Chemistry Builds a GREEN HOME

Reduce, Reuse, Recycle!

By Roberta Baxter

You probably learned that slogan in first grade when you celebrated Earth Day. But beyond recycling aluminum cans and newspaper lies the building of an environment-friendly home. Builders across the country are competing to design and build green homes. Not greenhouses, for growing plants—green homes, meaning environmentally responsible homes and construction practices. The idea is to reduce waste in the building process, create energy-efficient, water-saving homes, and promote the use of sustainable materials.

Sustainability is a hot buzzword in the "green" arena, but what does it mean? The U.S. Environmental Protection Agency (EPA) defines sustainability as "the ability to achieve continuing economic prosperity while protecting natural systems of the planet, providing a high quality of life for its people." This calls for everyone taking responsibility for solving the problems of today and caring for the planet for the generations of tomorrow.

The U.S. Green Building Council (USGBC) has created a pilot program called LEED, or Leadership in Energy and Environmental Design. The program is an effort to move the home-building industry toward high-performance, sustainable practices. Certain criteria are used in giving a home-building project the "green building" label, using a common standard of measurement. For example, homebuilders can earn points by these actions, along with others:

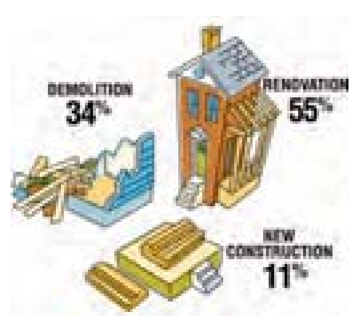
- reducing construction waste to less than 2.5 pounds per square foot of home;
- reducing energy costs by using efficient appliances;
- building a well-insulated structure;
- installing energy-efficient lighting, heating, and cooling systems; and
- reducing water usage with high-efficiency toilets and natural landscaping.

Homes receiving the highest number of points receive a platinum rating, followed by gold, silver, and certified ratings. The USGBC hopes to increase consumer awareness of the benefits of green building, stimulate green competition, and transform the practices of the building industry.

JIM NUTTLE

Reduce

The residential construction industry generates 58 million tons of waste per year, according to a study conducted for the EPA. Home renovation projects account for 55% of the waste, demolition accounts for 34%, and new construction accounts for 11%. Any reduction in the amount of this waste is a step in the right direction.



JIM NUTTLE

One of the biggest costs of homeownership is energy. The chemical company BASF sponsored the construction of a Near-Zero-Energy home in Paterson, NJ. The home was built with concepts developed by the Oak Ridge National Laboratory in Oak Ridge, TN, and PATH/Build America, the Partnership for Advancing Technology in Housing. The demonstration home is claimed to be 80% more energy efficient than a typical home. On sunny days, the home could easily produce more energy than it uses. It is also more durable, has a lower environmental impact, and is faster to construct than conventionally built homes.

Rather than using wood studs and siding for the walls, the Near-Zero-Energy home was constructed with foam-insulated concrete forms. These are rigid plastic foam forms that hold concrete in place while it hardens, and they remain in place afterward to offer extra thermal insulation. The foam insulation keeps heat and cold out of the house by trapping air in the holes of the foam. Air is a very poor conductor of heat, which makes it a good resistor, impeding the flow of heat. Note that it's not the plastic foam (or in other cases, fiberglass, stone, wool, or feathers) that slows the heat loss, but the air that's trapped in between the layers of an insulating material.

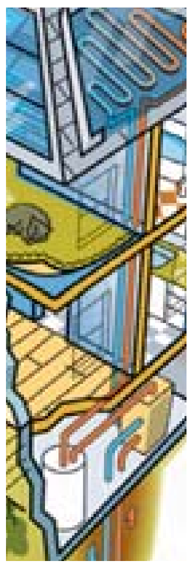
The concrete form technique is quicker than building a traditional block foundation, and the concrete can be poured and allowed to harden in more extreme climates than normal poured concrete. Concrete is an artificial stonelike material that is made by mixing wet cement, sand, and gravel together. The cement gradually sets, binding the other components together to give the rock-like material you are familiar with. Using concrete for the structure eliminates the need to cut down trees—a green advantage.

COURTESY OF GREEN BUILDER MAGAZINE

Vision House 2006 in Albuquerque, New Mexico.

A home in New Mexico was chosen as the VISION House 2006 for *Green Builder Magazine*. This is one of over 1 million homes using a geothermal system to reduce the cost of conditioning indoor air. The concept behind a geothermal heating system is to use the heat energy of the earth to moderate the air temperature in our homes: geo (earth) + thermal (heat). Over most of our planet, the top 10 feet of the surface stays consistently in the 50–60 °F range (10–16 °C). That means there is a giant, mostly untapped heat and power source right below our feet.

A geothermal system runs a refrigerant or a water and antifreeze mixture through pipes buried in the ground below frost depth.



A pump and compressor circulate the mixture through a heat exchanger. In the winter, when the temperature underground is warmer than the surface, the thermal energy of the earth is drawn up through the pipes, moved into the home, and is allowed to disperse into the rooms. Usually, duct fans distribute the heat throughout the house. The process is reversed in the summer when the ground temperature is cooler than the surface, helping to cool the house. Unwanted heat is concentrated, sent on down the line and absorbed by the earth, while cool air is returned.

Geothermal systems are quiet and, compact, and they emit no gases so they can be placed indoors. A side benefit is that they provide inexpensive hot water throughout the summer. Best of all, the heat source is renewable—a sustainable system that uses no fossil fuels and emits no greenhouse gases.

In the early 1990s, the U.S. Department of Energy contributed significantly to the development of low-E window coatings. Also referred to as low-emissivity, these windows use tin or silver metallic oxides that greatly reduce the amount of energy needed to heat or cool a home. The coatings can be applied into the molten glass, sprayed on, or added as a thin film pressed between layers. The windows are designed to be solar selective, admitting as much daylight as possible while

CESAR CAMINERO

Low-E windows are spectra-selective; they allow selected portions of the solar spectrum to pass through while restricting others.

blocking transmission of the infrared, or "heat" radiation. Low-E windows are more insulating than normal windows because they reduce radiative heat transfer. They cut down on solar heat gains in the summer and prevent loss of interior heat in the winter.

