Renewable Energy in Building Science Conceptual Framework

Developed for
High School Building Trades and Construction Teachers in Wisconsin

The Wisconsin K-12 Energy Education Program (KEEP)

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Framework Contents

*For the most updated version of this document, please visit the KEEP website at www.uwsp.edu/keep and click on *Resources*, then *Technology Education*.

Since a consistent building science curriculum does not exist at the high school level in Wisconsin, this framework was produced as a reference tool for teachers to use when developing their coursework. This framework serves as the foundation for a curriculum. The concepts contained within the framework provide the basis for a strong, organized and comprehensive curriculum.

In an effort to provide learning concepts in the evolving fields of building science and renewable energy, this framework aims to assist educators in building a curriculum that best fits the needs of their unique education programs. As this framework develops, we welcome constructive feedback and encourage teachers and curriculum developers to assist with modifications to make this reference tool even more comprehensive and useful for the classroom.

This framework and its concepts were derived from multiple sources, including energy education and renewable energy experts, organizations and resources, which are listed in the acknowledgment section.

Purpose

This framework provides high school building trades and construction teachers with a combined reference tool that incorporates key building science and renewable energy concepts that are the most central to this area of learning. Merging building science and renewable energy concepts will provide students with a comprehensive knowledge of not only the importance of energy-efficient building, but also, the how to on correctly integrating renewable energy technologies in construction.

Goals

The goals* of this framework are to:

- Provide construction teachers with concepts that enhance their renewable energy technology teaching competencies in an easy-to-use framework
- Provide students with current knowledge and skills on renewable energy technologies within the construction field
- Ensure that tomorrow's builders have introductory knowledge and skills on renewable energy technologies and can appropriately integrate them into building practices

*The goals of this framework are not meant to train teachers or students on the installation of renewable energy systems. Individuals interested in becoming qualified system installers may independently seek further training to secure Focus on Energy Full Service Installer status or satisfy NABCEP installer certification requirements. Contact the Midwest Renewable Energy Association for more information.

Objectives

By using this framework, teachers will be able to:

- Teach renewable energy concepts within building science courses
- Network with other teachers who teach building science concepts within the We Energies service territory
- Incorporate activities involving renewable energy technologies into current projects and lessons
- Assess students' knowledge and skills in renewable energy technologies

By using this framework, students will be able to:

- Assess the feasibility of renewable energy technologies in construction
- Discuss the value of renewable energy in relation to building science
- Explain the different renewable energy technologies that can be incorporated into a building
- Enter a construction career after graduation with the introductory knowledge and skills of renewable energy technologies and how they can be integrated into building practices

Framework Development Process

The following activities outline the framework development process:

1. Collected existing construction curricula from high schools across Wisconsin.
2. Met with industry professionals to identify building science concepts related to renewable energy technologies that students in building trades and construction courses should know by the time they graduate from high school.
3. Met with teachers from the We Energies electric service territory to organize concepts into a useable format and assign academic standards to each concept.
4. Identified teaching ideas and activities that already exist that address building science concepts.
5. Invited experts to review the content of the framework.
6. Shared framework at the March 2010 Wisconsin Technology Education Association (WTEA) Conference and obtained feedback from participants.
7. Printed final framework and posted on the We Energies and the Wisconsin K-12 Energy Education Program (KEEP) websites.
8. Disseminated printed framework to high school building trades and construction teachers in the We Energies electric service territory.

Overview

This framework builds upon basic renewable energy concepts. Students must understand what renewable energy is and how it generates electricity and/or heats water and air before they can implement the concepts in this framework properly. To learn more about resources and opportunities in renewable energy, review the Appendix section.

This framework will include concepts that pertain to the following renewable energy technologies:

- Photovoltaics (PV) or Solar Electric
- Solar Thermal
  - active (domestic hot water and space heating)
  - passive (space heating)
- Small Wind (100 kW or less)
- Biomass
- Geothermal

These technologies are used to generate electricity, and to heat water and air. The Appendix includes additional information about each renewable energy technology and its construction implications. Hydropower however will not be explored in this framework, due to its separation from building science concepts and its commercial application focus.

What is Building Science?

Building science is the branch of science dealing with the construction, maintenance, safety and energy efficiency of buildings.

Rationale for Building Science Education

It is important to provide a consistent and comprehensive building science education for students at the high school level to build renewable energy and energy efficiency awareness and appreciation early. Additionally, by incorporating building science topics on renewable energy technologies into the curriculum, students' knowledge and practice of cutting edge techniques in the construction industry will grow.

Importance of Utilizing Renewable Energy

Energy-efficient, renewable energy homes can use 30- to 100-percent less energy than a typical home built to Wisconsin's current Uniform Dwelling Code (Focus on Energy 2003). Using less energy has many benefits, including reduced heating and cooling expenses. For these benefits to be realized, renewable energy systems need to be installed correctly, and the building needs to be energy efficient prior to the installations.

Before you purchase any renewable energy system, it is important to first maximize the energy efficiency of your home or business. As a general rule, every dollar you spend on energy efficiency could save you three to six dollars on the cost of a renewable energy system.

Residential Energy Efficiency Programs

ENERGY STAR® is a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Homes recognized as ENERGY STAR homes through this national program are at least 15 percent more energy efficient than homes built to the 2004 International Residential Code (IRC), and they include additional energy saving features that typically make them 20- to 30-percent more efficient than standard homes.

1) The Focus on Energy New Homes Program replaced the Wisconsin ENERGY STAR Homes Program because of the significant increase in the ENERGY STAR requirements and cost to the building. The Focus on Energy New Homes Program was developed in partnership with Wisconsin's building community ensuring that the program meets the specific needs of the state of Wisconsin. Every home in the Focus on Energy New Homes Program undergoes a series of performance tests and must meet specific program standards before being certified. The certification is your assurance that your new home is comfortable, safe, durable, and energy efficient.

   When you build a Focus on Energy New Home, an accredited building performance consultant works with the builder to streamline the certification process. The consultant does all the testing.

   One of the first things the consultant does is run a REM/Rate®—software model on the architectural plans for your home to estimate its energy efficiency. If needed, the consultant will make best-practice recommendations to keep your new home on track for certification.

   The consultant completes two site visits for each Focus on Energy New Home.

Visit 1: Framing and Insulation Installation Review
All new homes are not created equal. Focus' consultant works with the builder to ensure the home is framed in a way that reduces air infiltration. They also review the installation of the insulation to ensure it meets program requirements.

Visit 2: Performance Testing
After construction is complete, the consultant will conduct the required performance testing, which includes testing your home's air tightness. The whole-house ventilation equipment will also be reviewed to ensure compliance with ASHRAE 62.2-2007 and program requirements. All Focus certification standards are also verified at this time. The computer modeling is then updated to calculate the homes estimated energy efficiency.

Finally, the homeowner is presented with a homeowners manual, a certification report, and a plaque, which allows the homeowner to manage their new home efficiently and maintain its performance and value.

There are many benefits of building and certifying a home as a Focus on Energy New Home:

- They are estimated to be at least 10% more efficient than the Wisconsin Uniform Dwelling Code requires, and you have the test results to prove it
- You get external validation that sets you apart from other builders
- 3rd party testing - having a 3rd set of eyes will drastically decrease call-backs
- Peace of mind for the homeowners knowing that their home is more energy efficient, durable, and comfortable than the cookie-cutter home next door
- Environmental benefits – reduces fossil fuel consumption and air emissions
- Increases the market value – if 2 homes were next to each other, one a certified Focus on Energy New Home and the other not, most people would choose the energy-efficient home after learning the benefits; energy efficiency is a selling point.

2) The <u>Home Performance with ENERGY STAR Program</u> is for existing homes that are undergoing renovations or remodeling. Standards for Home Performance with ENERGY STAR include testing and measuring the house for air leaks, inspecting insulation levels, mechanical systems, exhaust fan ventilation, identifying sources of excessive moisture, and evaluating safety issues like combustion appliance venting and carbon monoxide levels. The customer (homeowner) receives a list of home improvement recommendations, which students can complete with the guidance of a consultant. At the end of the project, the consultant will return to retest the house and verify the work was completed correctly and that problems were resolved. It is a valuable learning experience to have student’s present results after final testing is performed.

The Home Performance with ENERGY STAR program is designed to improve the "envelope" or "shell" to an existing home by adding air sealing and insulation. Through the Home Performance with ENERGY STAR Program, homeowners receive a comprehensive, whole house energy assessment and recommendations on energy-saving improvements that are smart for you and your family.

Homeowners that participate in the program receive:

- FREE installation and FREE energy-saving products such as compact fluorescent lamps (CFLs), high efficiency showerheads, and water-saving kitchen and bathroom faucet aerators.
- An energy assessment performed by a Home Performance Trade Ally.
- Rewards of 33.3% of the energy-saving improvement cost up to $1,500.

- Savings bonus up to $700 based on the percentage of energy saved through the installed eligible measures.
- Customizable reports detailing home energy assessment and retrofit recommendations.
- No hassle reimbursements for customer incentives.

To learn more about these programs, visit focusonenergy.com. Click on Residential Programs and then Building a New Home or Home Improvement.

Concept Organization

Areas of Emphasis
Learning concepts have been organized into the following four areas of emphasis:

1. Consumer Awareness (CA)
2. Systems (S)
3. Materials (M)
4. Processes (P)

Consumer Awareness concepts are general and can be incorporated into many courses to help students understand the importance of energy efficiency and renewable energy, as it relates to constructing, renovating and maintaining a building. Exploring these concepts will show students the impacts energy consumption has on home maintenance, appliances and the economy.

