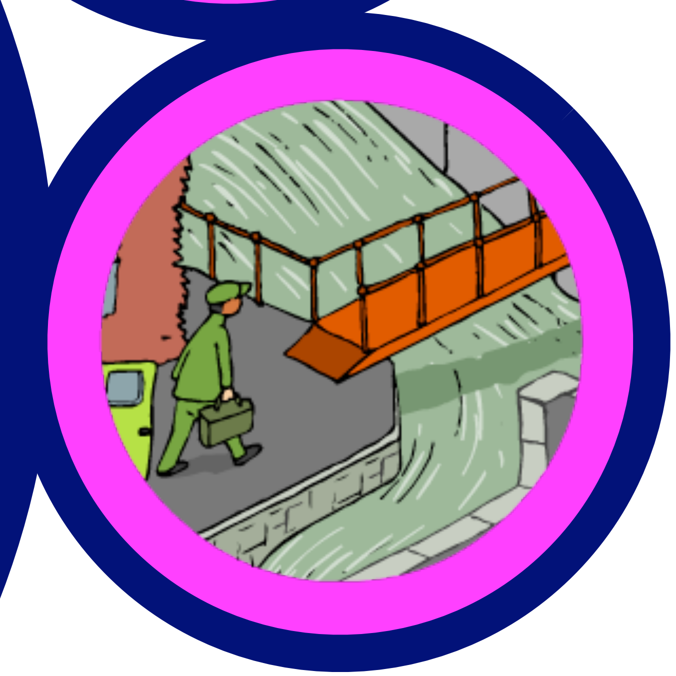
Renewable Energy

6th Lecture

Rolling in the Deep
Adele



Renewable Energy

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Renewable Energy

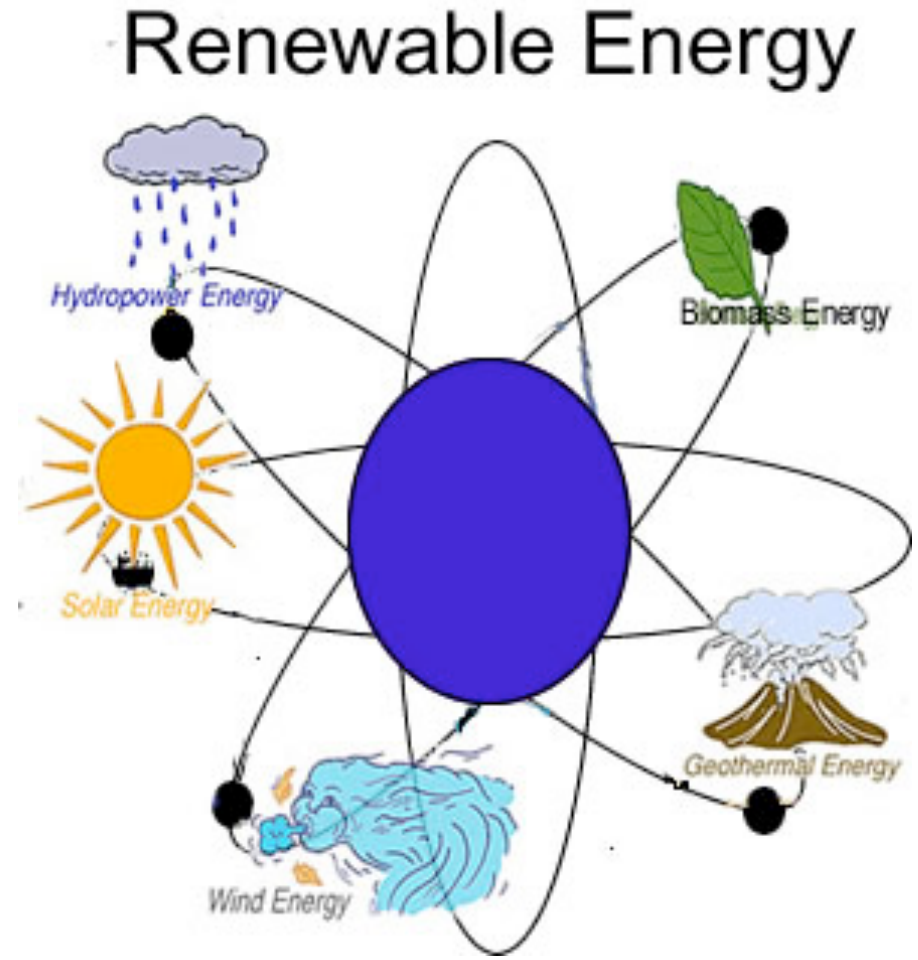
is energy which comes from natural resources such as *sunlight, wind, rain, tides, waves and geothermal heat*, which are renewable (naturally replenished).

- About 16% of global final energy consumption comes from renewables, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity.
- New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly.
- The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables.

- The use of wind power is increasing at an annual rate of 20%, with a worldwide installed capacity of 238,000 megawatts (MW) at the end of 2011, and is widely used in Europe, Asia, and the United States.
- Since 2004, photovoltaics passed wind as the fastest growing energy source, and since 2007 has more than doubled every two years. PV power stations are popular in Germany and Italy. Solar thermal power stations operate in the USA and Spain, and the largest of these is the 354 MW SEGS power plant in the Mojave Desert. The world's largest geothermal power installation is the Geysers in California, with a rated capacity of 750 MW. Brazil has one of the largest renewable energy programs in the world, involving production of ethanol fuel from sugarcane, and ethanol now provides 18% of the country's automotive fuel. Ethanol fuel is also widely available in the USA.

Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization. New government spending, regulation and policies helped the industry weather the global financial crisis better than many other sectors. According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within 50 years, dramatically reducing the emissions of greenhouse gases that harm the environment

Over view

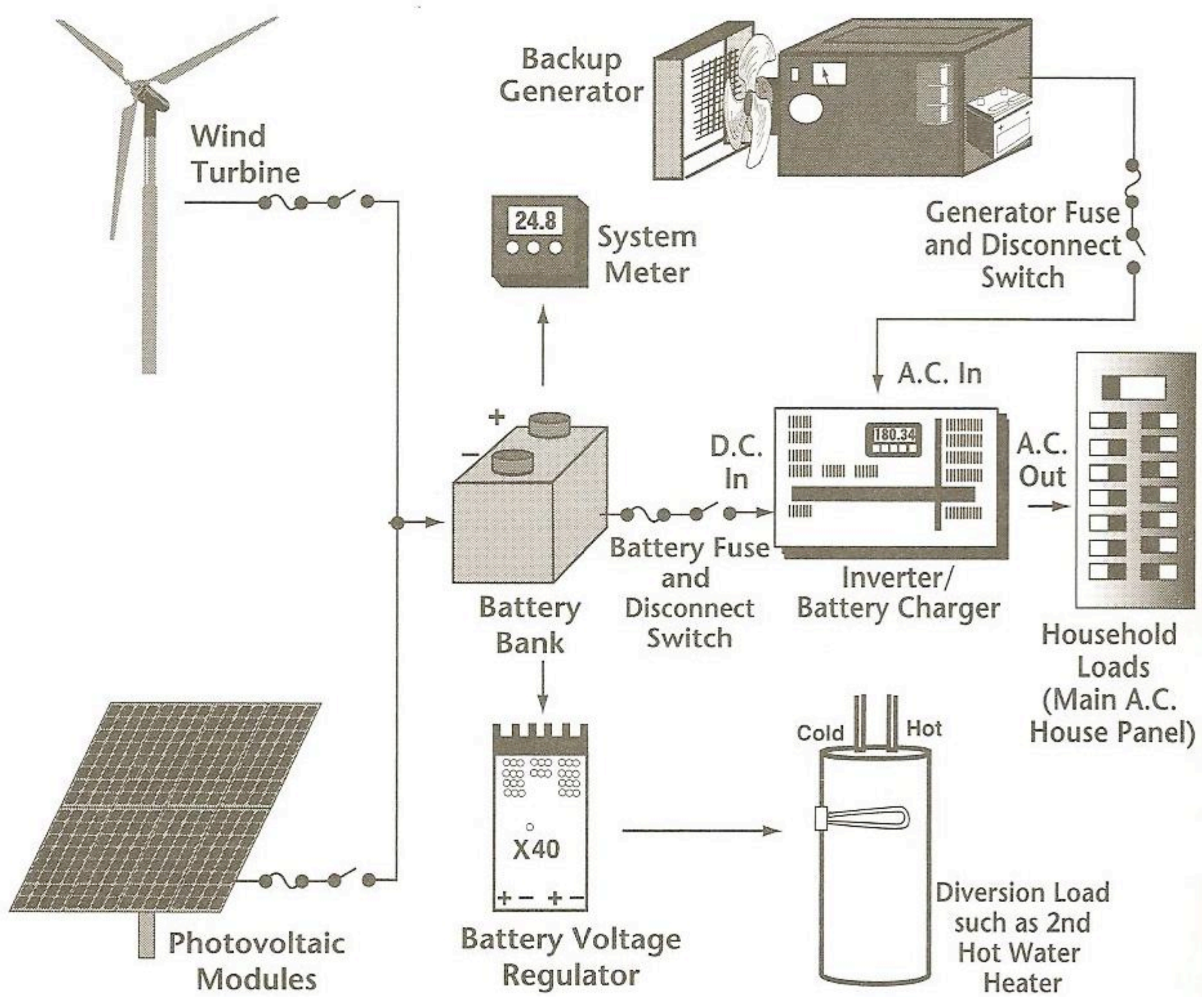


- Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains:
- Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

History

- Prior to the development of coal in the mid 19th century, all energy used was renewable, with the primary sources being human labor, animal power in the form of oxen, mules, and horses, water power for mill power, wind for grinding grain, and firewood. A graph of energy use in the United States up until 1900 shows oil and natural gas with about the same importance in 1900 as wind and solar played in 2010.
- By 1873, concerns of running out of coal prompted experiments with using solar energy. Development of solar engines continued until the outbreak of World War I. The eventual importance of solar energy, though, was recognized in a 1911 Scientific American article: "in the far distant future, natural fuels having been exhausted [solar power] will remain as the only means of existence of the human race".
- In the 1970s environmentalists promoted the development of alternative energy both as a replacement for the eventual depletion of oil, as well as for an escape from dependence on oil, and the first wind turbines appeared. Solar had always been used for heating and cooling, but solar panels were too costly to build solar farms until 1980. The theory of peak oil was published in 1956.
- By 2008 renewable energy had ceased being an alternative, and more capacity of renewable energy was added than other sources in both the United States and in Europe.

Off-Grid System



신·재생에너지 도입의 제약요인

	장소 제약	에너지원 제약	보급의 성숙도	난이도	제약요인
태양광 발전				B	○ 도입단가 높음 ○ 주택의 지붕등 일사가 양호한 공간확보 ○ 출력 불안전에 따른 타 발전원 필요
태양열 이용			○ (가정용)	C	○ 주택의 지붕등 일사가 양호한 공간확보 ○ 출력 불안전
풍력발전	○			A	○ 출력 불안전 ○ 소음 ○ 입지(풍황, 도로확보, 송전설비 확보, 법적 허용)
폐기물 발전	○	△		B	○ 다이옥신문제(환경영향평가와 주민의 이해) ○ 소각처리 폐기물 양의 한계 ○ 재료재생에 따라 자원확보문제
폐열이용	○	△		B	○ 환경영향평가와 주민의 이해 ○ 열원에서 2㎞이내 ○ 잠재적인 열이용 가능량 한계
온도차에너지 등	○			B	○ 열원에서 1㎞이내 ○ 자연열원 시설의 주변에서 냉난방 등 열수요 확보 곤란
폐자재	○	△	△	A	○ 에너지 수요에 대응하는 공급력 확보 한계

Energy Cost

	Energy cost(2001)	Potential future energy cost
Electricity		
Wind electricity	4–8 ¢/kWh	3–10 ¢/kWh
Solar photovoltaic electricity	25–160 ¢/kWh	5–25 ¢/kWh
Solar thermal electricity	12–34 ¢/kWh	4–20 ¢/kWh
Large hydro energy	2–10 ¢/kWh	2–10 ¢/kWh
Small hydro energy	2–12 ¢/kWh	2–10 ¢/kWh
Geothermal energy	2–10 ¢/kWh	1–8 ¢/kWh
Biomass energy	3–12 ¢/kWh	4–10 ¢/kWh
Coal	4 ¢/kWh	
Heat		
Geothermal heat	0.5–5 ¢/kWh	0.5–5 ¢/kWh
Biomass-heat	1–6 ¢/kWh	1–5 ¢/kWh
Low temp solar heat	2–25 ¢/kWh	2–10 ¢/kWh
All costs are in 2001 US$-cent per kilowatt-hour.		

