Affordable resource efficiency| An introduction to living within our means

Laura Armstrong
The University of Montana

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AFFORDABLE RESOURCE EFFICIENCY:

An Introduction to Living Within Our Means

by

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B.A., Biology/Environmental Science
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for the degree of
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Approved by:

[Signatures]
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The Evolution of Efficiency

*Unless we change direction, we are likely to end up where we are headed.*

—Chinese Proverb

In the early 1970s, scientists and scholars began to impress on a wide American audience that the quantities of natural resources on and in the Earth are limited. In 1974, economist Robert Heilbroner surmised that, "...ultimately there is an absolute limit to the ability of the earth to support or tolerate the process of industrial activity, and there is reason to believe that we are now moving toward that limit very rapidly." Our dependence on natural resources was thrust into the limelight when the oil crisis of the 1970s publicized the feeble ability of the United States to function without foreign oil. The popularization of energy efficient homes and businesses as well as research into alternative energy sources resulted from our gasoline-starved panic.

Although the national focus on efficiency vanished during the Reagan/Bush era, new attention is being focused on energy efficiency as we gauge more clearly the consequences of human resource consumption on the health of the natural environment. Efficiency is again becoming a primary concern to energy producers and energy consumers alike. Some of the concerns are financially based. Utility companies are
fostering energy efficiency in an effort to avoid the expense of opening new powerplants, while their customers are beginning to realize, once again, that when less energy is used, money is saved on the monthly fuel bill. Energy conservation is also spurred by consideration of the environmental degradation caused by energy extraction and use, as well as the knowledge that energy supplies are indeed limited. Even those who conserve energy simply to save money realize that the more scarce energy becomes, the more expensive it will become, so they too are thinking for the future.

Conservation of energy is not the exclusive concern. Water and air pollution, forest depletion, hazardous mine tailings and overflowing landfills help convince many that rampant consumption of other natural resources is of consequence as well. The combination of energy efficient technologies and careful materials choices is collectively termed resource efficiency. Current trends in the environmental movement are coinciding with developments in the design and construction industries resulting in the rapid spread of “green building” technologies.

Contrary to popular belief, resource efficient design and construction is not a concept conceived in the 1990s. Rather, the creative application of used building materials to construct solid and practical buildings is historically well-documented. As an 11-year-old, I visited Saint Albans Abbey in Hertsfordshire, England. This 900-year old church, in which services are still held, was constructed primarily of then 1000-year-old bricks recycled from the nearby ruins of ancient Roman roads.

Henry David Thoreau’s famous cabin on Walden Pond was constructed of salvaged floorboards, recycled bricks and second-hand windows. Thoreau marveled at the cost
savings he enjoyed by collecting and transporting used building materials on his own as he detailed the materials with which he built his cabin:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boards</td>
<td>$8.03 1/2 (mostly old shanty boards)</td>
</tr>
<tr>
<td>Refuse shingles for roof and sides</td>
<td>$4.00</td>
</tr>
<tr>
<td>Laths</td>
<td>$1.25</td>
</tr>
<tr>
<td>Two second-hand windows with glass</td>
<td>$2.43</td>
</tr>
<tr>
<td>One thousand old brick</td>
<td>$4.00</td>
</tr>
<tr>
<td>Two casks of lime</td>
<td>$2.40</td>
</tr>
<tr>
<td>Hair</td>
<td>$0.31</td>
</tr>
<tr>
<td>Mantle-tree iron</td>
<td>$0.15</td>
</tr>
<tr>
<td>Nails</td>
<td>$3.90</td>
</tr>
<tr>
<td>Hinges and screws</td>
<td>$0.14</td>
</tr>
<tr>
<td>Latch</td>
<td>$0.10</td>
</tr>
<tr>
<td>Chalk</td>
<td>$0.01</td>
</tr>
<tr>
<td>Transportation</td>
<td>$1.40 (I carried a good part on my back)</td>
</tr>
<tr>
<td>In all,</td>
<td>$28.12 1/2</td>
</tr>
</tbody>
</table>

These are all the materials excepting the timber, stones and sand which I claimed by squatter's rights. I also have a small wood-shed adjoining, made chiefly of the stuff which was left after building the house."

Thoreau justified his listing of the costs of the materials by observing that, "...very few are able to tell exactly what their houses cost, and fewer still, if any, the separate cost of the various materials which compose them." With this thought, Thoreau encapsulates a central principle of resource efficiency—knowing the physical makeup of the buildings we occupy and realizing the origins of those materials. The modern addendum to this concept, of course, is that we must be mindful not only of the monetary costs of the resources we use, but of the ecological costs.
The American Dream: A Consumptive Nightmare

*There is something fundamentally wrong about treating the Earth as if it were a business in liquidation.*

--Herman Daly

Many in our society see more as better and measure quality of life by the quantity of material goods individuals are able to afford. For some, the more clothes, cars, appliances, and toys we can buy, and thus the more raw materials we consume, the better our lives. It may seem like our personal resource use is extremely small compared to the amounts of resources that exist on the planet, so it is hard to imagine that the resources we use, or choose not to use, make any difference. In actuality the average American, “accounts for the use of 540 tons of construction materials, 18 tons of paper, 23 tons of wood, 16 tons of metals, and 32 tons of organic chemicals” over a lifetime. Much of this resource use is a result of the pursuit of the single-family home, the most prevalent symbol of the American dream and for most Americans, the single most important measure of quality of life.

The Destruction of Construction

The bigger is better attitude typical of American consumers has found a comfortable niche in the construction industry. As the average family size decreases, the amount of space allocated for each person grows. According to the 1990 Census, the average new house built in the United States is 1,945 square feet and houses 2.5 people. Thirteen percent of the new homes built in the United States have more than 3,000 feet in floorspace and 12% of new homes have three-car garages.
The nationwide move away from traditional, climate-oriented construction practices toward monothematic tract housing following World War II marks a significant shift in the efficiency of housing in the United States. Prior to the suburbanization era of the 1950s and 60s, houses were usually designed and sited individually, according to climate and topography, using materials available locally. Designers typically made the most of solar gain without overheating the occupants by using logical site orientation and appropriate window sizes. Efficient housing prior to World War II resulted largely from generations of solid common sense.

The return of the soldiers from World War II sparked a tremendous housing boom as developers such as William J. Levitt and Henry J. Kaiser made their mark from New York to California. These new developments of tract houses used standardized plans in different orientations on lots, largely ignoring solar orientation and geographic constraints. Locally available and indigenous building materials were forsaken as wood emerged the building material of choice to construct the clusters of identical homes spreading across the countryside.

Ninety percent of the new houses built in the United States each year are framed of wood, or stick-framed. According to the United States Forest Service, construction of new housing accounts for 50% of the annual lumber consumed in the U.S. Remodeling and repair of the existing housing stock consumes an additional 20% of lumber produced. Not only does construction account for the majority of wood used, global statistics show that huge percentages of other natural resources are dedicated to building as well.
The Worldwatch Institute asserts that partial responsibility for much of the environmental damage occurring today, including the destruction of forests and rivers, air and water pollution, and climate destabilization, "belongs squarely at the doorsteps of modern buildings." An estimated one-tenth of the global economy is allocated to the construction and operation of buildings. Buildings consume between one-sixth and one-half of the planet's physical resources, as approximately 3 billion tons of raw natural resources are fabricated into building materials each year. The monetary costs of construction are enormous, as well. Global construction, "...dollar for dollar...uses several times as much wood, minerals, water and energy as the rest of the economy."11

Because the processes involved in converting virgin resources into houses are typically disruptive to the land and highly energy intensive, the environmental degradation created prior to actual construction should also be considered. An interesting example is the energy consumed by the construction and operation of buildings. The operation energy of buildings is well-documented and often discussed. This energy use for heating, cooling, lighting, hot water and other operations is quantified each month by utility bills around the country. The embodied energy of the building, that is, the energy required for extraction, processing, manufacture, transportation and installation of the materials which comprise the building, is often overlooked. The operation of buildings in the United States is estimated to consume 36% of the total U.S. energy budget. When embodied energy is considered, energy allocation to the building sector jumps to 45%, which is greater than any other use.12
In addition to embodied energy, other hidden costs of construction leave behind a toxic legacy. Consider, for example, the purification and smelting of low-grade copper ores to provide 530,000 tons of copper each year for production of plumbing pipes and electrical wiring in the United States. The byproducts of copper manufacture include huge tailings piles, release of substantial quantities of heavy metals, such as cadmium and arsenic, and production of sulfur dioxide, a constituent of acid rain.¹³

Not only do our buildings contain incredible quantities of natural resources, we waste an inordinate amount of materials and energy in both the construction and operation of our homes. The National Association of Home Builders Research Center estimates that each 150 ton house that is built results in 7 tons of refuse. One-quarter of this waste is wood products. In fact, 10% of the lumber and plywood produced in the United States each year winds up in our already overflowing landfills.¹⁴

Uninformed Consumers

Lack of realization of the types and amounts of materials which make up a home provides a vivid illustration of the mental distance which separates North American consumers from the origins of the products they buy. Just as some children are surprised to learn that milk isn’t made at the grocery store but instead comes from a cow, most Americans are ignorant of the travels of their consumer goods prior to the day of purchase. The myriad materials which we combine to form our houses are no exception to this lack of understanding. A 1,700 square foot home is made of an average of 150 tons of building materials, including 9,700 board feet of lumber (roughly the same as one
acre of clear-cut forest), 55 gallons of paint, 55 cubic yards of concrete and 300 pounds of nails. Even the semantic trick of calling trees that have been taken from the forest, “wood”, “lumber”, and “boards”, works to distance consumers from the natural origin of their built surroundings. How many people realize the natural resources captured by their home?

The destruction of construction does not merely constitute an environmental problem. The widespread acceptance of conventional construction practices indicates a symptom of a larger societal acceptance, even a promotion, of consumption and waste. We treat the Earth like a big shopping mall with unlimited merchandise, running here and there to find the best bargain on the newest trend, then throwing it out after a few months when the next trend comes along. Many of us realize that environmental degradation is occurring, but we blame industry and big business and fail to see our personal connection to the destruction. Increased consumer consciousness will allow the realization that every purchase we make impacts the natural world in a variety of ways. Careful consideration of the source, use, durability and disposal of each purchase we make can help minimize these impacts.

A Place to Call Home

Lack of affordable housing in the United States is another symptom of an unsound construction ethic. The concept of affordable housing is hard to define because affordability is a relative term. Criteria for affordability differ from person to person and from region to region. Our personal concept of affordability depends largely upon the
amount of money we make and the amount we wish to allocate to monthly housing expenses. A regional definition of affordable might depend on the availability of housing in general and the financial standing of local home buyers.

According to the United States government, housing is affordable if people who make less than 80% of the median income spend less than 30% of their household income on housing. Affordable housing is further classified into the following components: moderate income is considered 61% to 80% of the median, low income is considered 51% to 60% of the median and very low income is below 50% of the median. In 1991, the median net household income in the United States was $29,943. In 1991 then, affordable housing would have cost between $457 and $572 per month for a family of moderate income, between $381 and $449 per month for a family of low income, and less than $374 per month for a family of very low income.

Tragically, housing at even these levels, which seem rather expensive, is not abundant. According to a study by the Joint Center for Housing Studies at Harvard University, people who rent houses or apartments are paying an average of 31% of their gross incomes for monthly housing costs. This is the highest proportion in 25 years.

The national trend of scarce affordable housing is evident in Missoula, Montana. According to a 1993 study of housing affordability in Missoula, "...large segments of Missoula’s population are facing serious problems of affordability and the availability of decent housing." The study suggested that the occupational structure of Missoula, like much of the United States, is changing from largely working class to a mixture of, "professionals on one hand and service workers on the other." This shift has resulted in
larger and larger disparities of income. Rising living costs are making it difficult for many people to afford housing in western Montana. In a recent article in The Missoulian, Bill Carey, the director of Missoula's Food Bank stated that, "...many of the 3,700 households served by the Food Bank last year were spending more than half of their incomes on housing and utilities." Similar trends are being experienced across the country as many families actually spend upwards of 50% of their income on housing. The lack of affordable housing seems an incredible injustice, particularly with consideration of the quantities of resources wasted by conventional construction methods.

**An Efficient Solution?**

After seven years of academic study of the human-made environmental disasters threatening the Earth, it could be easy for me to face the future with pessimism and dismay. Some days, I have little wish to work to preserve the planet for human habitation because I am not sure we deserve it. But most days, I feel an internal drive to find ways to safeguard the natural world for future generations and foster a positive relationship with the Earth. I was taught for many years to look at ecological problems and try to think of ways to solve them. But how, from a college campus in Maine or Montana, do I help to solve the problems of forest depletion, water and air pollution, and exponential growth of solid waste? The realization that I cannot effectively focus on solving the problems until the causes of our most serious environmental crises are explored has opened what I believe to be a doorway to potential solutions.
Study of the North American housing industry reveals the depressing truth about the natural resources sacrificed daily to construct our built environment. A look beneath the surface, however, unveils the promise of a better method and hope that many ecological problems can be addressed through a comprehensive shift in modes of thinking and an in-depth investigation of our consumption of natural resources.

Early in my first ecology course, I learned that all living things are interconnected; the planet is an enormous living system, the life of one organism affects the lives of others. This tenet provides valuable clues about the most intelligent approach to addressing environmental catastrophes. When environmental problems are examined individually, short-term, band-aid solutions often result which are insufficient to deal with the issues over the long-term. If we approach all aspects of all environmental problems concurrently, the complexity and devastation are overwhelming and we may fail to see the solutions buried in the pollution. Consider then the causes of the environmental destruction. A main, if not the main cause of environmental devastation is human consumption of natural resources. We devote tremendous amounts of natural resources to the construction of our built environment. Perhaps through explicit consideration of the built environment as part of the global system and subsequent reduction of the resources allocated to construction, we can begin to abate environmental problems ranging from forest depletion to land degradation to water and air pollution to global warming and to cultivate a fundamentally different approach to human interaction with the natural world.
Housing design is most effective when the house itself is considered a system. This consideration is the first step towards making housing a more sustainable component of the global system. Resource efficient design and construction, though practiced unofficially through the ages, is emerging as a newly recognized alternative to conventional building. Resource efficiency involves the conscious choice and evaluation of the natural resources we incorporate into the built environment resulting in buildings which require less energy and fewer materials. Some of the qualities which contribute to the efficiency of a building material are: durability, low embodied energy, regional or indigenous production, recycled content, recyclability, functionality, and manufacture resulting in relatively little pollution. The essence of resource efficiency is an understanding of the aggregate ecological significance of the materials we use — from extraction and processing of the raw natural resources, to manufacture, packaging, transportation, and installation of the finished product, to the duration of the product’s functionality and ultimately to disposal of the product after its useful life. Such a systematic evaluation provides an understanding of the way our houses and the materials which comprise them fit into the global system. If introduced effectively into mainstream thinking, resource efficient thought can be an effective method of curbing our voracious appetites for natural resources and slowing the current tide of ecological destruction.
Or Just Another Yuppie Trend?