Systems concepts include the installation of renewable energy technologies, such as photovoltaics, solar thermal, small wind, geothermal and biomass. These concepts allow students to identify and describe different residential systems, such as HVAC, electrical and plumbing; how systems relate and interact with each other; how each system functions; and key components in each system. Systems concepts can be incorporated into Renewable Energy, Environmental Science, Construction, and Energy and Society courses.

Materials concepts comprise information related to the manufacturing of renewable energy and energy-efficient components, and the specific material requirements for renewable energy and energy-efficient applications. The materials concepts identify the advantages and disadvantages of materials used in the construction of an energy-efficient and a renewable energy ready building. These concepts will be useful in courses such as Drafting, Architectural Design, Architectural Engineering, Estimating, and Building Research and Development.

Processes concepts focus on the actual construction of a building. Included in these concepts are building codes, framing techniques, the installation of insulation and vapor retarders, and the placement of windows and doors. These concepts can be integrated into construction courses as well as home maintenance courses.

Topic Areas

The concept table also is grouped according to topic area, which is intended to help teachers find information quickly when teaching a specific unit or skill. These topic areas are arranged so that they build upon each other. For example, before understanding how renewable energy systems are integrated into construction projects, students first must understand general building science concepts that are integral to successful renewable energy integration.

There are many building science concepts; however, this framework focuses on those most directly related to renewable energy systems.

I. General
II. Building Envelope
   a. Heat Transfer
   b. Ventilation and Indoor Air Quality
   c. Insulation
   d. Windows/Doors
   e. Moisture
III. Site/Placement/Orientation
IV. Building Codes/Zoning Laws
V. Energy Efficiency
VI. Renewable Energy Systems
   a. Solar (in general)
   b. Photovoltaics
   c. Solar Thermal
   d. Small Wind
   e. Biomass
   f. Geothermal

Wisconsin's Model Academic Standards for Technology Education

The Wisconsin's Model Academic Standards for Technology Education that coincide with concepts contained within each Area of Emphasis have been identified. The Academic Standards are divided into four components:

1) *Nature of Technology:* Students in Wisconsin will understand that technology is an extension of human capability.

2) *Systems:* Students in Wisconsin will recognize that systems are made up of individual components and that each component affects the operation of the system and its relationship to other systems.

3) *Human Ingenuity:* Students in Wisconsin will be able to define problems, gather information, explore options, devise a solution, evaluate the outcome, and communicate the results.

4) *Impact of Technology:* Students in Wisconsin will understand that technology affects society and the environment in ways that are both planned and unplanned and desirable and undesirable.

Additional information on Wisconsin's Model Academic Standards can be found at www.dpi.wi.gov/.

International Technology Education Association Literacy Standards

In the following Concept Table, the International Technology Education Association (ITEA) Literacy Standards are listed after the Wisconsin Standards in the Academic Standards column. The five ITEA literacy standard categories are:

1) *The Nature of Technology:* This category describes what students should understand about the nature of technology in order to become technologically literate.

2) *Technology and Society:* This category deals with how the use of technology affects society and the environment, as well as how society influences the development of technology.

3) *Design:* This category addresses how design is at the core of the problem solving process of technological development. It also addresses the premise that becoming literate in the design process requires acquiring the cognitive and procedural knowledge to create the design, in addition to familiarity with the processes by which the design will be carried out to make a product or system.

4) *Abilities for a Technological World:* This category addresses the development of important abilities for a technological world, which include applying the design process, using and maintaining technological products and systems, assessing products and systems, and others.

5) *The Designed World:* This category approaches the designed world as the product of a design process, which provides ways to turn resources such as materials, tools and machines, people, information, energy, capital, and time into products and systems.

Additional information regarding on ITEA's Literacy Standards can be found at www.iteaconnect.org/TAA/Publications/TAA_Publications.html.

Concept Table

Wisconsin's Model Academic Standards for Technology Education are listed first in the Academic Standards column.

Concepts	Academic Standards	Areas of Emphasis			
I. General		**CA**	**S**	**M**	**P**
1. Buildings work as a system of interrelated elements.	WI: A.12.3, A.12.4, A.12.7, B.12.1, B.12.2, C.12.1, C.12.5, D.12.4, D.12.5, D.12.6 ITEA: 2, 4, 5, 12, 20	X	X		X
2. Achieving a healthy and safe building with optimal indoor air quality means controlling heat, air flow and moisture.		X	X		
3. Occupants affect the durability and comfort of a building by the way in which they operate its mechanical systems.		X	X		
II. Building Envelope		**CA**	**S**	**M**	**P**
4. Energy-efficient construction minimizes air leakage with careful framing details, application of exterior wraps and flashing, and sealing all gaps and seams using sealants, foams and tapes.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20		X	X	X
5. Constructing a building with a thermal boundary, which is made up of a continuous envelope of insulation, an air barrier, and vapor retarder, is a vital component of building science.			X		X
a. Heat Transfer (loss or gain)		**CA**	**S**	**M**	**P**
6. There are three methods of heat transfer: conduction, convection and radiation.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20		X		X
7. Conduction is the process of heat flow from molecule to molecule in a solid substance.					X
8. Convection is the process where heat is transported by the movement of liquids and gases. Heat flows from areas of higher temperatures to lower temperatures. Heat itself does not rise; warm air rises. As warm less dense air rises in a building, cool denser air is brought into lower areas of a building, creating a thermal and pressure gradient. Heat is also carried by air which flows from high pressure to low pressure (a pressure gradient). Pressure gradients have no effect on the heat itself; only on the air that is carrying the heat.					X
9. Radiation is energy transfer, including heat transfer, via electromagnetic waves. The two types of radiation important to the study of building science and renewable energy is solar energy and infrared radiation from cooler					X

		CA	S	M	P
objects on earth, emitted as different wavelengths.					
10. Air leakage is perhaps the most important and least evident source of heat loss. It can account for as much as one-third of a building's heat loss, which can result in high heating and cooling costs.		X	X		X
11. Heat transfer (loss or gain) from air leakage (convection) could range from 15-25%, mostly from the attic and the foundation/house connection. Heat transfer (loss) from conduction through an uninsulated foundation could range from 30-40%.		X	X		
12. Building airtight can significantly reduce heat loss due to air leakage. A common misunderstanding is that you can build too airtight. This is not true. If a building is airtight, it must have adequate ventilation.		X	X		X
b. Ventilation and Indoor Air Quality		**CA**	**S**	**M**	**P**
13. Controlled ventilation provides a building occupant the ability to manipulate when and how much ventilation the building needs and to guide the path of the air.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20	X	X		
14. The purpose of ventilating a building is to provide the occupants with a healthy and comfortable space, that is, less indoor pollutants and excess moisture, which could lead to microbiological problems. See Moisture concepts below.		X	X		X
15. There are three basic ventilation strategies: natural, whole-house and spot ventilation.		X	X		X
16. As a building becomes more airtight, a controlled ventilation system must either be present or installed to provide adequate air exchange.		X	X		X
c. Insulation		**CA**	**S**	**M**	**P**
17. Insulating basements and crawl spaces is critical to reduce heat loss.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20	X	X	X	X
18. Insulation traps air or other gases, slowing conductive heat loss.		X		X	
19. Choosing the appropriate type and amount of insulation, and installing it correctly are critical in reducing heat loss.		X		X	X
20. Insulation is rated in terms of thermal resistance called R-value, which measures the ability of a material to slow down the transfer of heat. The higher the R-value, the better the material is at insulating.		X		X	
d. Windows/Doors		**CA**	**S**	**M**	**P**
21. Advancements in window and door technology over the last decade have improved the thermal performance of buildings.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4,	X	X	X	X
22. Windows are often the most poorly insulated element of a building, and are		X	X	X	

		CA	S	M	P
often the first surfaces on which condensation occurs. See Moisture concepts below.	C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20				
e. Moisture		**CA**	**S**	**M**	**P**
23. The dew point is a function of temperature and relative humidity. Dew point is the temperature at which water vapor condenses to liquid. Relative humidity is a term used to describe the amount of water vapor in the air compared to the maximum amount possible.	WI: A.12.1, A.12.7, B.12.2, B.12.4, B.12.5, B.12.7, B.12.8, C.12.2, C.12.3, C.12.4, C.12.5, C.12.6, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 9, 11, 16, 20				X
24. Warm air from an interior space can hold a lot of moisture. As this moist air exits the building through air leakage, if it contacts a surface that is below the dew point, it will condense on that surface which may be within the building envelope. This water can lead to structural failure from disintegrating gypsum wallboard or rotting wood. It can also affect indoor air quality by fostering the growth of biological pollutants such as mold and mildew.		X	X	X	
25. Maintaining an indoor relative humidity in the range of 25- to 35-percent is optimum.		X			
26. Placement of a vapor retarder on the warm side of the building envelope prevents the transport of water vapor to an area in the wall or ceiling where it could condense.			X	X	X
III. Site/Placement/Orientation		**CA**	**S**	**M**	**P**
27. If a building is strategically positioned, it will be able to use natural lighting, heating, cooling and ventilation, which will save energy and money.	WI: A.12.2, A.12.3, A.12.4, A.12.7, B.12.2, B.12.4, B.12.5, B.12.6, B.12.7, B.12.8, C.12.1, C.12.2, C.12.3, C.12.4, C.12.6, C.12.7, C.12.9, C.12.10, C.12.11, D.12.1, D.12.2, D.12.4, D.12.5, D.12.6, C.12.10, D.12.1, D.12.4 ITEA: 2, 3, 4, 5, 8, 9, 11, 16, 20	X	X		X
28. Passive solar design is accomplished by siting a building with proper solar orientation, appropriate placement of windows and the use of specific building materials to create thermal mass.			X	X	X
29. Buildings constructed into south-facing slopes allow the basement to be open to day lighting and passive heating.			X		X
30. Buildings constructed into south-facing slopes can more easily take advantage of earth berming, which uses the earth as insulation.			X		X
31. Trees, particularly deciduous trees that provide shading, will keep a building cooler in the summer.		X			X
32. Shade trees or shrubs planted along the west and north walls reduce heat gain on summer afternoons and heat loss from winter winds.		X			X