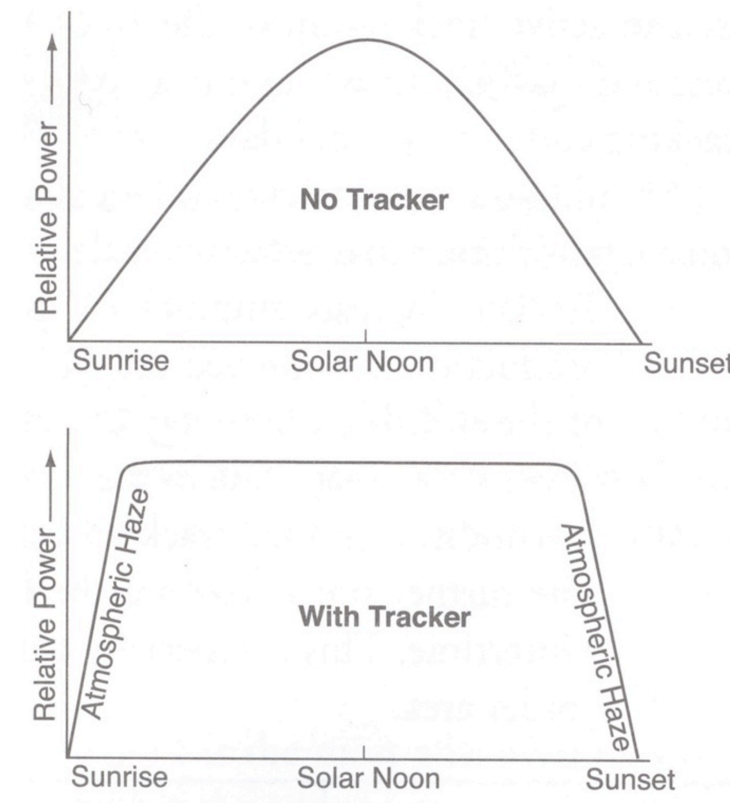
Grid Parity- 2010, 2020

신 · 재생에너지 지원제도

구분	제도	내 용
보급 보조사업	그린홈*100*만호보급사업	2020년까지 신재생에너지주택(Green home) 100만호 보급을 목표로 추진하는 사업으로 태양광, 태양열, 지열, 소형풍력,바이오 등의 신 · 재생에너지원을 일반주택 및 공동주택에 설치 시 설치비의 일부를 무상 지원
	태양광주택*10*만호보급사업	주택용 태양광 발전설비의 범국민적 이용을 확대하여 관련 기업의 안정적 투자환경을 조성하고 태양광 시장 창출과 확대를 유도하며, 기술발전을 통한 중장기 수출전략분야로 육성하기 위하여 설비설치비의 일부를 무상 보조 사업목적: 신에너지 및 재생에너지 개발 · 이용 · 보급 촉진법 제27조(보급사업) 및 제10조(조성된 사업비의 사용)/신재새에너지설비의 지원 · 설치 · 관리에 관한 기준(산자부고시 제2006-9호)
	태양열주택보급사업	낮 동안 무한한 자연에너지인 태양열만으로 섭씨 95도까지 물을 데워 난방과 온수에 직접사용하거나 저장할 수 있어(온수사용 우선, 난방보조) 전기와 기름 값을 줄일 수 있는 친환경 기기 기반구축사업(교육연수홍보, 자원 및 타당성 조사, 정책개발 및 보급계획, 통계조사, 모니터링사업), 설비보급사업
	지방보급사업	지역특성에 맞는 환경친화적 신재생에너지 보급을 위하여 지방자치단체에서 추진하는 제반 사업을 지원
	그린빌리지사업	태양열, 지열, 태양광발전 등 신재생에너지를 일상생활에 활용하는 50호 규모의 시범마을 태양열, 태양광, 풍력, 지열 등 신재생에너지 설비설치 지원/주택의 태양광 발전설비는 태양광 10만호 주택보급사업으로 추진유도

Solar Power

태양력

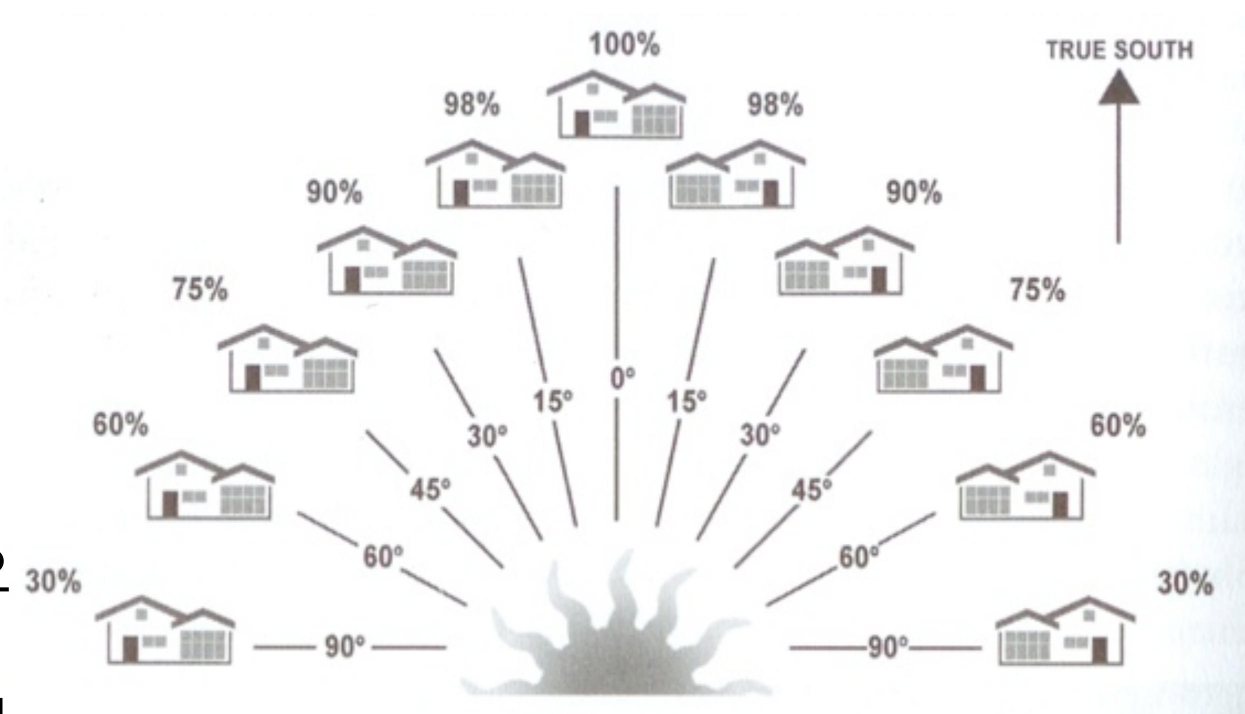


장점

- 태양 에너지의 양을 이용하여 고갈될 염려 없음
- 환경 오명 물질의 배출 없음
- 발전용량에 신축성이 있고, 발전시설의 유동성이 있음
- 여러 분야에 적용이 가능
- 20년 이상의 장수명, 자동화로 유지관리가 용이

단점

- 에너지 밀도가 아주 낮아 수집하는데 많은 비용필요
- 자연 조건에 출력 변동이 큼
- 태양전지등을 만들 때 필요한 반도체의 경우 오염물질 발생



건물 방위에 따른 태양력 효율

Solar energy

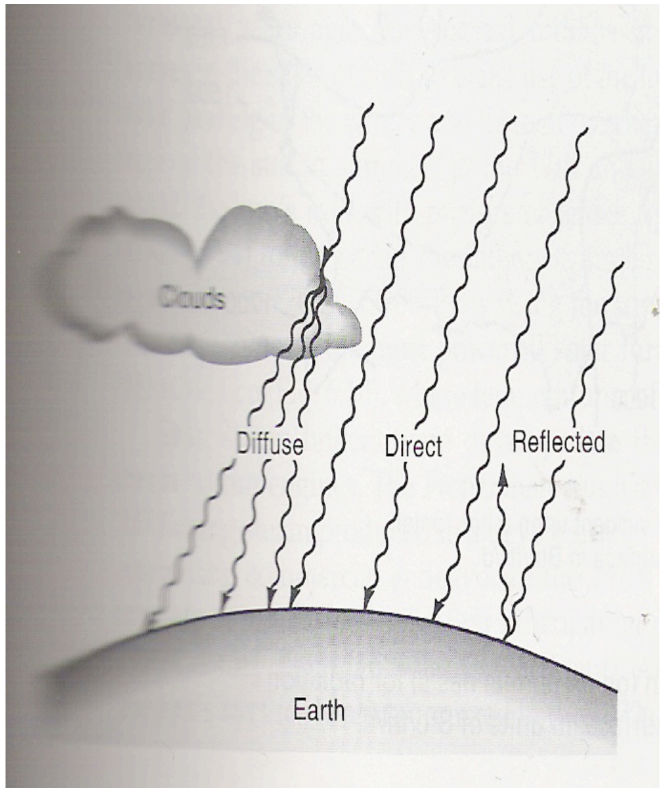
- Solar energy is the energy derived from the sun through the form of solar radiation. Solar powered electrical generation relies on photovoltaics and heat engines. A partial list of other solar applications includes space heating and cooling through solar architecture, daylighting, solar hot water, solar cooking, and high temperature process heat for industrial purposes.
- Solar technologies are broadly characterized as either passive solar or active solar depending on the way they capture, convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels and solar thermal collectors to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light dispersing properties, and designing spaces that naturally circulate air.

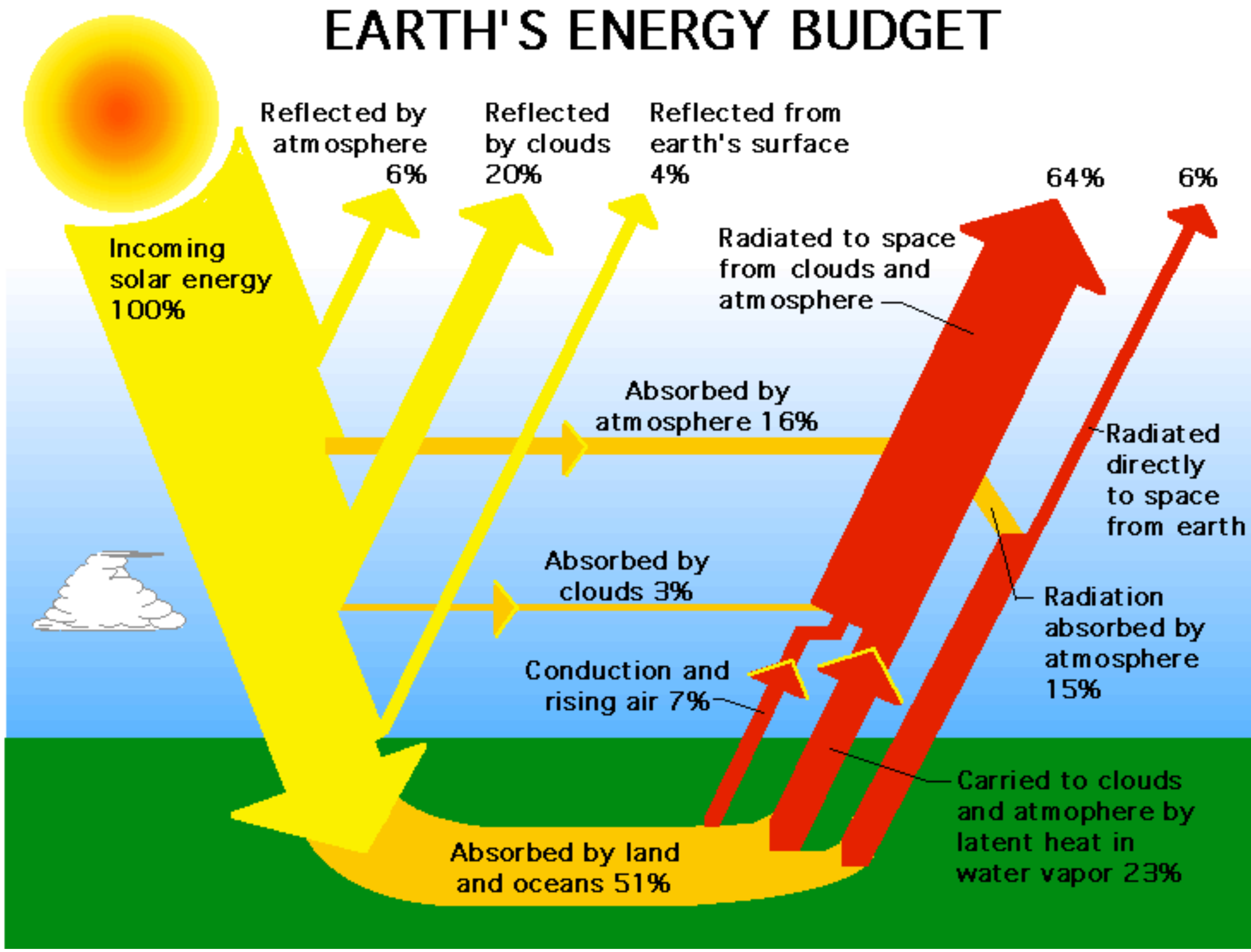
Characteristics of Isolation

Isolation is the amount of solar radiation reaching the earth. Also called Incident Solar Radiation. The sun's energy is created from the fusion of hydrogen nuclei into helium nuclei.