Reuse

The "reuse" part of the slogan also comes into play in green homes. Contractors are working hard to reuse pieces of wood and drywall to cut their costs during new home construction. Several companies reclaim old wood from demolished houses, buildings, and barns. Some lumber is even dredged up from river bottoms where logs have sunk during logging operations. The wood is cut and sanded and fashioned into wood flooring. Using the hardwood from these reclamations saves trees and reuses wood that would otherwise be headed for landfills.

MIKE CIESIELSKI

An unusual application is kitchen and bath cabinets made from wheat straw. The straw is a waste product from agriculture. Wheat heads are cut off the plant, leaving the stems behind. The chopped straw is glued together with nonformaldehyde containing adhesives and pressed into shape. The cabinets look and feel just like wood, and they are produced from 85% renewable materials.

Recycle

Recycling is a vital part of any green home. Environment-friendly contractors search for materials that have been recycled and those that can be easily recycled at the end of their use.

One popular product made from recycled materials is carpet. About half of the polyester carpet in the United States is made from recycled plastics. It takes five two-liter bottles to make one square foot of carpet, so there might be 500 recycled bottles on your living room floor.

MIKE CIESIELSKI

Recycling: part of Green Living includes sustainability, taking responsibility for the protection of our natural resources.

Plastics are synthetic polymers, and polymers are long chains of repeating molecules linked together ("poly" means many, and "mer" means unit, or part). The typical two-liter bottle is made of a polymer called polyethylene terephthalate, or PET for short. You might have seen this familiar logo on the bottom of some plastic product.

PET is a thermoplastic, meaning it can be repeatedly reheated and reshaped. Once a bottle is used, it can be recycled by cutting it into pieces, then cleaning and remelting the pieces. Once it has been warmed, the plastic can be either molded to make new bottles or spun into fibers to make items such as carpet and even clothing.

PET is made via a condensation reaction, in which molecules are joined together while a molecule of water is split out.

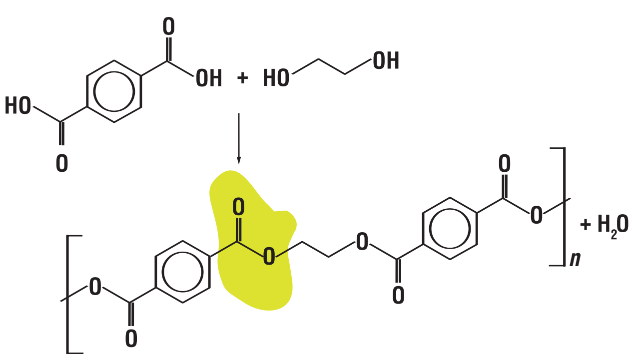
Another important aspect of the carpet story is keeping old carpet out of landfills. Representatives of the carpet industry estimate that 3.5 billion pounds of carpet waste goes to landfills each year. Mostly, it is old carpet that cannot be reused, but industry giants DuPont and Antron are implementing carpet-recycling programs. If carpet can be cleaned and reused, it is donated to charity or sold. If reuse is not possible, the carpet is recycled into new plastic products, such as filtration devices, furniture, and automotive parts.

Another homebuilding material that is often made of recycled plastic is composite lumber. Used for decks and window and door frames, this material is a 50/50 mixture of wood fibers from sawdust and recycled plastic. The wood fibers reinforce the plastic lumber, so that it is stronger than 100% recycled plastic. Furthermore, the plastic protects the wood from rotting. So the combination of natural and synthetic materials brings out the positive characteristics of both wood and plastic.

A huge advantage for the homeowner is that plastic lumber does not have to be painted. Color can be added during the manufacturing process. As a further blessing to the environment, composite lumber is made of plastic and sawdust that would otherwise end up in a landfill.

Glass winds up in landfills about as often as plastic, and concrete waste places a huge burden on landfills. Kitchen countertops for the VISION 2006 house were made from 75% recycled concrete and glass. The material looks like natural stone.

As homebuilders and the public become more aware of the possibilities of building green homes, more innovative products will come along. Your next home may be green enough to save thousands of dollars in construction and maintenance costs. Just think what you could do with that green!



The condensation reaction that forms polyethylene terephthalate (PET). PET is a polyester polymer; one of the ester groups is highlighted.

Ways To Be Green

Many techniques for being green were presented to you way back in first grade or were offered by your parents. Here are a few ideas:

1. Turn off lights and electronics when not in use.
2. Recycle anything possible: paper, aluminum, glass, and plastic.
3. Close curtains on sunny summer days and open them on sunny winter days.
4. Buy energy-efficient appliances and electronics when possible.
5. Use appliances wisely; for example, it's usually more efficient to heat with a microwave than an oven, and run clothes and dishwashers only when full.
6. Set thermostats at 68° in winter and 72° in summer.
7. Caulk around doors and windows.
8. Use fluorescent light bulbs.
9. Drink tap water rather than bottled water.
10. Use indoor plants like Golden pothos or English ivy to remove indoor air pollutants.
11. If you are an outdoor gardener, use ladybugs rather than chemical insecticide to get rid of plant-eating insects.

Roberta Baxter is a science writer who lives in Colorado Springs, CO. Her most recent *ChemMatters* article, "Battling Zits", appeared in the April 2005 issue.

ChemMatters October 2006 Teacher's Guide

Chemistry Builds a Green Home

About the Guide

William Bleam, Donald McKinney, Mark Michalovic, and Ronald Tempest, TG Editors, created the teacher's guide article material.
bbleam@verizon.net

Susan Cooper prepared the national science education content, anticipation, and reading guides.
coopers@hendry.k12.fl.us

Terri Taylor, CM Administrative Editor, and Carl Heltzel, Editor, coordinated production and prepared the MS Word and PDF versions of the Guide.
chemmatters@acs.org

David Olney created the puzzle. djolney@rcn.com

Student Questions

Glass: More Than Meets the Eye

1. Name the two most often used methods of glass analysis.
2. What two substances are added to silica as glass is made?
3. What does the term “amorphous” mean?
4. What does the index of refraction measure?
5. What is the important ingredient in bullet-proof glass?
6. What are the two types of glass fractures?

Chemistry Builds a Green Home

1. List 3 energy-saving devices or characteristics of a “Near-Zero-Energy Home”.
2. How does using cement siding and “studs” (or wall supports) save energy when compared with using wood materials for the same functions?
3. What additional energy-saving characteristics are used in the New Mexico “Vision House 2006” that are not listed for the “Near-Zero-Energy Home”?
4. How do low-emissivity (Low-e) windows reduce heat gain in a house?
5. What property of foam insulation reduces the amount of heat from leaving a house?
6. What role do the wood fibers play in plastic lumber?
7. List two advantages of using plastic lumber rather than regular lumber.