33. Properly sized roof overhangs protect south-facing windows from summer sun, but allow the winter sun to enter and warm the building.					X
34. Thermal mass, such as tile, stone, or brick, allows heat storage, which maintains the interior temperature of a building.			X	X	X
35. Passive cooling elements include using an open floor plan, strategically placing operable windows to make use of prevailing breezes for cooling the building at night; and installing operable ceiling vents and skylights to keep hot air moving up and out of the building.			X	X	X
36. Energy-efficient buildings with passive cooling elements do not use air conditioning as often as buildings without passive cooling elements.		X	X		
37. Using the sun as an indoor light source is known as day lighting.		X	X		
38. Day lighting is best done with reflected cool light. Small, shaded windows mounted high on all but the north walls provide the best day lighting. Skylights that get direct sunlight should be avoided. Light-colored paint on overhangs outside of windows reflects light into the building.		X		X	X
39. Windows, sunspaces, solariums or greenhouses located primarily on the south side of a building allow sunlight to pass through heating the interior spaces. Placing large windows or sun-collecting structures on the west and north sides of a building should be avoided.					X
40. Reflective sunlight tubes can provide plenty of light without significantly increasing heat gain or loss through the roof. These are particularly useful for windowless areas.		X		X	X
41. To maximize solar access, the roof surface and pitch should be within 30 degrees of due south and unobstructed from both winter and summer sun.					X
IV. Building Codes/Zoning Laws		**CA**	**S**	**M**	**P**
42. Wisconsin's energy building code is a minimum requirement.	WI: A.12.3, A.12.4, A.12.5, C.12.4, C.12.6, D.12.4, D.12.6 ITEA: 4, 5, 6	X			X
43. Wisconsin State law does not allow zoning or covenants that restrict the use of a solar energy system, except for reasons of health and safety.		X	X		X
44. Permits may be needed to ensure renewable energy systems comply with local ordinances and state building codes. See page 19 for a chart showing Wisconsin Building Issuing of Permits.		X	X		X
45. Walls, windows, attics and foundations should be insulated beyond what is required by state code to provide additional energy saving benefits.		X	X	X	X
V. Energy Efficiency		**CA**	**S**	**M**	**P**
46. The more energy efficient a building is, the less energy is used, meaning less money will need to be spent on renewable energy systems to meet the energy demands of the building.	WI: A.12.7, B.12.7, B.12.8, C.12.2, C.12.5, C.12.10, D.12.1, D.12.4	X	X		

47. Energy efficiency strategies typically cost less than renewable energy technologies, particularly when included in the original construction.	ITEA: 2, 5, 9, 12, 13	X			X
48. Electricity is the most expensive and inefficient option for sources of heat, such as furnaces, heaters, water heaters, stoves and clothes dryers. Therefore, other options should be considered before using electricity for heating purposes.		X		X	X
49. ENERGY STAR qualified lighting, appliances, and heating, ventilating, and air conditioning (HVAC) systems should be incorporated for efficiency.		X		X	X
50. A load analysis should be included as an important step in the process of understanding energy use and making efficiency improvements.		X	X		
51. Choosing to build a smaller building is a critical step toward being energy efficient.		X	X	X	
VI. Renewable Energy Systems		**CA**	**S**	**M**	**P**
52. When consumers consider purchasing renewable energy systems, they are often concerned about payback. Payback refers to recovering the initial cost of purchasing and installing a renewable energy system through its production of energy, which reduces or avoids future energy costs. The Return on Investment (ROI) is also important to consider. The ROI is the savings generated by installing a renewable energy system expressed as a percentage of the cost.	WI: A.12.2, A.12.3, A.12.4, A.12.7, B.12.2, B.12.4, B.12.5, B.12.6, B.12.7, B.12.8, C.12.1, C.12.2, C.12.4, C.12.6, C.12.7, C.12.9, C.12.10, C.12.11, D.12.1, D.12.2, D.12.4, D.12.5, D.12.6 ITEA: 2, 3, 5, 6, 11, 20	X	X		
53. It is always more cost effective to use energy more efficiently than to generate larger amounts of energy with a renewable energy system. By correctly sizing the building's heating, cooling and water heating systems, energy loads can be reduced or minimized.		X	X	X	X
54. A site assessment of the property determines if there is adequate space and proper orientation for a renewable energy system.		X	X		X
55. Renewable Ready buildings have proper solar orientation and spaces for water pipes and electrical conduits - simple measures that cost little. Renewable energy systems can be added to a Renewable Ready building at a later date.		X	X		X
56. Renewable energy systems that produce electricity can be stand alone, meaning they are off the grid and without utility power at the site, or grid-tied, wherein any excess power produced is backfed in to the utility power lines. Grid-tied systems receive electricity from the grid if the renewable energy system does not produce enough electricity needed by the building and its occupants.		X	X		X
57. Renewable energy systems can be directly tied to the grid and have zero battery storage, be grid-tied with battery back-up, be off-grid with batteries,		X	X		X

		CA	S	M	P
and be off-grid without batteries. This last option usually has a combination of renewable energy systems that complement each other, with one system providing energy while the other doesn't.					
58. In a renewable energy system, the balance of system (BOS) refers to all components of the system, including the mechanisms and support structures used to transfer energy from the collection devices to the storage systems, the buildings' end uses or to the grid.			X		X
59. Adequate space inside the building is needed to allow room for mechanical components of a proposed renewable energy system.		X	X		X
a. Solar (in general)		**CA**	**S**	**M**	**P**
60. Solar energy is used to generate electricity or to heat air or water. Solar heating can be passive or active. A passive solar heating system captures the sun's energy within a structure and converts it into low-temperature heat, which then naturally circulates. In an active solar heating system, collectors absorb solar energy, and then pumps or other devices are used to circulate the heated fluid.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, C.12.1, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X	X		X
61. Solar systems are modular, which means: • there is flexibility in the way they can be arranged • they can be moved if needed • they can be added to as money allows and occupants' needs change.		X	X	X	X
62. Solar systems are reliable and quiet, and they can be installed quickly and easily. They are also easily maintained.		X	X	X	X
63. Installing blocking under the roof provides surfaces to mount collectors for solar systems.			X		X
b. Photovoltaics		**CA**	**S**	**M**	**P**
64. Photovoltaic (PV) systems can consist of a fixed array (mounted on a roof or pole) or an array mounted on a tracker on a pole.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.4, B.12.5, B.12.7, C.12.1, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.1, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X	X	X	X
65. Building Integrated Photovoltaic (BIPV) systems are incorporated directly into the design and construction of a building, replacing traditional building materials used in roofs, window overhangs and walls.		X	X	X	X
66. BIPVs are less obtrusive but cost more than standard PV panels mounted on a building or pole.		X	X	X	X
67. Specific roof load capacities should be taken into account before installing a PV system on the roof of a building.			X		X
68. Adequate space is necessary to provide access to electrical components of a PV system. This space can be reserved in the attic, basement or separate control room.			X		X

c. Solar Thermal		CA	S	M	P
69. Most buildings that use solar thermal heating systems often require a backup heating system, whether or not the solar thermal system stores the energy collected.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.7, C.12.1, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X	X		X
70. Specific roof-load capacities should be taken into account before installing a solar thermal collector on the roof of a building.			X		X
71. For domestic water heating provided by a solar thermal system, adequate space is needed in a basement or utility area for an additional water storage tank.			X		X
d. Small Wind		CA	S	M	P
72. There are three different tower options for a wind system: tilt-up, lattice and freestanding. A sizeable area of land or property is recommended for all tower types for maintenance and safety precautions.	WI: A.12.7, B.12.1, B.12.2, B.12.7, C.12.1, C.12.5, C.12.6, C.12.8, C.12.9, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X		X	X
73. Wind turbines need to be located at least 30 feet above any trees or buildings that are within 500 feet of the wind turbine to prevent air turbulence.			X		X
74. Mounting a wind turbine to a building is not recommended. Vibrations from the turbine can cause noise and structural problems. Excessive turbulence can also shorten the life of the turbine.		X	X		X
75. Adequate space in a control room is necessary to house the electrical components of a small wind system. Other components housed inside can include a transformer, controller, inverter, and possibly a battery bank.			X		X
e. Biomass		CA	S	M	P
76. Wood can be burned in a fireplace, wood stove or masonry heater.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.7, C.12.1, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X	X	X	
77. An open fireplace includes a chimney where much of the heat escapes, making open fireplaces an inefficient heat source. Zero clearance fireplaces have doors that close which makes them more efficient.		X			X
78. A wood stove is a closed apparatus making it more efficient than an open fireplace.		X			X
79. A masonry heater allows wood to burn very quickly at high temperatures and stores the heat released by the wood in the masonry mass of the heater. Masonry heaters also have great design flexibility allowing for a wide variety of heated benches, bake ovens and variable chimney placement.		X			X
80. All wood burning devices are best placed centrally in a building with a chimney that exits at the highest part of the roof.		X	X		X
81. The simplest and least expensive biomass installation choice is a wood or pellet stove. The next level of cost and complexity is a zero clearance		X			X