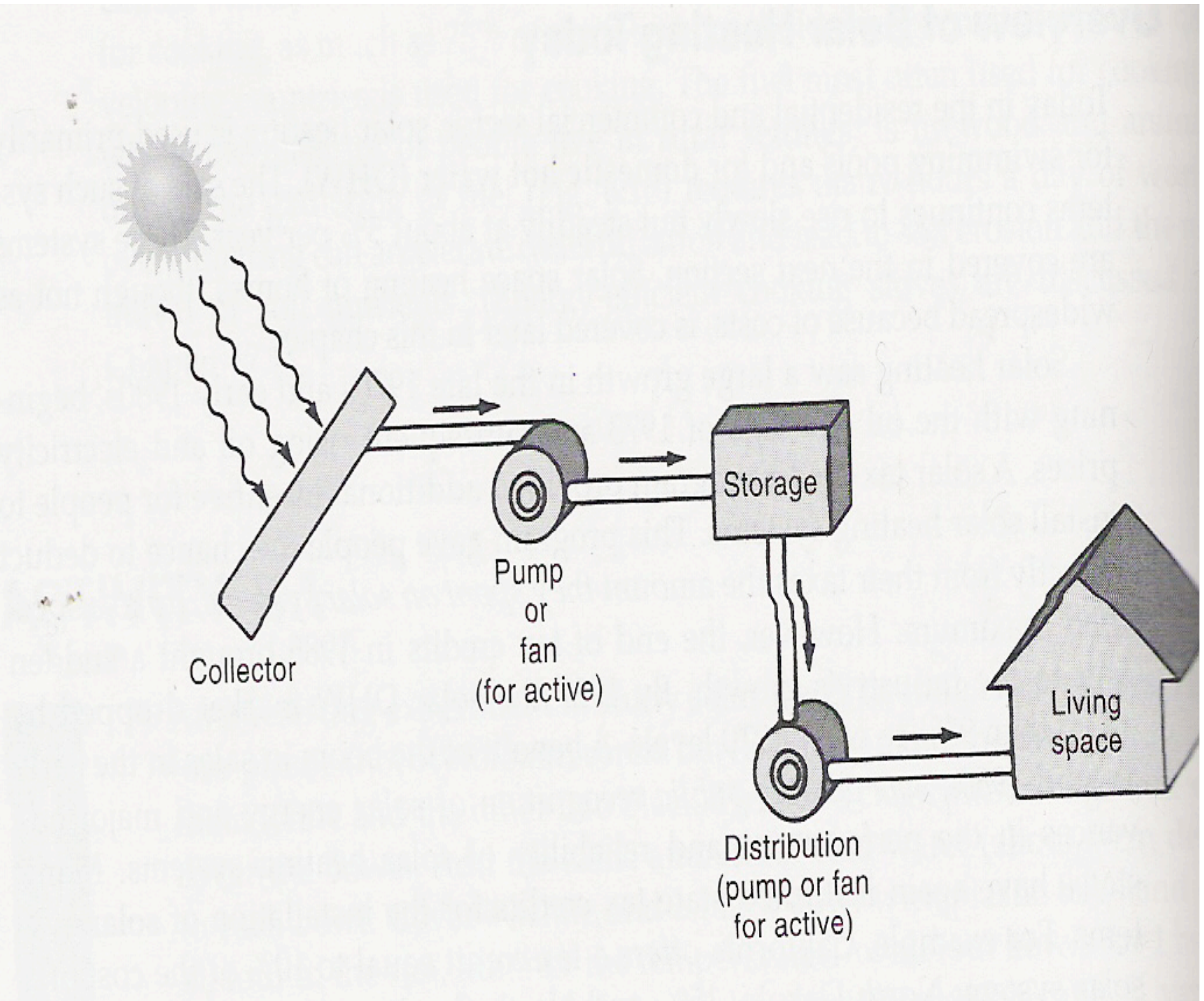
Components of Solar Radiation:

- Direct radiation
- Diffuse radiation
- Reflect radiation





SOLAR HEATING TODAY



Used mostly for heating pools and domestic hot water (DHW)

Two types of solar heating systems:

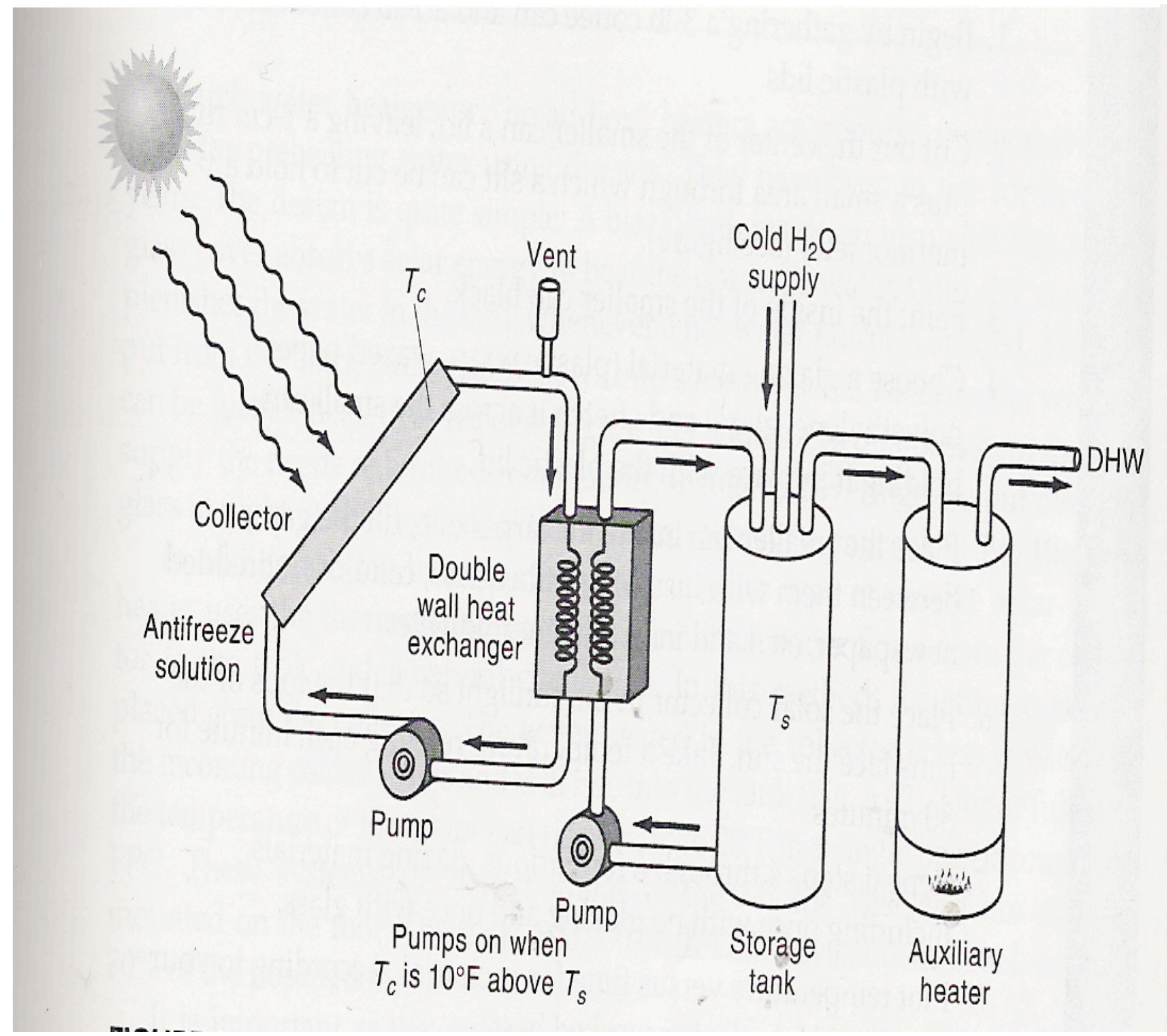
- Active Solar Heating System
- Passive Solar Heating System

ACTIVE SOLAR HEATING SYSTEM

A system that uses water or air that the sun has heated and is then circulated by a fan or pump.

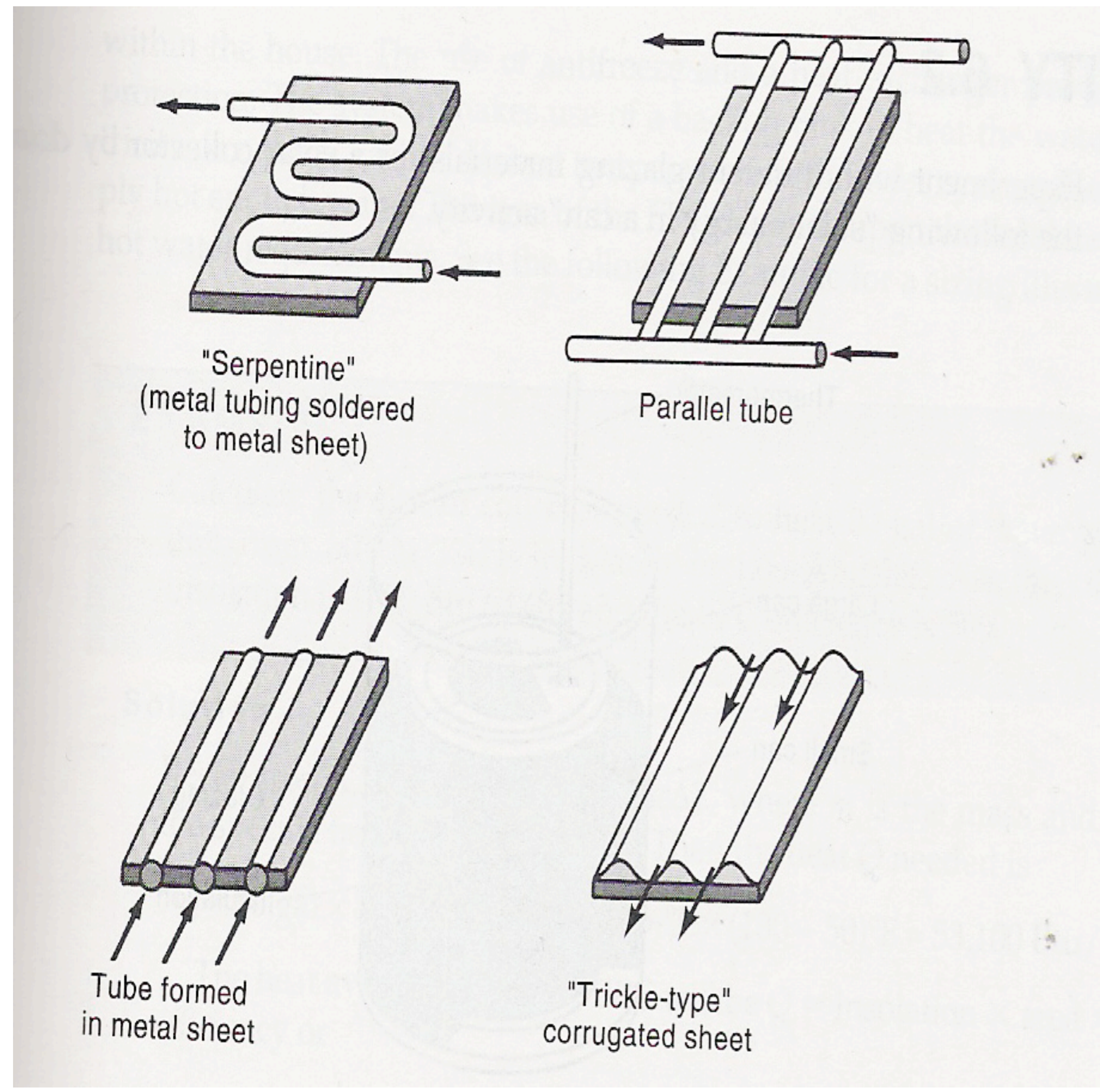
Three Types:

- Flat Plate Collectors
- Batch Water Heaters
- Thermosiphon



FLAT PLATE COLLECTO RS

A thin flat metal plate is used to absorb the sun's radiation. Tubes carry water into the absorber plate where it is heated by the sun and sent to a pump or fan into storage and distributed from there to the living space.



