PDH Academy

Designing for Energy Efficiency

3 PDH/ 3 CE Hours/ 3 AIA LU/HSW Hours

AIAPDH192

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ANSWER SHEET

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Designing For Energy Efficiency – AIAPDH192

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PDH Academy

DESIGNING FOR ENERGY EFFICIENCY

FINAL EXAM

1. Cool roofs are best described as ______________________ .
   a. Those incorporating a misting system on the surface
   b. Those encouraging societal trendsetters to occupy the building
   c. Those with at least double the minimum recommended insulation below them
   d. Those surfaced with light or reflective materials

2. When heat moves through an object in an assembly, that is more conductive than materials around it, that is described as ______________ .
   a. An end around
   b. A thermal bridge
   c. Conducive transfer
   d. A complete design fail

3. If heating and cooling loads for a region are roughly balanced, some choose to _______ .
   a. Omit a vapor barrier altogether
   b. Maximize fenestration to encourage natural ventilation
   c. Use dark roofing to control solar gain
   d. Depend on exterior stucco for waterproofing

4. The ultimate goal of venting is to allow _____ and ______ levels in an attic to equalize with those same conditions outdoors.
   a. Wildlife, moisture
   b. Temperature, air pressure
   c. Moisture, barometric pressure
   d. Temperature, humidity

5. When melting snow above warm attics, flows down to freeze on eaves, it creates _____ .
   a. An ice dam
   b. A sheet of running water needed diverted
   c. Potential ice hazards down below on paved surfaces
   d. An instant thermal bridge

6. Block core filling with any type of insulation, offers little in savings because ________ .
   a. Its very difficult to put in place after the block has been laid
   b. To maintain flexibility, core insulation must be kept very thin
   c. It is only made in two locations and the high shipping costs are difficult to recoup
   d. The many block webs still conduct heat as thermal bridges

7. The type of energy that travels away from surfaces and heats anything solid that absorbs energy is called ___________ .
   a. Radiant heat
   b. The microwave spectrum
   c. Radon
   d. Ultraviolet (UV) energy

8. The two types of foam insulation, closed-cell and open-cell, are both made from ______ .
   a. Polyicystyrene
   b. Recycled materials
   c. Polyurethane
   d. Fiberglass

9. _________________ typically forms the core of structural insulated panels.
   a. Powerful adhesives
   b. Structural sheathing panels
   c. T-studs at a spacing of 16”
   d. Foam board insulation

10. Air leakage can account for _____ % or more of a home’s energy costs.
    a. 25
    b. 30
    c. 35
    d. 80

11. When inside air pressure is less than pressure outside, air is pulled into the building by the process of _________ .
    a. Infiltration
    b. Exfiltration
    c. Transpiration
    d. Migration

12. The windows that leak the most air tend to be those where operable pieces ________ .
    a. Are made of solid material
    b. Do not rest against the frame when closed
    c. Slide in a track unless locked
    d. Do not come together in a tongue and joint

13. **Windows collecting** solar energy should face within ____ degrees of south.
    a. 28
    b. 30
    c. 35
    d. 5

14. __________ is a systematic way to promote water conservation, primarily in arid regions.
    a. Parsimony
    b. Xeriscaping
    c. Slow-drip irrigation
    d. Selective landscaping

15. A good rule of thumb is to provide enough glazing to equal ____% of the conditioned square footage.
    a. 12
    b. 20
    c. 7
    d. 5

16. Ground below the frost line is almost always a constant temperature of ______ degrees Fahrenheit.
    a. 40-46
    b. 4-6
    c. 33
    d. 15-40

17. _____________ can be elevated in earth-sheltered houses.
    a. Summer humidity levels
    b. Plumbing lines
    c. Solar heat gain
    d. Rodent populations

18. ___ is the anachronym used to describe an air system component typically involving two primary aspects, mechanical ventilation and heat recovery.
    a. HVAC
    b. MVHR
    c. HEPA
    d. VFAE

DESIGNING FOR ENERGY EFFICIENCY
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COURSE

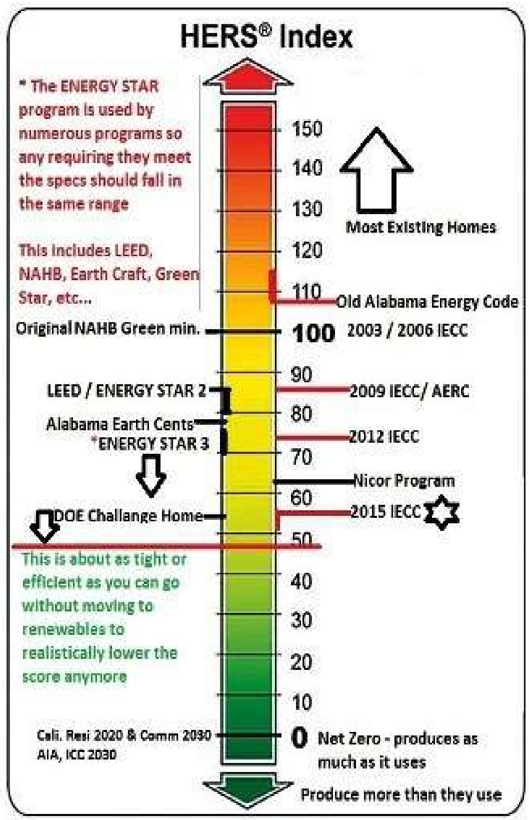
Introduction – Available Cards in the Deck

Decisions to improve energy efficiency stem from multiple sources. Enforceable energy codes dictate some choices in new construction. Budget concerns will determine the difference between the best life-cycle cost choices and what can actually be afforded. Home energy audits can identify existing points of energy loss and areas of potential improvement. Becoming aware of very old and emerging technologies that result in energy efficiency is enough to get the wheels turning for some. A desire to be part of improving the environment is motivation for many. Whatever the reason, the decision to help conserve our natural resources is a good investment in the future.

Some Motivation Factors

<u>Energy Codes</u>

In the U.S., buildings account for 40% of all energy used and 70% of electricity used. Energy codes being adopted and implemented are slowly changing building practices, resulting in reduced environmental impact, reduced energy bills and increased resale values for buildings. Advances in energy products like cool roofs and new lamp technologies make much of this possible.

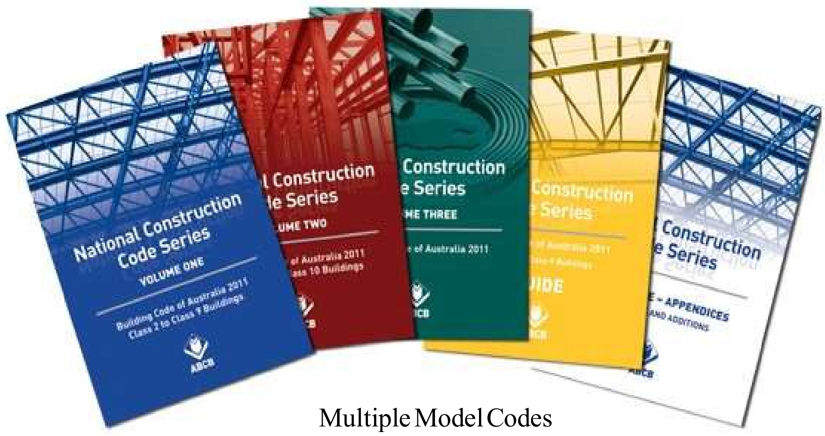


Energy Code Comparison

These new model energy codes are minimum energy efficiency requirements for new buildings, additions and renovations. When adopted, they carry the same force of law as other building codes. The two model codes which are most in use are the International Energy Conservation Code (IECC), for all buildings and ANSI/ASHRAE/IES Standard 90.1 (ASHRAE Standard 90.1), for only commercial buildings.

The IECC includes ASHRAE Standard 90.1 by reference, sometimes letting it supersede IECC provisions. Once energy codes are adopted, expect state and local governments to perform inspections to ensure compliance.

Both the IECC and ASHRAE Standard 90.1 are continually updated in public forums. This transparency has resulted in widespread acceptance of these standards. Multiple market segments help maintain their relevance. These include: designers like architects, lighting designers, mechanical and electrical engineers, code enforcement personnel, legislators, builders, building owners, manufacturers, utilities, advocacy groups, the academic community and federal agencies like the Department of Energy (DOE).



Multiple Model Codes

The IECC is authored by the International Code Council through a process of consensus. ICC codes are updated every three years. Anyone who has established eligibility can submit proposed changes. They can participate in public hearings and comment processes, from which changes to the next code edition will be generated. Final votes on all proposed changes are made by members of government and honorary members. The revised version is then presented as an updated model code, available for state and local jurisdictions to easily adopt, implement and enforce.

ASHRAE Standard 90.1 also uses a consensus process, meeting ANSI requirements. Anyone may participate by submitting a maintenance proposal, addressing committees during their deliberations or submitting comments on proposed changes during a public review. Proposed changes are voted on by a committee tasked with updating and maintaining the standard. Revisions occur on an ongoing basis, but publication of updated versions occurs every three years.

Before adopting either model energy standard, state and local jurisdictions may make changes reflecting regional practices or their own specific energy-efficiency goals.

<u>Budget Concerns</u>

Energy efficiency is the most cost-effective strategy to reduce utility bills. Passive ways to do so are the most effective. Passive solar design uses features of the site, the climate and the building design to minimize the use of energy. Use reduction is the primary goal, regardless of the source of the energy. For example, given the minor heating demands of modern homes, south facing glass should be kept down in size and properly shaded to reduce solar gain and resulting cooling demands.

Caring for the Environment

It is possible to use eco-friendly materials in new constructions. Determining whether to use a particular material may require research to determine how friendly available options really are to the environment. Some are considered eco-friendly because they reuse other materials, like recycled cork panels and flooring, newspaper wood, bark siding and recycled steel, that are otherwise destined for landfills. Alternatives to using concrete for walls include straw bales, grasscrete, bamboo and hempcrete. Take time to find out what materials your builder is willing to use and ask if they will consider alternatives that are of interest. If enough consumers request use of certain materials, more builders will use them.

Review Questions

1. In the United States, buildings account for ________________% of all energy used
   a. 25
   b. 40
   c. 92
   d. 16
2. Which of the following is one of the model energy codes commonly adopted by jurisdictions?
   a. International Energy Conservation Code (IECC)
   b. SMACMA
   c. OSHA Rule 19
   d. Southern Building Code Council on Energy

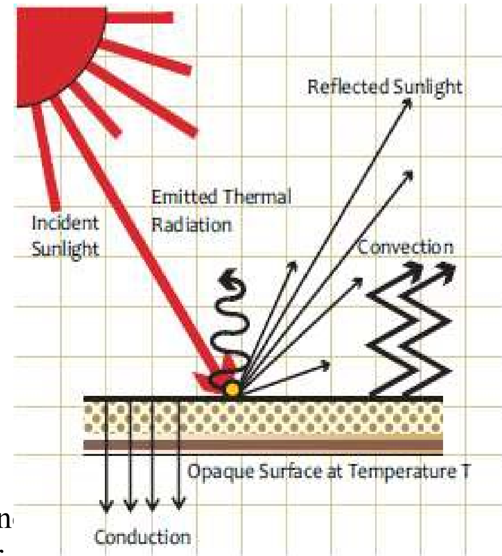
GENERAL BUILDING ENERGY CONCERNS

This section will examine tried and true, mostly passive, ways to reduce energy use by means of how building envelopes are constructed. It focuses on how to make buildings more airtight and energy tight, and how to deal with leakage and loss points of conditioned air between internal and external environments.

Roof and Wall Considerations

Cool Roofs

Cool roofs are best described as roofs made of reflective materials, designed to reflect sunlight and absorb less of its heat. This keeps buildings below them cooler during hot weather. These roofs use highly reflective paint, a reflective surface ply or highly reflective tiles or shingles to repel light. Climate will be a large factor in deciding whether to install one. Standard, dark roofs can reach 150° Fahrenheit in the summer. Changing the surface to make them a cool roof can drop surface temperature by up to 50°, reducing the air conditioning load inside.



Roofs Can Be Cool

Cool roofs can not only reduce air conditioning loads, but improve comfort levels in rooms like garages that are not served by air conditioning. They can also extend roofing material life before replacement.

Cool roofs are best used in hot climates. In cold climates, they can actually increase energy costs by reducing the solar gain through a roof that would have been beneficial for heating.

Cool roofs can benefit a microclimate, when widely used in on local air temperatures in an urban island, lowering peak power reducing demand on power plants supplying the area. This results in fewe on dioxide, sulfur dioxide, nitrous oxides and mercury.

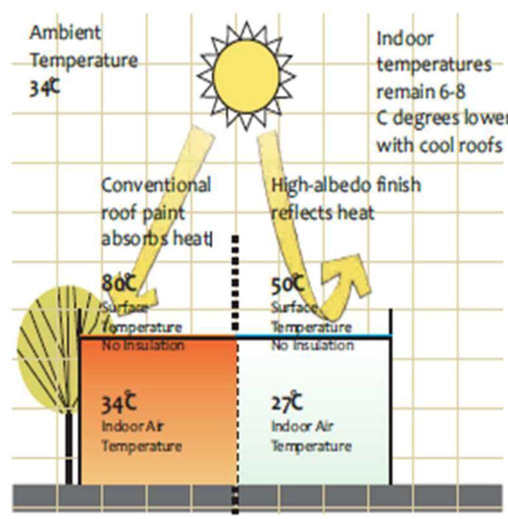
In warm, moist locations, cool roofs where moisture can condense are more susceptible to algae or mold growth. Some coatings include special chemicals inhibiting surface mold or algae growth for a few years. Care must also be taken in design and construction to ensure moisture does not accumulate in the assembly below the roof surface.

<u>Making Roof Types Cool</u>

Many roof systems are available, but the surface material exposed to the sun is what determines if a roof is cool. This means, with the appropriate surface or coating, almost any roof can be made to be cool.

Cool roof coatings are white or have special reflective pigments. Some are like very thick paints, protecting roofs from ultra-violet light and chemical damage, while also offering moisture protection. Products are available for most types and slopes of roofs.

- Systems for Low Sloped Roofs



Single-ply membranes are pre-fabricated sheets, held down to a substrate with mechanical fasteners, chemical adhesives or the weight of ballast like stones or pavers. If not already light in color, they can be made cool by resurfacing them with a reflective coating.

Built-up roofs consist of a base sheet, fabric reinforcement layers and a protective surface, usually bound together with asphaltic compounds. Sometimes they are also protected by a gravel ballast.

The usually dark surface layer can be made cool in several ways. Reflective marble chips can be substituted for dark colored ballast. A coat of reflective mineral granules can be applied on site, or if new, in a factory. A cool coating can also be applied directly on top of the last asphaltic coat.

Modified bitumen sheet membranes are layers of plastic or rubber with reinforcing fabrics, surfaced with mineral granules or a smooth finish. These are sometimes used to resurface built-up roofs. Many sheet membranes can be obtained from manufacturers with a cool coating.

Spray polyurethane foam coverings mix two liquid chemicals together to react and expand into one solid piece, adhered to and covering a roof. These are very prone to mechanical, moisture and UV damage, and must have a protective coating. Those protective coatings are usually already reflective and cool.

- Systems for Steep Sloped Roofs

Shingle roofs are protected by overlapping pieces of fiberglass asphalt, wood, polymers or metal. The best option is to purchase cool asphalt shingles, surfaced with special coated granules that reflect sunlight. Coating existing asphalt shingles in place is neither recommended, nor approved by manufacturers. Other shingle types can also have cool coatings applied in the factory.

Tile roofs come in clay, slate or concrete pieces. They can be coated to provide custom colors and surface properties. Some are already reflective enough to be cool and others can be transformed with reflecting coatings into cool roof tiles.

- Systems for Low and Steep Sloped Roofs

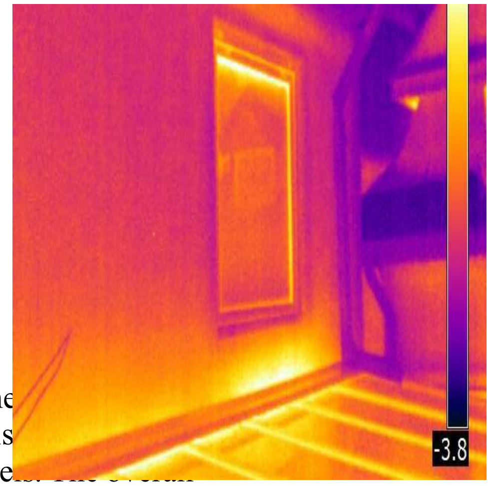
Metal roofs come with natural metal finishes, oven-baked paint finishes or granular coatings. Unpainted metals are good solar reflectors but perform poorly thermally, so they don't qualify as cool roofs. Paint can increase solar reflectance and thermal emittance, allowing metal roofing to meet cool roof requirements. Cool reflective coatings can also be applied to metal roofing.

- Green Roofs

These are not actually reflective, though they are considered to be cool roofs. Green roofs are used on flat or shallow-pit roofs, and range from basic plant cover to a full garden. These are used to manage storm water and create enjoyable open spaces on rooftops. They also insulate, lower A/C loads and reduce the urban heat island effect. They are expensive to put in place and must be carefully planned to ensure durability and drainage.

Green Roof

Avoiding Thermal Bridging



Thermal Bridges In Infrared

Thermal bridging is a major cause of heat loss in buildings. It occurs when heat moves through an object in an assembly that is more conductive than materials around it. The energy flows through the path of least resistance.

