LAST LOOK

ENERGY FOR PIONEERS

Energy efficiency has become a dominant issue in house design, as conventional energy sources become scarce. The same is true of water conservation. Have we done enough to prepare your house for the future?

Yes, we have. Super-efficiency is a prime goal throughout your design, in a way that is fully compatible with the other super-features of your house, including comfort, health, safety, beauty, and strength.

Still, you may have noticed that we did not include a number of conservation measures and energy sources that are enthusiastically promoted today, such as solar energy or rain barrels. That was not an oversight. The measures that we omitted are less desirable than related efficiency features that we do recommend. Or, they have serious shortcomings, including a large potential to fail.

As we progressed through the design of your ideal home, we stressed reliability and economy. If an energy conservation measure doesn't work, it doesn't save energy. Instead, it wastes energy and other resources. So, we have limited our recommendations to efficiency features that can provide energy savings with certainty.

To provide assurance that your home's design has not missed any good bets, we will take a last look around to survey other energy-saving and "green" features that you may have heard about. One purpose is to examine their promises and pitfalls. Another is to help you to improve the chance of success if you decide to include one or more of these alternatives in your home.

Some of these energy options can be made to work. But, unless you are willing to make an exceptional effort to learn about them, install them properly, and maintain them, they are certain to fail. You will be left with an expensive and unattractive mess. On the other hand, if you can afford the price and if you are willing to deal with the risks, more power to you.

How about the thrill of innovation? Most of the following energy options are no longer "innovative." They may be uncommon because they haven't worked well. It's best to think of them as high-stakes hobby projects, only rarely a best choice. Let the reliable energy-saving advances introduced in this book satisfy your appetite for innovation.

We call this extra part of the book *Energy for Pioneers*. The word "pioneer" has a double meaning. We look at some home features that were used by pioneers of the past, such as wood burning. And, we examine technology that needs further pioneering to succeed, such as geothermal heat pumps. Even if you don't use these features in your home, I hope that you will find it interesting to learn about them.

Heating with Firewood and Other Solid Fuels

The rationale for heating with wood and other solid fuels is that these fuels may be less expensive than conventional fuels. Or, these fuels may still be available when conventional fuels are curtailed or exhausted. From the standpoint of appearance, a stove or a fireplace can provide an elegant focus for a room, and it provides an excuse to add a fancy chimney to the exterior.

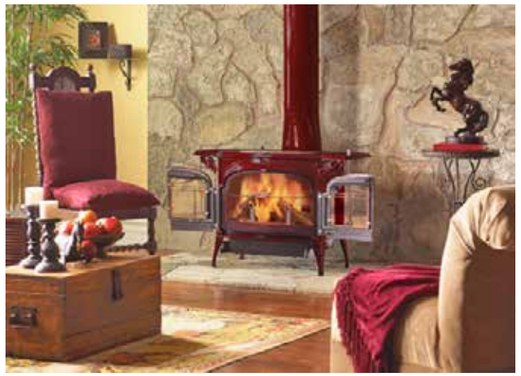
However, a super-efficient house needs only a small amount of heating, and a wood fire is a troublesome way to provide it. Wood burning requires a commitment to a different lifestyle. The delightful fireplace of your imagination will become a chore.

Starting the fire requires a significant amount of time. The fire must be tended continually. Your hands will be burned. Your clothing will get dirty. You must remove ashes every few days, and sweep the flue every year. The house will become smelly and dusty unless the installation is perfect and the draft is managed properly. Any solid fuel heater requires a large safety zone that must be kept free of combustible material.

The air pollution from wood burning has caused wood heaters to be restricted or banned in some areas. Forcing your neighborhood to breathe toxic smoke on a regular basis is not responsible.

