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. Implementing the whole-house approach involves first reducing the need to use energy and then using energy efficiently when energy is required. Understanding and implementing this approach in one's home can result in a significant long-term reduction in energy use. This fact sheet discusses how energy is used in typical Colorado homes, how to analyze one's energy bills, how to reduce energy demand in a home, and use of energy efficient equipment.

How Energy is Used

As shown in Figure 1 below, the average home in Colorado uses the majority of its energy for space heating, followed by appliances, electronics, and lighting, and then water heating. 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. In addition, because prices of electricity and particularly natural gas and propane can fluctuate from one year to the next it is also important to understand where energy dollars are spent in the home.

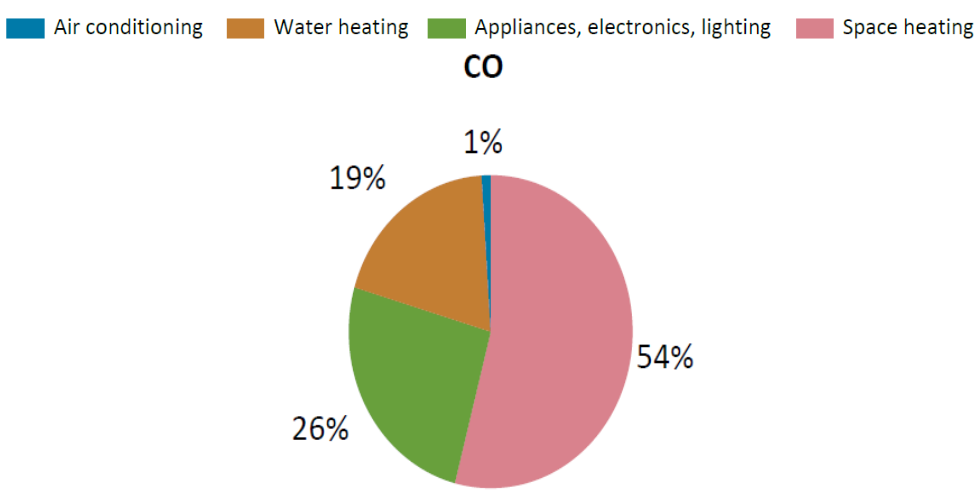
Determining a Baseload

There are a number of ways to determine where your home uses 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 your home's baseload, heating, and cooling energy use and expenses.

In the sample home's monthly energy use figures provided in Table 1, one can see that electricity use is noticeably 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 home.

A home's 'baseload' is the amount of energy used under the least demanding set of conditions (when energy use is lowest). For electricity in Colorado, this is typically in the spring or fall when no cooling is required, when furnace fan use is minimal, and

Figure 1. Energy Use in an Average Colorado Home (U.S. Energy Information Administration).



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Quick Facts

- There are two steps to the whole house approach: 1) reducing energy demand; and 2) using efficient equipment.
- Analyzing your energy bills can help you understand how much energy you use for your 'baseload', heating, and cooling.
- A home's 'baseload' is the amount of energy used under the least demanding set of conditions – when heating and cooling are not needed.
- The whole house approach can dramatically reduce energy expenses in the long-term.

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when natural lighting is fairly abundant. Electricity use is mostly restricted to appliances, lighting, electronics, and other small loads. One can calculate the annual electricity baseload for this home by multiplying the monthly low of 550 kWh (October) times 12 months = 6,600. At $0.10 per kWh, this home spends $660 per year on its baseload electricity use.

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, multiply the monthly electricity baseload of 550 kWh times five for the five warm months in which there is a spike in electricity use (May-September). Then subtract that number (2,750) from the total kWh used in those warm months (3,990) = 1,240 kWh. At $0.10 per kWh, this home spends about $120 per year on electricity for cooling

For natural gas in Colorado, the baseload occurs in the summer when no space heating is needed. Natural gas use is restricted to the water heater and stove/oven. One can calculate the annual natural gas baseload for this home by multiplying the monthly low of 10 therms (July/August) times 12 months = 120 therms. At $0.60 per therm, this home spends $72 on its baseload natural gas use.

To understand how much natural gas is needed to heat this home, multiply the monthly natural gas baseload of 10 therms times 12 for an annual baseload of 120 therms. Then subtract that number from the annual total (750 therms) = 630 therms. At $0.60 per therm, this home spends almost $400 per year on natural gas for heating.