Many so-called resource efficient homes currently documented average over 2,000 square feet of floorspace and sell for greater than $200,000, which makes it difficult to dispute the image of resource efficiency as an elitist trend. The “Resource Conservation House”, for example, is a 3,600 square foot house built in Maryland from largely recycled materials. This house will go on the market for well over $200,000. ReCraft ‘90 a resource efficient demonstration home in Missoula, Montana is 2,400 square feet, and cost roughly $250,000 to build. These high profile examples of resource efficient construction lend credibility to the prevalent notion that environmental consciousness is reserved for people who have the benefit of both money and education. These houses are certainly showplaces for resource efficient technology, but such homes do not adequately represent the applicability of resource efficient living to everyday life. Additionally, they violate one of the primary guidelines of resource efficiency -- keep the size of the house to a minimum to reduce the materials required for construction and the lifetime operating costs.

Other demonstration projects exist or are in progress around the country which suggest that progress towards more effective and accessible resource efficiency is being made. South Wall Builders, the builders of ReCraft ‘90, are currently building a resource efficient house as an example of affordable urban infill in Missoula, Montana. The 970 square foot “Timber-Tech” house will likely be priced competitively with similar-sized

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*a Urban infill is the utilization of vacant lots within an existing urban area or neighborhood as an alternative to developing land on the edges of an urban area. Urban infill can result in reduced pressure on undeveloped land at the edges of existing communities. Not only can urban infill reduce urban sprawl, the presence of an existing neighborhood allows less expensive access to such infrastructure items as sewer, water, and power.
new houses in Missoula. By incorporating a wide variety of alternative building materials, South Wall hopes to illustrate that an affordable, attractive and comfortable house can be built which, through careful planning and design, makes use of fewer natural resources. The particular focus of the Timber-Tech house is substitution of engineered wood products to replace conventional solid-sawn lumber (See Appendix A).

On a larger scale, The Conner Group of Bellevue, Washington built an entire community of what they term Earth Sense homes incorporating such engineered wood products as oriented strand board and finger-jointed studs. The builder evaluated more than 50 different products for cost-effectiveness, energy efficiency, and comfort before including them into the Earth Sense Home. The Earth Sense package added just over $4,000 to the purchase price of the home, but homebuyers were not deterred. The entire development quickly sold out as people were attracted to the reduced environmental costs of the houses plus the long-term benefits of lower operation costs through energy efficiency and water conservation.

The Model of Energy Efficiency

The financial benefits of energy efficiency have been apparent since the energy crisis of the early 1970s. Improvement of energy efficiency in homes and businesses has saved $275 billion per year since the oil embargo of 1973. Despite the seemingly obvious financial and ecological benefits of energy efficiency, most consumers in the nineties are not vigorously demanding efficiency. According to Paul Lipke of the Northeast Sustainable Energy Association (NESEA), "...energy efficiency is not a priority with the majority of home buyers." Lipke goes on to mention, however, that once a house is
proven to be, "comfortable, durable, healthy and of top quality," the owner's are happy to have lower operation costs. 

Debbie Palermini of the Sustainable Building Collaborative in Portland, Oregon asserts that the biggest drawback in the building industry at present is that builders don't know enough about energy conservation and recycled or alternative building materials. She contends that there is consumer demand for environmental products in both residential and commercial areas and the builders are willing to try the products which have been proven to be effective and economical.

Until builders, architects, and designers have proven to their customers that resource efficient homes will be durable, safe, comfortable and resaleable, consumers would rather stick to conventional houses, despite higher operation costs. Likewise, most builders, architects, and designers do not want to risk failure by marketing alternative technologies which might not prove profitable. Thus, resource efficient design may be caught in a vicious cycle, waiting for the adventurous and open-minded to choose the road less traveled. The national prevalence of resource efficient demonstration projects is doing much to dispel concerns regarding the feasibility and durability of many alternative building materials.

Affordable Success Stories

While some consumers ignore the financial and environmental benefits of energy efficiency, others have incorporated energy efficiency into their lives at great monetary savings. For middle and low income people, the money saved by having an energy efficient house can make a significant difference in the monthly budget. While many
advanced energy efficient technologies can be prohibitively expensive to implement, more basic techniques exist which allow energy efficiency to be affordable initially and which subsequently result in considerable monetary savings over the operating life of the building.

Weatherization, for example, provides an impressive return on initial investment. In a 1989 pilot study by the Oak Ridge National Laboratory in Tennessee, the weatherization of 189,000 homes reduced energy use in the following year by an amount equivalent to 601,000 barrels of oil. Over the estimated 20-year lifetime of the weatherization measures, the 1989 work will save the equivalent of 12 million barrels of oil. Total costs of the program averaged $1,550 per dwelling in 1989. The net energy dollars saved by 1992 averaged $1,609 per dwelling -- representing a three year payback of 109%.28

Several chapters of Habitat for Humanity, an international organization providing affordable housing to low-income people, make use of energy efficient design techniques and technologies in the specifications for the houses they build. Several of Habitat’s basic design tenets lend themselves well to a discussion of energy and resource efficiency Habitat asserts that the houses they build, “...should be modest in size and the design should take advantage of renewable resources.”29 Patrick Murphy, director of the Denver chapter of Habitat for Humanity, is an adamant supporter of further implementation of energy efficiency in the design specifications of Habitat’s houses. In a speech at the Energy Efficient Building Association’s 1991 Conference, Murphy stated:

"In order to more properly meet its goal of providing simple and decent shelter to all people, it is critical that Habitat for Humanity continue to develop energy efficient systems and techniques within its projects. As has been seen energy efficiency and conservation are issues both of economy and comfort, even
survival. It is an area of concern that should not be set aside because of shortsighted concerns about simple up front economy. Habitat for Humanity is the second largest housing provider in the world. Involvement of Habitat in energy efficiency and resource efficiency is extremely significant. For the environmental movement to have continued impact on the lives of the American people, environmental thinkers need to appeal to a wide array of people, from government leaders and business people to blue-collar workers and religious organizations. Energy and resource efficiency provide an excellent opportunity for broadening the base of support for environmental protection. Not only can resource efficient housing provide long-term economic savings to people with limited incomes, the personal exposure to resource efficiency will emphasize the need for individual responsibility for resource conservation for people of all economic levels.

Living Within Our Means
In setting out to produce an illustrative booklet on affordable resource efficiency, my purpose is to increase the accessibility of resource efficient thought. Much information is already available regarding resource efficiency, but it is largely aimed at construction industry professionals. There is a distinct need for a general, readable, accessible presentation of the ideas and methods of resource efficiency. Additionally, very few publications combine the concepts of resource efficiency and affordable construction.

A movement towards sustainable living cannot be accomplished solely from within the ivied walls of academia. To begin to effect reduced consumption of natural resources, environmental consciousness must be introduced into people’s homes. The
purpose of, "Affordable Resource Efficiency: An Introduction to Living Within Our Means" (Appendix A), is to allow homeowners and renters from a variety of income levels to gain access to basic information regarding resource efficiency. This booklet gives the average homeowner or renter a solid foundation with which to frame the issues of sustainable housing. The common denominator of the need for practical and affordable housing will motivate individuals to conserve natural resources through resource efficient building and maintenance.

In this booklet, I present resource efficiency as a potential method for saving money in the construction and maintenance of housing. For now, it doesn't matter if people conserve resources for purely environmental reasons, or because they can save money with reduced consumption. The savings of natural resources and the subsequent lessening of environmental degradation is significant whatever the motivation for that conservation. After a time, increased personal awareness of the human connection to environmental quality will encourage reduced consumption for the sake of resource conservation.

Because resource efficiency cannot result from a series of spur of the moment purchases, adequate information must be available to help people make environmentally responsible decisions when they choose to consume. Resource efficient choices are not cut and dried -- the appropriateness of a given material or construction technique depends on a great variety of factors including climate, local availability of a product, existence of a more suitable indigenous product, current pricing of the alternative material and its conventional competitors, and the specific use intended for the material. Because of
these varied considerations, I have not set out to list the exact materials everyone around the country should use for home construction and maintenance. Instead, I have presented an introduction to conscious conservation of natural resources with an emphasis on materials used for housing.

By addressing the main components of any new or remodeled building -- structural, mechanical, functional, and aesthetic -- I have given the potential reader/user in most construction and maintenance situations ammunition with which to effect real environmental and economic change. The goal is to provide people with enough basic knowledge of resource efficiency to begin to ask informed questions. Most architects or builders, for example, are not going to specify an alternative construction technique unless the client specifically asks for it. The client, therefore, must be have access to background information. The same concept applies to people who are building or remodeling their own homes. Without knowledge of alternative techniques, they will not know to ask suppliers and manufacturers for more environmentally sound materials, because they won’t know the materials exist.
Towards Thoughtful Conservation

*The most lasting legacy our generation can leave for the next is not simply a better building stock but a new building ethic: one that recognizes the relationship between the built environment and the natural one.*

--The Worldwatch Institute

Dependence on the natural environment for survival is a binding characteristic for all people. This being the case, we each have a responsibility to be aware of our personal influence on the health of the planet. Increasing the applicability of resource efficiency provides an avenue for including a much wider variety of people in a new movement of environmental awareness.

In turning to resource efficient construction technology to begin to change the historically wasteful building industry, we must be careful not to blindly follow popular trends. Subscribing to the use of alternative building materials does not release us from the responsibility of being aware of the quantity of natural resources we consume. It is not appropriate to simply shift our current quantity of consumption blindly from one material to another and call ourselves successful. Rather, we must look rationally and objectively at our habits and patterns and carefully choose those materials which can most efficiently serve our purpose. Thus, resource efficiency begins with a reduction of demand for resources overall, then moves to careful discretion in choosing those materials that we do employ.

We cannot expect to make an instantaneous leap to sustainable living; we must make the journey one step at a time. Resource efficient construction alone is not the final
solution, but conservation-minded housing is a large positive step with the potential for great ecological, social, and economic rewards. Other steps must follow along the path to sustainability. The future must include such measures as a shift away from the single-family home and an emphasis on conservation-minded community planning. Improved resource efficiency is an excellent beginning toward a more healthy balance of human needs and environmental protection.

Only the Beginning

Quite significantly, the ideas behind resource efficient design and construction are relevant to all facets of our lives. Training ourselves to consider carefully the origin, contents, function, and disposal of each good we purchase would likely cut down on frivolous, spur of the moment decisions, saving both money and precious natural resources.

One resource which greatly affects the decisions we make is time. Staffan Linder suggests that the rise in consumption of consumer goods in the United States in the 1960s was a direct result of time pressures causing consumers to make purchase decisions without complete information. The manic behavior of American consumers is a huge stumbling block for effective resource conservation. This consumptive behavior is largely a result of consumers’ thoughtlessness and inability to realize the connection between their own daily resource use and the environmental degradation caused by resource extraction, as well as the lack of availability for resources to people in other countries and to future generations around the world.
A shift toward conscious conservation is anything but an automatic human response. We are psychologically conditioned to continue along familiar paths. It is much more comfortable to uphold the status quo than to break old habits and revamp our consideration of natural resource use. The struggle toward thoughtful resource conservation requires a dedicated effort and a commitment to lessening our personal impact on the current and future condition of the natural world.

The ideas of resource efficient design and construction provide a significant springboard for the examination of natural resource consumption and conservation. Resource efficiency influences the core of American consumerism—our homes. The ideas and methods of resource efficiency allow people to take control of their built surroundings and improve the balance between the built environment and the natural world. Fostering a relationship of understanding and respect between people and the natural environment is a critical step toward preserving the planet for future generations.

Endnotes

4 Ibid. 90.
24 As reported in *Professional Builder* 29(5): 34.
27 Op cit.
31 Brown, L. R.. 112.
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Affordable Resource Efficiency:  
An Introduction to Living Within Our Means

A Note to the Reader: Please do not be overwhelmed by the wide variety of information contained in this booklet! This booklet is intended to be an introduction to saving both money and natural resources using resource efficient design, construction, and home maintenance techniques. It is not meant as a step-by-step guide to building or remodeling a house or apartment. If your aim is to build or remodel your own house, please consult your local Building Department to determine appropriate codes and regulations.

Feel free to skip to the section that interests you most. If you are interested in saving money by reducing the amount of water you use, consult the section on water conservation. If your windows are drafty and are letting heat escape, consult the weatherizing section. If you want to learn general tips for saving money while conserving resources, skim the whole booklet!

Take the time to look through this booklet and discover ways to save money and help the earth by using fewer resources. With creativity, you will be able to improve the quality of your home or apartment while protecting the planet.

If you have an interest in learning more about resource efficiency, there is a brief bibliography at the end of the booklet. Please consult your local library for more information on do-it-yourself home improvement and for more ideas on how to save money while saving the Earth.

RESOURCES IN RESIDENCE

Have you ever stopped to think about the materials it took to construct your home? No matter where you live in the United States, in a big city or in a rural area, in an apartment or a trailer or a single-family house, your home is made of a surprising quantity and variety of natural resources.

It may be hard to imagine the building materials which were required to construct your house. Even more difficult is to realize that the materials which comprise your familiar surroundings were once trees, rocks and minerals, fossil fuels, and other resources in their natural condition.
The average 1,700 square foot American home is made of 150 tons of materials. The National Association of Home Builders provides the following breakdown of the materials used to build the average new house. Every year, we add over a million houses to the housing supply in the United States. Consider that each of the 1,039,000 new houses built in the U.S. in 1993 was constructed with an average of 9,700 board feet of lumber, 4,600 square feet of sheathing for roof, walls, and floors, 55 cubic yards of concrete (3/4 of which is poured and 1/4 of which is block), 2,520 square feet of exterior finish, whether aluminum siding, brick, wood, 6480 square ft of gypsum wallboard, 90 linear feet of ducting, 55 gallons of paint, 300 pounds of nails, 750 feet of copper wiring, 280 linear feet of copper pipe for water supply, 100 plumbing fittings for water supply pipe, 170 feet of plastic pipe for drain, 2000 square feet of roofing shingles, 12 windows, 10 interior doors, 4 exterior doors, one sliding glass door and 15 kitchen cabinets. (See Figure 1.)

Figure 1. A selection of construction materials.
When standard building practices are used, an average of 7 tons of materials are wasted during the construction of each house in the United States. If we saved the scraps from 21 new houses, we would have enough materials to build a whole new house. Studies of the makeup of construction waste have shown that 10% of the lumber and plywood produced in the United States winds up wasted at the job site and dumped in our already overflowing landfills. Figure 2 presents a breakdown of the materials contained in the waste produced by housing construction in the United States. Notice that 25% of construction waste is wood. If wood waste were eliminated in new housing construction, the demand for wood would be cut by the equivalent of 4 million acres of forest.