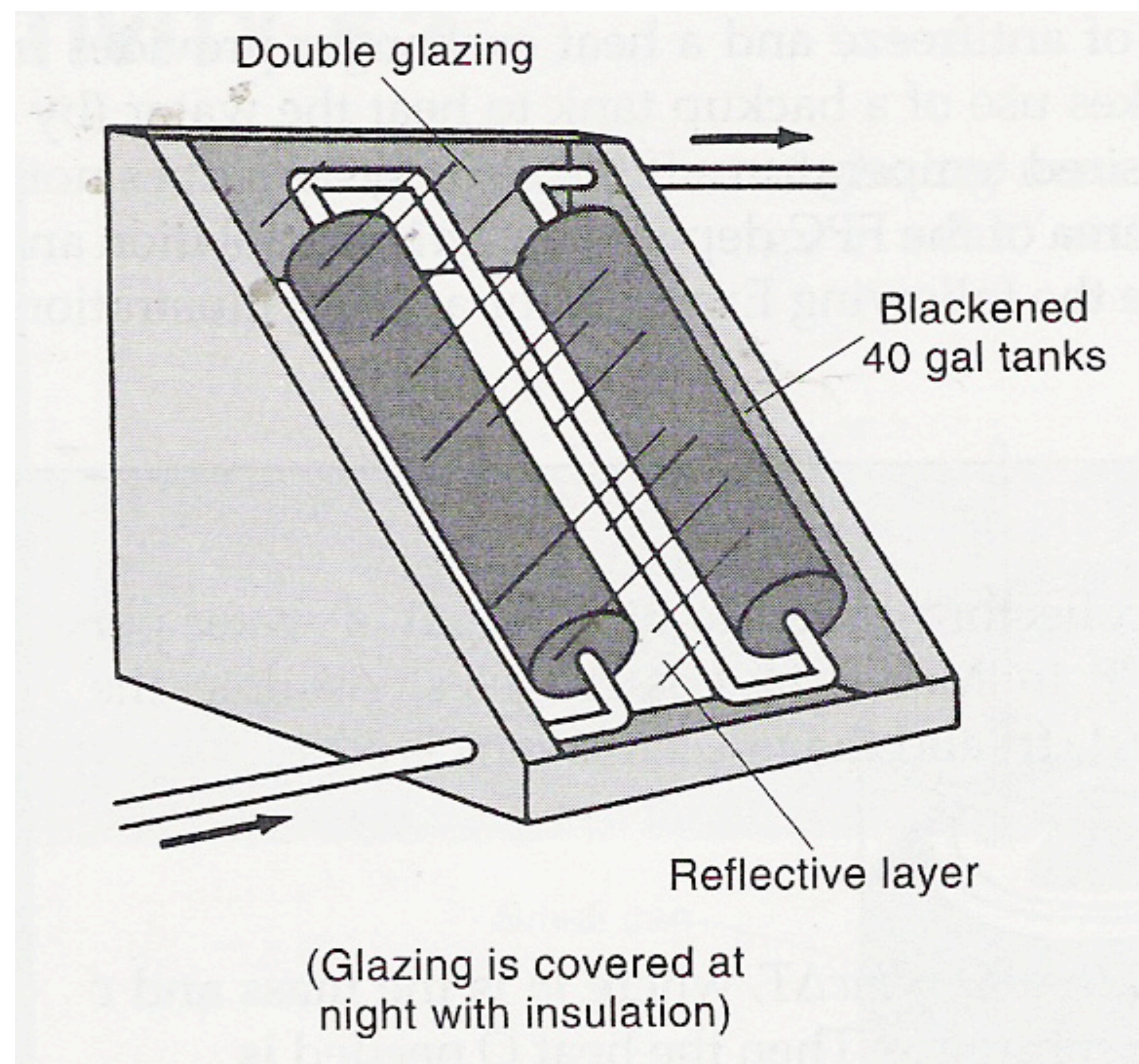
BATCH WATER HEATERS

Pre-heats water using the sun by having a black tank inside an isolated box with a glass cover.

Solar energy is absorbed within the box to heat the water.

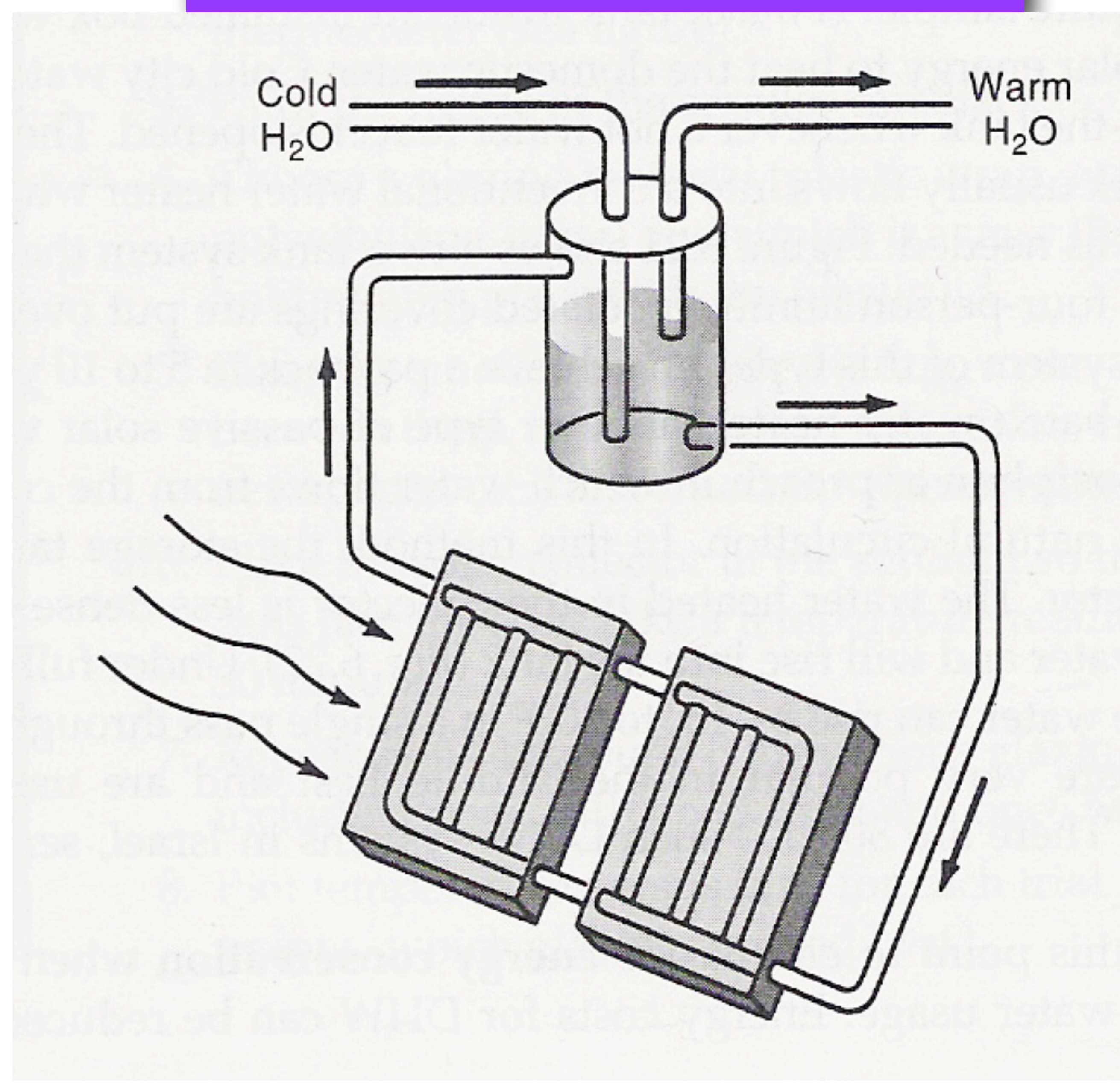
The water outflow is sent into a conventional water heater for further heating.

They are also called "Bread-Box" heaters.



THERMOSIP HEN

This method places the storage tank above the solar collector.
Cold water is put into the bottom of the storage tank where it is circulated through a flat plate collector and pumped back into the top of the storage tank. The heated water can then be taken from the top and used.



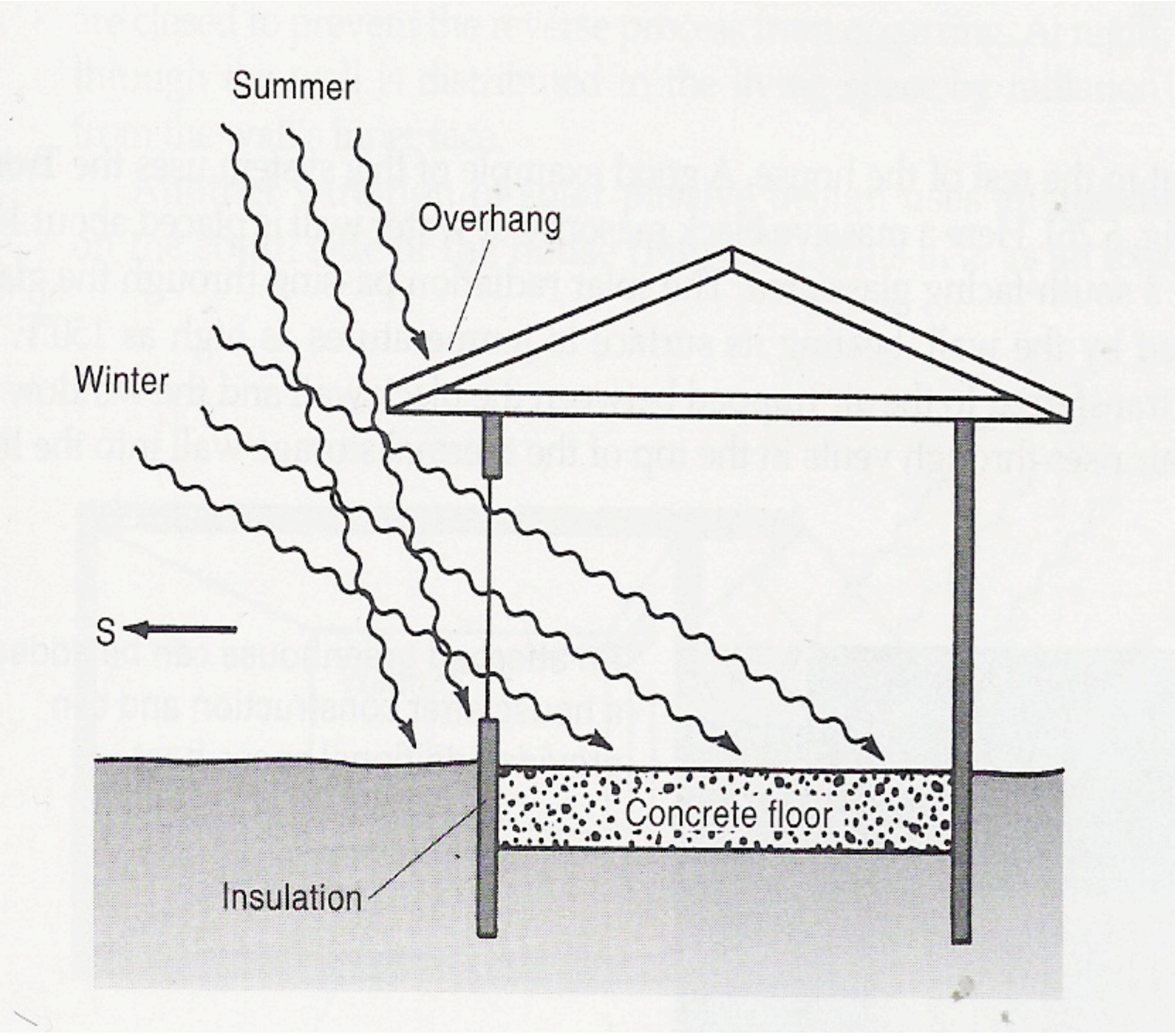
PASSIVE SOLAR HEATING SYSTEMS

The house itself acts as the solar collector and storage facility.
No pumps or fans are used.
This system makes use of the materials of the house to store and absorb heat.
Three Types:

- Direct-Gain
- Indirect-Gain
- Attached Greenhouse

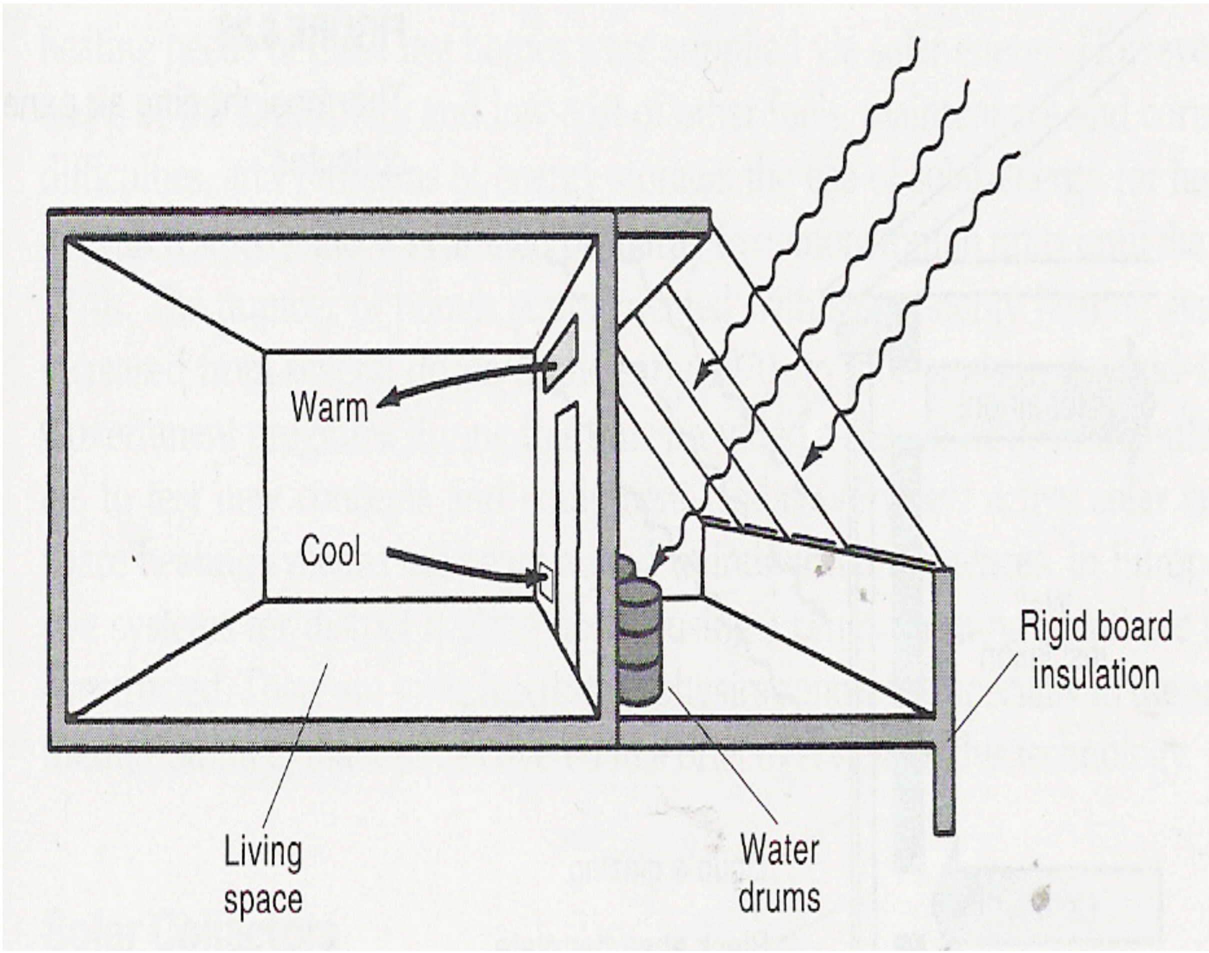
DIRECT-GAIN

Large south facing windows that let in the sunlight.
Thermal mass is used to absorb the radiation.
At night the absorbed heat is radiated back into the living space.



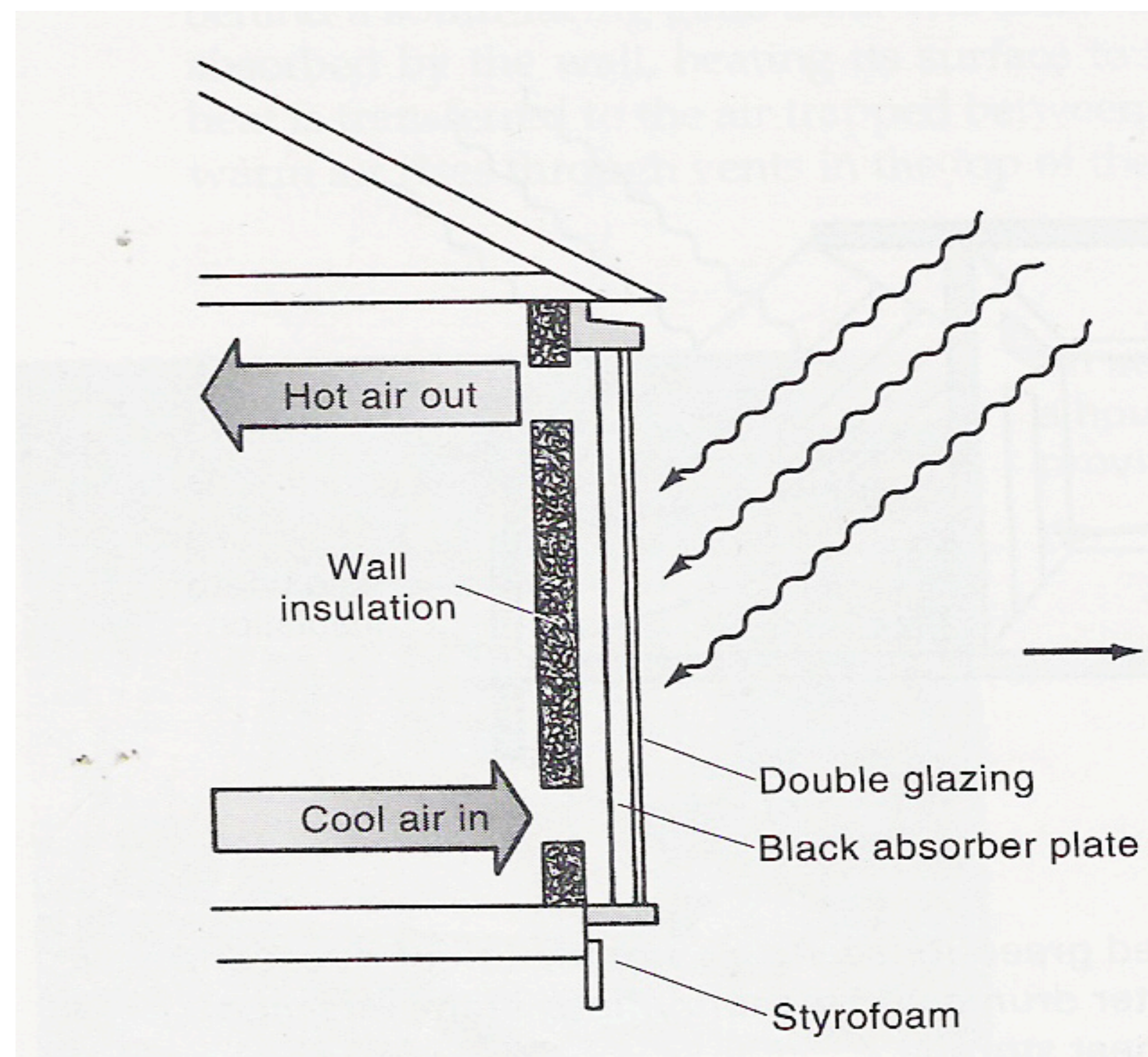
INDIRECT-GAIN

Collects and stores the solar energy in one part of the house and use natural heat transfer to distribute heat to the rest of the house.
Popular method is to use a Trombe Wall which is a massive black masonry that acts as a solar collector and a heat storage medium.



ATTACHED GREENHOUSE

Uses a combination of Direct and Indirect-Gain systems that use water drums and a masonry floor as heat storage in the attached greenhouse. Thermosiphoning can use direct-gain from the flow of air created by the difference in pressure between the less dense warmer air of the room and the cooler air near the ground.



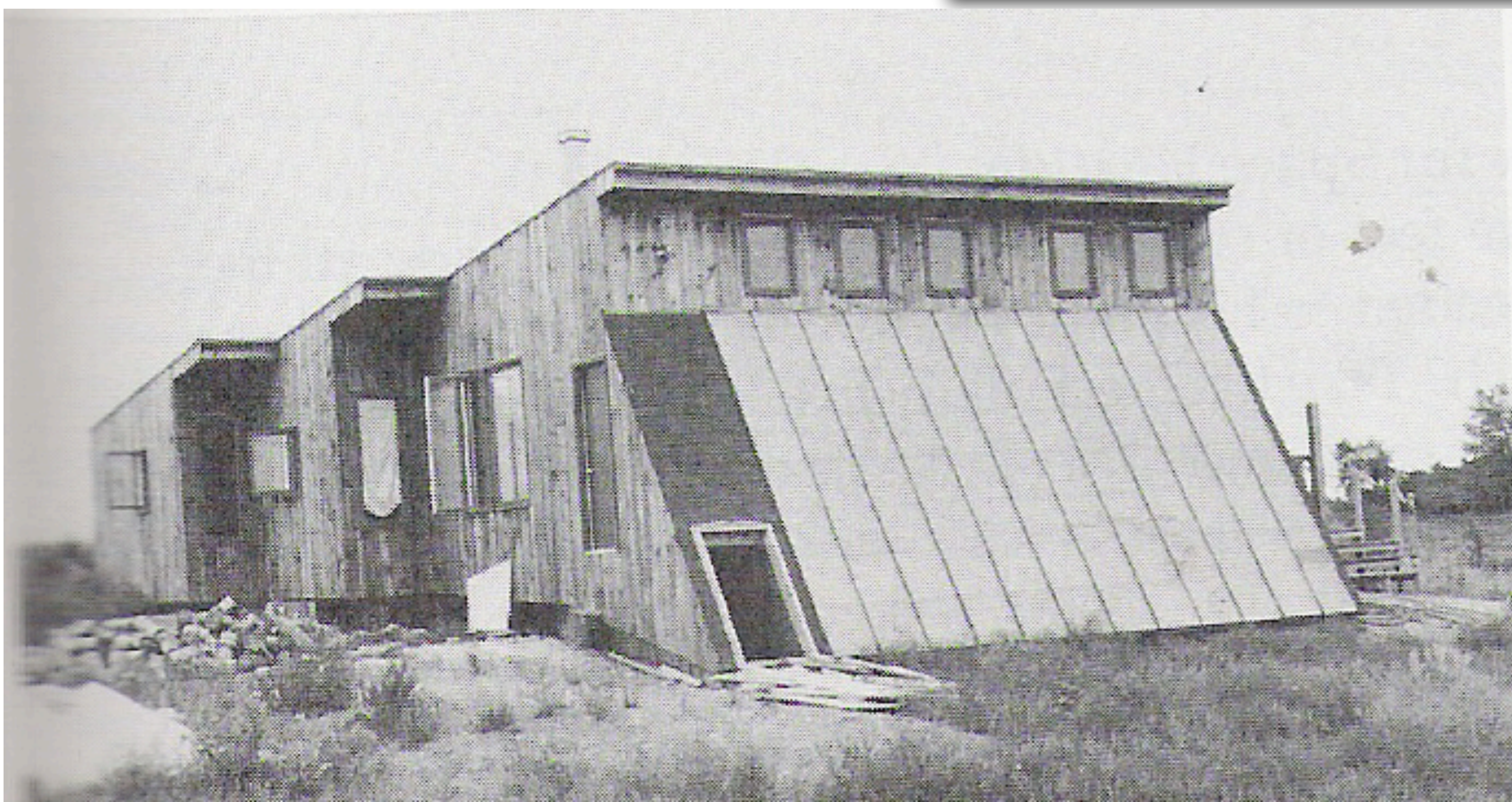
THERMAL ENERGY STORAGE

Solar energy heating systems must be able to store energy for night time use and for cloudy days. Different materials absorb different amounts of heat.