Sick Buildings: Air Pollution Comes Home

1. Name three major indoor air pollutants.
2. What does the abbreviation “SBS” stand for?
3. What is the half-life of radon-222?
4. Give two other names for formaldehyde.
5. What is the name given to the complex that forms when carbon monoxide combines with hemoglobin?

The New Alchemy

1. How are elements heavier than iron formed?
2. What was the first element discovered to be radioactive?
3. What are the three main kinds of radiation that radioactive materials give off?
4. What particles are found in the nucleus of the atom?
5. What does the atomic number of an element signify?
6. How did Ernest Rutherford turn nitrogen into oxygen?
7. What is one element formed when uranium nuclei are split?

MSDS: Passports to Safety?

1. What does the acronym OSHA mean?
2. In what year did OSHA establish the Hazard Communication Standard?
3. List the three requirements of the Hazard Communication Standard.
4. If the Hazard Communication Standard does not apply to state and local government, why do students in high schools need to be aware of MSDSs?
5. Are all MSDSs equally accurate?
6. Is OSHA responsible for enforcing consistency and accuracy in their MSDSs? Explain.
7. Who probably produces/provides the best MSDSs?

Answers to Student Questions

Glass: More Than Meets the Eye

1. Name the two most often used methods of glass analysis.
   determination of density and index of refraction
2. What two substances are added to silica as glass is made?
   s*odium carbonate and calcium oxide*
3. What does the term “amorphous” mean?
   m*olecules arranged in a random fashion, much like those of a liquid*
4. What does the index of refraction measure?
   how much an object bends light
5. What is the important ingredient in bullet-proof glass?
   a polycarbonate layer
6. What are the two types of glass fractures?
   r*adial fractures and concentric fractures*

Chemistry Builds a Green Home

1. List 3 energy-saving devices or characteristics of a “Near-Zero-Energy Home”.
   Energy-saving devices in a “near-zero energy home” include 1) photovoltaic panels for generating electricity, 2) low-e windows, 3) heat pumps for cooling and heating, 4) solar heating of domestic water, and 5) judicious siting of the house relative to the sun.
2. How does using cement siding and “studs” (or wall supports) save energy when compared with using wood materials for the same functions?
   Cement siding and “studs” save energy compared to wood materials because the thinner cement devices allow for more insulation both on and between the studs.
3. What additional energy-saving characteristics are used in the New Mexico “Vision House 2006” that are not listed for the “Near-Zero-Energy Home”?
   Advantages of the New Mexico “Vision House 2006” over the “Near-Zero-Energy Home” include using the residual heat of the earth to heat the home through a heat pump arrangement. Additionally, low-e windows are standard in the “Vision House”.
4. How do low-emissivity (low-e) windows reduce heat gain in a house?
   Low-e windows reduce heat gain by reflecting transmission of solar IR radiation back out of the window, while allowing the visible light to enter. Heat within the house is reflected back into the house when it reaches the window as IR, reducing heat losses in winter.
5. What property of foam insulation reduces the amount of heat from leaving a house?
   The property of foam insulation that reduces the amount of heat from leaving a house is the foam’s use of trapped air as an insulator. Since the air is a poor conductor of heat and is unable to move, this reduces or eliminates convection currents that would move heated air to a cooler location and result in the subsequent loss of thermal energy.
6. What role do the wood fibers play in plastic lumber?
   Wood fibers act as a binder to the plastic, giving more strength to the mixture because of non-directional composite “fibers” or strands.
7. List two advantages of using plastic lumber rather than regular lumber.
   Advantages of using plastic lumber instead of regular lumber include taking advantage of two materials, recycled plastic and reused sawdust, thus saving energy in the manufacturing process; and no preservatives are needed for the plastic wood, unlike regular wood.

Sick Buildings: Air Pollution Comes Home

1. Name three major indoor air pollutants.

Any three from this list: radon, formaldehyde, biological contaminants, lead, asbestos, carbon monoxide, secondhand smoke, household products and combustion by-products.

2. What does the abbreviation "SBS" stand for?
   Sick Building Syndrome.
3. What is the half-life of radon-222?
   3.8 days
4. Give two other names for formaldehyde.
   Either methanal, methylene oxide, or formalin
5. What is the name given to the complex that forms when carbon monoxide combines with hemoglobin?
   Carboxyhemoglobin

The New Alchemy

1. How are elements heavier than iron formed?
   Elements heavier than iron are formed in supernovae.
2. What was the first element discovered to be radioactive?
   Uranium was the first element discovered to be radioactive.
3. What are the three main kinds of radiation that radioactive materials give off?
   The three kinds of radiation are alpha particles, beta particles, and gamma rays.
4. What particles are found in the nucleus of the atom? *Protons and neutrons are found in the nucleus.*
5. What does the atomic number of an element signify? *The atomic number tells you the number of protons in the nucleus of an atom.*
6. What did Ernest Rutherford do to turn nitrogen into oxygen? *Rutherford fired alpha particles into the nuclei of nitrogen atoms.*
7. What is one element formed when uranium nuclei are split?
   Barium is one element formed when uranium nuclei are split. Krypton is another.

MSDS: Passports to Safety?

1. What does the acronym OSHA mean?
   OSHA stands for the Occupational Safety and Health Administration.
2. In what year did OSHA establish the Hazard Communication Standard?
   OSHA established the Hazard Communication Standard in 1986.
3. List the three requirements of the Hazard Communication Standard.
   The three requirements of the Hazard Communication Standard are:
   a. *Chemical manufacturers and importers must evaluate the hazards of the chemicals they produce or import.*
   b. Prepare labels and material data safety sheets (MSDS) to convey the hazard information to their customers.
   c. All employers with hazardous chemicals in their workplaces must have labels and MSDSs for their exposed workers and train them to handle the chemicals safely.
4. If the Hazard Communication Standard does not apply to state and local government, why do students in high schools need to be aware of MSDSs?
   Students in high school need to be aware of MSDSs because most states have enacted similar legislation or have endorsed the OSHA legislation.
5. Are all MSDSs equally accurate?
   No, accuracy varies a great deal from one company's MSDS to another's. That is part of the reason for the 2004 study report.
6. Is OSHA responsible for enforcing consistency and accuracy in their MSDSs? Explain.
   No, OSHA is not responsible for enforcement. In their original legislation, OSHA leaves it to the individual manufacturers to ensure accuracy of their MSDSs.
7. Who probably produces/provides the best MSDSs?
   Laboratory chemical suppliers probably write the best MSDSs.

