CONSERVATION PRACTICES:

WATER, MATERIALS, ELECTRICAL POWER AND FUEL RESOURCES

LARRY BELL

We are beginning to use precious resources more wisely:

- **More efficient and clean technology standards are being applied to energy processing, industrial production, space conditioning and other purposes.**
- **R&D programs are providing better alternatives.**
- **Government incentives are expanding investments / markets for conservation-oriented products and services.**
- **Recycling and adaptive reuse initiatives are converting wastes to energy and useful materials.**

PBS
Aero Ecology
Sower Project

U of Strathclyde
FCIPT
Ymparisto

Energy and resource conservation is realized in many forms.

CONSERVATION PRACTICES **NATURAL PRINCIPLES**

New and emerging technologies alone cannot resolve imminent energy shortages and environmental crises.

Real progress will require responsible conservation, actions, on the part of everyone to reduce consumption through the purchase and use of efficient products and avoidance of wasteful lifestyles.

Primary goals of responsible conservation practices are to extract maximum resource benefits while minimizing wastes and hazards.

Source Reduction

Minimize consumption and waste through responsible technology selection and utilization.

Recycling

Recover, sort, and treat waste materials so that they can be reclaimed for useful purposes.

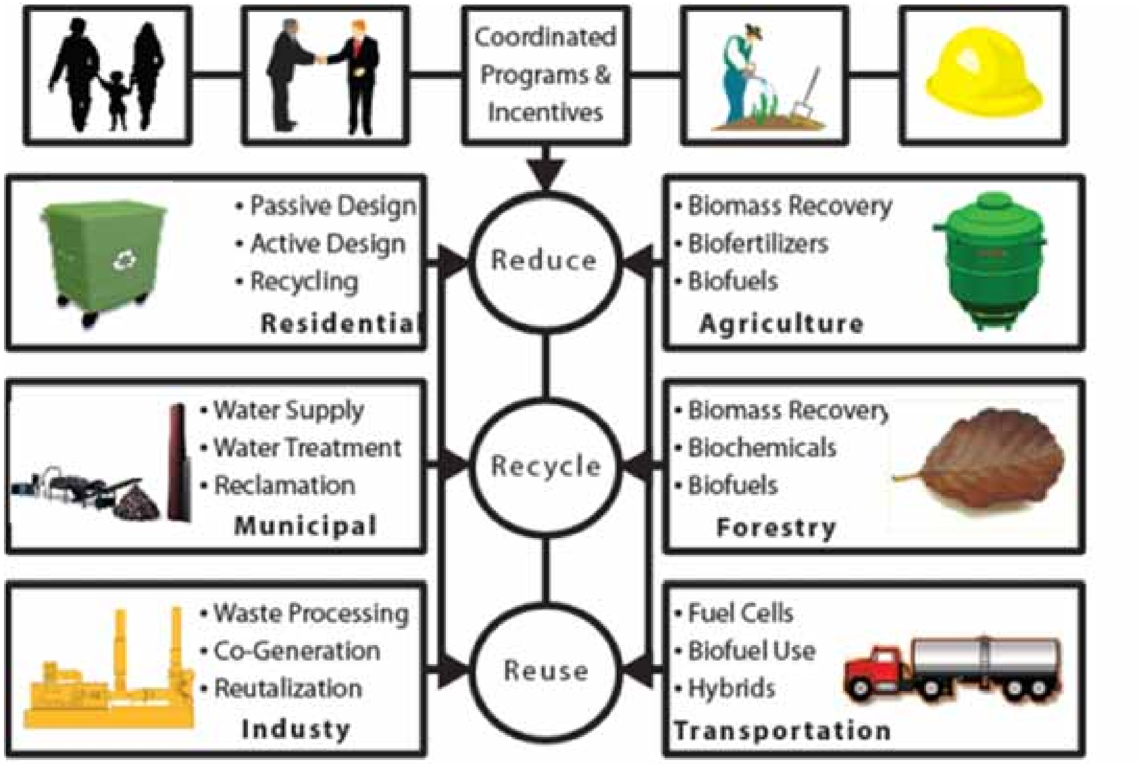
Reuse

Reapply waste and discarded products in their current or in altered form.

Primary Conservation Practices

Many municipalities, industries, business and households are working to do more with less applying three basic principles:

- **Reduce consumption.**
- **Recycle rather than discard leftover products.**
- **Reuse salvaged products, including biomass and heat.**

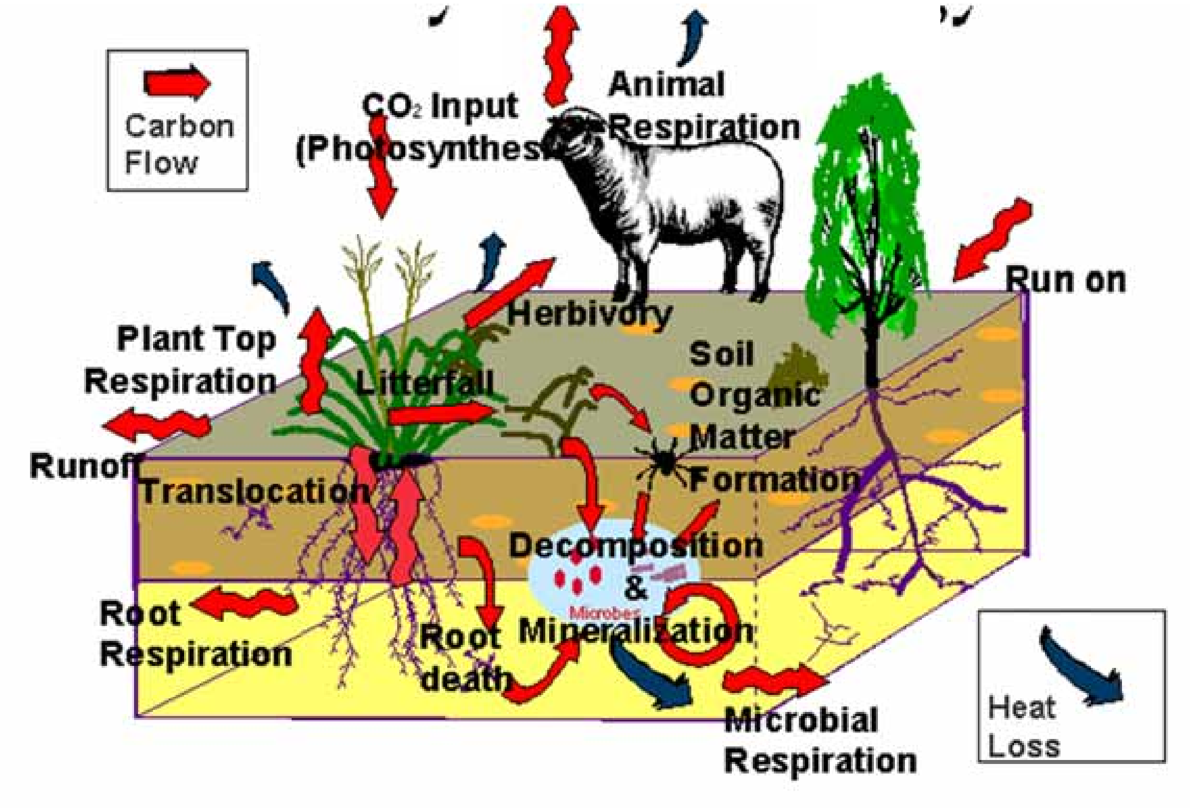


Shared Responsibilities

CONSERVATION PRACTICES **NATURAL PRINCIPLES**

We can learn much about conservation principles by observing natural systems where all parts are connected and syngertic.

Nature's grand model demonstrates ways all parts are used, and while transformable, can never be destroyed.



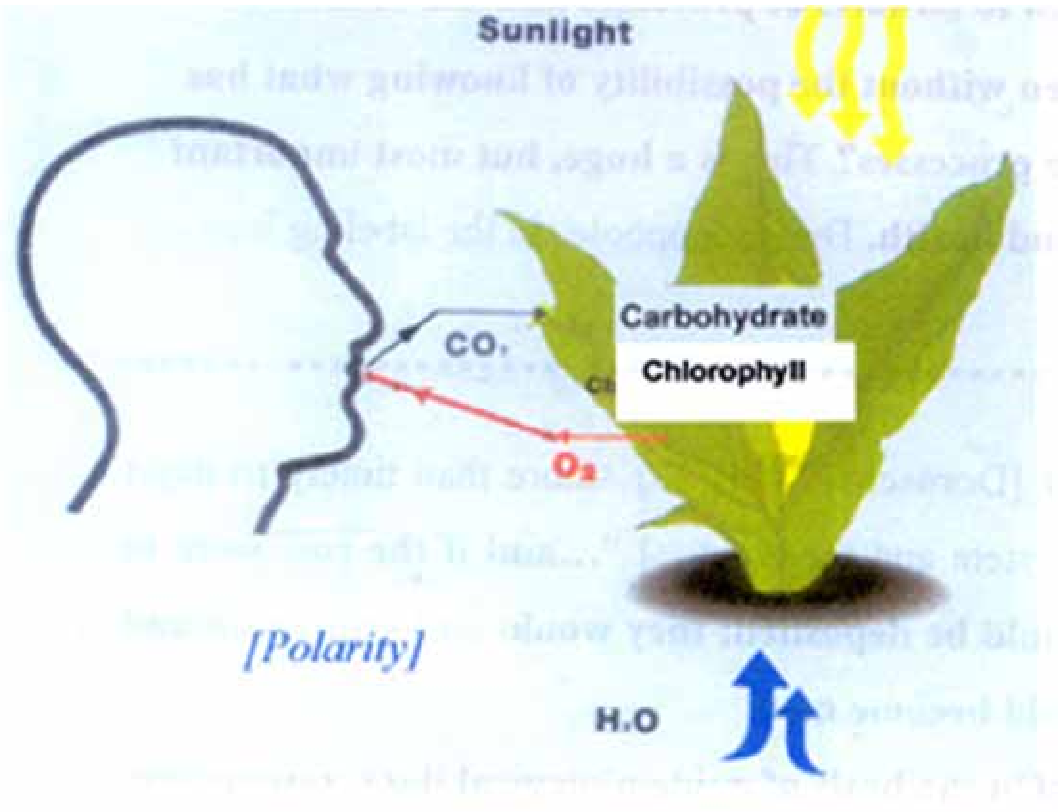
Carbon Cycle and Energy Flow

Applying Nature's Lessons

CONSERVATION PRACTICES **NATURAL PRINCIPLES**

Synergetic exchanges between plant and animal respiration processes are an example of natural recycling.

Green plants use photon energy from the Sun to help convert water and carbon dioxide into glucose carbohydrates for growth energy, and release excess oxygen that we and other creatures depend upon for life.



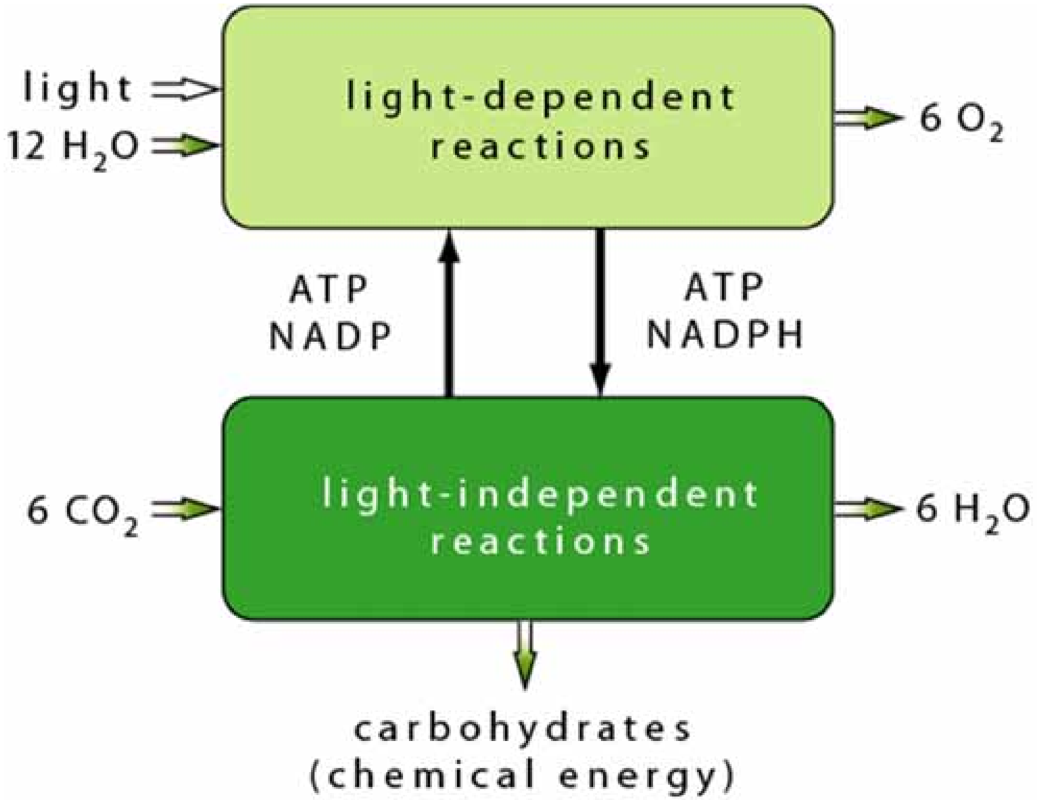
Plant/Animal Respiration

CONSERVATION PRACTICES

NATURAL PRINCIPLES

Plant photosynthesis and respiration are accomplished in two stages that apply light-dependent and light-independent reactions.

Plants use photosynthesis to convert light and water into oxygen during the day, and respiration (an opposite process) to convert CO_2 and NADPH into NADP, water and carbohydrate energy at night.



Plant Photosynthesis and Respiration

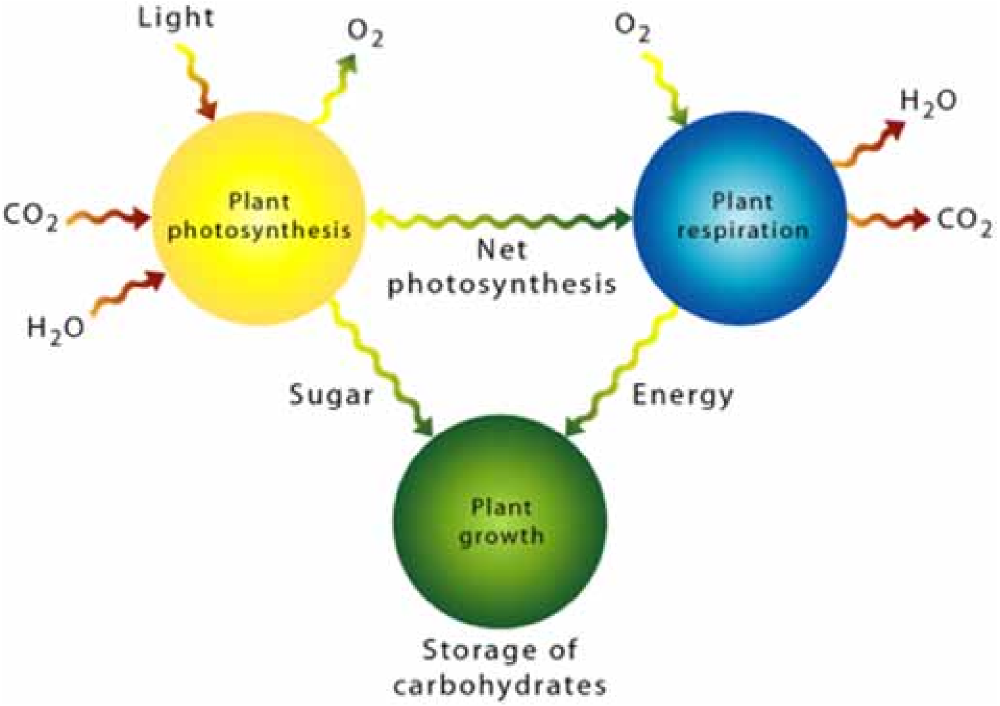
Connected, Synergetic Processes

CONSERVATION PRACTICES

NATURAL PRINCIPLES

Plants use photonic energy to produce chemical carbohydrates and oxygen we and other creatures require for food and breathing.

From a plant's perspective, the CO_2 that we and other sources produce is a feedstock along with water-derived oxygen that enables their growth and survival.



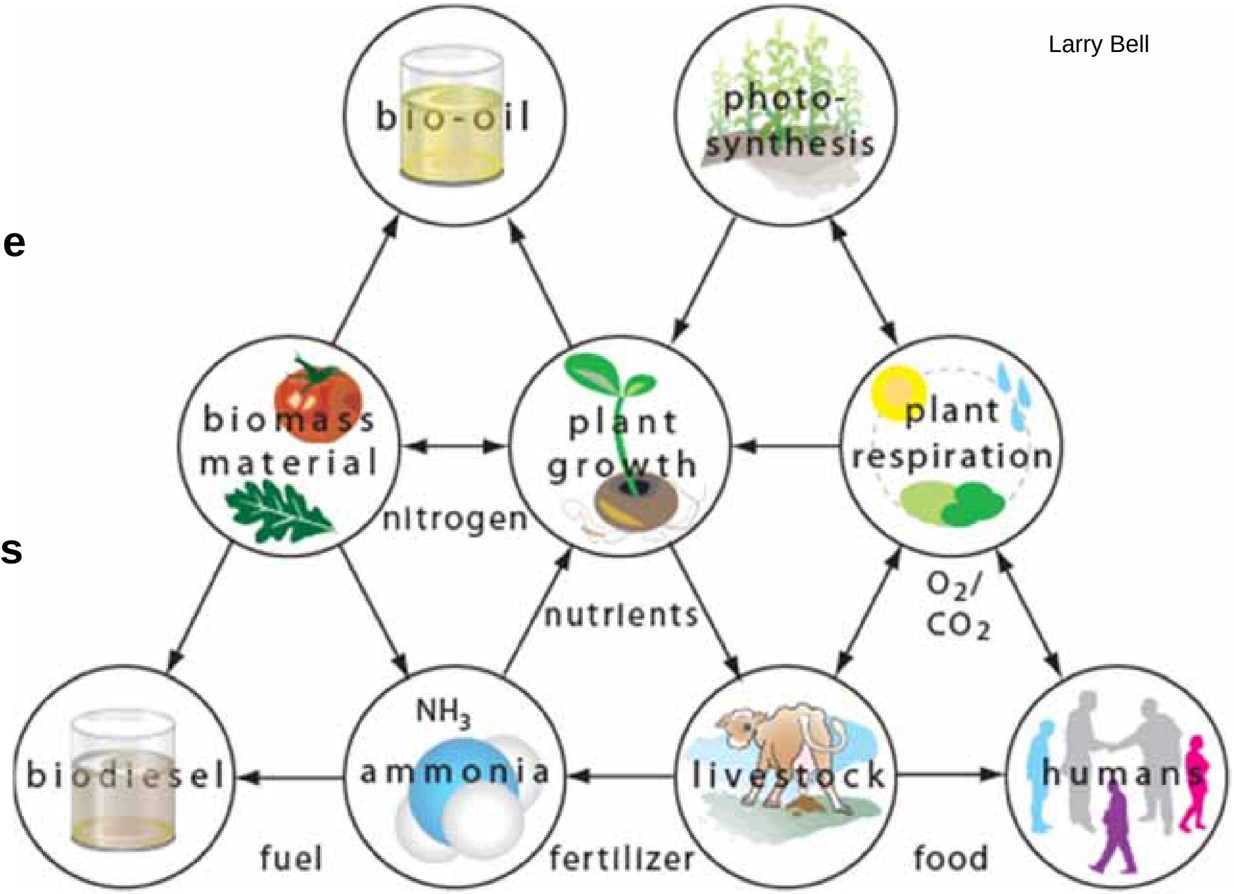
A Natural Conservation Model

CONSERVATION PRACTICES **NATURAL PRINCIPLES**

Larry Bell

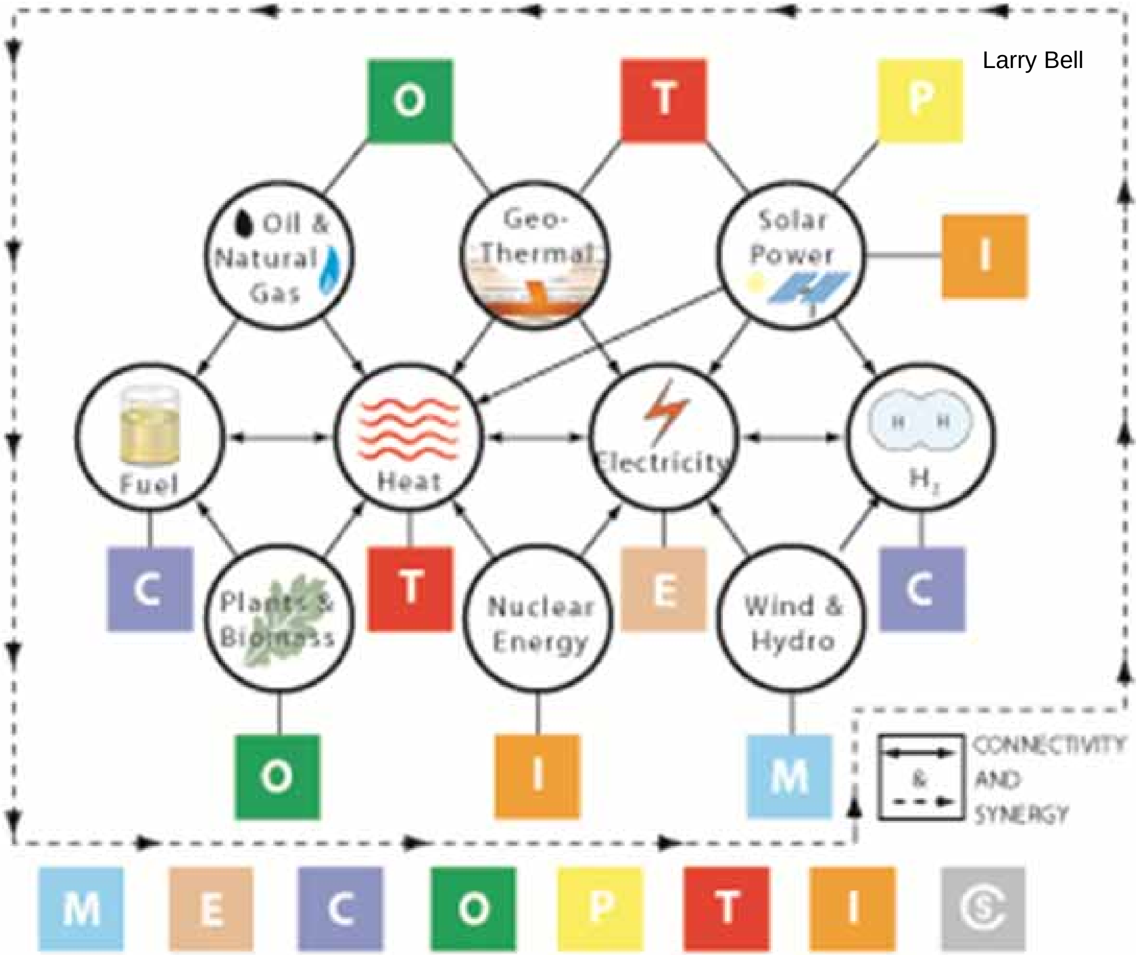
In Nature, all parts and processes connect and interact in diverse and complex ways.

Broader awareness of the interrelationships can provide better understanding of conservation opportunities, and the consequences of choices and actions.



Outgrowths of Photosynthesis

CONSERVATION PRACTICES **NATURAL PRINCIPLES**



In Nature, and in natural conservation, everything is important, everything connects, and everything works together.

MECOPTICS In Practice

CONSERVATION PRACTICES

MECOPTICS

Larry Bell

M= Mechanical
These systems collect or produce kinetic energy that can be converted to electrical power.

E= Electrical
These systems generate, store and/or transfer electricity for power and heating.

C= Chemical
These systems process organic and inorganic materials into other forms through molecular and atom reactions.

O= Organic
These systems use microorganisms to combine or breakdown molecules and compounds into derivative products.

P= Photonic
These systems convert solar radiation into electricity, heat or means to create photosynthetic products.

T= Thermal
These systems use heat energy to produce chemical reactions and to drive turbines and engines.

I= Isotopic
These systems produce heat energy through the natural decay of radionuclide, atoms that can be converted to electricity.

C= Connectivity
Refers to ways various systems functionally relate to one another.

S= Synergy
Characterizes shared or interdependent relationships between two or more systems

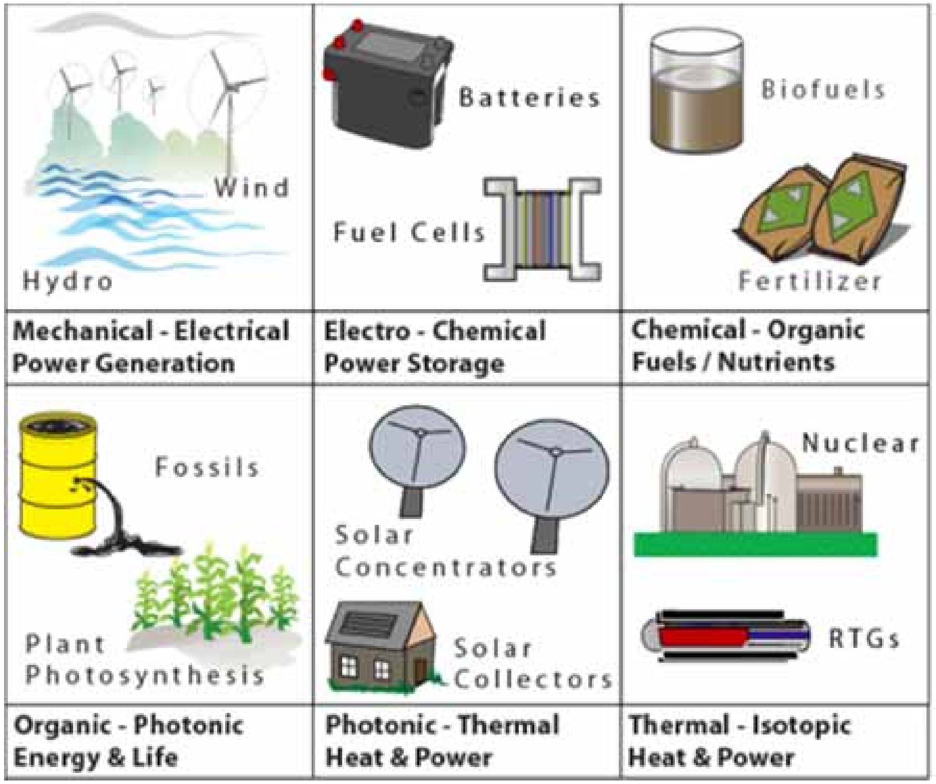
MECOPTICS Terms

CONSERVATION PRACTICES

MECOPTICS

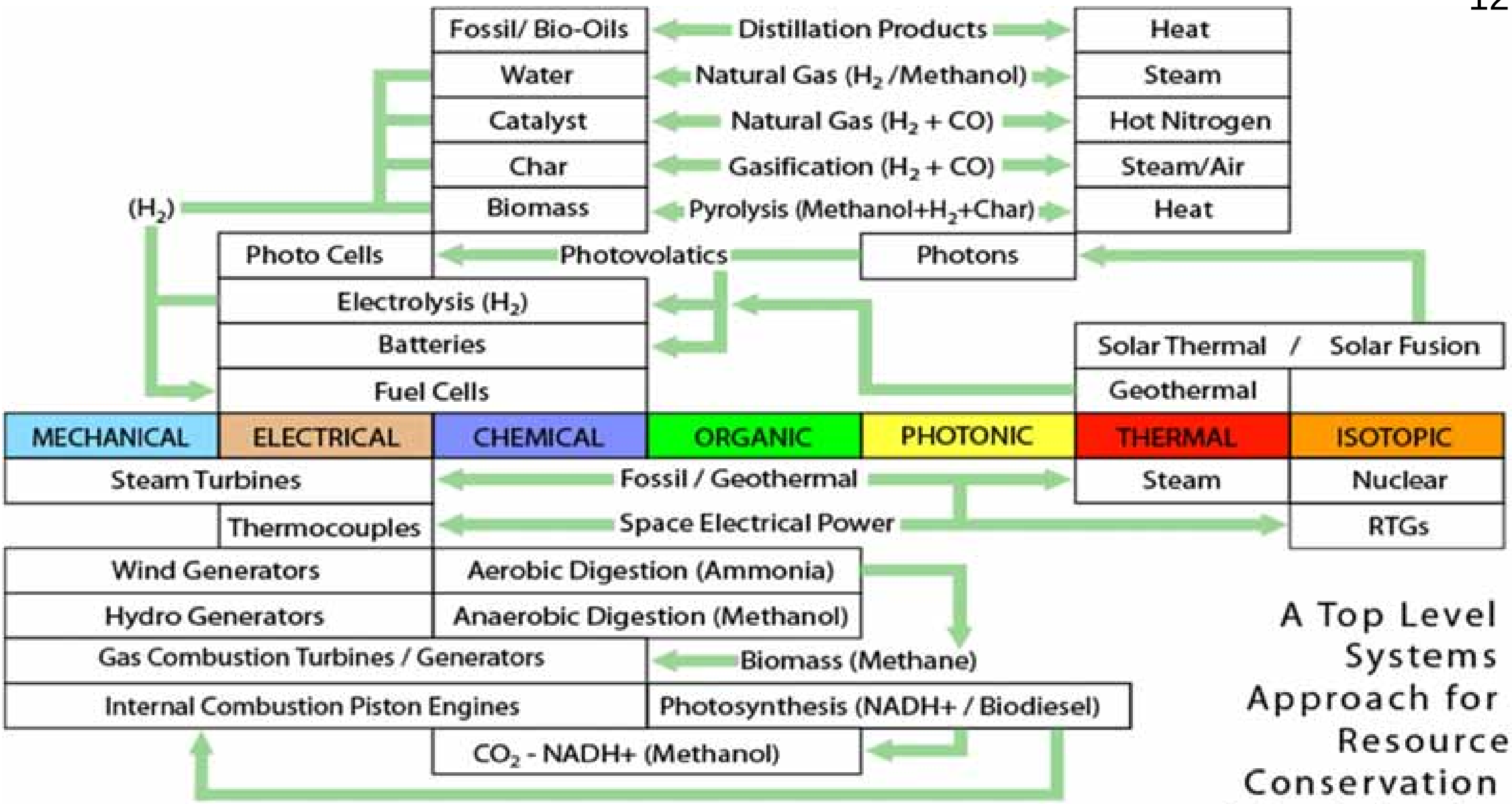
Man-made processes / devices combine basic MECOPTICS elements into a wide variety of simple and complex forms:

- **Mechanical-electrical devices convert kinetic energy to a transmittable / storable form and back again.**
- **Electro-chemical devices enable energy to be stored and transported in electrical and gas or liquid forms when and where needed.**
- **Chemical-organic forms convert natural fossil and plant / animal materials into foods and nutrients.**
- **Organic-photonic processes convert photon energy into hydrocarbon life, food, fuels and other resources.**
- **Photonic-thermal devices convert photon energy through conversion processes into heat and power.**
- **Thermal-Isotopic devices convert the natural decay of radioisotopes into heat and power.**



Applied Processes and Devices

CONSERVATION PRACTICES **MECOPTICS**



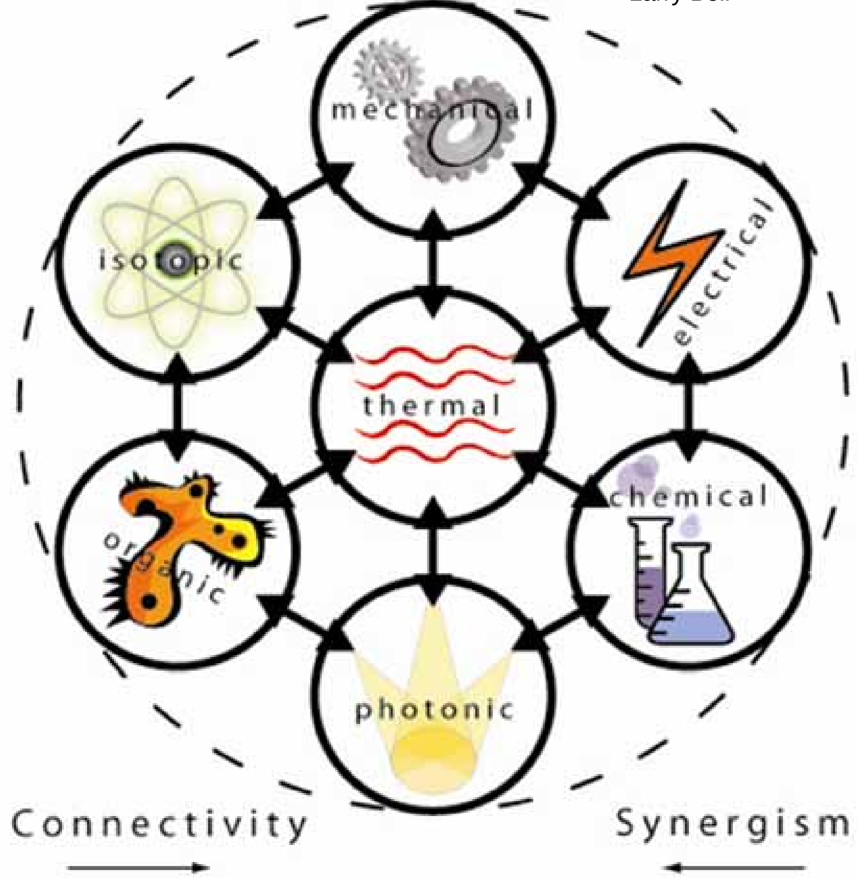
A Top Level
Systems
Approach for
Resource
Conservation
& Optimization

MECOPTICS

Mechanical•Electrical•Chemical•Organic•Photonic•Thermal•Isotopic Connectivity and Synergism

Thermal energy often has central roles in interactions with other elements.

Heat is energy in its purest form that originates from a variety of sources, including solar fusion, the natural decay of radioisotopes, chemical reactions and electro-mechanical phenomena.



Central Importance of Heat Energy

Heat is the universal medium of exchange that forms the basis of energy economics.

This thermodynamic energy transfers the capacity to do work or raise temperatures back and forth by exciting molecules and atoms to move more rapidly and become hotter.

Heat energy is a fundamental resource that enables mechanical and electrical processes to do work, and is measured in a variety of ways:

- **Joule** (**J**): the amount of force required to move a certain weight a certain distance (1 J= 0.737 foot pounds)
- **Watt** (**W**): the power or rate of work accomplished (1 W= 1 J/second)
- **Horsepower** (**hp**): a measure of power needed to lift 550 pounds off the ground for one second (1 hp= 746 W)
- **British thermal unit** (**Btu**): the heat energy needed to raise the temperature of one pound of water one degree Fahrenheit (1 Btu = 1,055 J)

Measuring Heat Energy Products

Matter is composed of molecules made of atoms connected together by attractions between electrons around the atoms.

When molecules break apart to create other molecules, a change of motion of their bonding electrons causes them to either absorb heat from the reaction or release energy.