All that being said, if you plan to build your home in a rural area, consider using an efficient wood-fired heater as a primary source of heat, perhaps in tandem with one of the modern systems covered in Step 4. If you want to burn solid fuel, there are three types of solid fuel heaters to consider:

- ***heating stoves*** are the least expensive option, and they have visual charm. However, they have the lowest standard of comfort. They occupy a significant amount of living space, including their safety zone. Figure LL-1 shows a typical installation.
- ***solid-fuel air heating furnaces*** provide better comfort than heating stoves, and they can heat multiple rooms effectively. They use a fan to circulate air through one or more rooms using ducts. Most furnaces are plain steel boxes, as in Figure LL-2, and these typically are installed in a separate furnace room where they provide no visual appeal.
- ***solid-fuel hydronic boilers*** provide the ability to serve multiple rooms independently. Except for the boiler, the system can be identical to the hydronic systems that we covered in Step 4, so it can provide excellent comfort and energy efficiency. The boiler can be installed in a fireproof room inside the house, as in Figure LL-3, or it can be installed outside as a freestanding assembly. The same hydronic heating system can use both a solid-fuel boiler and a boiler fired by gas or oil, providing fuel versatility.



Vermont Castings

Figure LL-1. A typical wood-fired heating stove.

I didn't include an open fireplace among the options. A beautifully built fireplace and chimney is an expensive indulgence. Any open fireplace is very wasteful of fuel, and it is a major source of air leakage into the house. I can't recommend an open fireplace to anyone who wants an efficient home. Even so, we will discuss fireplaces in case you may want to have one in a room that can be isolated from the rest of the house.

If the visual charm of a wood fire is the primary attraction for you, a heating stove is probably your best choice. But, if your home will be heated primarily by a modern heating system, having a fireplace or heating stove is likely to waste more energy while it is idle than it saves when you use it. That's because the portion of the flue that is inside the house (even if it is hidden in a chimney) is a source of air leakage and conduction heat loss.

If you want to use solid fuel as your prime source of heating in a climate that has a cold season, a ducted furnace or a hydronic boiler is a much better choice than a heating stove.

In the following pages, we will cover all the main types of solid fuel heaters in enough detail that you will be able to select the best equipment and install it properly. But before we get to the equipment, we need to learn about the fuel.

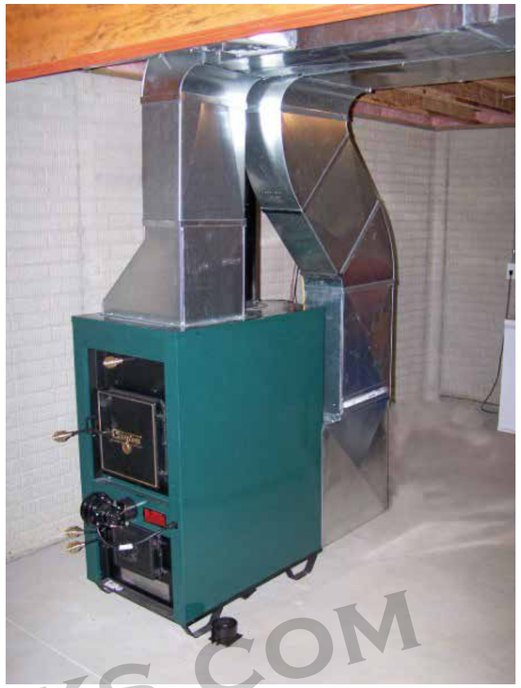


Figure LL-2. A typical wood-fired furnace for a ducted heating system.

YOUR FUEL SUPPLY, THE DOMINANT ISSUE

The cost of fuel is not a big issue if you install a fireplace or stove only for occasional use. If you don't own a woodlot, you will simply pay the exorbitant price for an occasional bundle of firewood and enjoy the evening. Or, you can burn wax logs, or you can buy a gadget that rolls up newspapers into logs, or you can burn wood scraps from your workshop. Or whatever.

If you live in an urban or suburban area, don't expect to use your fireplace as a primary source of heat when conventional energy prices become too high in the future. Everybody else will have the same idea. Wood and other fireplace fuels will become scarce and expensive. When the Age of Petroleum ends sometime during the 21st century, wood will be an energy source that is available economically only to people who live in rural areas.