The R-value rating of a wall or roof assembly does not mean the resistance level. Thermal bridges from framing materials and dis in holes in the thermal envelope that insulate at much lower leve performance of the whole assembly lowers when these areas are avera

It is not hard to find thermal bridges. Run a hand along a wall on a cold day and they will find you. These points of leakage not only impact energy use, but also quality of life. We tend to avoid really cold or hot walls and spaces, so bridges can make parts of a home unusable in certain times of the year.

Wood, metal and concrete spanning from face to face of an assembly conduct far more heat than insulation around them. But we usually have little choice other than to use some heat conducting material for framing. Studs made of rigid foam won't carry snow loads.

That said, there are existing methods to move toward bridge-free construction, and new and promising framing materials are being developed and tested.

- Some wood used in exterior framing, all of which acts as bridges, can safely be eliminated. Examples include headers in non-load bearing walls, unnecessary cripples and redundant corner studs.
- The use of metal fasteners of any kind that span from face-to-face should be avoided.
- If basement walls can be built of wood, that concrete thermal bridge can be eliminated.
- Leave batt insulation out of metal stud cavities. Instead, give up a couple inches of inside space and install a thick, seamless layer of board insulation over the face of the studs.

Using Reflective Surfaces

Radiation plays a large part in heat transfer in both heating and cooling scenarios, even with typical temperatures involved and no sunlight in play. It is a critical consideration for surfaces in sunlight or where large temperature differences exist between surface and surroundings, like with radiant heating, refrigeration, hot industrial surfaces and ice rinks. Reflective (low-emissivity) products are useful in most of these, but in certain applications, a high-emissivity (non-reflective) surface performs better. A basic understanding of reflectivity and emissivity helps in evaluating the use of reflective products.

Reflectivity and emissivity are surface properties affecting radiation heat transfer, or how a reflective product performs. Radiation arrives at a surface and the percentage of radiation reflected back from it is called its reflectivity. Emissivity is a surface's tendency to emit radiation to other bodies. High emissivity means a surface will readily absorb radiation striking it, depending on the wavelength of radiation striking it, and emit it later. For example, a surface may reflect most of the wavelength of light hitting it, but not much ultraviolet or infrared radiation coming at it. Knowing these properties are interrelated can be helpful in understanding them. Low emissivity (Low-E) materials will save energy, should you want to reduce heat transfer.

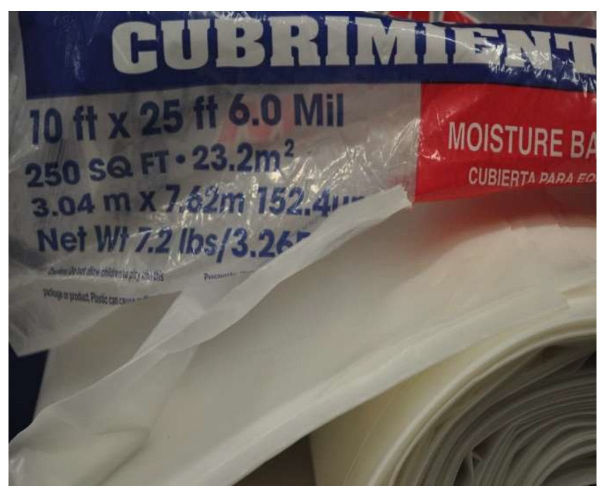
Places where it's a good idea to reduce heat transfer include:

- Between interior objects (including people) and between interior and exterior surfaces of exterior wall assemblies, when interior air is being conditioned differently than the outdoors.
- Between exterior surfaces of a building and outside air, on both hot and cold days. Low-E glazing saves energy by reducing heat transfer with its surroundings.
- A low-emissivity ceiling in an ice rink, like one painted with a reflective aluminum paint. This may result in very good energy savings, by reducing radiation heat transfer between the warmer ceiling and the surface of the ice.
- A surface used as a radiant heater, like a radiator or a radiant floor, is a place where high emissivity is beneficial to enhance heat transfer from the radiator.
- Low-E surfaces on windows or walls are bad in rooms with high internal gains, like computer server areas or telephone rooms. In these, you usually want to get rid of heat at all times. The only time low-E surfaces help you in server rooms is when it gets so cold outside that you have to begin heating the space.

<u>Use of Vapor Barriers and Their Location</u>

A vapor barrier is a material used to retard water movement into and through walls. It is applied independently over the warm side of exterior walls or as an integral part of another facing material.

Vapor barriers are also referred to as vapor diffusion retarders. These interfere with the movement of airborne vapor inside a wall cavity. They should be installed on the side of the cavity consistently exposed to the highest vapor pressure. In very hold or very cold climates, that distinction is easily made as being the warm side. In more temperate climates, that decision on location becomes more difficult.



Vapor Barrier

In any event, care must be taken that only one vapor barrier, or material that can act as one, be placed in a wall or roof system. Otherwise, moisture may become trapped between multiple barriers. Plastic sheeting, Kraft paper, foam plastic sheeting/insulation, solid vinyl wall covering and asphalt-impregnated building paper are all building materials known to act as vapor barriers. Not as well-known are unfaced insulation, building paper without asphalt compounds, plywood sheathing and building wraps like Tyvek. These all retard vapor flow to some degree.

Vapor barriers must be correctly installed to be effective. Insulation in cavities should fill all voids prior to installation of a vapor barrier. The vapor diffusion retarder must then be properly sealed at its seams, per its manufacturer's recommendations. Care must be taken to properly seal window and door openings. When fastening them to the building, they must be secure, but with no fasteners allowed to tear through a barrier, leaving holes through which moisture can migrate.

Vapor barriers in roof and wall systems should be on the warm inside of the exterior insulation in cold climates (some define this as 8,000 heating degree days or more). Vapor barriers in roof and wall systems should be on the exterior side of the exterior insulation in warm climates, where the greater demand is for cooling. A surface material impermeable to vapor is a good idea in these climates.

If heating and cooling loads for a region are roughly balanced, some choose to omit a vapor barrier altogether. They focus instead on paying more attention to balancing air pressure inside and out, as well as controlling infiltration. As a general rule, it's better not to have a vapor barrier than to install one in the wrong location. A good (bad) example of this would be placing vinyl wallcovering on the inside of outside walls in warm climates.

Roof to Ceiling Considerations

Venting Roofs to Control Energy Loss

- Guaranteeing Airflow

Roof ventilation works due to the fact that warm air rises. In the summer, solar gain heats air inside the attic and in the winter, heat escaping from your home does the same. In either case, venting needs to occur as cool air enters attics near eaves and ceilings and rises to exit near the peak. Ideally, equal amounts of air should enter low and exit high. The ultimate goal is for temperature and humidity levels in the attic to be allowed to equalize with those same conditions outdoors.

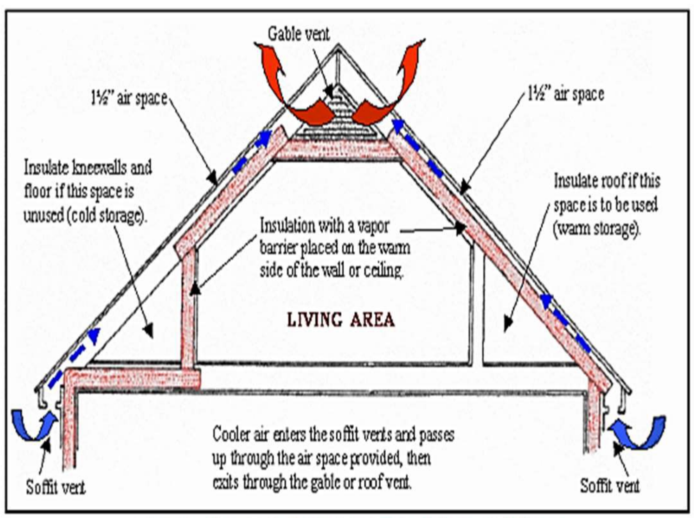


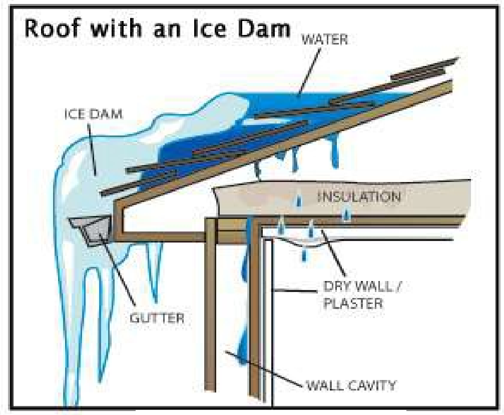
Figure 1 - Proper method of insulating and ventilating a typical 1½ story

Airflow

Soffit vents work very well for intake air, which can then exit passively through ridge vents or hood vents. Turbine vents use exterior wind energy to create vacuums that in turn, pull air out of the attic. Electric-powered vents are the ultimate air movers, but are unnecessary in most situations. Gable vents allow air in and out, but don't help air flow evenly throughout the attic.

- Poor Ventilation Equals Damage

Moisture damage is one result of poor ventilation. Warm, humid air tends to migrate upwards into an attic through ceilings. Condensation then forms on roof framing and sheathing, which can support rot and cause serious structural damage. The condensed water can also drip back down, on and through ceilings, causing mold and other issues.



Badly Vented Roof

Ice dams also result from bad ventilation. If an attic gets warm enough, escaping heat will melt snow on the roof, while the eaves still remain cold. When melting water from above flows down to the eaves, it freezes there again, forming a dam. Melting water still coming down the roof then encounters that dam and may back up under the shingles to cause damage.

- Ventilation Code Requirements

Building codes usually require 1 SF of vent area for each 300 SF of attic. This proportion assumes half the supplied vent area is high on the roof for outgoing air, and half is low near the eaves for incoming air. Otherwise, the required vent area must be doubled to 1 SF of vent area for each 150 SF of attic. These suggested numbers are minimums. There cannot be too much ventilation.

Insulation Systems

An obvious part of a well-insulated building shell will be the insulation placed therein. There are many products, available in many forms, to do just that. The following information may help in choosing which insulation product to include in an assembly.

Available Options for Insulation

Type	Material	Where Applicable	Installation Methods	Advantages
Blanket: batts and rolls	Fiberglass Mineral (rock or slag) wool Plastic fibers Natural fibers	Unfinished walls, foundation walls, floors and ceilings	Fitted between studs, joists and beams, sometimes stapled in place through flanges on facings.	Do-it-yourself. Widths available for standard stud and joist spaces, that are relatively free of obstructions. Relatively inexpensive.
Concrete block insulation and insulating concrete blocks	Foam board, placed outside of walls (in new construction) or inside walls (in existing homes). Sometimes, foam beads or air are included in a concrete block mix to in crease R-values	Unfinished foundation walls in new construction or major renovations, or inside walls (when using insulated concrete blocks)	Require specialized skills to properly install. Insulating concrete blocks are sometimes dry-stacked mortar and surface bonded	Insulating cores increases wall R-value. Insulating outside of block walls puts their thermal mass inside conditioned pace, to moderate indoor temperatures. Aerated concrete and autoclaved cellular concrete blocks have 10 times the insulating value of poured concrete walls.

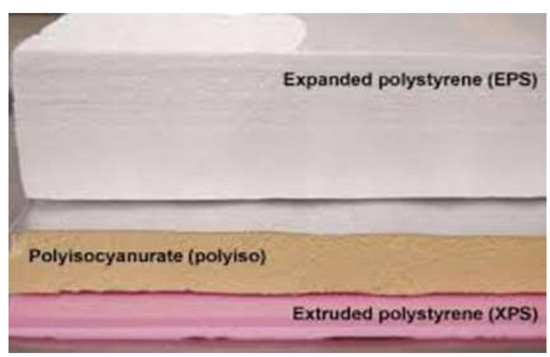
Foam board or rigid foam insulation	Polystyrene Polyisocyanurate Polyurethane	Unfinished walls, including foundation walls Floors and ceilings Unvented low-slope roofs	Interior applications must be covered with 1/2-inch gypsum or other code approved fire barriers. Exterior applications must be covered to be weatherproof	High insulating value for relatively little thickness. Can block thermal bridges if installed continuously over framing.
Insulating concrete forms (ICFs)	Foam boards or hollow foam blocks with internal supports for reinforcing, used as forms when placing concrete	Unfinished walls, including foundation walls, for new construction	Installed and poured full of concrete to become part of the building structure	Insulation is literally built into the home's concrete walls, creating high thermal resistance
Loose-fill and blown-in	Cellulose Fiberglass Mineral (rock or slag) wool	Enclosed existing walls and other hard-to-reach places, cavities in new walls Unfinished attic floors	Blown into place using special equipment, sometimes poured in place inside cavities	Can add insulation to existing finished areas, irregularly shaped voids and around obstructions.
Reflective insulation products	Foil-faced kraft paper, plastic film, polyethylene bubbles, or cardboard	Unfinished walls, ceilings and floors	Foils, films or papers fitted between wood framing members or over their face	Easy to use in standard spaced framing. Bubble-form is used if framing is across a space or other obstructions are present. Effective at preventing downward heat flow depending on spacing.

Rigid fibrous or fiber insulation	Fiberglass Mineral (rock or slag) wool	Forms air ducts in unconditioned spaces and elsewhere needing insulation to withstand high temperatures	HVAC contractors fabricate this insulation into ducts, either in shops or at job sites	Can withstand high temperatures.
Sprayed foam and foamed-in-place	Cementitious Phenolic Polyisocyanurate Polyurethane	In existing wall cavities, new open wall cavities, unfinished attic floors	Applied using small spray containers or in larger amounts as a pressure sprayed (foamed-in-place) product	Good for adding insulation to existing finished areas, irregularly shaped areas and around obstructions.
Structural insulated panels (SIPs)	Foam board Liquid foam Insulation core Straw core insulation	Unfinished walls, ceilings, floors and roofs in new construction	Construction workers fit SIPs together to form walls and roof of a house	SIP-built houses result in superior and uniform insulation, compared to more traditional methods and also take less time to build.

Besides the overview above, it is beneficial to take a closer look at these various options for insulation products.

- Blanket - Batt and Roll Insulation

Blanket insulation is the most common insulation, widely available in batt or roll form. It consists of flexible fibers. These are often made of fiberglass, but can also be from mineral wool (rock and slag), plastic fibers or natural fibers, like cotton and wool. These products are available in widths made to fit standard spacings of stud, truss or rafter and floor framing. 2 x 4 walls can hold R-13 or R-15 batts; 2 x 6 walls accommodate R-19 or R-21 products.



A Few Types of Insulation

Continuous rolls are hand-cut and trimmed to fit empty cavities and available with or without facing materials. These facing materials, like Kraft paper, foil-Kraft paper or vinyl, can double as vapor or air barriers. Batts with special flame-resistant facings are used on basement walls and other places where the product will be exposed. Facings also help with installation by offering flanges through which fasteners may be driven into framing members.

The table below offers an overview of standard and high-performance (medium-density and high-density) fiberglass blankets and batts. It is for general comparisons only. Actual thicknesses, R-values and cost should be verified with a local building supplier.

Thickness in inches	R-Value	Est cost in cents/sf
3 1/2	11	12-16
3 5/8	13	15-20
3 1/2 (high density)	15	34-40
6 to 6 1/4	19	27-34
5 1/4 (high density)	21	33-39
8 to 8 ½	25	37-45
8 (high density)	30	45-49
9 1/2 (standard)	30	39-43
12	38	55-60

- Concrete Block Insulation

Concrete block walls are sometimes insulated, or built using insulating concrete blocks. Block walls in existing homes can be insulated from the inside, in some cases.

There are several ways to insulate concrete blocks. If the cores aren't already filled for structural reasons, empty ones can be filled with insulation to raise the wall's average R-value. Be warned though: block core filling with any type of insulation offers little in savings. This is because the solid parts of the block units, like webs and mortar joints, will still act as thermal bridges to conduct heat straight through.

It is more effective to place sheet insulation over block walls, either on the exterior or interior side. Exterior placement contains the thermal mass of the wall inside the conditioned space, helping to moderate indoor temperatures.

Some manufacturers incorporate polystyrene beads into materials used to make blocks, while other masonry units are formed to accommodate rigid foam inserts.

Autoclaved aerated concrete (AAC) blocks, and autoclaved cellular concrete (ACC) blocks are now both in market use. Precast ACC blocks use fly ash instead of high-silica sand, distinguishing them from AAC blocks. Developed in Europe, AAC blocks contain about 80% air and have 10 times the insulating value of poured concrete walls. These blocks are large, light and easily modified by ordinary tools. But AAC blocks will also readily absorb water, so they must be protected from moisture.

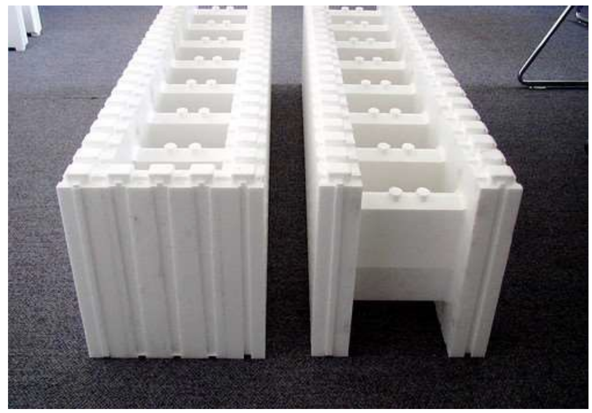
Hollow-core masonry units made of concrete and wood chips are also available. These blocks tend to be stacked without using mortar, then cores are filled with concrete and structural steel to hold them in place. Their wood component is also susceptible to moisture and insects.