If a molecule contains more energy than the product molecules can absorb, excess heat is released (an “exothermic” reaction).

If the product molecule requires additional heat energy, the process is “endothermic”.

Fire is an exothermic chemical chain reaction that produces heat and light when a combustible fuel is rapidly combined with a reactant (oxygen).

Heat as an Exothermic Chemical Output

Electric current passing through a conductor transfers kinetic energy that agitates atoms and converts the kinetic energy to ohmic (resistance) heat.

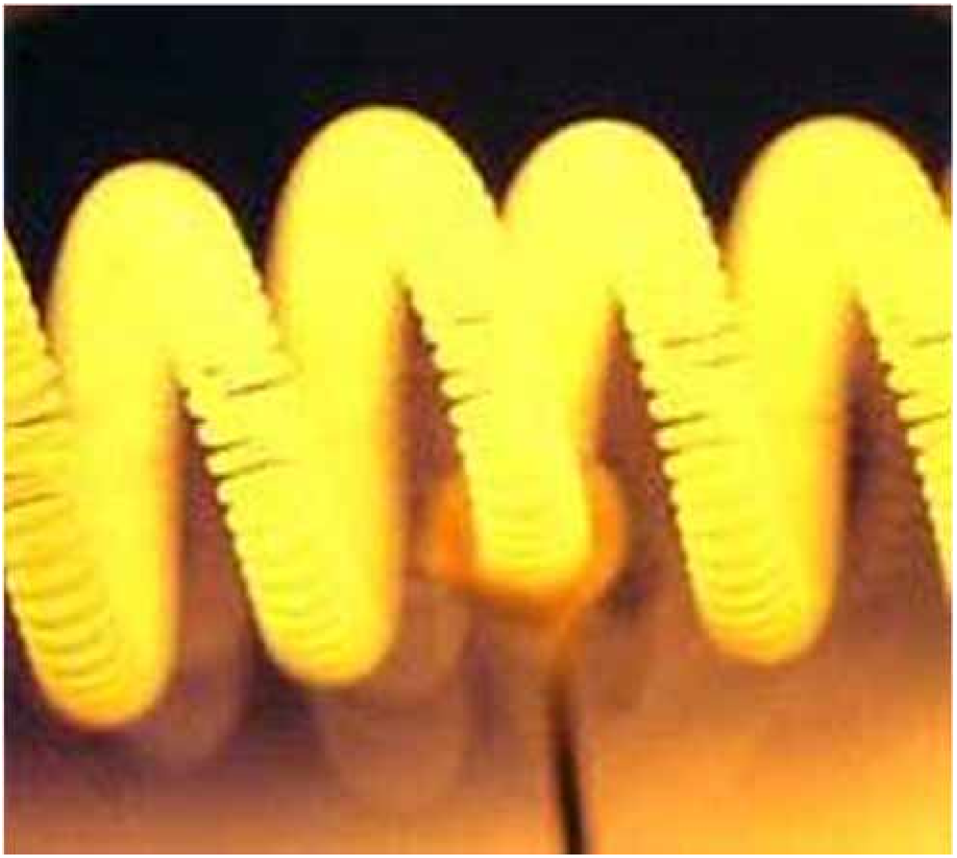
The resulting electron agitation releases heat energy proportional to the square of current strength times the conductor resistance in Joule's law:

$Q = I^2(R \cdot t)$, where:

Q = Heat by constant current (I)

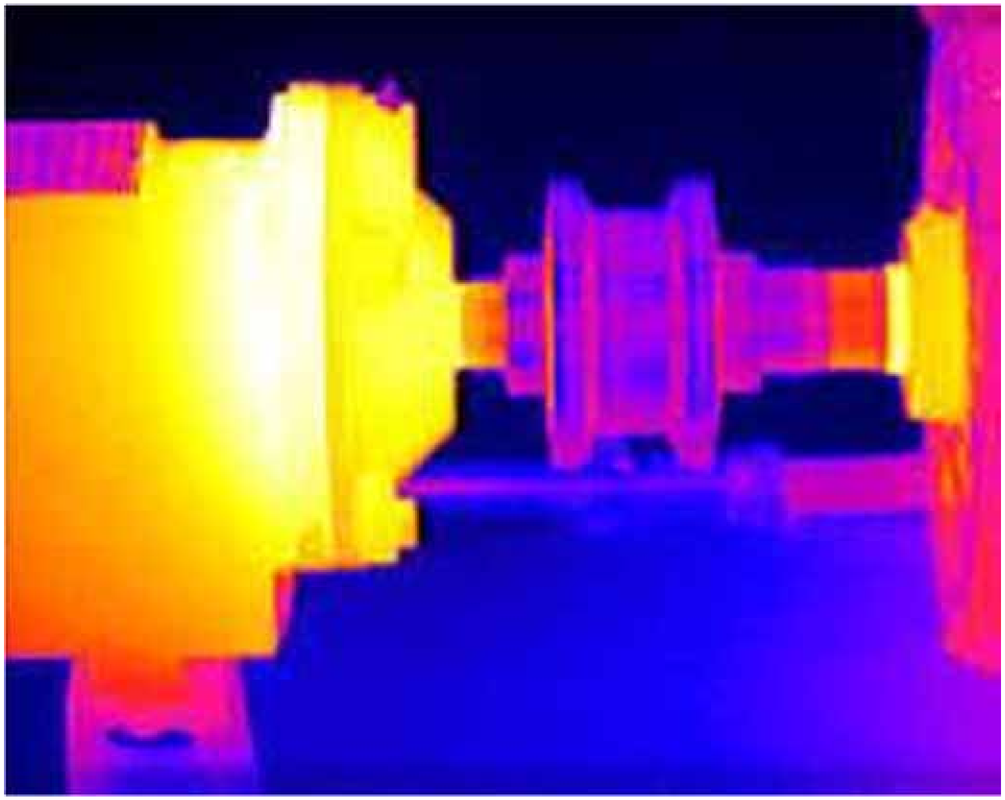
R = Resistance

t = time



Heat as Electrical Resistance

Sierra Pacific Innovations



Thermal Image of an Electric Motor

All mechanical systems convert some of their kinetic energy through friction to heat.

Energy conservation reduces waste heat by making conversions and transfers as efficient as possible, and sometimes reinvesting product heat energy to do other work.

Mechanical Heat Losses

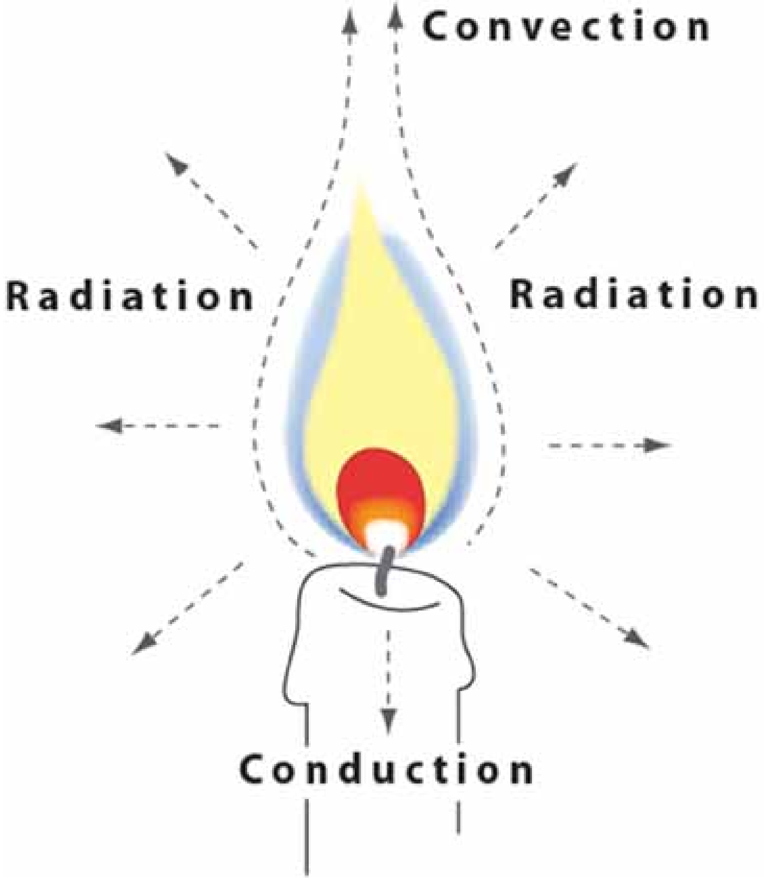
Friction heat energy losses can be reduced by minimizing contact surfaces and making them slippery:

- **Roller and ball bearings convert sliding function into smaller rolling friction.**
- **Lubricants convert “solid friction” into “liquid friction”.**

Reducing Frictional Heat Losses

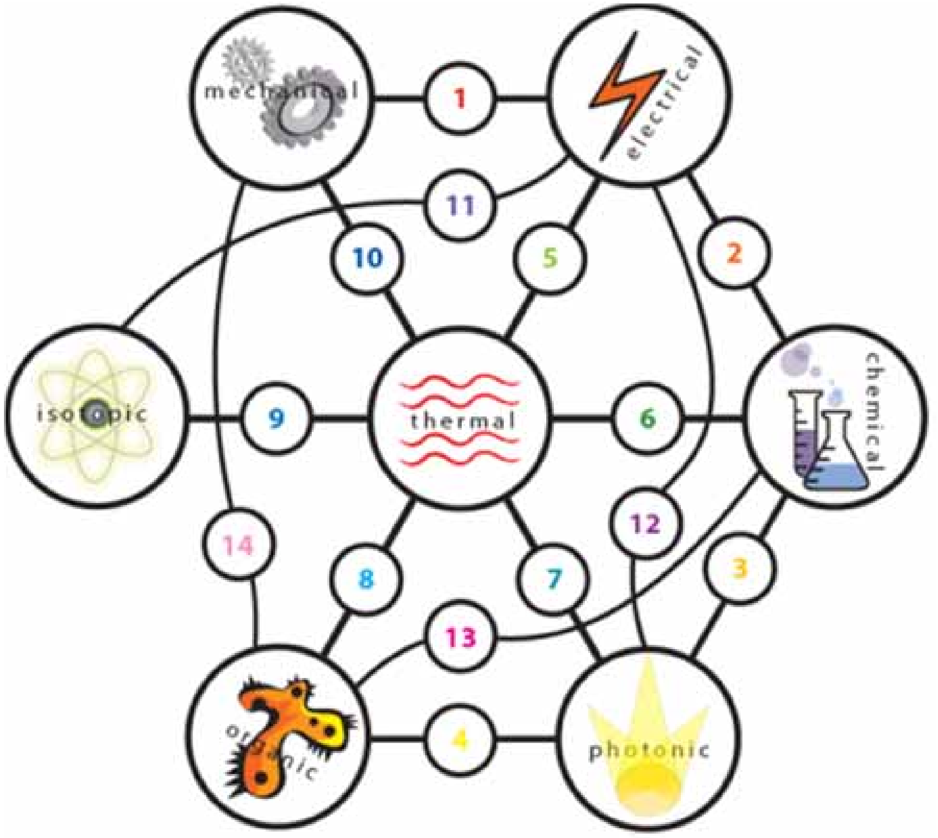
Bodies lose or gain heat energy through conduction, radiation and convection:

- **Conduction transfers heat from a hot to a cold body as adjacent atoms vibrate against each other or are exchanged.**
- **Radiation occurs through electromagnetic atom vibrations in the heat spectrum.**
- **Convection transfers thermal energy through circulation of a heated medium (from or to fluids or gases).**



Conduction, Radiation and Convection

1 Motors/Generators
2 Batteries/Fuel Cells
3 Water Electrolysis
4 Photosynthesis
5 Thermocouples
6 Distillation
7 Water/Space Heaters
8 Pyrolysis/Gasification
9 Nuclear/RTGs
10 Engines/Turbines
11 Thermocouples
12 Photovoltaics
13 Biodigesters
14 Cultivation/Processing



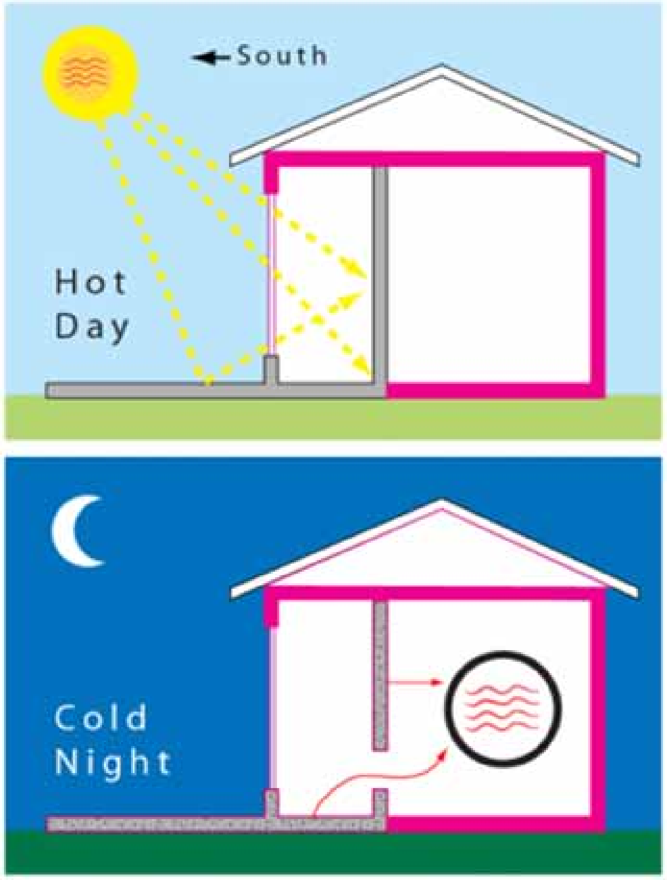
Synergetic Processes and Devices

CONSERVATION PRACTICES

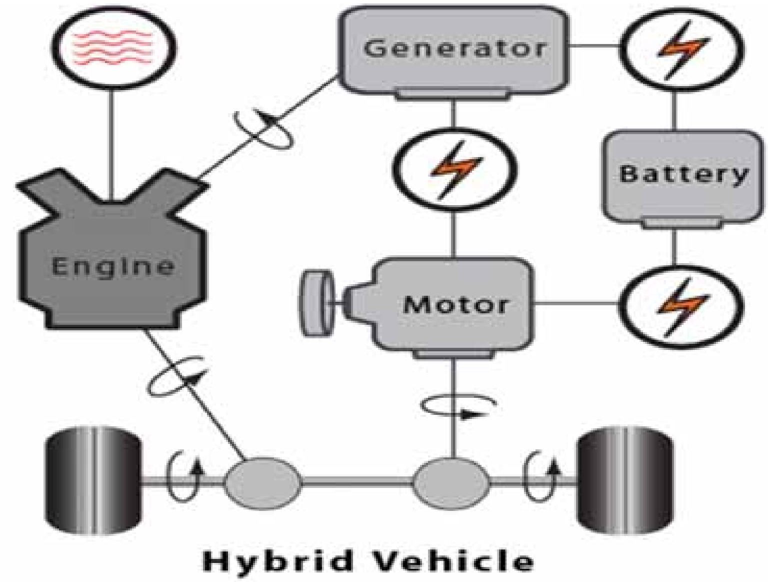
MECOPTICS

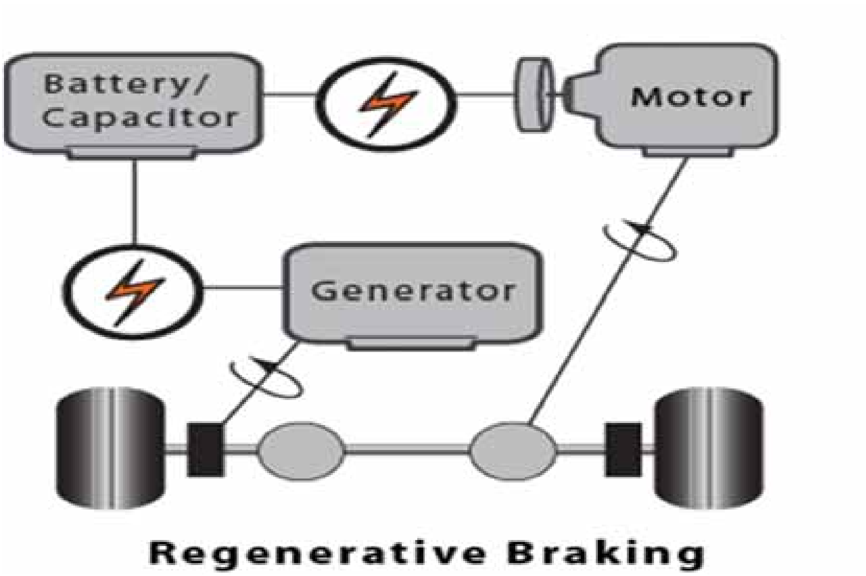
Passive solar design strategies consider influences of building location and seasonal climate conditions upon appropriate window orientations to Sun angle, shading elements, natural ventilation, insulation and other factors.

Use of heat-absorbing material mass can collect radiant energy during the day and release it at night similar to the way growing plants do.



Storing Heat in Structures

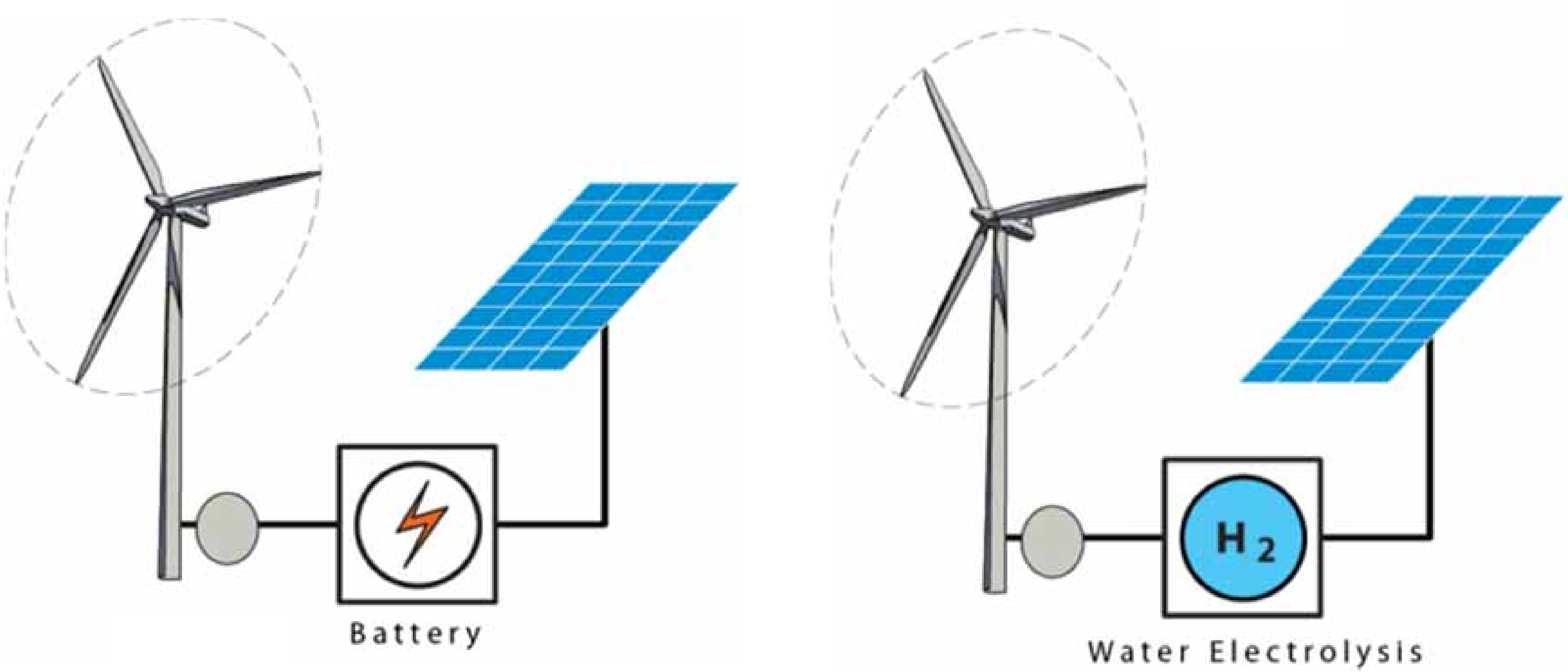




Hybrid vehicles combine engine and motor power, selectively using each when they are most efficient.

Regenerative braking converts mechanical energy via a generator to recharge the electrical storage.

Source Optimization in Vehicles



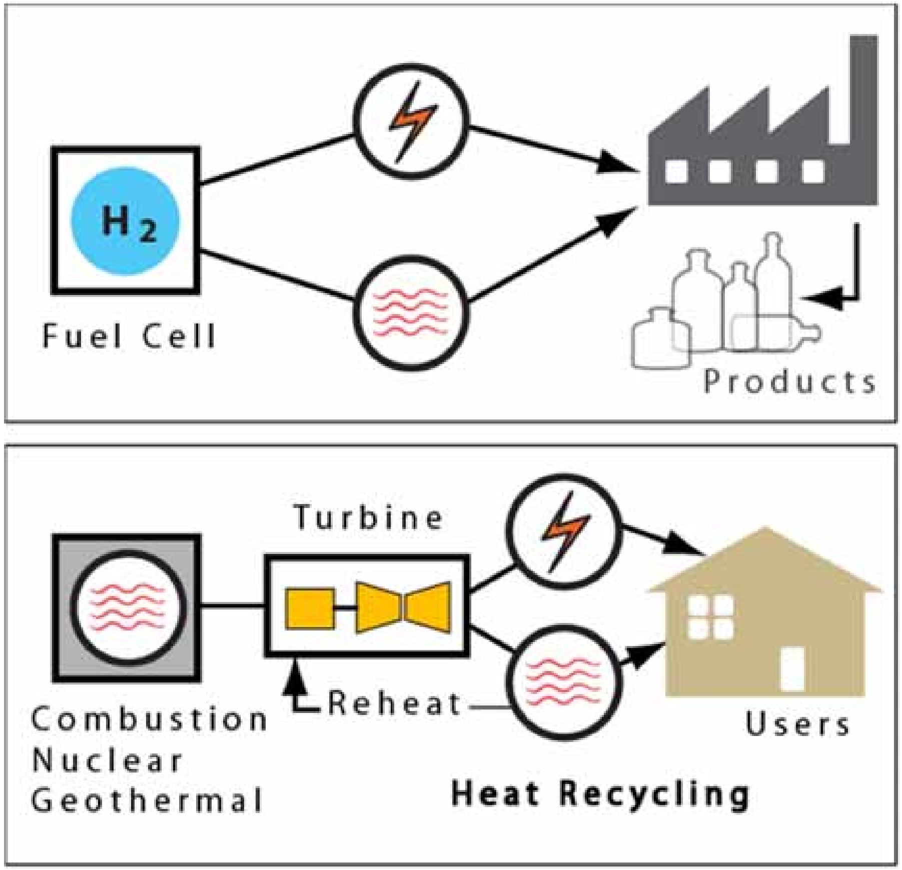
Hybrid photovoltaic / wind generator systems can balance electrical supply and demand cycles, storing energy in batteries or in the form of hydrogen using water electrolysis when wind and / or sunlight aren’t available.

Supply / Demand Balancing

Combined heat and power (CHP or cogeneration) applies logical natural recycling principles.

Some applications use fuel cells as electricity and heat generating sources.

Other systems use heat from fuel combustion, nuclear or geothermal sources to drive steam turbines for electricity, and either recycle product heat back into the turbines or use it for other benefits.



Combined Heat and Power

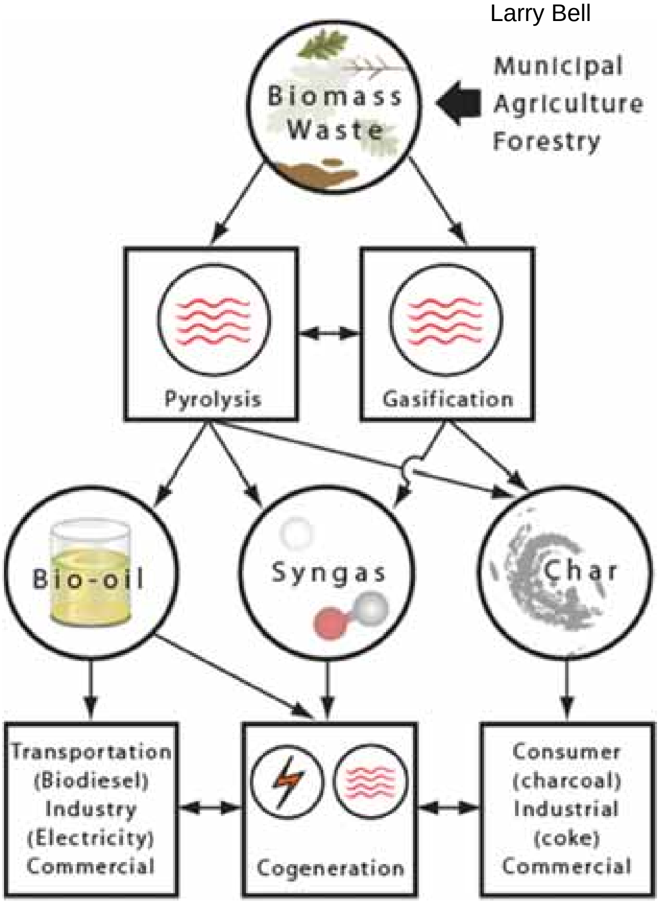
Recycling Heat through Cogeneration

Cogeneration can be used in combination with other technologies to convert / recycle organic municipal, agricultural and forestry wastes into fuels and electrical power.

Pyrolysis heats carbon-rich materials under pressure in an oxygen-deprived environment to produce bio-oil, syngas and char (charcoal or coke).

Gasification heats pyrolysis products at higher temperatures in an oxygenated environment to produce syngas for cogeneration along with char.

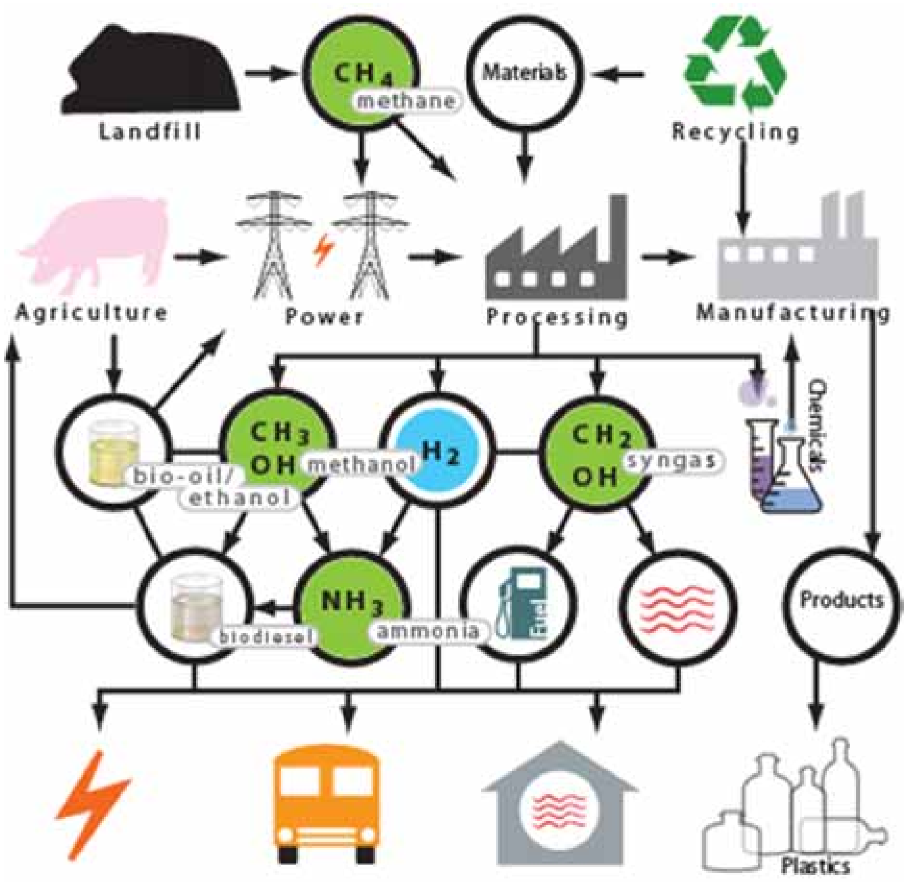
Larry Bell



Recycling Waste to Energy

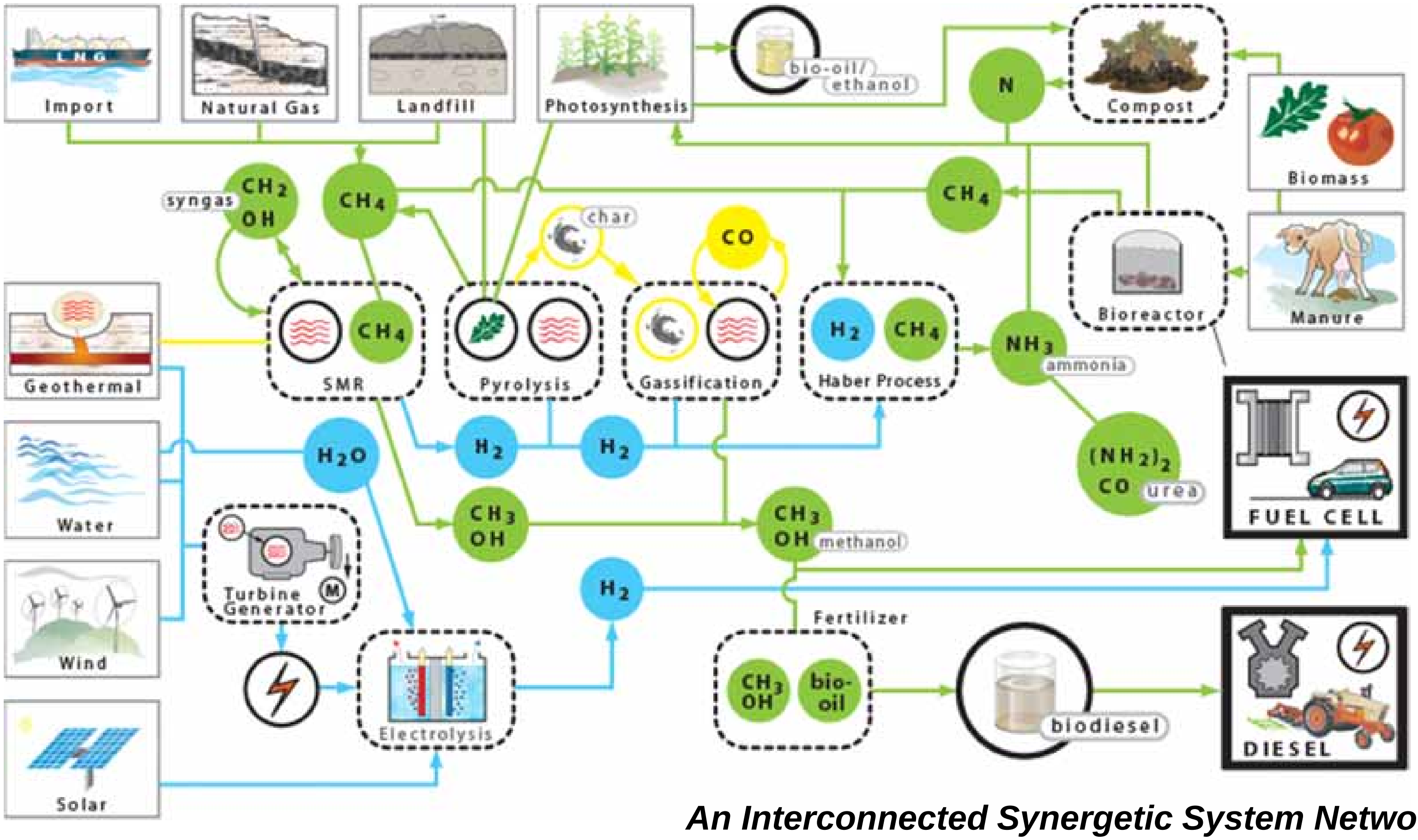
Methane from municipal landfills and biodigested agricultural biowastes can supplement natural gas for energy, fertilizers and chemical product feedstocks.

Commercial exploitation of these sources is gaining interest, and this trend is likely to expand as fossil fuel costs rise.



Methane from Landfills and Agriculture

Larry Bell



An Interconnected Synergetic System Network

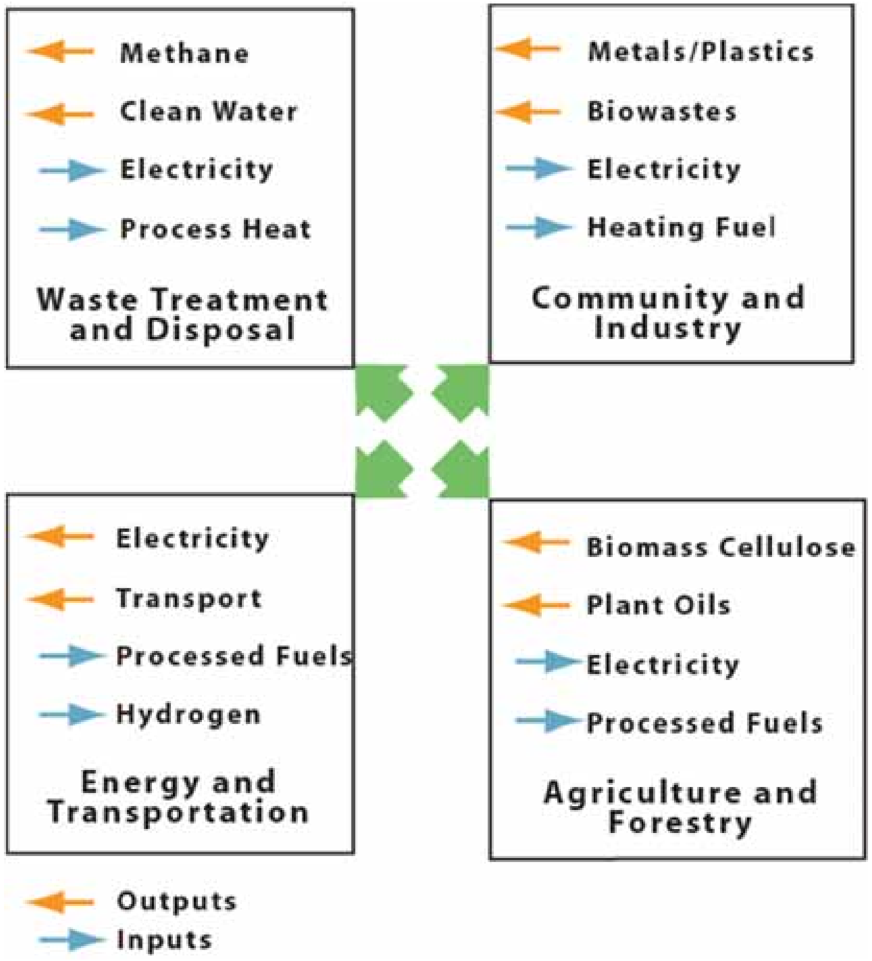
CONSERVATION PRACTICES

MECOPTICS

Coordinated networks of different public and business sectors can combine capabilities and exchange services for mutual conservation benefits.