Depending on the weather and the amount of thermal energy stored will determine how long a house can continue to be heated by the stored solar energy.

Phase-change material can be used to add additional heat to the living space.

This House Uses an Active Air System



Photovoltaic Cells use in Energy Production

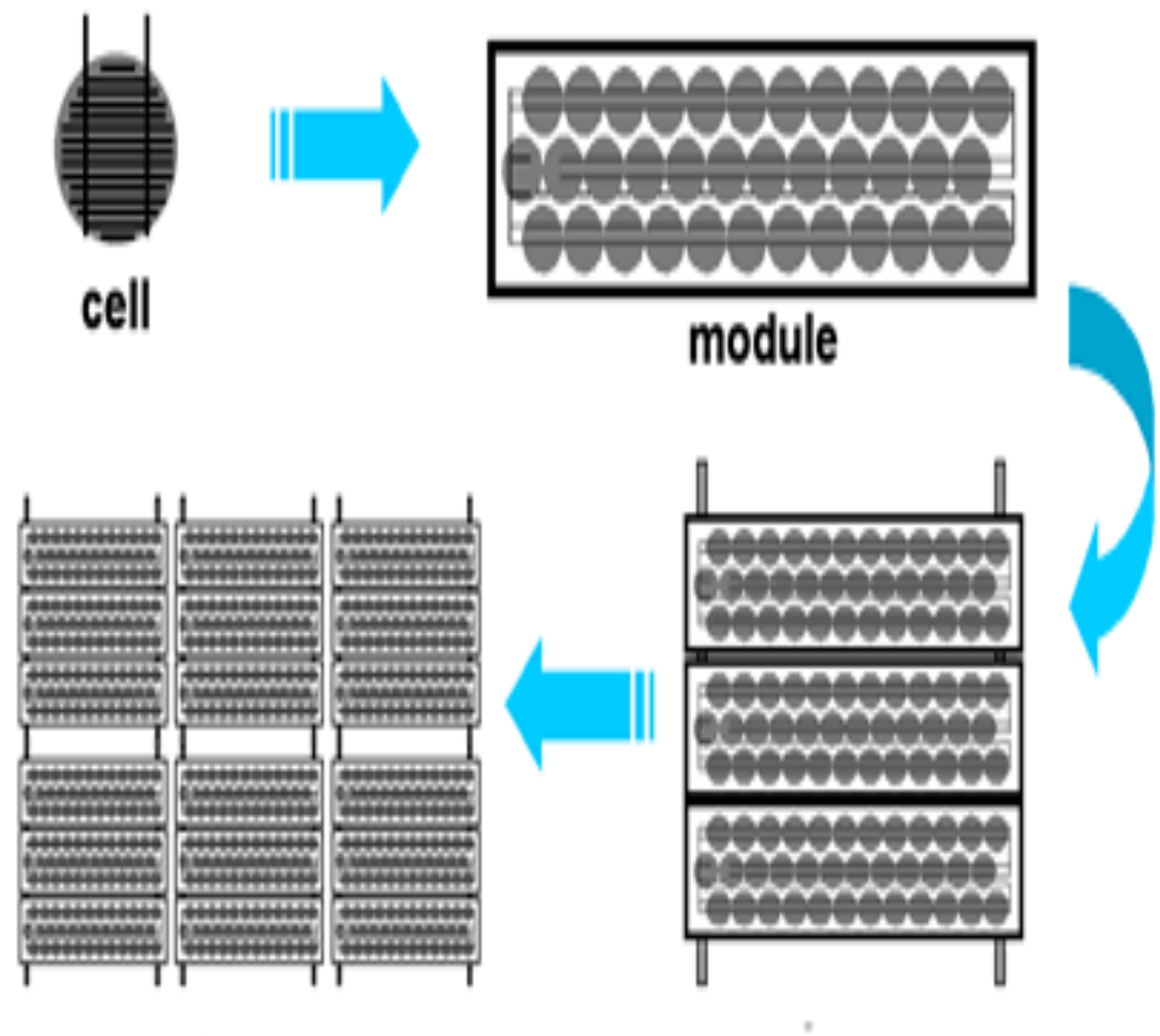
- How cells are built
- The Photoelectric Effect
- Pros and Cons of PV

4 types of PV cells

Selective – Emitter Cell (SEC)
Emitter wrap- through cells (EWC)
Thin Film Photovoltaic
Single Crystal Silicon Cells

How Does A Cell Become A Module?

A solar cell is the basic building block of a PV system.
A typical cell produces .5 to 1V of electricity.
Solar cells are combined together to become modules or if large enough, known as an array.
A structure to point the modules towards the sun is necessary, as well as electricity converters, which convert DC power to AC.
All of these components allow the system to power a water pump, appliances, commercial sites, or even a whole community.

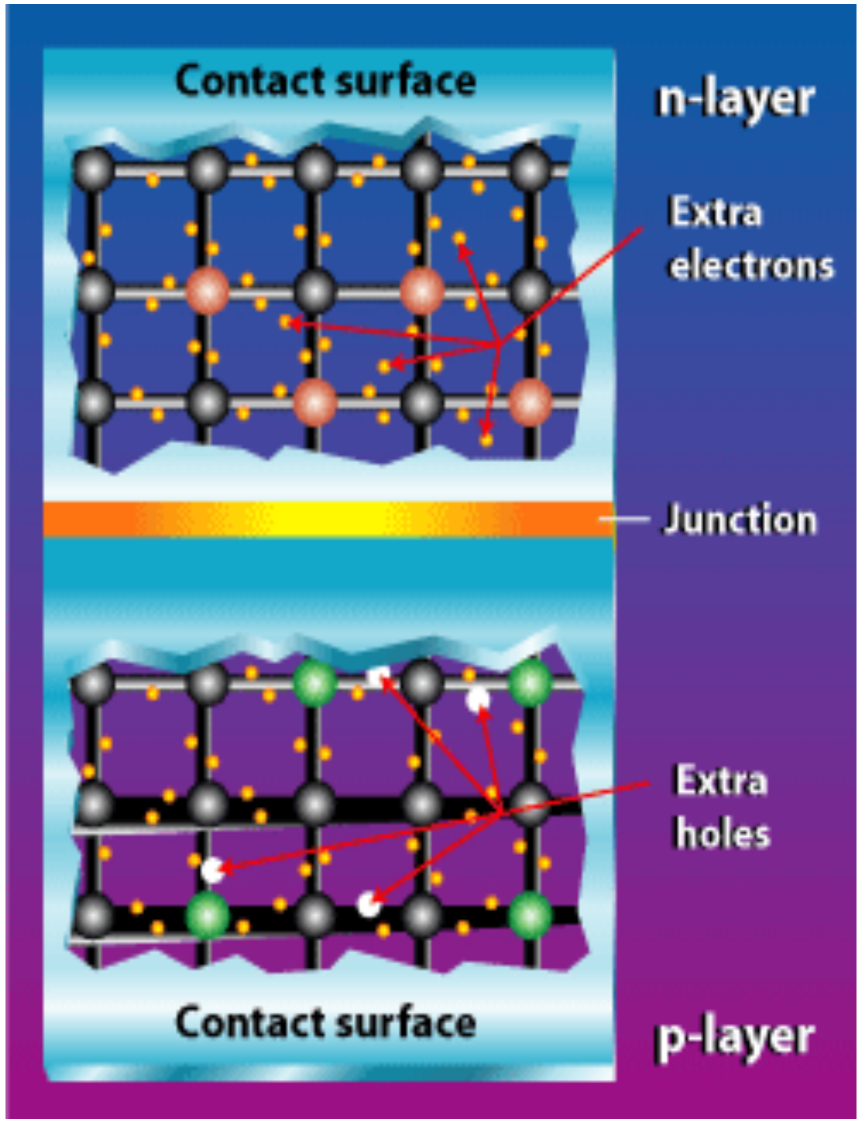


The Photoelectric Effect

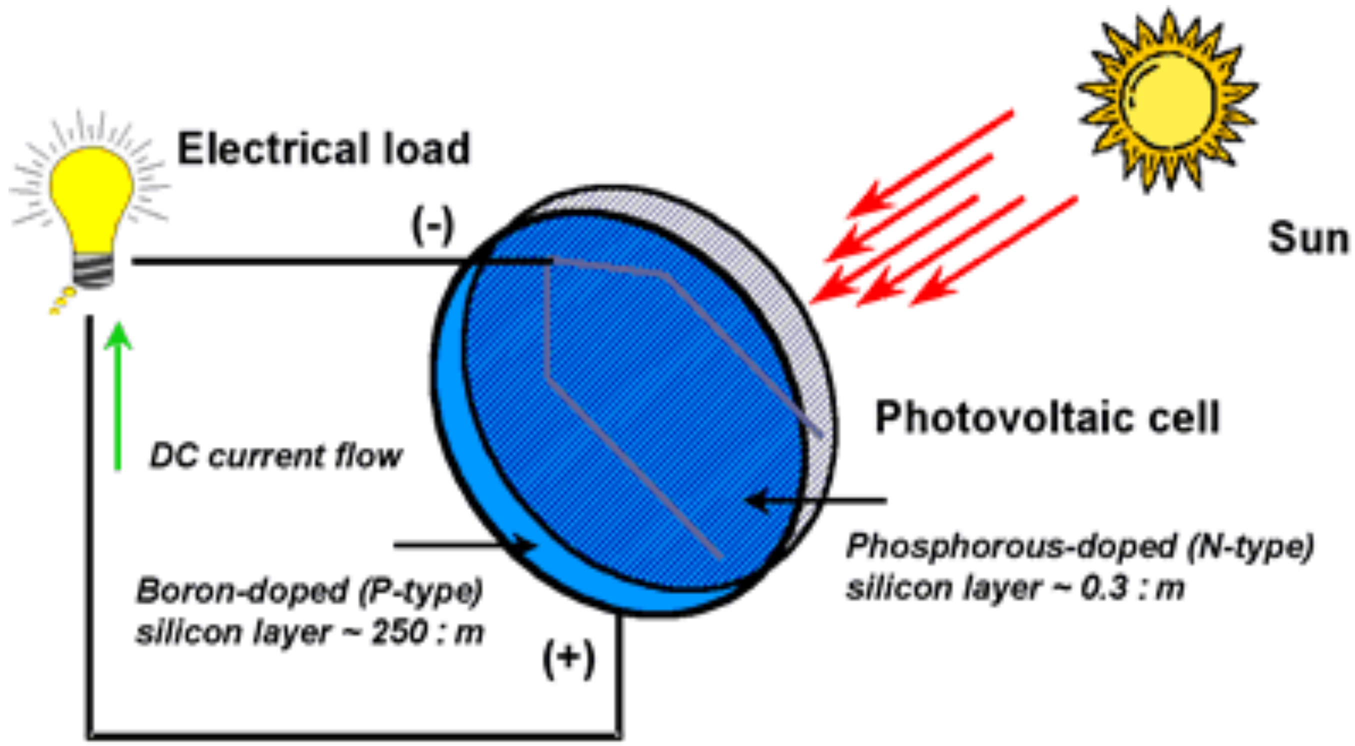
The photoelectric effect relies on the principle that whenever light strikes the surface of certain metals electrons are released.