- Foam Board or Rigid Foam Panels

Rigid foam insulation panels can be used almost anyplace, from the roof down to the foundation. They are placed as exterior wall sheathing, interior basement wall sheathing and in special applications like attic hatches. They can offer R-values up to twice that of other insulating materials of the same thickness. Being continuous, they interrupt thermal bridges through structural elements like studs. Foam boards are commonly made from polystyrene, polyisocyanurate and polyurethane.

- Insulating Concrete Forms

Insulating concrete forms are interlocking forms made of foam insulation, into which reinforcing is placed and concrete is then poured. The forms remain in place as part of the wall assembly. This results in exterior walls having a typical R-value of around R-20.



Insulating Concrete Forms

The forms are available as interconnecting foam boards or interlocking, hollow-core foam insulation blocks, to be locked together with plastic ties. Horizontal steel rebar reinforcing is usually added inside the block forms, along with vertical bars inside the cores, before concrete is poured.

The foam webs of which the forms are made can provide easy access for insects to bore through and groundwater to migrate. So some manufacturers make ICF forms treated with insecticide, and promote ways to thoroughly waterproof the resulting walls.

- Loose-Fill and Blown-in Insulation

Loose-fill insulation is small particles of fiber, foam or other materials that fill in and conform to any cavity, without disturbing structure or finishes. This makes it very useful for retrofits and locations where it is difficult to place other types of insulation.

Loose-fill insulation is commonly cellulose, fiberglass or mineral wool. All are made from recycled waste materials: cellulose from recycled newsprint, fiberglass from recycled glass and mineral wool from post-industrial waste. The table below compares these three materials.

Recommended Specifications by Loose-Fill Insulation Material			
	Cellulose	Fiberglass	Rock Wool
Density in lb/ft3 (kg/m3)	1.5–2.0 (24–36)	0.5–1.0 (10–14)	1.7 (27)
Weight at R-38 in lb/ft2 (kg/m2)	1.25–2.0 (6–10)	0.5–1.2 (3–6)	1.6–1.8 (8–9)

For Attic Applications			
	Cellulose	Fiberglass	Rock Wool
OK for 1/2" drywall, 24" on center?	No	Yes	No
OK for 1/2" drywall, 16" on center?	Yes	Yes	Yes
OK for 5/8" drywall, 24" on center?	Yes	Yes	Yes

Less common loose-fill insulation materials include polystyrene beads, vermiculite and perlite.

Blowing In Insulation

Loose-fill insulation can be used in either enclosed cavities like walls, or unenclosed spaces like joist spaces in attics. Cellulose, fiberglass and rock wool are typically blown in to achieve specified density and R-values. Polystyrene beads, vermiculite and perlite are typically poured.

The Federal Trade Commission issued a "Trade Regulation Rule Concerning the Labeling and Advertising of Home Insulation" (16 CFR Part 460). It contains the R-value Rule to prohibit unfair or deceptive practices. This Rule requires those who sell home insulation to disclose each product's R-value and information like thickness and coverage area per package, on package labels and fact sheets. R-value ratings of the product in place can vary, even between products of the same type and form.

For loose-fill insulation, each manufacturer determines R-values at settled densities and creates charts showing minimum settled thickness, minimum weight per square foot and coverage area per bag for various total R-values. This is because, as the installed thickness of loose-fill insulation increases, its density also increases due to compression under its own weight. So the R-value of the placed product does not change proportionately to its thickness. Coverage charts specify bags of insulation needed per SF of coverage area; coverage area for one bag of insulation; minimum weight per SF of installed insulation and the needed initial and settled thickness of that insulation, to achieve a particular R-value.

- Radiant Barriers and Reflective Insulation Systems

Unlike insulation systems resisting conductive and sometimes convective heat flow, radiant barriers on reflective insulation act to reflect radiant heat. These are usually installed in attics to reduce summer heat gain and lower cooling costs. Reflective insulation incorporates radiant barriers, like very reflective foils, into insulation systems with a variety of backings. These can include Kraft paper, plastic film, polyethylene bubbles or cardboard, as well as other insulation materials.

Radiant heat travels away from surfaces and heats anything solid that absorbs energy. It is mainly the sun's radiant energy that makes a roof hot. Most of that heat travels by conduction through the roofing assembly and into the bottom surface of the assembly. The heated bottom assembly surface then radiates heat energy down to cooler attic surfaces like air ducts and attic floors. Radiant barriers reduce the heat transfer from below the roof to other surfaces in the attic. They must be installed so the reflective surface faces an air space.

Radiant barriers are effective in hot climates, when cooling ducts are located in the attic. Radiant barriers in warm, sunny climates can lower cooling costs 5-10%. The reduction may be enough to justify a smaller A/C system. In cool climates, it's usually more cost-effective to just install more insulation.

- Rigid Fiber Board Insulation

Rigid fiber or fiber board insulation is either fiberglass or mineral wool panels, used mainly to form insulated ducts through which to distribute conditioned air. It is also useful when insulation must withstand high temperatures. Panels are readily available in thicknesses from 1-2.5 inches.

Air ducts of this material are fabricated by HVAC contractors. When placing it over the outside faces of metal ducts, they impale it on weld pins and secure it with speed clips or washers. They can also use special weld pins with integral washers. Unfaced boards can be finished with insulating cement, canvas or weatherproof mastic. Faced boards can be installed, with joints between boards being sealed with pressure-sensitive tape or glass fabric and mastic.

- Sprayed-Foam and Foamed-in-Place Insulation

Liquid foam insulation can be sprayed, foamed-in-place, injected or poured. It can be blown into walls, on attic surfaces or under floors to insulate and reduce air infiltration. Many installations yield a higher R-value than batt insulation of the same thickness. The expanding foam can fill even the smallest cavities, creating an effective air seal. Small pressurized cans of the material are used to seal holes and cracks at window and door frames, as well as electrical and plumbing penetrations.

Today, most of these materials use foaming agents without chlorofluorocarbons (CFCs) or hydrochlorofluorocarbons(HCFCs).

Sprayed Foam Insulation

There are two types of foam insulation, closed-cell and open-cell, both made from polyurethane. In closed-cell foam, high-density cells are filled with a gas to help the foam expand to fill spaces around it. Open-cell foam is not as dense and is more filled with air, giving the insulation a spongy texture.

The type of foam insulation chosen should depend on its use and your budget. Closed-cell foam has a greater R-value and better resistance to moisture and air leakage. It is also denser and more expensive to install. Open-cell foam is lighter and less expensive, but if used below ground level, could absorb water.

Common foam insulation materials include cementitious, phenolic, polyisocyanurate (polyiso) and polyurethane. Less well known are Icynene foam and Tripolymer foam. Icynene can be either sprayed or injected, making it very versatile. It also resists both air and water intrusion. Tripolymer foam, a water-soluble foam, is injected into wall cavities and offers excellent resistance to fire and air intrusion.

- Structural Insulated Panels

Structural insulated panels (SIPs) are prefabricated insulated structural panels, used as building walls, ceilings, floors and roofs. Offering superior and uniform insulation, compared to traditional construction, they offer energy savings of 12-14%. When installed properly, SIPs are very airtight, making a building quieter and more comfortable.

Structured Insulated Panels

SIPs have both high R- values and high strength- to-weight ratios. A SIP often consists of 4-8” of foam board insulation, laminated between two sheets. These can be of OSB or other sheathing materials. The interior and exterior face materials can be customized to meet specific requirements. The composite materials of each panel are glued, then pressed or placed in a vacuum to bond them together. Panels can be factory produced in various sizes or dimensions, up to units that are 8’ x 24’, requiring a crane to set them in place.

Manufacturing quality is critical for high-performing SIPs. They must be properly glued, pressed and cured, so they don’t delaminate. They must also have smooth surfaces and edges, to be able to connect on a job site without gaps. SIPs are often also available with different insulating materials, but are filled most often with polystyrene or polyisocyanurate foam.

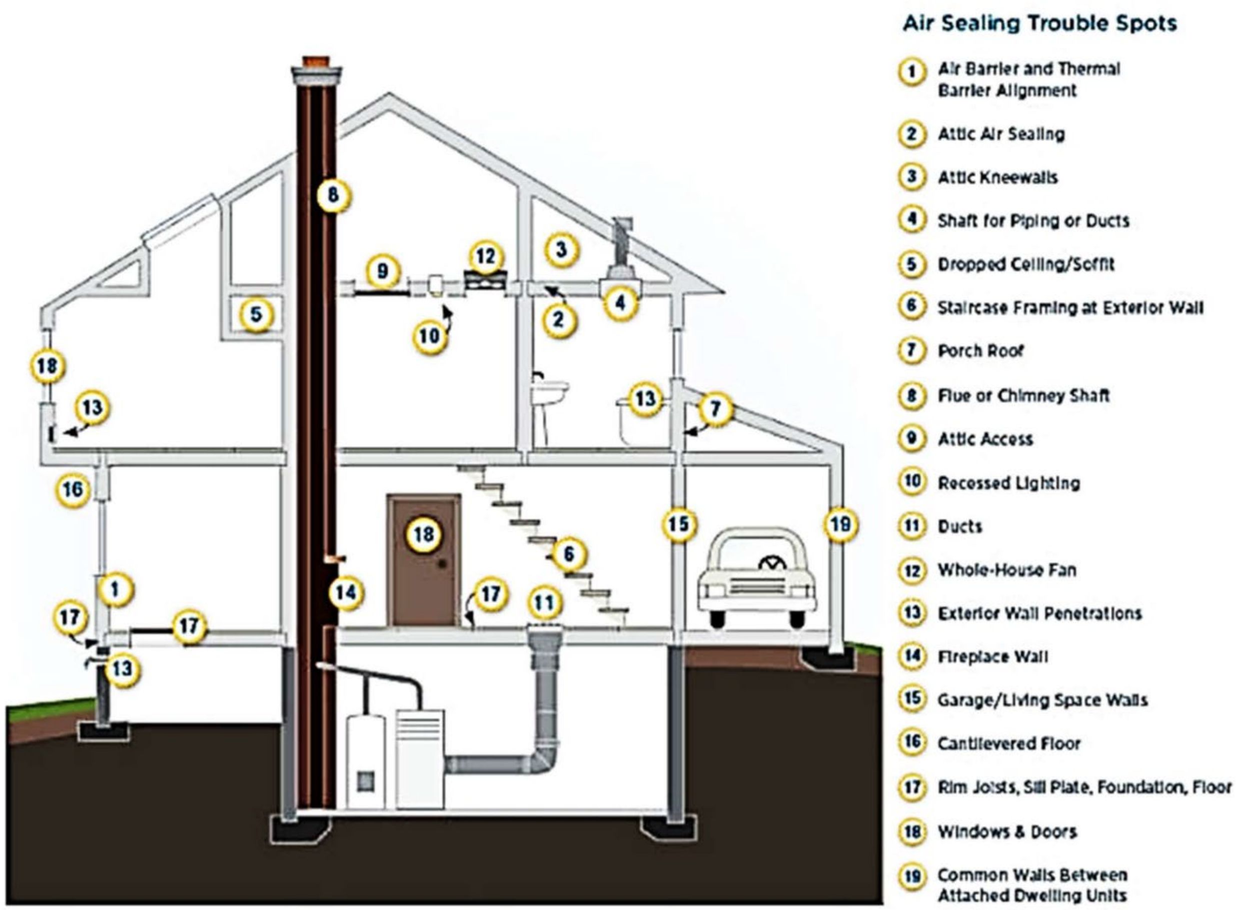
Review Questions

3. Materials used to retard water movement into and through walls are called ________________.
   a. Waterproofing
   b. Exterior envelope guards
   c. Vapor barriers
   d. Rigid insulation boards

4. ______________________ is a material used to form ductwork in uninsulated spaces.
   a. Foam core plastic sheets
   b. Rigid fiber insulation
   c. Extruded plastic tubing
   d. Small SIP products

Air Infiltration

Despite care taken in the other aspects of creating a building envelope, there will always be small or large gaps through which air can either infiltrate or exfiltrate. Care should be taken to find those gaps and manage the air flow through them. The illustration below shows known points of leakage.



Common Trouble Spots – US DOE

<u>Common Leakage Points – Holes through the Envelope</u>

- Air Sealing Your Home

Reducing the amount of air infiltration is a cost-effective way to cut utility costs, improve durability and increase indoor comfort. Caulking and weatherstripping are simple, effective sealing methods offering quick returns on investment. Caulk is used in cracks and openings between stationary house components, like around door and window frames. Weatherstripping seals between components that move, like doors and operable windows.

Making New Homes Airtight

Controlling air movement in and out is necessary for energy efficiency and controlling moisture. Climate-specific instructions on how to do this can be found at https://www.energy.gov/eere/buildings/building-america-climate-specific-guidance. But there are also general techniques and materials used to seal against air infiltration.

- Air Barriers

Air barriers block movement through building cavities, preventing leakage that can account for 30% or more of a home's energy costs. Although they stop air movement, such barriers may not also be vapor barriers. The proper location of either air or vapor barriers in building assemblies is dependent on climate and should be researched if there is any question.

Many structural and finish components act as air barriers. Sealing and caulking holes and seams between sheet goods like drywall, sheathing and subflooring will reduce air leakage. In addition, densely-packed insulation in wall cavities can reduce airflow and heat loss.

- House Wrap

House wraps are common air barriers, wrapped around a building exterior during construction. These are often fibrous spun polyolefin plastic, matted into sheets and rolled for shipping. House wraps may have other materials in them to help resist tearing. Sealing wrap joints with tape improves their performance up to 20%. All wrap manufacturers offer special tape for this purpose.

- Airtight Drywall Approach

An airtight drywall approach (ADA) or a simple caulk and seal (SCS) approach, can also create a continuous air barrier inside a house. Either will significantly reduce air leaks and improve energy efficiency.


Maybe a Bit Too Airtight

Using ADA, seams, joints and openings in the interior drywall face are thoroughly sealed during construction. SCS is less disruptive to construction, because seams and gaps are sealed after the house is dried in and drywall has been completed. SCS is less comprehensive though, and some critical points inside building cavities may be missed that will be inaccessible once the drywall is in place. Tests on ADA and SCS-detailed homes indicate similar savings. It is prudent to install a heat or energy recovery ventilator after using either method of sealing, to ensure proper ventilation with fresh air.

Passive and Active Fresh Air

If too little outdoor air enters a home, pollutants can accumulate inside and build to levels causing health and comfort problems. Unless they are built with mechanical means of ventilation, homes designed and constructed to minimize outdoor air leakage may contain higher pollutant levels than other homes. However, because some weather conditions will drastically reduce how much outdoor air enters a home, pollutants can even build up in homes that are normally considered "leaky."

Replacing Exhausted Air with Treated Air

One way to lower concentrations of indoor air pollutants is to increase how much outdoor air comes inside. Many home heating and cooling systems, including forced air heating systems, do not mechanically bring fresh air in. Opening windows and doors, operating window or attic fans or running a window air conditioner with the vent control open, all increase the outdoor ventilation rate. Local bathroom or kitchen fans that exhaust outdoors remove contaminants directly from the room where the fan is located and create negative pressure, indirectly increasing the outdoor air ventilation rate.

Many new homes are now designed with mechanical systems bringing outdoor air inside. Some designs include energy-efficient heat recovery ventilators (also known as air-to-air heat exchangers).

Radon – Not Just Hype

In homes that are too airtight, an unseen danger called radon may slowly become apparent.

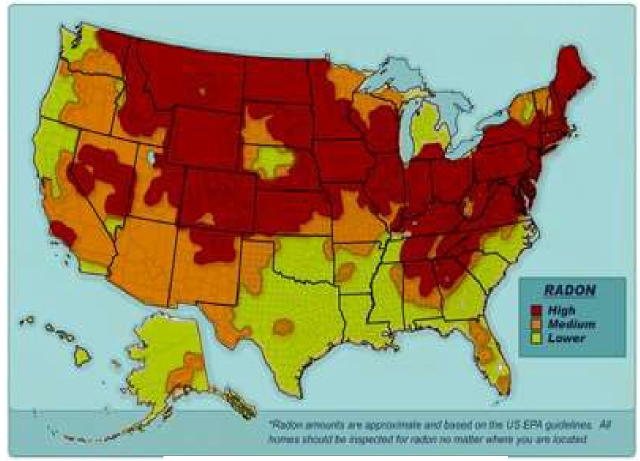
- Dealing with Radon

Any home may have a radon problem: new and old homes, well-sealed and drafty homes, and homes with or without basements.

The most common source of indoor radon is uranium in the soil or rock on which homes are built. As uranium naturally breaks down, it releases radon gas which is a colorless, odorless, radioactive gas. Radon gas infiltrates up into homes through dirt floors, cracks in concrete walls and floors, floor drains and sump pits. When radon becomes trapped in buildings with airtight envelopes, concentrations build up indoors and increasing exposure to radon becomes a concern.

Sometimes radon enters the home through well water. In a small number of homes, the building materials can give off radon, too. However, building materials rarely cause radon issues by themselves.

- Health Hazards of Radon



U.S. Map of Radon Levels

The predominant health effect associated with exposure to elevated levels of radon is lung cancer. Research suggests that swallowing water with high radon levels may also pose risks, but these are believed to be much lower than breathing air containing radon. Major health organizations (like the Centers for Disease Control and Prevention, the American Lung Association and the American Medical Association) agree with estimates that radon causes thousands of preventable lung cancer deaths each year. The Environmental Protection Agency (EPA) estimates that radon causes about 14,000 deaths per year in the United States; however, this number could range from 7,000 to 30,000 deaths per year. If you smoke and your home has high radon levels, your risk of lung cancer is especially high.