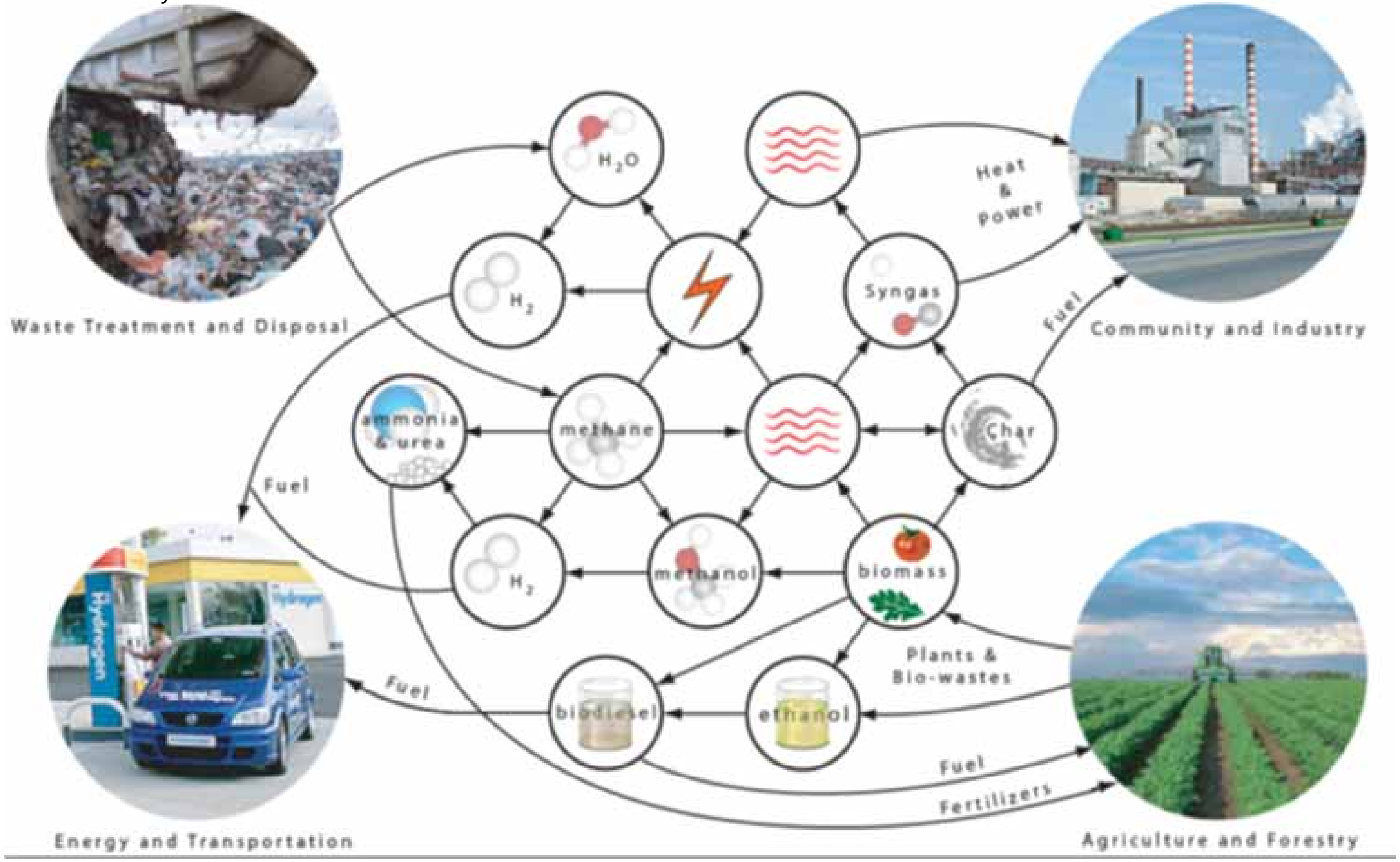
Waste outputs of some organizations and activities can provide feedstocks for others.

Energy consumers can create markets for cleaner, more efficient products that expand business opportunities.



Conservation Stakeholders

Larry Bell



A Natural Resource Network

Water is a precious resource to sustain life.

While approximately 70% of the planet is covered with water, only about 2.5% is freshwater, and about 70% of this is frozen in ice caps of Antarctica and Greenland.

Less than 0.08% of the world’s freshwater is readily accessible for human use.

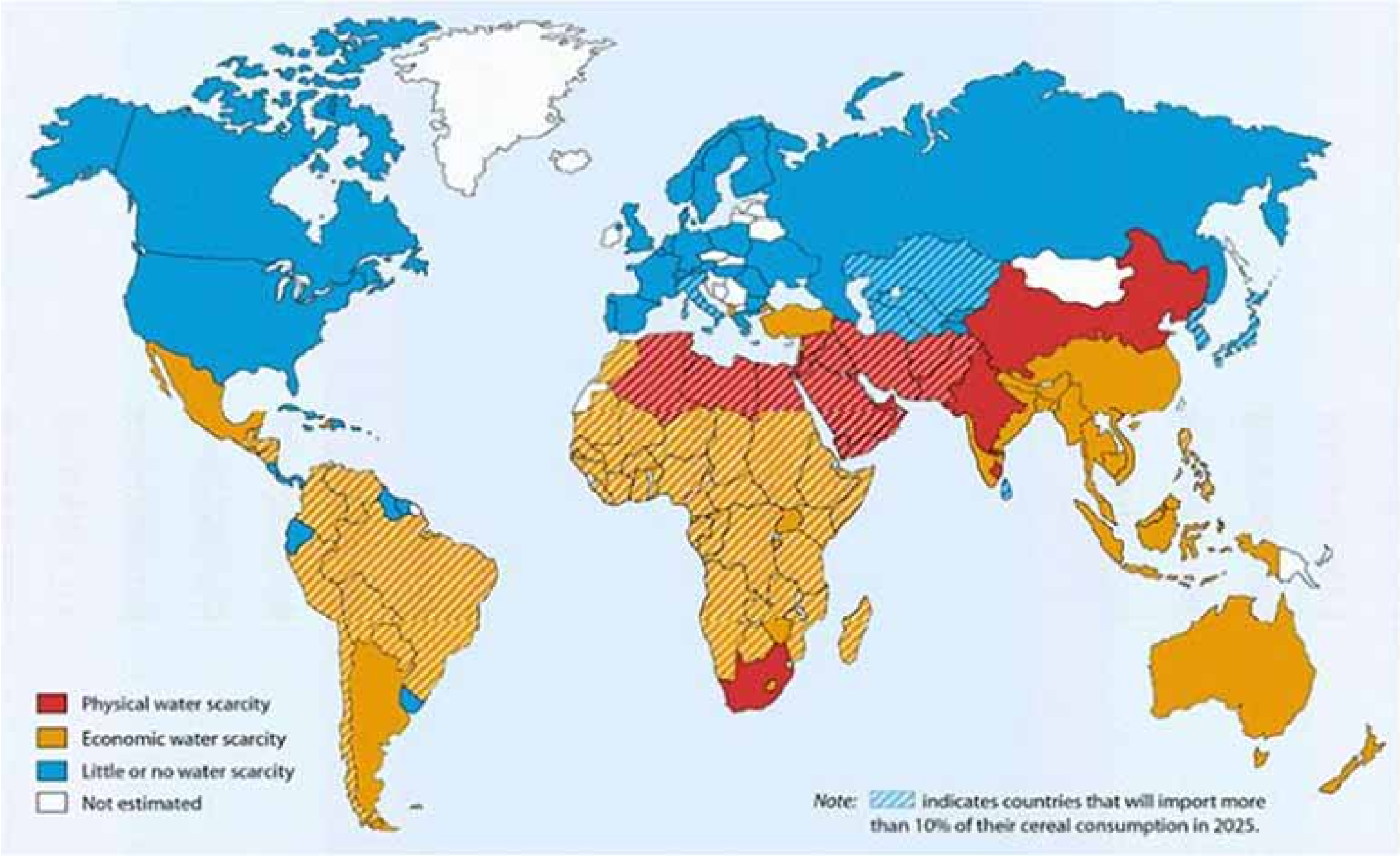
Rec. Travel USA-Canada
Petr Amadek

The Pasty
Carla Perrotti

Earth’s Freshwater Supplies

CONSERVATION PRACTICES

WATER



Global Water Scarcities

CONSERVATION PRACTICES

WATER

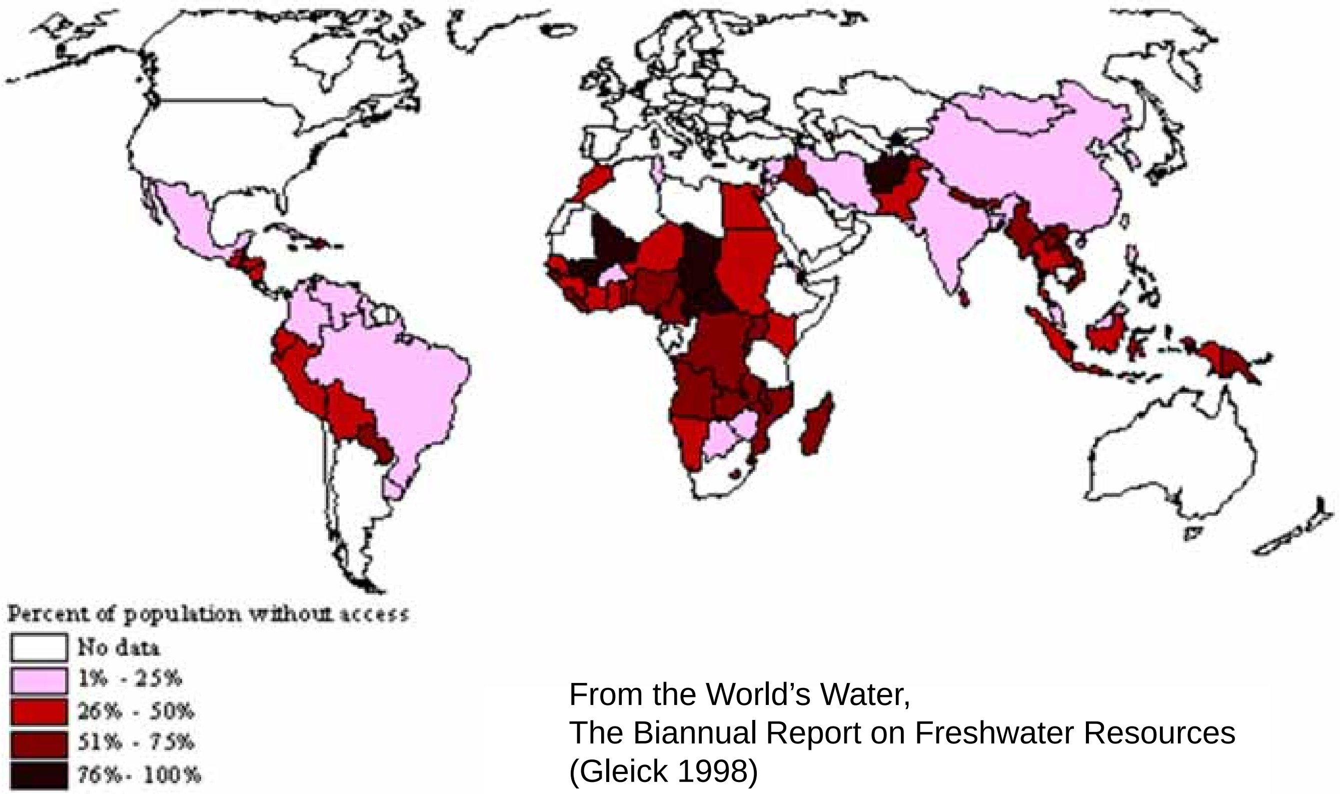
Leia

An estimated 1.1 billion people currently lack safe water, resulting in huge numbers of deaths and illnesses.

About two-thirds of the world's population may face clean freshwater shortages by 2050.

As global populations grow, lakes and shallow groundwater aquifers will be depleted even more rapidly through over-exploitation and quality degradation.

Freshwater Shortages



From the World’s Water,
The Biannual Report on Freshwater Resources
(Gleick 1998)

Populations Without Access to Safe Drinking Water

About 4,000 cubic kilometers of water are used by global populations each year for domestic, agricultural and industrial purposes.

Per capita use in Central Africa is only about 2% of the water consumed by people in North America.

China, India, and the US use the most overall, but per capita consumption in the US is about three times higher than either India or China.

Georgie Sharp

Freshwater Consumption

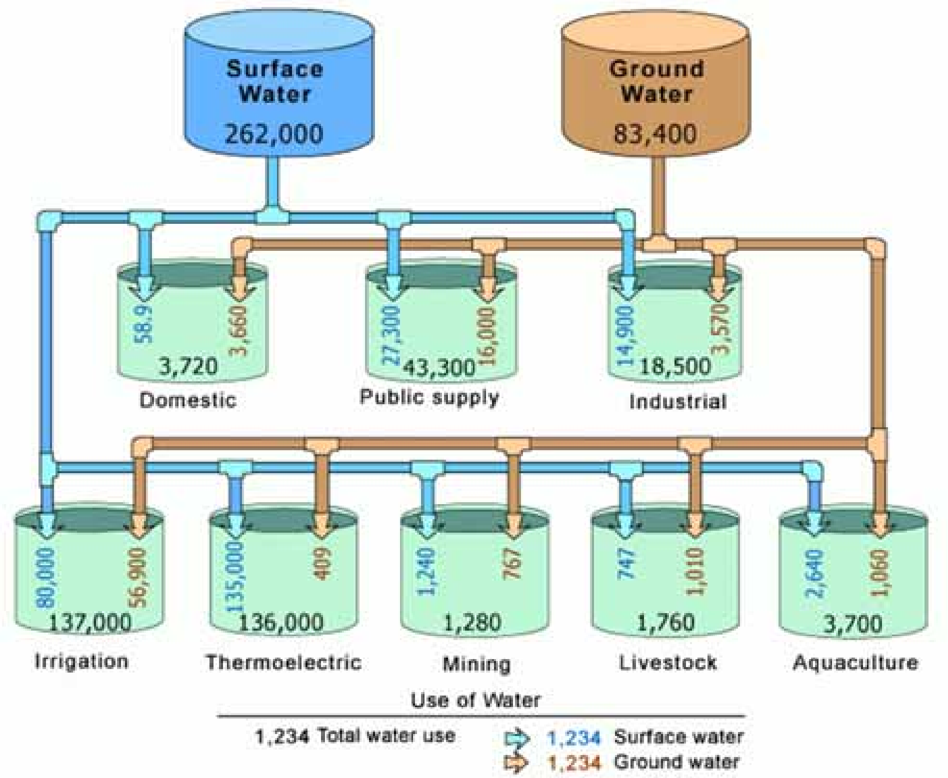
Each American uses an average of about 60 gallons of water per day, more per capita than any other developed country.

More than two-thirds of the freshwater is from surface sources.

Irrigation is a major user from surface and groundwater sources.

Domestic consumption primarily uses groundwater, and surface water provides most industrial water.

USGS Circular 1268



Sources and Uses of Freshwater in the US (2000)
Millions of Gallons / Day

Although seawater desalination is being expanded, the processes are energy-intensive and costly.

Reverse osmosis (RO), the most common process, requires power to push seawater through semi-permeable membranes at high pressure.

Half or more of the seawater volume is a soupy brine that presents disposal problems due to toxic discharge impacts upon aquatic life.

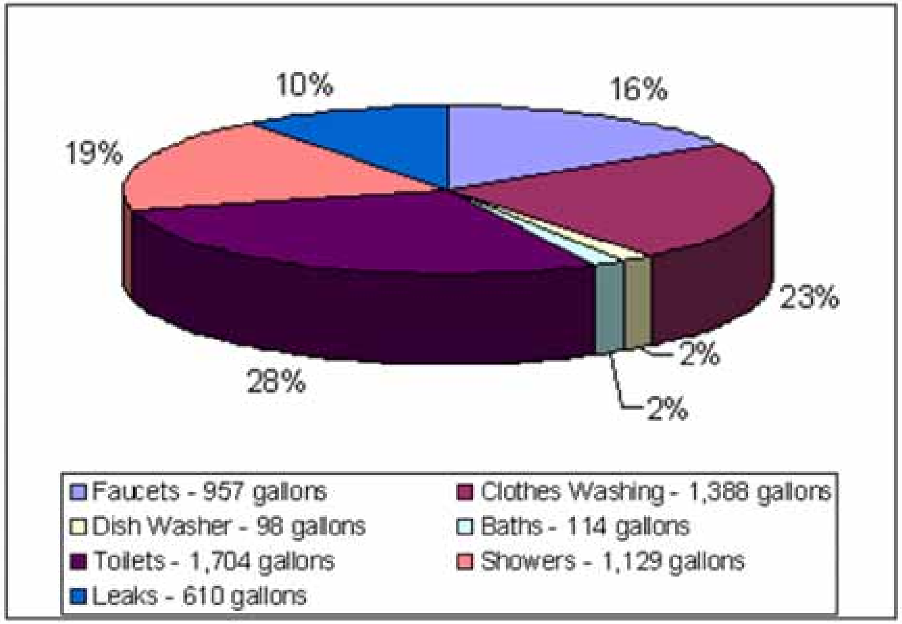
Water recycling using conventional treatment is much less expensive, and water conservation is always important.

Treehugger

Seawater Desalination

The US Green Building Council (USGBC) sponsors a *Leadership in Green Energy and Environmental Design* (LEED) program that recognizes credits for water conservation in their certification ratings:

- **Two credits are awarded for reducing potable water use for irrigation.**
- **One credit is given for reducing potable water use for sewage conveyance.**
- **Two are issued for reducing potable water use inside a building.**



Average Monthly Indoor Residential Water Use (6,000 gallons Without Conservation)

Outdoor	Indoor
• Cover pools and spas to reduce evaporation.	• Replace older toilets with ultra low flush system types.
• Plant hardy, water-saving plants (particularly native species).	• Don’t use toilets as trash cans for facial tissues, etc (flush less often).
• Plant grass only where practical and functional to reduce watering.	• Test toilets periodically for leaks to prevent wastes/expenses.
• Minimize evaporation by watering in early morning or evening.	• Purchase *Energy Star* model washing machines and dishwashers.
• Install drip irrigation systems with automatic timers.	• Run full loads of clothes/dishes to optimize use.
• Mulch to retain water (create/use compost if possible).	• Program washers to eliminate additional rinse cycles when possible.
• Mow less frequently during dry times to retain moisture.	• Use less shower and bathtub water (shorter showers/less full bathtubs).
• Use a shut-off nozzle when washing cars (don’t run water continuously).	• Install low-flow showerheads with aerators.

Household Conservation Tips

Composting toilets can conserve water and are most often used where public water and sewage aren't available.

They operate using the same natural decomposition process that occurs in a garden compost heap, and don't produce objectionable odors or health problems when functioning properly.

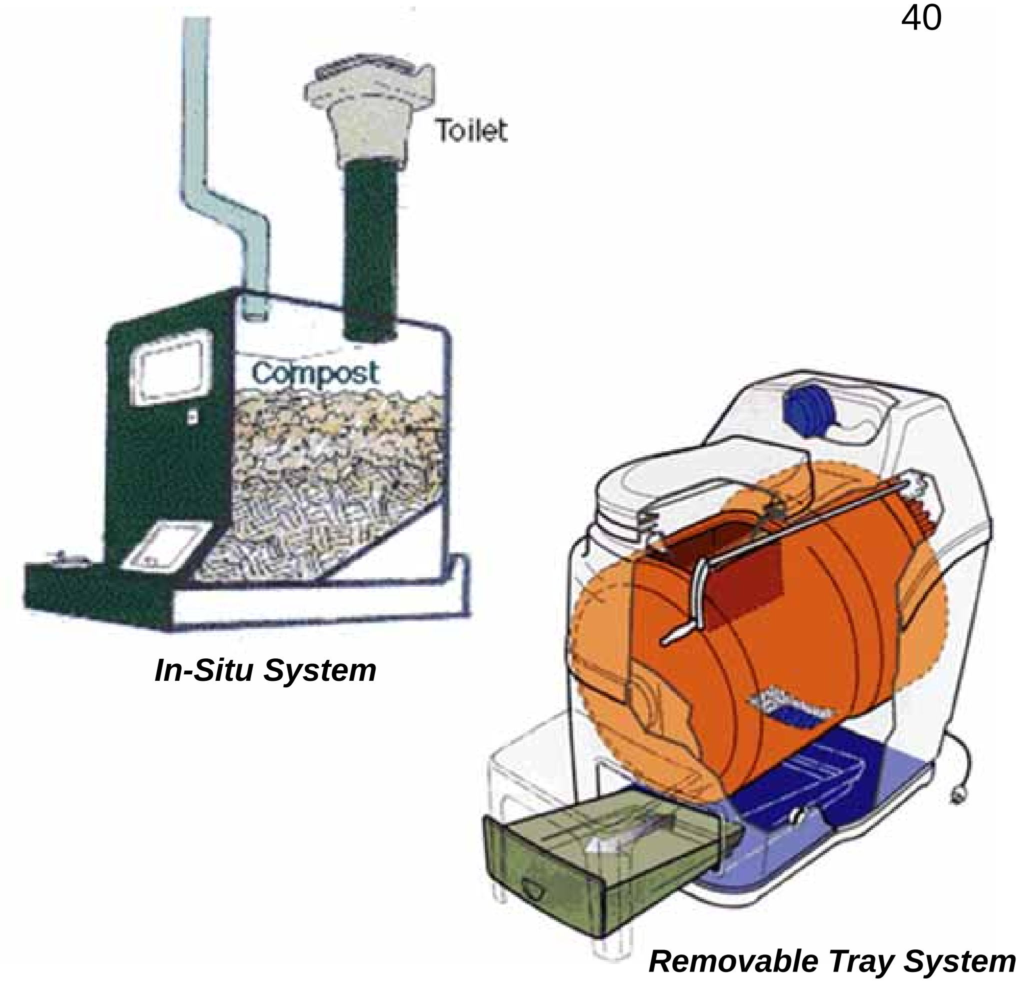
In some applications, they can convert human wastes into solid and liquid fertilizers.

Composting Toilets

Composting toilets are technically quite simple, but require more attention than flush-type WCs.

They must be operated separately from grey water collection systems and often need special installation and operation accommodations.

The composted material must be removed when sufficiently decomposed (frequently dependent upon container size, amount of use, and climate conditions).



In-Situ System

Removable Tray System

Compost Toilet Types

Odors can be controlled using natural air ventilation or low-voltage extractor fans, by separating urine and feces, and by adding a high carbon-content peat mixture to absorb liquid.

Fecal materials should be either heated to destroy pathogens, or allowed up to a year to disappear naturally.

Envirolet

Special Compost Toilet Considerations

Waterless compost toilets have been used in Scandinavia for many decades, and are gaining broader public acceptance in the US.

They have demonstrated odor-free operations, and enable use in drought areas where water isn't available over long time periods.

Fertilizers from human wastes can legally be used for horticulture and agriculture after a specified time period.

Public Compost Toilet Installation Along a Highway in Sweden.

Growing Public Acceptance

Spiral Island

Compost Nutrient Products

Conversion of human waste into safe and usable compost material can take be three months to a few years.

Warm climates expedite natural decomposition.

In 4 – 6 years, the compost takes on properties of highly mineralized soil.

Urine (rather than feces) contains the major fertilizer nutrients (about 90% of the nitrogen and 70% of the phosphorous).

markmason.net/house/rainsys.jpg

Incompletely composted feces contains pathogens that present health risks.

Human wastes should not be used as fertilizer unless composting temperatures reach at least 100°F - 125°F.

In cool climates, full decomposition can’t be guaranteed to produce fertilizer safe for food crops.

Safety Compost Toilet Sanitary Issues

Waterless incinerating toilets are useful in small-scale applications, such as:

- **Places where septic systems aren’t practical.**
- **In remote areas where piped sanitation systems aren’t available.**
- **For marine vessels to avoid waste discharges into water.**
- **In drought areas and other locations where water conservation is most urgent.**

Cold Climates

Roadside Services

Marine Vessels

Drought Areas

Incinerating Toilets

CONSERVATION PRACTICES

WATER

Incinerating toilets are simple in design, consisting of traditional commode-type seats and holding tanks with electric or gas-fired heating / combustion systems.

Incineration products are mostly water and small amounts of sterile, fine ash.

Units are portable, easy to install, and relatively odorless.

The Incinolet usually incinerates waste after each use but can accept a maximum of 2-4 “flushes” before incineration is necessary

Incolet Electric System

The Starburn toilet can be used up to 60 times before incineration. It can meet the needs of 8-10 people in an average 8-10 hour workday, or about 6-8 people over a 16 hour period. It cannot be used during the 4.5 hour burning cycle.

Starburn Gas-Fired System

Incinerating Toilet Types

Disadvantages and Limitations

Incinerating toilets present certain limitations and disadvantages:

- Incineration destroys waste nutrients (ash is inadequate for fertilizer).
- Incineration requires energy (adds costs for users).
- Both electric fuel-fired types produce some combustion pollutants.
- Some models cannot be used while the incineration cycle is in progress.
- Anti-foam agents, catalysts or other additives are often required.
- Annual inspections are required if a catalyst is used.

Maintenance Requirements

System maintenance requirements depend upon type and model used but includes:

- Periodic cleaning of burner and regular removal of ash.
- Cleaning of outer surfaces (e.g., bowl halves of electric types).
- Regular (90 day) cleaning of blower motor and occasional replacement of parts.
- Cleaning/lubrication of foot pedal mechanism (electric types).
- Removal of bits of paper and dust from combustion chamber.
- Regular emptying and cleaning of the ash collection pan.

Incinerating Toilet Considerations

Necessary potable water purification processes are influenced by the supply sources and quality standards applied.

Most groundwater is naturally filtered through soil and rock layers before entering a treatment plant or well.

Shallow groundwaters often contain bacteria and toxic metals.

Upland lakes and reservoirs make contain contaminants from livestock and human activities.

Rivers, canals, and lowland reservoirs may contain bacteria, algae, and pesticides.

Deep Groundwater

Shallow Groundwater

Upland Bodies

Lowland Bodies

Natural Sources

CONSERVATION PRACTICES

WATER

Contamination Hazards

• Potentially low concentrations of pathogenic bacteria or protozoa. •May contain dissolved solids (carbonates and sulphates of calcium and magnesium) and ions (chloride and bi-carbonate). •May be unpleasant for drinking, cooking and washing (sulphur, iron and manganese). •Is equivalent to lowland surface water where recharge is practiced. **Deep Groundwater**	•Often sited above human habitation, and protected by a protective zone to restrict contamination levels. •Bacteria and pathogen levels are usually low, but some bacteria, protozoa or algae will be present. •Where uplands are forested or peaty, humic acids can color the water. •Many upland resources have low pH conditions that require adjustment. **Upland Lakes and Reservoirs**
• Bacterial quality depends heavily upon the nature of the catchment. •A variety of soluble materials may be present, including toxic metals such as zinc and copper. •Arsenic contamination is a problem in some areas such as wells in Bangladesh and Ganges Delta. •May be contaminated by leaching of undigested human, animal, and industrial wastes. **Shallow Groundwater**	•Are likely to have very significant bacterial loads. •May contain algae, suspended solids and a variety of dissolved organic and ion constituents. •Upstream human, agricultural and industrial wastes combined with watershed pesticide/herbicide can inject contaminants. •Ships and other water vessels may release petroleum and human wastes. **Rivers, Canals and Lowland Reservoirs**
Natural Water Source Considerations	

Potable water purification treatment involves three processing stages:

- **Primary treatment collects, screens, and stores water from sources.**
- **Secondary treatment removes find solids and most contaminants using filters, coagulation and other processes.**
- **Tertiary treatment "polishes" the water, adjusts the pH, removes bad tastes and smells, and kills remaining organisms.**

Walkerton Clean
Water Centre

US Fire Admininistration
Matt Kingston

Potable Treatment

US Army

New Water Treatment Plant in a Small Iraqi Village, Created by the USA

The United Nations estimated that in 2000, about 2.6 billion people (44% of the global population) had inadequate sewage treatment and / or disposal, and about half of the people in Africa had no access to wastewater treatment at all.

Eliminating Environmental and Health Hazards

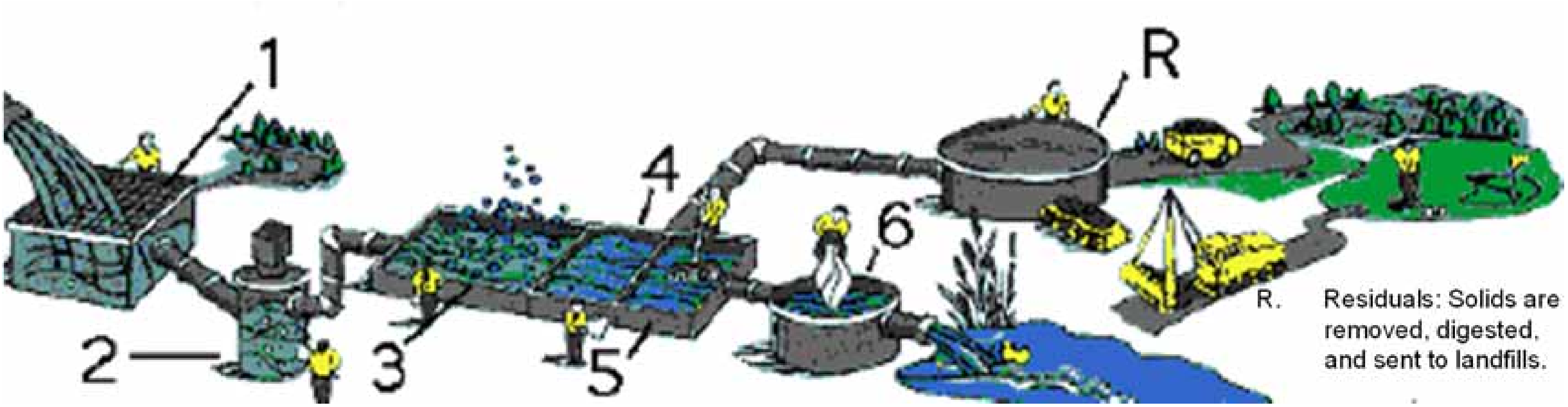
Wastewater treatment facilities treat and reclaim water from sewage and /or ground and surface water to produce potable water or "industrial water":

- **Preliminary treatment removes oils, grease, fats, sand, grit and settled soids.**
- **Secondary treatment digests and degrades biological waste contents.**
- **Tertiary treatment involves additional finishing processes such as "lagooning", microfiltration and disinfection.**

Wastewater Treatment Outlet Into a Small River

Wastewater Treatment

United States Geological Service



R. Residuals: Solids are removed, digested, and sent to landfills.

1. Screening: Debris such as wood, rocks and even dead animals are removed and disposed of.
2. Pumping: If the plant is above ground level, wastewater must be pumped up to aeration tanks for processing.
3. Aerating: Sewage enters long concrete tanks where air is pumped through to replenish oxygen and suspend organics.
4. Sludge Removal: Wastewater enters sedimentation tanks (digesters) where organic materials are removed.
5. Scum Removal: Grease, oils, plastics, soaps, and other floating scum is skimmed off and digested.
6. Bacteria Destruction: The wastewater flows into a chlorine tank where bacteria are killed.

Wastewater Treatment Steps

Primary wastewater treatment uses mechanical means to reduce oils, grease, grit and course settled solids:

- **Large objects are removed by manual or automated rake devices.**
- **A “sand catcher” removes sand / grit.**
- **Floating particles are sifted or chopped into small particles and removed.**
- **Floating fecal solids and other materials are transported to settling tanks for further treatment / disposal.**
- **Natural methane may be collected for useful purposes.**

Primary Sedimentation Tank at a Rural Sewage Treatment Plant

Primary Treatment Stages

Secondary treatment degrades the biological content of sewage using aerobic processes:

- **Roughing filters sift out large organic contents for treatment in digesters.**
- **Various oxygenation mechanisms digest organic materials and convert ammonia to nitrates and nitrites.**
- **Oxidizing beds filter and aerate settled matter for bacterial digestion.**

Secondary Oxidizing Bed

Secondary Treatment Stages

Tertiary treatment raises effluent quality to a safe level for discharge into a natural environment:

- **Sand filtration removes much of any remaining suspended matter, and activated carbon removes residual toxins.**
- **Lagooning in man-made ponds uses plants and small invertebrates to digest fine particles.**
- **Biological oxidation, bacteria, sand filters and reed beds remove nitrogen and phosphorous.**
- **Remaining living organisms can be reduced using ozone, chlorine and / or UV light.**

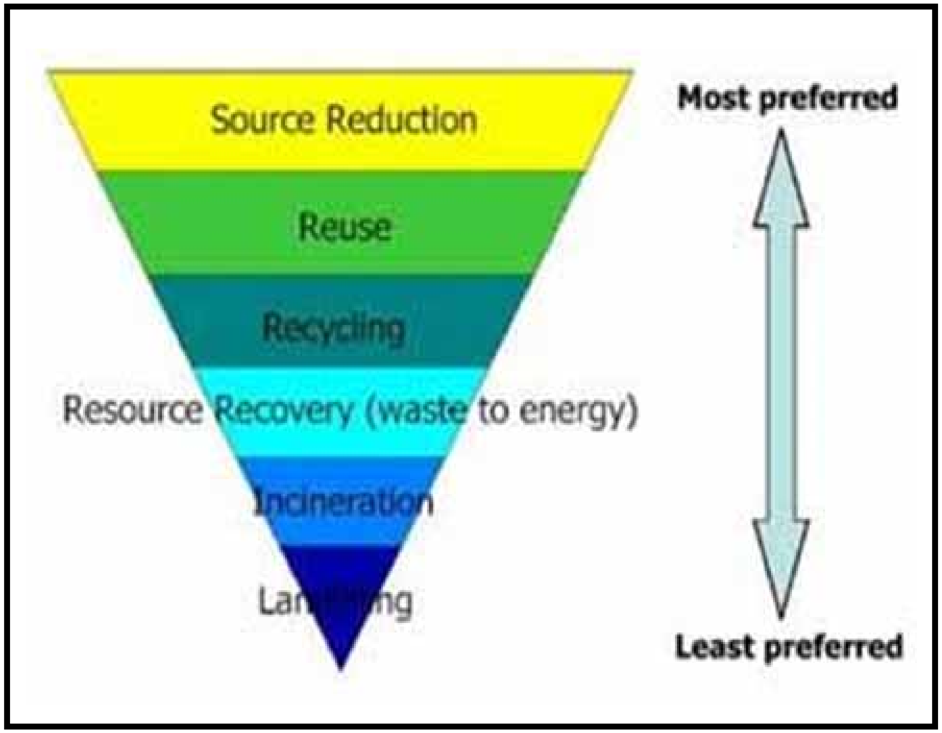
Falke Bruinsma

Lagoon

Tertiary Treatment Stages

Waste management involves the collection, transport, processing, recycling and disposal of materials produced by human activities, along with effort to minimize their production.

Primary aims are to extract maximum benefits from these products and minimize the amount of waste through source reduction, resource recovery, and recycling.



