How to Build & Operate a Super-Efficient House

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More than one third of the world's energy is used in buildings. A majority of that energy is used in houses and apartments. You can help humanity and save a lot of money for yourself by building a super-efficient house.

A super-efficient new house uses only 10% to 30% as much energy as a house of similar size that is built to contemporary standards. Yes, you read that correctly. You can make a radical improvement in the efficiency of your house without any sacrifice of comfort, convenience, or appearance. Indeed, the effort that you put into designing your efficient house will improve it in every way.

How much will your super-efficient house cost? If you do it properly, the cost premium will be less than 10% of the cost of the house itself, with no increase in the cost of the land. The small additional cost will pay back quickly, and your super-efficient home will keep you comfortable and secure in a world of increasingly expensive and unreliable energy resources. There is no longer any excuse to build inefficient houses.

On the following pages, you will learn how to build a super-efficient house. The design features are divided into groups for convenience. Put *all* these features into your new house, and have a secure energy future.

Maintain a sense of perspective as you design your super-efficient house. Put most of your effort into the most important energy savings, and don't get fixated on minor issues. The biggest users of energy in housing are:

- **heating**
- **air conditioning (in warmer climates)**

Next in importance are:

- **refrigeration**
- **water heating**

The smallest energy users in typical dwellings are:

- **lighting**
- **cooking**
- **laundry**
- **dishwashing**
- **electronics**

Optimize your house for your own conditions. For example, in Minnesota, heating is a big cost but air conditioning is not. The opposite is true in Florida. Fortunately, most of these techniques will save you money in all climates and all kinds of dwellings.

It's not difficult or exotic to build a super-efficient house. For the homeowner, it's mostly a matter of careful planning and selecting the best available equipment and methods. No new materials or unusual technology are needed. In fact, you want to *avoid* "innovative" technology and conservation fads.

For the builder, the only major changes are in some of the carpentry procedures, especially for the walls and the roof. The builder needs to enforce the best practices of each trade, and to avoid common construction mistakes that waste energy and cause long-term problems. Construction requires no new skills, but workmanship must be excellent.

The details matter! Refer to the ***Energy Efficiency Manual*** to see how to properly accomplish each of the features described on the following pages. Work out each energy conservation feature with your builder before you begin. Order your own copy of the ***Energy Efficiency Manual***, and make sure that your builder (and architect, if you have one) uses it too. For more information, visit our Web site:

www.EnergyBooks.com

Finally, you don't need to use alternative energy sources, such as wind generators and photovoltaic systems. These will be very important in the future, but they generally belong "on the grid," not on your roof. Leave alternative energy sources to utility companies. Your goal is to build an efficient house that requires very little energy, not to install expensive technology to provide energy for a conventional, wasteful house.

Here is a firm promise. If you do your homework before you build, you will be rewarded with a home that is beautiful, exceptionally comfortable, incredibly strong, trouble-free, and very inexpensive to operate.

Please note. This brief set of tips applies only to housing. It does not apply to commercial buildings, such as stores, schools, hospitals, and office buildings. Commercial and industrial facilities use energy in ways that are more complex, and they require a broader range of energy saving features. Commercial facilities require the full range of energy efficiency improvements in the *Energy Efficiency Manual*.

THE LAYOUT AND STRUCTURE OF YOUR HOUSE

1. Design a layout that tailors energy usage to your lifestyle.

The primary purpose of your home's layout is to provide pleasant living. A good layout allows convenient travel between rooms, provides easy accesses to outside areas, exploits views, isolates noise, keeps you comfortable under all conditions, and does all this with elegance. For example, you will orient the living room windows toward the waterfront or the mountains, put bedrooms on the quiet side of the house, and so forth.

At the same time, use the layout to minimize your energy requirements. Create a core area that consists of the cluster of rooms where your daily life occurs. Rooms that are occupied sporadically should be located outside the daily traffic pattern so that they do not need to be heated, cooled, or lighted most of the time. For example, locate guest bedrooms and storage rooms in a separate wing. In general, keep large spaces out of the daily traffic pattern.