fireplace. Masonry heaters tend to be the most costly and complex biomass installation choice.					
82. Masonry heaters can be added to existing buildings, but are more easily incorporated into new buildings. In general, existing buildings that have a centrally located masonry hearth are good candidates for a future masonry heater installation.			X		X
83. Preparing for a masonry heater includes installing a footing, and framing floors and roofs to accommodate the foundation and chimney.			X		X
f. Geothermal		**CA**	**S**	**M**	**P**
84. Geothermal installations require space outdoors, which could include space underground beneath a yard or a body of water with adequate depth where the water stays at a consistent temperature year round.	WI: A.12.1, A.12.7, B.12.1, B.12.2, B.12.7, C.12.1, C.12.3, C.12.4, C.12.5, C.12.6, C.12.8, C.12.9, C.12.10, C.12.11, D.12.4 ITEA: 2, 3, 4, 11, 12, 16, 20	X	X		X
85. Geothermal systems can be installed vertically or horizontally in the ground.			X		X
86. If placing geothermal tubing in soil, heavy machinery is needed to dig trenches for tubing and to cover tubing after installation.					X
87. Trenches can be dug and tubing installed as the building's foundation is being poured.					X
88. Space inside the building is required for the heat pump and an additional water tank where the heated water from the geothermal system is to be stored.			X		X

Wisconsin Building Issuing of Permits

This chart is a guideline for educators to teach about the permit process. As the chart is basic, it may not be applicable to the individual project or permits that fall under specific municipalities' regulations.

Plan Review (2 sets of plans)	Permit Issue	Erosion Control	Footing Inspection	Foundation Inspection	Rough-in Inspection (framing, plumbing, electrical, HVAC)	Insulation Inspection	Occupancy or Final Inspection
Site Placement and Orientation	X	X	X	X	X	X	X
Photovoltaics	X	X	X	X	X		
Solar Thermal	X	X	X	X	X	X	
Small Wind	X	X	X	X	X		
Geothermal	X	X			X	X	
Biomass	X		X	X	X		

LEED Certificate Note: LEED stands for Leadership in Energy and Environmental Design. LEED for Homes promotes the design and construction of high-performance green homes. If you would like to build a LEED-certified home, contact the U.S. Green Building Council to learn more.

Activities and Teaching Ideas

The following activities can be obtained by taking Natural Resources (NRES) one-credit graduate level KEEP courses offered through Continuing Education at the University of Wisconsin-Stevens Point. Information on upcoming KEEP course offerings can be found on the KEEP website under Professional Development.

NRES 730 – Energy Education in the Classroom
NRES 731 – Selected Topics in Energy Education
NRES 732 – Renewable Energy Education in the Classroom (Doable Renewables)
NRES 733 – Energy Education: Concepts and Practices (online course)
NRES 734 – School Building Energy Efficiency Education
NRES 735 – Renewable Energy Education (online course)

1) *At Watt Rate?* (NRES 730) – Students complete a survey to determine how much electricity various appliances use in their homes.

   Objectives
   Students will be able to:
   - Calculate the energy use of various appliances in their home
   - Compare the amount of energy used by appliances
   - Analyze their energy use patterns and suggest ways to save energy

2) *Careers in Energy* (NRES 730) – Students investigate energy related careers through research, interviews and job shadowing.

   Objectives
   Students will be able to:
   - Identify and describe different energy related occupations and careers
   - Research the skills and education required for a particular energy related occupation

3) *Community Energy Use* (NRES 730) – Students survey local residents and businesses to learn how their community uses energy.

   Objectives
   Students will be able to:
   - Identify representative energy users from each economic sector in their community
   - Summarize the various end uses of energy in their community

4) *The Cost of Using Energy* (NRES 730) – Students calculate the cost of energy used by various products found in the home and at school.

   Objectives
   Students will be able to:
   - Calculate the cost of energy used by various products
   - Compare the costs of buying and operating lights and appliances

5) *Don't Waste Waste* (NRES 732) – Students harvest celery to demonstrate waste accumulation from timber practices and brainstorm uses for the waste products.

Objectives

Students will be able to:

- Describe the parts of a tree
- Define biomass
- Identify alternative uses of the wood that is left behind after harvesting
- Explain how biomass can be used to create energy

6) *Energy Action Plan* (NRES 730) – Students develop an action plan that addresses an issue related to energy resource management.

Objectives

Students will be able to:

- Contrast possible solutions to an energy related issue
- Develop an energy action plan
- Implement the energy action plan to promote positive behavior regarding energy use, to help resolve an energy-related issue, or both
- Judge the effectiveness of their action plan

7) *Energy Investigations* (NRES 730) – Students investigate and develop a report on an affect of energy resource development, use or both.

Objectives

Students will be able to:

- Analyze a problem or issue related to how energy development and use affects human societies and the environment
- Develop a report that clearly and accurately presents the results of their analysis

8) *Geothermal Gazette* (NRES 732) – Students will act as reporters assembling a newspaper on geothermal energy.

Objectives

Students will be able to:

- Describe how a geothermal heat pump works
- Provide examples of geothermal energy use in Wisconsin

9) *Green Home Design* (NRES 732) – Students design plans for a green-built house.

Objectives

Students will be able to:

- Explain green building design
- Understand the four principles of green building design
- Explain what components go into the design of a green home.

10) *Insulation Creations* (NRES 732) – Students test various insulating materials while trying to prevent a liquid from cooling.

Objectives

Students will be able to:

- Define what insulation is
- Compare the insulating capacity of various materials
- Recognize the connection between insulation and energy conservation

11) *Let the Sun Shine In* (NRES 732) – Students calculate how much solar energy contributes to their home or school heating.

Objectives

Students will be able to:

- List the factors that affect the solar heat gain of their home or school
- Determine the amount of solar heat gained through windows

12) *Placement Matters* (NRES 732) – Through a series of experiments, students investigate how placement and orientation of a solar cell affects electricity production.

Objectives

Students will be able to:

- Demonstrate how PV cells best should be positioned for solar collection and electricity generation
- List factors solar consultants consider when placing solar panels on homes and businesses

13) *So You Want to Heat Your Home?* (NRES 730) – Students calculate the amount of fuel needed to heat an average-sized home using different types of fuel and different heating system efficiencies.

Objectives

Students will be able to:

- Recognize how different fuels and different heating system efficiencies contribute to the cost of home heating
- Determine which heating system is most efficient and economical

14) *Sustainable Communities* (NRES 732) – Students identify current energy-use practices and incorporate renewable energy use into community planning.

Objectives

Students will be able to:

- List considerations for renewable energy use in a subdivision
- Define solar access
- Discuss cost benefits and drawbacks to developing a community utilizing renewable energy

15) *Where the Wind Blows* (NRES 732) – Students use their senses and observational skills to assess wind speed.

Objectives

Students will be able to:

- Measure wind speed using activity equipment
- Describe characteristics of wind

Sample Activity – *Green Home Design*

Green Home Design

Summary: Students design plans for a green built house.

Grade Level: 9-12

Subject Areas:
Family and Consumer Science, Mathematics, Science, Technology Education

Setting: Classroom

Time:
Preparation: One hour
Activity: Three to five 50-minute periods

Vocabulary:
Energy efficient design, Green building, Green design, Whole-building design

Major Concept Areas:
Theme III
- Quality of life
  - Lifestyles
  - Economic

Theme IV
- Management of energy resource use

Academic Standards:
FCS: C.3
MA: C.12.1, D.12.3
SC: A.12.5, G.12.1, G.12.3, G.12.4, H.12.5
TE: A.12.2, A.12.7, B.12.2, B.12.4, B.12.5, C.12.2, C.12.4, C.12.6, C.12.9, D.12.4

Objectives
Students will be able to
- explain green building design;
- understand the four principles of green building design; and
- explain what components go into the design of a green home.

Rationale
Involving students in designing a model home allows them to relate renewable energy and energy efficiency concepts to a practical experience.

Materials
- Internet and resources on green home design (see **Resources** and the KEEP Web site)
- Copies of ***Green Home Design Project***
- Graph paper
- Writing utensils

Background
The average square footage of today's houses has greatly increased, while family size has decreased. In the 1950s, an average American family of six would fit into the space of today's family garage. These larger residential and commercial buildings affect land, water, air, and energy elements on which all living things depend for survival. Americans spend 90 percent of their lives indoors within built environments that contribute to increases in allergies and health issues. On a global scale, buildings affect the environment drastically; they use 40 percent of global resources, or 3 billion tons of raw materials, 25 percent of hardwoods, and 35 percent of energy resources annually. Of the materials used to manufacture a new building, about 30 percent end up as construction and demolition debris. Buildings create half of the global outputs of greenhouse gases.