Basic Approaches

Organic wastes can be made safe and converted to useful components through biochemical and thermal / chemical processes:

- **Biological processes include composting and anaerobic digestion to decompose matter, kill pathogens, and stabilize nutrient fertilizers.**
- **Thermal / chemical processes primarily involve pyrolysis and gasification to convert organic materials into solid, liquid and gaseous fuels.**


Composting


Anaerobic Digestion

Biological Processes


Pyrolysis


Gasification

Thermal/Chemical Processes

Biological and Thermal/Chemical Processes

CONSERVATION PRACTICES

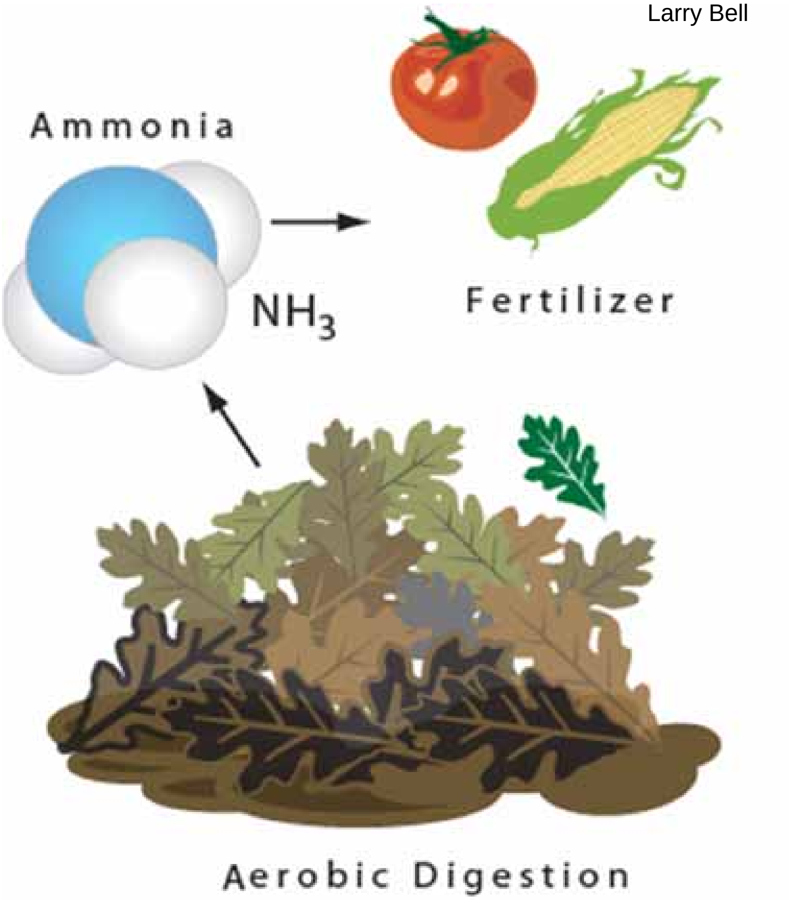
WASTE REDUCTION AND USE

Larry Bell

Composting enables organic materials such as plant biomass, food scraps and paper to be recycled into nitrogen-rich ammonia fertilizer.

This aerobic process decomposes organic wastes with assistance from bacteria, fungi, worms, and other organisms.

Early Greeks and Romans used composting, and the same methods are applied to modern, environmentally-sound gardening practices.



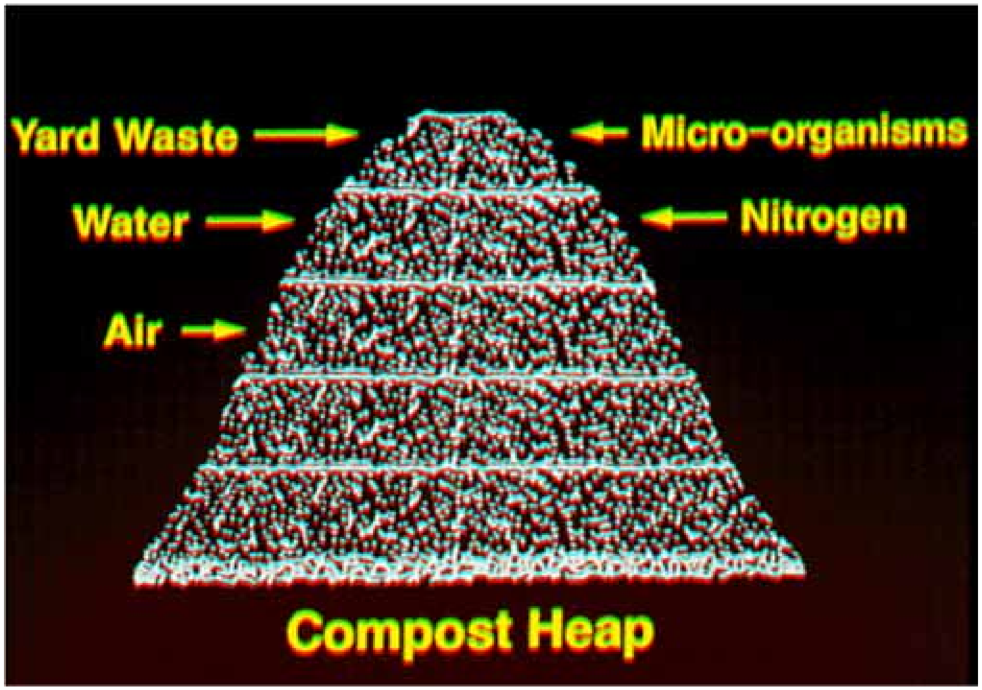
Recycling Waste into Nutrients

Composting operations range from small residential activities to large municipal facilities.

Typical residential decomposers are ventilated containers of about 1m^3 volume.

A City of Edmonton, Alberta, Canada composting facility covers 38,690 m^2 (about the size of eight football fields), and produces about 80,000 tons of compost annually.

TAMU



Composting Process

Residential composting can substantially reduce municipal waste management costs, eliminating 20% - 50% of curbside garbage comprised of landscape and kitchen wastes.

Waste source reduction diverts large amounts of material away from landfills, and saves transportation and other disposal expenses.

The composting product provides soil nutrients, assists moisture retention, loosens tight clay materials, and produces landscaping mulch.

TAMU

Important Composting Benefits

CONSERVATION PRACTICES

WASTE REDUCTION AND USE

Larger-scale applications generally use active (or “hot”) composting techniques, and small ones are usually passive (“cold”):

- **Active techniques used for commercial and industrial applications regularly turning the pile, temperature monitoring, and adjusting mix ingredients to speed the process.**
- **Passive methods (home and farm applications) let Nature take a slower course.**

KNOWASTE

Active composting can produce finished product with useful fertilizer constituents for plant growth.

Water . . . 10-15%
Organic matter . . . 10-20%
Nitrogen . . 0.8%
(Highest yields-manure)

Phosphorus . . . 0.45%
Potassium . . . 1.45%
Lime . . . 1.25%
Magnesium . . . 0.3%

Compost Fertilizer

Active Composting

- Is used by a few urban centers around the world for large-scale co-processing of solid wastes and de-watered bio-solids.
- Is also used in smaller-scale agricultural operations to recover nutrients from plant residues and animal manure.
- Provides the most effective composting approach to enable decomposing bacteria to thrive, killing most pathogens and seeds.
- Produces higher temperatures (reaching 110° - 160°F) to achieve rapid decomposition with high-quality fertilizer products
- Is most effective when high-nitrogen organics (such as corn) are mixed with high-carbon materials.

Passive Composting

- Is simpler and more often used in rural/farm applications (throw everything in a pile and leave it for a year or two).
- Often used as a means to eliminate and treat organic kitchen and garden wastes to produce fertilizer mulch.
- Lets Nature act more slowly, leaving pathogens and seeds alive and/or dormant in the pile.
- Longer curing periods tend to increase the amount of useful nutrients (particularly nitrogen) to leach out, reducing fertilizer value.
- Requires that non-biodegradable materials (including colored paper, foils and plastics) be avoided. (Also applies to active systems).

Active and Passive Composting Techniques

Arrow Bio Israel

Large Twin-Stage Biodigesters for Waste and Wastewater Treatment

Source reduction through anaerobic digestion breaks down organic matter in sealed vessels to produce heating fuel, electrical power, or both.

Digesters have been commonly used for sewage treatment and animal waste management for many years, and are gaining widespread utilization.

Most biodegradable materials can be processed.

Anaerobic Digestion

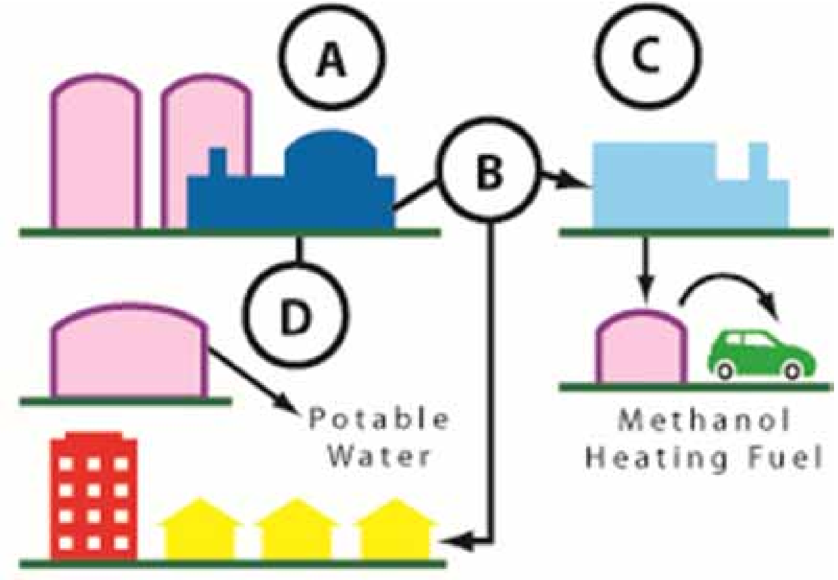
CONSERVATION PRACTICES

WASTE REDUCTION AND USE

More than one hundred US energy co-ops are using biomass in their power supplies, including farm by-products, wood wastes, aquatic plants and landfill methane.

Landfill methane energy programs offer opportunities for large and small communities and agribusinesses to supplement power sources and revenues.

Municipal wastewater processes can capture methane for heating and methanol production in combination with water purification.

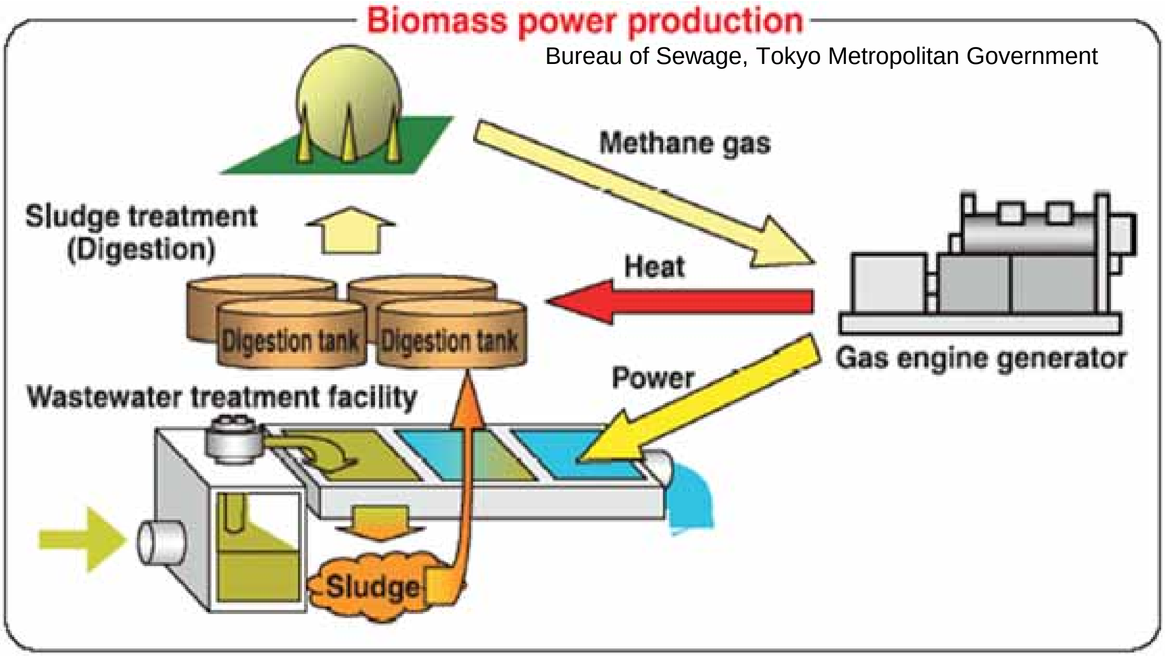


A - Wastewater Treatment
B - Methane Gas
C - Methane Plant
D - Water Purification

Municipal Waste Application

Biodigestion of wastewater sludge can produce methane fuel for district power and heat.

The heat can also be used to carbonize sludge as a low-ash emission fuel source for power through incineration.



Bureau of Sewage, Tokyo Metropolitan Government

Municipal Waste Conversion

CONSERVATION PRACTICES

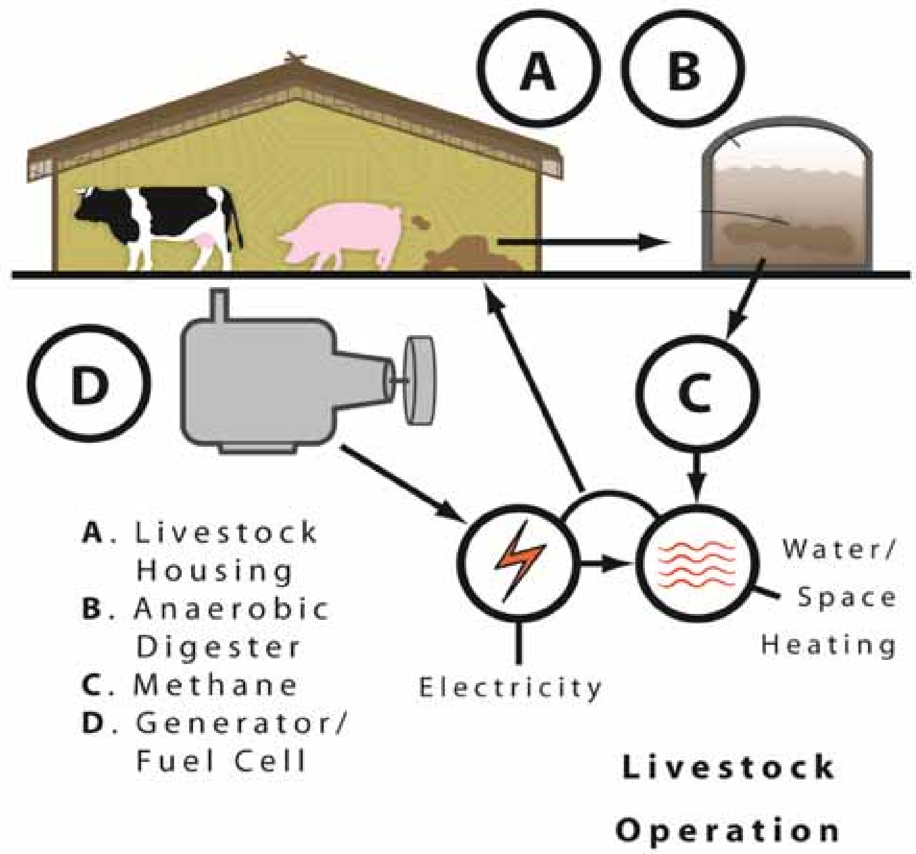
WASTE REDUCTION AND USE

Larry Bell

Farm-scale biodigesters can provide heat and power that can be applied using methane-fueled engine generators or fuel cells.

Each 100 pounds of manure can yield about 4 pounds of methane over about 20-25 days.

Process heat can be used for space and water heating, and electricity can be used for milk coolers, vacuum pumps, lighting, and other purposes.

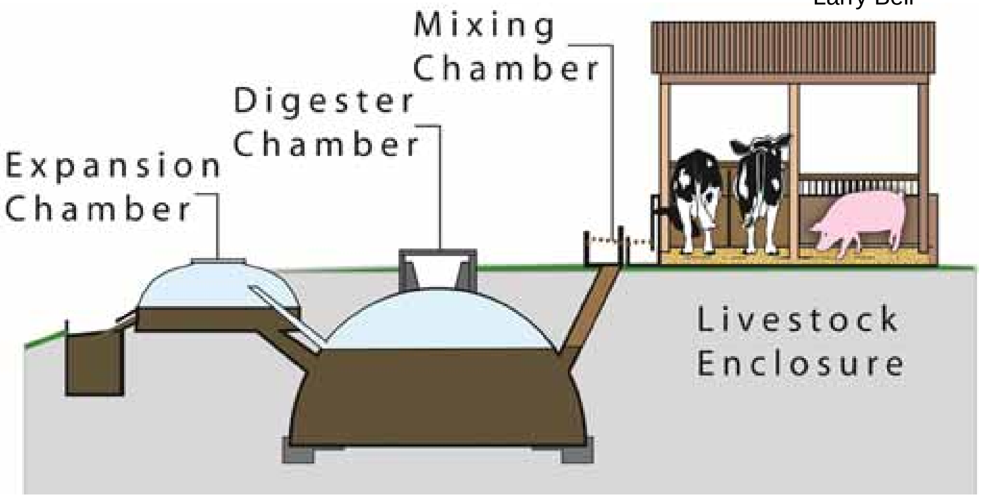


Bioreactor Power and Heat

CONSERVATION PRACTICES **WASTE REDUCTION AND USE**

Some general rules of thumb for planning manure bioreactors:

- **Must have a minimum of three cows or ten breeding pigs to sustain operations**
- **Livestock enclosure must be within 65 ft (20 meters) of the bioreactor**
- **Animals must be in the enclosure all night (a minimum of 12 hours)**
- **Requires year-round access to ground water within 65 ft (20 meters).**
- **Biogas should be used within 330 ft (100 meters) of the reactor**



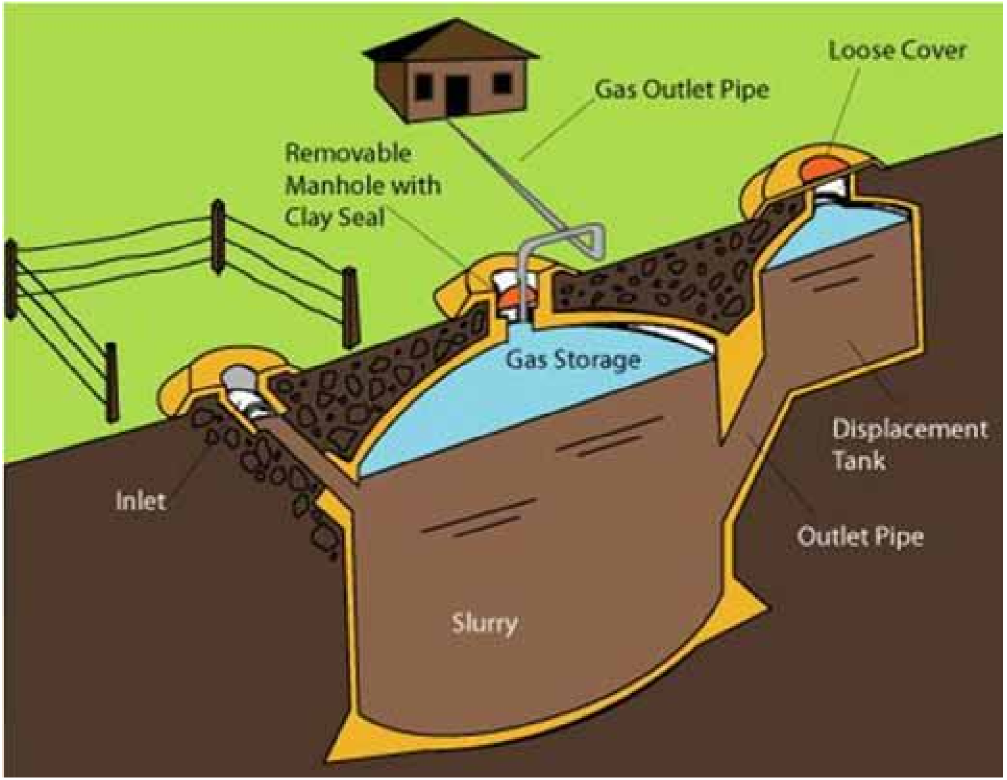
Larry Bell

Practical Action

Farm bioreactors can also recycle fertilizer and water in addition to yielding heat and power.

Livestock manure is a good source of nitrogen-rich fertilizers.

Anaerobic digestion can generally reduce pathogenic organisms and enable water to be recovered that is safe for irrigation.



Manure bioreactors can provide biogas and fertilizer for on-site farm use.

Manure Bioreactors

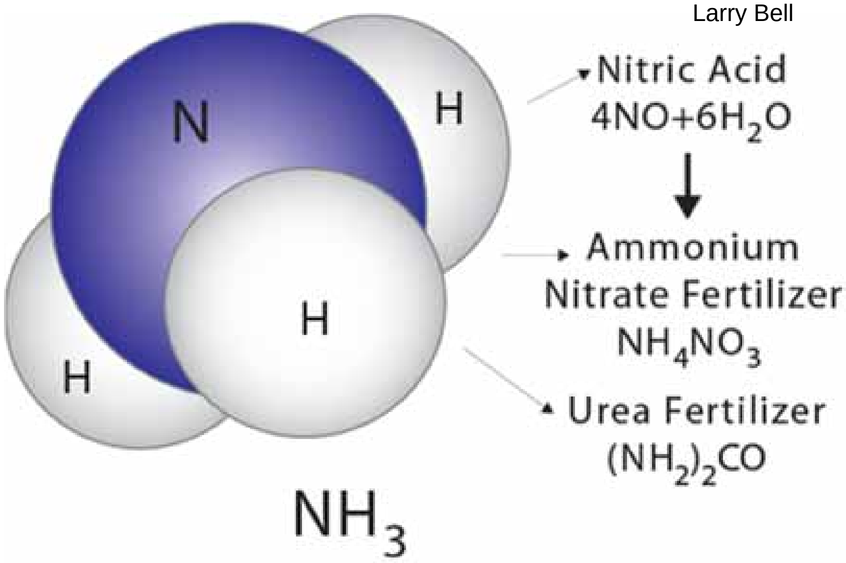
CONSERVATION PRACTICES **WASTE REDUCTION AND USE**

Ammonia Fertilizer

Ammonia is produced naturally by anaerobic putrefaction, and is one of the most commonly manufactured inorganic chemicals.

This nitrogen-hydrogen compound is used primarily for commercial fertilizers, explosives, and polymers.

Ammonia can be used to create urea fertilizer, or can be directly mixed with irrigation water for growing nitrogen-dependent crops such as corn.



Larry Bell

Ammonia is a colorless, pungent lighter-than-air gas.

- ***Ammonia gas does not sustain combustion unless mixed with oxygen, but can catch fire and become explosive when combined with chlorine..***
- ***Anhydrous ammonia corrodes copper and zinc alloys, and liquefies under pressure at ambient temperatures and when refrigerated below -28°F for transport and storage.***

The Haber process begins after the hydrogen has been removed from natural gas/methane by SMR, or from coal/char through gasification:

1. **Sulfur compounds are removed through catalytic hydrogenation by converting them to gaseous hydrogen sulfide (H_2S).**

2. **The H_2S is absorbed and removed by passing it through zinc oxide beds that convert it to zinc sulfide (ZnS).**

3. **Catalytic steam reforming of the sulfur-free feedstock is used to produce carbon monoxide and hydrogen ($CO + 3H_2$).**

4. **A catalytic shift conversion coverts the carbon monoxide to carbon dioxide and more hydrogen ($CO_2 + H_2$).**

5. **Carbon dioxide is removed by absorption, and catalytic methanation removes residual carbon monoxide from the hydrogen.**

6. **The hydrogen is then catalytically reacted with nitrogen from processed air to form anhydrous liquid ammonia.**

The Haber Process for Ammonia Synthesis from Hydrogen

CONSERVATION PRACTICES

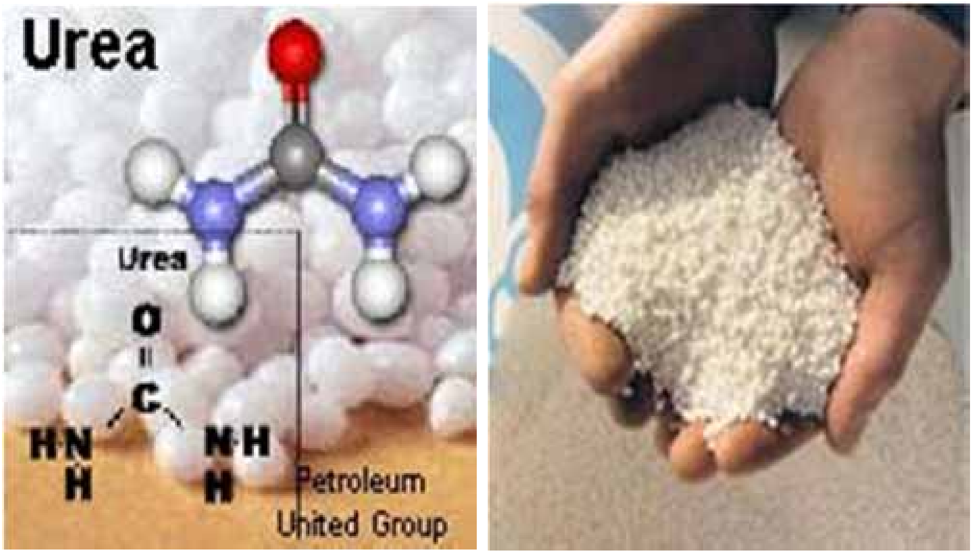
WASTE REDUCTION AND USE

Urea is formed in nature as a waste product in the livers of mammals during the process of converting toxic ammonia through the “urea cycle” and is present in abundant quantities in livestock excretions.

More than 90% of the urea produced world-wide each year is used as fertilizer.

The chemical has the highest nitrogen content of all nitrogenous fertilizers (46.4%), offering the lowest transportation costs per unit of nitrogen content.

University of Minnesota SOS-Arsenic



Commercial urea is available in the form of granules, flakes, pellets, prill, crystals and solutions.

Urea Fertilizer

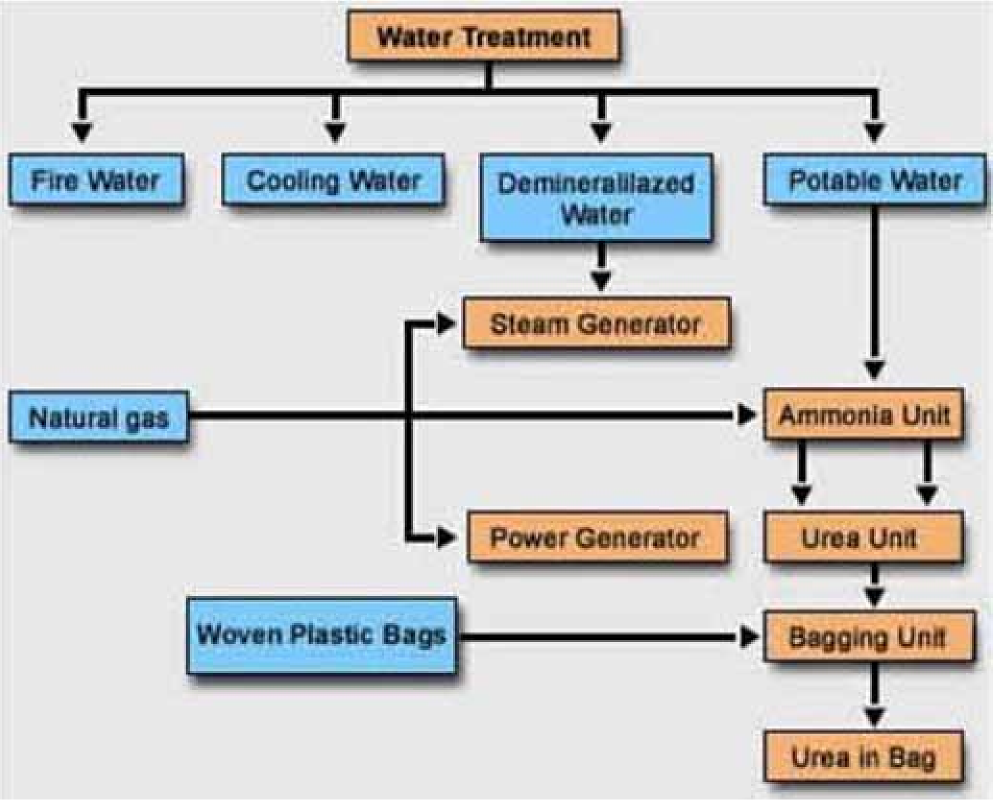
CONSERVATION PRACTICES

WASTE REDUCTION AND USE

Commercial urea is produced in connection with standard ammonia manufacturing processes using natural gas/methane, water, and air:

- **First, the natural gas/methane and water are processed to produce nitrogen, hydrogen, and carbon dioxide.**
- **Next, the nitrogen and hydrogen are processed to produce ammonia (NH_3).**
- **Finally, the ammonia and carbon dioxide are processed to produce tiny urea "prill" pellets.**

PT Pupuk Kujang



Commercial Urea Fertilizer Production

Huge amounts of solid wastes are produced throughout the world each year are disposed of using landfills and incineration.

Countries/regions with large land areas and low population densities typically use landfills, while densely populated areas tend to rely primarily upon incineration.

Poorly managed landfill sites present a variety of health and odor problems, and incineration can be highly wasteful and polluting approach.

Objectionable landfill and incineration features can be reduced by applying improved methods.

Utah State
Univ

Penn State
AP

Landfills

Incineration

Landfills and Incineration

Although solid waste incineration is sometimes termed “Energy from Waste” (EfW) there are better ways to recover energy from waste than burning it:

- **Burning destroys raw material, and the energy converted through combustion to produce steam for electricity is relatively small.**
- **Incineration release atmospheric pollutants along with ash residue that can leach into the ground and contaminate sub-surface aquifers.**

Incineration

Landfills are the most traditional solid waste disposal method used world-wide, but new ones often face opposition from nearby landowners and residents.

Common objections are odors, wind-blown litter, attraction of vermin, and pollutants such as leachate that can contaminate groundwater and rivers.

Landfills

Some changes in landfill planning and management are realizing progress in addressing public concerns:

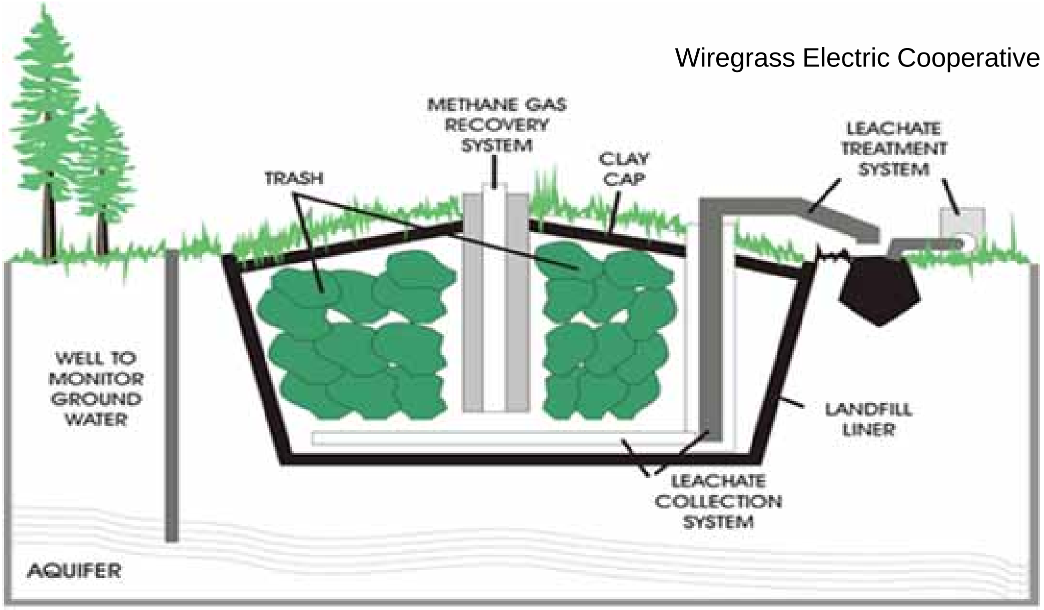
- **Improved gas extraction technologies are reducing odors, capturing methane more effectively, and providing leachate collection and ground barriers.**
- **Recycling of discarded metals, paper, and plastics rather than recovering them from landfills after disposal reduces waste mass and makes good practical sense.**

Hot Air Zone
Bottles and Cans

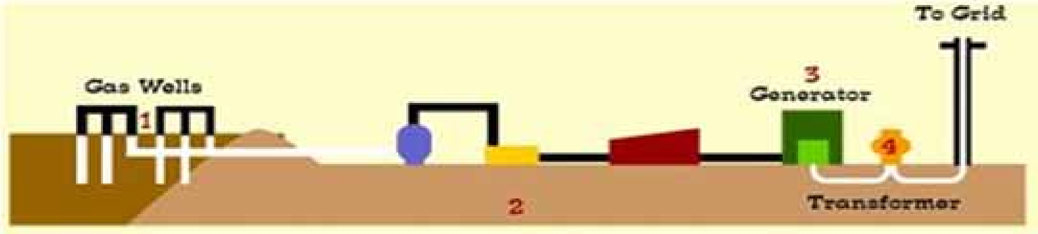
RRT
University of Oklahoma

The Wireglass Electric Cooperative in southeast Alabama produces electricity using landfill methane, solar, wind, geothermal, and hydro sources.

Landfill methane is used to fuel a gas-to-energy power station that generates about 4.8 MW of electricity.



Wiregrass Electric Cooperative



Landfill Methane Recovery

“Secondary resource recovery” is increasingly being practiced in metropolitan areas around the world, particularly where spaces for new landfill sites are becoming more scarce.

There is a growing awareness that simply disposing of useful materials is unsustainable, short-sighted, and irresponsible.

Earth Works Recycling, Inc.
Rochester Environment

Truman State U
State of South Dakota

New recovery methods and technologies are constantly being developed, creating economical business opportunities for equipment developers and product reclaimers.