- Reducing Home Exposure to Radon

Measure levels of radon in your home. You can't see radon, but it's not hard to find out if you have a radon problem. Testing is easy and should only take a little time. There are many inexpensive, do-it-yourself radon test kits available through the mail, in hardware stores and other retail outlets. Buy a test kit that has passed EPA's testing program or is state-certified. These kits will usually display the phrase "Meets EPA Requirements." Then refer to the EPA guidelines on how to test and interpret your results.

If you prefer, or if you are buying or selling a home, you can hire a trained contractor to test it for you. EPA's voluntary National Radon Proficiency Program (RPP) evaluates testing contractors. A contractor who has met EPA's requirements carries an EPA-generated RPP identification card. EPA provides a list of companies and individual contractors on a web site, available to state radon offices. These offices can supply you a list of qualified contractors in your area. You can also contact either the National Environmental Health Association (NEHA) at http://www.neha.org or the National Radon Safety Board (NRSB) at http://www.nrsb.org for a list of proficient radon measurement and/or mitigation contractors.

You can learn more about radon through EPA's publications, A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family From Radon and Home Buyer's and Seller's Guide to Radon. This publication is also available from your state radon office.

Ways to reduce radon in your home are discussed in EPA's Consumer's Guide to Radon Reduction. There are simple solutions to radon problems in homes. Thousands of homeowners have already fixed them. If lowering high radon levels will require technical knowledge and special skills, you can find contractors trained to fix radon problems. A trained radon reduction contractor can study the problem in your home and help you pick the correct treatment method.

Positive and Negative Pressure

Inside air temperature is important to occupant comfort, but air pressure is also a critical factor. Air pressure is defined as "the pressure within a container due to the compression of atmospheric gases." If the container is a car tire, the proper amount of air pressure inflates the tire and will affect gas mileage. If the container is a building, air pressure will affect temperature, air flow through the interior, air flow from interior to exterior and subsequent energy usage.

Interior air pressure will be either negative or positive, relative to air pressure outside. That will depend on the air-tightness of the building, the wind, air being exhausted and amounts of make-up air. Some definitions may help clear up confusion.

- Negative indoor air pressure – occurs when the inside air pressure is less than pressure outside, causing air to be pulled into the building as infiltration.
- Positive indoor air pressure – occurs when inside air pressure is greater than outside pressure, causing conditioned air to flow outside as exfiltration.

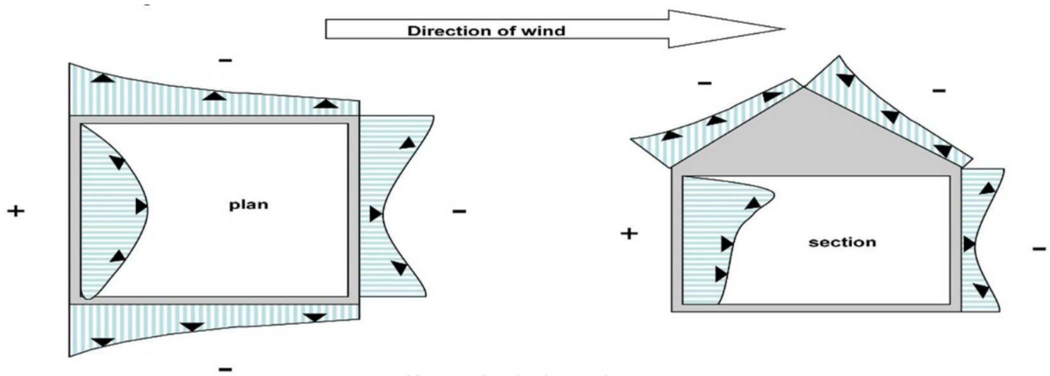
In general, it is best to have a slightly positive indoor pressure, especially during heating seasons. It is just too expensive to heat cold air pulled inside, when interior pressure is negative. Positive pressure also helps improve indoor air quality, because contaminants like smoke and dust will flow outside along with conditioned air from the interior atmosphere.

Realize that air exhausted out of a building must be made up. For every cubic foot of air exhausted, another cubic foot of air must be brought in and conditioned. If there is no make-up air system, or an HVAC system exhausts more air than is made up, the pressure inside the building will balance itself by drawing in outside air through every usable crack or opening.

There are obvious indicators of too much negative pressure in a building. People will begin complaining of cold drafts coming in openings. Exterior doors will be difficult to open and close. Odors will linger, like from diesel fuel or fork lift exhaust. High levels of carbon monoxide, radon or other dangerous gasses will also begin to accumulate.

Other indicators of too much negative pressure are not as obvious. A pilot flame will not stay lit. Visible soot or flame might roll out of the bottom of a furnace. Water heater recovery will slow down. You might experience back drafting of combustion appliances like gas water heaters, furnaces or fireplaces. Mold and mildew will begin forming, along with a musty smell of stagnant, stale air. There will be a rush of air coming in when opening an exterior door. Exhaust fans will also stop working properly.

The results of negative pressure will quickly become unsustainable. These are higher energy costs, higher maintenance costs, higher housekeeping costs and uncomfortable and unsatisfactory workplace or living conditions. The illustration below demonstrates how wind direction affects pressure inside a structure.



Effects of Wind on Air Pressure

Plugging the Holes

Larger gaps in building energy envelopes are sometimes known as windows, doors, and skylights. These fenestration elements are significant holes in energy conservation strategies. Striving to make them as energy efficient as possible will save energy, reduce heating, reduce cooling and lighting costs and improve comfort levels inside.

The Danger Inherent in Airtight

Infiltration, into and through buildings and materials, occurs for multiple reasons. Wind can literally push itself in, can be drawn up by rising hot air, sucked in by ventilation fans and pulled up to higher spaces by a chimney effect. The force called infiltration does not transport liquid water, but it does bring in humidity in the air entering and surrounding structures. In the past, buildings were far looser in construction and frequent air changes helped control moisture by moving it out as easily as it was drawn in. Our newer, tighter buildings have lower rates of infiltration, and therefore fewer natural air exchanges. Moisture that does enter via infiltration has more time to saturate materials and then be drawn into and out of those materials, increasing humidity levels inside the building. Inadequately ventilated, damp air will cause rapid deterioration of many building materials. To stop the penetration and entrapment of this humidity, joints and cracks must be sealed (making the building even more airtight) and controlled air exchanges must be introduced through operation of the HVAC system. It is a bit of a balancing act though: an airtight building that cannot breathe at all will quickly become an unhealthy building to occupy.

Solutions to air quality problems in buildings include eliminating or controlling sources of pollution, increasing ventilation or installing air cleaning devices. Often a resident will improve indoor air quality by removing a pollution source, altering an activity, unblocking an air supply vent or opening a window to temporarily increase ventilation. In other cases requiring renovations or upgrading of building components, only the building owner or manager will be in a position to remedy the problem.

Window Frame Types

Windows are becoming more energy efficient while durability, aesthetics and functionality are being improved. When selecting new windows, consider frame materials, glazing or glass features, gas fills and spacers and the window's method of operation.

- Improving a frame's thermal resistance can contribute to its energy efficiency, especially its U-factor, or rate of heat transfer. Each type of frame materials has pros and cons, but vinyl, wood, fiberglass and some composite materials provide much better thermal resistance than metal.
- Although strong, light and almost maintenance free, metal or aluminum frames conduct heat quickly, making metal a poor insulating material. To reduce heat flow, metal frames should have a thermal break between the inside and outside of a frame or sash.
- Composite window frames are of composite wood products, like particleboard and laminated strand lumber. Some have polymer plastics mixed in. Composites are very stable, have equal or better structural and thermal properties than wood, and have better resistance to moisture and decay.
- Fiberglass frames are dimensionally stable, containing air cavities filled with insulation. This results in better thermal performance than wood or uninsulated vinyl.
- Vinyl frames are made of polyvinyl chloride with stabilizers to keep ultraviolet light from breaking down their material. These frames require no painting and resist moisture. Their hollow cavities can also be filled with insulation, making them thermally superior to standard vinyl and wood frames.
- Wood window frames insulate well, but require regular maintenance. Cladding them with aluminum or vinyl reduces maintenance, but using metal cladding will result in slightly lower thermal performance as heat transfers through it.

Window Glass Types and Coatings

Beside choosing frames, a type of glazing or glass should be selected which improves energy efficiency. Based on factors like orientation, climate and building design, different types of glass may even be more appropriate in different faces of the same home.

For very good information on energy efficiency of different glass types, visit the website of the Efficient Windows Collaborative at https://www.efficientwindows.org/gtypes.php

All Glass is Not the Same

Here are some terms that may be encountered when shopping for windows:

- Insulated window glazing refers to windows with two or more panes of glass. These are held apart by spacers and hermetically sealed to create an insulating air space inside. Insulated window glazing primarily lowers the U-factor of a unit.
- Low-emissivity (low-E) coatings on glass control heat transfer through insulated glazing. Windows with these coatings typically cost 10-15% more than regular windows, but reduce energy loss by 30-50%. Low-E coatings are microscopically thin metal or metallic oxide layers, deposited directly on one or more of the panes. The low-E coating lowers the U-factor, and different coatings are available to allow for high solar gain, moderate solar gain or low solar gain. Most low-E coatings are applied in factories, but do-it-yourself products are available as films.
- A special type of low-E coating is one that is spectrally selective. These filter out 40-70% of normal heat transmission, while allowing in full transmission of light. They do this by reflecting only particular wavelengths of light like the infrared portions, while remaining transparent to others in the visible part of the energy spectrum. Advanced window glazing with spectrally selective coatings can reduce cooling requirements in hot climates by more than 40%.
- Gas filled layers of glass can also minimize heat transfer between the interior and exterior. Argon or krypton gasses are typically used, as both are inert, non-toxic, clear and odorless. Krypton is used when the space between layers must be thin, about 1/4”. It performs better than argon at stopping energy transfer, but costs more. Argon can be used when the spacing between panes is larger, closer to 1/2”. Sometimes argon is mixed with krypton to keep cost low, but increase the thermal performance.
- Spacers are used to keep and maintain layers of glass the correct distance apart. They accommodate thermal expansion and pressure differences, while preventing moisture and gas leaks.

Window Operating Types

Another consideration of energy efficiency has to be how windows operate, because some types have lower air infiltration rates than others.

- Awning windows are hinged at the top and open outward. Since the closed sash presses against the frame, they tend to have low air infiltration.
- Hopper windows hinge at the bottom and open inward. They also have lower air leakage, with closed sashes pressed against the frame.
- Single and double-sliding windows have two sashes that slide horizontally in a double-slider and one sash that slides in a single-slider. With no pressure against them when they are closed, they have higher air leakage rates.
- Fixed windows don't open. When installed properly, they're airtight, but not very useful where egress or ventilation is needed.
- Single and double-hung windows have two sashes that slide vertically. Both sashes slide in a double-hung window. Only the bottom one slides up in a single-hung window. With no pressure holding them closed against a frame or each other, these sliding windows have a high air leakage rate.
- Casement windows are hinged on one side and open outward. Since the closed sash presses against the frame, they also tend to have low air leakage.

Traditional Window Types

Selecting Windows

When choosing windows, there are multiple factors to consider. Look for those with ENERGY STAR labels. In cold climates, consider gas-filled windows with low-E glass to reduce heat loss. In warm climates, pick windows with coatings that reduce heat gain. In cold climates, the lower the U-factor, the better the thermal resistance. Look for U-factors for the entire window unit, not just the center-of-glass U-factors. You want to know the numbers that accurately reflect the performance of the entire product.

Storm Windows

Replacing single-pane windows with high-performance double-pane windows can be cost-effective. Another less expensive option might be installing exterior storm windows instead. They produce similar savings at a lower initial cost. Some storm windows can be installed by those living in apartments, to reduce air infiltration and reduce utility costs.

Older storm windows were clear glass, but new models offer low-E coatings to lower emissivity and reduce heat transmission. Storm windows with a low-E coating reflect heat back inside in the winter and reflect it back outside in the summer. Uncoated glass has an emissivity around 0.84, but low-E coated glass can be 0.16 or lower.

Storm windows can be operable or fixed in place to reduce air leakage. In climates where heating is most in demand, low-E insulating storm windows and insulating shades are effective in reducing heat loss and energy costs. In warmer climates, solar control low-E storm windows will work better for energy savings.

Low-E storm windows offer multiple benefits. They cost about a fourth of complete window replacements. They are aesthetically pleasing, operable, reduce drafts, reduce noise and increase comfort. They offer similar energy savings to completely replacing windows and reflect radiant heat 35% more effectively than clear storm windows. They can help seal against air leakage and reduce it as much as 10%. Finally, low-E exterior or interior storm windows can save 12-33% on utility costs. These advantages yield a payback period of about 5-7 years.

Energy-Efficient Skylights

Energy-efficient skylights can provide daylighting and ventilation and minimize lighting costs.

Skylights on roofs can result in unwanted summer solar gain and winter heat loss. Various technologies can reduce these negatives, including heat-absorbing tints, insulated glazing and low-E coatings. A translucent insulation material like aerogel can even be inserted between layers of glazing for a more thermally efficient unit.

Choosing Skylights

Before selecting a skylight, determine what type will work best and where to place it, to optimize its contribution to daylighting and ventilation. Whether daylighting or heating potential is maximized or minimized will depend on a skylight's position. Skylights on north-facing roofs provide constant but cool illumination. Those on east-facing roofs get maximum light and solar gain in the morning. West-facing skylights provide afternoon lighting and heat gain. South-facing skylights offer the most heat gain in the winter, but also the most heat gain in the summer.

The actual size of a skylight affects the amount of illumination and solar gain in the space below. A skylight's area should not be more than 5% of the floor area in rooms with lots of windows, or 15% of the room's floor area in spaces with few windows.

Unwanted heat gain can be mitigated by placing skylights in the shade of deciduous trees or adding a movable window shade inside the skylight. Some units have special glazing to help control solar gain.

<u>Energy-Efficient Doors</u>

Exterior doors contribute significantly to air leakage and waste energy through conduction, especially when they are old, uninsulated, improperly installed or improperly sealed. Replacing weatherstripping or caulking exterior doors can save money and energy by reducing energy losses due to air leakage.

- Selecting New Exterior Doors

New exterior doors tend to fit and insulate better than older ones. Replacing existing doors with new ones might have a surprisingly short payback. If building new, consider buying the most energy-efficient doors possible. When seeking energy efficiency, first consider energy performance ratings relative to the local climate and your home's design.

The National Fenestration Rating Council (NFRC) label helps compare energy performance of different doors. An example is below.

National Fenestration Rating Council

The label shows the solar heat gain coefficient (SHGC) and U-factor for a door. A low SHGC is needed in warm climates and a high SHGC is best in a climate that is cool. SHGC measures how well a door keeps out solar gain, ranging from 0 to 1.

- Types of Doors

One popular door has a steel skin with a foam insulation core. It usually includes a magnetic strip seal as weatherstripping. If installed right and not bent, this door needs no further weatherstripping.

Most steel and fiberglass-clad entry doors offer R-values from R-5-R-6, excluding any windows in them. A 1-1/2” thick fiberglass door without a window offers over 5 times the insulating value of a solid wood door of the same size.

Sliding glass doors lose far more heat than other door types, because glass is a poor insulator. Moreover, all the air leakage around weatherstripping on a sliding glass door can’t be stopped and still allow use of the door. After years of use, the weatherstripping wears down, so infiltration increases. Sometimes, worn weatherstripping on sliding glass doors can be replaced.


Choosing Doors

Most modern glass doors offer metal frames with a thermal break between inner and outer parts of the frame. Models with several layers of glass or low-E coatings or gas between panes are a good investment, especially in extreme climates. When buying or replacing doors, swinging doors offer tighter seals than sliders. A door with one fixed panel will have less leakage than a similar door with two operating panels.

Review Questions

5. Which of the following is not a common air sealing trouble spot?
   a. Joints between foundation walls and footings
   b. Staircase framing at exterior walls
   c. Common walls between attached swelling units
   d. Shafts for piping or ducts

6. ___________ doors lose more heat than any other door type.
   a. Patio
   b. Out-swinging
   c. Antique
   d. Sliding glass

EFFICIENCY BY DESIGN

This section will explore ways to save energy, based on design strategies and the employment of specific design approaches. The ideas explored here tend to work equally well for all buildings, regardless of the specific construction details involved.

Passive Energy-Efficient Design

Passive House Design is an all-encompassing strategy that relies on orientation, prevailing winds, airtight buildings, insulation, fresh air exchange and the use of energy-efficient components. Thick walls, triple pane windows and proper use of thermal mass contribute to success. Energy-efficient construction is a first step in long-term conservation of energy. Other factors included in this comprehensive strategy include:

- If using solar access for passive heating or cooling is intended, and solar access is not protected in your area, choose a deep lot with a north-south orientation and place your building on the north end of the lot so no one can block your sunlight coming from the south.
- The design of efficient space in a home is a good place to begin conserving resources. Don’t build more space than is absolutely needed. Wasted space equates to more raw materials consumed, more energy lost in building and more energy lost in heating and cooling an unnecessary volume of conditioned air.
- The judicious use of landscaping can reduce HVAC loads on a home, as well as mitigating heat gain from surrounding surfaces.
- A heavily-insulated building envelope reduces heat loss through conduction. Even inside, if surfaces are of neutral temperature, our skin does not bleed heat out to them or absorb it from them, increasing personal comfort levels.
- Some recommend using up to 50% of a home’s south side for glass. That works well in temperate zones, but is a huge heat loss in very cold weather. Using about 20% of the south side for glass results in moderate heat gain and loss, and pays off in a smaller demand on the HVAC system.
- In a fairly sealed home, indoor air quality will assume greater importance. Obtaining quality will be easier if low-processed materials like plywood, timber, tile, and cellulose or mineral wool insulation, were used in the construction. Finishes that will not continue to emit gasses like Volatile Organic Compounds (VOCs) are also a great idea, but will require some research to identify.