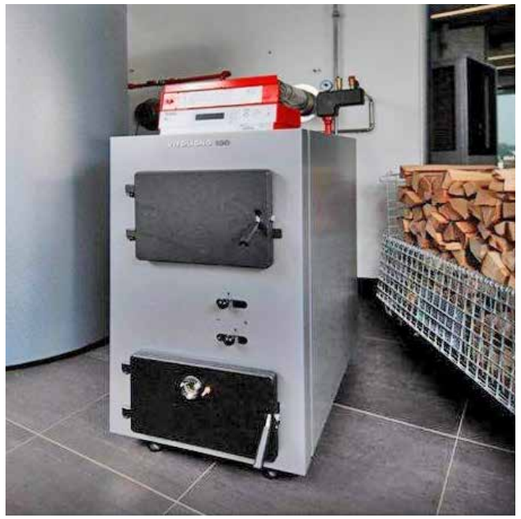
Even if you live in the country, heating with firewood is economical only if you own a woodlot or if you have a reliable long-term access to firewood. A woodlot is a stand of trees that is large enough so that the firewood grows at least as fast as you harvest it. A self-sustaining woodlot can be surprisingly small. In a mid-latitude climate, you should be able to heat a super-efficient home for a year with the wood from one typical large tree. So, a well managed stand of about 40 trees can fuel your fireplace indefinitely.

Anticipate a lot of work to prepare wood for burning. In addition to a woodlot, you will need a chain saw, log splitter, and other paraphernalia. Using this equipment is dangerous. Or, you will need to hire someone to cut your firewood every year or two.

Freshly cut wood contains a lot of water, usually more than half its weight. It takes a long time for a log to dry to a desirable moisture content of 20% or less. Expect to dry your wood for a year or more before burning it. If you burn fresh wood, it will waste a lot of its own energy to dry itself. This will reduce its heat output and greatly increase smoke and creosote deposits. And, fresh wood is a bitch to light.

Don't expect to buy firewood that has been dried properly. You will need a storage location on your property for drying your wood after you cut it or buy it. Make a shelter that keeps your firewood off the ground, shelters it from rain and snow, and allows air to circulate around it. Wood that is exposed to rain and snow will rot and lose a significant part of its fuel energy. Make your shelter large enough for at least a one-year supply of firewood.

In addition to logs, you need to maintain an ample supply of kindling to start your fires. Kindling should be very dry. You can dry and store the kindling in a decorative metal bucket inside the house. The bucket should have a lid to keep sparks from igniting the kindling.



Viessmann

Figure LL-3. A high-efficiency wood-fired boiler.

Solar Electricity Generation

One of the major breakthroughs of the semiconductor revolution was direct generation of electricity from sunlight. This type of electricity generation uses "photovoltaic" (PV) cells. These can be seen everywhere, powering small calculators, navigational aids on waterways, spacecraft, and many other small applications. Any number of PV cells can be mounted on large panels to increase their total power output.

Photovoltaic generation seems almost too good to be true. It has no moving parts, requires little maintenance, makes no noise, requires no input of water or other substances from the environment, and produces no pollution (except in the manufacturing process). It is not especially ugly. And, unlike wind generators, photovoltaic generation does not interfere with communications or endanger birds.

At present, the big obstacle to photovoltaic generation is the high cost of the systems. This is a reflection of the amount of energy required to make and install the materials. Everyone is hoping that the cost can be reduced drastically by future developments.

A fundamental issue for home design is whether it makes sense for each house to generate its own electricity. Usually, the answer is no. The only exception is building in a location where access to a public utility network is not available. You may also want to install a PV system to take advantage of tax credits or utility rebates. However, such artificial economic incentives do not save energy or help the environment.

Here are the highlights of PV systems, which will help you decide whether you want to become involved with them.

HOW PHOTOVOLTAIC CELLS WORK

A photovoltaic cell is astonishingly simple. It consists of a semiconductor material (silicon, germanium, or some less common materials) that is made in two microscopically thin layers. One layer is "doped" with a small concentration of another material. This causes the boundary between the two layers to act as a one-way gate for electrons.*

When sunlight falls on the semiconductor material, the photons of energy in the sunlight knock electrons from one layer to the other, but they can't get back across the boundary. As the electrons pile up on one side, they create a voltage. The voltage can force the electrons through a circuit as an electric current.