Puzzle: Elements Galore

Instructions:

In the ladder below are spaces for inserting the letters in the names of fourteen elements. One letter in each name is given, so as to spell out the phrase ELEMENTS GALORE. The blanks shown are where you are to insert the remaining letters. As an aid, we've listed at the bottom a clue for each name used, sorted by the number of letters in that name(but otherwise in no special order).

For example, the first element has four letters in its name, the second of which is E. Of the five elements with just four letters in its name, NEON and LEAD match such a placement, but clue c, "glows red when excited" under 4 letters selects NEON as the answer. (Notice none of those three clues describes lead.)

You may prefer to begin with the clues, match them to its element, then fill in the ladder.

```
          _ E _ _
    _ _ _ L _ _ _
          _ E _ _ _
    _ _ _ M _ _ _ _
          _ E _ _ _ _
        _ _ N _
        _ _ T _ _ _ _
        _ _ S _ _ _
    _ _ _ G _ _ _ _
          _ A _ _ _ _
        _ _ L _
          _ O _ _ _
        _ _ R _ _ _ _
_ _ _ _ _ _ E _ _ _ _
```

4 letters

a. used to galvanize steel _ _ _ _

b. a metal almost twice as dense as lead _ _ _ _

c. glows red when excited _ _ _ _

5 letters

d. its electron configuration ends in $5p^6$ _ _ _ _ _

e. used in "doping" semi-conductors _ _ _ _ _

6 letters

f. the heart of organic molecules _ _ _ _ _ _

g. was discovered in the sun before on earth _ _ _ _ _ _

h. most active alkali metal in water _ _ _ _ _ _

7 letters

i. most positive oxidation potential _ _ _ _ _ _ _

j. a liquid at room temp _ _ _ _ _ _ _

k. the <u>other</u> liquid at room temp _ _ _ _ _ _ _

8 letters

l. filaments in light bulbs _ _ _ _ _ _ _ _

m. extracted from bauxite ore _ _ _ _ _ _ _ _

11 letters _ _ _ _ _ _ _ _ _ _ _

n. the newest of the elements; (It's name was adopted by IUPAC in 2004.)

Answer to Puzzle

ANSWER	clue letter
N**E**ON	c
GAL**L**IUM	k
X**E**NON	d
ALU**M**INUM	m
H**E**LIUM	g
ZI**N**C	b
LI**T**HIUM	i
CE**S**IUM	h
TUN**G**STEN	l
C**A**RBON	f
GO**L**D	b
B**O**RON	e
ME**RC**URY	j
ROENTG**E**NIUM	n

Content Reading Guide

National Science Education Content Standard Addressed

National Science Education Content Standard Addressed As a result of activities in grades 9-12, all students should develop understanding	**Sick Buildings**	**The New Alchemy**	**MSDS**	**Chemistry Builds a Green Home**	**Glass: More Than Meets the Eye**
Science as Inquiry Standard A: about scientific inquiry.	✔	✔	✔	✔	✔
Physical Science Standard B: of the structure of atoms.	✔	✔			
Physical Science Standard B: of the structure and properties of matter.	✔	✔	✔	✔	✔
Physical Science Standard B: of chemical reactions.	✔		✔		✔
Physical Science Standard B: of motions and forces.					✔
Physical Science Standard B: of interaction of energy & matter.		✔			
Life Science Standard C: of matter, energy, and organization in living systems.	✔				
Earth and Space Science Standard D: about the origin and evolution of Earth System.	✔	✔			
Earth and Space Science Standard D: about the origin and evolution of the universe.		✔			
Science and Technology Standard E: about science and technology.	✔	✔	✔	✔	✔
Science in Personal and Social Perspectives Standard F: of personal and community health.	✔		✔	✔	✔
Science in Personal and Social Perspectives Standard F: of science and technology in local, national, and global challenges.	✔	✔	✔	✔	✔

Science in Personal and Social Perspectives Standard F: of environmental quality.	✔		✔	✔	
Science in Personal and Social Perspectives Standard F: of natural and human-induced hazards.	✔		✔	✔	✔
History and Nature of Science Standard G: of science as a human endeavor.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of the nature of scientific knowledge.	✔	✔	✔	✔	✔
History and Nature of Science Standard G: of historical perspectives.	✔	✔	✔	✔	✔

Anticipation Guides

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss their responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

Directions for all Anticipation Guides: In the first column, write “A” or “D” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Chemistry Builds a Green Home

Me	Text	Statement
		1. Green homes contain indoor greenhouses for growing plants.
		2. Sustainable materials promote prosperity while protecting the Earth.
		3. Most of the waste produced by the residential construction industry comes from new home construction.
		4. Trapped air in foam is a good insulator.
		5. The top three meters of Earth’s surface varies widely in temperature, by more than 40°C.
		6. There are window coatings available that can admit daylight but block ultraviolet and infrared radiation from the sun.

		7. Wheat straw can be used to make kitchen cabinets that look just like wood.
		8. About one-fourth of the polyester carpet in the United States is made from recycled plastic.
		9. Old polyester carpet can be recycled.

Reading Strategies

These matrices and organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Chemistry Builds a Green Home

As you read, please cite examples of how green homes can be environmentally friendly. You should be able to find at least three examples for each "R."

	Green Home Examples
Reduce	
Reuse	
Recycle	

Chemistry Builds a Green Home

Edition: October, 2006

Background Information

This article is about energy conservation through the design of the home and in the actual building of the home. The construction of an energy efficient home (or "green" home) starts with the actual design, a deliberate use of strategies that include site orientation of the home relative to sun, construction using modular units that are more efficiently manufactured and of more consistent quality, integrated efficient energy-transforming devices (heat pumps fine tuned to solar panels, solar panels for hot water, solar-produced electricity through photovoltaic cells), low-emittance (low-E) windows, and judicious use of insulating materials.

In building the home, some energy savings are possible through

- reusing building materials and/or
- using recycled materials.