Figure 2. Composition of construction waste in the United States.
ENERGY CENTS

When you think about the natural resources it took to build your home, it is important to remember the origins of the materials and the path they took to your house. Imagine the energy it took to extract the resource from its natural state, to transport the raw material from the point of extraction to the manufacturing facility, to transform the raw materials into building materials, to transport the finished product to your region and then to your site, and the energy it took to install the material in your house. The total energy required to extract, manufacture, deliver and install a material in a structure is the energy embodied in the structure—or the embodied energy. (See Glossary, p. 59.)

Some building materials, such as concrete, require a very large amount of energy for production, thus they have a high embodied energy of production. Embodied energy of transportation varies depending on your location and the location of the extraction and manufacture of the product. So, lumber that was grown in the Pacific Northwest has a higher embodied energy if it is purchased and used in Georgia than it would have if used in Oregon because of the added energy of transporting the wood 2,700 miles. Figure 3 illustrates the embodied energy pathway of lumber from the forest to the job site.

Figure 3. The embodied energy pathway for lumber.
In addition to the energy embodied in construction materials, buildings also require operating energy. One-fifth of the energy consumed in the United States is used to power our homes. Our homes waste an amazing amount of this energy because of widespread inefficiency of lights, heating systems, air conditioners, hot water heaters and appliances. Even more energy is wasted due to lack of insulation. According to Amory Lovins of the Rocky Mountain Institute in Colorado, if every building in our country were equipped with advanced, energy-saving technology and proper insulation, we would cut energy use by 75%. This energy savings would result in significant financial savings, more than repaying the initial purchase costs of the technological improvements within ten years. Remember that the energy required to operate your home has embodied energy as well; it takes a great deal of energy to extract, process, transport and burn the energy which powers your home.

One reason to reduce our energy consumption is to lessen our use of fossil fuels like oil, coal, and natural gas. These fuels are non-renewable resources which means that once we burn them for the energy they contain, they are used up. There are limited supplies of non-renewable resources on the planet, so we all need to be careful about how fast we consume them. It is also important to reduce our use of fossil fuels because the extraction, production, transportation and burning of fossil fuels results in water and air pollution and land degradation.

The sun is the source of the most readily available renewable energy, which we call solar energy. You have no doubt experienced passive solar energy, which occurs when the direct warmth of the sun heats objects or rooms without the aid of mechanical equipment. An example of passive solar heating is the warmth of the sun on your face when you are outside, or the warming of a room when sunlight streams through the window. We can benefit from the heating and natural lighting of passive solar energy through thoughtful design of homes and other buildings. (See the Cost-Effective Design section, p. 11) Figure 4 illustrates the principle of passive solar heating.

Figure 4. The principle of passive solar heating.

1. DIRECT HEAT FROM THE SUN
2. HEAT GAINED THROUGH THE GLASS
3. HEAT GAINED AND STORED IN THE FLOOR.
"AFFORDABLE" HOUSING

Affordable to Purchase?
The concept of affordable housing is hard to define because affordability is a relative term. Criteria for affordability differ from person to person and from region to region. Our personal concept of affordability depends largely on the amount of money we make. A regional definition of affordable might depend on the availability of housing in general and the financial standing of local home buyers. According to the United States government, housing is affordable if people who make less than 80% of the median income spend less than 30% of their household income on their monthly mortgage or rent payments. In 1991, the median net household income in the United States was $29,943. For families who made 79% of the median income, or $23,655 that year, monthly housing costs of $572 would have been considered affordable. Table 1 provides a more detailed breakdown of the monthly housing costs which would be considered affordable according to the government definition.

<table>
<thead>
<tr>
<th>Income</th>
<th>Yearly Net Income in Dollars</th>
<th>Affordable Yearly Housing Expenses (30% of net income)</th>
<th>Affordable Monthly Housing Expenses (30% of net income)</th>
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<tr>
<td>Moderate</td>
<td>61%-79% of median</td>
<td>$18,265-$23,655</td>
<td>$5,480-$7,096</td>
</tr>
<tr>
<td>Low</td>
<td>51-60% of median</td>
<td>$15,271-$17,966</td>
<td>$4,581-$5,390</td>
</tr>
<tr>
<td>Very-Low</td>
<td>50% of median and below</td>
<td>less than $14,972</td>
<td>less than $4,491</td>
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Table 1. Affordable housing expenses according to government definition.

Affordable to Operate?
The definitions of affordable housing outlined above focus on the purchase cost of a house or the base rent. Rarely are the financial and environmental costs of operation considered. Whether you own your home or live in a rented home or apartment, you probably realize that utility costs and maintenance can cost a lot of money. Additionally, failing to install adequate insulation and other features for improved energy efficiency often result in outrageous utility bills. According to studies by the National Center for Appropriate Technology, “Failure to invest in energy and water efficiency in new, low-cost housing is costing our country at least $70 million a year. The cost of this waste to those who can least afford it is about $350 to $1,000 annually for each household.” Due to a combination of a nationwide shortage of affordable housing plus high operation costs many families spend upwards of 50% of their income on housing.
Affordable to the Environment?
In addition to lacking appropriate energy-saving measures, some inexpensive houses are built of inferior materials which may be cheap to purchase but which ultimately result in non-durable, uncomfortable, high-maintenance structures. A house made of flimsy materials is a disastrous waste of natural and financial resources. It makes much more financial and environmental sense to spend the time and the money designing and building housing that is both financially and environmentally cost-effective housing through practical use of appropriate building materials.

An Obligation to Our Children
The construction and operation of homes contributes to such environmental problems as air and water pollution, deforestation, overflowing landfills, and land degradation from mining and fossil fuel extraction. It is sometimes hard to visualize the amounts of natural resources we personally consume simply by buying (or renting) and maintaining a house or apartment, but our personal resource consumption does have an effect on the overall quality of the natural environment.

We don't need to waste time feeling guilty about our individual resource consumption. Instead, let's focus our energy on the realization that the solutions to our most pressing ecological problems depend on changes in our own attitudes and behavior. If we emphasize cautious consumption, we can learn ways to creatively use fewer resources while creating a better quality of life.

One of the primary reasons to be concerned about protection of the environment is the health and welfare of our children and that of our children's children. Future generations will not have access to the energy and resources we use up in our lifetimes, but our descendants will have to deal with the devastating effects of the waste we leave behind.

Another excellent reason to conserve resources now is that as supplies of resources get smaller and smaller, the resources will get more expensive. Thus, unless we begin to control the waste and expense of housing today, housing costs will only continue to increase in the future.

Take Control of Your Home!
Even if you live in a rented home or apartment, you can use many of the techniques in this booklet to improve the quality and function of your surroundings. By doing so, you can begin to take control of the operating costs of your home. Great satisfaction can result from personal involvement in the improvement and upkeep of your house or apartment. Even greater satisfaction is likely once you realize that you are taking action to protect the environment, and your actions are saving you money.
WHAT IS RESOURCE EFFICIENCY?

Resource efficiency is a movement in the design and building industries towards consuming fewer natural resources through a combination of energy efficiency and materials efficiency. Resource efficiency relies on careful choice of design and materials in an attempt to use less energy and fewer materials. Some of the qualities which contribute to the efficiency of a material are: durability, low embodied energy, regional or indigenous production, recycled content, recyclability, functionality, and manufacture resulting in relatively little pollution.

These diverse qualities of resource efficient products combine to create variations in regional pricing and product applicability making an absolute recommendation of the most resource efficient and cost-effective materials impossible. The hope is that armed with a background in basic efficient design and construction ideas, you will be able to ask informed questions which will lead to truly informed decisions.

Please keep in mind that there is no right answer or miracle material in resource efficiency. Think carefully about the materials you use in construction and maintenance of your home. The suitability of each material will depend on your climate, current materials pricing, and the scope of your project. The one consistent factor is that the fewer resources you use, the less money you will spend.
Efficient Choices--Ask the following questions when deciding if a material is efficient. A material does not have to meet all of these standards, but the more it meets, the more appropriate it is.

Does the material:
• Use fewer natural resources than the material conventionally used for the same purpose?
• Have a low embodied energy?
• Have a high recycled content (especially post-consumer)?
• Produce less pollution and hazardous waste in its production than conventional materials?

Is the material:
• Recyclable after use?
• Highly durable and low-maintenance?
• Regionally produced or indigenous to the area?

INVESTING IN THE FUTURE

There are many ways that resource efficiency can save you money. It is important to remember that while the initial cost of a project may seem prohibitive, most resource efficient techniques pay for themselves through savings of energy and maintenance costs after just a few years.

Many of the ideas contained in this booklet will result in a savings of energy which will result in a lower utility bill each month. Other ideas will save money because the materials you will use will be more durable than conventional materials, thus your maintenance and replacement costs will be lower. Still other ideas will be less expensive than the average construction or maintenance project because you will simply use fewer materials.

It makes sense to start with a simple and relatively inexpensive project like weatherstripping your windows and doors. Weatherstripping is an example of a project which saves both energy and money and improves the comfort of your home for a fairly small price, thus you get a large bang for the buck! (See the Weatherization section, p. 51) You might even use the savings from the first project you complete to work on a second. As you help your house to use energy and materials more efficiently, the monetary savings you enjoy will continue to grow. A move towards resource efficiency is an investment in your home, in your quality of life and in the Earth.
FROM THE GROUND UP
Before we discuss specific strategies for resource efficiency, let's get familiar with the parts of a house. Figure 5 is a cross-section of the typical house.

Figure 5. The basic parts of the basic house.
COST-EFFECTIVE DESIGN

Once you train yourself to think about the resources you are using, you will begin to consume fewer resources and will make better use of the materials you do use. Many of the design ideas contained in this section will be most practical for someone who is building a house or remodeling an existing building. People who are not building or remodeling, however, can learn the thought process behind resource efficient construction and begin to translate this creative and thoughtful conservation of resources into other aspects of daily life.

Cost effective design results from a careful combination of space efficiency and energy efficiency, blended with the selection of appropriate materials for each function. Sensible application of the ideas of resource efficient design makes building modest, comfortable, healthy and affordable houses possible.

Bigger is Not Better

Always remember that the smaller a house is, the fewer natural and monetary resources it will take to build and maintain it. The 900 square foot houses common in the United States just after World War II, were much more affordable than the 1,700 square foot house typical in 1991. Today's houses are not only too expensive for most people to afford, we are using too many natural resources to build and maintain them. Reducing the size of a house drastically reduces the amount of natural resources used to build and operate the house. By building a 1,150 square foot house instead of the average of 1,700 square feet, you will use 25% less lumber. Smaller houses require less energy to heat and cool simply because there is less space. Additionally, the smaller house can be built on a smaller, less expensive lot. Building a smaller house may also allow room for a money-saving vegetable garden on a lot which otherwise would have been filled up by the house.

Builders might suggest that you build the largest house you can afford to give it a high resale value. While it is true that large houses are the current trend, consider that families are getting smaller, real incomes are shrinking and energy costs are likely to keep increasing. The combination of these factors will make small, well-designed, well-built homes quite desirable on the resale market in the future.

The secret to successfully designing and building a functional, comfortable, efficient and cost-effective small home is careful design and planning. Efficient and clever use of space can make a small house seem spacious. An open floor plan is the first step. Not only does eliminating most interior walls and partitions make your home feel larger, you save the material and labor costs of framing and finishing the extra walls. Remember, however, that some interior walls are necessary for structural support. Such walls are called bearing walls,
because they bear the load of the house's weight. It is wise to include enough interior walls to provide privacy. Another important step in efficient space design is to minimize the space wasted on hallways and to turn unused space into built-in storage areas.

**Get In Shape**

Besides the size, the shape of a house is one of the main factors in the expense of construction. The basic rectangle is the most efficient shape for a house, and the most efficient rectangle is a square. In fact, a square floorplan is 12 to 15% more efficient than the traditional rectangle.\(^{13}\)

The size and shape of the foundation is called the **footprint** of the house. (See Figure 6.) Remember that the bigger the footprint, the bigger the house. To keep construction costs in check, make sure the footprint of the house suits your needs. It is possible to make the house bigger through the use of bay windows, gables, and other details, but it is not practical to make the house smaller than the initial footprint. Starting out with the most appropriate size and shape footprint will reduce the costs of almost all aspects of construction including the foundation itself, framing, roofing, and costs of interior and exterior finish work.

When deciding the shape of your footprint, try to avoid complicated angles. It is much easier and less expensive to build straight walls. Thus, the fewer angles and corners there are in the plan, the less expensive the house will be. Simple is also better for roofs. Each time a roof changes angles, the cost increases, plus each angle on a roof is a potential area for leakage. Every roof angle must be covered with flashing material to avoid leakage, thus each angle requires more materials and more labor and results in greater expense.

Figure 6. (A). A simple footprint with few corners. (B). A complicated footprint with many corners.
Let the Sun Shine In (Sometimes)

You can save money on your electrical and gas bills by planning window locations carefully. Smart window placement can help control heating and cooling needs and allow access to desirable natural light. Design the main living area or the rooms to be used most during the daylight hours with south facing windows to benefit from the warmth and light of the winter sun. In the Northern Hemisphere, the south side of the house receives the most sun in the winter and the least in the summer. Avoid large windows on the north and west sides of the house in cold climates to reduce the chilling effects of winter winds and lack of light. West facing windows also allow too much heat into a building in hot climates. Put storage areas and rooms which don’t need windows on the north side of the house.

A well-designed roof overhang will block the summer sun, which is higher in the sky, from entering the south facing windows and overheating the room. Large roof overhangs will also shed water effectively, avoiding the need for gutters which are not only expensive, they are a high maintenance item. The actual design of the roof overhang should correspond to the solar exposure in your region of the country. Consult your state’s energy department for more detailed information relevant to your area of the country.

One Floor or Two?

Building a two-story house generally costs less per square foot of floor area because you only have half as much foundation and half as much roofing per square foot of area. Some additional costs are incurred with the second story, including stairs and the potential for increased infrastructure such as plumbing and electrical wiring will have to reach to the second floor.

It is probably easiest to implement the ideas of resource efficiency if you have the luxury of designing and building or remodeling your own home. Please remember, though, that many resource efficient techniques are maintenance projects which can reduce the operating costs of an existing home or apartment and save natural resources.
EFFICIENCY: PIECE BY PIECE

Foundation
The purpose of the foundation is to support the load of the building safely. The conventional foundation consists of a concrete block wall or a poured concrete wall on top of a footing, which spreads the load of the building equally. The footings must be placed deep enough in the ground to avoid being displaced by frost heave.