The green building approach reduces the adverse effects of building construction. There are varying aspects and degrees to building "green." For example, green buildings include traditional and manufactured houses built with natural materials, as well as solar- and wind-powered homes. On the whole, green built houses are more energy efficient and healthy.

Compare the photographs of winter and summer to see where the shadow falls on the house. Why is this beneficial?

Energy use is one of many aspects considered in green home construction. Green homes can be powered with renewable energy sources such as passive and active solar, wind, or geothermal when practical. The places we live in rely on incoming energy to function. The majority of homes are connected to natural gas supply lines or LP tanks, the electric grid, water supply lines, and sewer systems. The energy efficiency of a home depends not only on the energy source a home utilizes, but ultimately on how the resources are used in the building envelope, mechanical equipment, and appliances once they reach the home. Green buildings can reduce energy use 50 percent over the state building code. Decreased energy consumption reduces use of fossil fuels and global warming contributions. One unit of electricity generated or saved by a green building prevents three or four units of fuel (often coal) from being burned at a power plant to generate electricity. An average green built home in America reduces CO_2 emissions by almost 90,000 lbs over its 30-year lifetime.

Energy is just one component of the principles of green design. See the ***Four Principles of Green Design***. This is not an exhaustive list; rather, it highlights some of the more important elements to consider when designing a green building. See the **Resources** section for additional comprehensive listings and rating systems.

Other components considered in green building include utilizing materials and furnishings intended to sustain the quality of the environment. Green homes are designed to assure a healthy indoor environment for their occupants. They typically have lower operating and maintenance costs. These factors combined result in a home that is better for the occupants and for the environment. Green buildings have fewer negative effects on the environment, on human health, and on our pocketbooks.

Procedure

Orientation

Instruct students to work individually or in pairs to quickly design their dream home. Invite students to share their designs with the class. Discuss the positive aspects of the design. See if they considered heating and cooling, water use, appliance use, and other typical activities. What are the energy sources for electricity and heating and cooling? Next, ask if there are negative aspects to the design. Encourage them to consider how their building construction and resource use might affect the environment. Did students consider indoor air quality and the health of the occupants?

Ask students if they know of any homes in the community built to be resource and energy efficient? If so, ask them to list aspects of the home that they think are efficient or "green." Have students revisit the dream home they sketched. How might students redesign it to be more "green"?

Steps

1. Introduce the concept of green home design, discussing the ***Four Principles of Green Design***. Encourage students to research further into the green design principles by browsing the Internet and visiting the library. If possible, invite guest speakers, such as green architects or ENERGY STAR certified builders, to share information with students on green design.

2. Tell students they are going to practice green home building design. Have students work in small groups, providing each group with a copy of ***Green Home Design Project***. Make sure students understand the assignment. NOTE: The activity involves students creating floor plans to illustrate their designs. If time and resources are available, students can build three-dimensional models.

3. Allow students one week to design their homes. Given the potential scope of this project, it might be wise to have students focus primarily on one component, such as energy efficiency and renewable energy. Continue to remind them, however, of the importance of all the principles including whole-building design. Have them support their design process with research from the Internet, library searches, and communications with home owners and designers. Visit the KEEP Web site for additional illustrations and links to green home design.

Closure

Have students share their home design and reasoning for site, product, and design decisions. Post the design principles on the board and have each group identify how their plans address the principles. Ask the class to assess the positive and negative aspects of each home. Ask the class to share their views about the importance of green home design.

Assessment

Formative

- Did the students incorporate green design elements, including energy efficiency and renewable energy components, into their home design?
- Have students list the principles of green home design.
- Can students explain the importance of incorporating the green design principles into home building?

Summative

Have students write a paragraph detailing what choices they made in their design that are essential to developing a green home. Give the students an example of a poorly designed home in terms of green building principles and have them suggest ways of improving the design.

Extensions

Have students modify their home design to provide all of the typical amenities of modern living (heat, electricity, hot water, etc.) but functioning as a completely off-grid unit. All electricity, heat and hot water must be produced or harvested on-site. Remind students to analyze appliances used, and the lifestyle changes they will need to make to adapt to the conversion. Have students give a detailed description of the systems they plan to use, the technology involved, and a discussion of cost relative to a conventional system.

Another extension is to have students analyze the home or apartment that they live in currently (See KEEP Activities "So You Want to Heat Your Home?" and "At Watt Rate"). What changes could be made to increase energy efficiency and sustainability at home? What lifestyle and economic requirements would these changes require?

Four Principles of Green Design

1. Design the building and orient it on the site with natural elements in mind to use:

- Prevailing winds (for natural ventilation)
- Solar access (for daylighting and passive and active solar design)
- Landscaping (e.g., trees that provide shade)
- The ground (e.g., building into hillsides, avoiding heavily trafficked areas)

2. Design for resource efficiency:

Water efficiency
- Water efficient site landscaping (e.g., use of native species, rain gardens, cisterns, green roofs)
- Indoor water use reduction techniques (e.g., appliances, fixtures)

Energy efficiency in the design
- Use renewable energy (e.g., solar electric, solar thermal, wind, geothermal, wood)
- Energy efficient design, construction, and mechanical and fixture choices (e.g., lighting fixtures, ENERGY STAR appliances, HVAC, electronics)

Building materials efficiency
- Materials efficiency in design
  (1) Minimize the building's footprint (avoid redundant spaces like having both a formal living room & family room)
  (2) Avoid use of excessive or superfluous building materials
- Locally or regionally extracted materials (rather than importing from environmentally sensitive or endangered regions of the world)
- Renewable, reused, recycled materials, ENERGY STAR appliances

3. Create a healthy home:

- Non-toxic materials and finishes (e.g., glues, paints, cleaning products, non-absorptive materials such as hard surfaces versus carpet)
- Design for proper ventilation

4. Take an integrated "whole-building" design approach:

Whole-building design considers all construction components during the design phase. It integrates how all the subsystems and parts of the building work together to save energy and reduce environmental impact. This whole-building philosophy considers site, energy, materials, indoor air quality, acoustics, natural resources, and their interrelation. For example, a building that uses daylighting techniques will not need as much artificial lighting, reducing the amount of heat given off by light fixtures, resulting in the need for a smaller air conditioning system.

Green Home Design Project

Project Guidelines

1. Indicate which direction your graph paper is oriented by drawing an arrow and indicating which direction is north.

2. Draw floor plans on graph paper including a scale of measurement, room identification, permanent fixture identification, and square footage for rooms and the whole house.

3. Design your house, pointing out how your design addresses the following green design principles:

Consideration for the natural elements of the building site
Resource efficiency, including energy (see #4 below)
Promoting healthy living
Whole-building design

4. Below is a limited list of energy design considerations. On a separate page, list how you might use these or other energy efficiency and renewable energy components in your home. Include definitions and information about each component and how it is integrated, used, or built into your home.

Selected Energy Efficient and Renewable Energy Design Considerations

Photovoltaic solar panels
Energy efficient lighting options (ENERGY STAR® qualified CFLs and LEDs)
Passive solar design
Window design, type, and orientation
Insulation & R-value
Heating, cooling, and ventilating systems
Energy efficient appliances & electronics (ENERGY STAR qualified)
Masonry stoves

Credentials and Certifications

1) Midwest Renewable Energy Association
   Certified Site Assessors
   Certified System Installers
   www.midwestrenew.org

2) Wisconsin Cooperative Education Skill Certification-Construction
   Wisconsin Department of Public Instruction
   http://dpi.wi.gov/cte/coopconst.html
   608-266-2683
   Contact: Brent Kindred

3) Construction Career Academy
   AGC of Wisconsin
   http://www.buildwisconsin.com/teachers.php

4) Heat & Frost Insulators Joint Apprenticeship Committee
   Local 19
   12032-R West Adler Lane
   Milwaukee, WI 53214
   www.milwbuildingtrades.org/apprenticeships.php#I
   Apprenticeship Coordinator: Brett Large
   262-548-9606

Further Training Opportunities

To receive further training in renewable energy or energy efficiency, contact the following organizations:

- Wisconsin Focus on Energy www.focusonenergy.com
- Midwest Renewable Energy Association www.midwestrenew.org
- Energy Center of Wisconsin www.ecw.org
- Wisconsin Technical College System www.wtcsystem.edu

Glossary

A glossary for building science and renewable energy terms can be found on the KEEP website: www.uwsp.edu/keep.