Energy conservation in the design of the green home includes

- reducing energy usage for cooling and heating through insulating materials and low-emittance windows (low-E),
- using efficient energy transforming devices such as heat pumps, solar heated panels (air and water), and photovoltaics
- orienting the home for maximum solar gain in winter, reducing solar gain in summer by judicious planting of deciduous trees.

More on reusing building materials

In the reusing of building materials, organizations and companies exist such as the Portland Cement Association (www.cement.org/tech/cct_aggregates_recycled.asp). that promote and provide for reprocessing of various construction materials. After slabs of concrete that have been removed from highways or dismantled buildings have been processed by breaking and crushing, the concrete aggregate as it is called is ready for reuse directly, without any further processing. Applications include general bulk fills, bank protection, fill for drainage structures, road construction (underlay), noise barriers and embankments.

The crushed concrete can also be used as aggregate when new concrete is made from cement. Sand and stone, among other things, are added to give "structural" durability to cement (the cement is the binder). This mixture is called concrete. For instance, recycled concrete aggregates that replace natural rock pass the same tests for quality and strength as required of conventional aggregate, i.e., natural rock. Higher porosity of recycled concrete aggregate requires more water when used in the cement mix. But the effect of different combinations in the mix and their effect on the final concrete product have been tested. There are all kinds of materials that can be mixed in with the cement in addition to the aggregate from recycled concrete.

More on using recycled materials

One organization that promotes recycled materials and alternative construction techniques can be found at Toolbase Services and their Green Building program, www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=2&CategoryID=17
This is a very extensive resource for builders, contractors and those who remodel dwellings. For a builder who selects a particular choice of building material (let's say, precast concrete panels for a solar home), the site not only describes how the panels are used and their ease of implementation, but also how they function in creating energy savings for heating and cooling,

what their initial and operational costs are, what field evaluations have concluded, and U.S. code acceptance when using these materials.

Under the general category of concrete construction, there are myriad categories of materials, from “autoclaved aerated concrete” to “spray-applied concrete walls” with construction guides, best practices, performance reports, field evaluations, questions and answers and web links.

If you go to the home page, you will find a variety of categories for technical information – building systems (appliances, floors, landscaping, electrical, etc), home building topics (energy efficiency, green building, land use, zero energy homes), design and construction guides, construction methods, technology inventory, field evaluations, and newsletters. In essence, this site is **very** extensive in terms of explaining all aspects of the building trade when it comes to energy-saving techniques and materials as well as the rationale for choosing the listed alternatives versus traditional building practices. This is especially important when trying to have builders and contractors switch from techniques they are most comfortable with, and when they cannot afford to make costly mistakes in adopting new ways to build.

More on existing “green homes”

The Department of Energy (DOE) at Oak Ridge Tennessee is actively involved in helping with the design and promotion of what is called the Near Zero Home (NZH). An outline of the DOE’s goals can be found at their website, www.ornl.gov/ornlhome/print/press_release_print.cfm and at Solar Today, www.solartoday.org/2005/may_une05?ZEh.htm. An important consideration for these homes is that they make more use of solar to generate electricity, so that homeowners can reduce their electricity consumption from the public grid and add their excess electricity to the electric company’s generating capacity, with compensation (electric meter runs backwards as a type of credit).

More on insulating materials

The choice of insulating materials, including the sealing of outside walls and joints, depends many times on synthetic materials rather than natural materials for many reasons, including cost and moisture resistance or water-impermeability. An insulator, in contrast with a conductor of heat depends on the properties of non-metallic materials, as is true when thinking about electrical conductors and electrical insulators. The characteristics of thermal conduction are based on that of electrical conduction – electrons that are freer to move in metallic substances compared with non-metallic. On the other hand, insulation material will sometimes contain reflective material (metallic) for preventing or reducing transmission of infrared (IR), which would be heat escaping from a home. And the reflective material on a wall surface would face into the house, the source of heat loss. That is the same principle for the reflective surface of the low emittance (low-E) window glass. Reflectivity, like conductivity, depends upon “loose” electrons, electrons that can easily move within a collection of metallic atoms, the so-called “sea of mobile electrons”.

More on low-emittance windows (low-e)

The use of the sun as an energy source for homes is as simple as providing enough windows that face along an arc from southeast through south to southwest. These windows have to perform in two ways – transmit light, including infrared (IR), into the house during the cooler months of the year, and reduce light transmission, in particular IR and ultraviolet (UV), in the warmer months. The window must also reduce losses of heat as IR, from within the house. There are different types of windows of low emittance (low – e) for use in different climates (think California vs. Maine). The basic construction of these windows depends upon two things – a layer of gas between two layers of glass, and coatings of reflective metallic oxides on the glass. The idea behind the layer of gas is to use a substance of low thermal conductivity, an

insulator. The choice of gas is based on its density because you want to have minimal movement of the gas within the space – otherwise more heat within the space will be transmitted from the outer glass surface to the inner (summer) or vice versa (winter) through convection.   Air can be used but the gas of choice is argon – a compromise between cost and density. The density factor affects how easily the confined gas is able to move about in the space – higher density means less convection and less conduction. Krypton, which is more dense than argon, is also used but it is more expensive. The depth of the space is also critical – too much space allows for more convection. Too thin a space means less insulation. Restricted space means more difficulty for the gas to move. The space between the glass layers using argon is 11-13 mm; for krypton optimum spacing is 9 mm. Melding cost savings and density is accomplished by using a mix of argon and krypton.
http://www.efficientwindows.org/lowe.cfm
http://www.bobvila.com/HowTo_Library/Understanding_Low_e_Window_Coatings--A2077.html

The metallic oxide coating on low-E windows is applied both to the outside glass layer to act as a reflective mirror outward while a second metallic coating is placed on the inside glass layer facing into the house to reflect back IR (heat related) escaping from the house interior. Depending on climatic conditions, low-E windows have different characteristics regarding transmission of visible light, IR and UV. One is called the U-factor and refers to extent of heat loss. The other is called Solar Heat Gain Coefficient (SHGC). Windows for Florida, for example, should have a U-factor of 0.7 (for high heat loss) and a SHGC of 0.35 or lower. In Maine, the numbers are: a U-factor of 0.3 or less and a SHGC as high as possible. The specifics of these choices is given in more detail at http://www.efficientwindows.org/lowe.cfm

More on heat pumps

One of the more recent ideas for producing heat energy through a heat pump is to connect the heat pump to a heat source in the ground at a depth which is constant at 55°F.   Either the soil itself or contained water, as in a well, can be used as a heat source. The pipes in the soil or water deliver the heated medium (usually water) to a heat pump which operates the same way as a refrigerator or air conditioner. The heat in the piped water is lost to a cooler fluid in the heat pump's circulation pipes.