Slab-on-grade
The simplest and least expensive foundation to build is a slab-on-grade foundation. This type of foundation consists of a concrete pad placed on concrete footings which are buried in the ground. A new version of this technique is the monolithic slab-on-grade foundation. The monolithic slab combines the floor slab with the footing which reduces both the time and labor required to pour the slab, thus making it less expensive to build.\(^\text{14}\)

It is important to plan the placement of the plumbing, heating, and electrical systems before the slab is poured, because some pipes, ducts, and wires are actually located beneath the slab.

Crawlspace
A crawlspace is a shallow foundation. The benefit of a crawlspace is that it is easier to install the mechanical systems for the house than the slab. Additionally, crawlspaces work well on hilly sites where slab foundations are not as practical, and in place of a basement in areas where the groundwater is close to the surface. Building a crawlspace requires more poured concrete or concrete block than a simple slab foundation. Figure 7 illustrates common foundation designs.

Figure 7. Standard types of foundations.
### Basement

Choosing a basement foundation can be an effective way of increasing the floorspace of your house. Keep in mind that basements are not a good option in areas where the water table is close to the surface. Basements also use a great deal of concrete and require more excavation than both slab-on-grade foundations and crawlspaces. Be sure to include adequate insulation in your basement, especially if you plan on using it for living space. (See page 27 for basement insulation specifications.)

### New Ideas for Foundations

Concrete is the most widely used material for foundations, but it is expensive and is very energy intensive to manufacture. New technologies are emerging which use less concrete and are easier to install than the average foundation.

#### Fly Ash

Concrete is a mixture of cement, sand, and water. One new idea is to substitute fly ash, which is a byproduct of coal-burning power plants, for 30% of the cement in concrete. Using fly ash to replace cement makes sense because it is much less expensive than cement and it is a waste material which otherwise would be land-filled. The substitution of fly ash for cement in concrete also makes the concrete more durable. Consult your local cement distributor for sources of fly ash.

Concrete foam blocks are another new foundation and framing idea. These blocks, which look like Legos, are labor saving and make efficient use of resources. They are typically made of a mixture of recycled styrofoam and cement. When set in place, they are anchored with steel rebar and spaces in the center of the blocks are filled with cement. This system can be used to replace framing lumber, insulation and plywood to result in a well-insulated wall (R-24) that is relatively easy to build. The lightweight blocks are earthquake and fire resistant, cost-effective, and can be finished with paint, stucco and other standard exterior finishes. They are available at most lumberyards.
Framing

Framing accounts for 70-85% of the wood used in a house, and over 90% of the houses built each year in the United States are stick-framed, that is, the skeleton of the house is made of wood. These figures mean that a lot of trees are cut to construct buildings in the United States. Framing is an excellent area to reduce materials use and construction costs.

Conventional framing is highly inefficient and produces a lot of waste. The main reason for this is that the framing methods which have developed over the years include more framing members than are actually necessary. Additionally, without careful planning, the builder must cut a few inches off each board to make it fit the plans; these inches add up to a great deal of wasted wood.

Not only is it possible to reduce the amount of wood used in framing by making framing techniques more efficient, it is also possible to replace conventional dimensional lumber with alternative framing materials.

Engineered Wood Products

Conventional construction relies on solid-sawn lumber -- boards which are cut from a single tree. Rising environmental concern with the depletion of our nation's forests and the decreasing supply of old-growth timber have created a growing market for engineered wood products. Engineered wood products are generally standard sized building elements which have been made from small pieces of wood or wood fibers, held together with adhesives. Because they can be made of smaller diameter trees, scraps of trees, and wood waste, engineered wood products reduce the need for the large trees which are found only in our oldest forests. New engineered lumber products use up to 50% less wood to achieve the same structural efficiency of standard wood framing products. They also make better use of each tree by using 70-80% of a tree as opposed to the 40-50% used by standard lumber milling processes. Engineered wood products can take the place of conventional studs, joists, beams, rafters and other framing materials.

On the whole, engineered wood products are stronger and more uniform than solid-sawn lumber. Manufacturers can design engineered wood products in lengths, widths, and depths which are not possible when limited to the dimensions of a single tree.

The purchase costs of engineered wood products are normally slightly higher than for the dimensional lumber products they replace. Prices for engineered wood products do not fluctuate as widely as dimensional lumber prices because a greater variety of wood can be used to manufacture the engineered wood products. As the supply of large standing trees required to produce dimensional lumber decreases, it is likely that the costs of engineered wood products will become more competitive. Keep in mind that
although the purchase costs of engineered wood products may be slightly higher than dimensional lumber, savings results from reduced waste, reduced labor, need for fewer studs, joists or trusses, and the ability to span longer distances with single members, resulting in less need for structural bracing and support. Figure 8 illustrates some common engineered wood products. For more information on engineered wood products, see Table 2.

Figure 8. Common engineered wood products.
Table 2. Engineered Wood Products

The following table contains a partial list of the manufacturers of a variety of engineered wood products, tells how the products are made, what they can be used for, the environmental advantage of the product over conventional dimensional lumber, and the cost comparison you might expect. If you are interested in learning more about engineered wood products and the potential for substituting some of these products in your building projects, please call or visit your local lumber supplier.

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
<th>Description</th>
<th>Uses</th>
<th>Ecological Significance</th>
<th>Cost Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Champion International</td>
<td>Finger-jointed Lumber</td>
<td>Lumber of specific length machined at both ends to accept similarly machined pieces. Forms solid, straight piece of lumber. As strong as similar grade, non-jointed lumber</td>
<td>Sills, studs, beams, plates</td>
<td>Structurally engineered so there are no wasted pieces at the job site. The defects from short stud-grade material are removed so the wood is fully utilized.</td>
<td>Depends on the time of year and the lumber market, but currently is comparable to solid sawn lumber</td>
</tr>
<tr>
<td>Louisiana Pacific</td>
<td>Engineered Studs</td>
<td>Remove defects from short stud-grade material and remanufacture--available in longer lengths than solid sawn lumber</td>
<td>Structural framing for floor, roof, and wall</td>
<td>Structurally engineered so there are no wasted pieces at the job site--the defects from short stud-grade material are removed so the wood is fully utilized.</td>
<td>Comparable to the dimensional lumber it is replacing--savings result from reduced waste and because the members can be spaced further apart</td>
</tr>
<tr>
<td>Alpine Structures</td>
<td>ASI-Joists</td>
<td>Engineered wood I-joist with solid sawn lumber flange and plywood and enhanced OSB web</td>
<td>Floor and roof framing</td>
<td>Uses less wood fiber than conventional wood framing, limiting demand on old-growth resources</td>
<td>Historically ASI joints have been more expensive per linear foot than solid sawn lumber, but with rising lumber prices, the cost for smaller 1-joists has dropped below the cost of conventional solid sawn joists. Even if the cost per linear foot is higher for the 1-joists, the economy comes in the reduced labor and material cost</td>
</tr>
<tr>
<td>Boise Cascade</td>
<td>BCI-Joist</td>
<td>Plywood webbing and laminated veneer flanges joined with structural adhesive</td>
<td>Floor and roof joists</td>
<td>Engineered framing member with greater strength, longer spans, and less wood product than solid sawn lumber.</td>
<td>Cost is competitive with conventional lumber--the savings comes from less waste, longer spans, and larger spacings</td>
</tr>
<tr>
<td>Georgia Pacific</td>
<td>Wood I-Beam</td>
<td>Engineered structural I-beam with plywood web</td>
<td>Floor and roof framing; window, door, and garage door headers</td>
<td>Engineered framing member with greater strength, longer spans, and less wood product than solid sawn lumber.</td>
<td>Cost is competitive with solid sawn lumber</td>
</tr>
<tr>
<td>Louisiana Pacific</td>
<td>Inner-Seal 1-Joist</td>
<td>Engineered structural 1-joists with OSB web</td>
<td>Floor and roof framing</td>
<td>Engineered framing member with greater strength, longer spans, and less wood product than solid sawn lumber.</td>
<td>Cost is comparable to the dimensional lumber it is replacing--there is a savings from the reduced waste and the members can be spaced further apart</td>
</tr>
<tr>
<td>Trus Joist MacMillan</td>
<td>TJ-Joists</td>
<td>Engineered wood 1-joist</td>
<td>Floor and roof framing</td>
<td>For every 2 to 3 trees needed to build a conventional floor, only one tree is required for the 1-joist floor.</td>
<td>Cost is comparable to dimensional joists, savings results from reduced site material waste, longer spans, use of fewer joints</td>
</tr>
</tbody>
</table>
Wall Framing

Usually, the boards used for framing are spaced 16 inches apart from each other along the length of a wall. The most commonly used board types for wall framing are 2 x 4 studs, and 2 x 6 studs (See Figure 9).

![Figure 9. Diagram of 2 x 4 and 2 x 6 studs.]

Reducing Framing Costs

Conventional construction uses more framing members than are necessary to construct a strong, safe and stable building. The first strategy for reducing the materials used for framing is to increase the spacing of framing members from the conventional 16 inches apart to 24 inches apart which results in using fewer boards for framing overall. The Uniform Building Code allows this method as spacing for 2 x 4 stud walls for one-story houses and for the top floor of multi-story houses. When 2 x 6 studs are used, 24 inch spacing is suitable for both one- and multi-story houses. Please consult your local building department for special considerations in your area.

It is typically allowable to substitute 2 x 3 studs for 2 x 4s in walls which are not structural (non-load-bearing walls). The use of 2 x 3s reduces both material cost and the total amount of wood used. Please consult a building contractor or structural engineer if you need help determining which walls in your home are structural.

Framing with 2 x 6 studs makes effective insulating easier than when 2 x 4 studs are used. This is because the 2 x 6 wall is thicker, thus there is more space for insulation, therefore a higher R-value can be attained (See page 25) - resulting in reduced heating and cooling costs. This is an excellent example of the thought required when deciding which materials to choose. If you use 2 x 4s you will likely save on the initial cost of the wood and you will use less wood for framing. But, if you use 2 x 6s, you will be better able to install adequate insulation, thereby reducing the long-term demand for energy to heat and cool the house. It makes sense to figure out and compare the short-term and long-term costs in terms of both money and resources, then choose the strategy which makes the most economic and environmental sense to you. The answer to this question depends on the current price of lumber and the heating and cooling costs in your area.

Another way to cut down on the amount of wood used for framing is to substitute finger-jointed lumber for standard framing studs. Finger-jointed lumber is an engineered wood product made by combining short pieces of wood, which normally are thrown away, into a longer piece of lumber (See Figure A-19).
10). The ends are glued together and the resulting board is as strong or stronger than conventional studs. Finger-jointed lumber is available in widths of 2 x 6, 2 x 8, 2 x 10, and 2 x 12 and in lengths up to 72 feet. One of the benefits of finger-jointed lumber, and other engineered wood products, is that they can be made into much longer lengths than are possible with solid-sawn lumber. This can reduce the need for structural supports such as columns and beams. Finger-jointed lumber is typically about 10% more expensive than regular dimensional lumber. While finger-jointed lumber is available in the majority of lumberyards, it must be special ordered in some areas due to low local demand. (See Table 2.)

**Floor Framing**

The boards which make up the skeleton of the floor are called joists. Like wall studs, floor joists are typically spaced 16 inches apart. Floor joists can be spaced 24 inches apart and still result in a structurally sound floor, while reducing the total number of joists required. Consult your local building department for exact specifications regarding joist spacing, allowable spans (lengths) and width of appropriate sheathing material for flooring uses. Engineered wood I-joists (or I-beams) are suitable to replace the conventional 2 x 10 floor joist (See Figure 11). I-joists can be used at 24 inch spacings to reduce the number of joists required. Besides making more efficient use of wood, I-joists are both lightweight and strong which results in a sturdy structure while using less wood overall. Typically, I-joists are 25% more expensive per lineal foot than 2 x 10s.

Figure 10. Side view of finger-jointed lumber.

Figure 11. Comparison of standard 2 x 10 joist to engineered I-joist.
Roof Framing

Conventional roof framing is similar to floor framing. Roofs can be stick-framed with large dimensional lumber or engineered I-joists. A less expensive solution for simple roofs, however, is the use of trusses (See Figure 12). Trusses are premanufactured from 2 x 4s and 2 x 6s so on-site labor expenses are reduced and less wood is used than in conventional roof framing. Like wall and floor framing, the conventional spacing of structural members is 16 inches apart. Roof trusses spaced 24 inches apart are structurally sound and this technique reduces the total number of trusses required.

Consult your local building department for the load limitations of various spans of roof trusses. Engineered I-joists (or I-beams) are suited to replace standard beams. Again, I-joists are typically 25% more expensive per lineal foot than conventional trusses, depending on the current price of dimensional lumber.

Figure 12. Standard styles of roof trusses.
Other Alternatives to Conventional Framing

Structural Wall Panel Systems
The walls of most homes in the United States are built at the construction site itself. In some cases it is more cost-efficient to buy wall panels that have been manufactured elsewhere. Not only can using pre-made wall panels reduce the time required to frame the house, many producers of wall panels focus on reducing the wood wasted during framing by making the panel conform to existing dimensions of lumber and boards.

One example of a wall panel system is stress-skin panels. These panels are made of a 3 1/2 inch to 7 inch thick layer of hardened foam insulation sandwiched between two sheets of oriented strand board (OSB) (See page 23). The thicker the layer of foam, the better insulated the wall will be. The panels reduce the labor time needed for framing the walls and can reduce wood usage by 40% compared to conventional stick-framing, plus they result in a well-insulated wall. The distributors of wall panel systems typically build the walls to your specifications, incorporating appropriate openings for windows and doors, and deliver the panels to your site. Panel sizes generally range from 4 foot by 8 foot sections to entire walls, 8 feet tall and 24 feet long.

Steel Studs
Another alternative to conventional wood framing is framing with steel studs. Steel framing is durable, fireproof, and strong. The cost-effectiveness of steel wall, roof, and floor framing depends on the local market for steel, as well as the knowledge and know-how of the local labor force. In general, steel prices are more stable than wood prices, which makes the cost more predictable. In the effort to reduce wood use, many builders have switched to steel stud framing.

The environmental costs of steel framing may outweigh the benefits, however. Steel is not a renewable resource and the energy of extraction and processing are enormous. It is true that most steel studs contain some recycled steel, but the recycling process itself requires a lot of energy. The embodied energy in steel framing is estimated to be 3 times as great as that for wood framing. Steel studs also conduct more than double the amount of heat through the walls than wood studs, resulting in a need for increased insulation to make steel-framed buildings energy efficient.
Structural Sheathing Materials

Plywood

Sheathing is basically the skin of the building. Once the frame is built, structural panels are attached to the exterior of the house to provide stability and protect the house from the elements. Sheathing is also used for flooring and roofing. Plywood is by far the most commonly used sheathing material. Plywood is made from thin layers of wood (also called veneers) which are peeled from trees, then glued and pressed together. The glues used to make plywood often result in *offgassing*, which means that toxic vapors are released from the wood which can create poor indoor air quality. Plywood manufacturers rely on large, high-quality trees for the veneers they use.