* The semiconductor materials for PV cells and LED chips are similar. An LED light is essentially a PV cell operating in reverse.

At the present time, two kinds of semiconductor material are used to make photovoltaic cells. One type consists of pure, specially treated crystals of certain materials, usually silicon. Cells made in this manner have the best efficiency, but they are expensive. A second kind of semiconductor is called "amorphous" (which means "not crystalline"). Amorphous semiconductors are less expensive, but they are substantially less efficient and they lose efficiency as they age.

The best hope is that efficient photovoltaic material can be made in large sheets, without the need to connect arrays of individual small cells. Effort in this direction continues, but a fundamental breakthrough is needed to achieve a combination of cost and efficiency that can make photovoltaic generation suitable for widespread application.

ENERGY OUTPUT

The energy output of a PV system is limited by the low energy content of sunlight. At the earth's surface, the maximum power of solar energy is somewhat less than one kilowatt per square meter of collecting area. And, most of the time, only a fraction of that amount is available.

Let's calculate the average output for a collector panel of one square meter (about 10 square feet). A cell efficiency of 20% yields a maximum output of about 190 watts. An average of 12 hours of daylight reduces this to about 95 watts. If the collector panel is fixed, i.e., it does not track the sun, the output is reduced to about 60 watts. Atmospheric losses and shading at low sun altitude reduces this to about 50 watts. Average sky clarity of 70% lowers this to 35 watts. If the effective coverage of the panel area by the semiconductor material is 80%, the panel output is down to 28 watts.

Thus, a good contemporary fixed solar panel, installed in a favorable location, has an average power output of about 28 watts per square meter, or about 2.6 watts per square foot. That's not much.

The energy output in terms of weight is much more favorable. The photovoltaic material itself is almost weightless. Most of the weight of a typical system is in the structure that holds the PV material. The weight and cost of the structure is determined primarily by the need to keep wind from blowing the solar cells away. This has prompted ideas for eliminating the support structure, for example, by making the photovoltaic material part of a roof or wall surface.

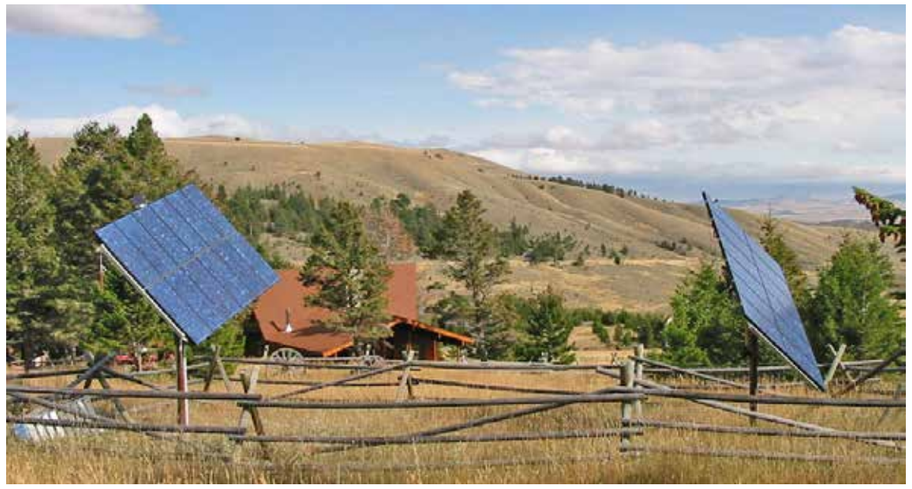


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Figure LL-34. The photovoltaic panels for a Wyoming ranch house electrical system. They are installed on mounts that allow them to track the sun.

PHOTOVOLTAIC SYSTEMS

In the past, photovoltaic systems were limited to isolated applications that could not be served economically by a public utility system. For example, Figures LL-34 through LL-36 show a photovoltaic system for a remote cattle ranch.