Provide attractive means to thermally isolate large occasional rooms that you want to include visually within the main part of the house. For examples, if you want a "great room" for social functions, avoid heating and cooling it most of the time by using elegant glass doors or partitions. These allow you to merge the large room with related spaces when needed.

If the temperature in an unoccupied space can rise or fall a lot, thermally isolate the space from the rest of the house by using doors and insulated interior walls. Insulate the interior walls of garages, sun porches, rooms with large amounts of glass, and rooms that have an open fireplace. Insulation of interior walls is an inexpensive way to isolate noise and minimize the spread of fire.

If your house has more than one level, provide convenient doors at the top or bottom of the stairs. The doors prevent uncomfortable temperature stratification and energy waste. Make the doors as wide as the stairs, and provide ample maneuvering space near the stairs.

2. Install lots of insulation in the walls, the roof, and exposed floors.

Insulation is your primary tool to slash your two biggest energy costs, heating and cooling. Use lots of it. For example, in typical middle-latitude climates, install 12" of insulation in the walls, 20" of insulation in attics, and 16" of insulation in vaulted ceilings.

This calls for a big change in carpentry practice. Walls that are thick enough to accommodate adequate insulation will require studs of the same width, which should be rigid and strong. The wooden I-beams that are popular for joists and rafters will also function as wall studs.

Generally, use conventional non-flammable glass or mineral fiber insulation for the walls, roof, and floors. Don't die in a house fire because you used foam insulation to save space. Installation workmanship is critical for both the insulation and the vapor barriers.

Increasing the wall thickness does not greatly increase your materials cost. You can space the studs on 24" centers to save cost.

With a masonry structure, you may still need a thick frame wall inside the masonry to act as a holder for batt insulation. Alternatives are thick non-combustible fiberboard insulation, or external foam board insulation covered by a non-combustible surface.

In termite areas, consider metal studs, but be careful to minimize thermal bridging.

Selecting and installing insulation involves a variety of critical issues. The *Energy Efficiency Manual* gives you the essential details for all types of walls and roofs.

Install the windows in the usual way, attached to the outside surface of the wall. The thicker openings create a very nice "window box" interior. We installed Corian sills in all our windows. They make great shelves for flower pots and knickknacks. We can even sit in our living room windows.

3. With frame walls, use plywood exterior sheathing, caulked and nailed securely.

A strong exterior surface is an essential part of your wall structure. It prevents air leakage, makes the house very resistant to wind damage and earth movement, prevents cracks in the interior finish, and provides a good nail base for siding.

Don't use foam insulation board as a substitute for the exterior sheathing, not even partially. It has no structural strength, it can cause moisture damage in the wall, and it does not work as a nail base. In frame construction, all the insulation should be inside the wall.

Don't install house wraps, except in certain climates. They are unnecessary with properly applied sheathing, and they may cause trouble. The *Energy Efficiency Manual* explains why.

4. Avoid excessive window and skylight area. Limit glass to locations where it will do some good, either for a good view or for daylighting.

Windows and skylights create a large fraction of your total heating and cooling costs. Unfortunately, glazing remains a weak link in the energy performance of houses. Even the best windows have poor insulation value compared to insulated walls. Also, windows and skylights account for most cooling cost by allowing sunlight to enter the house directly.

If your house has too much glass, no other improvement to the structure can compensate. It's like a boat that has a big hole in the hull. So, budget your use of glass wisely. Plan the sight lines from inside your daytime rooms to get the best view in relation to the glass area. In bedrooms and bathrooms, design the window sills high enough to provide privacy, allowing you to use the windows for lighting.