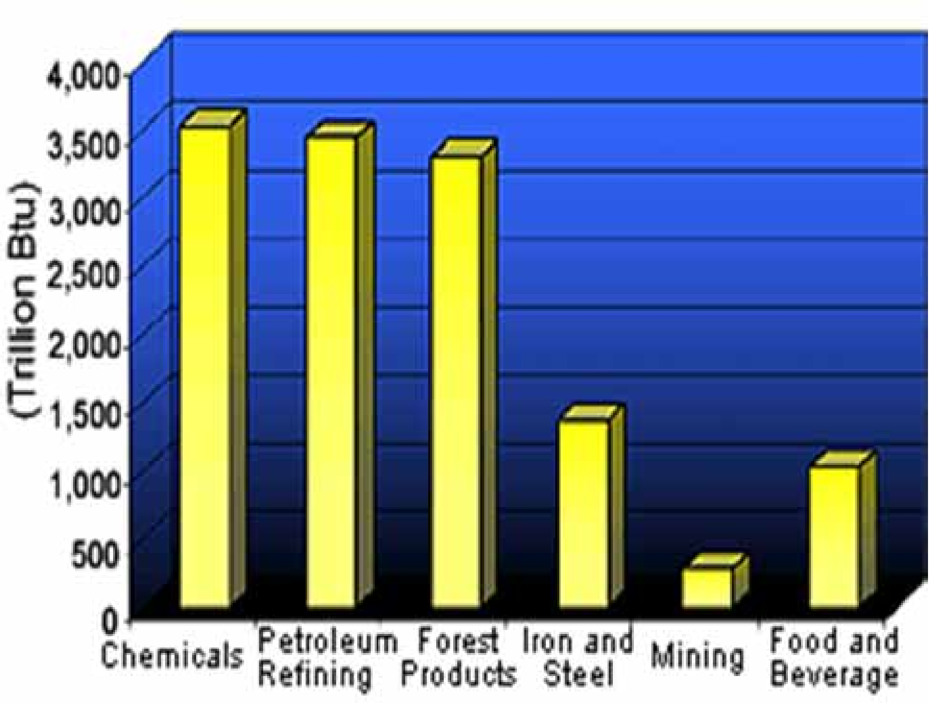
Secondary Resource Recovery

The industrial sector consumes about one-third of all US energy.

Forest product processing is the largest user of steam and combined heat-power systems, while petroleum refining is the largest user of fired heating systems (iron and steel are third).

Chemicals are the largest users of electrical motors, and motors also represent about 25% of mining energy use.

Agency for Natural Resources



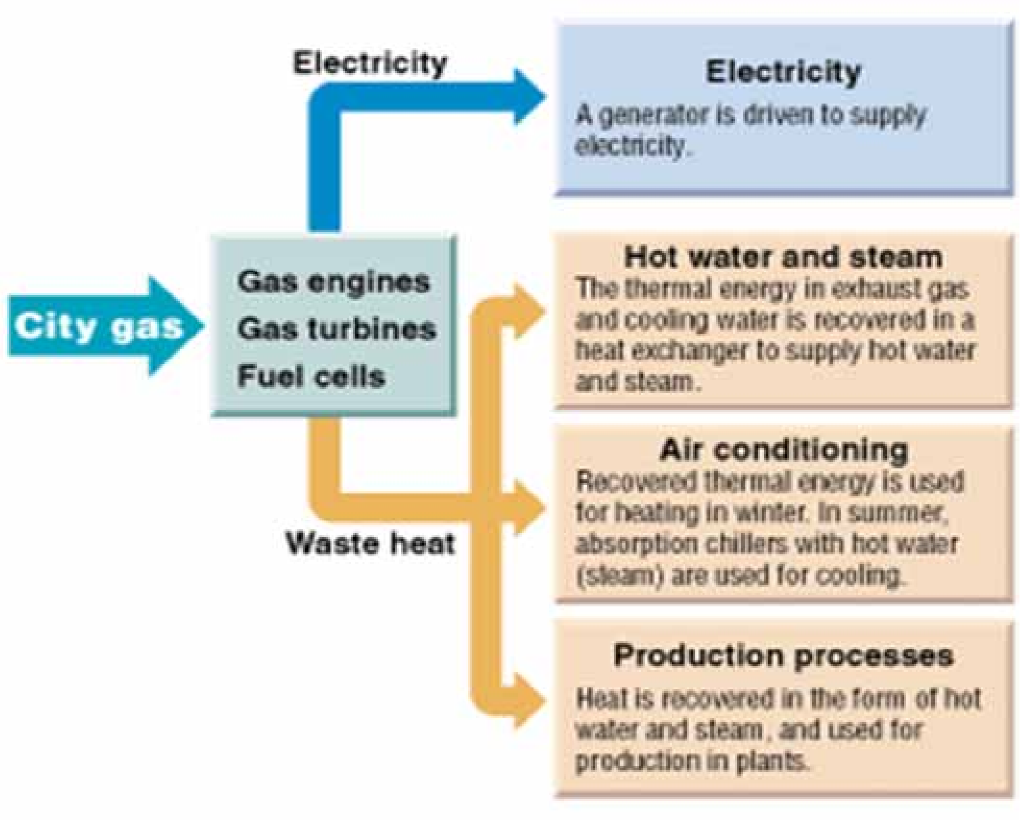
Top Six US Energy System Users (Trillion BTU)

Combined heat and power (CHP) is contributing large energy economy gains for industrial applications.

In some cases the “waste” output heat is recycled to reduce energy required to sustain electricity generation.

In other instances the excess heat is used to proved hot water/steam to drive air-conditioning systems, or is exported for other purposes.

Japan Gas Association



Electricity

A generator is driven to supply electricity.

Hot water and steam

The thermal energy in exhaust gas and cooling water is recovered in a heat exchanger to supply hot water and steam.

Air conditioning

Recovered thermal energy is used for heating in winter. In summer, absorption chillers with hot water (steam) are used for cooling.

Production processes

Heat is recovered in the form of hot water and steam, and used for production in plants.

CHP Energy Recycling

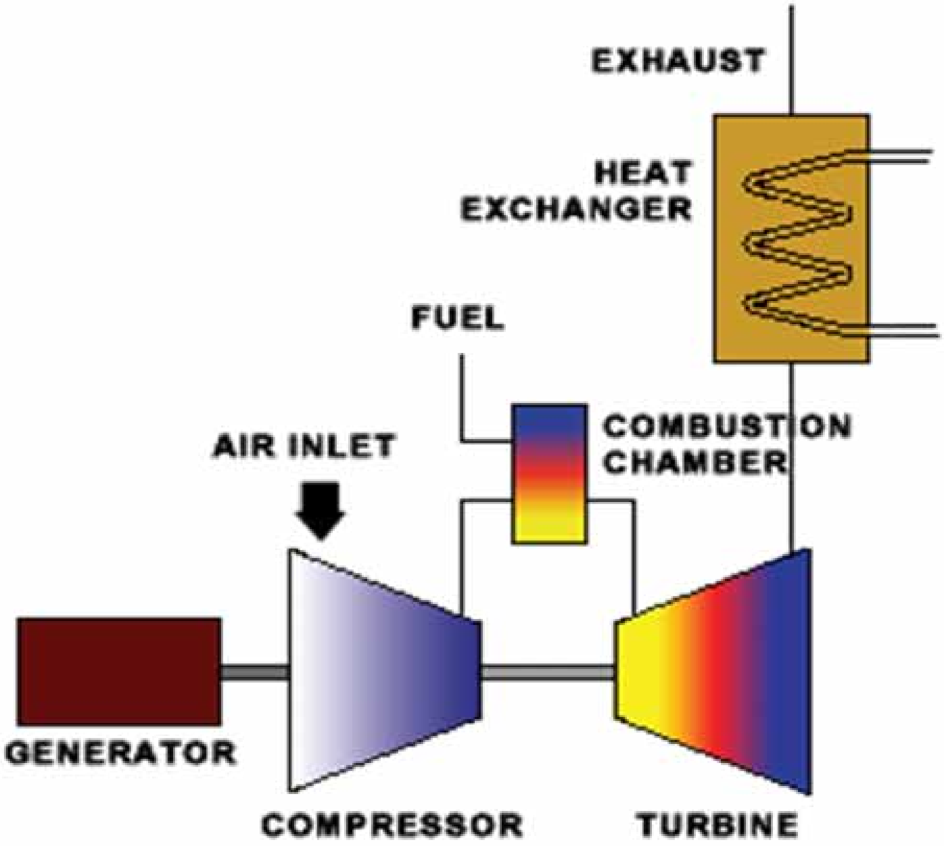
CONSERVATION PRACTICES

ENERGY SYSTEMS

CHP cogeneration plants can be powered by a variety of different fuels.

Cogeneration plants can yield efficiencies of 85% or more, reducing energy consumption, CO_2, and other pollutant emissions.

Cleaner operations enable plants to be located closer to population centers where power is needed, resulting in shorter electrical power transmission distances and reduced line resistance losses.



Cogeneration Benefits

Fuel cells generate efficient heat and power continually without use of generators.

CHP applications emit significantly less CO_2 than reciprocating engines per unit output, and operate at lower noise levels that enable plants to be located nearer to users to reduce electricity transmission losses.

Current high implementation costs are a disadvantage.

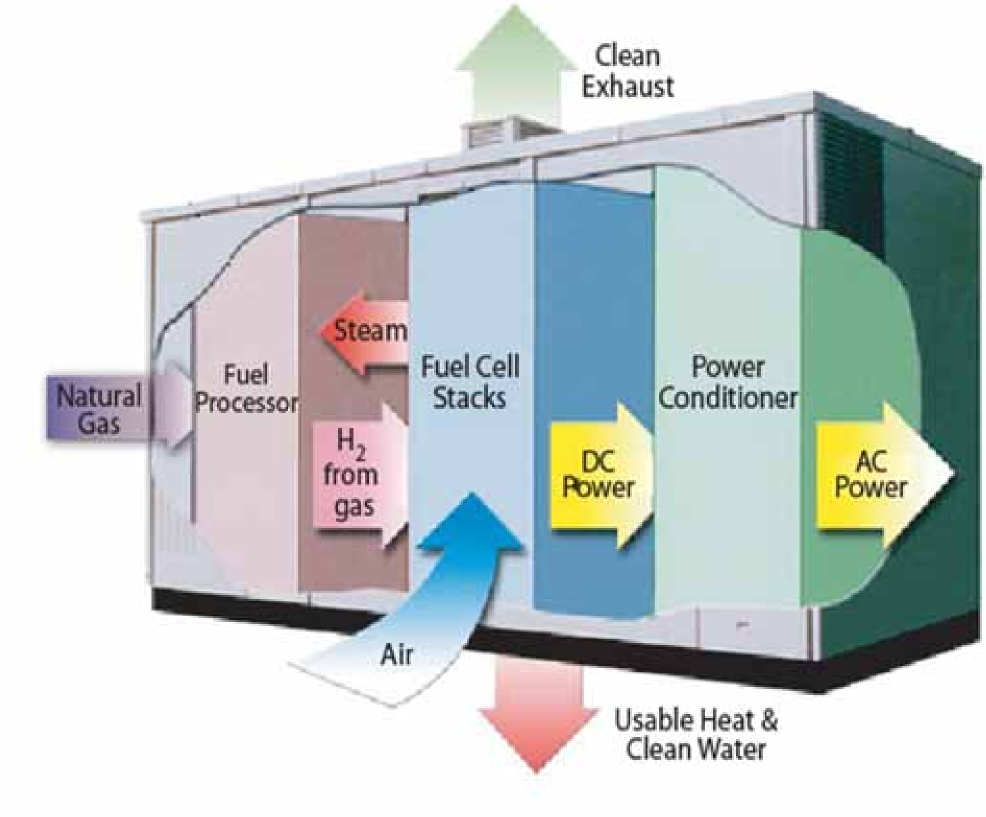
Wisconsin Distributed Resources Collaborative

Combined Heat and Power Fuel Cell Use

Fuel cell power plants are typically comprised of three primary system elements:

1. **A fuel processor** (or reformer) extracts hydrogen from natural gas or other fuel.
2. **A power section** containing fuel cell stacks produces electricity and releases water and heat byproducts.
3. **A power conditioner** converts DC to AC current.

Whole Building Design Guide

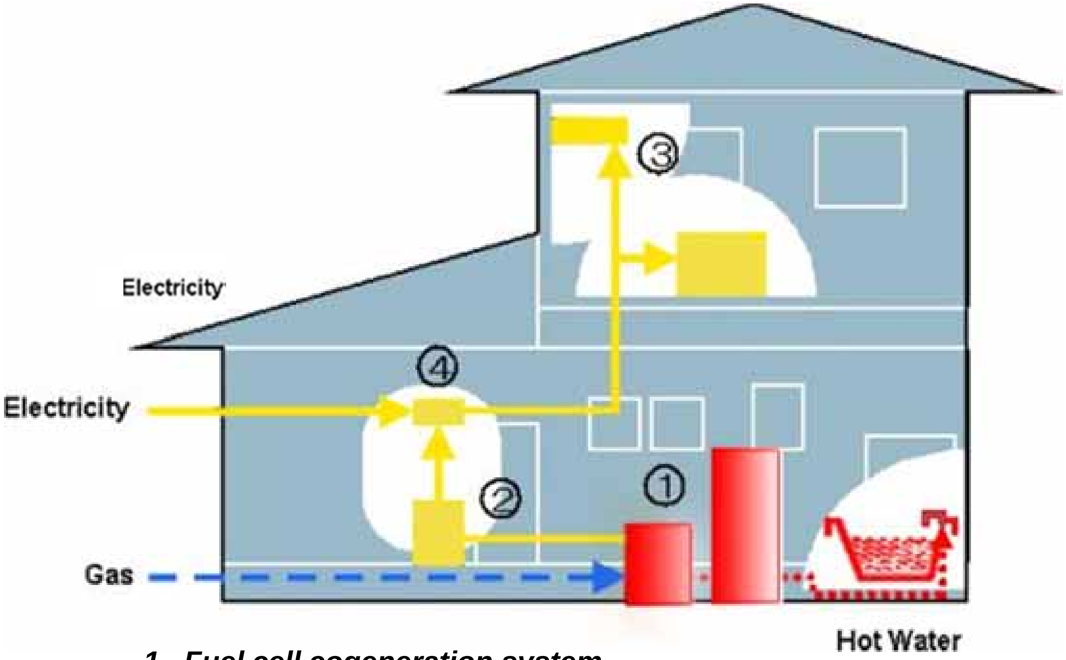


Typical Fuel Cell Power Plant

Matsushita Electric (Panasonic) has developed a compact CHP fuel cell system that can generate enough electricity and heat to supply a typical home (with backup power from a public utility grid).

The fuel cell power efficiency is about 35%, and operating noise is comparable to a standard air-conditioner.

Panasonic



1. ***Fuel cell cogeneration system***
2. ***Commercial power splitter (for connection to a system-linked inverter.***
3. ***Electrical appliances (such as air conditioners)***
4. ***Electrical distribution panel***

Matsushita Home CHP Fuel Cell System

Mass production is driving the costs of PV systems down, and they offer the most practical power option for some applications.

They are often ideally suited for remote locations, such as cottages, recreational vehicles/boats, agricultural water pumping and electric fences, and signage systems.

NASA

IEA PV

Europ. Solar Ener. School

Energy Supermarket

Photovoltaics

Fraunhofer ISE

Fraunhofer ISE

Off-grid autonomous and hybrid "island" PV systems provide power for homes, farms, and other businesses:

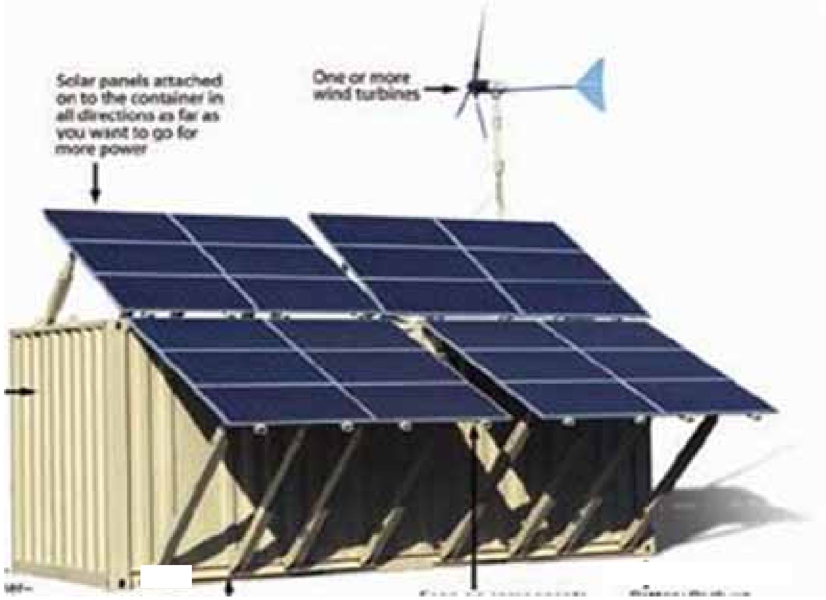
- Residents of warm, sunny areas can often use autonomous PV-battery systems to good advantage.
- Residents of colder, windy areas can use hybrid systems to accommodate long winter "solar gap" periods.
- Off-grid stand-alone and hybrid systems are broadly used for public functions such as parks, emergency facilities, and communications.

Roof-Mounted PV Installation

Two-Array Ground-Mounted Installation

Off-Grid PV Applications

Provision Technologies, Inc.



A solar-wind hybrid Mobile Power Station (MPS) developed by SkyBuilt Power of Arlington, Virginia, provides air-conditioned space for telecommunications, medical, emergency operations and other functions within a standard shipping container.

Sky Built Power

A modular and transportable Solar Powerhouse developed by Provision Technologies generates AC electricity for diverse purposes, including construction sites, water pumping, and emergency and village sites.

Portable PV Stations

National Photovoltaics

Grid-connected PV installations can ensure continuous energy access, eliminating the need for battery storage.

They are particularly useful for applications requiring substantial winter or year-round power level access.

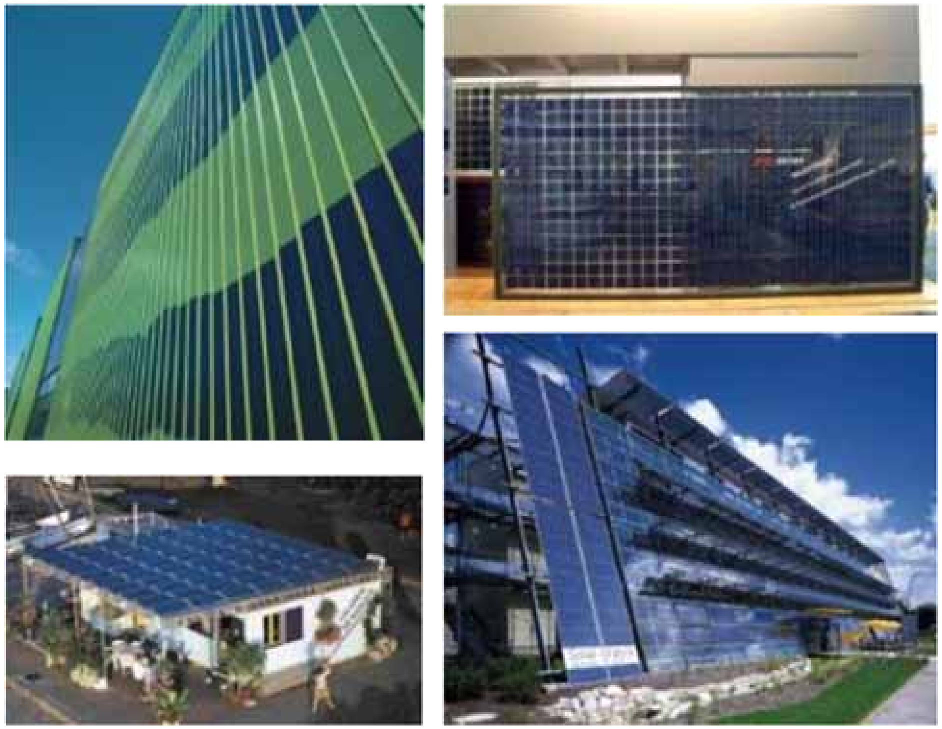
Relatively high up-front installation expenses can often be offset by energy tax credits and opportunities to sell excess electricity back to grid providers.

Typical Grid-Connected PV Home Installation

CONSERVATION PRACTICES **ENERGY SYSTEMS**

Building PV systems can be integrated directly into structures in various ways:

- They can be incorporated into weather membranes or external claddings.
- Cells can be incorporated into glazing laminates as foil sheets.
- Solar glazing can be used in double-glazed units, curtain walls, and glazing systems mounted onto rooftop frames and shading devices.



Lawrence Berkeley National Lab

Building Integrated Photovoltaics

PV systems combined with fuel cells and other energy systems can offer a variety of possible small-scale applications in remote locations.

Solar panels supported by batteries can provide power during the day, and fuel cells can produce supplementary and backup electricity when sunlight isn't available.

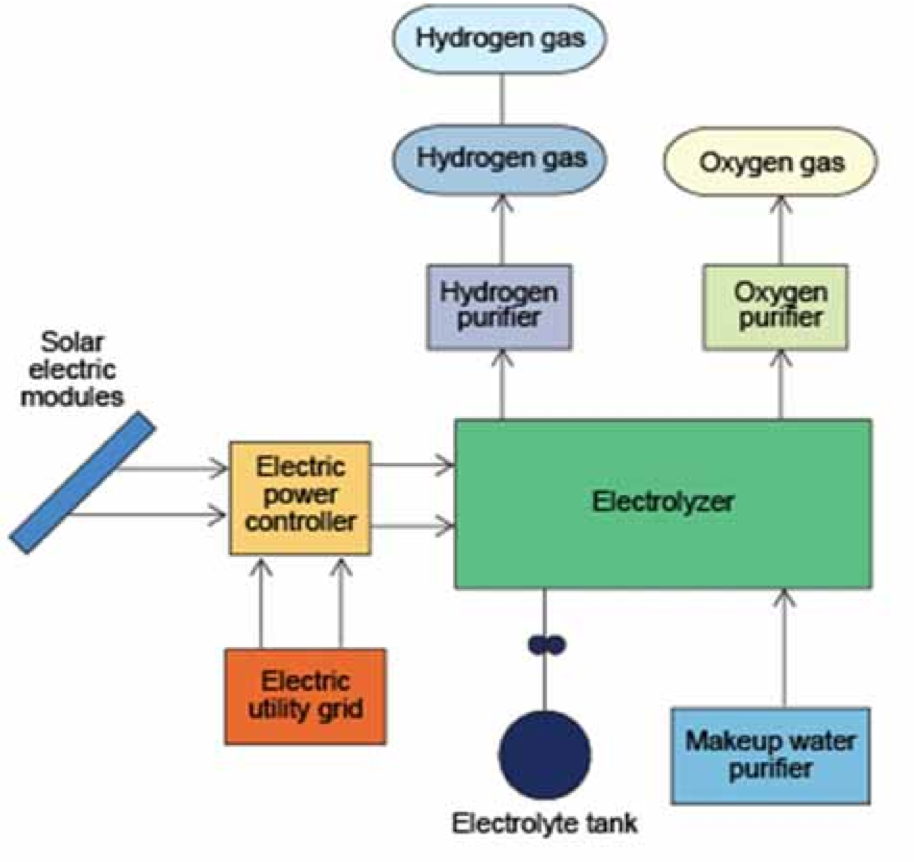
This microwave repeater station in the Redwood National Park draws a continuous 100 watt load powered by solar panels and a fuel cell.

Hybrid Microwave Repeater Station

Watt Pyle, et al., Home Power

PV systems have been used to electrolyze water to produce hydrogen for hybrid solar/fuel cell applications along with electrical power to compress or liquefy the H_2.

Although electricity supplied directly to an end use would be more efficient than electrolysis-hydrogen-fuel cell conversion back to electricity, this approach can avoid needs for recharging storage batteries, offers CHP opportunities, and can provide higher energy densities.



Solar Hydrogen Production

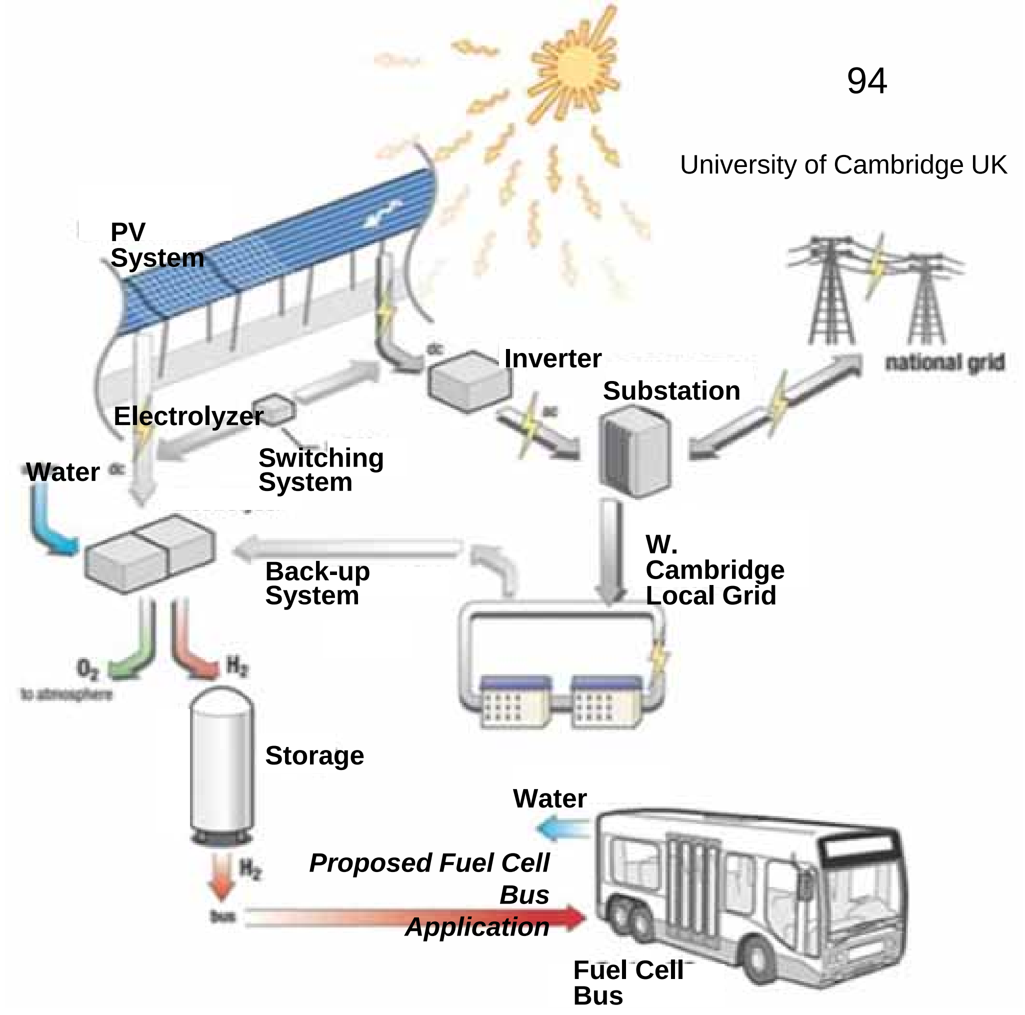
CONSERVATION PRACTICES

ENERGY SYSTEMS

Solar (or wind) energy can provide an inexpensive source of power to produce hydrogen for fuel cells using water electrolysis.

This has been proposed as a way to supply fuel cell buses in Cambridge, England, using a colonnade roof-mounted PV system.

University of Cambridge UK

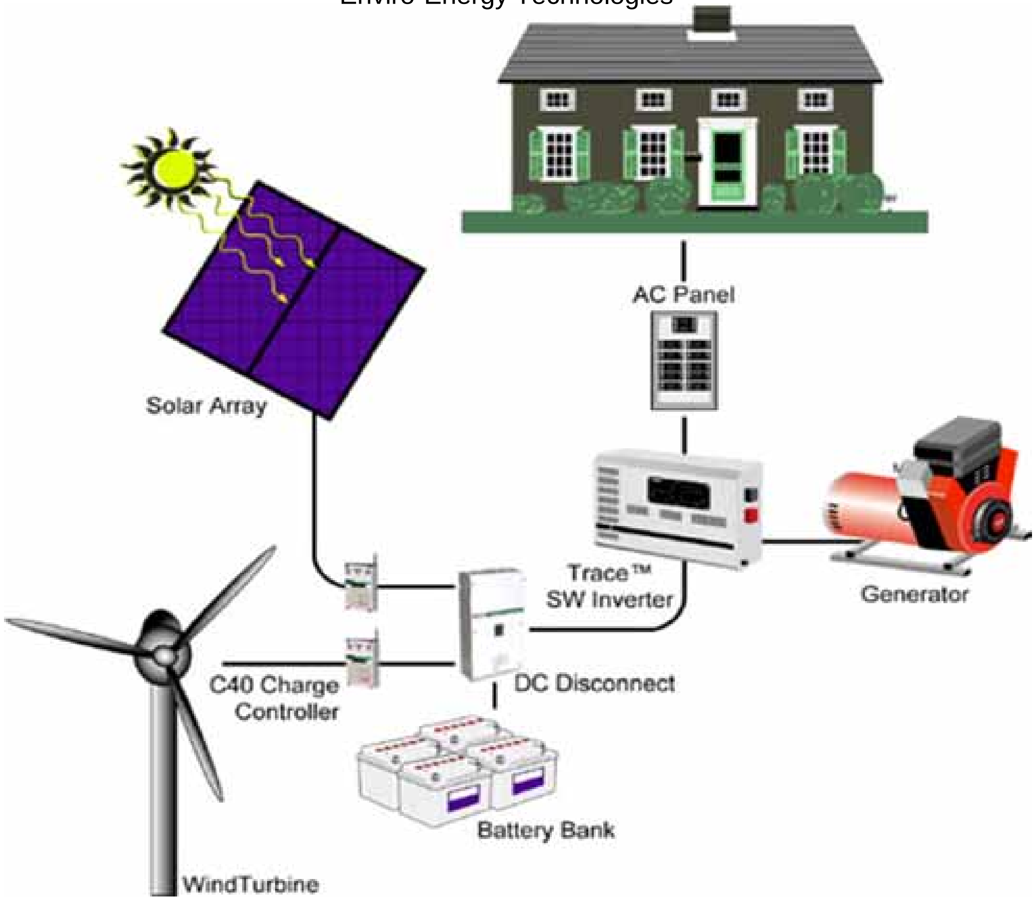


Solar Hydrogen Production Application

Off-grid hybrid PV/wind installations provide electrical power for many consumers who lack access to public utility lines.

Since wind and sunlight aren't always available when needed, DC power generated is usually stored in batteries and converted to AC by inverters for general use.

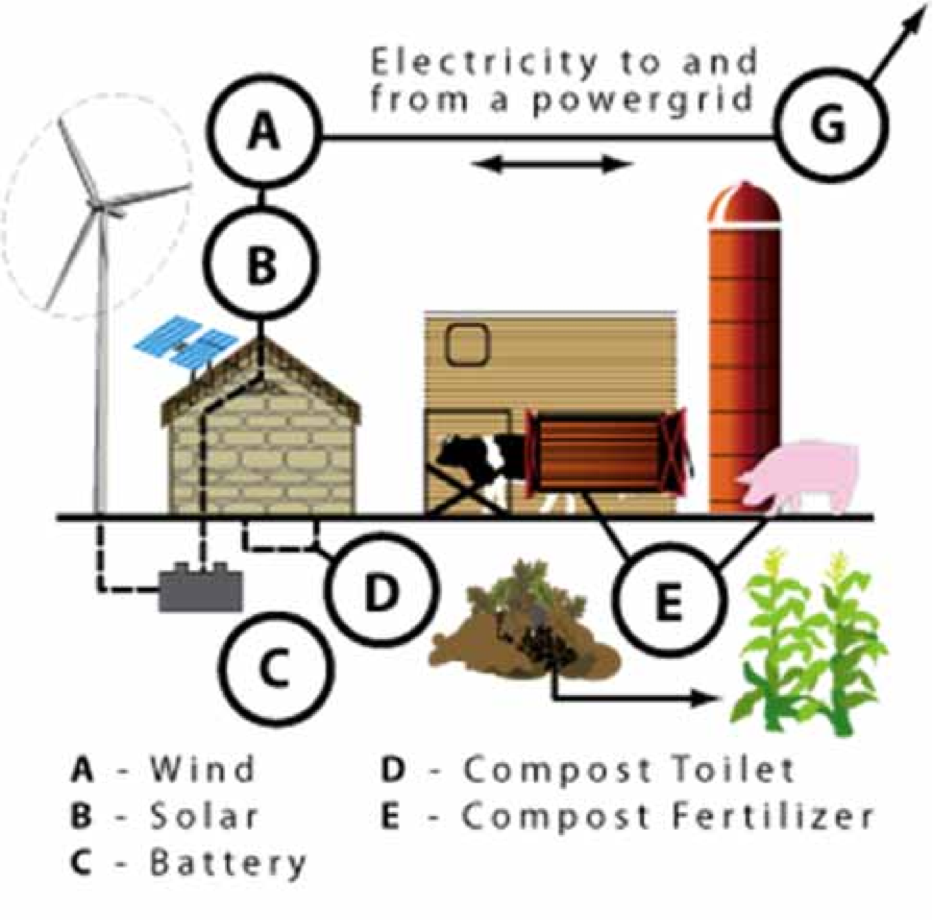
Enviro-Energy Technologies



Off-Grid Solar-Wind Application

Optimal selection and use of renewable resources depends upon each site and application.

A small farm located with good wind and Sun conditions might combine turbines and PV with battery storage for electricity, along with composting for fertilizer.

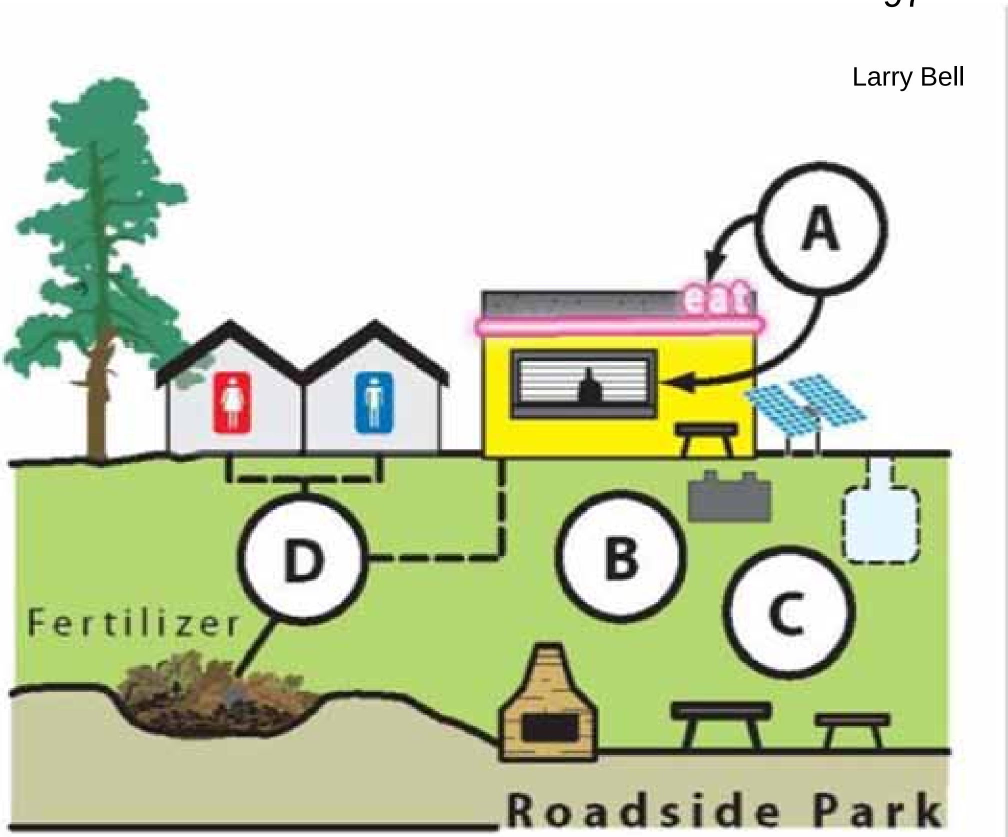


Private Farm Example

Larry Bell

Remote public parks and rest areas can sometimes use PV supplemented by fuel cells or gas generators to power signage, lighting, food vending machines, water pumps, and other devices.