Recommended Resources

1. Organizations
   - Energy Center of Wisconsin
   - Focus on Energy
     - Fact Sheets (available at focusonenergy.com)
       - *Electricity basics for renewable energy systems*
       - *Using renewable energy in your home*
       - *Building new homes that are ready for solar energy systems*
       - *Grid-connected solar electric systems*
       - *Heating with solar air collectors*
       - *Passive solar design in Wisconsin*
       - *Solar hot water systems*
       - *Small rooftop wind turbines*
       - *Using wind energy: small-scale systems*
       - *Geothermal heat pumps for Wisconsin homes, businesses and schools*
       - *Heating your home with wood*
       - *Heating your home with wood pellets*
     - Case Studies (available at focusonenergy.com)
       - *Building a new home*
       - *Energy assessments identify cost saving opportunities*
       - *Comfort and cost savings from clean energy: solar energy for new home (Bircher Home)*
       - *Owning a PV/Wind Hybrid System: Being your own utility*
       - *Renewable heat for a dream home: Davenport home*
   - Green Building Alliance
   - Midwest Renewable Energy Association
   - ReNew Wisconsin
   - re-ARCH: The Initiative for Renewable Energy in Architecture: www.rearch.umn.edu/

2. Websites
   - Visit the KEEP website for various links to other organizations and resources: www.uwsp.edu/keep
   - Visit the We Energies website for energy efficiency and renewable energy information: www.we-energies.com

3. Guest speakers
   - Visit Resources on the KEEP website to view a listing of guest speakers and field trip sites: www.uwsp.edu/keep

4. Books
   - Solar Water Heating: A Comprehensive Guide to Solar Water and Space Heating Systems by Bob Ramlow and Benjamin Nusz.
   - Glenco McGraw Hill textbook Modern Carpentry with accompanying workbook, math book, and safety sheets
   - Indoor Air Hazards Every Homeowner Should Know About by Healthy Indoor Air (Kindle Edition, June 2009)

- How Buildings Work: The Natural Order of Architecture by Edward Allen
- Green From the Ground Up: Sustainable, Healthy, and Energy-Efficient Home Construction (Builder's Guide) by David Johnston and Scott Gibson
- Consumer's Guide to Home Energy Savings: All New Listings of the Most Efficient Products You Can Buy by Alex Wilson, Jennifer Thorne, and John Morrill
- A Primer on Sustainable Building by Dianna Lopez Barnett & William D. Browning – Rocky Mountain Institute (www.rmi.org)
- Builder's Guide to Cold Climates - Energy & Environmental Building Association – Building America (2001 – Joseph Lstiburek) – Out of Print
- Energy-Efficient Building: The Best of Fine Homebuilding by various authors (Taunton Press – 1999)
- Energy-Efficient Houses (Great Houses)
- Energy Performance of Residential Buildings: A Practice Guide for Energy Rating and Efficiency
- Energy Saving Home Improvements from A to Z by Guy Cozzi
- Green Home: Planning and Building the Environmentally Advanced House by Wayne Grady (1993)
- Greening the Building and the Bottom Line: Increasing Productivity through Energy-Efficient Design by Joseph Romm and William D. Browning – Rocky Mountain Institute (www.rmi.org)
- Insulate and Weatherize: Expert Advice from Start to Finish (Build Like A Pro) by Bruce Harley (Taunton Press – 2002)
- No Regrets Remodeling by the editors of Home Energy Magazine www.homeenergy.org
- Residential Energy: Cost Savings and Comfort for Existing Buildings by John Krigger and Chris Dorsi (2004)
- Understanding Ventilation: How to Design, Select, and Install Residential Ventilation Systems by John Bower

5. Technical Guides
    - A Guide to Photovoltaic (PV) System Design and Installation, California Energy Commission, June 2001

6. Videos/Webinars
    - Hometime (a home improvement television show) Videos: www.hometime.com
    - GreenBuilder *Renewable Energy for Builders* Webinar: www.greenbuildermag.com

7. Tools
    - Therma-Stor psychrometric calculator for predicting dew point and water condensation
    - Thermal Laser Gun
    - Air Current Tester (Smoke Pen)
    - Watt's Up? PRO Watt Meter

Renewable Energy Technologies and Construction Implications

This section introduces five renewable energy systems, and the implications they have on construction practices.

Photovoltaics (PV) or Solar Electric

Solar cells convert sunlight directly into electricity. Most cells are made of silicon, a material that comprises 28- percent of the Earth's crust. To produce electricity, cells are wired together to create solar panels, more accurately known as modules, with the modules wired together to form a solar electric array. Solar systems are modular, which means you can start with a small system and add on as your budget allows or as your need for additional energy increases.

Components of System: Array, mounting system, combiner box, inverter, and optional back-up battery and battery charge controller

Construction Implications: The construction implications of a photovoltaics system depends on the technology being installed. Photovoltaic systems can consist of a fixed-array or an array mounted on a tracker, either single or dual axis, which follows the sun's apparent movement across the sky. Systems can also be mounted onto the roof of a building or on a separate pole. Building Integrated Photovoltaic (BIPV) systems are incorporated directly into the design of a building and can include solar shingles and awnings. When building a new home, it can be helpful to make the home solar ready. (See the Building New Homes that are Ready for Solar Energy Systems fact sheet in appendix for more details). The process of making a home or building solar ready is simple and costs little. There are incentives through Focus on Energy to help pay for this process. A south-facing roof with no trees directly to the south is important if the building will include a roof-mounted photovoltaic system. While there may be some real benefits to a ground-based array, typically an array mounted on top of a mast or pipe cemented in the ground, PV arrays are sensitive to even partial shading, and if shade exists at the ground level, the roof may be the better choice. If a roof-mounted array is being considered on an existing building, condition of the roofing material should be evaluated as re-roofing can include the additional expense of array removal and re-installation over the new roof.

If the PV system will be situated on the roof, specific roof load capacities should be taken into account before system installation. PV systems typically weigh no more than 3-4 pounds per square foot. Most roofs can accommodate two to three times that amount of dead load weight; however, blocking may need to be installed under the roof to provide mounting surfaces for the panels. And if the modules are mounted at an elevation angle steeper than the pitch of the roof, wind loading may be a bigger concern. Sunlight has much lower energy density than energy produced with fossil fuels, and therefore energy efficiency measures should be implemented prior to the installation of a photovoltaic system. Such efficiency measures are typically three to five times more cost effective than simply installing more PV capacity to power the less efficient loads. At a minimum, the home should satisfy the Wisconsin ENERGY STAR Homes Program building performance standards, and where possible, incorporate ENERGY STAR qualified lighting, appliances and HVAC systems.

For new construction, maximize solar access by facing the position of the roof surface and pitch within 30 degrees of due south. The roof should be relatively unobstructed from both the winter and summer sun and preferably have a slope of at least 30 degrees. An open and accessible attic space may simplify the installation of a roof-mounted solar system resulting in a lower installation expense. For ground-mounted arrays, location of septic systems, well heads, wires and driveways may become an installation obstacle that increases installation costs - and in new construction should be planned for. Remember to always call Digger's Hotline before digging.

BIPV replaces traditional building materials such as roofs, window overhangs and walls. If wiring individual tiles or shingles together, more time will be needed for proper installation and the importance of attic accessibility increases.

For existing buildings, it is easiest to place solar electric panels on the roof, on a separate pole, or attach them as awnings. Solar electric systems can also be installed as part of the roof by replacing standards roofing products; however, these solar shingles are more costly and less productive than other options and their serviceable life is probably much reduced over that of framed modules.

Consumer Awareness: Solar systems are reliable and quiet, and they can be installed quickly and easily. They are also mobile and easily maintained. Solar electricity has many benefits. Solar electric systems have no fuel costs, low operating and maintenance costs, and produce virtually no air emissions or waste.

While most PV systems being installed today are direct grid-tied, and therefore, battery-less, off-grid or standalone systems are well-suited to rural areas, developing countries and other communities that do not have access to centrally generated electricity. These systems utilize a storage battery because solar energy is not available at night and is less available during cloudy days, making it necessary to store the produced electricity. Backup generators can also be used to support these systems during unusually long cloudy periods. PV systems are typically designed to withstand 110 mile per hour winds, and the module surfaces can tolerate heavy hail. If severe weather conditions result in damage to a PV system, damage will be apparent to other property and buildings resulting in an insurance claim.

Activity/Teaching Idea: *Placement Matters* – Through a series of experiments, students investigate how placement and orientation of a solar cell affects electricity production. Students will be able to demonstrate how PV cells should be best positioned for solar collection and electricity generation and list factors solar consultants consider when placing solar panels on homes and businesses.

Use the Solar Calculator at www.findsolar.com/Widgets/CalculatorEmbed.aspx?t=pro&id=993 to estimate the cost and size of a solar energy project in your area.

Visit www.pvwatts.org/ and click on The PV Watt Photovoltaic Solar System Performance Calculator, then Version 1, PVWatts Version 1 Calculator. Next, click on WI and the city nearest your location. Enter an array size (Try 1 kW.) and use fixed or tracking. Hit Calc and see what production estimates are. Try it with different tilt and azimuth angles. If the array is facing 140 degrees, how does it compare to an array facing south 180 degrees?

Additional Resource: Focus on Energy Fact Sheet: *Building new homes that are ready for solar energy systems*

Solar Thermal

Solar energy used for heating is measured in British thermal units (Btu). There are two ways to use solar energy for heating: active and passive.

Active: A solar collector is used to heat a fluid (e.g. water or air), which then pumps or blows the fluid through tubes or ducts to deliver heat where it is needed. The heat can also be stored in an insulated tank that holds a heated liquid or in heated materials like brick or stone. Residential-active solar heating systems use rooftop collectors to capture sunlight. The collected heat is most often used for water heating, space heating and for heating swimming pools. Some industries use active solar heating systems for manufacturing.

Passive: Buildings must be designed so they capture solar energy and use it to heat the interior. Rooms called sunspaces or solariums, as well as greenhouses, can be built onto the south side of a home or building to collect solar energy. The building is often designed so that the warmed air from these spaces can naturally circulate to other rooms. Some buildings use brick or stone walls and floors to store solar energy for nighttime heating. These systems are called passive solar heating systems. They differ from active solar heating systems in that they do not use mechanical systems to collect or transfer heat.