Glass does provide the benefit of daylighting, which is pleasant if it is well planned. However, lighting cost in houses is small, whereas heating and cooling costs are large. (This is different from commercial buildings, where lighting may cost more than heating or cooling.) Think of windows and skylights as light fixtures that cost a lot of money to install and operate, and plan them accordingly.

5. Install double- or triple-pane windows that open easily and close tightly, with good thermal barriers in the frames.

The insulation value of windows depends mainly on the number of panes. Other features, such as "low-E" coatings can improve performance somewhat, but their benefits tend to be exaggerated. The *Energy Efficiency Manual* explains these features.

For your openable windows, select models that close very tightly, and stay tight for the life of the house. Slider and hinged windows are available in tight-sealing models, but you have to look for them.

Remember that windows also serve as the inlet for outside ventilation air, which you should use for cooling whenever possible. Slider windows combine a large opening area with the ability to control the open area precisely.

I prefer windows with enameled aluminum frames. Wood frames warp, and plastic frames become brittle with age. Make sure that your aluminum frames have a good thermal barrier to minimize heat loss through the metal.

In a cold climate, consider installing removable interior storm windows to provide additional savings. See the *Energy Efficiency Manual* to avoid condensation problems.

A Special Caution about Daylighting and Passive Solar Heating

Daylighting uses relatively small skylights and clerestories to provide daylight in addition to the light that you get from normal windows. Well designed daylighting provides a pleasant ambiance while saving a relatively small amount of energy. The cost is modest, but it takes a long time to pay back in energy savings. I recommend limited use of skylights or light pipes, mostly as an ambiance feature, coordinated with intelligent window design. Be careful to avoid increased heating and cooling costs, condensation problems, and glare. Refer to the daylighting section in the *Energy Efficiency Manual* to make sure that you get it right.

Passive solar heating is the use of direct sunlight through large windows and skylights to provide heating. In many locations, passive solar heating could eliminate the cost of heating energy almost completely. However, it is expensive to build and it is much more complex than it appears to be. Most passive solar installations have been failures, wasting energy, causing discomfort and moisture problems, and ruining the appearance of the house. I recommend that you avoid passive solar unless you are deeply committed to making it work. See the *Energy Efficiency Manual* before you start. For now, you will gain much more by investing your money in insulation.

6. Install doors that have good insulation and excellent weather sealing.

We installed Stanley metal-faced insulated doors in our house 22 years ago, and I haven't found any better doors since then. They have magnetic gaskets that are still tight. However, metal doors need a good grade of enamel paint to prevent rusting of the exterior surface.

Don't install storm doors. They break or become leaky in a short time, and they are a nuisance to use. If you live in a cold or windy location, consider an entry vestibule or "mud room." These are great for taking off boots, stowing snow shovels, etc.

Spend a little extra for a garage door that seals tightly. For example, a good bi-fold door seals much better than a roll-up door.

7. Minimize air conditioning cost by shading all windows.

Most home air conditioning cost comes from sunlight that enters through windows. Try to prevent any direct sunlight from entering any window during warm weather. The *Energy Efficiency Manual* gives you a wide range of shading options, along with their design issues.

Use permanent structural features in preference to window accessories that need action by occupants. Deep roof overhangs are a great feature. They also prevent basement moisture problems and extend the life of exterior wall surfaces. Attic trusses that are designed to allow deep attic insulation will have wide overhangs anyway, so make the most of them. Where roof overhangs are not sufficient, consider soffits and other architectural features for shading.

Awnings are an effective alternative, but they tend to become shabby with age. All exterior shading requires careful orientation with respect to the sun's motion.

Interior shading is inexpensive, but it is less effective and it interferes with views. Ordinary Venetian blinds and roller shades work well, but only if you use them properly. Avoid shades that are installed between the panes of windows, because you can't repair them.

8. Radically vent the air space above attic and cathedral ceiling insulation.

Do everything you can to open the space above the roof insulation to air flow. The roof surface should work like an umbrella and a parasol, not like a tight fitting raincoat. Good ventilation of the underside of the roof surface reduces air conditioning cost, prevents moisture condensation, and prevents ice dams during cold weather.