Using Site Features to Advantage

The side of a building facing south plays a large part in passive solar design. At least part of the structure should have an unobstructed "view" of the sun. Consider in planning that small trees will still grow, and later, buildings can be built to block your sunlight. If there are no solar access regulations in your area, use a lot that is deep from north to south and place the building on the north end. The goal is to collect heat coming with sunlight through south-facing windows and then store it in materials with thermal mass. What portion of the building's heating load this will provide depends on window size, season length, thermal storage mass and climate. Excess heat can be expelled with ventilation, but the windows will still provide natural light all year, lowering lighting costs.

Basic Elements that Work Together

- Windows collecting solar energy should face within 30° of south and not be shaded during heating days, from 9 AM-3 PM. During cooling seasons, windows should be shaded to avoid excess solar gain. Roof overhangs of a proper depth, relative to the seasonal inclination of the sun, can be used to control this gain.
- Thermal mass, like concrete, brick, stone or tile, can absorb heat from sunlight on heating days and absorb it from warm inside air during cooling days. There are other materials used for thermal mass, but it's best to use materials that can double for structural use. Dark colors absorb more heat than lighter colors.
- Solar heat stored in thermal mass can be distributed to other building areas by conduction, convection and radiation. Small fans and blowers can assist. Conduction is heat moving between two objects in direct contact, like a warm floor heating your feet. Convection is heat moving through air or water, from warmer areas like a sunspaces to the rest of the building. Radiation is energy traveling and penetrating other things, like our skin.
- The amount of incoming energy should be controllable. Roof overhangs can shade south windows during summer months. Other approaches include electronic sensors like differential thermostats that signal fans to turn on; operable vents and dampers allowing or restricting heat flow, low-emissivity blinds, operable insulating shutters and awnings.

Creating a passive solar home that works requires these variables be balanced. Insulation and air sealing, window location, glazing type and window shading, the location and type of thermal mass and auxiliary HVAC systems must fit the site and the owner's budget. Such aspects of design should also consider principles of direct gain, indirect gain and isolated gain.

- With direct gain, sunlight enters through south-facing windows and is absorbed into masonry floors and/or walls. As cooling occurs later in the day, that thermal mass releases stored heat back into the house. Water can store twice as much heat as masonry, but containers of water require additional structural support. Some existing buildings cannot support that weight.

- With indirect gain, mass for thermal storage is placed between south-facing windows and living spaces. The best example of this is a trombe wall, often an 8-16" thick masonry wall. One or two layers of glass are set about an inch in front of dark-colored masonry, which absorbs and stores heat. That stored energy then radiates into the living areas at a speed of about an inch per hour, so heat stored at 12 PM in an 8" wall will reach the living space around 8 PM.

- With isolated gain, the best example is a sunspace. These rooms, with plenty of windows for solar gain, can be closed off from the house with doors, windows and other operable openings. They can also be opened, to allow the heat from solar gain inside them to move inward into the rest of the home. Sunspaces can be a source of auxiliary heat, a sunny space for plants and a nice living area.

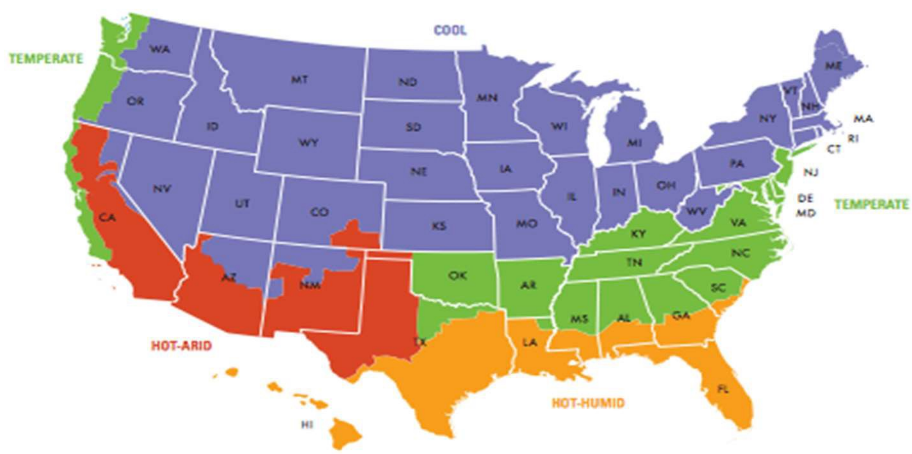
Passive Design for Site Considerations

In addition to winter heat, passive solar design should also consider summer comfort. This will entail design consideration of details and careful siting of the structure. Overhangs, awnings, shutters, and window coverings can be used to block summer solar gain. Careful use of deciduous landscaping will provide shade in the cooling season. Cool wind can also be pulled through a home by intentionally creating a chimney effect (we'll discuss this effect again later).

Landscaping for Climate

A microclimate is what immediately surrounds your home, and is important to consider when landscaping for energy efficiency. Your home may likely receive more sun, shade, wind, rain, snow, moisture or dryness than other nearby areas. For example, a sheltered building on a sunny southern slope will have a warmer microclimate, even in a cool region. In a hot-humid area, your site may be comfortable because of shade and access to predominant breezes. Nearby water affects humidity and air temperature. Many site-specific factors determine which plants will grow, and that will matter. A well-placed and healthy tree, shrub or vine can offer shade, act as a windbreak and reduce energy use, sometimes up to 25%. Indigenous plants require much less water to keep them alive.

How landscaping is used to help conserve energy depends on where you live. The U.S. is roughly divided in four climate regions: temperate, hot-arid, hot-humid and cool.



Broadest Categories of Climate

The map above shows these four climate zones for the lower 49 states. Understanding the climate zone helps determine the best energy-saving landscaping strategies. Landscaping strategies vary by region.

- In temperate regions:
  - Maximize solar gain in the winter
  - Maximize shading of the building in the summer
  - Protect from winter winds with trees and shrubs on the north and northwest sides
  - Focus and aim summer breezes at the home
- In hot, arid regions:
  - Shade roofs, walls and windows

- Allow summer winds if using natural cooling
- Block or deflect winds from homes predominantly depending on air-conditioning

□ In hot, humid regions:

- Focus and aim summer breezes at the home.
- Plant deciduous shade trees that allow low-angle winter sun to penetrate below them
- Don't place planting beds requiring a lot of water, near the home

□ In cool regions:

- Plant dense windbreaks to block cold winter winds
- Allow the winter sun to hit south-facing windows
- Shade south and west windows from the summer sun, to prevent unwanted solar gain

Landscaping for Shade

Given that solar gain increases cooling costs, landscaping can save money in the long run. Shading and evapotranspiration from trees can lower surrounding temperatures by up to 6° F. Temperatures directly under trees can be 25° F cooler than those above asphalt. Knowing the size and shape of the shadow a tree will cast is very useful in planning, unless you are in a cool zone where cooling a building is a rare need. Then shade may not be desired at all.

Shade trees come in all shapes, sizes and densities. To block solar gain in the summer and let it in during the winter, choose deciduous trees. In warmer climates, plant them to the south of the building if they have high spreading crowns, and to the west if they have lower crowns, to block the setting sun. Don't plant deciduous trees on the south side in cooler climates, since solar gain will be desired year round. To continually block the sun and wind, use evergreens.

Slower-growing trees take awhile to generate full benefits, but usually live longer than faster growth varieties. With deeper roots and stronger branches, they better withstand damage from wind and snow. They also tend to be more draught resistant. Research the canopy spread of chosen trees and plant them far enough away that roots don't attack foundations and branches don't damage roofs. A 6-8' deciduous tree, planted near a building, will shade windows the first year. In 5-10 years, it can shade the roof.

Trees, shrubs and groundcover plants also shade pavement near the home, reducing radiation before it reaches your windows. Use plants to shade paved areas, like hedges by walks. Climbing vines on a trellis can shade patios. Vines on walls block solar gain but let breezes through. While shrubs near a home can also shade walls, take care that dense foliage doesn't hold water against building materials to create other issues. Let wind continue circulating around the home to keep the building and adjacent soil dry.

Landscape Windbreaks

Properly placed landscaping windbreaks also reduce heating costs, ever more effectively as the plants mature. They do so by reducing the wind chill near your home. Wind chill measures the rate of heat loss from surfaces exposed to wind and cold. That rate increases as the wind speed increases. Windbreaks reduce that wind speed as far away as 30 times their height. For maximum protection, windbreaks should be planted 2-5 times the mature height of the trees, away from the building, using trees and shrubs with low crowns. Evergreens on the north and northwest sides of the building are commonly used. Planting areas can be combined with walls, fences or earth berms to deflect wind up over the building. Windbreaks can also block unwanted sights, sounds and smells, protect livestock, help enhance the landscape and create a wildlife habitat. Avoid placing windbreaks where they will block desired solar gain from a winter sun.

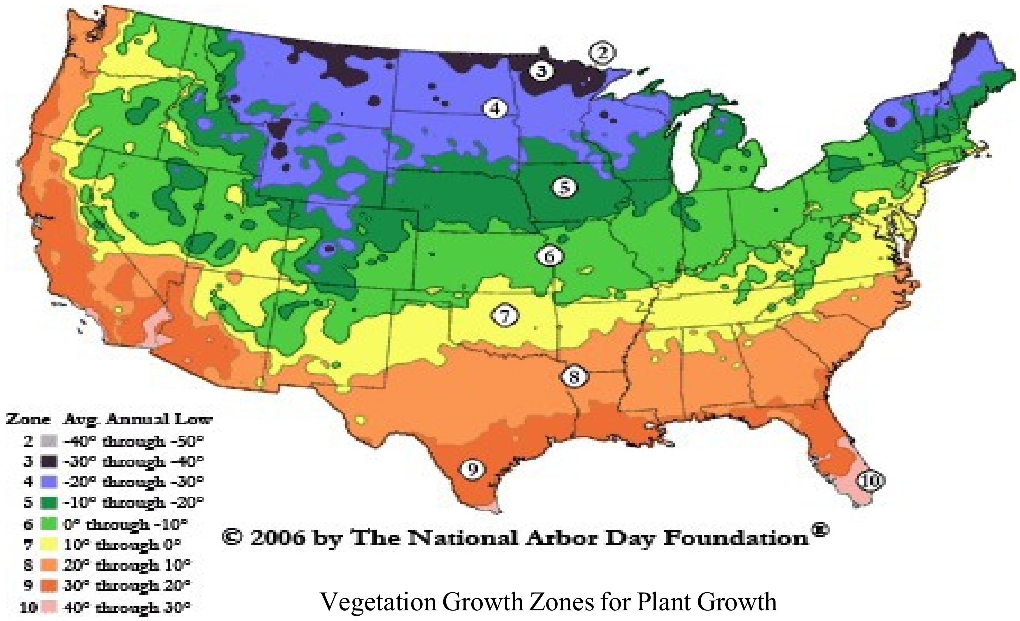
Low shrubs or snow fences on the windward side of a windbreak will trap snow before it can pile up against a house. Shrubs planted to leave a clear foot of distance between them and the house also create dead air spaces that help insulate a house in the winter. If a building is not naturally ventilated and is air conditioned, the same shrubs can keep hot summer winds away from the house.

Water Conservation and Landscaping

Properly designed landscaping conserves water as well as energy. Certain plants have specific watering requirements. Evapotranspiration (Et) is how much water evaporates from the soil and transpires through the plant's leaves, requiring replacement by watering. Local water districts can supply information on the local Et rate, so irrigation can be planned accordingly. Then plants can be irrigated in the early morning, when Et rates are low, and before mid-day, when they are the highest.

Xeriscaping is a systematic way to promote water conservation, primarily in arid regions. Here are seven basic xeriscaping principles:

- Plan ahead of time: set a game plan for water and energy conservation strategies based on regional climate and microclimate.
- Select plants and planting locations based on what already flourishes in your regional climate and microclimate. Group plants together that have similar water needs.
- Limit grass areas and avoid bluegrass that requires a lot of water. Use a hardier grass.
- Improve soil so it absorbs water better and encourages deeper roots.
- Use irrigation methods that water plants in each area most efficiently.
- Mulches keep plant roots cool, slow evaporation, keep soil soft and lower weed growth.
- Keep plants healthy by weeding, pruning, fertilizing and controlling pests.



Vegetation Growth Zones for Plant Growth

Use plant species that thrive in the local climate. Once established, they require little maintenance and will not act as an invasive species. Local nurseries are happy to provide information on plants that are local to regions.

Passive Design Considerations for Sunlight

Lighting versus Fenestration

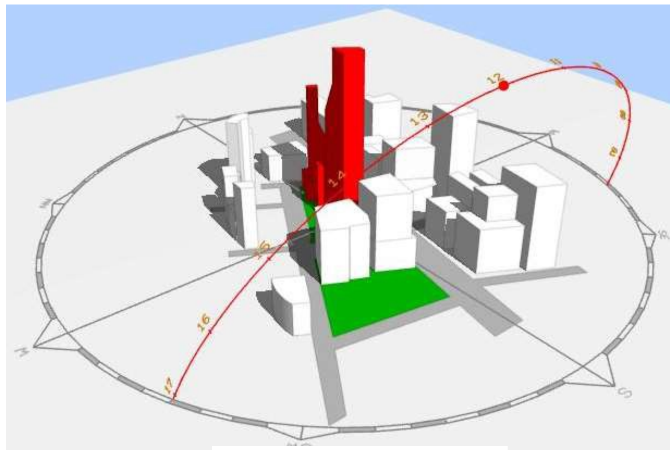
Our main source of natural light on Earth is the sun, coming at us during daylight hours whether we want it or not. We don't control the amount, duration and intensity of natural light coming to us. Sunlight contains the entire visible spectrum, from violet at one end to red at the other. It is necessary for our health and for photosynthesis for plants. Fire is another source of natural light.

Since sunlight is available only in the daytime, we also convert electricity into artificial light, using incandescent lamps, compact fluorescent lamps (CFLs), light-emitting diodes (LEDs), etc. We control its quality, quantity and duration. We need it to work during hours of low lighting, but it does not cover the entire light spectrum and is usually neither conducive to photosynthesis nor the health of life forms.

Certain well-established levels of light (expressed in lumens) are required in order to perform certain tasks and do so safely. Natural lighting that can be introduced at sufficient levels is a preferable way to obtain that illumination. If natural light sources are not present, or are insufficient to provide needed levels of illumination, artificial lighting must be added or relied upon to obtain desired levels.

Compass Orientation

Site planning and building orientation play a large part in best utilizing incoming sunlight. This is especially true when planning building openings and windows and choosing suitable materials to separate inside and outside climates. These tips on site orientation can definitely help optimize or minimize heat gain.



Plotting the Sun Path

- Orient the plan, not just the building profile, toward the sun. Place frequently-used rooms, like kitchens and living room, on the south side. This way, they can get sun in the winter and relief from the sun in the summer. Place patios and decks on the south side where sunlight enhances use for more hours per day and more days per year. Put lesser-used spaces like garages and laundry rooms on the north side of the house, to protect high-use living areas and act as buffers against winter winds.

- The north/south sun differential is exaggerated in mountainous regions, with significant climate differences within short distances. The best building locations are on south-facing slopes of mountains because low-angled sunlight may not reach a mountain's north face. Halfway up a mountain slope is best, since peaks are exposed to strong winds, and cold night air and water both flow down into valleys.
- Trees can provide needed shade on summer days, but can also block natural light when it is needed most. Deciduous trees on the south side will lose leaves in the winter, letting natural light through, while evergreen trees provide shade all year long. Age, species, growth rate and the mature canopy cover of existing trees on a site should also be considered in orienting a structure.
- Install windows, but not too many, basing the amount on the local climate. A good rule of thumb is to provide enough glazing to equal 5% of the conditioned square footage. But remember that while windows let light through, heat also leaks out, so too many windows can be detrimental during winter months.
- An east-west orientation is best, but the ridgeline orientation can be adjusted for other reasons by up to 20°, with the change having only a minimal impact on heat gain.
- Driveways and parking lots are made of materials that get hotter than the rest of the site. Stored heat there can affect the microclimate around an adjacent house; putting drives or parking north or east of the building reduces summer heat buildup in warm climates. In cold winter months in cold climates, a south or west oriented driveway can absorb solar gain, helping melt snow on it faster.
- Glass need not be placed completely vertically. It can be tilted relative to the angle of the sun, to maximize reflection in the summer and minimize reflection in the winter months.
- Consider prevailing winds, which predictably blow in from a single, general direction. This can be used to take advantage of summer winds for cooling and to block cold winter winds from chilling the home or piling snow against it. Detailed information about

prevailing winds is usually available from local airports, libraries, the Internet or county agricultural offices. In the United States, cold winter winds usually blow in from the north and west, so minimal or insulated glazing is best on those building sides. Summer winds usually blow in from the south and west, so outdoor living spaces are oriented facing those. In coastal areas, breezes usually blow in from off the water. In mountain areas, cool winds will also flow downslope while warmer winds will tend to rise up the mountainsides.

- Property dimensions and layout may prevent the best possible building orientation to realize gains from passive design, but energy savings can still be realized. Features like low-E windows, good insulation, selective sealing against infiltration and the use of cool roofs can still be effective.
- Homes oriented to take advantage of the path of the sun, and that of prevailing winds, will require less heat and cooling, resulting in lower energy bills and increased indoor comfort.