The photovoltaic cells produce direct-current electricity when the sun shines. This electricity is used to charge conventional batteries, similar to automobile batteries. Another device, called an "inverter," converts the electricity from the batteries to alternating current at the proper voltage for the house.

The system also needs a conventional fuel powered generator to cover extended periods of cloudy skies or occasional periods of high power consumption.

The batteries and the fuel powered backup generator are major costs. Batteries have a limited number of storage cycles, so they must be replaced periodically. They pollute the environment when they are discarded or recycled. For safety, the batteries should be located in an isolated room or structure that is well ventilated. To minimize the noise of the backup generator, the equipment usually is installed at some distance from the house.

More recently, photovoltaic systems have been installed on individual houses in locations where electricity is readily available from public utilities. In home systems, the collectors commonly are installed on the roof, as in Figure LL-37. Photovoltaic collector arrays are not attractive, but they are not ugly either.

Photovoltaic systems of this kind typically do not have batteries or a backup generator. Instead, electricity is produced in tandem with a connection to the public utility. If the house system cannot produce as much electricity as the house needs, additional electricity is purchased from the public utility. If the house system produces more electricity than needed, the utility typically is required to buy the excess from the homeowner.

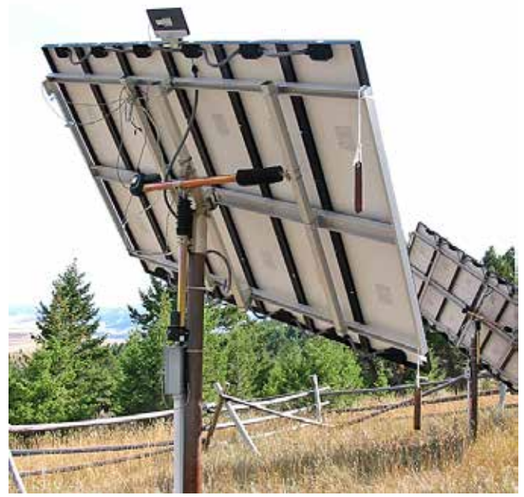

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Figure LL-35. The back of a photovoltaic panel, which is thin and light.

Rainwater Recovery

At first glance, collecting rainwater from your roof and storing it in a cistern or rain barrels seems like a simple way to provide water for your home and to reduce the load on public water resources. But usually, it isn't. Like many conservation concepts, rain harvesting is an appealing delusion that fades in the face of basic calculations and practical difficulties.

Municipal water systems are one of the most important developments of civilization because individual collection of rainwater is unreliable and unhealthy. If your home site lies within the jurisdiction of a public water system, you should almost certainly get your home water from the public system.

If you are outside the reach of a public water system, a water well probably will be your best water supply. Well water is essentially filtered water from a source that does not support biological contamination. Some well water does contain noxious contaminants, and it should be treated as we recommend in Step 5.

In a limited range of situations, the best water source may be an open body of water, such as a river or lake. However, water wells usually are available near such bodies of water, and they are preferable to the open water.

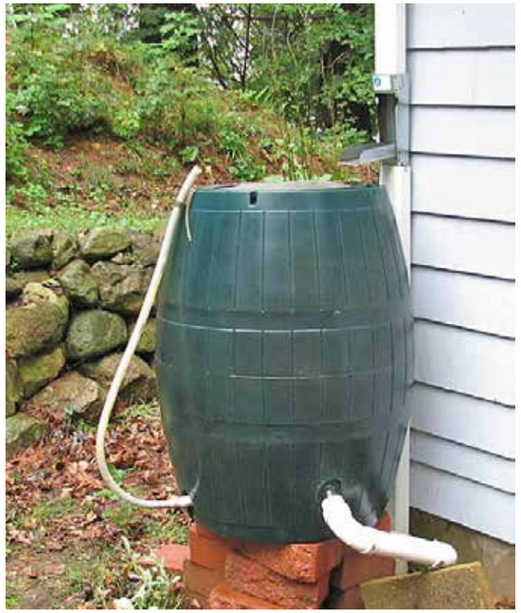
If your home site is one of those rare places where rainwater recovery is worth considering, these are the main issues.