In both conventional attics and vaulted ceilings, install a continuous ridge vent. Also, install a continuous row of large openings completely around the bottom edges of the roof to feed air to the underside of the roof surface. In warm climates, the ridge vent and bottom openings should have much more opening area than are commonly used today.

With a vaulted or cathedral ceiling, leave a 6" freely ventilated air space above the insulation. This is much more space than is typical today. It will eliminate the moisture damage that is common in vaulted ceilings. Along with the added insulation, this will result in a much thicker roof. This is a significant change, so work it out carefully with your builder.

9. In warm climates, make the roof top surface shed heat as effectively as possible.

This is a tricky issue. The *Energy Efficiency Manual* shows you what to do. In snowy climates, a darker roof surface helps to remove snow and prevent condensation.

10. Plant trees around the house in a way that optimizes shading and makes your yard beautiful.

If you live in a climate that can be warm for extended periods, make trees an integral part of your house's design. The *Energy Efficiency Manual* tells you how to select the right species, how plant them to avoid problems, and how to enhance the appearance of your property.

THE ENERGY-USING EQUIPMENT OF YOUR HOUSE

The Most Important Principles …

11. Select high-efficiency models of all energy using equipment.

All the equipment in your house that uses energy – including furnaces, air conditioners, water heaters, refrigerators, freezers, dishwashers, washing machines, clothes dryers, televisions sets, computers, light bulbs, etc. – is available in a wide range of high-efficiency versions.

Make it a habit to always select high-efficiency appliances. This powerful action requires no special skills, and it adds very little to the cost of your house. You can find the efficiencies of all current models on the Internet. For example, see www.ACEEE.org/consumerguide.

12. Turn off heating, cooling, lighting, and other energy-using equipment when you don't need them.

Turn off all equipment when it is not needed. If it's not running, it's not using energy!

Don't believe the myth that says you should leave the air conditioner running all day while the house is empty. That is simply not true.

However, don't bother to unplug appliances that are turned off. Electronic equipment that is operating in "standby" mode uses very little energy.

Heating and Cooling Efficiently …

13. Select heating and cooling systems that are tailored to individual spaces.

You live in your house one room at a time. For example, you don't need to heat the living room while you are in bed. So, select equipment that can heat and cool rooms individually only when you occupy them.

Also, use separate systems for heating and cooling. This avoids big compromises in efficiency and comfort. (In some locations, heat pumps may be your most practical choice, but heat pumps have significant liabilities.)

Avoid heating and cooling systems that need ducts for air distribution. Ducts leak badly and control temperature unevenly. Ducts collect dirt and cause health problems. Furnaces and central air conditioners have trouble when you try to isolate rooms by closing duct dampers.

For heating, favor hot water ("hydronic") convectors or radiators, with a separate heating circuit and thermostat for each room. Hydronic heating is the favored heating method in most advanced countries. (The U.S. still needs to catch up in this area.) Convectors are completely silent. It's easier to install pipes or wiring for convectors than to install ducts. Get a high-efficiency boiler to heat the water.

For cooling, you get the best combination of efficiency and comfort by using a number of "split system" air conditioners, each serving an individual room or a group of rooms that are used at the same time. I installed the Mitsubishi "Mr. Slim" model in my house because it is quiet, easy to install, and user-friendly.

The *Energy Efficiency Manual* shows you how to select high-efficiency boilers, furnaces, air conditioners, and heat pumps.

14. Install programmable thermostats.

Programmable thermostats turn off heating and cooling automatically. They can turn on the heat before you arise, and cool the house before you return. Many inexpensive models are available. See the *Energy Efficiency Manual* to make sure that you get the right features.