Mind the Wind

Ascertaining Wind Direction

Besides its predominant temperature being based on its origin, wind generally moves at 10-15 mph, and creates positive pressure on the façade it is striking. As the wind goes around a corner, it speeds up considerably, creating strong negative pressure at building corners and some negative pressure on the rest of the building walls and roof. That positive or negative pressure will have a direct impact on air leakage in and out of buildings. Remember, it is the pressure differential between inside and outside atmospheres that determines whether infiltration or exfiltration occurs.

A chimney effect is an internal wind inside of buildings. Created by hot air rising, it is really a difference in atmospheric pressure at the top and bottom of a building due to temperature variances. With a source of intake air and a place to exhaust, a chimney effect can move large volumes of air through a building. In the winter, warm air in a heated building is also lighter than cold air outside the building. That warm air bubble wants to rise up and out. When it does, it also pulls cold air in through gaps at the bottom. The reverse occurs when air conditioning.

The chimney effect is very useful for natural ventilation. Cool air can be drawn in low on the north side of a building, while air on the south side can be heated by solar gain through windows. Opening windows on the high south side will allow air to rise from the low northern openings, up and through the structure, and back out the high southern openings. In the process, cool ventilation air can be brought in from the north side and distributed through the whole building.

Review Questions

7. If trying for a passive house design, and solar access is not protected in your area, its best to build on a deep lot with ______________________.
   a. A mature stand of evergreen trees
   b. A north-south orientation
   c. An opening in landscaping for prevailing summer winds
   d. Neighborhood covenants restricting amounts of paving

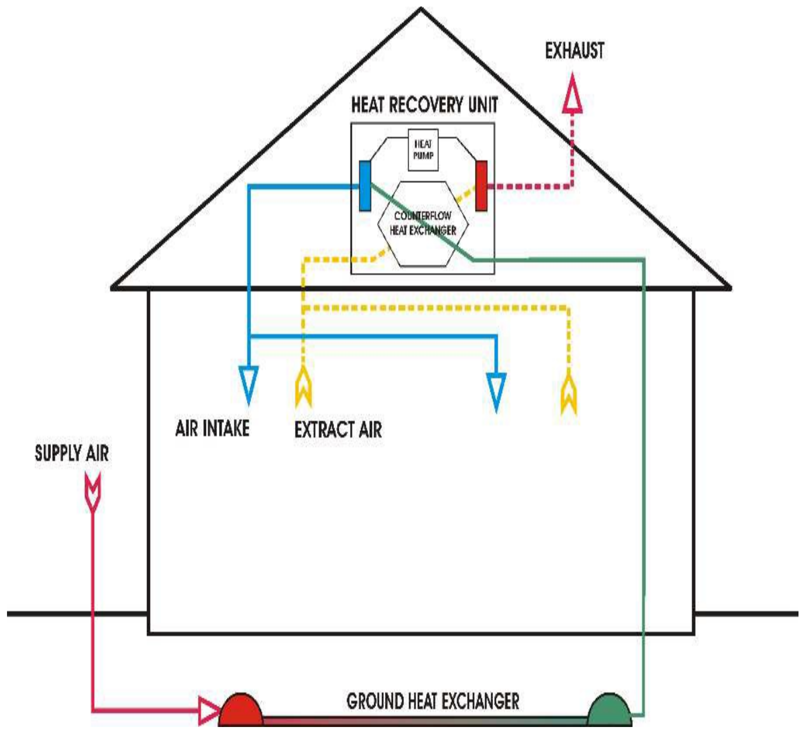
8. Air temperatures directly under trees can be 25% cooler than those above ______________.
   a. Asphalt
   b. Concrete pavers
   c. Swimming pools
   d. Wood shake roofs

Energy Transfer from the Ground

Heat transfer will occur between buildings and ground, especially in earth-bermed and underground buildings. Passive cooling occurs as heat transfers into the ground. Ground-coupled heat pumps do the same thing mechanically. However, direct earth-contact heat transfer has many potential applications, since virtually every building is in contact with the ground by way of a basement, slab or crawl space. These are ways to capitalize on that guaranteed energy flow.

Earth Tubes

Many geothermal projects don't rely on tapping the heat of the Earth's core, but rather the difference between the desired indoor temperature and the earth's relatively constant temperature below the frost line. That ground is almost always at 4-6° Celsius, or 40-46° Fahrenheit. That is not an amazing difference in temperature, but it is reliable and useful, especially for geo-exchange ground source heat pumps. A more passive system for earth-contact heat exchange is called an earth tube, or an earth to air heat exchanger. These are simply plastic or concrete pipes, buried underground, through which air is drawn into a building. As the air flows through the earth tube it is pre-warmed or pre- cooled by the ground's constant temperature, depending on the seasonal needs inside. The longer the tube, the more energy transfer occurs.



Earth Tube Heat Exchange

It doesn't seem like it would have much effect. But it's much cheaper to temper and pre-cool 98° F summer air with the temperature of the earth, than by using power. Likewise, it's much easier to temper and pre-warm 46° F incoming air to 76°, than it is to deal with incoming air coming straight inside at -10° F. A temperature swing of just 42° F Celsius saves tons of energy on air conditioning alone. The HVAC system gets a huge boost from the free pre-heating and pre-cooling of incoming air. Some experts estimate it can result in energy savings of up to 50%.

All this from a simple tube in the ground. The only mechanical component normally involved is a fan to draw air in through the tube. And the major cost of earth tubes isn't even the pipes, it's digging the trench, so most earth tubes are installed during construction, when there is earth-moving equipment on the site anyway.

Berms and Buried Houses

One way of course, to benefit from the known heat transfer that occurs between buildings and earth is to surround your building with dirt. Besides being energy-efficient, homes built this way can be surprisingly comfortable and durable. There are two ways to surround a structure with earth: either place it below grade, or place it on grade and bring dirt up around it.

An underground structure is one that winds up being completely underground. Built on flat sites, these normally use an atrium or courtyard in the center of the design to provide an open feeling. Major living spaces surround the central open courtyard or atrium. Windows and doors on walls facing the courtyard provide light, solar heat, views and access to ground level by means of a stairway. Passive solar gain through windows will be a bit more limited than when the structure is above grade. Courtyard drainage and snow removal should be carefully thought out beforehand.

A bermed house is one built partially or wholly above grade, but with earth then banked up against one or more walls. An "elevational" design exposes one face, usually the south side, but covers the other sides with earth, to protect and insulate the house. Sunlight is allowed in through the exposed face to light and heat the home. Common areas and bedrooms usually access the exposed face, so legal egress can be made from sleeping areas. Skylights above shafts through the earth cover can be used for natural light and ventilation in other sheltered portions of the house.

In another version of bermed designs, windows and doors are protected by small retaining walls that protrude out like wing walls. Then earth is built up around the walls everywhere else, allowing cross-ventilation and natural light to enter from more than one side.

Partially Underground Dwelling

- Advantages and Disadvantages

As with any other design decision, there are pros and cons to creating earth-sheltered houses.

On the pro side, extreme outdoor air temperatures have less effect on an earth-sheltered home. There is less of an exterior to maintain, the earth provides insulation from both outdoor temperatures and from sound, and the home blends into the landscape. These homes can cost less to insure, being somewhat protected from wind, tornadoes, hurricanes and hailstorms.

On the con side, initial costs of building an earth-sheltered home can be as much as 20% more than conventional construction. These structures require more effort to protect them from water, both during construction and thereafter. They tend to be harder to resell, as some lenders will erect hurdles in the financing process.

- Site Microclimate

Before proceeding with the construction of an earth-sheltered home, analyze a building site's climate, topography, soil and groundwater levels.

- When considering climate, earth-sheltered houses are better options in zones having significant temperature extremes and low humidity. In these areas, earth temperatures vary less than temperatures of surrounding air, so the earth will absorb heat from the house in hot weather and insulate it during cold weather.
- Topography determines how easy it will be to build up and maintain earth around the building. Modest slopes require more excavation than steep ones, and flat sites will require extensive excavation. A south-facing slope in a region with moderate to long winters is ideal for an earth-sheltered building. South-facing windows can let in sunlight for direct heating, while the rest of the house is set back into the insulating slope. In regions with mild winters and hot summers, a north-facing slope might be ideal.
- Soil type will also impact the feasibility of earth-sheltered buildings. Granular soils like sand and gravel work best. They compact well for weight bearing, but their permeability also allows water to drain quickly. Cohesive soils like clay have poor permeability and tend to expand when wet. Bearing capacity of soils on a site can be determined by testing.
- A way to drain water away from a building is the best way to reduce water pressure against walls below grade. Natural drains to daylight are best, but other types of drainage systems can also be installed.

- Considering Construction Materials

Materials used for underground homes will vary based on site characteristics and design features. But all must provide a good substrate for waterproofing that can withstand pressure from moisture that will be present in the surrounding ground.

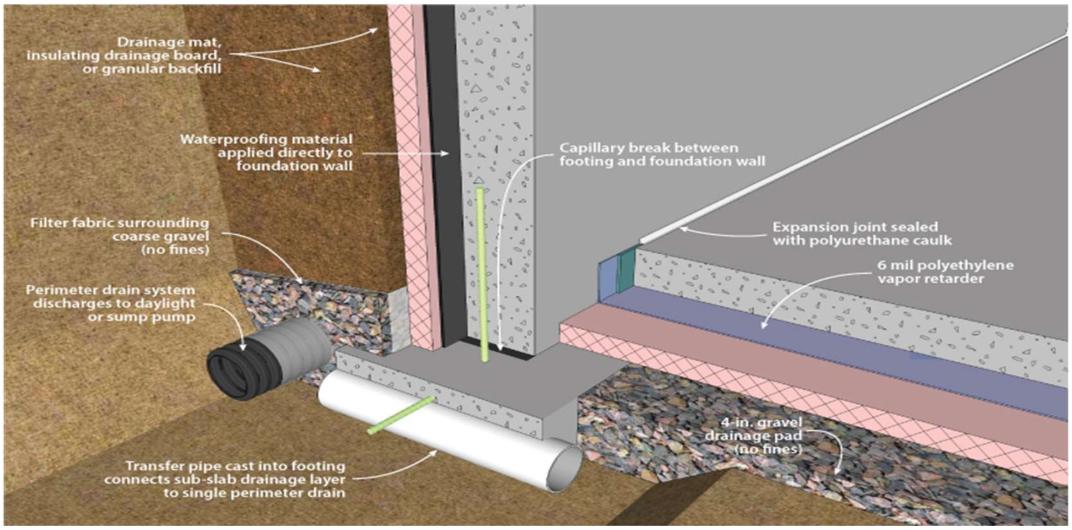
- Concrete is a common choice for perimeter walls, offering strength, durability and fire resistance. Concrete blocks with reinforced cores are also used and cost less than cast-in-place concrete.
- Steel is used for beams, bar joists, columns and reinforcement. If exposed to groundwater or precipitation, this metal must be protected against corrosion. If used, it must be done efficiently, as steel is also a relatively expensive material.
- Wood is used for both interior framing and light structural elements.

- Waterproofing

There are three primary ways to lower water damage risk to underground homes: choosing the site, drainage at and below the house surface and waterproofing the house. Several options are available for the last.

- Rubberized asphalt is coated with a polyethylene layer and applied directly to walls and roofs as sheets. This has a long life expectancy.
- Plastic and vulcanized sheets are common. Plastic options are high-density polyethylene, chlorinated polyethylene, polyvinyl chloride and chlorosulfonated polyethylene. Vulcanized membranes and synthetic rubbers include isobutylene isoprene, ethylene propylene diene monomer, polychloroprene (neoprene) and polyisobutylene. Seams with all of these must be properly sealed to prevent leaks.
- Liquid polyurethanes can be sprayed on where applying sheet goods is difficult. They can also be applied over insulation.
- Bentonite is panels made of natural clay, nailed to walls. It can also be applied as a

sprayed material. When bentonite contacts moisture, it expands and seals the surface.



Waterproofing Takes Many Forms

- Humidity

Summer humidity levels can be elevated in earth-sheltered houses. This moisture can create condensation on interior walls. Insulation on outside wall faces can stop walls from cooling to earth temperatures, but that also negates the idea of cooling in the summer using the differential between temperatures of the walls and earth. Other ways may be needed to lower humidity levels inside.

- Insulation

Underground buildings won't need as much insulation as conventional houses, but they must still be made comfortable. If insulation is placed on the outside of exterior walls, after the waterproofing has been installed, a layer of board should be installed to protect it from the earth. The heat generated, collected and absorbed in the earth-sheltered envelope will thereby be retained inside the building envelope.

- Air Exchange/Air Quality

Adequate ventilation must be ensured inside earth-sheltered buildings. Combustion appliances should have a direct source of outside air for combustion and vent gases directly to the outside. Avoid indoor pollutants by avoiding the use of building materials and fabrics that continue emitting gasses, keeping indoor air healthy. An energy recovery system, exchanging heat in outgoing exhaust air with that of incoming fresh air, will lower heat loss and help insure good indoor air quality. In any case, these energy recovery systems are useful additions to any would-be energy-efficient home.

Options for HVAC Systems

Since these are the primary users of energy in a home, the type, size and efficiency of the HVAC system that will condition inside air must be considered.

Life Cycle versus Initial Cost

One variable in choosing an HVAC system involves its life-cycle cost, long-term payback or gain versus initial cost.

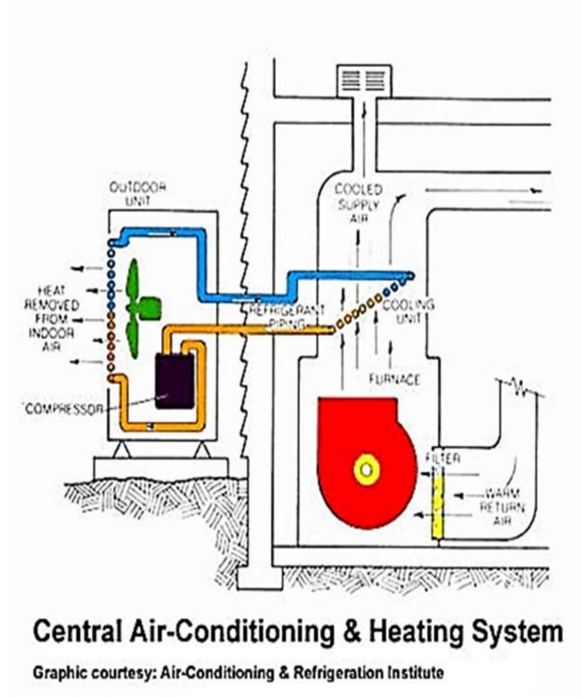
There's no right or wrong reason to invest in energy efficiency, whether for savings or reducing environmental impact, but cost does need to first be weighed against gains. For example, would you forsake hot water in favor of a gravity shower on the deck? Cook all your meals on a rocket stove? There is a stopping point most people reach when placing the need of the planet over their own comfort.

But comfort must not always be sacrificed to save money and increase efficiency. Instead, research the return on investment of various options to accomplish certain tasks. For example, one researcher claims gas water heaters are always cheaper than electric, but installing a solar water heating system will pay for itself in seven years, even though the solar system costs more up front.

This is a concept that holds true in many cases. An option that will save the most in the long run is usually a bit more expensive up front. That means extra capital spent initially can be treated as an investment for the future. That's only pertinent if finances permit extra expense up front, because few are willing to endure financial hardship on other fronts in order to save energy in the long run.

Pros and Cons of HVAC Choices

Most homes need HVAC systems to keep the building at a comfortable temperature all year round. Besides heating and/or cooling components, they are controlled by thermostats and incorporate filters to remove impurities and keep the air clean. Most systems also use ducts with vents to distribute conditioned air throughout the house.



A Basic Split System

- Four Basic HVAC System Types

- Split systems are the most common HVAC system. They typically have a heating unit inside, fueled by gas or electricity, and a cooling unit outside that is powered by electricity.
- Hybrid split systems are very similar, but with one additional feature. The heating component can be switched between gas and electric, allowing owners more control and potential savings as energy prices of each fuel fluctuate.
- Duct-free systems, or mini-split systems, put individual HVAC units in each space, each with its own indoor and outdoor component, so there is no ductwork.
- Packaged systems combine heating and cooling capabilities in one unit and are usually powered by electricity.

- Pros of HVAC Systems

The annual cost to operate an HVAC system year-round is a big factor in choosing one. Some types are more economical to run than others. Ductless systems are the most energy efficient and will result in the biggest savings over time.

HVAC system choices also depend on the house size. Split systems tend to be more energy efficient for large homes. Packaged systems offer better value for small houses and apartments. When adding a system to a stand-alone space, like a workshop that sees infrequent use, duct free systems that are individually controlled make more sense.

- Cons of HVAC Systems

The main drawback of HVAC systems is the upfront cost of units and ductwork. If a functioning system of vents and ducts is in place, replace the existing unit with another split or hybrid split system. Just installing ductwork can cost $35-55 / lineal foot. And upfront costs do not factor in yearly maintenance expenses. Duct-free systems, offering the lowest energy costs, also require the most ongoing maintenance. Even when well maintained, HVAC systems may need replacement every 10-15 years.

Physical appearance may be an issue in choosing a system. Ductwork and vents are easy to hide, making split systems aesthetically pleasing. There will still be a large cooling unit in sight somewhere outdoors. Duct-free systems may not have ducts, but they are large units, must be mounted on a wall in each room and are very hard to camouflage.

Pros and Cons of Creating Zones

It is difficult to condition air uniformly throughout a home. Things like direct sunlight, drafty windows, old equipment and bad ventilation mean you can switch from being warm to being chilled just by entering another room. Another factor in reduced comfort may be an outdated HVAC system that just can't keep up with changing outdoor temperatures. Since heating and cooling accounts for half the energy use in a home, replacing a worn out system may pay itself back pretty quickly. But if doing so, consider using zoning with the new system.