Components of System:

Active: solar collector, pumps or blowers, tubes or ducts, insulated tank

Passive: sunspace or solarium, greenhouse, windows, mass such as brick or stone

Construction Implications:

Active: To prepare a building for a future installation of a solar thermal system, it is extremely helpful to make the home solar ready. The process of making a home or building solar ready is simple and costs little. There are incentives through Focus on Energy to help pay for this process. A south-facing roof with no trees directly to the south is important if building for installation of a solar thermal system.

For new construction, a significant design item that can impact the installation of a solar water heating system is the need for space in the utility area for an additional storage tank. The additional storage tank is essentially the same size as the existing water heater. In homes with large basements, this is not an issue, but in some homes and buildings, the utility room is barely adequate to house the traditional mechanical systems and there is no additional room for even one additional tank. Maximize solar access by facing the position of the roof surface and pitch within 30 degrees of due south. The roof should be relatively unobstructed from both the winter and summer sun and have a slope of between 30-60 degrees.

For existing buildings, it is helpful to know the design roof load. It is very important to design the roof structure so that it can support the addition of solar collectors. Solar thermal collectors typically add less than five pounds per square foot to the dead load of the roof. A common problem is that builders specify roof structures that just barely meet the minimum weight load capacity that is set forth in the uniform building code and therefore adding anything extra puts one over the limit and requires additional structural modifications later when solar collectors are mounted there. Note that this is a very easy thing to do that has minimum impact on the cost of the building but has a large impact on the cost and difficulty of adding solar collectors. Again, the designer/builder only needs to add five pounds more capacity to the roof structure and this cost is virtually nothing. Blocking may also need to be installed under the roof to provide mounting surfaces for the panels.

Passive: For new construction, windows, a sunspace, solarium or greenhouse on the south side of the building, will allow sunlight to pass through heating the interior spaces. Thermal mass can also be easily achieved by using tile, stone or brick on the interior.

For existing buildings, a sunspace, solarium, or greenhouse can easily be added on the south side at any time. The more challenging task for an existing building is to be sure there is adequate mass that will collect and store the heat from the sunspace, solarium, or greenhouse. Stone or brick may need to be added to the floor or walls. There also needs to be a way for the stored heat within the mass to enter the building, heating the interior spaces and a way to eliminate heat loss at night.

Consumer Awareness: Solar heating offers several benefits. Solar heating systems have minimal, if any, fuel costs. Passive solar heating systems have very low operating and maintenance costs, although costs for active systems are somewhat higher. Solar heating systems produce virtually no air emissions or waste. They can be built quickly and in many sizes. They are also easily adapted to the needs of rural and developing communities and are well-suited for communities with limited access to other energy resources. One limitation of solar heating is that the sun is not available at night and is less available on cloudy days. Solar heating systems either need to store the heat they collect or use backup heating systems (e.g., a woodstove, an electric heating system, or a small oil furnace).

Activity/Teaching Idea: *Let the Sun Shine In* – Students calculate how much solar energy contributes to their home or school heating. Students will be able to list the factors that affect the solar heat gain of their home or school and determine the amount of solar heat gained through windows.

Additional Resources: Focus on Energy Fact Sheets: *Solar hot water systems, Building new homes that are ready for solar energy systems;* Focus on Energy Case Study: *Renewable Heat for a Dream Home*

Small Wind

The output of a wind energy system is measured in kilowatts (1,000 watts) or megawatts (1,000,000 watts). Energy is power multiplied by time. Wind-generated electricity is measured in kilowatt-hours, a unit of energy. One kilowatt-hour of electrical energy equals 3,413 Btu. The energy in wind is converted into electricity using wind turbines. Wind turbines can be used to provide electricity to single family homes, especially in rural areas. The electricity produced can be stored in batteries for use when wind speeds are low or when high winds could damage the turbine. Small-scale wind turbines (with a capacity of 100 kilowatts or less) are different from the utility-scale wind turbines that make up wind farms. This framework will focus on small wind, which is utilized for residential purposes. You may also hear about building-mounted wind systems. These systems are attached to the roof or another part of a building. The industry professionals involved in the development of this framework do not recommend the attachment of wind systems to a building. (See Construction Implications to learn more.)

Components of System: A wind turbine is made up of an electrical generator mounted on a tower and connected to a rotor. The wind turns the blades of the rotor, causing the generator to spin and produce electricity. Residential turbines have blades that are 3.5-15.5 feet long, and generators that produce 1-20 kilowatts of electrical power. In the control room, the wiring goes through a transformer, which transforms the voltage down to 24 volts alternating current (AC). From the transformer, the AC electricity is converted to direct current (DC), regulated through a controller and stored in a battery bank (optional for an off-grid system). For grid-tied systems, the power will usually go into an inverter which inverts the power into grid-compatible AC electricity.

Construction Implications: To house the many electrical components of a wind system, adequate space in a control room is necessary.

Building-mounted: Mounting a wind system to a building is not recommended. Roofs of residential homes are not designed to accommodate the forces exerted on the wind turbine by the wind. In addition, the turbulence caused by nearby trees and buildings can wear out a turbine and reduce its life expectancy. The wind resource at the tops of buildings is of poor quality and greatly diminished when compared with tall towers that achieve vertical separation from the clutter on the ground and get the turbines into uninterrupted laminar air flow.

Siting: Before erecting a wind turbine, you need to know the long term average wind speed for your area at the height that the wind turbine must be mounted to access the free flow of wind. Turbines need to be located at least 30 feet above any trees and within 500 feet of buildings to prevent air turbulence.

There are three different tower options available to mount a wind system. A tilt-up tower is anchored by guy wires and requires a sizable amount of open area needed during maintenance. A lattice tower, which also has guy wires, does not get lowered during maintenance so it does not need as much space as a tilt-up tower. The third type of tower is freestanding in which no guy wires are used. It has a smaller footprint but is more costly because of the extra materials needed (i.e. steel, concrete, labor). A sizable area is recommended for any tower for safety precautions.

Consumer Awareness: Wind energy has many benefits. Wind turbines have no fuel costs and low operating costs. They produce virtually no air emissions or waste. However, wind energy is unreliable because the wind does not blow steadily in most places. Therefore, the electricity produced by home wind turbines needs to be sent to the grid, stored in batteries, or a backup generator must be available, which increases the total cost of a wind energy system. If the home is connected to the grid, the electricity can be sold to the utility company when more is being produced than consumed. Electricity can be consumed from the grid when more is needed than is being produced. Some concerns about wind turbines are aesthetic problems, noise and bird and bat interference. (Cell towers, electric lines and domestic cats pose comparable threats to bird and bat flight and populations).

Activity/Teaching Idea: *Where the Wind Blows* – Students use their senses and observations skills to assess wind speed. Students will learn to measure wind speed using equipment and be able to describe characteristics of wind.

Additional Resources: "How to buy a wind electric system" by Sagrillo and Woofendon, and the Focus on Energy Fact Sheets: *Harvesting your own wind-generated electricity*, *Small rooftop wind turbines*, and *Using wind energy: Small-scale systems*

Biomass

Biomass fuels are created from agricultural wastes, alcohol fuels, animal wastes and municipal solid waste. Wood is also a type of biomass fuel. The energy content of biomass fuels is usually measured in British thermal units (Btu). The energy produced by a lit match is roughly equal to one Btu.

Wood was the main energy resource used during the early history of the United States, but now it plays only a small role in meeting the nation's energy needs. Still, in certain parts of the country, including Wisconsin, wood provides people with a cheap and plentiful source of energy for heating. Wood can be burned in a fireplace, wood stove or masonry heater. A fireplace is an open apparatus with a chimney where much of the heat escapes, making fireplaces an inefficient heat source. A wood stove is a closed apparatus, thus making it more efficient than a fireplace. A masonry heater uses a wood-burning technology developed in central and northern Europe several hundred years ago. They allow the burning of wood very quickly at high temperatures, capturing the heat released in the masonry mass of the heater. When the fire is burned out in three or four hours, the damper is then closed to prevent the accumulated heat from escaping up the chimney.

Other biofuel heating options are wood or pellet-fired boilers, which are typically installed by HVAC professionals and integrated into central heating systems. There can be a great range in emissions from these devices, with pellet- fired boilers generally capable of achieving low emissions. Cordwood fired boilers installed without large thermal storage tanks will often have very high emissions because of their tendency to burn with smoldering fires. These devices are currently unregulated by the EPA, although a voluntary program to certify lower emissions is currently being developed. The EPA Phase 2 white tag for wood fired boilers certifies these boilers to have 90-percent less emissions then the norm.

Some homeowners may burn wood pellets that are manufactured from finely ground wood fiber, which requires more processing. Pellet fuel can be made from sawdust, shavings and fines leftover after processing trees for lumber and other wood products. Pellets also can be made from corn.

Components of Systems: Contemporary masonry heaters incorporate a refractory firebox, a long heat-accumulating flue surrounded by a masonry veneer, and a chimney damper. Parlor stoves, zero clearance fireplaces, and pellet stoves all require chimneys specific to the device.

Construction Implications: The simplest and least expensive biomass choice is the installation of an EPA Phase 2 wood stove or pellet stove. The next level of cost and complexity is a zero clearance fireplace. From an environmental viewpoint, zero clearance fireplaces should also meet EPA Phase 2 emissions standards (Most do not as they are exempted at this time.). The choice of a masonry heater tends to be on the higher end in terms of cost and complexity although in a similar range to a classic style fireplace.