15. Buy a thick, cozy goose down comforter, and turn off the heat at night.

Comforters are essential bedroom equipment in a climate that gets cold. They feel so good on a winter's night! The programmable thermostat will warm your bedroom before you get up.

16. If your heating equipment burns fuel, draw combustion air from the outside.

Most high-efficiency furnaces and boilers can easily draw combustion air from the outside through a small pipe. Exploit that feature. It avoids potentially serious problems, including carbon monoxide, inefficient combustion, and air leakage into the house.

17. Install the condensing units of air conditioning equipment in cool, clean locations.

The condensing unit is the outside metal box that makes all the noise. Its location is critical. Try to install it in a cool location, such as a shaded side of the house. Give it wide open air flow. Install it so that it will not be fouled by debris, such as leaves and dirt. Never, never install a condensing unit in the attic.

18. Install a quiet, high-volume ventilation fan to provide outside air cooling.

It makes no sense to run air conditioning when it is cool outside. For those times, install a quiet whole-house ventilation fan. The fan exhausts warm air from the house and cool air enters through windows. This works well for cooling bedrooms at night.

In houses with attics, a common method is to install the fan above an opening in the ceiling, so that the fan exhausts into the attic. The opening needs a good one-way damper, which may be included with the fan. Design the opening so that you can close it tightly during cold weather. To minimize noise, the fan should be large and slow. Make the installation as quiet as possible by installing the ceiling opening at a distance from the rooms being cooled.

Control the fan with a manual switch and two simple thermostats. One thermostat is located at the ceiling opening and it turns off the fan when the temperature drops too low. The other thermostat prevents the fan from running when the outside temperature is too high. A really deluxe installation would control the fan speed with the inside thermostat.

19. In a warm climate, install ceiling paddle fans.

Paddle fans are economical and pleasant. They substitute for air conditioning during mild weather, and they reduce air conditioning cost during hot weather. Unlike whole-house ventilation fans (above), they work even when the weather is too hot to cool with outside air.

Paddle fans are much quieter than other types of in-room circulation fans, and they don't get in the way. Models are available to fit any décor. Choose a model that has many speeds and user-friendly speed controls.

Paddle fans work better will taller ceilings, including vaulted ceilings. Install paddle fans directly above the people, if possible. E.g., over the bed in a bedroom. In a large room, install several fans.

Don't install a paddle fan underneath light fixtures. The sweep of the blades in front of lamps creates a very annoying flashing effect.

20. Manage your windows and ventilation.

Opening a window very slightly will provide enough ventilation to avoid indoor air quality problems in a room. Even a small window opening admits a lot of air.

Don't leave your windows wide open while you are heating or air conditioning! You will be paying to heat or cool the whole outdoors.

Don't rely on windows for ventilating a kitchen. See the next tip. To ventilate a bathroom that doesn't have windows, you need a ventilation fan that is controlled by a timer.

In the Kitchen …

21. Install a high-volume range hood, combined with a separate outside air supply to the kitchen.

A good range hood sucks a lot of air out of the kitchen, so you need to replace it with an equal amount of air from the outside. Supplying air directly to the hood area avoids the need to heat or cool a lot of outside air, and it improves the effectiveness of the hood.

This is standard practice in commercial kitchens, but you may have to explain it to your homebuilder. It's important to install a damper in the air supply that closes tightly when the hood fan is turned off.

22. Install your refrigerator and freezer in cool areas that isolate them from heat producing equipment, including the range, water heater, and dishwasher.

Refrigerators and freezers may reject heat through their rear, sides, and/or bottom. Provide ample clearance for the heat to escape. If necessary, install a partition to block heat from adjacent equipment.

If the climate is cool most of the time, install your food freezer on a shaded outside porch if practical. Let nature do as much of the cooling as possible.

23. Get a microwave oven, and use it.

Yes, they really do use much less energy than stoves. This is because they heat only what matters. The inside of the microwave oven itself stays cool.