Conducting this analysis can help you understand where energy and money are spent and can focus your priorities for making energy efficiency improvements.

Reducing Energy Demand

Energy 'demand' is the amount of energy needed 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. Reducing demand can be done in a number of ways, many of which are simple behavior changes.

To reduce lighting demand, one can let natural light into the home by opening window coverings. To reduce hot water demand, one can set the water heater to 120 degrees, take shorter showers, run dishwashers only when full, run clothes washers using cold water, insulate pipes, and insulate water heaters that are hot to the touch. Unplugging appliances when they're not in use will reduce their electricity demand. For heating and cooling, energy demand depends on how we choose to counteract the extreme temperatures that make us uncomfortable. In Figure 2, ways in which the home loses heat are represented by the arrows pointing right, while ways to 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.

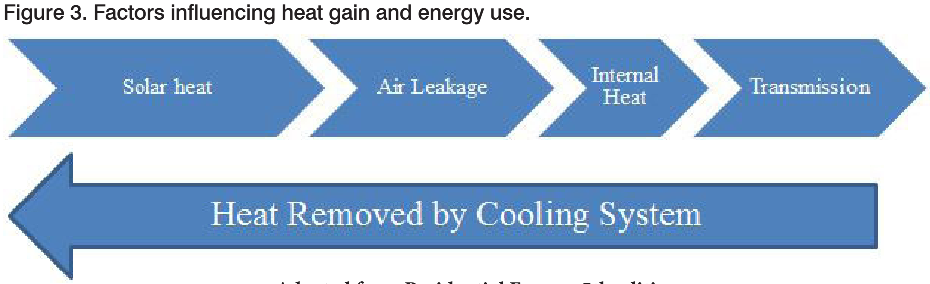
In warm weather (Figure 3), hot air enters the home as direct radiation from the sun, through leaks in the building envelope, as internal heat, and by transmission through the building envelope as warm air naturally moves to colder indoor spaces. Excess warm air needs to be removed until we are comfortable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

The whole-house approach to energy efficiency dictates that instead of utilizing large heating and cooling systems, it is more cost-effective in the long-term to decrease the forces that make us uncomfortable in the first place. This means: 1) reducing air leakage by air sealing; 2) slowing the transmission of heat with insulation and energy efficient windows; and 3) making solar heat work to our advantage by managing windows and window coverings and also by landscaping for energy conservation. In addition, sealing and insulating ducts prevent the hot and/or cold air generated by heating and cooling systems from getting wasted

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

on their way to living spaces. Utilizing a thermostat can also reduce our heating and cooling demand.

By minimizing energy demand through such "passive" techniques, one can then minimize the need for "active" energy systems like heating and cooling systems, water heaters, and artificial light. Money is saved not just through the reduction in energy demand, but also through the gained ability to purchase smaller or less equipment.

Using Efficient Equipment

After reducing energy demand – the need for energy in the first place - step two of the whole house approach is to purchase energy efficient equipment. As mentioned above, some equipment could be smaller or even unnecessary after energy demand is reduced. Although the up-front cost of more efficient equipment is higher than standard equipment, financial incentives and long-term reductions in energy use can offset much of these additional costs.

To more fully illustrate the impact of both reducing demand and using efficient equipment, Table 2 provides 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.

In comparing the tightly sealed, well insulated home (column 2) with the conventional home (column 1), 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. Financial incentives (like utility rebates) would make the up-front investments less expensive and rising energy prices would make payback periods even shorter. And because a tightly sealed home isn't prone to air leaks, the homeowner can avoid uncomfortable drafts and cold spots.

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

Table 2. Comparison 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
Net cost	$1,500	$2,200	$3,200
Incremental cost	-	$700	$1,700
Therms per year	1,140	640	540
Annual operating cost	$680	$380	$320
Annual savings	-	$300	$360
Payback period (years)	-	2.3	4.7
Lifetime operating cost	$13,600	$7,600	$6,400
Lifetime savings	-	$6,000	$7,200

**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. Comparison of costs for solar PV in conventional vs. more efficient homes.

	Conventional Home	10% More Efficient Home
Annual electricity use (kWh)	5,555	5,000
Size of solar PV system needed (kW)	3.6	3.2
Installed cost*	$14,400	$12,800

**Assumes 5.5 kWh/square meter/day, a 0.77 derate factor, $4/watt installation cost, and no financial incentives.*

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, heating, and cooling 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.