. Representation of conventional and whole house energy investments.





The difference in the long-term is that we save energy and money though reducing our energy demand with the whole-house approach.

It should be noted that this same principle applies to lighting, water heating, and other energy users. By maximizing the natural light we let enter into our home, we reduce the need to provide desired light levels through bulbs. By insulating our water heater storage tank, we reduce the need to heat that water through burning natural gas or via electricity. By sealing and insulating our ducts we prevent hot and/or cold air from getting wasted on their way to our living spaces. Examples abound.

Of course, occupant behavior in a home also plays a significant role in reducing energy demand. In addition to managing window treatments and windows themselves properly to maximize heat gain in winter and minimize it in summer, occupants can avoid blocking heat registers and vents, manage their thermostats, and take a number of other actions that treat the home as an interrelated energy system.

Using Efficient Equipment

Once we've reduced our need for energy in the first place (demand), we can consider ways to use energy as efficiently as possible to achieve desired ends. This means purchasing efficient heating and cooling equipment, lighting, appliances, and electronics. Although the up-front cost of more efficient equipment is higher than standard equipment, financial incentives can offset much of these additional costs and the costs will be made up through lower ongoing expenses. This is especially significant since energy costs tend to increase from year to year even beyond the rate of inflation.

To more fully understand the impact of both reducing demand and using efficient equipment, let's look at a sample comparison between: 1) a conventionally air sealed and insulated home with a large, inefficient furnace; 2) a tightly sealed, well insulated home with a small but inefficient furnace; and 3) a tightly sealed, well insulated home with a small and efficient furnace (see Table 2).

In comparing the tightly sealed, well insulated home (column 2) with the conventional home (column 1) in this example, the initial investment in an effective building shell (air sealing and insulation) is somewhat offset by the less expensive cost of a smaller furnace. The purchase of the high efficiency small furnace (column 3) significantly increases up-front costs. That said, both the investments in the building shell and the efficient equipment save a lot of money over the lifetime of the upgrades when compared to the conventional option. Additional utility, state, and federal financial incentives would make the up-front investments less expensive and rising energy prices would make payback periods even shorter. And because a tightly sealed house isn't prone to air leaks, the homeowner can avoid uncomfortable drafts and cold spots in the house.

Table 2. Comparision of heating expenses for conventional, low demand, and efficient homes.

	Conventional home*	Tightly sealed, well insulated home**	Tightly sealed, well insulated, home with efficient furnace***
Installed furnace cost	$1,500	$1,200	$2,200
Insulation and air sealing cost	$0	$1,000	$1,000
Utility rebates	$0	$150	$300
Net cost	$1,500	$2,050	$2,900
Incremental cost	-	$550	$1,400
Therms per year	1,140	640	540
Annual operating cost	$910	$510	$430
Annual savings	-	$400	$480
Payback period (years)	-	1.4	2.9
Lifetime operating cost	$18,240	$10,200	$8,600
Lifetime savings	-	$8,040	$9,640

*1 air change per hour; average of R-18; 60,000 BTU and 80% efficient furnace
**0.35 air changes per hour; average of R-24; 40,000 BTU and 80% efficient furnace
***0.35 air changes per hour; average of R-24; 40,000 BTU and 95% efficient furnace

Table 3. Comparision of costs for solar PV in conventional vs. efficient homes.

	Efficient Home	Conventional Home
Annual electricity use (kWh)	5,000	5,555
Size of solar PV system needed (kW)	3.2	3.6
Installed cost*	$16,000	$18,000

*Assumes 5.5 kWh/square meter/day, a 0.77 derate factor, $5/watt installation cost, and no financial incentives

Reducing the Cost of Renewable Energy

Another feature of the whole-house approach is that investments in energy efficiency tend to decrease the costs of renewable energy. If an energy efficient home uses 10% less electricity compared to a conventional home, for example, that homeowner would require a smaller solar photovoltaic system to offset that electricity use (see Table 3).

Financing the Whole-house Approach

While there are multiple ways to finance energy efficiency improvements, Colorado is a leader in offering a specific product called an Energy Star Mortgage. Through this program, one is able to reduce the interest rate of one's primary mortgage by committing to using a second, smaller mortgage to finance energy efficiency and/or renewable energy upgrades. The intended result is lower energy bills and little to no change in total monthly mortgage payments.

Colorado is also one of many states with an active Home Performance with Energy Star program for customers of certain utilities. Under this program, homeowners who have completed a qualifying home energy audit are eligible for significant rebates on multiple energy efficiency improvements. Contact your local utility to see if they participate in this program and for program details.

Avoiding Unintended Consequences

When making energy efficiency improvements it is important to consider that since energy systems in the home are interconnected there may be unintended consequences to your upgrades. For instance, when sealing and insulating a duct that runs through unconditioned space, any excess 'waste' heat previously given off by those ducts will no longer be given off. If any pipes are present in the space they may become vulnerable to freezing. In another example, sealing a home too tightly can result in problems with indoor air quality. Even sealing and super-insulating an existing home to recommended levels can result in moisture buildup in attics and other spaces. Replacing an inefficient furnace with an efficient model can mean that the size of your chimney vent needs downsizing.

Because it is difficult for those outside the energy industry to anticipate all of these interactions, it is best to consult a professional building practitioner before making major upgrades. A home energy audit is another tool that can recommend various home efficiency improvements while considering the big picture and secondary consequences of improvements.

Conclusions

It is important to understand the whole-house approach to energy efficiency in order to make sound long-term energy investments. Determining your home's baseload energy use is one way to get started prioritizing energy decisions. Once one better understands where energy is being used in the home, one can focus on reducing energy demand through energy conservation measures. Reducing one's energy demand can be a shift in upfront energy expenses rather than an increase in these expenses, and also results in long-term savings in ongoing energy costs. Becoming energy efficient can increase comfort as well as decrease the cost of renewable energy systems. Home energy audits can both help homeowners learn where to prioritize energy decisions and also minimize unintended consequences of those decisions.

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