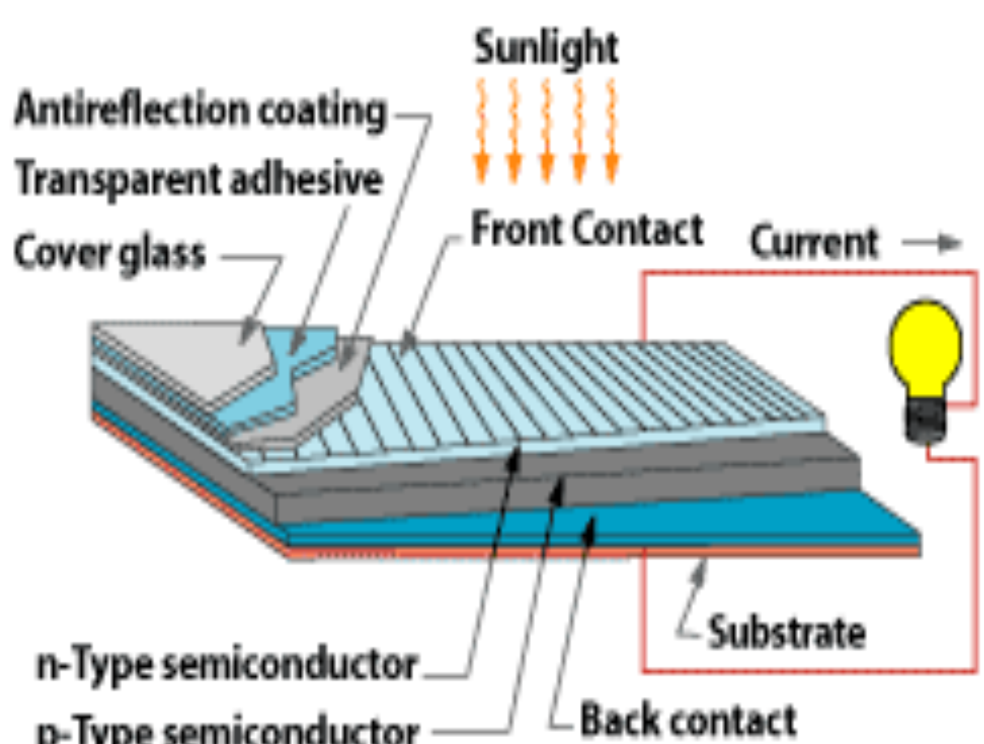
In the p-n junction the n-type wafer treated with phosphorus has extra electrons which flow into the holes in the p-type layer that has been treated with boron.

Connected by an external circuit electrons flow from the n-side to create electricity and end up in the p-side.



Photoelectric Effect

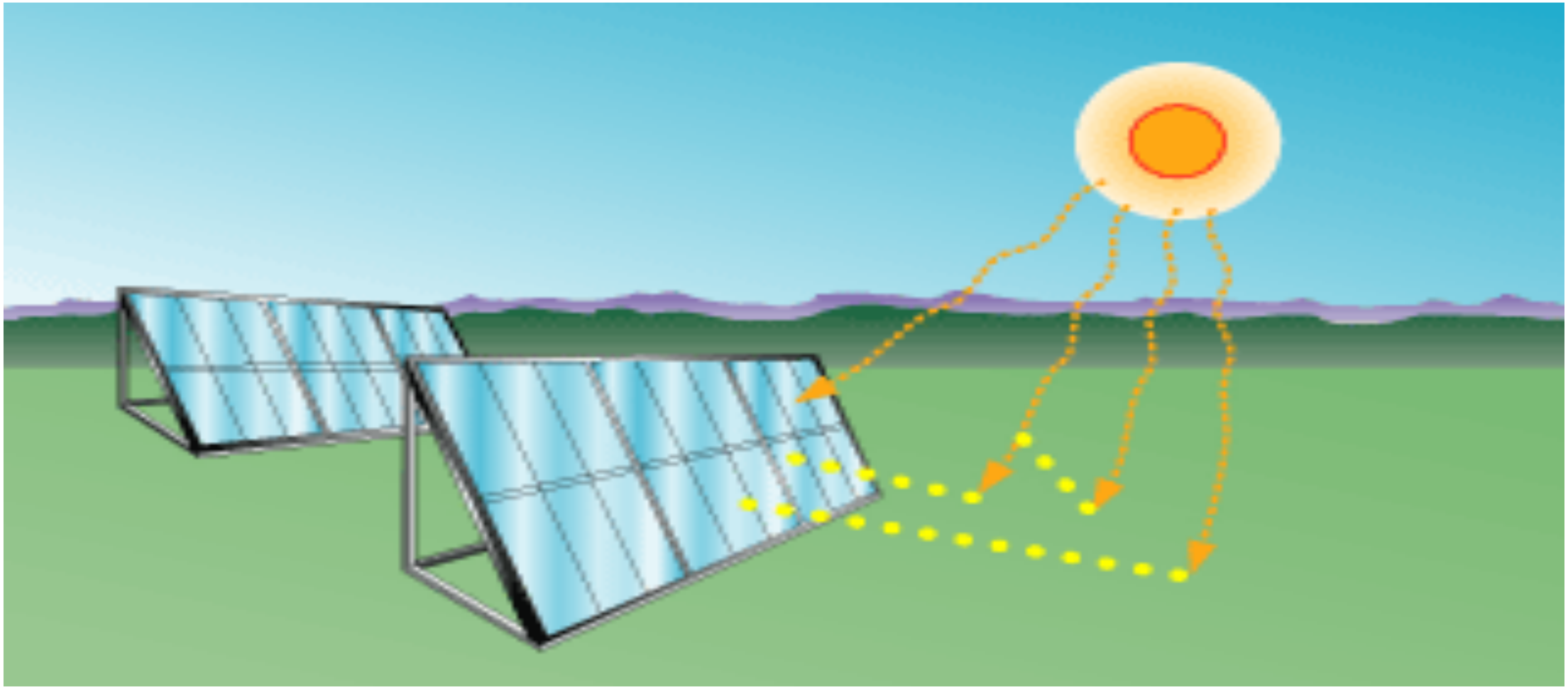




A picture of an typical silicon PV cell

Now a short video:

http://www.eere.energy.gov/solar/multimedia.html



- Sunlight is the catalyst of the reaction.
- The output current of this reaction is DC (direct) and the amount of energy produced is directly proportional to the amount of sunlight put in.
- Cells only have an average efficiency of 30%

Pros and Cons of Solar Electricity

Expensive to produce because of the high cost of semi- conducting materials, which could be avoided by reducing manufacturing costs. The PV Manufacturing Research and Development Project focuses on increasing manufacturing capacity so that the cost of manufacturing will decrease. They aim to achieve break even costs.

However, solar energy contributes positively to the nation's energy security because it is produced domestically, reducing reliance on energy imports.

The industry is still relatively new and extremely hi tech allowing for the creation of more jobs in the American market.

The government has many incentives program which vary from state to state, but they exist to encourage investment in forms of alternative energy.

Does not require the transportation of hazardous materials across country.

Sunlight is a <u>free</u> abundant source!

Pros and Cons cont.

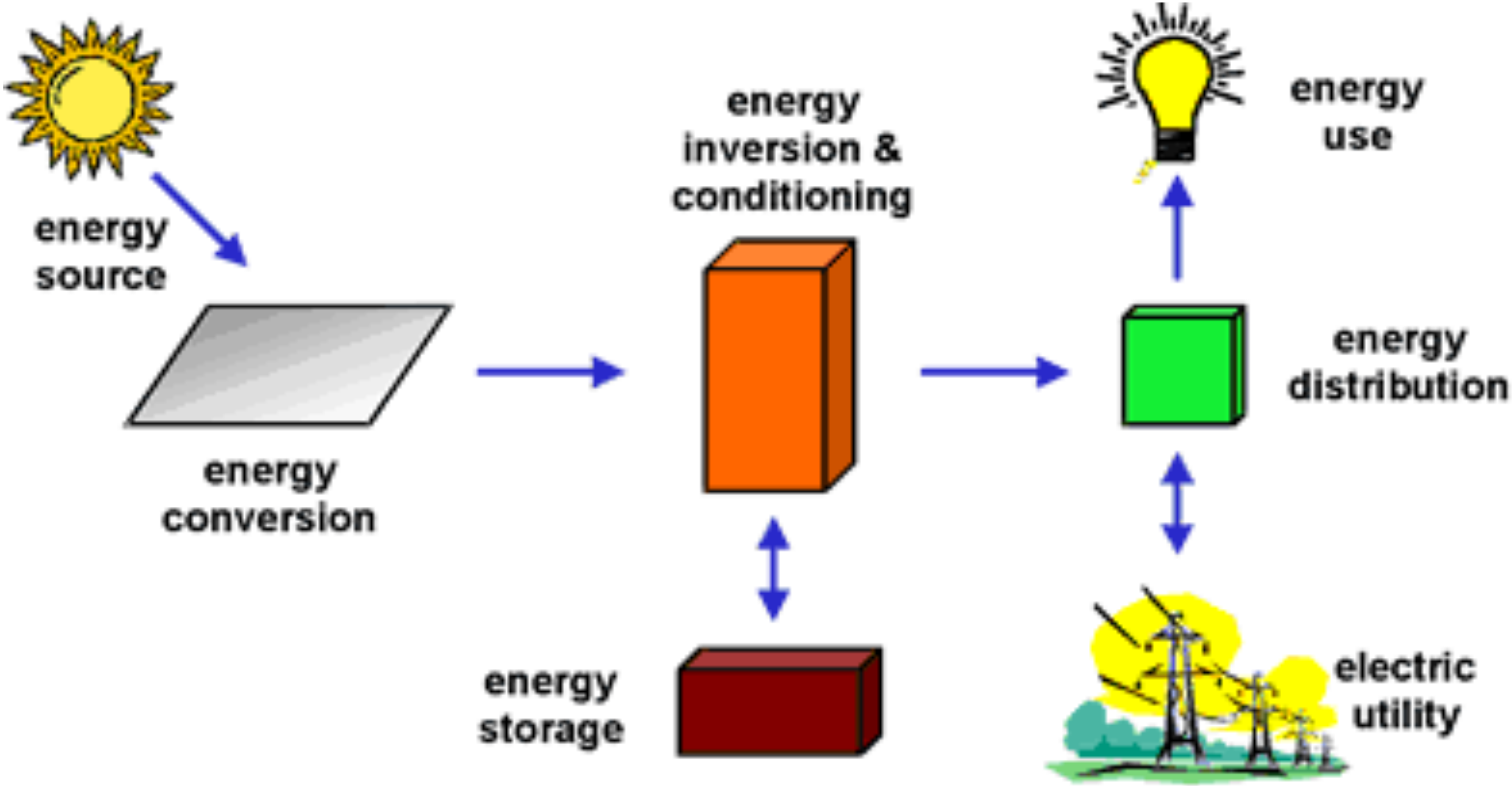
PV can be designed for a variety of applications
No noise or air pollution
Require minimal maintenance and have long service life times.
Power can be either centralized in individual homes or distributed by electrical companies.