Oriented Strand Board

A lower-cost and more resource efficient sheathing product is oriented strand board (OSB). OSB looks a lot like plywood, but is made of small chips of wood from small, fast-growing trees and wood scraps which are held together in layers by resin. OSB can be used for wall, floor, and roof sheathing and is installed just like plywood. Like plywood, OSB is available in 4 foot by 8 foot sections and can be purchased at most lumberyards. OSB production uses the same adhesives as plywood, so there may be similar problems with offgassing. OSB is manufactured with a low moisture content and it may swell as it absorbs moisture from the air. OSB is typically several dollars cheaper per sheet than plywood of the same size.

Non-Structural Sheathing Materials

Particle Board

Particle is a non-structural sheathing material made of sawdust held together with adhesives which is hardened under pressure. Because particle board makes use of sawdust, a waste product from lumber processing, it is more resource efficient than interior grade plywood, for example, which is made from virgin timber.

Sheet Rock/Gypsum Board/Drywall

Interior walls and ceilings are typically sheathed with materials such as sheet rock, gypsum board and drywall to provide a smooth surface to accept paint and other interior finishes. Many interior wallboard products exist which are made from recycled materials. Homasote, for example, is a wallboard made entirely of recycled newspapers. The cost-effectiveness of the various wallboard products will depend largely on local availability. Consult your local lumber suppliers for more information.

Siding

Wood

About 50% of the houses built in the United States have wood siding materials nailed on to their wood frames. Wood is an unfortunate choice for siding because it is not very durable and requires a good deal of maintenance including
periodic painting or staining. Additionally, wood is an extreme fire hazard. Cedar shakes are a particularly bad choice for siding as they rarely last more than 10 years and they require the sacrifice of the largest old-growth cedars for their production. (See the Roofing section, p. 41)

Aluminum
Aluminum siding is less expensive than wood siding. Aluminum siding has a high embodied energy, but almost all aluminum siding is made partially or completely of 100% recycled aluminum and is recyclable after use. Additionally, aluminum siding is more durable than wood and requires less maintenance.

Vinyl
Vinyl siding is less durable than aluminum and some of the alternative siding materials available and has a high embodied energy because vinyl originates as oil. Vinyl requires less maintenance than wood siding. Vinyl siding is not recyclable after use.

Alternatives
Extremely durable siding materials are being made of mixtures of cement and wood. Such products require less energy for manufacture than aluminum and vinyl siding and make use of wood scraps rather than the solid-sawn lumber required for conventional wood siding.

Insulation
Insulation is the blanket which protects your house from dramatic temperature changes. Adequate insulation is important to keep your house warm in the winter and cool in the summer. Despite the savings of money and energy that insulation provides, it is estimated that two-thirds of homes in the United States don't have the amount of insulation recommended by building codes and energy experts, and some homes have no insulation at all. If all houses were adequately insulated, heating and cooling systems would use 20-30% less energy.

If you are building a new house, it makes great sense to insulate properly. Most types of insulation are easiest to install before the walls are finished. Additionally, if you insulate well at the outset, you will be able to use a smaller heating and cooling system, thus saving money on the equipment you install. If you are thinking about adding insulation to your existing house or apartment, please consult the section on Weatherization (p. 51) and see Table 3.
R-value Explained

Insulation materials are compared to each other by using the term resistance. The higher the resistance of a material, the better it insulates. This resistance is described by the term **R-value**. A material with a resistance of 3 per inch of thickness (R-3) would block heat transfer three times better than a material with a resistance of 1 per inch of thickness (R-1). The higher the total resistance of a wall, or a floor or a ceiling, the better that part of the building will be at keeping the house warm in the winter and cool in the summer. Figure 13 illustrates the way insulation acts as a barrier to protect your house from the weather.

![Diagram](image)

**Figure 13.** Insulation acts as a barrier to outdoor heat and cold.

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R-value Really Adds Up!: To determine the total resistance of a wall, ceiling, or floor, add the R-values of the materials which make up that component. For example, if your wall is made of:

- 2 layers paint = R-.5
- 1 sheet thick--drywall=R-1
- 4 inches cellulose insulation = R-4.5 (4.5 x 4 = R-18)
- 1 layer OSB = R-1
- brick wall = R-3

The total R-value for the wall is the sum of the pieces, thus the R-value for this wall is: **R-23.5**
Table 3. Overview of various types of insulation.

Insulation comes in a variety of forms and has variable characteristics such as insulation value per inch of thickness (R-value), fire rating, durability, and of course, purchase and installation costs. Blown-in insulation is generally the most cost-effective insulation for any given R-value. A study by HUD concluded that the installation of blown-in insulation was 20 to 25% less expensive than batt insulation, considering both the cost of the material and the installation labor. Consult your state or local energy office for help in determining the most appropriate type and amount of insulation for your climate. More information on types and uses of insulation may be found in the Weatherization section of this booklet (p. 51).

<table>
<thead>
<tr>
<th>Type of Insulation</th>
<th>Form</th>
<th>Resistance Value</th>
<th>Uses and Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiberglass</td>
<td>blankets 16 to 24 inches wide which must be cut to fit in place or batts which are precut made from melted glass some brands of fiberglass insulation contains recycled glass</td>
<td>R = 3.5 per inch of thickness</td>
<td>most common type of insulation--walls, ceilings, and floors fire and vermin proof moderate in cost and easy to install comes with attached paper vapor barrier</td>
<td>over some years it will tend to mat down or settle on itself; the result is that the material is compressed a bit and loses some of its insulation value</td>
</tr>
<tr>
<td>Mineral Wool</td>
<td>rolls or batts made from melted rock and recycled byproducts of steel production</td>
<td>R = 3.5 - 5 per inch of thickness</td>
<td>similar to fiberglass</td>
<td>more expensive than fiberglass problems with matting are even worse than fiberglass</td>
</tr>
<tr>
<td>Insulating Sheathing</td>
<td>made from wood fibers 1/2 to an inch</td>
<td>R = 2 per inch of thickness</td>
<td>usually used on exterior walls as a backing for siding</td>
<td>extended exposure to moisture will cause mildew and rot</td>
</tr>
<tr>
<td>Foam Board</td>
<td>precut to standard sizes 1/2 to an inch</td>
<td>R = 5 per inch</td>
<td>good insulative value per inch used for perimeter insulation of foundations and can be added to existing walls during remodeling work</td>
<td>some foam board is made with chlorofluorocarbons (CFCs) which destroy the ozone layer</td>
</tr>
<tr>
<td>Loose-Granule Insulation</td>
<td>vermiculite and perlite (mineral-based) comes in bags and can be poured between ceiling and floor joists</td>
<td>2.5 per inch</td>
<td>fireproof won't deteriorate from rot, moisture, vermin good sound-deadening properties</td>
<td>settling can be a problem usually requires professional installation</td>
</tr>
<tr>
<td>Cellulose Fiber</td>
<td>made from recycled paper comes as loose-fill insulation and blown-in insulation</td>
<td>R = 4.5 per inch</td>
<td>usually the most cost-effective type of insulation chemically treated to resist fire, rot, and vermin good sound barrier can be added to in the future</td>
<td>usually requires professional installation settling problems if not installed properly</td>
</tr>
</tbody>
</table>
Where to Insulate and How Much??

When you are trying to figure out where to put insulation, picture the areas of your house that you make an effort to keep warm or cool. For example, you might like to keep the living room and bedrooms warm but aren’t too worried about heating the garage or the attic. The strategy is to put insulation between the heated (or cooled) areas and the outside. The idea of insulation is to surround the living space of a house and protect it from fluctuations in outdoor temperature. Be aware that if you squish insulation to make it fit into a smaller space than it was meant for, the insulative qualities will be reduced. While the amount of insulation needed for your house to be efficient depends on climate, the R-values included in this section are recommended by building industry experts. Check with your local building department to determine the amounts of insulation that make the most sense in your area of the country.

Attic

Because heat rises, a lot of heat can be lost through an uninsulated or underinsulated attic and roof. Additionally, heat enters the house through the roof and the attic because of the direct exposure to hot summer sun. The placement of attic insulation depends on whether the attic is heated and used for living space, or if it unused or used for storage. Houses with an unused attic should have insulation totaling R-25 between the ceiling joists (the floor of the attic). Attic rooms which are used should have a similar amount of insulation between the roof trusses or rafters with insulation of R-20 included in the exterior walls. It is a good idea to use small vents or fans to provide good ventilation in an unused attic. This ventilation helps to get rid of moisture that rises through the ceiling in the winter and helps to prevent heat from building up in the summer. It is fairly easy to add insulation to the attic even after construction.

Walls

It is more difficult to add insulation to walls than it is to add it to the attic, so it is a good idea to install insulation totaling at least R-20 in walls during initial construction. There should be adequate insulation in all exterior walls, including those which are next to an unheated garage.

Foundation

The insulation suggested for foundations depends on the type of foundation you have. If you have a crawl space beneath your house, insulation between the floor joists of the ground floor should be at least R-20. The same is true if you have an unfinished basement or a basement used only for storage and utilities. A finished basement should have insulation all around the exterior walls (R-20) and under the concrete floor slab (R-5). If you are planning an unfinished basement with the potential for finishing it in the future, it makes sense to install adequate insulation at the time of construction. Ideally, slab-on-grade foundations should have at least an inch of rigid insulation below the frost line to maximize the temperature of the slab.
Vapor Barrier

To make the most of your insulation it is important to install a vapor barrier. A vapor barrier is a thin layer of moisture resistant material, usually coated paper or very thin plastic, which protects the insulation from the humid air inside the house. If this moist air were to get into the insulation, the water would condense when the air hit the cold outer wall. When insulation gets wet, its ability to trap heat is reduced, thus it can no longer protect the living area from the effects of outside temperature.

Figure 14 illustrates typical placement of insulation in the foundation, wall, and roof of a house.

Figure 14. Insulation placement.
The Plumbing System

Cost-Effective Plumbing Design

The secret to reducing the cost of plumbing is to design the house so that all of the rooms which require plumbing are close to each other. This strategy is called cluster plumbing. Ideally, in fact, these rooms should be either back to back, or should share the same vertical wall in a multi-story house. The kitchen sink, therefore, should share a wall with the bathroom. To be truly resource efficient, it is best to avoid building houses with more than one bathroom, but if two bathrooms are required by a large family, stack them one floor above the other or put them back to back. See Figures 15 and 16.

Figure 15. Schematic diagram of cluster (or stacked) plumbing.
The second aspect of cluster plumbing is to locate the hot water heater near the hot water users. Hot water traveling through pipes loses heat. This is a waste of energy and therefore a waste of money. When the kitchen and bathroom are located near the hot water heater, the water doesn’t travel far and much less heat is wasted. Another idea is to use a stall shower instead of a tub and install a small hot water heater in the bathroom itself. An additional benefit to cluster plumbing is that it reduces the lengths of pipe that are required to get water from the source to the spouts, thus the initial quantity of material is lessened. A builder in Georgia used cluster plumbing to minimize the water supply piping in his house plans and saved an average of $400 per home.²⁸

Figure 16. Floorplan with clustered plumbing.
Pipes
If you live in a house or apartment that is more than 20 years old, it is possible that your plumbing system could contain lead pipes or lead solder. Be aware that lead pipes can contaminate your water. Lead poisoning can lead to serious health problems, particularly in children, so it is important to determine if your house has lead plumbing pipes.

Today, copper pipes are conventionally used for plumbing. Copper pipes are fairly expensive and require great skill to install. Additionally, copper production is devastating to the environment. Plastic plumbing pipes are being developed which are much less expensive and are easier for non-plumbers to install. One of these is polybutylene piping which is a flexible plastic pipe which is easier to work with than copper. While the polybutylene pipe is generally less expensive than copper pipe, the cost of the fittings required is greater than for copper, so the overall cost is about the same. Money can be saved if you can install the plastic piping yourself. Polybutylene pipe is not accepted by all building codes so please consult your local building department for information on the types of plumbing pipe allowable in your area.

Water Wise
Water is an essential resource to all living things. Half of the people in the United States get their water for household use from groundwater which is water flowing beneath the surface of the Earth. Groundwater is a renewable resource, which means that we would have a sustainable supply if we consumed it at the rate at which it is naturally replenished. In many places in the United States, however, people are using groundwater supplies so quickly that the levels are falling. Groundwater was used so quickly in Tucson, Arizona in the 70s and 80s, for example, that the water table there fell 150 feet.

The average four person family in the United States uses about 300 gallons of water per day or 110,000 gallons of water each year as we quench our thirsts, flush toilets, wash our dishes, take showers, and clean our laundry. This figure doesn't even count the thousands of gallons of water used outside each day to water our lawns and gardens and wash our cars.

If we are aware of our consumption of water, and take care not to waste it, we can do our part to ensure that fresh water will remain a renewable resource. Almost a third of the water we use is hot water. Between one-tenth and one-quarter of a household's energy budget is spent heating water. Hot water loses heat as it travels through pipes to get to your sink or your shower, thus it is a great idea to insulate your hot water pipes to cut down on this wasted heat. Water conservation will help you reduce your energy bill and your water bill. Realize that water and sewer rates are expected to increase as the supply of clean water is reduced. By using less water now, we are showing concern for the future by protecting a crucial natural resource.
Thirsty Fixtures/Smart Solutions

Toilets: 120 gallons per day
- A new national regulation requires that all toilets manufactured must be low-flush, which means they must use 2 gallons or less of water per flush. The average flush of pre-1994 toilets uses 5 or 6 gallons of water. Installation of a low-flush toilet will cut this use water usage at least in half. New toilets can be purchased for less than $100. This investment in water efficiency will likely save thousands of gallons of water each year. If you live in a very dry area of the country, or if you have limited access to water, composting toilets are available which use no water whatsoever and rely on bacteria to break down wastes.

Bathing/Showering: 100 gallons per day
- Install a low-flow showerhead and save energy as well as water. The average showerhead sprays 3-6 gallons per minute, resulting in the use of 30-60 gallons of water for a 10-minute shower. Low-flow showerheads, which can cost as little as $5, use only about 2 gallons of water per minute, but they concentrate the spray, so there no loss of shower quality. A low-flow showerhead is a very good investment - you will easily make up the cost of the showerhead in savings on your energy bill. Most low-flow showerheads are easy to install yourself in just a few minutes.

Laundry: 35 gallons per day
- Wash full loads only, but do not overfill the washing machine. Much energy can be saved by washing only in cold and warm water, rather than using hot water. Front-loading washing machines are more efficient than top loaders because they rely partially on gravity to tumble the clothes which gets the clothes cleaner using less water.