From the point of view of the builder and designer, it is useful to understand that as a general rule all wood burning devices are best placed centrally in a house with a chimney that exits high in the roof. This is not always possible and is less of a liability in the case of Parlor stove and zero clearance fireplaces than it is for Masonry Heaters, which radiate heat in all directions. Masonry heaters are best understood as masonry fireplaces in terms of structural issues of footing and foundations. The other EPA Phase 2 choices can be lighter weight installations, which could require less structural support.

For new construction, preparing for a masonry heater includes installing a footing and framing floors and roofs to accommodate the foundation, dedicated combustion air and chimney.

For existing buildings, masonry heaters can be added with issues varying from case to case. In general, houses that have a centrally located masonry hearth are good candidates.

Consumer Awareness: Burning wood offers several advantages but consider cost per btu of fuel before making any decisions. When wood is burned at a high temperature, it has a minimal effect on air quality. Masonry heaters, because of their high combustion temperatures, have the lowest emissions of any cordwood burning technology available. Conventional steel or iron wood-burning heaters and zero clearance fireplaces need to be fired continuously to heat consistently. Typically, masonry heaters are fired only once or twice a day, and the fire burns out after three to four hours. The heater is then a consistent radiant heat source for 12 to 24 hours, which is well suited to the lower energy demands of an energy-efficient contemporary home. This convenience allows you to choose the time of day for enjoying your hearth fire while experiencing the radiating heating benefits 24 hours a day. Masonry heaters and parlor stoves do not typically require electricity to provide heat so they allow you to heat your home in the event of an electricity outage. Unlike steel or cast iron woodstoves which have high surface temperatures, the veneer on a masonry heater rarely exceeds 120 degrees. And because they burn so cleanly, chimneys that serve masonry heaters are much less likely to accumulate dangerous creosote deposits.

Masonry heaters have great design flexibility allowing for a wide variety of heated benches, bake ovens and variable chimney placement. The refractory core can be finished with a variety of brick, stone or tile materials in a manner unique to your home and design preferences.

Activity/Teaching Idea: *Don't Waste Waste* – Students harvest celery to demonstrate waste accumulation from timber practices and brainstorm uses for the waste products. By the end of this activity, students will be able to describe the parts of a tree, define biomass, identify alternative uses of the wood that is left behind after harvesting and explain how biomass can be used to create energy.

Additional Resource: Focus on Energy Fact Sheets: *Heating your home with wood* and *Heating your home with wood pellets*

Geothermal

Geothermal, or ground source heat pump systems, use a series of underground tubes to take advantage of the constant temperature just six feet beneath the Earth's surface. In winter, heat is transferred from the ground to your house or building. In summer, the process is reversed. Indoor heat is pumped back into the ground.

Components of system: There are locations in Wisconsin and other parts of the world taking advantage of the shallow ground sources of geothermal energy to help keep indoor temperatures comfortable. They use geothermal heat pumps to circulate water or other liquids through pipes buried in a continuous loop - either horizontally or vertically - next to a building. An extra storage tank and an air handler may also be needed.

Construction Implications: Any geothermal installation requires a sizable area outdoors, which could include yard space or a body of water that does not freeze. If placing the geothermal tubing in soil, heavy machinery to dig trenches for the tubing and to cover the tubing with soil after installation is necessary. Extra space inside the building is also required for an additional water tank where the heated water from the geothermal system is stored before it is transferred or mixed with water from the regular hot water tank.

For new construction, trenches can be dug and tubing installed as the foundation is being poured. This will allow the tubing to enter the foundation as it is being poured instead of having to cut the foundation at a later time to allow the insertion of the tubes.

For existing buildings, the foundation will need a hole cut in it for the geothermal tubes, which will enter the building and go to a heat pump system. For the tubes to enter through the foundation, the soil will need to be removed from one section of the foundation.

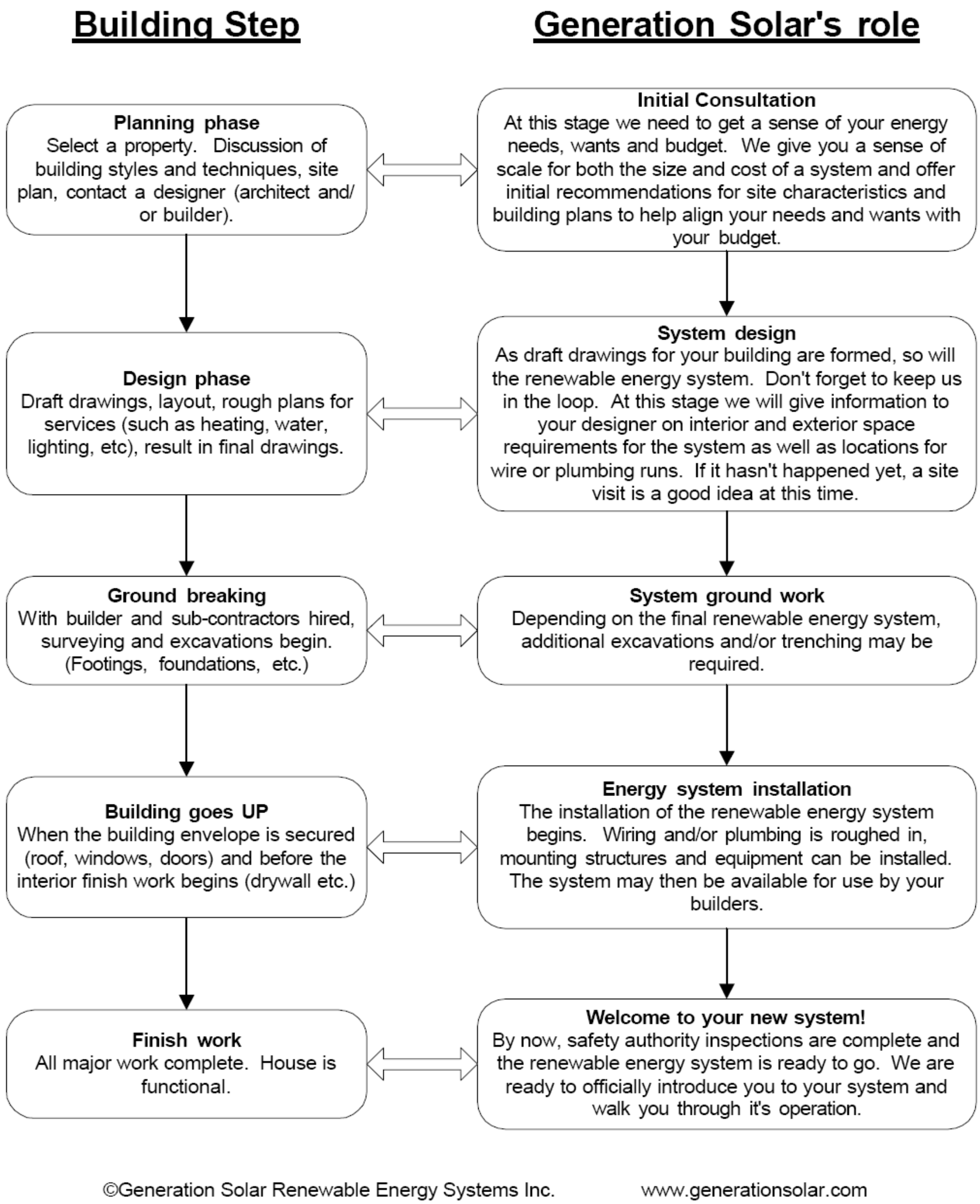
Consumer Awareness: The U.S. Environmental Protection Agency has rated geothermal heat pumps as among the most efficient heating and cooling technologies. The environmental impacts of direct uses of geothermal energy and geothermal heat pumps are minimal. The average home built in Wisconsin has sufficient yard space to accommodate the pipes needed for a geothermal system. However, geothermal energy is not available and/or feasible in all areas and there are some concerns about indoor air quality. With open loop systems, there is the chance that geothermal systems can pollute groundwater resources. Finally, low temperature geothermal systems are more efficient in the cooling cycle.

Activity/Teaching Idea: *Geothermal Gazette* – Students act as reporters assembling a newspaper on geothermal energy. By completing this activity, they will be able to describe how a geothermal heat pump works and provide examples of geothermal energy use in Wisconsin.

Additional Resources: Focus on Energy Fact Sheet: *Geothermal heat pumps for Wisconsin homes, businesses and schools*; Focus on Energy Case Studies: *Fond du Lac High School: A Showcase for Renewable Technologies* and *Washington Park Library: Geothermal Heat Pump System*

Generation Solar Flow Chart: How to Integrate Generation Solar into Your Design/Build Process

Generation Solar provides this schematic to help with the integration of renewable energy systems into new construction. Visit Generation Solar's website for more information. www.generationsolar.com



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These industry professionals gathered in Milwaukee to identify concepts (knowledge and skills) related to renewable energy technologies within building science that students in building science courses should know by the time they graduate from high school.

Allie Berenyi, Construction and Remodeling Program Director, Madison Area Technical College
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The following resources were consulted while developing this framework:

- Introduction to Renewable Energy Technologies
- Focus on Energy, Fact Sheets and Case Studies
- Generation Solar, Renewable Energy and New Construction schematic
- Montana State University Extension Housing Program
- Tom Brown, Architect, *Renewable Energy In Buildings* Brochure