You can feel the same kind of heat that is given off by a refrigerator or an air conditioner when it cools warmer air inside the refrigerator or in a room. This happens when a gas is compressed into a liquid (which heats up), then allowed to expand. Expansion of the liquid into a gas causes cooling in the environment; thermal energy is taken from the environment to expand the gas (increase in potential energy). Think of how it feels when water or, better yet, alcohol evaporates on your skin. There is a cooling sensation because thermal energy of your skin causes evaporation of the liquid by increasing the potential energy of the water or alcohol molecules

The piped water cools when it loses thermal energy to the cool gas in the heat pump. When the gas returns to be compressed back into a liquid, more heat is produced (the reverse of a liquid expanding into a gas). Some of the heat is transferred from the hot liquid in the heat pump's circulation pipes to the room air of the house (think of the back of your refrigerator). The cooled water is returned to the earth where transfer of additional heat will take place because the soil is warmer than the returning fluid. See "How Refrigerators Work" at http://home.howstuffworks.com/refrigerator.htm.
In addition, diagrams of heat pumps with earth heat sources (geothermal) can be found at www.fujitaresearch.com/reports/solarpower/html and http://www.geoexchange.org/pdf/GB-034.pdf.

More on solar heated panels (air and water)

If a house is equipped with an array of solar panels for heating air or water, light passes through glass (a 'greenhouse") and is absorbed on the dark surface of copper pipes that are coated with something like chromium oxide, which is black. The visible light (along with IR and some UV) is converted to heat and transferred by conduction through the metal to a circulating liquid, usually non-toxic propylene glycol which has a higher boiling point and density than water (though water is used in climates where freezing does not occur). Heat exchange between the propylene glycol and water in a tank occurs in copper tubing or fins. For warmer climates, water in a storage tank can be circulated to the solar panel, heated and returned to a storage tank with continuous cycling of the water between the tank and the solar panels.
www.azsolarcenter.com/technology/solarh20.html

For space heating, solar panels can be used to directly heat air rather a liquid http://www.solar-components.com/SOLARKAL.HTML. The heated air can also be passed through some kind of heat storage material such as water or stone for heat retrieval later. Ideally, one can "fine tune" a heat pump to extract heat from solar heated air. The fine tuning is meant to have the heat pump operate in very narrow heat range and not requiring back up of resistance heating (electrical) for the colder winter temperatures. The alternate is to heat water or propylene glycol in a solar system that would circulate though a hot "water" heating system in the house. But the cost of this kind of arrangement (more solar panels vs. those needed for hot water) usually does not justify this kind of system.

More on photovoltaics

Photovoltaic panels for generating electricity are nearly competitive with electricity generated the usual way (steam or water turbines). This is especially true in rural areas where new homes are built and new power lines have to be established. Then too, increasing the number of photovoltaic panels added to appropriately sited homes will collectively reduce the amount of oil and coal (and carbon dioxide emissions) used for making steam to generate the same amount of electricity.

Photovoltaic cells operate on the principle that light absorption at certain frequencies will displace electrons in the right material (the photoelectric effect). Photovoltaic cells are made in two layers. One layer of predominantly silicon has mixed in with it ("doped") some arsenic. Arsenic has 5 valence electrons and silicon has 4. With these two elements mixed together in a crystalline lattice, there are 9 electrons between two atoms, an excess of electrons (think of the octet rule) or mobile electrons. A second layer of primarily silicon with some doping by aluminum or gallium means that the octet rule is not satisfied and there is a deficiency of electrons (7 total between a silicon and an aluminum or gallium) or "holes".
As a result, electrons from the Si/As layer move to the Si/Al or Si/Ga layer, which makes the two layers charged (positive and negative). With such a situation, adding light of enough energy displaces the electrons that have migrated to the Al or Ga side (which has become negative from the extra electrons). The displaced electrons will migrate toward the positive layer containing the arsenic (it lost electrons to the Al or Ga layer initially). This means that a current is generated if an electrical conductor connects the two layers in the right way. View an animated version of this activity at http://j.solarhomes.com/photo-voltaic.html. A more technical reference is found at
www.howstuffworks.com/solar-cell.htm/

With the generation of the electricity, there has to be a storage system of special batteries. Entire photoelectric system packages are available for installation. If a home is completely independent of outside electrical service, then the home system has a backup generator powered by propane or natural gas.

Connections to Chemistry Concepts

1. Metals and non-metals – preventing heat loss either as thermal conduction or infrared radiation (IR) depends upon use of non-metallic materials (silica-based glass wool, carbon-based Styrofoam®) for reduced thermal conduction and metallic reflective materials to reduce IR losses. Metals are also important in the exchange of heat as in solar collectors and heat pumps.
2. Phase changes – necessary for thermal energy transfer in the operation of heat pumps ("refrigeration cycle" equivalent).
3. Potential and kinetic energy – changes in these energies occur in the transfer of energy from one source to another as in heat pumps, solar heating, and geoexchange of heat from the ground to a heat pump. Phase change salts such as sodium acetate with additives undergo changes in potential energy for both storage and release of solar energy.
4. Specific heat and heat capacity – these properties of matter determine which materials are most effective as storage materials for solar-produced heat; also important for heat transfer in solar collectors.
5. Photoelectric effect – production of electricity in a photovoltaic cell depends upon this effect by which light energy is transformed into electrical energy.
6. Metals, metalloids, non-metals – all three categories of elements necessary for the operation of a solar photovoltaic cell.
7. Octet rule – basis for creating movement of electrons from one part of a photovoltaic cell (electron number exceeds octet rule) to another (electron number less than octet rule).
8. Electromagnetic radiation (EMR) absorption and reflection – both visible (light) and invisible EMR, such as IR, are absorbed by solar collectors and photovoltaic cells and reflected by low-E windows, Metallic backing on wall insulation reflects radiating heat as IR back into the house, preventing heat loss from the house interior.
9. Polymers – these large molecules that are carbon-based are useful as insulation material.