Kitchen: 35 gallons per day
- Install an aerator on your kitchen and bathroom faucets. This reduces the stream of water and can save 2 gallons of hot water per day. In a year, this savings adds up to about $10. If your faucet is leaky, fix the leak with a new washer--this can save several gallons of water per day.

Lavatories (Bathroom Sinks): 10 gallons per day
- Try not to leave the water running while you brush your teeth, wash your hands, or shave. By turning the water off you will greatly reduce the water which just goes right down the drain.
The Heating and Cooling System
The effectiveness of your heating and cooling system plays a large part in determining the size of your utility bill. Heating and cooling accounts for about half of the energy consumed in the average home. Nationally, heating uses over ten times more energy than cooling.

Energy Choices
Houses in the United States are generally heated with electricity, natural gas, or propane. Over half of the homes in the United States are heated with electricity. Electric heat is the most expensive type of heating in areas with cold winters. Electric heat can be cost-effective in some parts of the southern United States because utility rates are lower and winters are not as cold as in the rest of the country. Natural gas is the cleanest burning fossil fuel and is probably the most cost-effective option for heating in colder areas of the United States. If you are in the position of choosing between electricity and natural gas for heating and cooling your home, ask your local building department or energy office what the most appropriate and cost-effective energy source is in your region.

Some people use wood-burning stoves as their sole source of heat, or to supplement their electric or natural gas heating system. This idea is practical in areas with abundant local wood sources and where air quality is not heavily affected by woodsmoke. From an energy standpoint it does not make sense to haul wood over 40 miles to heat your house. If the nearest source of wood is that far away, a different energy source makes more environmental and economic sense. Some areas of the country experience tremendous pollution as a result of wood-burning stoves and many towns and cities have implemented woodstove restrictions. New, highly efficient wood stoves are available which produce less pollution and provide more heat for the amount of wood burned. These efficient stoves may be allowed in areas where other woodstoves are banned. Again, it is important to learn the local regulations before you decide to choose one heating source over another. Fireplaces are not an efficient source of heat. In fact, fireplaces, are generally a luxury item which simply burn natural resources and release pollutants into the air.

Efficient Heaters
Don't skimp on the efficiency of your heater and your hot water heater. Buy the most efficient models you can afford because over a 10-year period the efficiency can save you hundreds of dollars.

Where gas heat is available, it is almost always more efficient and less expensive than electric heat. Many power companies have incentive programs in place for customers who are working on achieving energy efficiency. Consult your local utility provider for more information.
Saving Heating and Cooling Energy
If you have a woodstove or a fireplace, keep the damper closed unless you have a fire burning; up to 8% of a house's heat can be lost up an open chimney.\(^\text{32}\)

Shut the doors to rooms that you are not using during the day, and close the heat/air vent. This way the heater or air conditioner is not trying to heat or cool unused space. No matter what type of heating and cooling system you have, it will work more effectively if you keep all of its parts clean. A good rule of thumb is to clean the filters, blower, fans, ducts, vents and thermostat before you first turn the heat on in the winter or fall, and when you last use it in the spring or summer.

Design for Ventilation
In a small house with an open floorplan you can make use of ceiling and attic fans for ventilation and cooling instead of an air conditioner. If the house is designed so that an air conditioner won't be needed, you save the initial mechanical expense of the air conditioner and will have a lifetime of lower energy costs.

Figure 17. An example of an open floorplan which would promote good ventilation.
The Thermostat

The thermostat plays an amazing role in the amount of energy that is used to heat and cool a house. The thermostat is the brain of the mechanical system. It tells the heater or the air conditioner when to turn on and when to shut off. It is important to locate the thermostat where it can best determine the temperature needs of the house. If the thermostat is in a drafty, cold place, for example, it will tell the heater to come on even when the rest of the house is not cold which wastes energy and money.

Your heater will be more efficient if you keep the thermostat at a fairly constant setting. It does not make sense to turn the heater up very high to make the room heat up faster and then turn it down when you get too hot; this is simply a waste of energy. If you set the thermostat for 65-68 degrees or less during the winter days, and turn it down to 55-60 at night, you should stay fairly comfortable. Set the thermostat between 75 and 78 degrees in the summertime to lessen the use of air conditioning. If you are not home during the day, it is a good idea to turn the heater (or air conditioner) down so that energy is not wasted while you are out of the house.

Try layering your clothing in the winter to make yourself more comfortable and to be able to lower the thermostat setting. Try to wear at least one layer of wool clothing which is a very good insulator. If you are cold at night, try layering two or more thinner blankets instead of one thick one. The layered blankets trap a layer of warm air between them which insulates you from the colder air in the room.

The Electrical System

Design

The simplest way to save money in the design of the electrical system is to use as few outlets, fixtures and switches as your local building codes will allow. Building codes generally require more wall outlets for new construction than they do for remodeling existing buildings, so be sure to follow the code which corresponds to the type of work you are doing. Consult the National Electrical Code and your local building department for more information. Figure 18 shows where outlets and switches are commonly placed.
Light Up Your Life

Lighting of homes and businesses accounts for 25% of total electricity use each year. If all Americans used efficient lighting, we would save about $16 billion in energy costs and reduce carbon dioxide emissions and other air pollution from electrical plants by 12%. The first way to save money and energy is to turn off the lights you are not using. Secondly, we use much more energy to light our homes in the United States than is necessary because we depend largely on the incandescent lightbulb. Incandescent is simply the technical term for the standard lightbulb we are most familiar with. While the lightbulbs we are used to are usually fairly inexpensive to purchase, they use five to ten times the purchase price in energy costs over the lifetime of the bulb. Fluorescent lights have been developed which use about half the energy of standard incandescent bulbs and they last two to three times longer. When you compare the purchase price of the bulbs, it seems like incandescent bulbs are a better bargain, but if you take into account the cost of energy and the frequency of replacement, fluorescent bulbs are much more cost-effective, and save a great deal of energy. Fluorescent bulbs are now available which fit your standard light fixtures, so there is no need to purchase new fixtures to accommodate the more efficient bulbs. You will find fluorescent lights at most hardware stores, lighting shops, and even some supermarkets.
Windows

Windows can be one of the more expensive components of new construction. It makes sense to install a few high quality windows than many low-quality windows for the same amount of money. Careful choice and placement of windows can make a big difference in the cost of your home and in the operating costs over the building's lifetime. Consult the design section (p. 13) for window placement ideas.

Window Glazing

Because they are made of glass, windows are not good insulators, thus they have poor thermal efficiency. A single-glazed window has just one sheet (or pane) of glass, a double-glazed window has two panes of glass with a layer of air sandwiched between them, and a triple-glazed has three panes of glass and two layers of air (See Figure 19). Replacing your existing single-glazed windows with double-glazed windows, either by adding storm windows to your existing windows, or by buying new double-paned windows can be quite cost-effective. Splurging for triple-glazed windows enhances thermal efficiency even further, but the return on the investment is not as large. For more information on improving the thermal efficiency of your existing windows, see the Weatherization section.

Window Frames

In the past, most window frames were made of high-quality wood. The reduced supply of premium wood has caused manufacturers to seek other frame materials. Wood frames are still quite common, and some are made from finger-jointed lumber. Wood window frames can require a lot of maintenance and are susceptible to water damage.

Many inexpensive window frames are made of aluminum. Aluminum window frames are durable but the metal conducts heat resulting in energy loss to the outdoors. Additionally, the energy embodied in aluminum windows is quite large, because aluminum production is very energy intensive.

New window frames are emerging which combine the materials previously used alone. Aluminum-clad windows are aluminum window frames with a wood interior. Vinyl-clad are vinyl windows with a wood interior. These window frame materials make sense for several reasons. First less wood is used than with conventional wood window frames. Second, the aluminum and the vinyl require less maintenance than wood frames. Third, the wood provides better insulative value than solid aluminum or solid vinyl frames.

Fiberglass window frames offer perhaps the best combination of thermal efficiency, durability and low embodied energy, but fiberglass window frames tend to be more expensive than the other choices.
The large variety of window frames can make window purchases confusing. Careful research prior to purchase with consideration of the cost, thermal efficiency, durability, and production process of the framing material will help you arrive at the best window frame for your project.

Too Many Windows?
Because they are made of glass, windows are not good insulators. A double-glazed aluminum window, for example, loses heat about 12 times faster than a wall with R-20 insulation. The energy loss caused by low-quality windows will doom you to years of high utility bills. Building codes usually require living spaces to have windows equal to 8% of the floor area of the room. Thus, if the room is 100 square feet, there should be 8 square feet of window area. Most buildings have much more window area than is required by the building codes.

All windows, regardless of the glazing and frame material should be weatherstripped to reduce the amount of air infiltration (See the Weatherization section, p. 51). If you are building a new house, choose windows which will make the most of your construction budget while making the house as energy efficient as possible.

Figure 19. Single-, double- and triple-paned windows.
Types of Windows

Fixed Windows
Fixed windows don’t open, so there is typically a good seal between the window and the wall. Fixed windows are also typically the least expensive because they require no working hardware. The drawback to fixed windows is that they don’t allow any ventilation and they do not meet the standards for egress (which means they are not acceptable as a means of escape in an emergency). If you can, install fixed windows in areas where an egress window is not required. If you are planning on installing windows on the north side of the house, make them fixed, especially in northern climates, because they will help to reduce the chill of the winter wind. Installing a combination of fixed windows and windows that open will allow the best mixture of efficiency, ventilation and egress.

Awning and Casement Windows
The hardware that opens and closes awning and casement windows tends to latch the windows tightly closed, causing them to be tighter than double-hung and sliding windows. Because these windows do have fairly complicated hardware, however, they are typically more expensive than the other types of windows.

Double-Hung Windows
The bottom half of a double-hung window slides upwards, while the upper half typically remains fixed. Because the bottom must be able to slide, the double-hung window must be slightly loose in its track, thus leaving the potential for air leakage.

Sliding Windows
Because these windows must be loose in their tracks in order to slide, they leak a lot of air. Sliding windows are typically the least expensive, but the initial cost savings is quickly lost as your hot air leaks to the outside.

See Figure 20 for illustrations of standard window designs.
Figure 20. Standard window designs.
**Roofing**

Roof design should emphasize simplicity, durability, energy efficiency and protection from sun and rain. Simple roofs are much cheaper to build than roofs with many complicated angles. Metal flashing is required at any seams on a roof, such as valleys, dormers, chimneys and skylights to eliminate leakage. The more complicated the roof, the more flashing is required. This requires extra labor and materials and there is a great chance of leakage if the job is not done right.

**Roof Design**

Design the roof with a slope steep enough to allow water to drain quickly which will help the roofing materials last longer. A steep roof also results in a gain of space under the roof which can be very valuable for storage or for an extra room, for very little added cost. Balance the slope of the roof with costs of installation; the labor expense increases as the pitch of the roof gets steeper.

Figure 21 illustrates common roof designs and details.
Roofing Materials

The wide variety of roofing materials presents an excellent chance for a discussion of the benefits of durability. Because of the beating your roof takes from wind, rain, snow and sun, the roofing material must be tough. Replacing a roof is an expensive proposition and not a job you will want to complete every few years. For these reasons, it makes sense to install the best, most durable roof you can afford. For your reference, roofing prices are given per “square” which is 100 square feet of roof.

One additional factor to keep in mind is that the weight of the roofing material can affect the structural requirements of the roof and wall framing.

To determine the best roofing material in your region, for your roof type and within your budget, contact a number of roofing professionals for an estimate and for advice. Most roofers will guarantee their work for 25 years.

Table 4 describes several types of roofing materials.

<table>
<thead>
<tr>
<th>Type of Roofing</th>
<th>Cost</th>
<th>Benefits</th>
<th>Drawbacks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt Shingles</td>
<td>relatively inexpensive but don't settle for cheap asphalt shingles</td>
<td>good quality asphalt shingles will last 15 to 20 years</td>
<td>poor quality asphalt shingles will peel and may need to be replaced within 5 years</td>
</tr>
<tr>
<td></td>
<td>moderate labor costs</td>
<td>look for asphalt shingles which contain recycled asphalt</td>
<td></td>
</tr>
<tr>
<td>Cedar Shake Shingles</td>
<td>shingles themselves are moderately expensive but installation labor is the highest</td>
<td>NONE</td>
<td>expensive, not durable, extreme fire hazard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>production of cedar shakes requires the largest, old-growth cedar trees, a resource which most certainly should not be wasted.</td>
</tr>
<tr>
<td>Aluminum or Steel Shingles</td>
<td>materials and labor both moderately expensive</td>
<td>most are 90% recycled, lightweight so can reduce framing needs, durable, recyclable after use</td>
<td>high embodied energy</td>
</tr>
</tbody>
</table>

Table 4. Roofing materials.
**Finish Work**

Finish work presents many opportunities for do-it-yourself projects which may result in significant savings. Some of the interior details can be done in stages, completed as you have the time and money to allocate to them.

**Interior Walls**

An open floorplan not only increases the spaciousness and ventilation of a house, it decreases the number of interior walls. Fewer walls means a savings of money and materials not only for framing but for paint and other finishes.

To save money and increase the durability of your wall finishes, try to avoid wallpaper. Not only is wallpaper expensive, it is not very durable, can be difficult to install, the glue can be quite toxic, and it is possible that you might be tired of the pattern within a few years and want to start all over. You would do better to paint the walls a light color to increase a feeling of openness in the room. The light paint allows you to brighten the room with furnishings and accents and makes the walls less overpowering. You can also brighten the room with accents of vibrant colors to offset your light colored walls. Interesting detail can be added to the room with painted stencils which you can do yourself.

When choosing paint, be sure to choose a color you will not get tired of. Find a latex paint rather than an oil-based one. Oil-based paint is quite toxic and is extremely difficult to clean up which leads to rapid deterioration of paint brushes and rollers. Latex paint cleans off of brushes and clothing with water and is not as toxic as oil-based paint. Glidden Spread is a new non-toxic latex based paints which is available around the country. While the selection of colors is limited, the cost is roughly equivalent to oil-based paint and just slightly more than regular latex paint. If you can't find Glidden Spread locally, you can call Planetary Solutions (see information in the directory at the end of this booklet). Paint selection is yet another example of the importance of knowing the right questions to ask to find the most cost-effective and ecologically responsible product.