Odorless compost toilets at such locations can reduce waste and yield fertilizer for horticulture.



A. Solar Signage / Service
B. Battery
C. Water Pump
D. Compost Toilet / Waste

Public Facility Example

CONSERVATION PRACTICES

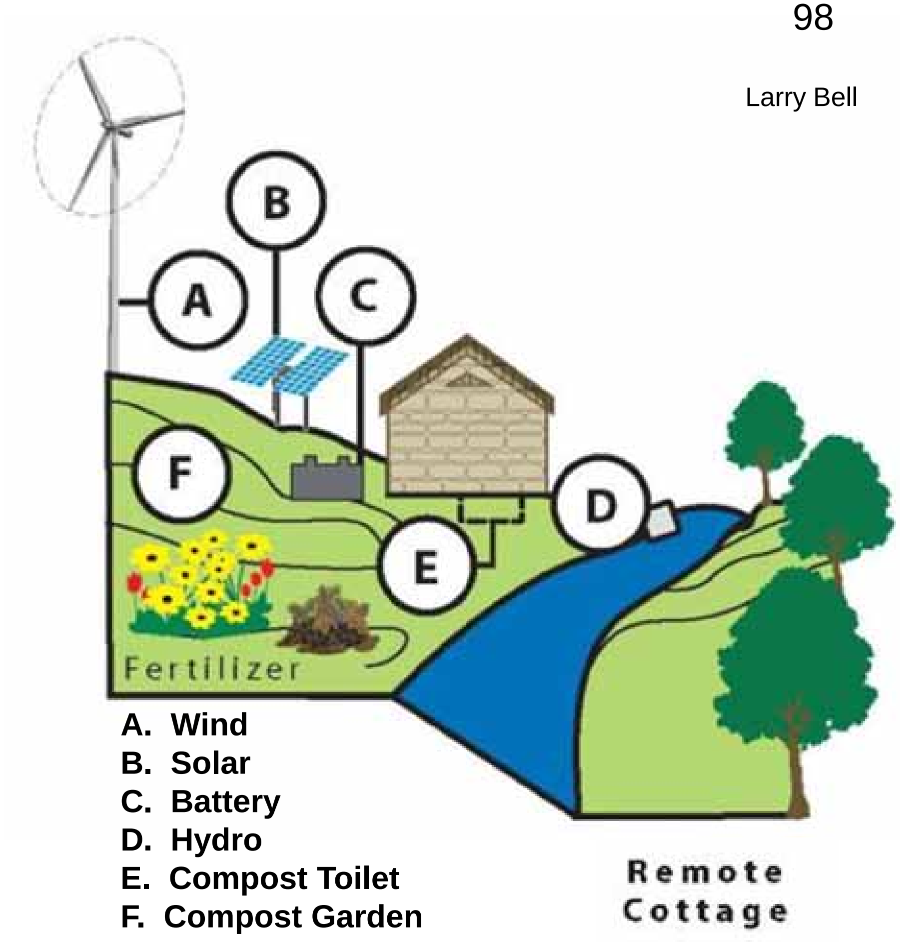
ENERGY SYSTEMS

Larry Bell

Selecting the most appropriate conservation approaches involves determining how options can be adapted and scaled to local conditions and needs.

Considerations include:

- **Times/periods of energy needs correlated with seasonal wind/solar availability.**
- **Potential hydropower impacts upon ecosystems (streams, marshes, and drainage diversions).**
- **Climate influences upon composting toilets/septic systems vs. incineration-type toilets.**



A. Wind
B. Solar
C. Battery
D. Hydro
E. Compost Toilet
F. Compost Garden

Vacation Residence Example

Residential and commercial heat and power constituted about 11.2% of all US energy consumption in 2005 (36% of all natural gas, and 6% of all petroleum).

Natural gas provided about 73% of all heating in these sectors.

Most of the remaining residential and commercial heating energy (about 21%) was provided by petroleum, competing with supplies needed for transportation and petrochemicals.

Derek Jensen
US Coast Guard

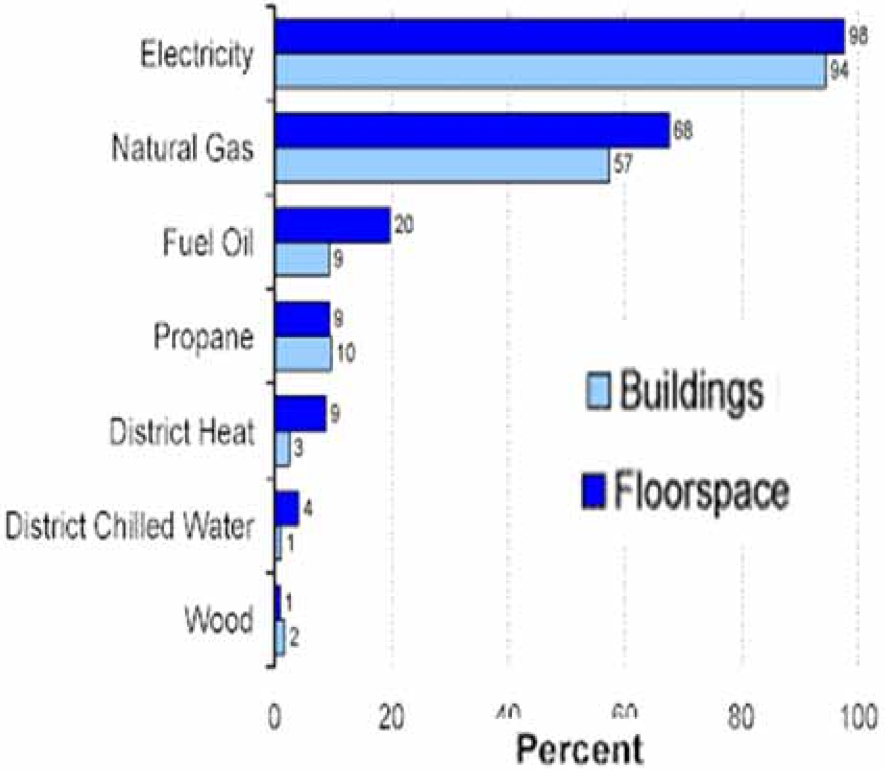
Enoch Lau
Dennis Mojido

The commercial sector consumes much of the energy used for space heating and lighting.

Lighting (about 25% of commercial energy use) is the most wasteful component, partly due to excessive illumination and use of incandescent fixtures that add to space cooling needs.

Fluorescent lighting (about four times more efficient than incandescent) has become a commercial standard, but is associated with certain health hazards.

US DOE EIA

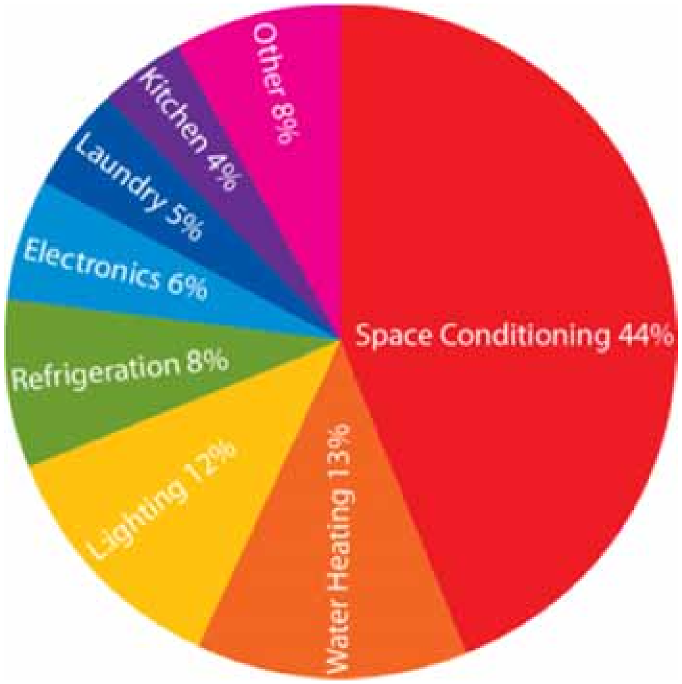


Energy Sources Used in Commercial Buildings

Although efficiencies of furnaces and air-conditioners have been improving, energy demands continue to rise due to American lifestyle changes:

- **Average US home sizes have increased from about 1,500 ft^2 (1970) to 2,300 ft^2 (2005).**
- **Single-person households are becoming more common.**
- **Homes with central air-conditioners increased from 23% (1978) to 55% (2001).**
- **Lighting and water represents about 25% of average energy budgets, and lighting alone can consume 40% or more of total energy in milder climates.**

US DOE - EERE



US Home Energy Consumption Averages

Simple and inexpensive methods can reduce energy budgets for air-conditioning and water heating.

As energy costs continue to rise, the market value of energy-efficient buildings will also.

Basic natural planning principles proven over many centuries remain to be fundamental.

The Apache Trail Archives

Anasazi Indians of Colorado applied effective solar design principles to cliff dwellings thousands of years ago.

Applying Natural Principles

National Renewable Energy Lab

Solar thermal radiation is broadly used in small-scale active and passive applications to reduce water and space heating costs.

Active Solar Collectors

Active systems tend to be somewhat technologically-dependent and use-specific, often using pumps and fans to circulate heat transfer fluids and air.

Powered Living

Active vs. passive uses are generally characterized according to the degree to which they depend upon technology to function:

Passive Solar Design

Passive solar systems rely primarily or entirely upon direct solar gain through natural conduction, convection and radiation.

European Solar Thermal Industry Federation

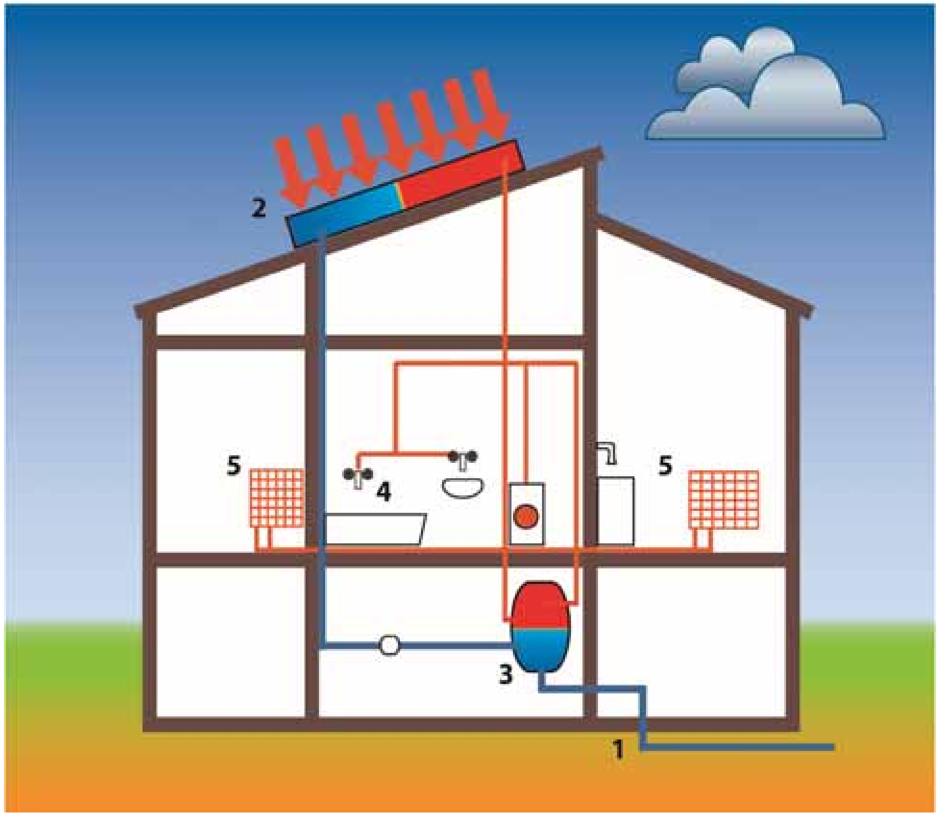
Solar systems and effective passive planning can significantly reduce energy costs for home water and space heating, air-conditioning, and electricity consumption for power.

Reducing Power Costs

Larry Bell/Olga Bannova

Typical active solar system components to heat water and air directly from the Sun are:

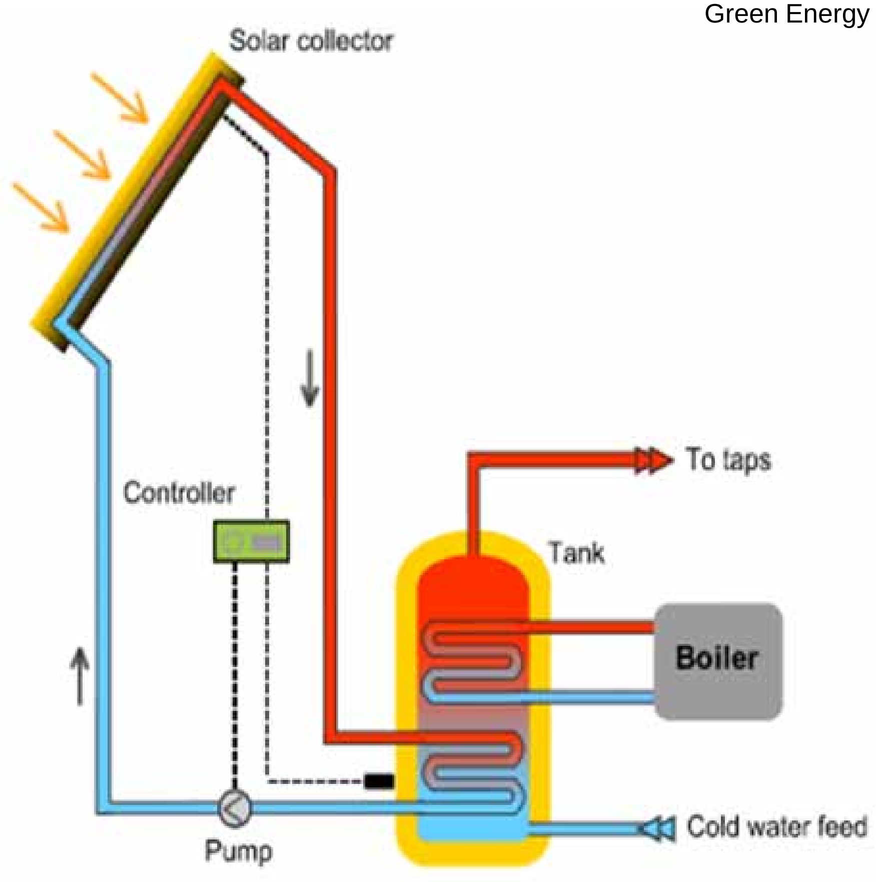
1. **Water supply**: potable water from a utility source or well.
2. **Flat plate collectors**: use radiant energy to heat water.
3. **Heat transfer and storage**: transfers hot water from collectors to a storage tank.
4. **Domestic hot water**: for kitchen, bathroom, washing machines, etc.
5. **Space heating**: hydronic heating systems (radiators).



Active Residential System

Key elements of an active solar water heater are relatively simple:

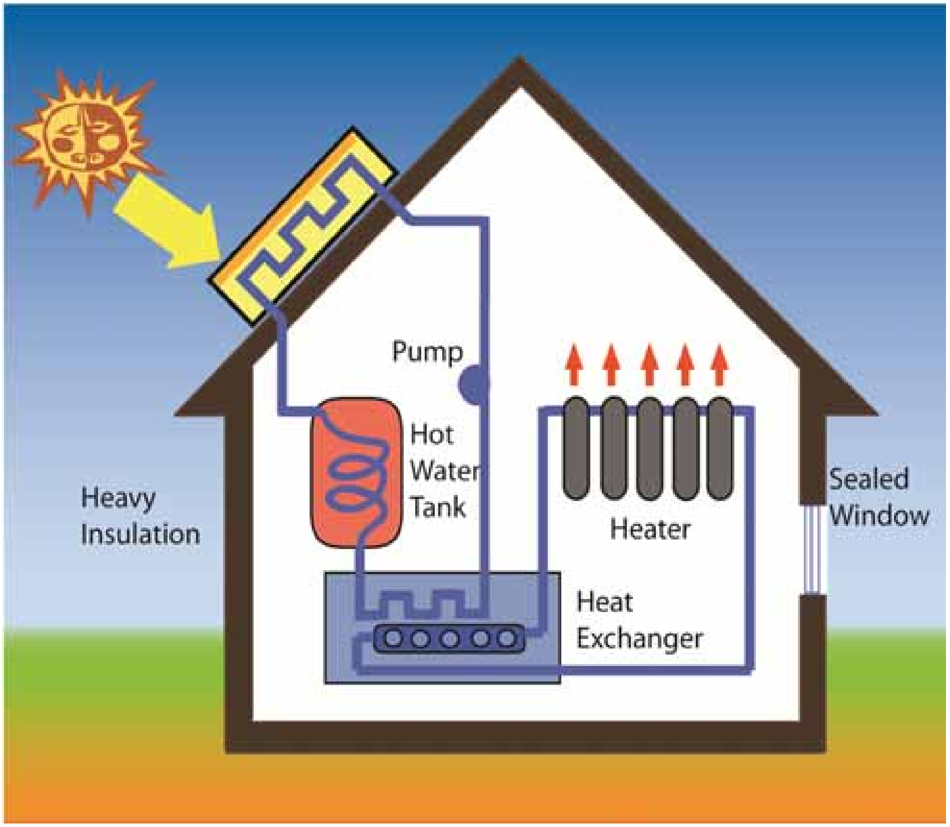
- **A controller constantly compares the temperature of the solar collectors with the temperature of the water in a tank cylinder.**
- **A circulating pump is switched on by the controller whenever the temperature of the collectors rises above that of the tank.**
- **A water/ antifreeze mixture is then circulated through the collectors and heat exchanger to heat the tank.**



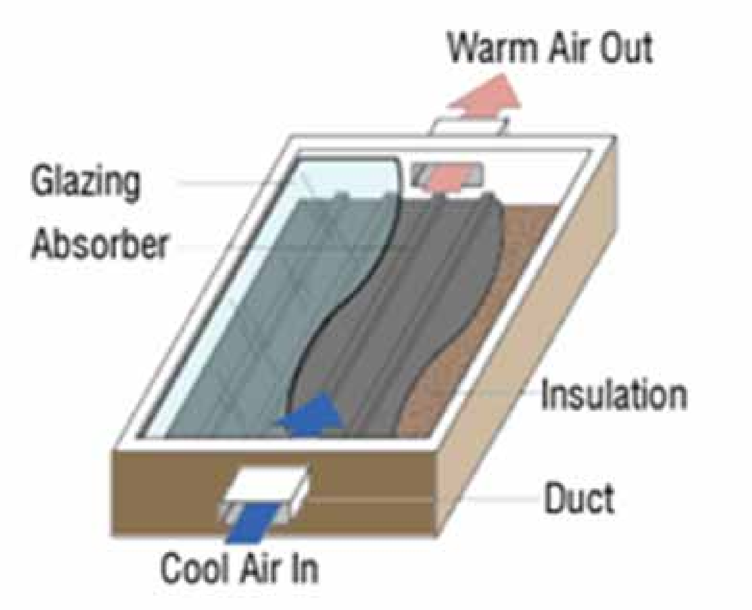
Active Hot Water Circulation

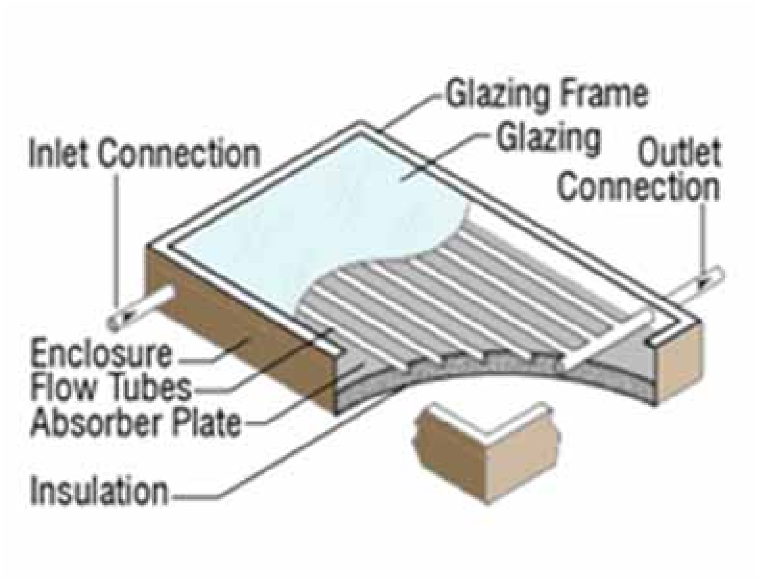
Space heating can be accomplished with solar-heated water using a flat plate collector:

- **Such a system requires a large hot water storage capacity, usually with an air-to-water heat exchanger.**
- **Heat from the storage tank can be transferred to a radiant floor heating system, baseboard radiation system, or through a fan coil to a forced-air system.**
- **Gas or electrical water heaters can supplement times of highest demands.**



Active Air-Based Heating System





Air flat plate collectors are primarily used for space heating and circulate heat by natural convection.

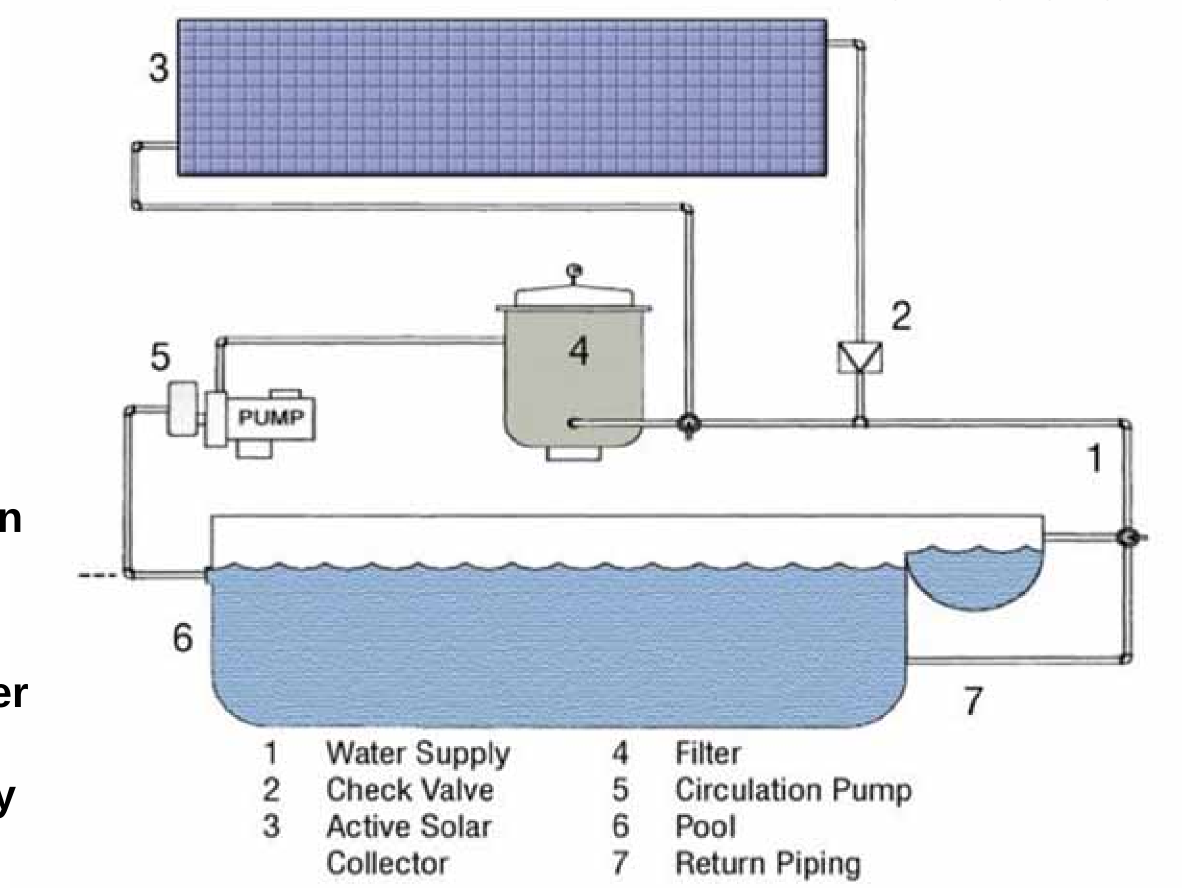
Liquid flat plate collectors heat a fluid (often water) as it flows through tubes and are often used to heat swimming pools.

Active Space Heating Collectors

Swimming pool heating can account for 50% or more of a household's summer power consumption (often more than energy required for winter heating).

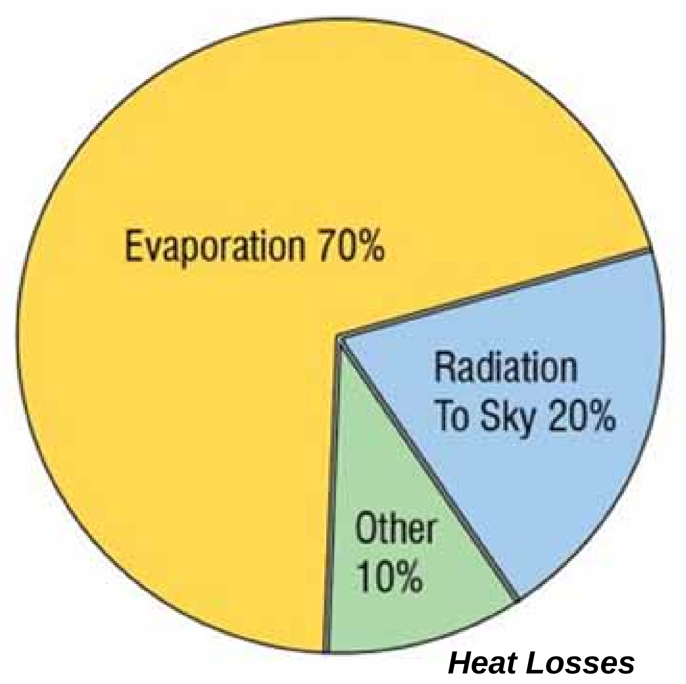
Simple active plastic or rubber collectors can dramatically reduce electricity use in many locations.

Norbert Lechner, Heating, Cooling, Lighting



Swimming Pool Heating

US DOE-EERE

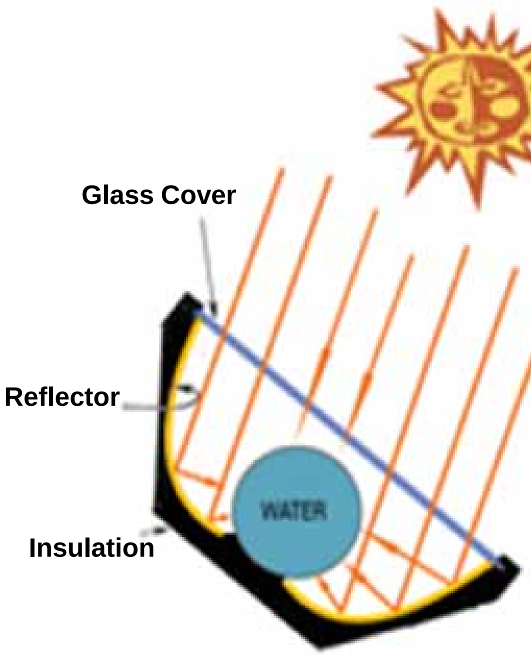


Swimming Pool Heat Retention

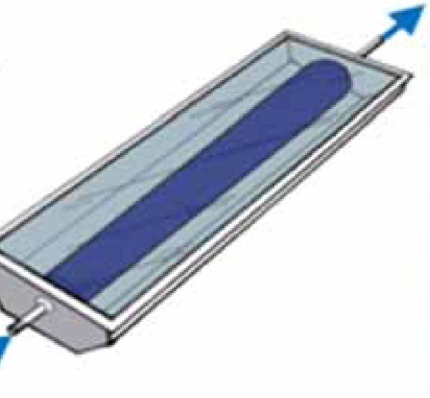
US DOE-EERE

An inexpensive translucent pool cover is another way to dramatically increase energy conservation by reducing evaporative cooling while permitting radiant heating.

Swimming Pool Covers



Solar hot water stand-alone units provide external building and outdoor applications using concentrating or flat plate collector types.



Batch-type Collector

Cold water from the supply circulates through the collector to a heat exchanger/storage tank.

Integral Collector Storage

Active Stand-Alone Water Heaters

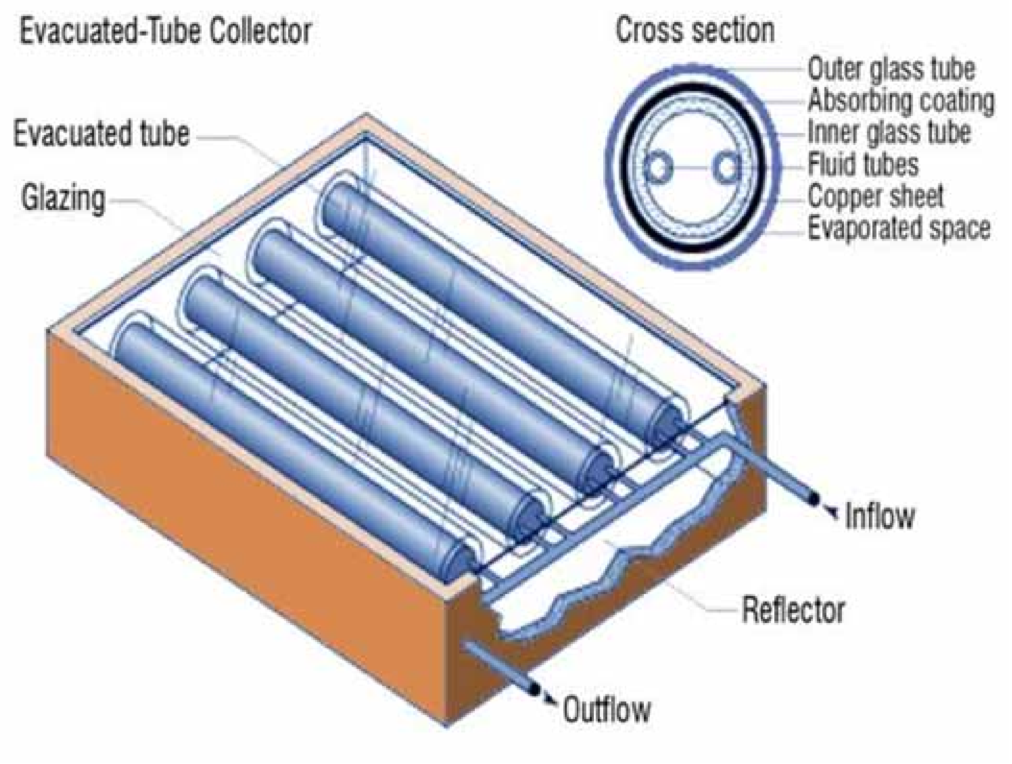
CONSERVATION PRACTICES

RESIDENTIAL AND COMMERCIAL

US DOE-EERE

Special types of active solar heating systems can provide large amounts of hot water for commercial and industrial uses.

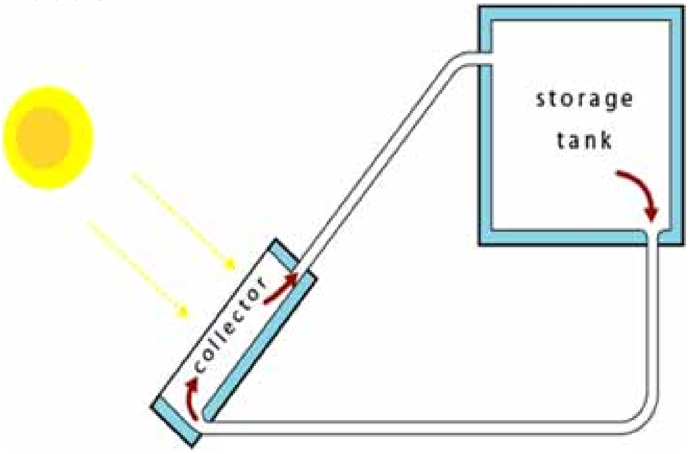
Evacuated-tube collectors are efficient at high temperatures (170ºF-350ºF), but are about twice as expensive as flat plate types.



Evacuated-Tube Collector for Commercial/Industrial Use

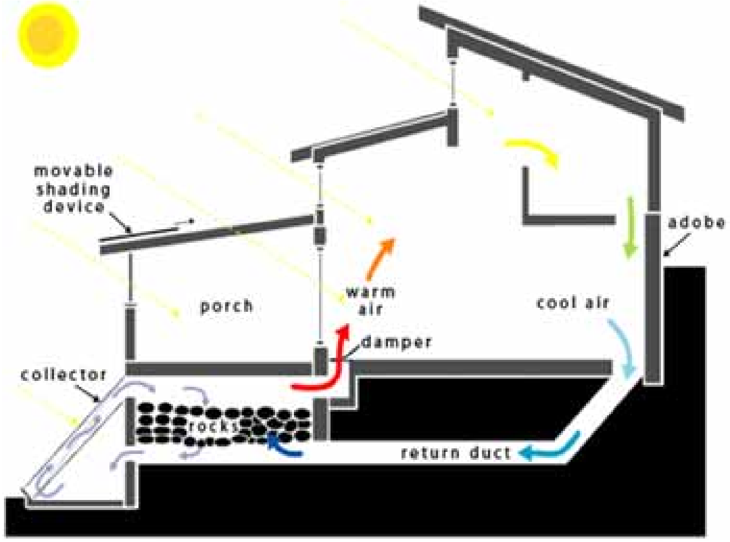
Heating, Cooling, Lighting, N. Lechner

Sunspaces can be augmented by "solar furnaces" that eliminate or reduce energy required for water and space heating. South-facing collectors heat water or air that is circulated through storage tanks or rockbeds.



Solar Furnace Hot Water System

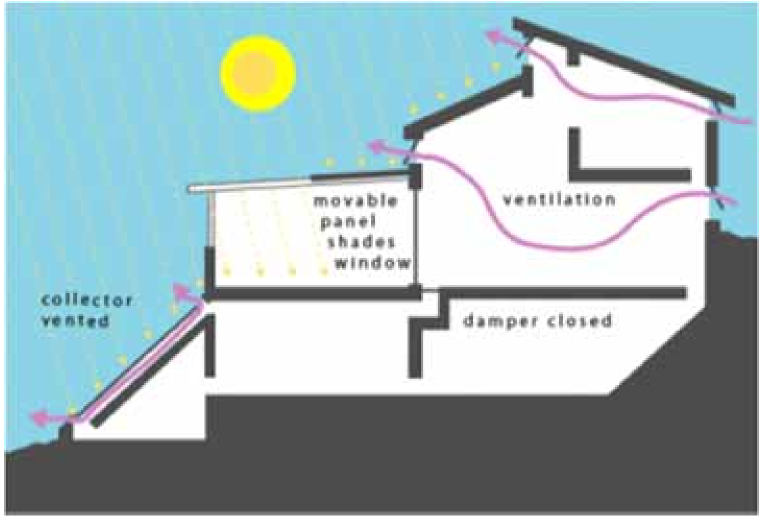
Heating, Cooling, Lighting, N. Lechner



Hot air rises up from a storage bed to provide warm air at night, and cooled return air flows back to the collector in a loop. An operable vent on a north wall exhausts hot air and allows cross-ventilation.