Zoning increase efficiency of use and reduces energy costs, because relying on a single HVAC setting for a whole building is wasteful. Zoned HVAC systems break down the geography of a building to provide solutions by individual floors, zones of use or even individual rooms, instead of sending the same conditioned air to all spaces. They usually have multiple thermostats controlling separate zones, diverting more cool air to hotter floors or spaces. A zoned system allocates the conditioned air, based on the needs of individual zones.

A typical zoning system uses a thermostat, a temperature control panel and dampers for each zone.

- Dampers installed inside ductwork control how much air passes through those ducts at a time. They are placed where ductwork is accessible, at the trunk, branches or the boot. Rather than shutting a vent, which means conditioned air will fill the branch duct and remain there, dampers reroute the volume of the airflow to where it's needed most. They work similarly to vents, but open and close automatically at the entry to ducts, rather than the terminal point. They maintain air pressure in the duct and just redistribute airflow as needed.
- When a zone temperature is set via a thermostat, the control panel opens and closes the appropriate dampers to meet the demands of zones.
- A zoned system has multiple temperature controllers, or thermostats, one for each zone.

Zoning distributes warm or cool air to individual zones on demand, instead of bringing an entire building to the temperature desired in one location. That can reduce utility bills by as much as 30%. That yearly savings will determine the financial feasibility of installing zoning capabilities.

Review Questions

9. ____________________ bermed house design exposes one face, usually the south side, but covers the other sides with earth.
   a. A semi
   b. An elevational
   c. A submerged
   d. A well insulated

10. The most common type of HVAC system used is a _________________.
   a. Duct-free system
   b. Split system
   c. Wood burning stove
   d. Package unit

Options for Lighting

Lighting accounts for about 5% of a house's annual energy budget. Switching to energy-efficient lighting will result in the same lighting levels, but also cut energy bills. Just replacing bulbs in the most frequently used fixtures with bulbs that are ENERGY STAR rated will save up to $45 each year. Money-saving bulbs, like halogen incandescent, compact fluorescent lamp (CFL) and light-emitting diode (LED) versions, are all readily available.

Traditional incandescent bulbs use a lot of energy and are no longer manufactured. This is because 90% of the energy used was lost as heat, money just being thrown away. New types of bulbs use power more efficiently, in the same color choices and light levels.

Task versus General Lighting

One effective energy saver is to focus light specifically where needed, as task lighting. When possible, use lights placed lower and closer to the task instead of more powerful lights mounted above. Use shielded lights to direct illumination to a work surface, without creating glare in other directions. Lighting experts also use step-down lighting levels between areas needing more and less illumination. This is because contrasts between areas of low light and areas of intense light make it difficult for eyes to adjust quickly.

Be aware that elements in various lamp types render color differently. Choose light sources and lamps that provide good color rendition where it is needed.

Maximizing Available Natural Lighting

- Window Coverings

These obviously allow incoming levels of natural light to be manually adjusted. Blinds reduce views, but can also block them out entirely, partially dampen sunlight or even redirect it up to the ceiling to indirectly light a space. Shades, whether automatic or manual, can provide complete protection from glare in various levels of opacity. Shades can be installed to pull from the bottom up or from the top down. Drapes are an older alternative to shades. They are also a bit more difficult to operate and bring cleanability issues with them. For any covering device, pull cords can be difficult for arthritic hands to operate. Circular chains are considerably easier to grip and manipulate.

Many Ways to Block Light

- Light Shelves

Light shelves are horizontal, reflective surfaces, inside or outside of windows. They are used to either reflect light back outside or bounce it further back into the interior of a space, increasing light levels in places where natural illumination doesn’t normally reach.

Energy-Efficient Lamp Technologies

Choices exist for energy-efficient lighting. As already mentioned, popular bulbs include halogen incandescent, compact fluorescent (CFLs) and light-emitting diodes (LEDs). They cost more than incandescent bulbs, but ongoing energy savings result in less life-cycle cost.

Controls, like timers, motion detectors and photocells turn lights off when not in use. Dimmers save electricity by lowering output. Fixtures must be chosen which are compatible with the bulbs and controls you intend to use.

When outdoor lights will remain on for long periods, it is best to use CFL or LED bulbs. Spiral CFLs can be used in enclosed fixtures that protect them from weather. CFLs and LEDs also come as flood lights, have been tested to withstand rain and snow and can be used in exposed fixtures. Some can be found with features like automatic daylight shut-off and motion sensors.

Halogen incandescent bulbs have a capsule inside, holding gas around a filament to increase efficiency. These come in many shapes and colors and can be used with dimmers. They meet minimum energy efficiency standards, but there are even more efficient options available now.

Halogen Incandescent

Compact fluorescent lamps (CFLs) are small curly versions of tube fluorescent lights from the past. Using about a fourth the power of an incandescent with the same output, typical CFLs have a payback of less than nine months, before savings begin accruing. CFLs use about a third the energy of a halogen incandescent.

CFLs

CFL bulbs come in multiple light color ranges, including warm (white to yellow) tones that were unavailable when first introduced. Covers over some versions further diffuse the light and provide a similar shape to traditional bulbs. Not all are dimmable, so packages must be checked if that capability is desired. Fluorescent bulbs do contain some mercury, so they should always be recycled when used up.

LEDs are solid-state lighting, using semiconductors to convert electricity into light. Once used mainly in traffic lights, LED lights are one of today's most energy-efficient technologies. ENERGY STAR-rated LEDs use 20-25% of the energy and last 15-25 times longer than traditional

LEDs

incandescent bulbs. They use 25-30% of the energy and last 8-25 times longer than halogen incandescent bulbs.

LED bulbs are available in many products and often replace 40W, 60W and 75W traditional incandescent bulbs, reflector bulbs for recessed fixtures, small track lights, desk lamps, kitchen undercabinet lighting and outdoor lights. LEDs come in multiple colors, some can be dimmed and some work with daylight and motion sensors. They are used indoors and outdoors due their durability and performance in cold environments. You can also find solar-powered outdoor lighting using LEDs. Prices of these types of bulbs are also coming down, as more manufacturers enter the market.

Active Renewable Energy Technologies

Energy efficiency can also be realized through the purchase of active mechanical equipment to perform specific functions that reduce overall use of power.

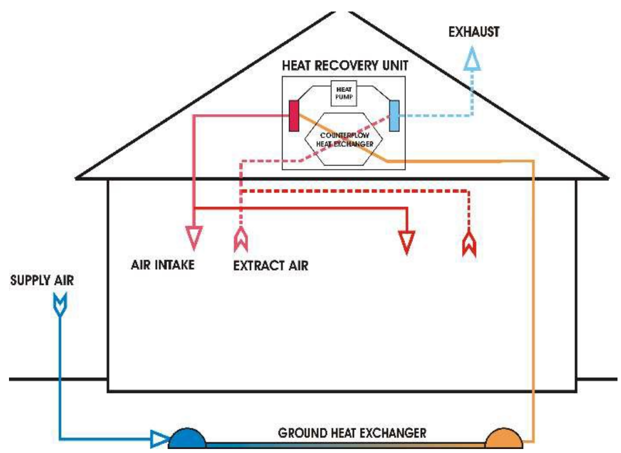
Energy-Efficient Kitchen Appliances

Energy can be saved in kitchens by purchasing more efficient appliances. ENERGY STAR ratings are available online for dishwashers, refrigerators and freezers, ranges and other common appliances.

Heat Recovery Systems

Heat recovery systems (MVHR) typically involve two primary aspects: mechanical ventilation and heat recovery.

Mechanical ventilation involves a duct working in conjunction with a fan to bring fresh air into a building. Another duct with a fan blows stale air out. Since both fans are powered and controlled, it is considered “mechanical” ventilation. A system with no power and no controls would be “natural ventilation.”



Heat Recovery Unit

Heat recovery uses a heat exchanger, taking heat from warm air and giving it to cold air. Inside air is often warm, having been heated to make rooms more comfortable. Outside air is typically colder than indoor air for most of the year, especially through the night. A heat exchanger warms incoming cool air from the exterior, preheating it by exchanging heat from warmer, stale indoor air being exhausted.

The two air paths don't intermingle, so stale or contaminated air is not mixed with fresh air. Only heat is transferred in the heat exchanger.

<u>Balanced Whole-House Ventilation</u>

One principle used with heat exchangers is called "balanced whole-house ventilation." With this, the amount of air coming into the building through the MVHR exchanger matches the amount of air being exhausted through the MVHR. This allows the maximum amount of heat to be recovered from outgoing air.

Balanced whole-house ventilation typically includes the following:

- There are two grilles on the outside face: one for fresh air coming in and one for stale air leaving.
- Behind each grille is a short duct going directly to the heat recovery unit. One duct has cold fresh air from the outside coming in. The other has cold stale air being blown out, because the heat has already been taken from it in the exchanger. These two cold ducts need to be insulated from the building interior, so condensation doesn't form on them, using vapor impermeable insulation. And as part of the thermal envelope, these ducts must be airtight, sealed to both the air barrier of building envelope and to the MVHR unit.
- These two ducts connect to and pass through the MVHR unit in insulated ducts.
- Inside the MVHR, fresh incoming air passes through a filter to purify it, prevent particulate in it from clogging the heat exchanger and ensure the air is clean and healthy.
- Both supply and exhaust air streams pass through a counterflow heat exchanger. This mechanism can recover 75-95% of the heat, as opposed to a non-counterflow exchanger, which is limited to about 50% of the heat. Many MVHR units also have a by-pass function, so when outdoor air is warm and no heat needs to be recovered, the by-pass function reduces any risk of overheating.
- Both ducts have a small fan inside to blow air in the right direction.
- Two ducts come out the other side of the MVHR. One goes to all habitable rooms, like living rooms, bedrooms, etc., to deliver fresh air. The other duct returns to the MVHR from the same rooms where air is being extracted.
- Extracted air also passes through a filter to remove particulate from entering and blocking the heat exchanger.
- Both ducts contain silencers near the MVHR, so fan sounds won't transmit through the ducts and into rooms. Humming sounds from fans, even if quiet, are uncomfortable and undesirable.
- Where the ducts supply or extract air from rooms, a grille or vent is used.

Design Features of Energy-Efficient Houses

Whole-House Systems Approach

Optimizing energy efficiency requires a whole-house systems approach to ensure all variables, details and interactions affecting energy are considered. Occupant behavior, site conditions and climate are primary considerations. Others can include appliances and home electronics, insulation and air sealing, lighting and daylighting, space heating and cooling, water heating and windows, doors and skylights.

Ultra-efficient homes combine state-of-the-art energy-efficient construction, appliances and lighting with commercially available renewable energy systems, like solar water heating and solar electricity generation. The intent is to reduce home energy use much as possible, then supply remaining needs with on-site renewable energy systems.

Cutting Edge Ideas to Achieve Efficiency

Some energy conservation ideas are utilized, but are not yet generally accepted as being time tested.

- Recycle, filter and reuse waste water from washing machines, dishwashers and showers. Do the same thing with rain water and use it for cooling and irrigation.
- Solar powered systems are available to heat water.
- Heat exiting the cooling system can be used to preheat water coming into the water heater.
- Water heaters and floor heating systems can use the heat from a solar thermal collector.
- Liquid desiccant waterfalls not only look great, but help maintain humidity control.
- Photovoltaic (PV) solar panels can generate enough energy to handle cooling, heating, LED lighting and common appliances found in a regular house. When PV solar panels provide more electricity than needed, excess energy can be stored for later use in batteries.
- Building shells made of SIPs (structural insulated panels) are very energy efficient. Costs are about the same as framing with wood, but labor is saved since panels are prefabricated and shipped to be assembled on site. They are strong enough to withstand heavy snow and strong winds, while still tightly sealing and insulating the interior.
- Deep rafters can be filled with foam insulation to ensure tight construction and high R-values. The same thing can be done between wall studs.
- Clearstory windows and vent skylights make use of natural light.
- A artificial lighting controller can be programmed to adjust light levels according to people's circadian rhythms and mimic natural lighting conditions.
- Fresh air supply can be delivered through ventilation tunnels coming in from underground, to precondition the air using the earth's temperature. These are the earth tubes mentioned earlier.
- There are high-end controls that can monitor and adjust temperature, lighting and levels of humidity.
- Natural ventilation and thermal comfort can be achieved with a heat-recovery ventilator.
- Energy Recovery Ventilator (ERV) units and heat and humidity exchangers can help

control temperatures inside.

- Vertical gardens allow growth of vegetables and fruits in small areas.
- Moveable curtains help reduce solar gain and maintain cool temperatures inside.

Proven Ideas with Low Cost to Implement

Some energy savings ideas are common sense, cost little or nothing to implement and rely on proactive users.

Lower Cost

- Install a programmable thermostat to lower costs and manage HVAC systems efficiently.
- Air dry dishes when possible, instead of using a dishwasher drying cycle.
- Turn things off when not in use, like lights, TVs, entertainment systems, computers and monitors.
- Plug home electronics into power strips and turn those off when equipment is not in use, to reduce wattage used in standby modes.
- Lower thermostats on water heaters to 120°F.
- Take short showers instead of baths, using low-flow showerheads to save hot water and reduce the need to heat more.
- Wash only full loads of dishes and clothes.
- Air dry clothes when possible.
- Change settings on thermostats when away from home. A change of just 3-5° F an lower utility bills. Changing settings by 10-15° F during a work day can save 5-15% of power used each year.
- Start a compost pile. Compost is organic waste kept in a pile or container, to decompose over time. It not only becomes valuable fertilizer for plants, but reduces the amount of trash produced on a daily basis.
- Installing low-flow showerheads improves water efficiency. These have a flow rate of less than 2.5 gallons per minute, rather than the conventional 5 gallons per minute.
- Seal air leaks in and around windows. If windows are drafty, add weatherstripping around frames. Add silicone caulk over cracks in drywall or apply shrink film to your windows. Sealing gaps and cracks is an easy way to lower energy costs.
- Electric and gas space heaters keep feet nice and toasty, but are really inefficient ways to heat space. Many use 1,500 watts of energy to run and will drain an energy budget. It’s better to layer on clothing or invest in blankets, than to crank up thermostats or use space heaters.
- According the EPA, homeowners can save about $170 a year just being careful of water use. Don’t run water while brushing teeth or shaving. Baths use 75 gallons of water, compared to an average of 17.2 gallons for a shower. Wait till there are full loads to run a clothes washer.
- Replace incandescent bulbs with more efficient varieties that offer longer lasting bulb life and use far less energy.
- Unplug cell phone and battery chargers, unless they are being used. According to Energy.gov, average chargers use 0.26 watts when not in use and 2.24 watts when connected to a phone. One charger won’t have much impact, but multiple chargers powered on together can account for a measurable percentage of a home’s energy use.

- Avoid washing clothes with hot water, using cold or warm water when possible. Some estimate that 90% of energy used by a washer is spent heating the water, with the rest running it. Using cooler water can save a lot of energy.

Proven Ideas with Higher Cost to Implement

Other energy-saving ideas are still easy to implement. They just require some expenditure up front.

Higher Cost

- Adding insulation to your attic can seal air leaks and reduce utility costs. How much insulation is needed obviously depends on house size and regional climate. But according to HomeAdvisor.com, an average cost to blow in additional insulation is about $1,356.
- Solar panels aren't cheap, but have become a popular way to heat water and generate power. They can help save money in the long run, promote lower fossil fuel use and might make you eligible for annual tax incentives. They are most often installed on roofs and generate energy independently of your utility provider.
- Even with efficient doors, adding storm doors offers an extra layer of weather protection. Newer storm doors usually have low-E glass or a protective coating to reduce energy loss by up to 50%. Storm doors can last 25-50 years and can cost as little as $75.
- Have a professional energy audit conducted to pinpoint inefficiencies and energy waste in your home. This can identify savings opportunities and areas needing improvement.
- Buy ENERGY STAR products like refrigerators, televisions, stoves, washers and air conditioners. These meet energy-efficient specifications set by the EPA and use 10-50% less energy than standard choices.
- An annual tune-up of an HVAC system will keep components running at peak efficiency, saving money every month. A HVAC check-up ensures connections are tight, parts are lubricated and coils are cleaned. It also helps extend the time needed to replace the system, which can run as much as $2,000-8,000.
- Replace a computer every four years and consider replacing desktop computers with a laptop. These use up to 80% less electricity than desktop versions.

Investing in Efficiency

Initial Cost

There are financial incentives to invest in energy-efficient purchases and improvements. These can be tax credits or rebates, or energy efficiency financing. Information can be found at:

- https://www.energy.gov/savings/dsire-page
- https://www.energystar.gov/about/federal_tax_credits

- https://www.energy.gov/energysaver/incentives-and-financing-energy-efficient-homes/financing-energy-efficient-homes


Long Term Savings

An energy-efficient mortgage (EEM) can help you qualify for a more expensive home with energy upgrades.

Emerging Energy Efficiency Programs

Programs and partnerships are emerging to help building owners navigate through the complexity of energy saving options.