Avoid dumping paint and other toxic fluids down the drain or on the ground because they can pollute the groundwater as well as disrupting the function of your local sewage treatment plant. Some communities have begun paint swap days where people bring any excess paint to trade with other people. Thus, you get free paint, plus less paint is wasted overall. In addition to the paint swap, many cities and towns now have days set aside for disposal of toxic substances such as paint, paint thinner and motor oil. Take advantage of these disposal days rather than dumping the paint and paint thinner down the drain.
Lead in paint
If you live in a house or apartment that was built before 1978, be aware that the paint could contain lead. It is estimated that 57 million homes still contain some lead-based paint. Lead exposure can be extremely dangerous, particularly to children, causing serious health problems including brain damage. It is important to be aware of the possible presence of lead in paint, particularly if you live in an older home and are planning on scraping the paint prior to refinishing. Contact your local health department for information on how to reduce lead hazards when removing old paint.

Storage
Kitchen and bathroom cabinets can be quite expensive. Shelving can be made of particle board rather than dimensional lumber to save both money and wood. You can then paint the shelves with a low toxicity latex paint. An excellent option is to use open shelving for storage. Not only does open shelving allow better access to food and dishes, there are no cupboard doors for head bumping. If you prefer cabinets with doors, you could design a mixture of closed cabinets and open shelves. A very nice looking storage option is cabinet doors with glass fronts. These can even be placed in front of windows to increase storage area while still letting light through. Not only does open shelving reduce the costs of cabinetry and use fewer materials, many homeowners are able to install this simple shelving themselves, avoiding labor costs. Still another idea is to install open shelving at the outset and add cabinet doors later, as finances allow. If you do choose to use cupboards with doors, avoid dark stains which can make a room feel heavy and enclosed.
Much wood is wasted on trim. Trim is used around windows and doors to cover up the spaces where the drywall doesn’t quite reach the window frame. Window trim can be eliminated if the drywall installer pays special attention to detail in the finishing of the drywall. It is possible that the extra time required for this finishing may increase the cost beyond the cost of the trim, but it is worth discussion with your drywall installer. Trim and molding along the base of the wall and at the top of the wall are expensive details which can be eliminated to save both money and wood.

If you would rather not do without trim, try milling wood salvaged from other buildings into trim for your house. This activity takes time and woodworking skills but can result in beautiful trim by reusing resources which might otherwise be wasted.

In an effort to reduce wood consumption, manufacturers have developed wood-like products made from plastic. These products are for use in non-structural applications like decks, fences and interior trim.

While it is certainly desirable to reduce our consumption of wood, thereby reducing pressure on our forests, we must think carefully before we jump to new products like plastic wood. Plastic production and recycling both require enormous amounts of water and energy and result in the release of many toxic air and water pollutants. On the other hand, many of the plastic products contain some recycled plastic and are priced competitively with wood used for similar purposes. These materials tend to be quite durable, requiring far less maintenance than their wood counterparts. The point is to think carefully about what type of product best suits your project in terms of both financial cost and overall effect on the environment.
Appliances

Appliances use about 20% of the energy in the average home or apartment. The choice of size and efficiency of appliances is important in minimizing their energy use. Even if you cannot buy new appliances, there are things you can do to make your current appliances work as efficiently as possible. Figure 22 indicates the percent of household energy used by each type of appliance.

It doesn’t make sense to throw away appliances which are in reasonably good condition for the sake of energy efficiency. Keep them clean and in as good working order as possible. More energy would be wasted by throwing away an appliance in working order than would likely be saved in buying a new one. The two exceptions to this idea are the furnace and the hot water heater (See the heating and cooling section, p. 33).

Figure 22. Average breakdown of energy use by appliances.
Refrigerator

New
If you are buying a new refrigerator, choose the smallest one which will fit your needs. A two-door refrigerator is more efficient because you can open the freezer without letting the cold air out of the refrigerator.

Existing
Make sure your refrigerator is in the coolest possible place. Try to avoid putting the refrigerator next to heat producing appliances like the oven, the dishwasher, or a sunny window. The hotter the surroundings, the harder the refrigerator has to work to keep food cold. Your refrigerator will work most efficiently if there is adequate air circulation on all sides, so try to leave about an inch of space all the way around.

Stove/Oven

New
Gas stovetops are more efficient than electric because the burners do not waste energy heating up. Additionally, gas is generally less expensive. The purchase price for electric and gas ranges is about the same. Some people contend that gas ovens do not bake as well as electric.

Existing
Don't use your stove or oven to heat your house, although it is fine to leave the oven door open a crack after you have used it to let the heat escape and help warm up the kitchen. For most recipes it is acceptable not to preheat the oven. Preheating simply wastes energy. You can turn off the oven a few minutes before the food is done, and the remaining heat will finish the job.

Dishwasher

New
Newer dishwasher models have settings which reduce water consumption and which allow you to bypass the heat-dry option. If you are buying a new dishwasher, keep these resource saving options in mind. If you are trying to reduce initial construction costs, it is not necessary to install a dishwasher.

Existing
If you have a dishwasher, you can save energy by turning off the dry cycle and letting the dishes air dry. Hand washing in a tub and using the dishwasher each use between 10 and 20 gallons of water to wash and rinse the same amount of dishes. If you let the water run while you wash the dishes by hand, however, about 30 gallons of water are used. The dishwasher will be most efficient if you scrape the plates clean and if you only run it when it is full.
**Washing Machine/Dryer**

**New**
If you are buying a new washing machine and dryer, look into front-loading models which stack vertically. These machines use gravity to tumble the clothes which gets them cleaner. Additionally, because the washer and dryer are stacked, half the space is required for the laundry area. Gas dryers are more cost-effective than electric in most areas of the country, but again the correct choice depends on price and availability of energy in your area.

**Existing**
Much energy can be saved by avoiding washing clothes in hot water because 90% of the energy used by the washing machine goes to heat the water. If Americans washed our clothes in cold or warm water only, we would save the equivalent of 100,000 barrels of oil a day. That oil would be enough to heat 1.6 million homes through the winter.\(^2\) If at all possible, it is best to dry clothes outside. If you must use a dryer due to space restrictions or the weather, dry full loads but do not overfill the dryer. If you have a dryer in your house, it is most likely vented to the outside. You can install a simple bypass damper with an extra lint filter to the vent and have the dryer exhaust vent into the house to help heat the house and keep the air humid enough in the winter.

**Hot Water Heaters**

**New**
The operating costs of an electric hot water heater are 3 to 4 times higher than those of a gas hot water heater. At today’s national average fuel costs, the annual cost of operation for most gas hot water heaters is between $120 and $150. For electric hot water heaters of the same size, the annual operating costs are between $350 and $400.\(^8\) Install the smallest hot water heater that will meet your needs, not only will the initial purchase cost will be lower, it takes less energy to heat less water, so your overall operating costs will be lower.

**Existing**
To keep your existing hot water heater at its most efficient, be sure to keep it clean. Your hot water heater should have an insulative blanket which are available at hardware stores and building supply stores. Additionally, the hot water pipes should be insulated to reduce the amount of heat lost as the water travels from the heater to the faucets. See the Plumbing section for more information (p. 29).
Landscaping

Trees and shrubs act well as natural insulation, protecting the house from sun and wind. Consult a nursery in your area to learn the types of trees and shrubs which will work best at your location and be sure to plant evergreen trees on the north side of the house and deciduous trees on the south and west sides.

Americans spend $25 billion each year maintaining 23 million acres of lawns." Kentucky bluegrass and other grass species commonly used for lawns are not suited for most parts of the country. To keep them looking green and lush we pour on water, fertilizers and herbicides. Then we use gasoline keeping the lawn cut the “right” length. Rather than focusing our time, money and natural resources on upkeep of lawns unsuited to our climate, we can choose plants which are better adapted to our area.

Consult your local nursery about native grasses and other native plants which are suited to the climate in your area. If you live in a dry climate, look into xeriscape gardening. Xeriscape makes use of plants, shrubs and trees which are suitable to your specific climate, resulting in beautiful and functional surroundings without the use of excess water. One of the secrets of xeriscape is to use mulch, such as grass clipping and leaves, around the base of plants, shrubs and trees to help the soil retain moisture.

Avoid the use of lawn and garden chemicals such as fertilizer, herbicides, and pesticides. These poisons can not only harm your family and pets, they can pollute your drinking water and nearby streams and lakes! Manual lawn mowers are available at most hardware stores. You save the expense of gasoline, cutting the lawn with a hand mower is quiet, does not produce fumes, and is better for the lawn.

If you have the space for a garden, you can produce inexpensive, healthy, pesticide free vegetables. With a vegetable garden you are able to reduce the embodied energy of your food. Many areas have established community gardens, making garden plots available to those who have insufficient space at home.

Garage/Driveway

A great way to reduce overall construction costs and use fewer materials is to avoid building a garage altogether. This reduces foundation, framing, insulation, roofing, and finish costs, not to mention the significant cost of a garage door. If you need protection for your car, a one-car carport is a better use of materials than a full garage. The carport can double as a covered deck for outdoor relaxation. A small storage shed for tools will also help alleviate the need for a garage. (See Figure 23.)

If you do choose to build a garage, consider placing part of the main living space above the garage. This
strategy makes use of the benefits of two-story building - with reduced foundation and roofing costs and more efficient use of space on the lot.

Concrete is an expensive and energy intensive material to use for driveways. A crushed rock driveway is a less expensive and less energy intensive alternative. Crushed rock, however, requires periodic additions of rock, because the rock sinks into the ground over time. Another idea is to make a strip or ribbon driveway instead of a solid slab driveway. Not only do these alternative types of driveways require less materials than the conventional concrete slab, they allow water to drain into the ground instead of running off the driveway and into the street.

Figure 23. Diagram of carport & storage shed with ribbon driveway.
WEATHERIZATION

Probably the best way to save energy in an existing home or apartment is to weatherize!!

Weatherization lessens the infiltration of cold air into the house in winter and hot air into the house in summer. The following weatherization techniques will not only decrease your energy consumption and save you money, they will make your house more comfortable!

Windows and doors can account for about 50% of the heat lost from your home. About 20% of the heat from your home is lost by convection which is when cold air sneaks into the house through cracks and warm air sneaks out. Additional heat is lost by conduction which means that energy is transferred from the warm room to the window or door and then from the window are door to the outside. Because of the great amount of heat that can be lost by windows and doors, it is important to choose windows and doors that are good insulators, and to make sure that all of the cracks are well-sealed.

The best weatherization strategy is to start with the smaller, easier tasks first. Weatherstripping, which is the least expensive weatherization project, will result in the largest amount of energy saved in relation to the amount of money spent. After weatherstripping, try caulking, then move on to storm windows and doors, then insulation, then more efficient heating and cooling systems. Realize that if you don’t start at the beginning, by sealing cracks with weatherstripping and caulking, the money spent on other weatherization improvements will be lost between the cracks.

Weatherstripping

The first step in weatherization is to weatherstrip windows and doors. This is the most cost-effective weatherization project and could be the very best thing you could do to your house to save money and conserve energy. You can buy weatherstripping materials at all hardware stores and lumberyards. Experts recommend the black weatherstripping with the fabric face rather than the white or gray plastic foam variety, because the foam is fragile and won’t last as long. Weatherstripping is not permanent; to be most effective you will need to weatherstrip about once every three years.
Apply weatherstripping in the following places, inside the house, and out:

- Where the window meets the sash (window frame) (Figure 24.)
- Where the door meets the door frame (Figure 25.)

Figure 24. Where to install weatherstripping on a window.

Figure 25. Where to install weatherstripping on a door.
Caulking

It is estimated that if every gas-heated home were properly weatherstripped and caulked, enough natural gas would be saved each year to heat four million homes. Weatherstripping and caulking can save the average home up to 10% annually on energy costs.

Apply caulk in the following places, inside the house, and out:

- Where the door frame meets the wall
- Where the sash meets the wall

(See Figure 26.)

Use rope caulk to seal cracks which are too wide for caulk from a tube. When you apply weatherstripping and caulk, make sure that the surface is clean and dry so that the weatherstripping and caulk will stick. Try to purchase caulks and sealants at a glass or window supplier rather than general hardware store. The selection will be better and you will likely save money.

Storm Windows and Doors

To decrease the amount of heat which is lost through your windows, you can add storm windows which effectively turns your single-glazed windows into double-glazed. Storm windows can be as simple as a piece of thick plastic tacked securely to the outer window frame. Other storm windows are actual glass windows in frames which attach to the outside of existing windows. The second layer of glass (or plastic) provided by the storm window reduces the conduction of heat through the window and the layer of air between the panes acts as insulation.

It can be hard to seal large cracks around an ill-fitting door - a well-fitted storm door can provide the protection you need from infiltration. The addition of storm windows and doors will decrease your heating and cooling bills and make your home much more comfortable. Experts assert that if your home is smaller than the 1,700 square foot average and the cracks are reasonably well sealed, adding storm windows is roughly equivalent to adding 2 inches of insulation to all of your walls."
If storm windows do not fit your current home improvement budget, another idea is to add insulating curtains or panels to cover your windows at night. After the sun sets, your house begins to lose heat, about half of which escapes around and through the windows. Pulling curtains across the windows at night reduce the amount of heat which is allowed to escape. These curtains will be most effective if they are fairly thick and if the weave of the material is tight enough to prevent the air from flowing through it.

Another practical idea is to make a curtain liner out of 2 inches of inexpensive fiberfill batt which is available at most fabric and craft stores. Cover the batt with a thin low-cost material like muslin. Sew the material together all the way around the edge of the batting and tack through the batting every 12 inches in both directions, horizontally and vertically. This liner can be hung from the same hooks your curtains are hung on and should hang between the curtain and the window. During the day the liner pulls to one side, while at night, it acts as a blanket keeping the warm air in the house in the winter and the cool air in the house in the summer. The materials for this project will likely cost less than $10 which will easily be paid back in reduction energy within a year.

If you live in a cold climate and you have more than one entrance to your home, you can seal off any doors on the windy side of the house during the winter to prevent cold air from rushing into the house every time you open the door. Seal all the edges of the door, including the bottom, with weatherstripping and tack a plastic sheet over the door. The door can then be covered with a sheet or a curtain and you can ignore it until springtime.

**Insulation**

To make sure that your house will keep you comfortable and to avoid wasting money and energy by heating the outdoors, it is important to have as much insulation in your house as you can afford. You will see the most dramatic reduction in energy use and cost if you improve the insulation in your house from none to R-16. Improvement from R-16 to R-32 is still a good idea if you can afford it, but the return on your investment will not be as dramatic. The first step is to insulate the attic, because hot air rises and will go right out the roof, plus the hot summer sun heats the attic and the house. Not only is the attic the best place to insulate in terms of energy saved, it is usually easiest to add insulation to an existing attic than it is to walls or floors. If you are already planning on overhauling the house, it makes sense to add insulation to the walls and the floor. Otherwise, you will make the most of your weatherizing investment by weatherstripping, caulking, adding storm windows and insulating the attic. Use Table 4 to calculate the costs and savings of weatherization projects.
Table 5. Weatherization Strategies
Use the following table to decide which weatherization techniques will make the most sense for your home at this time. Compare the cost of materials to the money saved in a year to see if the project makes good sense in the short term. Call building supply stores and window suppliers in your area to compare prices. It is wise to start with the simple tasks, such as weatherstripping, which provide the best return on your investment. Then move on to more involved projects like storm windows. The first entry in the table is an example using 1995 costs for Missoula, Montana.