Possible Student Misconceptions

1. **"Potential energy and kinetic energy are really the same thing."** Students need to understand the difference between potential energy and kinetic energy and their relationship to thermal energy and temperature. Phase changes in which temperature does not change but thermal energy is either absorbed or lost can be difficult to understand if students do not have a model for atomic/molecular behavior when a substance is undergoing a temperature change vs. a phase change.
2. **"Cold comes into the house from the outside in the winter time."** When dealing with the idea of energy transfer, students need to understand the basic laws of thermodynamics, that heat energy moves from an environment with a higher temperature to that of a lower temperature. Insulation does not act to keep out cold from a house in the winter, but rather it prevents heat transfer from the warmer house to the colder environment. Likewise, thermal transfer by some "heating" device such as a heat pump, in which outside air of 55°F is to be used to heat a room at 65°F would occur by

the cooling of that outside air (to an even lower temperature) by the heat pump, giving up its heat to the room (refrigeration cycle, air conditioner with heat expelled).

3. **“A green home means lots of green plants growing everywhere.”** No, green in this sense simply means that it is environmentally friendly – it doesn’t waste Earth’s resources.

Demonstrations and Lessons

1. To distinguish between heat energy and temperature, you can do a simple demonstration to heat two different volumes of water from the same starting temperature to the same final temperature, using two identical heat sources that are constant and are timed. (identical candles, electric heaters). Students will observe that it takes a longer heating time to get the container with more water to the same temperature as the one with less water. Alternatively, if you heat both containers for the same length of time, students will observe that, even though the same amount of heat was added to both containers, the one with more water had a smaller temperature increase than the one with less water.
2. To show the energy changes involved with a phase change, the simplest idea is to have students measure the temperature of a beaker of ice cubes periodically as the ice melts. The beaker of ice could be placed in a larger beaker of warm water that also has a thermometer to show the temperature change of the warm water. Why does the temperature of the warm water bath change while that of the beaker of ice does not? Where is the thermal energy absorbed by the ice? Distinguish between thermal and potential energy in the two systems.
3. Another simple demo to show thermal changes with a phase change is to completely melt sodium acetate in a test tube, with immersed thermometer. Allow the liquid to cool to room temperature. Adding a few crystals of the sodium acetate will cause an immediate crystallization with a dramatic rise in temperature. Sodium acetate, which is a hydrate, melts at 58 ^{o}C. With continued heating, the chemical dehydrates at 120 ^{o}C, forming a solution. When the solution cools to room temperature, it becomes a supersaturated solution. When some crystals of sodium acetate are added, the sodium acetate is able to condense around these seed crystals as well as rehydrate. This condensation occurs with a reduction in potential energy; the same is true for addition of water to the sodium acetate formula units. This reduction or loss in potential energy is transformed into thermal (kinetic) energy. You can relate thermal changes to what is happening at the molecular level in terms of distance between molecules and potential energy changes (dissolved sodium acetate crystallizing to the solid state and the bonding of “free” water molecules to the sodium acetate crystal).

   Sodium acetate is used in heat pads. A video clip of a working heat pad can be found at http://static.howstuffworks.com/mpeg/q290.mpg. Sodium acetate has also been used in the walls of homes for solar/thermal storage. The cycle of dissolving (becoming liquid) (solar heating) and crystallizing (solidifying) (thermal release into the home) degrades over time unless certain additives (certain salts and some polymers) are added to the sodium acetate to keep it from layering (crystals sink to the bottom of the acetate solution).
4. To illustrate kinetic energy changes and their relationships to thermal energy, you can demonstrate the effect of doing work (increase in kinetic energy) on confined air by accelerating the air using a plunger-like device called a fire syringe. It is no different than using a bicycle pump, except that the air is confined. This fire syringe can be

purchased from major school science equipment suppliers. This is a glass tube with a metal plunger. Inserting a small piece of loose cotton or "frayed" paper at the bottom of the tube, followed by a rapid push on the plunger, ignites the cotton or paper. Pushing the plunger down accelerates the air molecules which means they are moving faster and are at a higher temperature (you have added energy to the particles, you have done some work). The hotter air molecules ignite the cotton or paper in the syringe. Although there is obviously a decrease in the volume of the air and a corresponding decrease in the potential energy of the air molecules, this energy change is not the main contributor to the ignition of the paper or cotton.

5. The photoelectric effect (photovoltaic) can be demonstrated with an electroscope that has a strip of zinc metal (newly sanded) wrapped over the "bulb" of the electroscope. Charge the electroscope through the zinc strip, using standard electrostatic charging methods (a plastic strip or rod is rubbed with fur; the plastic charges the zinc when touched). The leaves of the electroscope now should be repelling each other. Now shine an ultraviolet source directly onto the zinc strip. The leaves should slowly lose their repulsion and the gap between them should close as the electroscope discharges due to the ultraviolet light photons forcing electrons off the zinc.
6. The behavior of different materials upon exposure to a light source (reflection, absorption, transmission) and subsequent heating to various degrees can be done through an experiment documented in:
   NSTA "Science Teacher", Idea Bank, Nov.1996, Vol.63, #8, p.60
   See complete description of experiment below under student projects
7. Specific heat and heat capacity (related to solar thermal storage) can be done through standard experiments using a variety of materials actually used in thermal storage – water, rock, propylene glycol (compare with metals!)

Suggestions for Student Projects

1. Students can build a non-silicon photovoltaic cell using copper plates in a salt solution. Instructions for construction can be found at:
   http://www.thesolarguide.com/solar4scholars/make-a-solar-cell.aspx
2. Instructions for construction of a solar air heater can be found at: http://www.solar-components.com/SOLARKAL.HTML
3. Students can duplicate, in simple terms, the idea behind energy conversions in a fuel cell. Set up an electrolysis-of-water apparatus, using carbon electrodes and a small beaker (100ml) of water (acidified for conduction). After some minutes of electrolysis, disconnect the power source (a nine volt battery) and attach a micro-ammeter. There should be an indication of current flow (amperage) because the hydrogen and oxygen are recombining to form water. Among many other technical problems to be overcome is the fact that a fuel cell requires a cheap source of hydrogen (think solar-based) electrolysis of water. The whole issue of fuel cells is worth a student's literature search.
4. Students can measure, through temperature changes, the different behaviors of conducting, insulating and reflective materials using a light source, a digital thermometer placed on a vertical piece of Styrofoam, then covered with various single layers of material (white paper, aluminum foil, saran wrap, dark paper). For a fixed period of time, students measure temperature as it changes. Data can be graphed for each material, time vs. temperature. (see National Science Teachers Association publication, "The Science Teacher", Nov. 1996, Vol. 63, #8, p. 60), www.nsta.org