- The HVAC/Water Heating/Appliance Subprogram partners with labs and industries to develop cost-effective energy technologies. Heat pumps can potentially save up to 50% of the energy used by conventional HVAC systems in homes. This program focuses on technology for new heat pumps, heat exchangers and advanced household appliances. Heat exchangers are used in almost every application generating waste heat, a major research opportunity. Emerging non-vapor compression technologies may also reduce energy consumptions by 50%, with little to no carbon emission.
- Whole-Building Energy Modeling (BEM) is a versatile tool for building design, code compliance, green certification, qualifying for tax credits and utility incentives and offering real-time building control. It is being used to develop building energy codes and inform policy decisions.
- Emerging window and building envelope advances will also reduce energy consumption. To be accepted, these technologies must be delivered at a market-acceptable installed cost. Development is focusing on highly insulating materials and systems and tools to measure and validate building envelope performance. Development is also underway for improved labeling standards to better inform customers as to product performance.
- The Sensors and Controls Sub-program focuses on monitoring operating conditions of buildings and building equipment, operating at desired settings. These monitors enable cyber-physical systems for building energy management.
- The Solid-State Lighting Program leads and coordinates national efforts in developing LED and Organic Light-emitting Diode (OLED) lamp technologies.
- The Buildings-to-Grid Integration is seeking opportunities for building assets to integrate and transact with power grid operations. It defines transaction-based controls needed to control building assets and operations, based on decisions incorporating values like cost, comfort, asset valuation and the renewable portion of power being used.

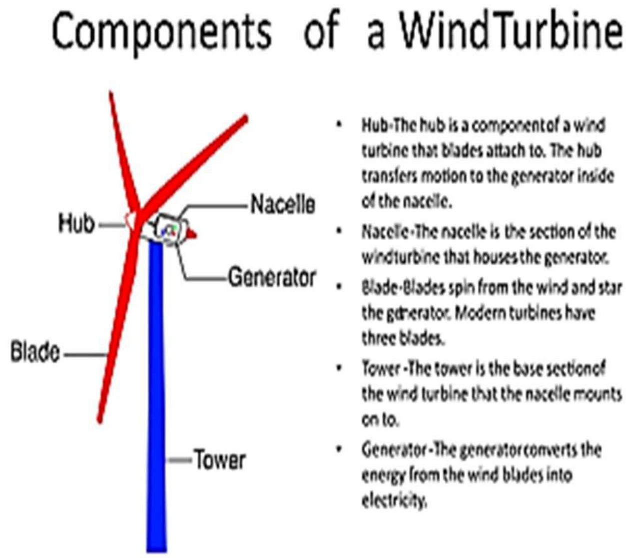
Buying and Making Electricity

Planning for Renewable Energy Systems

Before installing a renewable energy system, analyze existing power use and how it can be reduced, local codes and requirements, whether you want to operate your system on or off the electric grid and what energy generation options will work on the site. If a new home is being designed, incorporate provisions for power generation as part of a package, along with energy efficient siting and construction.

Renewable energy systems can be installed in building projects to generate power on site. Technologies to do so fall into broad classifications, like small solar electric systems, small wind electric systems, microhydropower systems and small hybrid electric systems (solar and wind).

- Small Wind Power Systems



Wind Power System

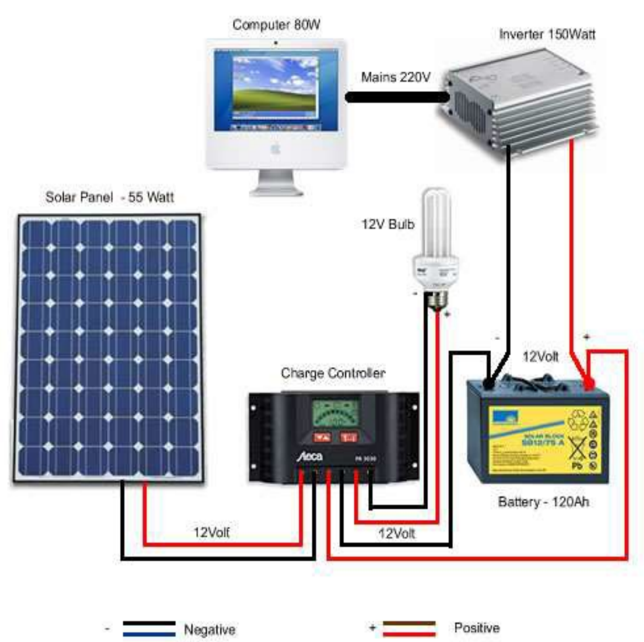
If you have enough access to wind on your home site, small wind systems are cost-effective renewable energy systems, having zero emissions or pollution. They can lower power bills by 50-90%, avoid the cost of running power lines to remote locations and offer power even in extended utility outages. They can also provide power to spot applications, like pumping water on farms.

Wind is a naturally occurring resource. Turbines are used to convert the kinetic energy in wind into electricity. When the wind spins turbine blades, a rotor converts the energy into rotary motion to drive a generator. Automatic overspeed-governing systems keep rotors from spinning out of control in high wind.

Wind systems can connect to the electric grid or stand alone off the grid. That makes these systems attractive in areas not already connected to a power grid.

- Solar Power Systems

Solar electric or photovoltaic (PV) systems can produce electricity as well. These are often installed by owners to offset electricity costs. Federal tax credits and other state, local or utility incentives can offset some upfront costs of rooftop solar systems. There are also several financing options available for such renovations for homeowners.

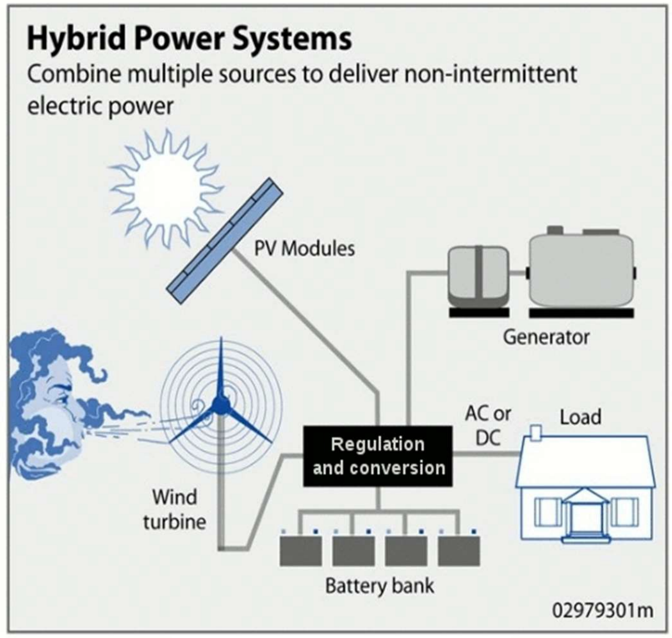


Solar Power

- Hybrid Wind and Solar

A "hybrid" system, combining wind power and solar power technologies, offers advantages over either single system. Wind speeds are low in summer months, but the sun shines the brightest and longest. Wind is stronger in winter months, when there is less sunlight. Using both technologies means hybrid systems are more likely to be able to generate electricity when it is needed.

Hybrid systems tend to be stand-alone systems, not connected to a power grid. When neither wind nor solar components are producing, power is provided through batteries where it was stored or a back-up generator powered by conventional fuels. If the batteries run low, the generator can also be used to recharge them.

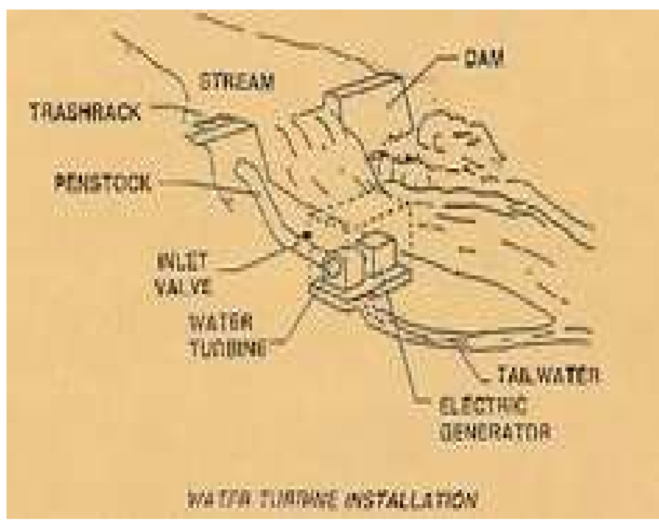


Hybrid Wind and Solar

Despite their complexity, electronic controllers can operate all parts of a hybrid system automatically. A back-up generator can also reduce the size of the other necessary components, especially the battery storage capacity. Usually these storage units are large enough to supply needs when systems aren't charging, or sized to supply power for 1-3 days.

- Microhydropower Systems

If you have water flowing through your property, a small hydropower (microhydropower) system can be a simple, consistent source of renewable energy. These systems are sized to generate up to 100 kilowatts of power. A 10-kilowatt microhydropower system can power a large home or hobby farm.



Microhydropower System

A microhydropower system needs a turbine pump or waterwheel to change the weight of flowing water into rotational energy, and from there into electricity. These systems usually contain some basic components. The water conveyance is the channel or pipeline delivering the water. A turbine pump or waterwheel uses the force of the water to rotate. An alternator or generator converts rotational energy into electricity. A regulator controls the generator and wiring delivers the power to the building or other point of use.

Net Zero

In building terms, “net zero” refers to achieving an overall balance between emissions produced and emissions eliminated from the atmosphere. It is the stated reason to develop alternative energy sources that do not consume fossil fuels. Though I don’t agree with them all, some interesting thoughts toward achieving net-zero construction were mentioned in a recent presentation I attended.

- Why guess when you can know? Use energy modeling and testing programs to identify failure points and places to improve.
- There is an entire Youtube channel set up to discuss ideas on how to reduce energy use.
- If net zero is set early as a goal, all team members can buy into it. Implementing it later in a project, as an afterthought, is difficult.
- Programs like PVWatts from the DOE help predict return on investments in alternative energy, based on available assets on a site.
- Geothermal systems are not really renewable, but are energy efficient when using a ground source heat pump.
- If streams are on site, small hydroelectric dams are useful. Very little return is realized on small wind turbines.
- The sun can be useful for solar heating of water, passive cooling via selection of overhangs and orientation on site, strategically placed glazing, trombe wall effects, light shelves to direct light inward, heating floors with the sun and heating other thermal masses.
- Right-sizing spaces means not building more area than needed, thus eliminating the need to heat, cool, ventilate and illuminate unneeded space. Design techniques can make smaller spaces seem larger and stacking floors is more energy efficient than putting spaces on a single level.
- Passive energy savings are better than active technologies. Ideas include; lots of insulation in walls and roofs, sealing against infiltration, efficient windows and doors, and reducing thermal bridges with framing at 24” on center, use of California corners and use of T-studs.
- Electrify everything, because while you can supply yourself electric power, you can’t produce natural gas.
- Ductless mini-split HVAC systems are considered the most efficient. Air source heat pumps are recommended for use as furnaces.
- Induction cooktops are more efficient than using gas and much more than standard electric ranges.
- Be picky, but buy smart. Look for ENERGY STAR ratings on appliances. Purchase LED fixtures with built-in motion detectors and automatic shut-offs. Use condensing dryers instead of those that vent to the exterior.
- Reduce, then produce. Put in empty conduits and an empty breaker box to make it easy to add solar power later or possibly replace asphalt roof shingles with solar shingles.

Older Efficiency Technologies

All ideas for energy efficiency and conservation of resources are not new ideas. Here are just a few much older concepts that still apply today.

Energy-Efficient Straw Bale Homes

Building with Straw Bales

Straw bale buildings were used often between 1895 and 1940, but in the late 1990s building codes began acknowledging them as a viable material. One method for using these is a non-load-bearing or post-and-beam style. This uses a structural framework and fills in with bales. The other is a load-bearing or "Nebraska style." Roof loads are supported on top of stacked bales.

Despite historical use, straw bale construction still faces barriers. These include getting approvals from local officials, getting building loans or mortgages, obtaining homeowner's insurance and a lack of acceptance by the community. Local officials can provide information on both building codes and energy codes being enforced.

Log Construction

Energy-Efficient Log Homes

Log homes use solid logs for structure and for insulation. Realizing the full potential of log construction requires careful design, construction, and maintenance to achieve and sustain efficiency.

Energy-Efficient Manufactured Homes

Manufactured homes, also known as mobile homes, are not quite like their early predecessors. Current versions must be built to meet Housing and Urban Development (HUD) guidelines. They are on a permanent chassis and can easily be moved. Caulking and weather stripping, air sealing and energy-efficient lighting and appliances can make these structures energy efficient.

SUMMARY

In review, it seems there are many steps that can be taken, both during the design process and after structures are completed, to reduce our use of energy. These include passive steps like insulating and tightening the building envelope and installing more efficient doors, windows and skylights which are normally holes in those envelopes. In the design phases, choices can be made while positioning buildings on site, to strategically allow or preclude solar gain, admit or deny natural ventilation and maximize or minimize shade as needed for different seasons. After all has been accomplished that can be done to passively minimize energy use, active technologies can be installed to recapture energy or generate power for internal use or storage.

Reasons differ for the decisions made in undertaking renovations to an existing structure, or building new, in a quest for energy efficiency. Some decisions are mandated by increasingly stringent energy codes being enforced. Some are enforced prior to plan approval with compliance software like ComCheck. Some decisions are economical in nature, in an effort to reduce future ongoing utility costs. Some are made from an altruistic desire to better preserve our environment and natural resources for future generations.

Whatever the reason behind them, such decisions all result in a desirable conservation of our natural resources.

DESIGNING FOR ENERGY EFFICIENCY
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REVIEW QUESTION ANSWERS

19. In the United States, buildings account for ______ % of all energy used.
    a. 25
    (Though these seems right intuitively, the number is far too low.)
    b. 40
    (This is the correct number, taken directly from the course material. Considering all the entities consuming energy, not the least of which is vehicles, this is an excellent motivation to seek ways to save energy consumption in buildings.)
    c. 92
    (This is far too high a number.)
    d. 16
    (This is far too low a number.)

20. Which of the following is one of the model energy codes commonly adopted by jurisdictions?
    a. International Energy Conservation Code (IECC)
    (This is the most used model code, published by the International Code Congress.)
    b. SMACMA
    (This is a good organization, but they do not develop codes.)
    c. OSHA Rule 19
    (This is a good organization, but their focus is on worker safety, not energy consumption.)
    d. Southern Building Code Council on Energy
    (To the best of my knowledge, no such organization exists.)

21. Materials used to retard water movement into and through walls are called ___________ .
    a. Waterproofing
    (Retard means to slow down, not prevent movement, as indicated by waterproof.)
    b. Exterior envelope guards
    (It's what they do, but that is not the term used to describe these materials.)
    c. Vapor barriers
    (This is the correct term for materials that resist water in its form as vapor.)
    d. Rigid insulation boards
    (These do act as vapor barriers, but do not describe all materials used as such.)

22. ___________ is a material used to form ductwork in uninsulated spaces.
    a. Foam core plastic sheets
    (This material does not resist heat well.)
    b. Rigid fiber insulation
    (This material is heat resistant, strong enough to resist minor deflection, and easy to work with.)
    c. Extruded plastic tubing

(These are not used for ductwork.)

d. Small SIP products
(These would work, but would be prohibitively expensive, when rigid insulation is also available.)

23. Which of the following is not a common air sealing trouble spot?

a. Joints between foundation walls and footings
(There's just not much air movement down there below grade.)

b. Staircase framing at exterior walls
(Movement from kinetic loading on the stairs tend to loosen joints and seals in this area.)

c. Common walls between attached dwelling units
(Flashing at the roof on either side of these demising walls is difficult to seal and tends to loosen over time.)

d. Shafts for piping or ducts
(It is difficult to seal around these and the seals tend to loosen over time.)

24. ____________ doors lose more heat than any other door type.

a. Patio
(With a single door leaf closing against a jamb, these seal fairly well.)

b. Out-swinging
(Out-swinging doors actually tend to seal better than in-swinging, as outside wind pressure pushes them even more tightly against their jamb.)

c. Antique
(Regardless of the age, any door can be well sealed using modern glazing and weatherproofing techniques.)

d. **Sliding glass**
(A slight gap usually exists so door panels can actually move past each other. With the moving parts, weatherstripping tends to loosen over time as well.)

25. If trying for a passive house design, and solar access is not protected in your area, its best to build on a deep lot with ______ .

a. A mature stand of evergreen trees
(These look nice, but will also create shade and block solar access all year long.)

b. A north-south orientation
(With this type lot, positioning a structure on the north end of the lot ensures a southern exposure that will not be blocked by anyone else building between you and the sun.)

c. An opening in landscaping for prevailing summer winds
(We are seeking access to the sun, not the wind.)

d. Neighborhood covenants restricting amounts of paving
(This is helpful in reducing heat gain from thermal mass storage, but does little for solar access.)

26. Air temperatures directly under trees can be 25° cooler than those above ________ .

a. Asphalt
(The dark color of this material, combined with the stone in its mix, make it an excellent sink for thermal storage.)

b. Concrete pavers
(These pavers are also good for thermal storage, but are light enough in color to reflect some sunlight.)
c. Swimming pools
(Water is excellent for thermal storage, but also tends to try to equalize with the temperature of the earth surrounding it.)
d. Wood shake roofs
(Wood is a fairly decent insulator against heat transfer.)

27. _______ bermed house design exposes one face, usually the south side, but covers the other sides with earth.
a. A semi
(This term is not used to describe underground homes.)
b. An elevational
(This is the term taken from the course material, to describe a house with one elevation exposed and the rest buried.)
c. A submerged
(If a structure were submerged, it would be totally underground.)
d. A well insulated
(That is a result, but is not the term used to describe such homes.)

28. The most common type of HVAC system used is a ____________ .
a. Duct-free system
(These are still a fairly new concept and due to higher initial costs, they are not used often.)
b. Split system
(This seems to be the best system to achieve both heating and cooling with reasonable efficiency at a reasonable cost.)
c. Wood burning stove
(These offer no cooling, are bothersome to those with asthma and are used only infrequently.)
d. Packaged unit
(These are used more often in commercial applications, as the outside unit is fairly large in size.)