<table>
<thead>
<tr>
<th>Weatherization Strategy</th>
<th>Ease of Task</th>
<th>Cost of Materials</th>
<th>Energy Saved</th>
<th>Cost of Energy</th>
<th>Energy Use Per Year</th>
<th>Money Saved Per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weatherstripping</td>
<td>Easy</td>
<td>$35.00-$50.00 for all windows in house lasts 3 years</td>
<td>10-30%</td>
<td>Gas: $4.268/MCF</td>
<td>150 MCF</td>
<td>$64.02-$192.06</td>
</tr>
<tr>
<td>Caulking</td>
<td>Easy/Medium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm Windows</td>
<td>Medium/Hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation-Attic</td>
<td>Medium/Hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation-Walls</td>
<td>Hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insulation-Floor</td>
<td>Hard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: MCF stands for thousand cubic feet and is the standard measurement for natural gas usage. 150 MCF is the average yearly gas usage in the state of Montana.

How to Determine the Savings:
- Cost of Materials: Weatherstripping materials are found at hardware and building supply stores, as well as window and door suppliers.
- Energy Saved: The experts at the supply stores likely have an estimate for the potential energy saved for each step in weatherization. Your state energy office likely has free publications regarding weatherization effectiveness in your region.
- Cost of Energy: Whether you have electric or gas heat and air conditioning, the cost of energy can be found on your monthly utility bill.
- Energy Use Per Year: Most utility bills indicate an average energy use per year. You can figure this value out for your home by adding the usage from your past years' energy bills and finding the average.
- Money Saved Per Year: Multiply the percent energy saved by the energy cost by the energy cost per year. Thus, weatherstripping in Montana saves between: 10% x $4.268 x 150 MCF=$64.02 and 30% x $4.268 x 150 MCF=$192.06.

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GIVING NEW LIFE TO OLD RESOURCES

Salvage and Reuse of Materials

Besides using fewer resources in general, reusing materials is one of the best ways to conserve natural resources. Reuse can be as simple as using a paper grocery sack more than once or washing out plastic bags to use again. Similarly, building materials can be reused, either in the same function they served previously, or adapted for a new use. In a recently completed medical clinic in northwestern Montana, maple flooring from an old gymnasium was refinished to make a beautiful hardwood floor for an exercise room. The weathered wallboards of an old barn can be fashioned into interior trim. Old buildings and junkyards are excellent sources of materials for all construction and remodeling projects.

Reusing materials benefits the environment in many ways, it:

- lessens demand for virgin resources
- reuses the embodied energy trapped in existing building materials
- prevents discarded building materials from ending up in landfills extending landfill life and saving land costs

You can save a great deal of money through persistent searching for used building material. Be aware, however, that salvage and reuse takes time and patience, as well as careful planning to be able to incorporate salvaged treasures into your construction and maintenance plans.

Sources of Salvage

Wherever you live, it is likely that there are old buildings which are being torn down to make way for new ones, in fact, each year Americans demolish 150,000 buildings. Much of the material in demolished buildings is reusable. Call your local building department (their phone number will be in the city or county government section of your phone book) and ask them if any buildings are scheduled to be demolished. You can then call the owner of the building and ask if materials will be available for free or at a reduced price. Sometimes the materials will already be spoken for, but with luck and patience you may find old bricks, wood, windows, doors, furnishings, door handles, cabinets, and other materials. Many of these treasures will add unique character to your house. You may feel comfortable collecting some of these materials yourself, or you may want to ask a friend or neighbor for help gathering and transporting the materials you salvage.

Salvage centers are being established in many places around the country, as well. These centers collect used materials from demolitions in the area, sort the materials, and make the materials available to people to purchase. A salvage center is a good place to find materials if you do not have construction or demolition experience. If there is not a salvage
center in your area, consider starting one. As the ideas of resource efficiency spread, there will be an increasing demand for sources of salvaged material.

If you do wish to try salvaging materials yourself, please be aware that salvage and demolition are very dangerous. Your best bet is to try to collect materials which have already been removed from the building in question, rather than trying to remove them yourself. Demolition is much more dangerous than construction because the building is likely to be old, thus it could be structurally unsound, there could be loose boards with rusty nails, or there may be spiders or rodents present. Please seek training in demolition before you attempt to salvage materials on your own. Protective clothing, leather gloves, sturdy shoes and a recent tetanus shot are all imperative before you start to demolish a building. Also remember that you must track down the owner of the building and ask for permission before you take any materials. Even buildings which look deserted most likely have an owner somewhere.

**LABOR COSTS**

One of the most expensive aspects of any home construction or repair is the labor. Some of the techniques mentioned in this booklet save money because they require less time of professional construction workers. You can also save money by doing some or most of the work yourself. If you are building, find a contractor who is willing to let you do some of the work yourself. If you are remodeling or doing maintenance projects, step-by-step books are available from public libraries which can guide you through the full range of construction work.

Another option is to consider forming a neighborhood group of fixer-uppers. Each person might have or develop a specialized skill which they could apply to their own house and then to their neighbors’ houses. If enough people work together, the knowledge and skills will likely be available to make some wonderful improvements. Not only will this help you build a sense of pride in your own house, but it helps the community grow while spreading the message of affordable conservation.

**Additional Costs**

If you are building a house from scratch, you will have to bear in mind the cost of the land, plus the development costs such as sewer and water, electricity and even sidewalks and streets if you are building in a previously undeveloped area. From an environmental standpoint there is less impact from the repair or remodel an older house than in building on open land. If you choose to build on a new lot, there are opportunities for urban infill which means to fill in the empty lots in an already developed area, rather then increasing the sprawl of a city of town.
Consider the environmental effects of the various types of housing, listed here in the order of increasing impact on the environment:

- repairing/remodeling of an existing building
- building new house on an old lot in a developed area; perhaps using the materials from the house which used to be on the lot
- building a new house on a new lot in a developed area
- building a new house in an undeveloped area.

**SPREAD THE WORD**

The best way to help make resource efficient construction technologies more affordable is to increase the demand. Many builders, designers and architects do not know about the innovative building materials available because their clients have not expressed an interest in resource efficiency. It is often time consuming to seek out information on new products and building techniques. As a housing customer, you have the right to request materials which can save you money and which have a smaller impact on the environment than conventional building materials. If you are planning to build a home, tell your builder or designer that you are interested in using resource efficient and environmentally conscious materials. If you rent your home, ask your landlord or apartment manager to improve the weatherization of your building to reduce your heating and cooling costs. Spread the word of resource efficiency to your friends and neighbors, your co-workers, or members of your church. As more people begin to understand the direct connection between the materials we use and the destruction of the environment, we can begin to work together to make a change in conventional building techniques.

**RESOURCE WRAP-UP**

You have learned about resource efficiency from the bottom of the house to the top. Hopefully, you have discovered ways to apply the ideas behind resource efficient design, construction and maintenance to your own home. Please remember that you do have control over your surroundings. Take it upon yourself to reduce your personal consumption of energy and other natural resources and help the environment as you make your house more affordable and a more comfortable place to live.

Please take the time to learn more about the steps you can take to make your life more resource conscious. This booklet is a basic introduction to a small part of resource efficiency. By taking the time to read this information and think about the ways you can begin to reduce your personal consumption of resources, you are taking positive steps toward ensuring that there is something left of the planet Earth to pass on to future generations.
GLOSSARY

2 x 4 stud: The 2 x 4 (pronounced two-by-four) is a standard dimension of a board. The numbers refer to the height and width of the board, in inches. Thus a 2 x 4 is two inches tall and 4 inches wide if it is lying flat on the ground. 2 x 4s are available in a wide range of lengths. Other boards are named in the same way, for example, 1 x 4, 2 x 6, 4 x 4, all refer to the dimensions of the end of the board. A stud is simply another term for a board used in framing.

Cluster Plumbing: A strategy where all rooms requiring plumbing (kitchen, bathrooms, utility rooms) are located back to back, or directly above or below one another. Additionally, these rooms are located near the hot water heater.

Embodied Energy: The amount of energy it takes to extract, process, manufacture, transport, and install a material. The more energy required for the use of the material, the higher the embodied energy.

Engineered Wood: Framing and structural materials comprised of small pieces of wood or wood fibers, held together with adhesives. Typically stronger and more lightweight than the dimensional lumber they replace, engineered wood products make more efficient use of wood than solid-sawn lumber.

Footprint: The size and shape of the foundation of a house.

HUD: The United States Department of Housing and Urban Development. This is the governmental agency which is involved in housing issues.

Non-renewable Resources: Resources like fossil fuels which can only be used once before they are used up.

Offgassing: The release of toxic gases from building materials which results in poor indoor air quality.

Operating Energy: The energy it takes to operate and maintain a building over the lifetime of the building.

R-value: Measurement of insulative value.

Resource Efficiency: Conservation of natural resources through creative applications of energy efficiency and materials efficiency.

Uniform Building Code: The Uniform Building Code is the set of laws which govern construction practices. Using these laws, building officials set national and local building standards. Contact your local building department to determine which standards apply to your construction project.

Urban Infill: Filling in empty lots in cities rather than encouraging urban sprawl.

Weatherization: Taking preventive measures to keep the cold air out and the warm air in winter and the hot air out and the cool air in summer.

Xeriscape: Gardening and landscaping using native plants and shrubs which require little water.

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WHERE TO GO FOR MORE INFORMATION

The first place to find information on natural resources, resource efficiency, energy efficiency, and building and remodeling techniques is your public library. If you cannot find information on the topics you want to learn more about, ask the librarian for assistance.

The second source for building information, particularly with respect to the local rules and regulations in your area, is the building department in your town or city. Your local health department will have information on such topics as indoor ventilation requirements and the effects of toxic materials in building products. Phone numbers for these offices are listed in the government section of the phone book and they likely have a large amount of information for no charge.

The following list of organizations is just a sample of the useful sources you can call or write for more information.

**Affordable Housing**

The Enterprise Foundation  
10227 Wincopin Circle  
Columbia, MD 21044  
(410) 964-1230

HUD Library  
U. S. Department of Housing and Urban Development  
Room 8141  
451 Seventh Street SW  
Washington, DC 20410  
(202) 708-3180

HUD USER  
PO Box 6091  
Rockville, MD 20850  
1-800-245-2691  
HUD USER publishes free information detailing the current events in affordable housing.

**Habitat for Humanity**  
Habitat for Humanity has local chapters around the United States. The number of the chapter nearest you will be in the white pages of your phone book.

**National Affordable Housing Network**  
P.O. Box 3706  
Butte, MT 59702

**National Council of State Housing Agencies**  
444 North Capitol Street, NW, Suite 412  
Washington, DC 20001  
(202) 624-7710
Building Industry Organizations

American Institute of Architects
1735 New York Avenue NW
Washington DC 20006
(202) 626-7300

National Association of Home Builders
Environmental Regulation Department
15th and M Streets, NW
Washington, DC 20005
(800) 368-5242

Community Planning
Consult your local planning department if you are interested in learning more about ecologically responsible community planning.

Additional information is available from:
American Planning Association (APA)
1313 East 60th Street
Chicago, IL 60637-2891
(312) 955-9100

Energy Efficiency
Most states have an energy office which focuses on regional energy issues. The number for this office will be in the State government section of the phone book.

Consumer Reports Home Appliance Buying Guide
Consumer Reports Magazine publishes this annual guide to appliances. The book rates appliances based on cost, features, energy efficiency, durability and cost of operation. The guide is available at (515) 237-4903 for $8.99. You can also find this guide and Consumer Reports Magazine at your public library.

Northgate Housing, Inc.
275 Northgate Road
Burlington, VT 05401
(802) 860-7090
Northgate Housing is a community of affordable housing which successfully reduced operation costs by completing a thorough weatherization project.

Energy Efficient Building Association
North Central Technical College
1000 Campus Drive
Wausau, WI 54401-1899
(715) 675-6331

Real Goods
966 Mazzoni Street
Ukiah, CA 95482-3471
(800) 468-9486
Real Goods is a catalog store which sells a wide variety of resource efficient, energy efficient and otherwise alternative products. Many of the items in the catalog are expensive, and some are questionable as to their resource efficiency, but if you are having trouble finding supplies in your area, such as compact fluorescent light bulbs, the free Real Goods catalog is a good source to try, as well as a good source of general information.

Rocky Mountain Institute
1739 Snowmass Creek Road
Snowmass, CO 81654
(970) 927-3851
rmi@igc.org
The Rocky Mountain Institute is a leader in energy efficiency research. The Institute has published many books and pamphlets which help people live more energy efficiently. Call for a free publications list.
Lead Safety
Consult your local health department for information regarding the potential presence of lead in your house or apartment.

The National Center for Lead-Safe Housing
205 American City Building
Columbia, MD 21044
(410) 992-0712

Planetary Solutions
PO Box 1049
Boulder, CO 80306-1049
(303) 442-6228
Store which specializes in low-toxicity paint, paint thinner, stain, recycled carpet and tile, energy efficient lighting and appliances and other resource efficient goods. Call for information.

Resource Efficiency

Center for Resourceful Building Technology
PO Box 100
Missoula, MT 59806
(406) 549-7678

Environmental Building News
RR 1 Box 161
Brattleboro, VT 05301
(802) 257-7300
A monthly update on emerging resource efficient technology. Call for subscription information.

Out on Bale
1037 E. Linden
Tucson, AZ 85719
(602) 624-1673
Out on Bale specializes in spreading the word about building well-insulated houses out of strawbales, as well as other indigenous building techniques.
Endnotes

5 This calculation based on 1,039,000 new homes built per year with an average of 9700 board feet per home (roughly equivalent to one clear-cut acre of forest).
15 Personal Communication, April 18, 1995. Tracy Mumma, Center for Resourceful Building Technology, Missoula, MT.
18 Ibid: 4-6.
27 Cost-Saving Construction Opportunities and the HOME Program: Making the Most of HOME Funds: 16.

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34 O'Hara, F. M., ed.: 20.


36 Laird: 56.


38 Based on 1995 estimates of the annual operating costs of the Sears Kenmore Power Miser series from Sears, Missoula, Montana. Sears estimated the annual costs based on average national costs of $.6054 per therm for gas and $.0824 per kilowatt hour for electricity.

39 Sinnes, A.C. 1995. Making a difference can be as close as your own backyard. The Missoulian, April 23: C1.

40 Ibid.: 174.

41 Energy Star Program: 2.

42 Ibid.: 125.