24. Keep lids on your pots and pans when you cook.

This simple habit can cut your cooking energy in half. And yes, water boils at the same temperature whether the pot is covered or not. To keep the pot from boiling over, just tip the lid slightly to one side. Use a pot or skillet that is larger than the burner.

25. Thaw frozen food in your refrigerator.

Thawing a large item like a pot roast takes about one day, so plan your meals in advance. This saves both refrigeration energy and cooking energy. This practice also reduces the risk of food poisoning.

Saving Water and Water Heating Energy …

26. Install separate hot and cold water faucets for all basins, tubs, and showers.

The most common arrangement – individual hot and cold water faucets with a single spout – is the best for all basins, including the kitchen, the bathrooms, and utility sinks. For kitchen and utility faucets, select the large, hospital-style handles that are now becoming popular for homes. They are especially convenient to use.

Avoid single-lever basin faucets. They encourage users to waste hot water, and they are expensive to repair.

Also avoid single-knob shower faucets. They are a nuisance for unfamiliar users, and they risk scalding. Absolutely avoid full-flow shower faucets, which waste water extremely.

27. Select low-flow shower heads with adjustable spray patterns.

Expect to negotiate with your spouse about these. An adjustable shower head may make everyone in the household happy. The *Energy Efficiency Manual* explains the features to select. *Consumer Reports* occasionally does a report on different models.

28. Select toilets that flush efficiently.

The U.S. government decided to design toilets to save water, resulting in many models that don't flush well. These actually waste water because they require repeated flushes. So, you will have to search to find toilets that work satisfactorily. See *Consumer Reports* for their latest toilet tests.

You probably want to select a good model of the conventional type. Pressure-flushing toilets are the most effective type, but they are loud and prone to trouble. Vacuum-flushing toilets are a newer type that is not well proven. Avoid composting and recycling toilets, which are an esthetic horror.

29. Install an efficient urinal.

It makes no sense to use a gallon or two of water to flush a few ounces of urine. Save most of that water by installing a type of urinal that uses little or no water for flushing. For example, see the Waterless Co. Web site. (Ordinary commercial urinals waste almost as much water as toilets.) Have a wall or shield on each side to protect against splash and bad aim.

30. Select an efficient washing machine.

Front-loading washers use somewhat less water than top-loaders, but top loaders are getting closer to them in efficiency. Check the latest *Consumer Reports* washing machine review.

31. Turn down the hot water temperature when the house is vacant.

If you're away for a week or longer, lower your hot water temperature to minimum. This is effortless. Just turn down the temperature control knob on your water heater when you leave. But, don't turn off the pilot light.

This may not be a good idea with electric water heaters, because tepid water may encourage growth of harmful organisms in the tank. See the *Energy Efficiency Manual* for guidance.

Efficient Lighting …

32. Use reflective interior colors.

Large dark surfaces are light traps, wasting lighting energy and making the space gloomy. For dominant colors, use light tints. Use deep colors only as accents.

33. Install fluorescent lighting in rooms where lights stay on for long periods.

The best types of fluorescent lighting are about four times more efficient than incandescent lighting. Some types of fluorescent lighting are much more efficient and economical than others. See the *Energy Efficiency Manual* for details.

Fluorescent lighting is good for kitchens, living rooms, and workshops. Fluorescent fixtures also provide pleasant, glare-free lighting over bathroom wash basins.

Do not use fluorescent lighting outside or in unheated spaces. Fluorescent lamps are unreliable and inefficient at low temperatures.

34. Make all light fixtures as efficient as possible.

Tailor all light fixtures to the application. For reading and work, get fixtures that concentrate the light on your material. Select shades that absorb as little light as possible. Substitute screw-in fluorescent lamps for incandescent bulbs in portable fixtures that are turned on for extended periods.

35. Install motion sensors to control lighting in appropriate locations.

Motion sensors are fun, but tricky to apply. The *Energy Efficiency Manual* shows how to install them properly.