HOW MUCH RAIN CAN YOU COLLECT?

If you expect rain to be your primary source of water, then the average rainfall at your location must exceed your average water usage. If rainwater harvesting is to supplement other sources of water, there should be enough rain to make collecting it economical and worth the bother.

If you determine that the total yearly amount of rainfall is adequate for your needs, here is the next thing that you need to understand: ***the longer the intervals between rainfall, the larger your water storage needs to be***.

Rain collection enthusiasts typically think in terms of recovering rainwater from the roof. This is done with a rain barrel that is filled from the house's gutters, as in Figure LL-53. When rainfall first begins, the rain barrel is bypassed to flush out the dirt coming from the roof and gutters. Then, a diverter is adjusted to direct the rain into the barrel.



U.S. EPA

Figure LL-53. A typical rain barrel installation. The adjacent gutter downspout has a diverter that can direct roof drainage into the barrel or can bypass it. This barrel has two bottom outlets, one fixed and one connected to a hose.

Unfortunately, if your roof is your rain collector, it probably won't collect enough water to run a household, or even major applications such as toilet flushing. Your roof area is competing with the entire land area of the region that feeds a public water supply, and that is no contest.

A roof collection system might serve a household if the climate is rainy all year, as in Ketchikan, Alaska. Indeed, a roof collection system might be your prime choice if your home in a wet climate is not served by a public water system.

In a climate with more normal rainfall, if the land area of your property is fairly large, and if it is graded toward a low point, you can use your acreage to collect rainwater in a pond. Unless the climate will reliably keep the pond filled, you will need to transfer the water to a cistern or tank as soon as it is collected.

HOW CLEAN IS RAINWATER?

We tend to assume that rainwater is pure. Unfortunately, it isn't. As rain falls, it collects dust and pollutants from the atmosphere, including some dangerous microorganisms (such as the bacteria that cause Legionnaires' Disease) that ride on dust particles. On the positive side, rainwater is "soft" in terms of dissolved minerals and it is free of many dangerous pollutants (such as radon, arsenic, and organic poisons) that reside in the ground.

Rain is further polluted by whatever lies on your roof and in the gutters used to channel the rainwater to the cistern. Take a look at a typical roof in your area and inside the gutters. You will find rotting vegetation, earthworms, bird droppings, small animal carcasses, an oily film from the asphalt in shingles, etc.

If you collect rainwater in a pond, it will contain an even greater variety of undesirable contaminants. Any river or reservoir that feeds a public water supply also contains those things, but they are removed by large filtration plants. Large water treatment plants clean water much more economically than you can clean the water for an individual home.

If you use your roof to collect rainwater, you can use rainfall to flush your roof and gutters before putting water into storage. However, such flushing eliminates only a fraction of the bad stuff on your roof and in the gutters. And, it wastes a large part of the rainfall.

APPLICATIONS FOR RAINWATER

At present, the primary application for small scale rainwater recovery appears to be gardening, along with limited irrigation of lawns and shrubbery. However, rain irrigates these applications directly. Storing rainwater would make sense only if you have periods of heavy rain separated by long intervals of drought. In that case, you would need a very large storage capacity.

In principle, the water treatment methods of Step 5 can be used to clean a rainwater supply for all your household applications, including drinking, cooking, and washing. But, this requires continuing monitoring and maintenance. A rainwater supply potentially contains many dangerous organisms and materials, so a lapse of maintenance could cause a tragedy.

Using rainwater for indoor applications requires a separate water system, in addition to a primary system that is served by a public water supply or by a well. The primary system must back up the rainwater system. This complicates the piping.

Usually, the only safe indoor application for rainwater is toilet flushing. Toilet flushing is the largest indoor user of water, estimated to account for 40% of U.S. residential indoor use, so using rainwater for toilet flushing might seem like a good idea. However, in a water starved location, you won't collect nearly enough rainwater to serve typical toilet usage.