Anticipating Student Questions

1. "**What's the difference between kinetic energy and potential energy?"**
   Kinetic energy is energy possessed by a moving object. If we are dealing with atoms and molecules, temperature is directly related to kinetic energy. An increase in temperature means an increase in the kinetic energy of those particles. Potential energy is best described as energy of position. In order to increase the distance between atoms or molecules, energy must be added. If the distance between particles decreases, then their potential energy decreases. A useful analogy is to think of masses that move away from or toward the earth. To move a mass further from the earth, an input of energy is needed – there is an increase in the potential energy of the mass. For that same mass to move closer to the earth, the mass gives up some energy of position, potential energy.
2. **"What's the difference between kinetic energy and thermal energy?**
   Kinetic energy, energy of motion of atoms, molecules and ions, is directly related to temperature. An increase in temperature correlates with an increase in kinetic energy of particles and vice versa. All matter has thermal energy. The more thermal energy a substance has, the greater the motion of its atoms and molecules. An increase or decrease in thermal/heat energy of a system can result from a change in the kinetic or potential energy of particles. As heat energy, it flows across a conducting boundary from a system at higher temperature to a system at lower temperature.
3. **"What is the difference between temperature and heat?**
   Temperature is a measure of molecular motion. Heat is a form of energy that flows across a conducting boundary from the higher temperature to the lower temperature. Temperature is stated in units of ^{o}C or K while heat is stated in units of joules or kilojoules.
4. **"Can I make a green home out of 100% recycled materials?"**
   It is possible but probably not practical. A combination of recycled and reused material is more likely. Energy savings are dependent on the energy expenditures of the builder who looks for and collects materials for reuse.
5. **"What is a low-emittance (Low-e) window?"**
   A low-e window is one that is designed to reduce what is called radiative heat flow. Thermal radiation refers to the transfer of thermal energy in the form of infra red (IR) which is electromagnetic radiation (EMR) just beyond visible red. A "heated" body emits IR which can be detected with special instruments as well as special photographic film. Night vision goggles and binoculars are electronic devices that can detect IR . A low-e window is designed to reduce this IR radiation, hence heat loss, from the warm side of a double paned window (the pane of glass closest to the house interior). Through the use of reflective coatings the IR is reflected or redirected back into the house. The heat associated with summer sunlight is also controlled the same way. A reflective metallic coating on the outer pane of glass reflects the IR of sunlight back out, away from the house.
6. **"How is it possible for air at 35^{o}F, that is drawn into a heat pump outside a house, to heat the interior of the house that is at a temperature of 75^{o}F?"**
   The heat pump operates like a refrigerator or air conditioner. Since the air at a temperature of 35^{o}F has to contain heat energy, it is a matter of removing some of that heat energy. This is done as in a refrigerator (see referenced materials in this teacher guide) which means that the refrigerator's so called compressor mechanism that compresses a gas into a liquid which causes heating due to both an increase in kinetic

as well as a decrease in potential energy. When this pressurized liquid is allowed to expand in another part of the refrigerator or heat pump, the gas cools the environment because the change in physical state from liquid to gas requires thermal energy from the environment. The cooled gas circulates and heat from the 35 ^{o}F air moves to the cold gas.

When this gas returns to the compressor, the gas becomes a liquid, with subsequent heating again. But this time the heat energy is greater because of the addition of thermal energy from the air to the cold refrigerant gas. As the recycling of the refrigerant repeats itself, some of the heat of the hot liquid is transferred into the interior of the house (there is always heat loss from the hot liquid refrigerant through coils that are exposed to the house interior, as with a refrigerator).]

Websites for additional Information

How does a solar photovoltaic system produce electricity? See www.thesolarcenter.com/learnmore/howsolarworks.cfm or www.howstuffworks.com/solar-cell.htm/printable

Interseasonal solar storage (in the earth) and recovery: www.fujitaresearch,com./reports/solarpower.html

Solar storage in ponds with salt gradients; ACS ChemMatters, 1989*

How a solar hot water system works: www.azsolarcenter.com/technology/solarh20.html

Animated model and chemistry of photovoltaic electricity: http://jc-solarhomes.com/photo-voltaic.htm

Heat pump operation (with images) and thermal extraction from underground: http://www.geoexchange.org/pdf/GB-034.pdf

Fiberglass – chemistry, properties, formation. This reference provides lots of useful information about the manufacturing process of glass wool that differs from the making of glass which has been done for more than a thousand years. Most of us do not know how raw materials from the earth are converted into the products we encounter every day, from an automobile tire to a cardboard cereal box. Students can use this article to learn more about the chemical and physical behavior of silica (glass and quartz). They can compare these properties of glass with those in silica-based photovoltaic solar panels. http://en.wikipedia.org/wiki/Fiberglass

Energy Education Resources: Two sites with many links to other sites involved with general energy education topics are www.eia.doe.gov/kids and http://www.eia.doe.gov/bookshelf/eer/kiddietoc.html. Even though the term “kid” is in both sites’ url, the information contained on the two sites ranges from K-12 and beyond.

“Wind, Water, Fire and Earth – Energy Lessons for the Physical Sciences”, National Science Teachers Assoc. (NSTA), 1986, ISBN # 0-87355-046-3, www.nsta.org

The history behind the design of the fire syringe in the 19th C. and its operational concept as the basis for Rudolf Diesel's engine design of the same name.
http://physics.kenyon.edu/EarlyApparatus/Thermodynamics/Fire_Syringe/Fire_Syrin

"Smart Windows", ACS ChemMatters, Oct. 1999, p. 7*

Solar storage transport in "Solar Chemistry", ACS ChemMatters, Feb. 1991, p.4*

"Recycle PET", ACS ChemMatters, Oct. 1994, p.8*

Development of extremely low density insulating materials is found in "When Good Ideas Gel", ACS ChemMatters, Dec. 1992, p. 14*

* (NOTE: articles from past issues of ChemMatters can be accessed from a CD that is available from the American Chemical Society for $25. The CD contains all ChemMatter issues from 1983 to 2003. Purchase information can be found online at http://chemistry.org/chemmatters/cd3.html