Solar Furnace Space Heating System

Heating, Cooling, Lighting, N. Lechner



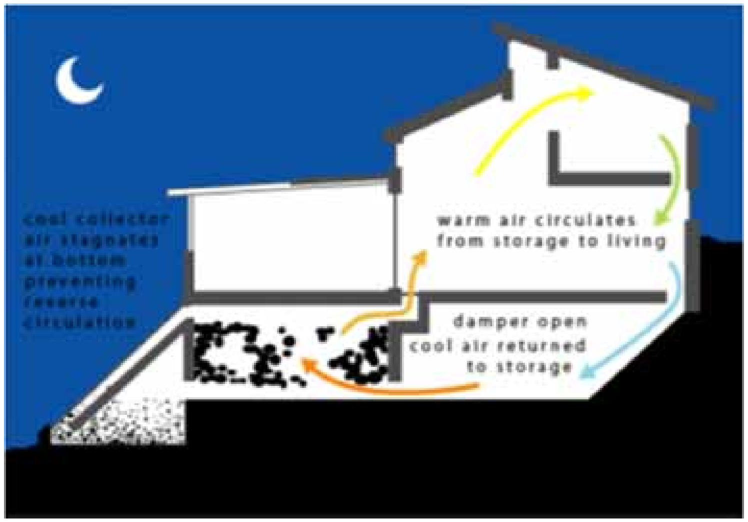
Summer Day

During the summer day, the sunspace is opened to the interior spaces.

- **The rock storage vent is closed, causing the furnace to act as a thermal flue.**

- Hot air is exhausted form the furnace.

- Cool air from the north side circulates through interior spaces by natural cross-ventilation.



Winter Night

During the winter night, the sunspace is closed from interior spaces.

- **Rocks provide the heat collector:**

- The rock storage vent is opened, allowing warm air to circulate from this area throughout interior spaces by natural convection.

US DOE-NREL

Transpired Collector at the Denver FedEx Building for Space Heating

Large buildings can consume vast amounts of energy to heat ventilated air in cold climates.

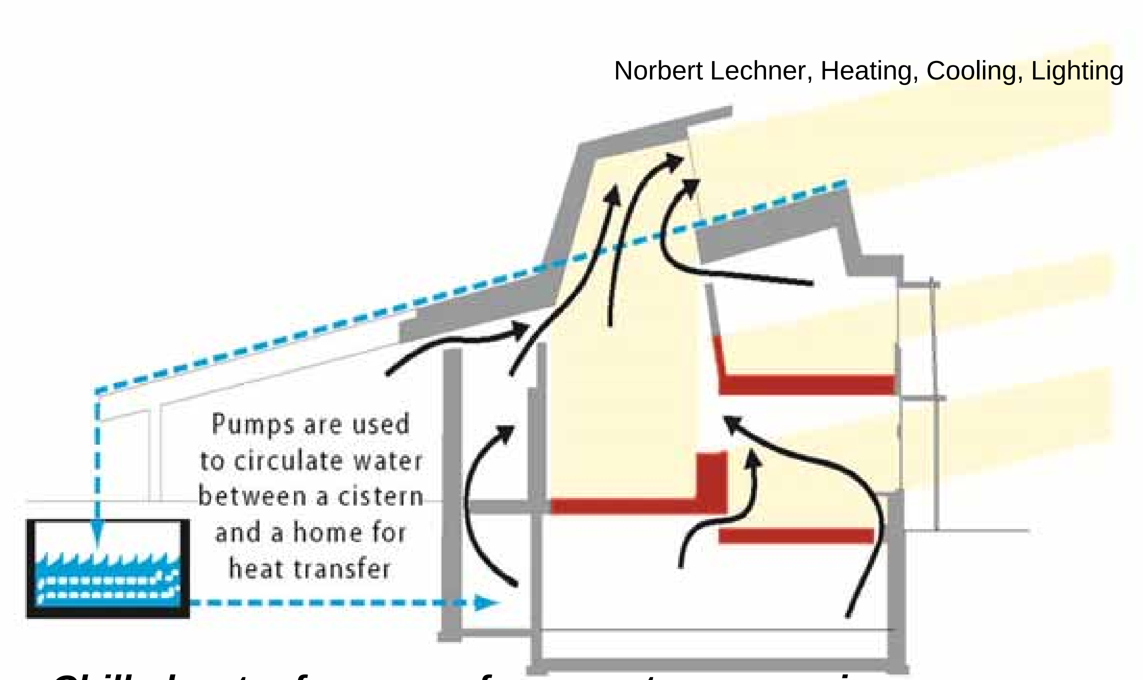
Simple transpired collectors consisting of thin, black, metal panels on south-facing walls can absorb solar radiation to preheat air before it circulates inside.

Since heat is fundamentally an energy source, it can also be used to cool building spaces.

This clearstory scheme uses ambient water from a cistern along with roof evaporation for summer cooling, and direct solar gain from winter Sun for heating.

Natural convection distributes the conditioned air.

Norbert Lechner, Heating, Cooling, Lighting



Chilled water from a roof evaporator reservoir can supplement cooling effects to further reduce summer air-conditioning energy loads.

Active / Passive Hybrid Approach with Water Transport from a Cistern

CONSERVATION PRACTICES

RESIDENTIAL AND COMMERCIAL

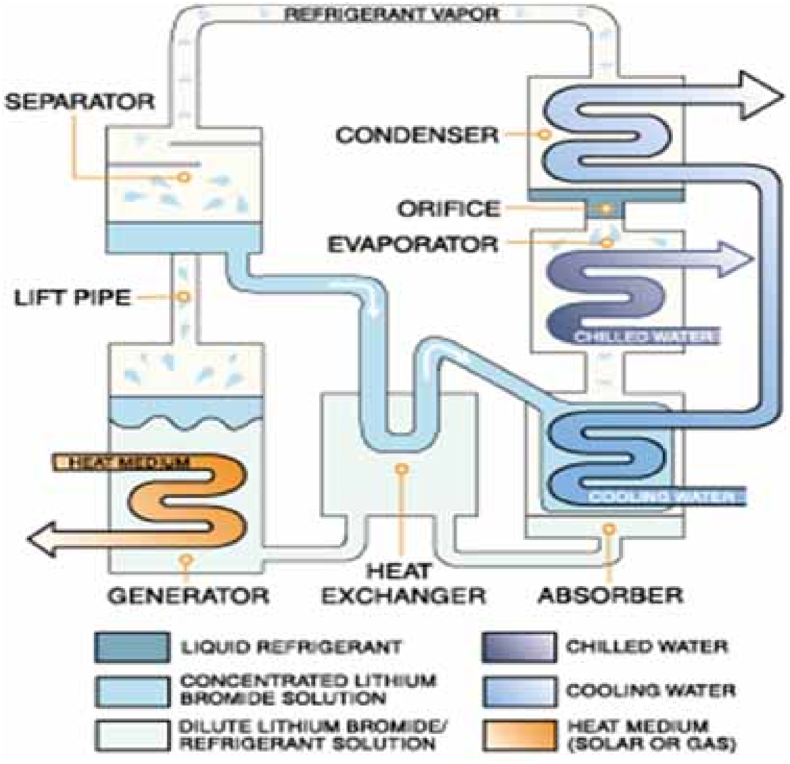
Space cooling can be accomplished using a solar-driven, thermally-activated cooling system (TACS) which functions much like an electrically-powered air-conditioner.

TACS apply thermal absorption or evaporative cooler devices (often called “swamp coolers”).

Systems can provide 30% - 60% of a building’s cooling requirement, often supplemented by natural gas for the energy balance.

TACS use is limited by high initial cost, a need for large solar fields to drive them, and ideal Sun locations.

US DOE-EERE

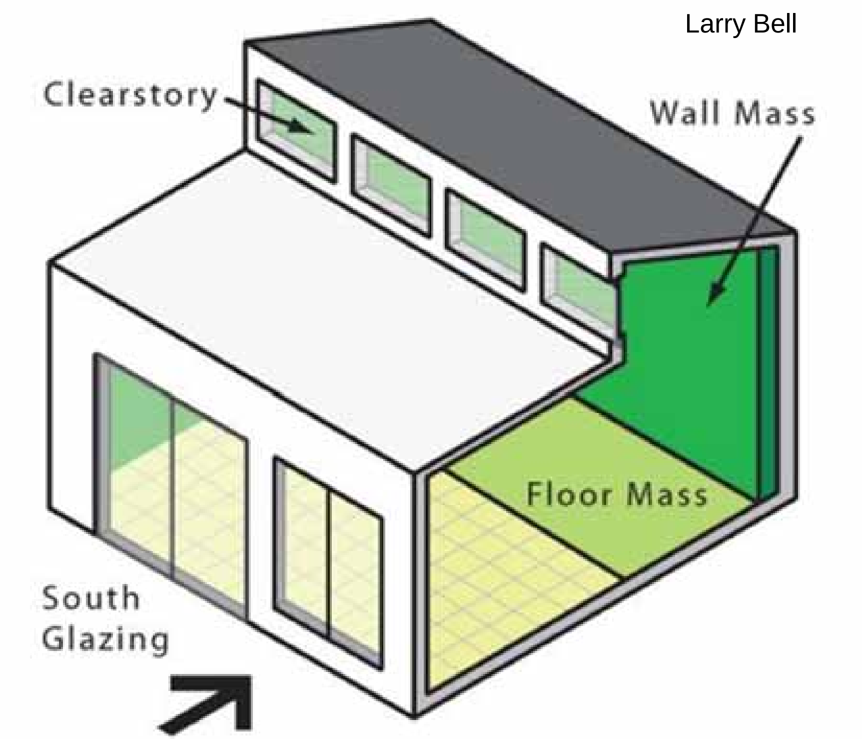


Active Thermally-Activated Cooling System (TACS)

Enormous space heating and cooling economies can be achieved through passive planning practices that require no mechanical devices or added construction costs.

Proper design optimizes direct solar heat gain and retention under cold conditions, and exhausts heat for comfort and cost-efficiency under hot circumstances.

Appropriate design / placement of windows and shading devices, natural convection / ventilation, and effective thermal insulation are important factors.

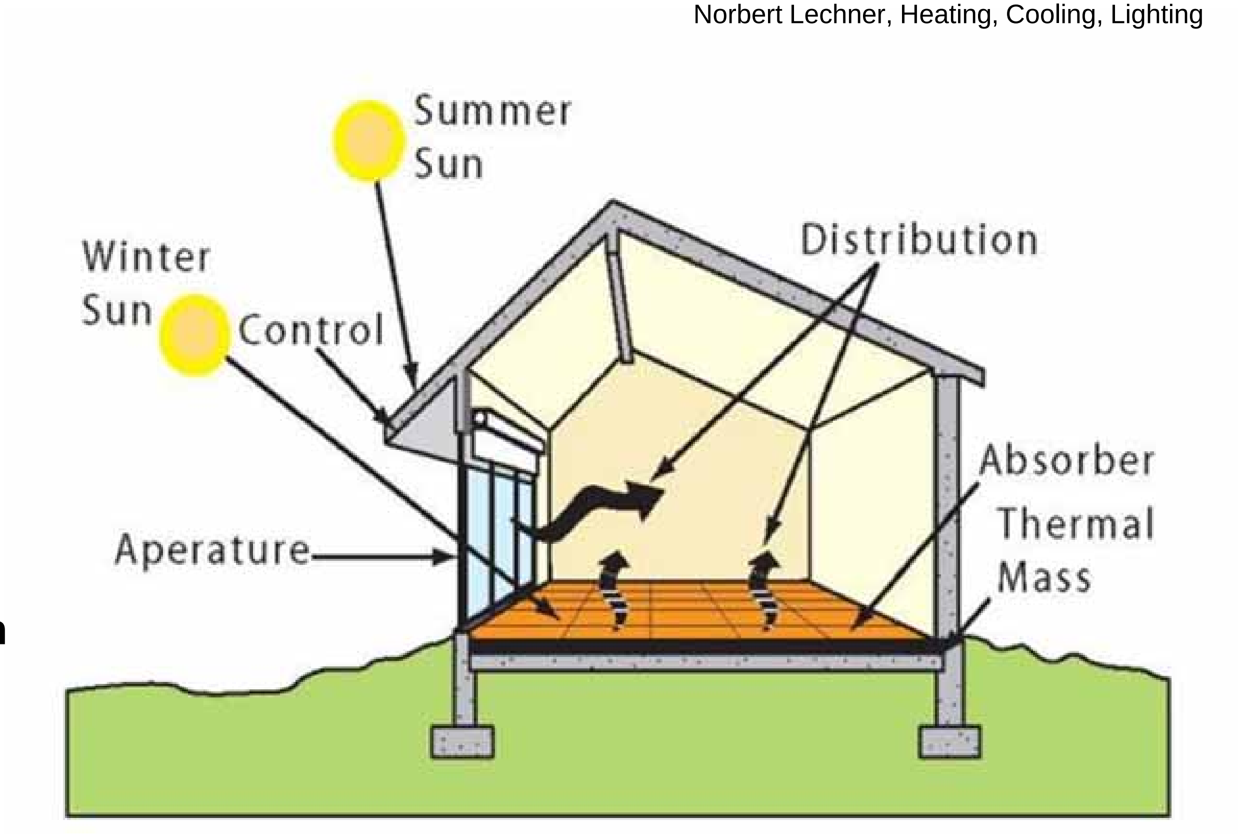


Direct solar gain utilizes sunlight that shines directly into a building to heat interior materials which release energy at night.

Direct Solar Gain

Distribution of solar heat throughout a building uses three different transfer modes: radiation, conduction, and convection.

- **Solar radiation is admitted by windows and is also stored in thermal mass.**
- **Thermal mass conducts heat to absorbers, which radiate it when needed.**
- **Convection circulates the warm air.**



Norbert Lechner, Heating, Cooling, Lighting

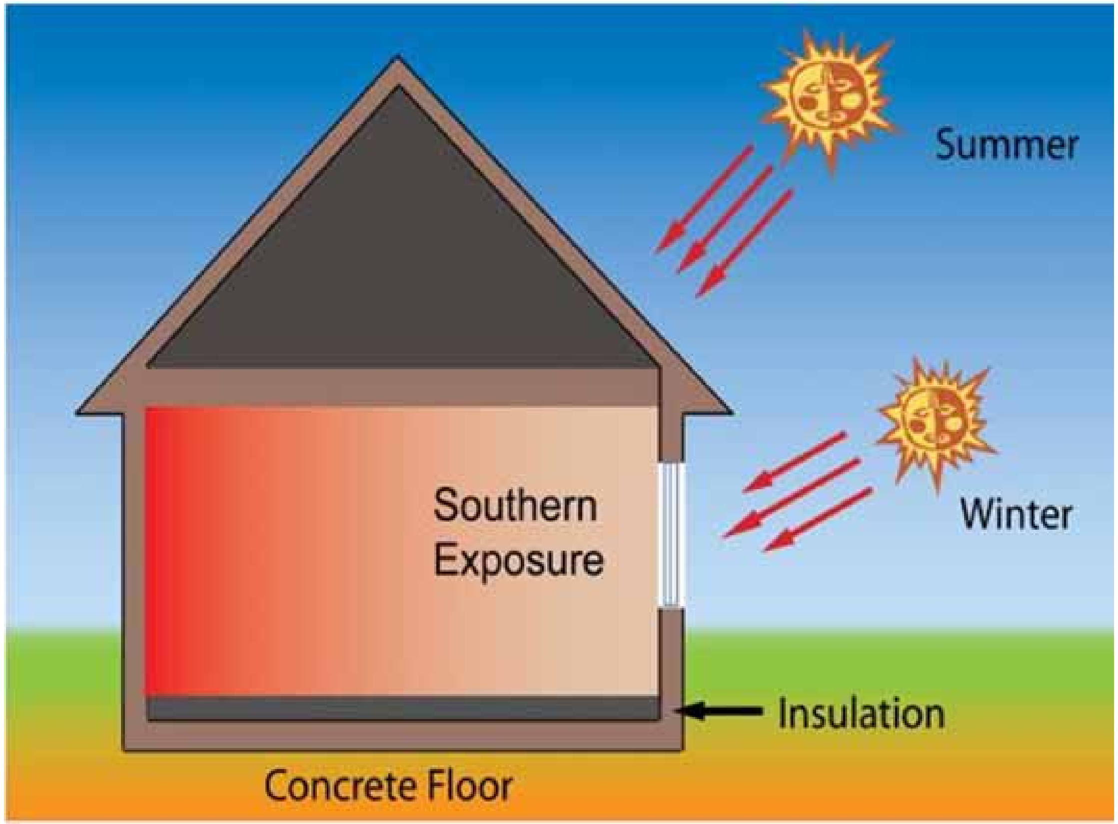
Moderating Solar Gain

Larry Bell

In cold latitudes, it is important to take advantage of direct solar gain through windows.

Large window areas oriented to the south will allow low winter solar angles to heat interior floors and walls.

Good insulation and well-sealed building envelopes hold heat inside.



Space Heating

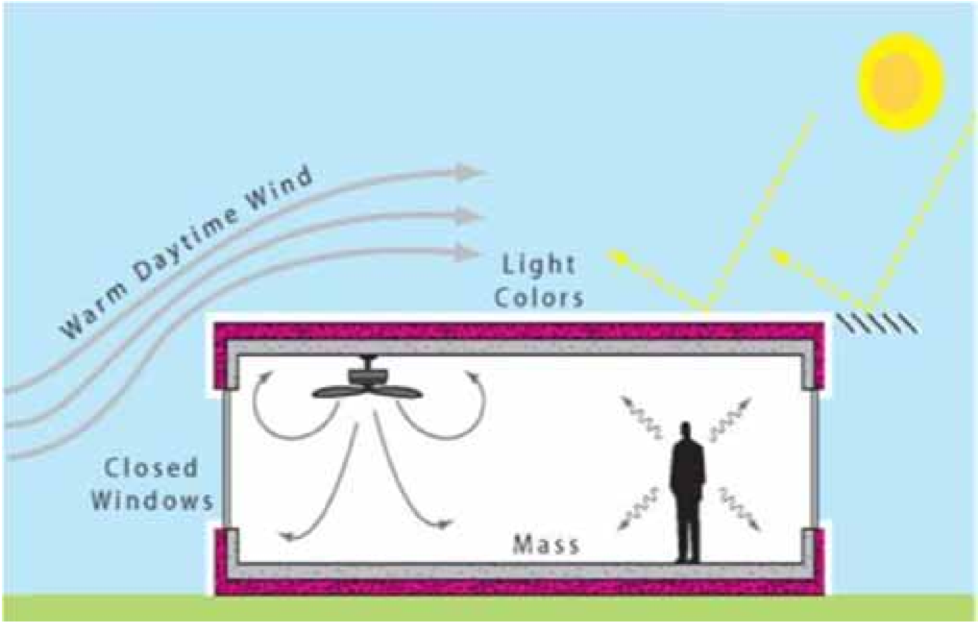
CONSERVATION PRACTICES

RESIDENTIAL AND COMMERCIAL

In hot regions, where space cooling is most important, the building envelope and floor mass provide a useful cooling strategy only for dry climates because mass doesn't "insulate" in the same sense that thermal insulation materials do.

Here, good insulation, shading, closed windows, and light reflective colors can minimize heat gain.

Norbert Lechner, Heating, Cooling, Lighting

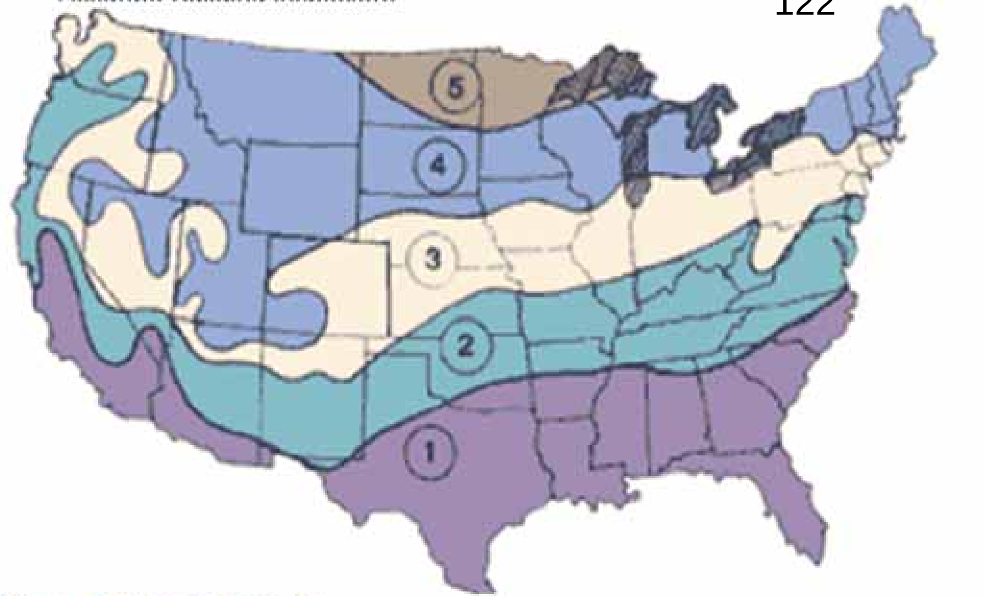


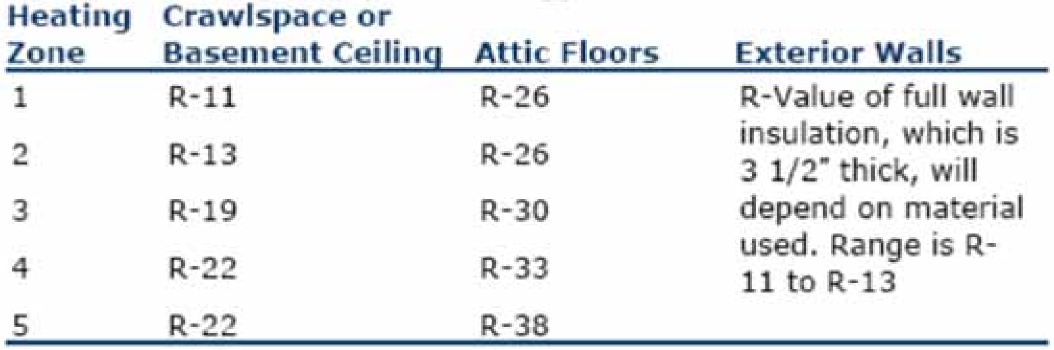
Fans can enhance comfort and reduce condensation, but do not save energy except through reduced air-conditioning use by residents.

Space Cooling

Good insulation with radiant and vapor barriers is very important for building energy conservation.

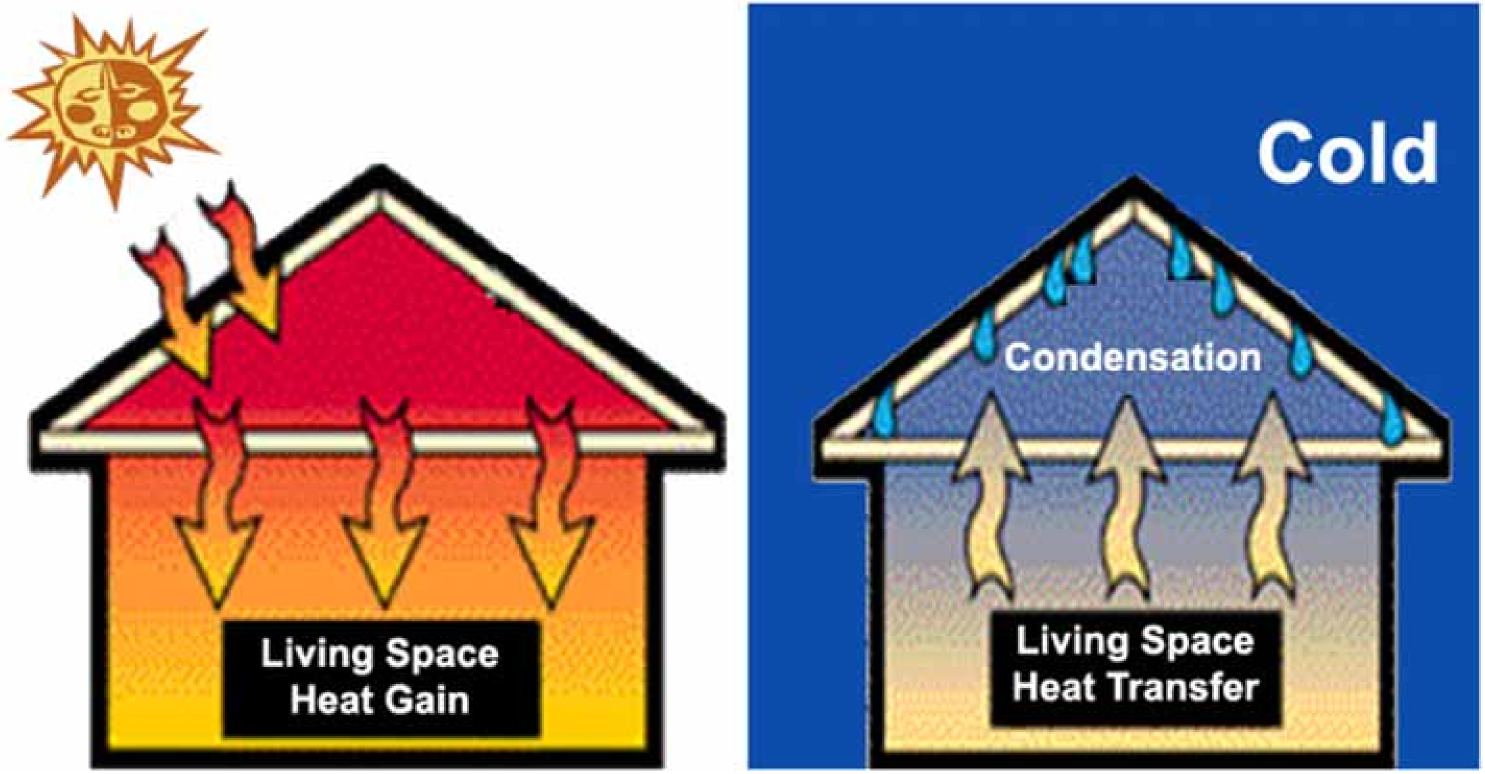
R-Values rate the minimum recommended total thermal resistance for insulating materials (higher numbers have better resistance).





Heating Zone	Crawlspace or Basement Ceiling	Attic Floors	Exterior Walls
1	R-11	R-26	R-Value of full wall insulation, which is 3 1/2" thick, will depend on material used. Range is R-11 to R-13
2	R-13	R-26	
3	R-19	R-30	
4	R-22	R-33	
5	R-22	R-38	

Recommended R-Values



Hot weather conditions demand thermal barriers to prevent attic heat transfer to lower levels, and cold weather barriers must prevent condensation from rising heat.

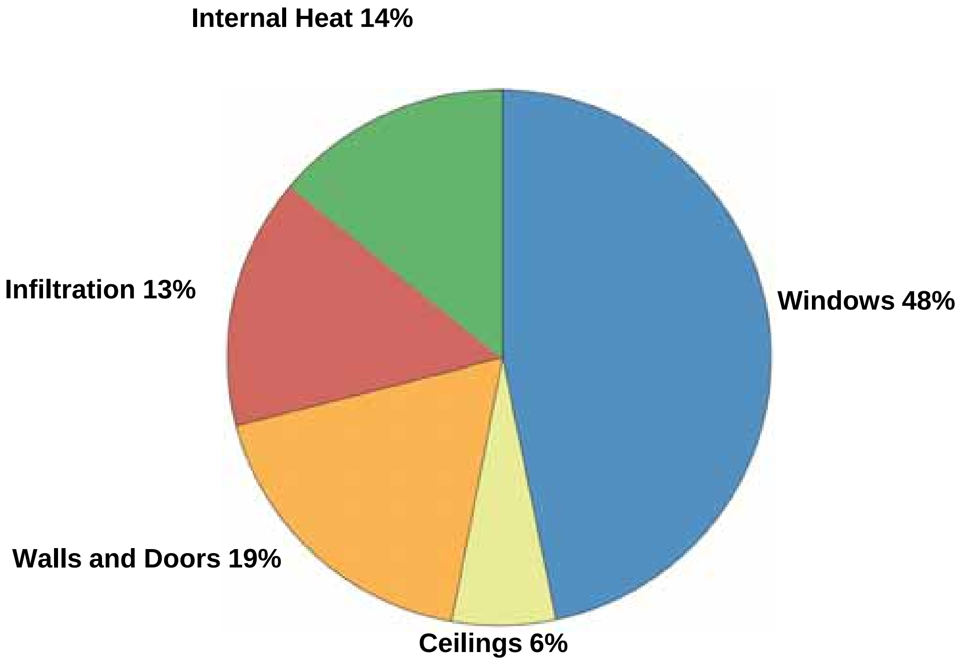
Heat Transfer Barriers

A fundamental way to avoid indoor overheating is to prevent solar radiation from entering a building during summer, and allowing it to enter in winter.

Window design, orientation to summer and winter solar conditions, and proper shading are important energy conservation considerations.

All orientations except south receive maximum summer radiation, and east and west window orientations are least desirable from heating and cooling standpoints.

US Department of Housing and Urban Development

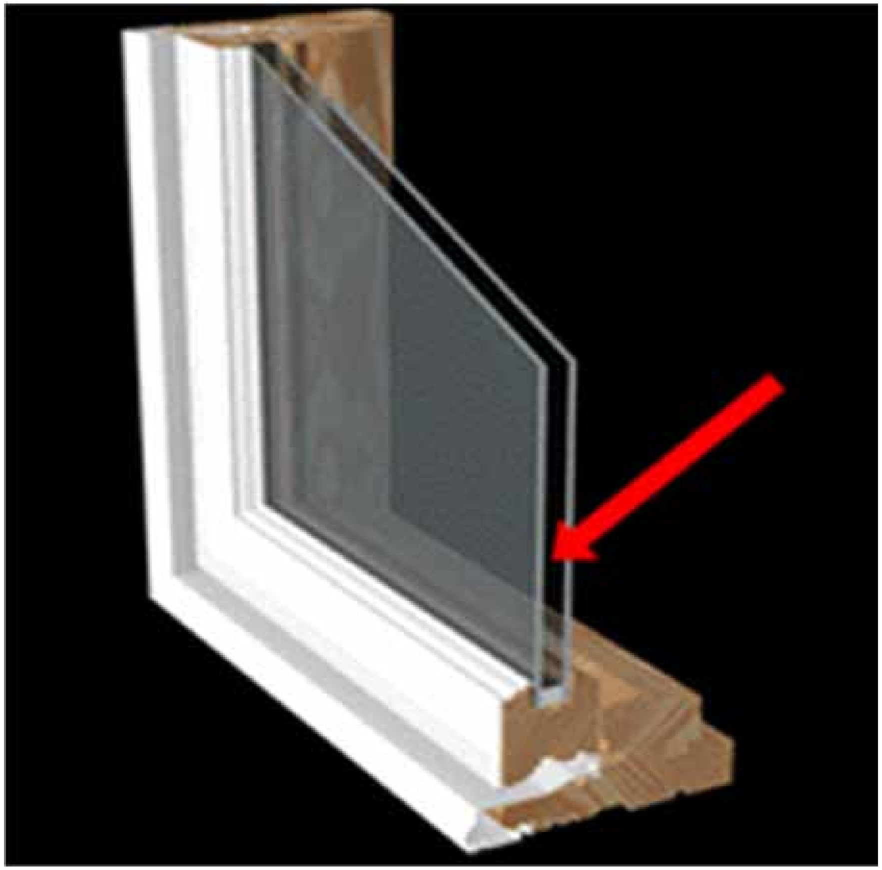


Sources of Summer Heat Gain in Homes

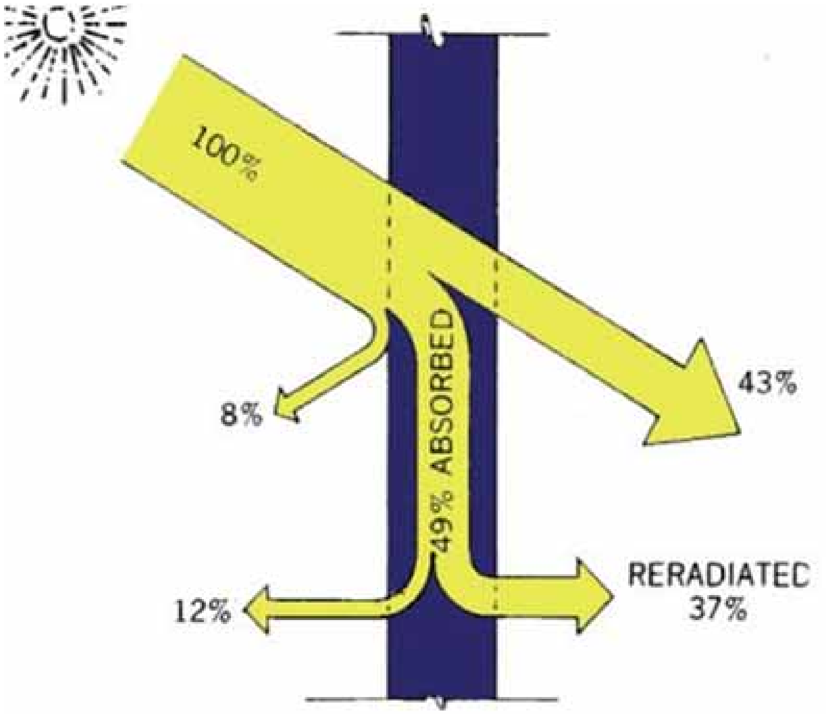
Heat transfer through windows can be minimized using coverings (such as outside shelters or transparent sheets) or multiple-pane installations.

Multiple-pane window units have 1/4 in – ½ in (63.5 mm – 127 mm) insulating air spaces between glass panels.

These spaces are sometimes filled with special gases to further reduce heat transfer through conductance between panes and convection within the spaces.

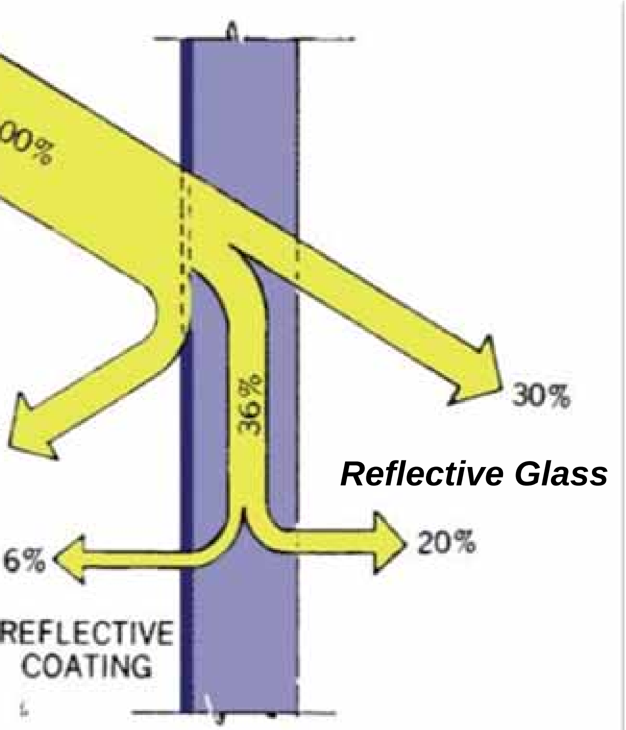


Insulating Windows



Tinted Glass

Tinted glazing reduces light transmission, but doesn't significantly decrease heat gain because much solar radiation absorbed is re-radiated indoors. Tinted curtain wall glass became popular in the 1960s for efficiency and appearance.

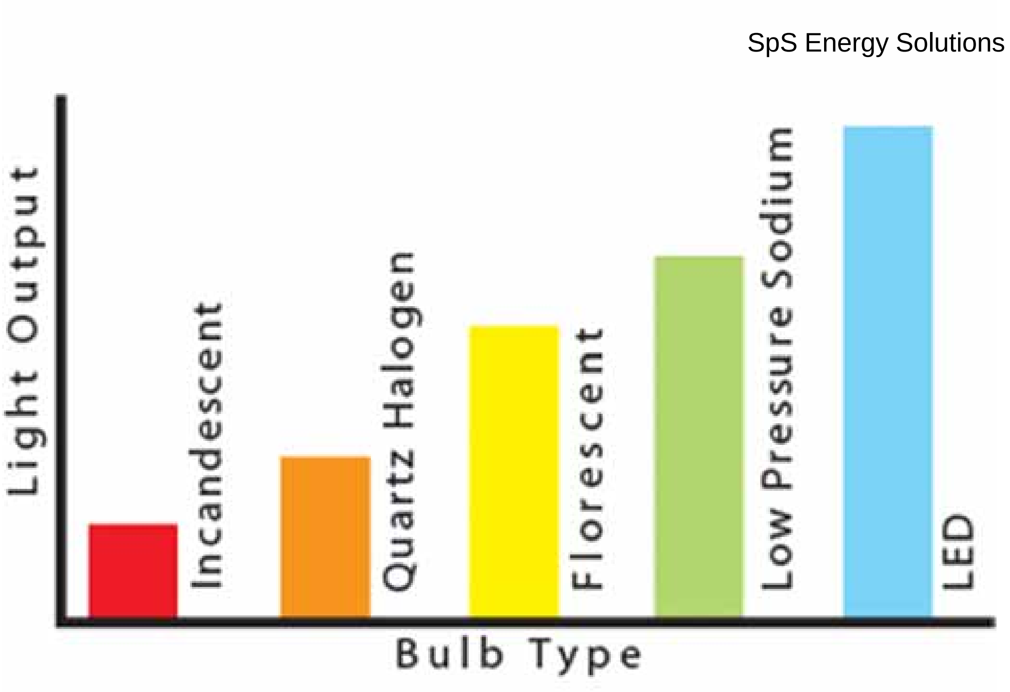


Reflective Glass

A glazing surface covered with a thin metallic coating can significantly increase the amount of solar radiation that is reflected while allowing outside viewing. This can be combined with tinted glazing to improve efficiency.

Window Glazing Treatments

- Lighting systems often account for large portions of total building power budgets.
- Flourescent fixtures are rapidly replacing incandescent lighting for interior applications due to much higher efficiencies, longer life, and pleasing warm color illumination.
- Quartz halogen, low-pressure sodium, and LEDs are primarily used for outdoor applications.



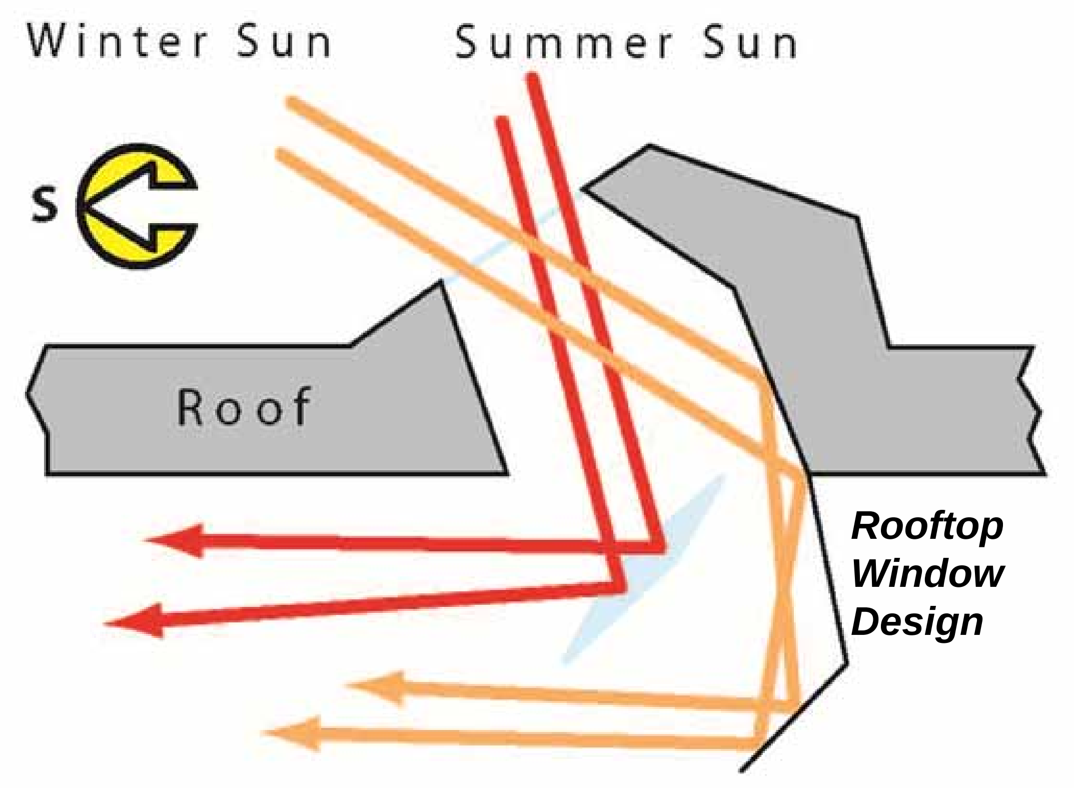
Energy Efficiencies of Various Lighting Technologies

CONSERVATION PRACTICES

RESIDENTIAL AND COMMERCIAL

Rooftop windows can be designed to enhance natural interior illumination and avoid glare by redirecting sunlight.

High-angle summer light can be dispersed using specular reflectors, and low-angle winter light can be redirected by solid reflectors for seasonal adaptation.



Conserving Lighting Energy

Oak Ridge National Laboratory

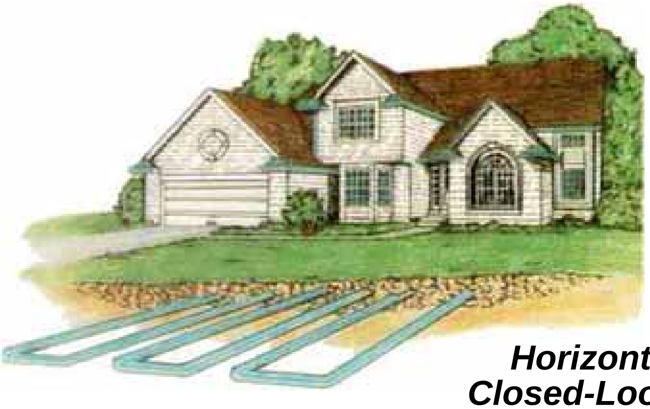
Hybrid solar lighting distributes natural sunlight through fiberoptic bundles to reduce electrical power consumption and heat loads.

The full-spectrum light energy exactly matches sunlight red shifts that occur during the day.

Hybrid Solar Lighting

Vertical
Closed-Loop
Installation

Lewis County Rural Electric Cooperative



Horizontal
Closed-Loop
Installation

Although relatively few places have suitable conditions for geothermal power production, many offer opportunities for small-scale building heating, cooling, and hot water applications.

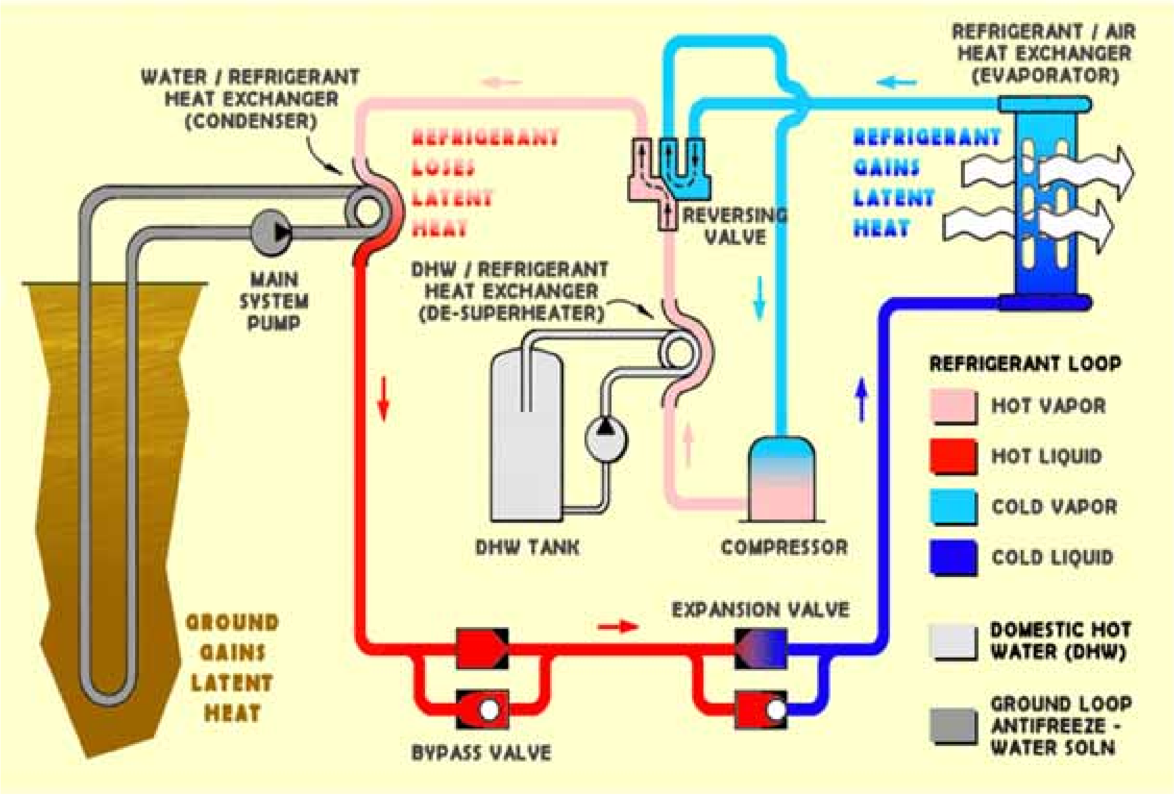
Geothermal heating and cooling can be more efficient than electric resistance, gas, or oil-fired systems, and can save homeowners 30% - 70% of heating and 20% - 50% of cooling costs according to EIA estimates.

Geothermal Heating and Cooling

Heat pipes move heat from a building into the ground or a well in summer, and reverse the process to provide heating in winter.

Key system elements typically include a heat exchanger, variable-speed blowers and multiple-speed compressors to circulate air and fluids.

Virginia Tech Department of Mines, Minerals and Energy



Typical Geothermal Heat Pump System

Public, commercial and personal transport accounted for about 28% of 2005 US primary energy consumption.

Petroleum provided about 98% of this energy, constituting more than half (68%) of total petroleum use.

Increased vehicle efficiencies and expanded of bio-fuels can help reduce petroleum consumption, and fuel cell-powered vehicles may also provide benefits if non-fossil sources are used to produce the hydrogen.

Carplus UK
Phoenix International

Ntnl Railway Historical Society
Mobile Review

The Transportation Sector

CONSERVATION PRACTICES

TRANSPORTATION

Use of public transportation can reduce energy consumption provided that these services operate at high average capacities.

Fuel cell buses and electric trains can offer good passenger mile efficiencies with low pollution.

Commercial airlines are often passenger mile-efficient, but release pollutants into the stratosphere.

Fair-PR
APTA

Mitsui – Bussan
Direct News

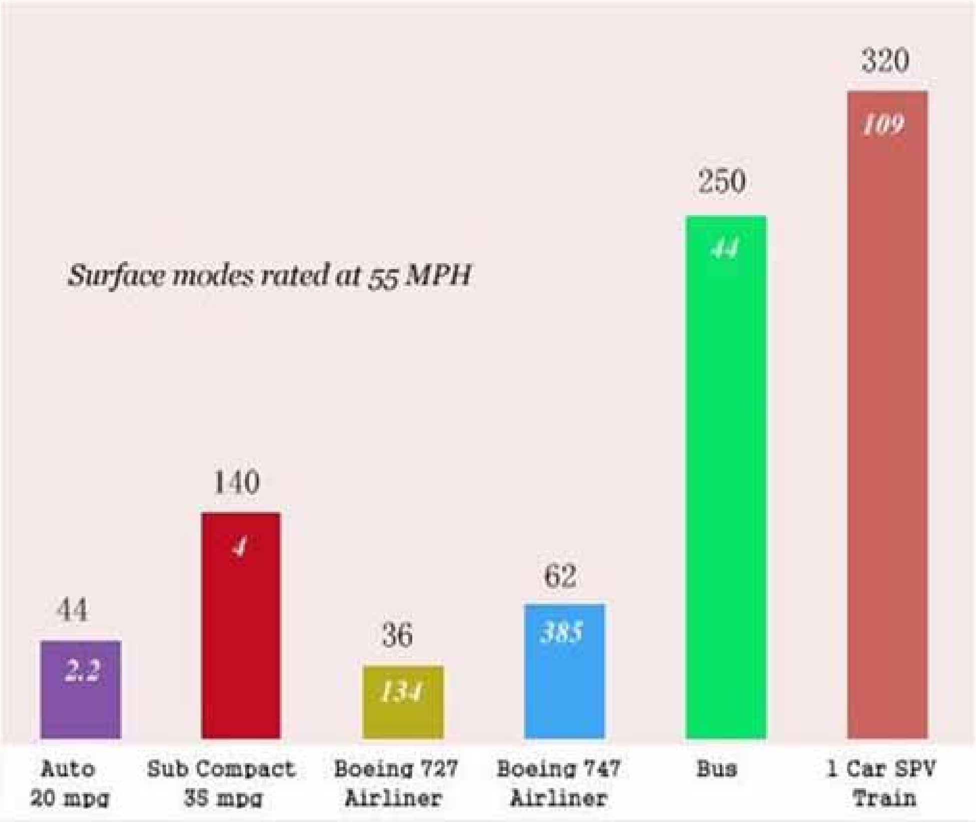
Public Systems

CONSERVATION PRACTICES

TRANSPORTATION

Automotive economy improvements and a “gas guzzler” tax assessed upon manufacturers following the oil supply crisis of the 1970s had positive affects that were offset after 1990 by growing popularity of utility vehicles, pickup trucks and minivans that fell under more lenient truck standards.

Public transportation, carpooling, “kiss-’n-ride” programs, high-occupancy vehicle lanes and speed limits help to reduce fuel consumption.



Unit = passenger miles per gallon of fuel (italicized number denotes passenger loads)

Fuel Efficiency of Various Transportation Modes

CONSERVATION PRACTICES

TRANSPORTATION

The “Clean Energy Development for a Growing Economy” bill (the Clean EDEG Act) introduced by the US Senate in 2006 requires many alternative refueling pumps to be installed across the nation.

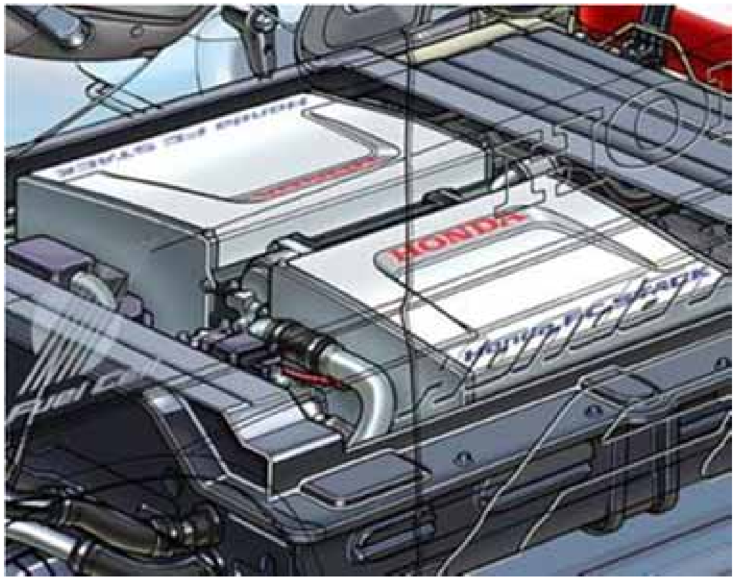
Flex-fuel vehicles and supplies provide a means to transition to renewables and offers the public opportunities to take advantage of the least expensive options.

Flex-Fuel Vehicles

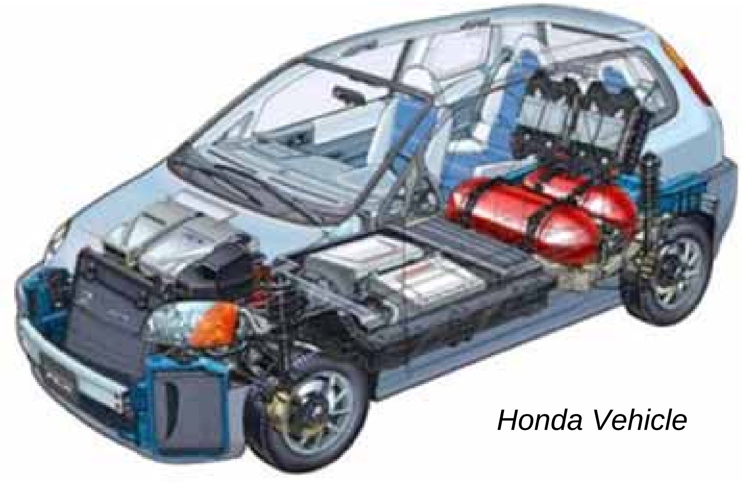
CONSERVATION PRACTICES

TRANSPORTATION

Honda



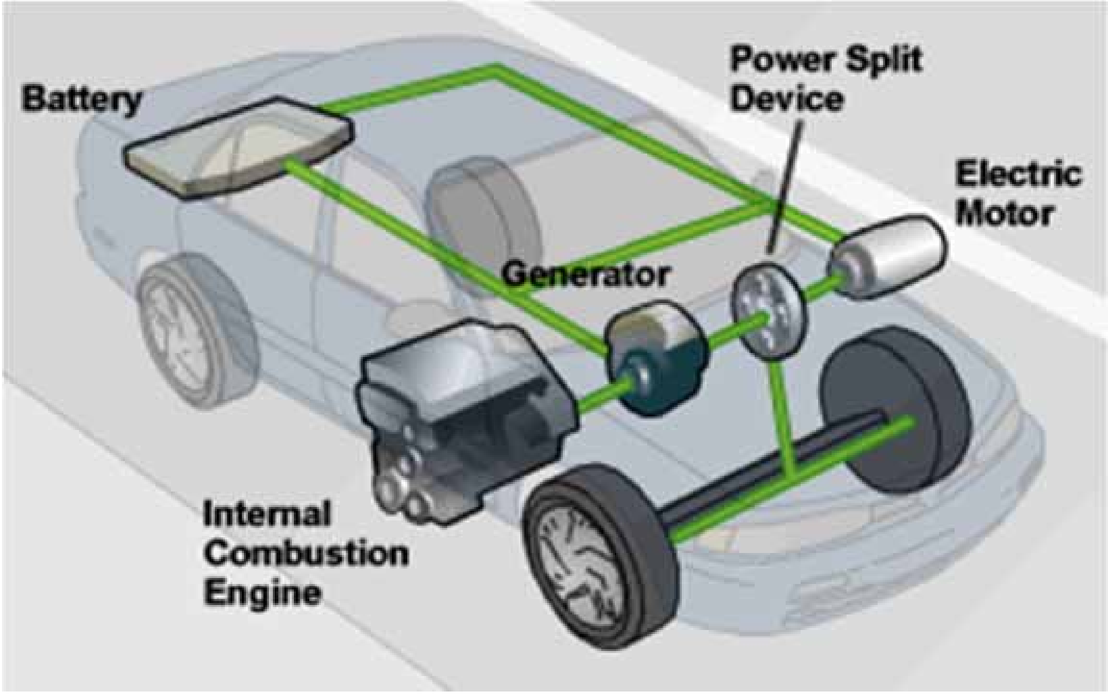
Honda


Honda Vehicle

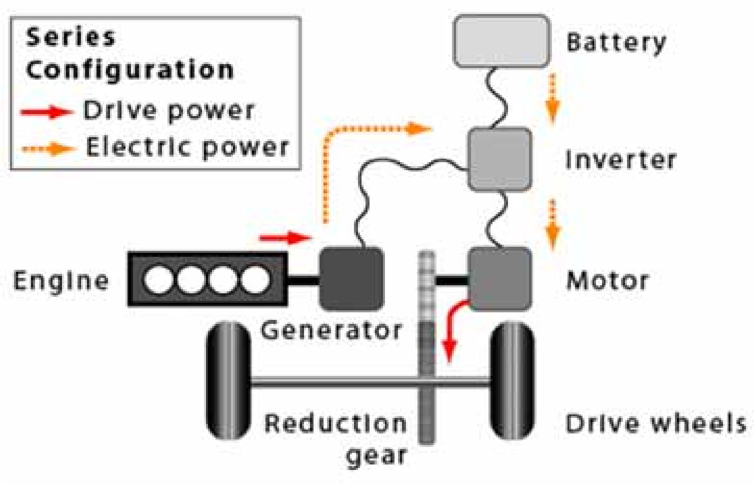
Fuel Cell Vehicles (FCVs)

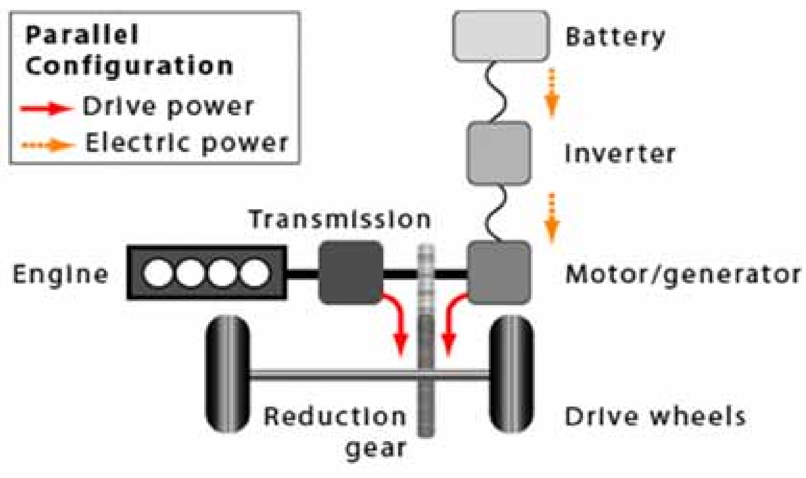
CONSERVATION PRACTICES **TRANSPORTATION**

Hybrid electric vehicles configured with engines and electric motors connected in parallel can use regenerative braking to slow the vehicle and convert kinetic energy that would otherwise be wasted in the form of heat into storable electricity.



Recycling Kinetic Energy





Hybrid electric vehicles typically use smaller engines than conventional, and they run at more energy-efficient speeds.

Most hybrids currently use engines oriented in a "parallel" configuration that separates the engine and electrical system to optimize efficiencies of each.

Hybrid Electric Vehicles

Direct Vehicle Leasing

Economy of Motion

The hybrid Toyota Prius mid-sized hatchback can achieve up to 55 mpg using either an internal combustion engine, an electric motor or both.

Phronk

Economy of Scale

The “Smart For Two” microcar produced by Daimler Chrysler can achieve more than 70 mpg using a turbocharged 3-cylinder internal combustion engine.

Rapid advancements and exploding popularity of personal computers and internet-based telecommunications can have major impacts on future American commuting and long-range transportation habits, making much travel unnecessary.

- **Telecommuting may replace physical commuting for many jobs.**
- **Teleconferencing with electronic data transfer may minimize needs for national and global business travel.**

Technological developments in certain fields can have influences upon others that may appear unrelated.

Computer and Internet Impacts on Travel Habits and Business

CONSERVATION PRACTICES

TRANSPORTATION

Government, industry, academia and the general public broadly recognize that better conservation practices are essential for many reasons:

- **Because they care about the future of children and generations who will follow.**
- **Because they care about the natural environment and fragile, endangered ecosystems.**
- **Because new and better solutions make good economic sense, providing jobs and profits needed for progress.**
- **Because change is an imperative, not an option.**

Children’s Research Center National Park Service

US Dept. of State Salem Cnty. AVA Center

Incentives for Progress

Missouri Secretary of State URFAN
Star Bulletin City of Cambridge

Each of us, individually and collectively, change the world for better or worse through daily decisions:

- **We influence leadership and policies through involvement and votes.**
- **We determine which businesses and products will succeed or fail through our purchasing power.**
- **We decide how many resources we will consume and waste through our lifestyle habits.**
- **We influence our children and others around us through values and example we demonstrate.**

Personal Choices and Influences

CONSERVATION PRACTICES **OUTLOOKS AND INSIGHTS**

Government programs can and do promote energy conservation in a variety of ways through representatives we help to elect and though the policies we influence.

The Natural Resources Defense Council (NRDC), an independent environmental action organization, advocates a number of initiatives the Federal Government can sponsor to advance these objectives:

- ***Expand information programs to promote energy efficiency in development and purchases of buildings and manufactured products.***
- ***Provide additional performance-based incentives for existing home retrofits and Energy Star provisions of the EPAct.***
- ***Fund the Low Income Home Energy Assistance Program (LIHEAP) and Westernization Assistance Program (WAP) already authorized.***
- ***Enact a national renewable portfolio standard advocated by EIA requiring major utility companies to increase power from renewable sources.***
- ***Extend production tax credits for electricity produced from wind and geothermal energy that are soon scheduled to expire.***
- ***Issue minimum energy efficiency standards for certain appliances, equipment products and federal buildings through the Department of Energy.***

NRDC Recommendations

Federal Government Initiatives

New technology advancements, however promising typically encounter large obstacles:

- **Most innovations require large development and implementation investments before they can demonstrate performance and be economically competitive with conventional approaches.**
- **Establishment of mass production, distribution and support infrastructures is usually very costly.**
- **Ultimately, public interest determines which alternatives will realize sufficient market demands to support economical production scales and profitability requirements.**

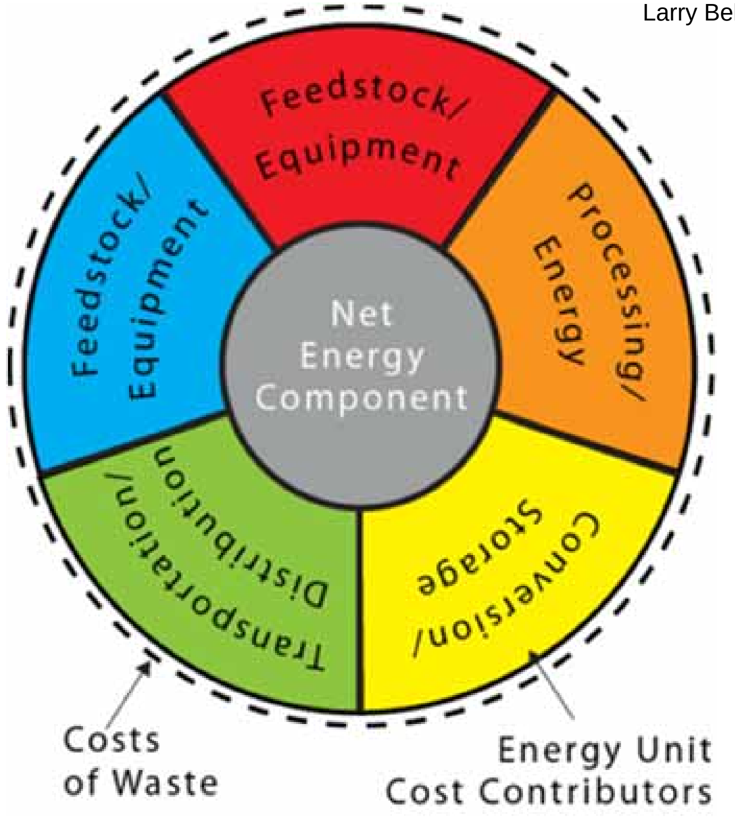
New ideas must compete with existing products that have established manufacturing capabilities, market demands, and distribution and service networks which offer advantages.

Innovation Requirements

While all are important, no single energy source, technology option or combination can satisfy needs of uncontrolled consumption.

Resourceful conservation principles demand we apply ways to do more with less:

- **Reduce** waste and pollution through more energy-efficient building design, lifestyle habits and technologies.
- **Recycle** natural energy and material resources using renewable, sustainable approaches that preserve and extend fossil fuels.
- **Reuse** production process heat and chemicals to maximize yields, economies and resource transfer benefits for other purposes.



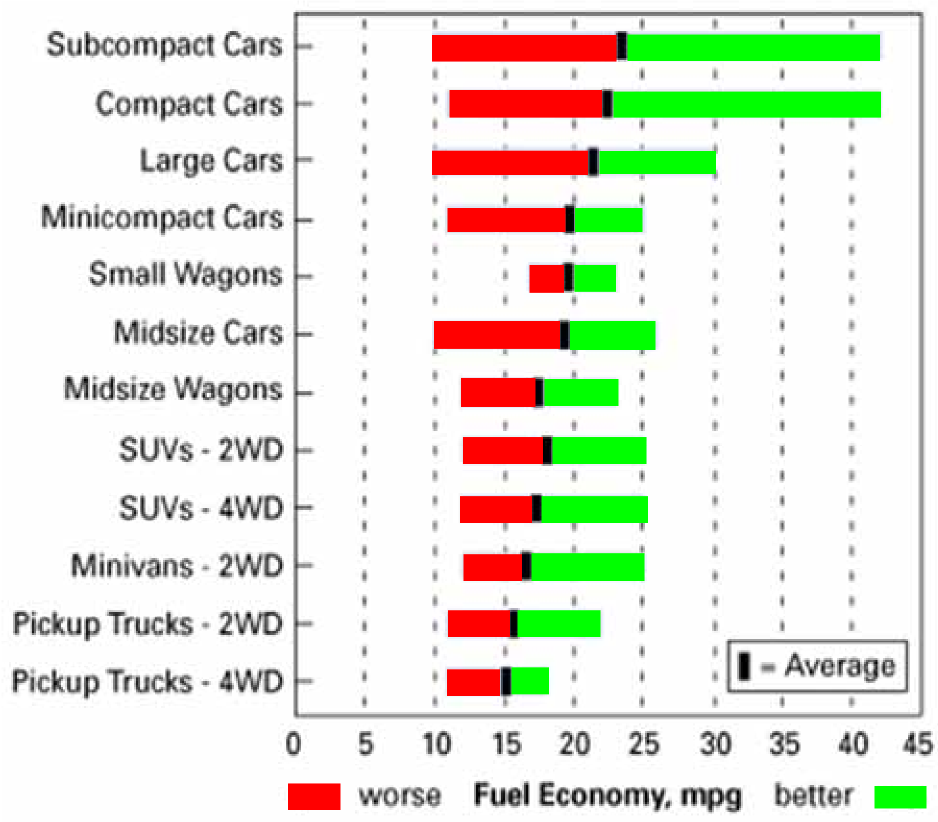
Each unit of energy conserved saves costs in the form of energy, money and pollution to create it.

Value of Conservation

Doing more with less makes good economical and moral sense, and can often be accomplished without serious lifestyle compromises:

- **Passive solar building design, when properly applied, can greatly reduce energy consumption and pollution.**
- **Purchasing energy-efficient cars and use of public transportation expands market and service demands that drive costs down even more.**
- **Combined heat and power systems and inexpensive solar water and space heating devices, can save money and fuel.**

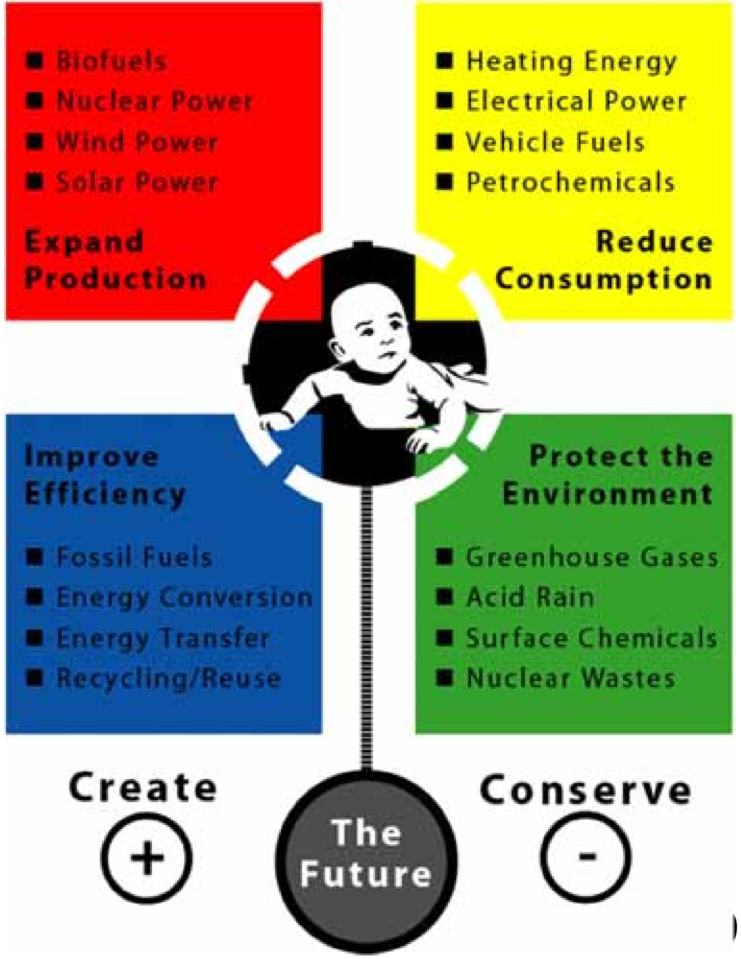
Chevron Corporation



Vehicle Fuel Economy Choices

Our only real options demand combined efforts to develop and expand more environmentally-friendly alternatives to fossil fuels, to make more effective use of all resources, and above all, to apply aggressive conservation practices at all levels of scale that reduce wastes:

- Global volatility and environmental vulnerability require that we enact decisive interventions now that allow time for transitions essential to prevent devastating crises later.
- Lives of today's children and those who will follow will be greatly affected by our actions.



The Only Real Options