How PV Systems Work

Stand-Alone Photovoltaic Systems
Grid-connected

BREAKDOWN

PV systems are like any other electrical power generating systems, except the equipment used to generate the power is different.
Specific components required, and may include major components such as a DC-AC power inverter, batteries, auxiliary energy sources, sometimes the specified electrical load (appliances), wiring, surge protection and other hardware.
Batteries are often used in PV systems for the purpose of storing energy produced by the PV array during the day, and to supply it to electrical loads as needed (during the night and periods of cloudy weather). Also to keep the system at full operational power

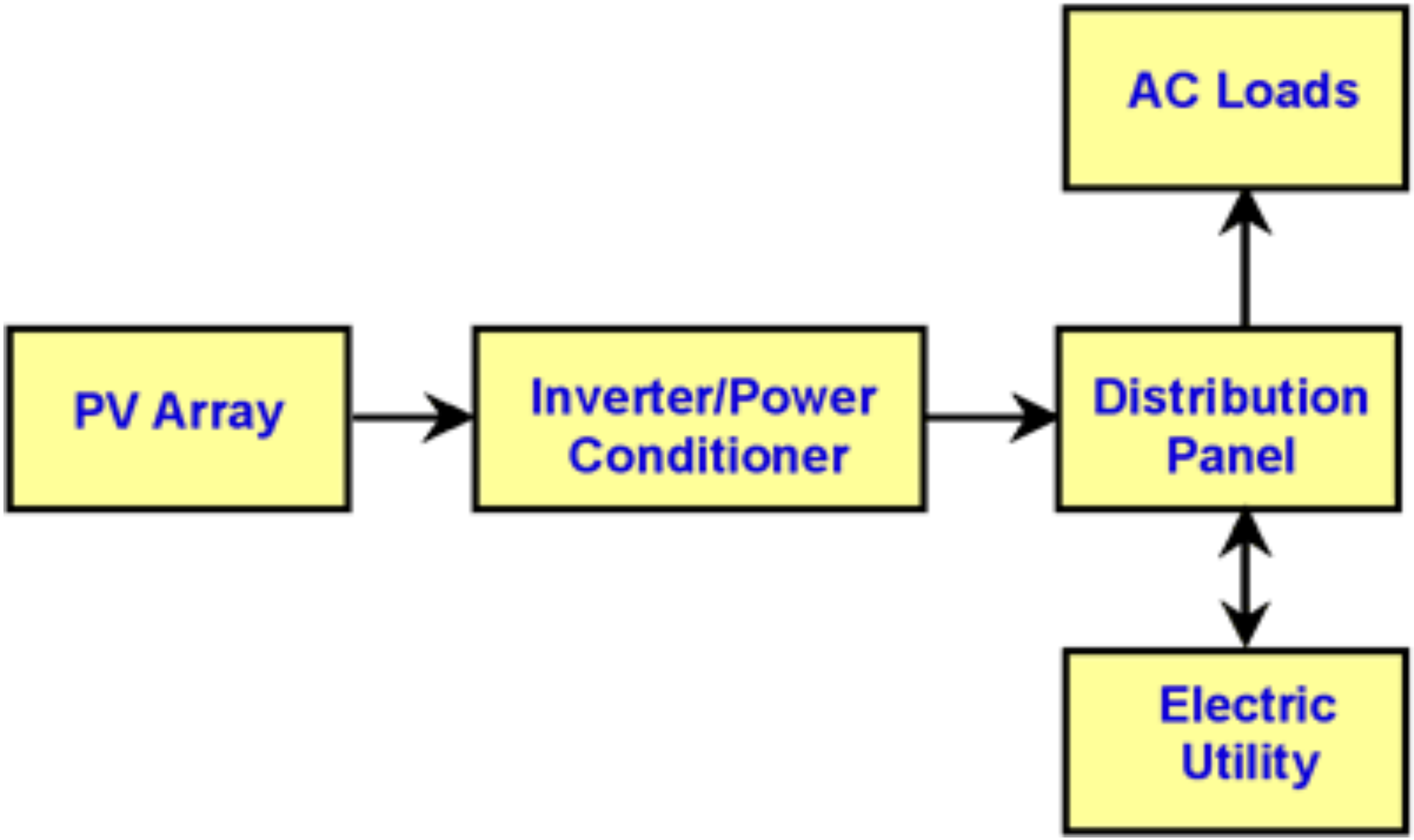

energy
source
energy
conversion
energy
inversion &
conditioning
energy
storage
energy
use
energy
distribution
electric
utility

Grid-connected or Utility-Connected

Grid-connected or utility-interactive PV systems are designed to operate in parallel with and interconnected with the electric utility grid.

These system contain an inverter, called a power conditioning unit (PCU) which converts the DC power produced by the PV array into AC power consistent with the voltage and power quality requirements of the utility grid.

A bi-directional interface allows the AC power produced by the PV system to either supply personal electrical loads, or return power back to the grid when the PV system output is greater than the personal demand.


AC Loads
PV Array
Inverter/Power Conditioner
Distribution Panel
Electric Utility

Stand-Alone PV Systems

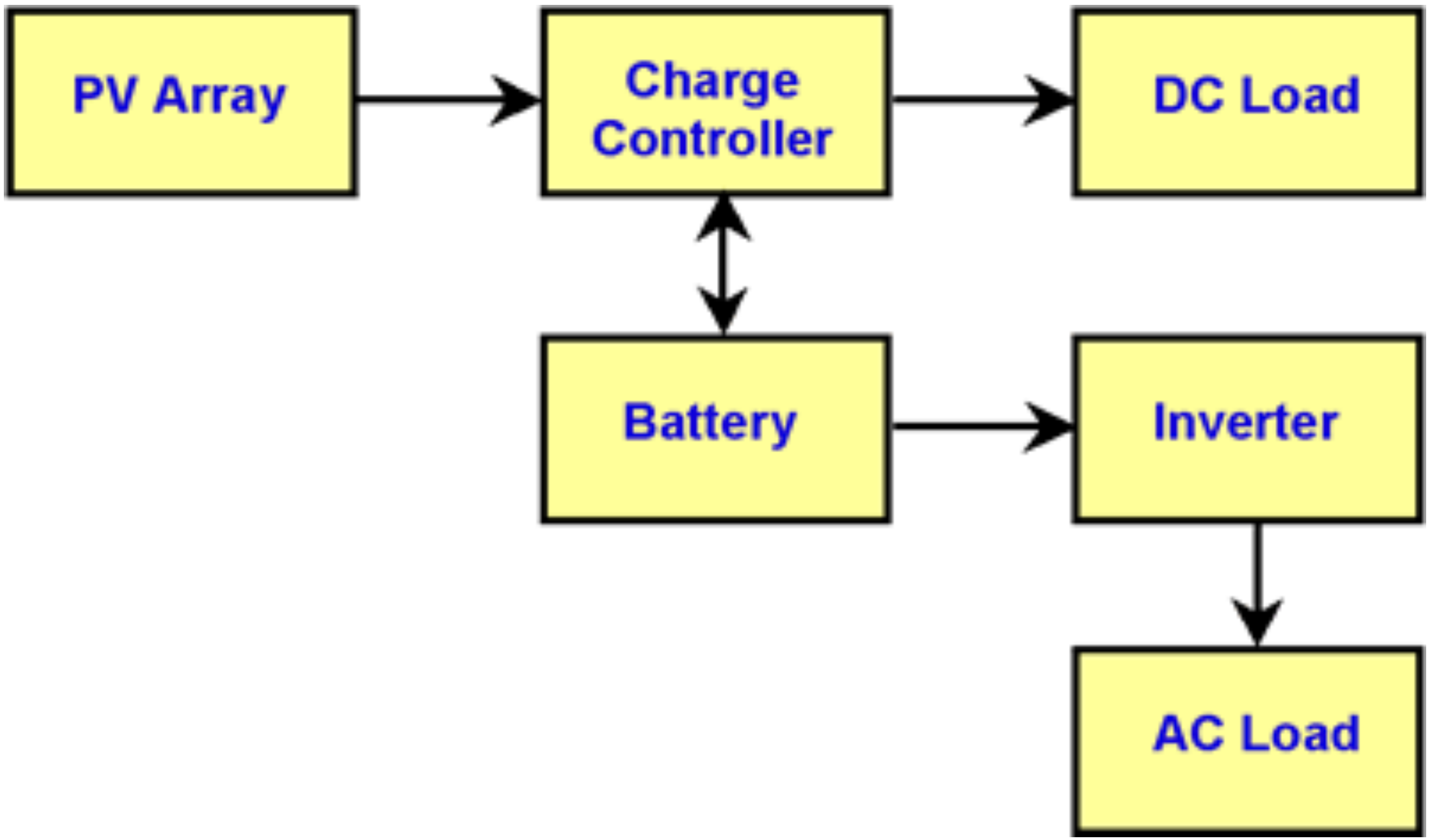
Stand-alone PV systems are designed to operate independent of the electric utility grid

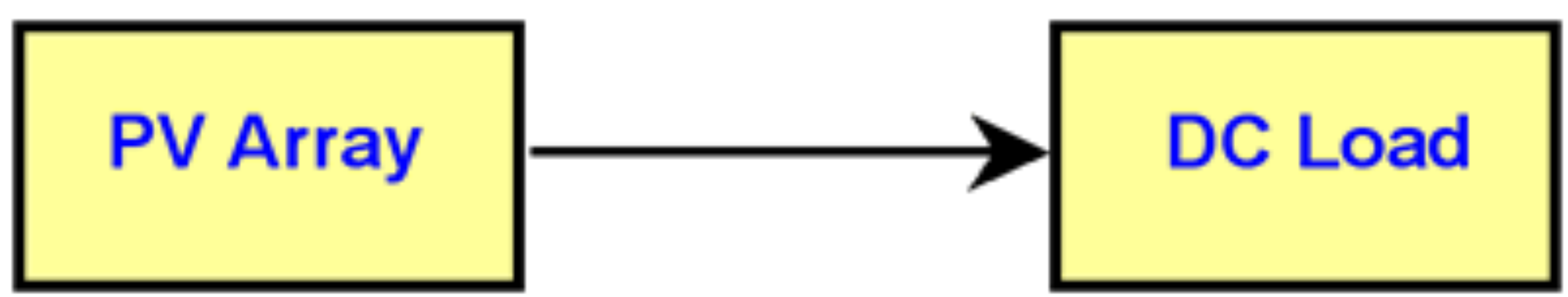
Supply DC and/or AC electrical loads

The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load

Since there are no batteries involved in direct load systems, stand-alone PV systems are suitable for such processes as heating and pumping water, ventilation fans, etc…Although they can only work in the day.

Stand-Alone systems may also power AC loads such as batteries. Like the AC adapter which powers your laptop.


PV Array
Charge Controller
DC Load
Battery
Inverter
AC Load


PV Array
DC Load

The Grid and All of It's Glory

Net metering allows a home or business owner to sell electricity generated by PV modules to the utility grid. This benefits both the consumer, and in some cases the utility.

The electric meter will run backward when there is an excess of electricity needed to power a building.

A safety measure cuts off the PV system from the grid in case of an emergency.

At the End of the Month, the Consumer will reek the benefits.

Benefits to The Economy, Environment, You, and Me

Americans yearn for reliable, clean, abundant, affordable energy, and safe energy.
Can prevent catastrophes such as "the blackout" on Aug 14, 2003.
Businesses are in turn investing in solar to avoid these instances
Solar electric power systems can be easily sited at the point of use with no environmental impact.
The current U.S. solar industry employs some 20,000 men and women in high-value, high-tech jobs, representing about 300 companies, universities, and utilities

- ✓ Solar thermal collector shipments surged 34% in 2001 to 11.2 million square feet.
- ✓ The total revenue for all shipments of solar thermal collectors was $32.4 million in 2001, up 18% from 2000.
- ✓ Nearly 73% of all solar collectors are for pool-heating applications.
  Solar water heaters comprise the remaining 27% of U.S. solar thermal applications.
- ✓ In 2001, the overall value of PV cell and PV module shipments rose by 13% to $305 million.
- ✓ In terms of price per peak megawatt, prices have remained stable at $2.46 for PV cells and $3.42 for PV modules.

Photovoltaic (PV) systems—have very little impact on the environment, making them one of the cleanest power-generating technologies available .

Solar power produces no air pollution.

Solar power produces no greenhouse gases, so it does not contribute to global warming.

Production

Combinations of haz and non-haz materials + High temperatures = high environmental cost

Cost decline as companies depend more on solar for production of cells/modules

Life

Average 20-30 years
Efficiency decrease 1% a year.
Research on manufacturing and output efficiency and recycling ongoing.
Payback or energy break even - 15 years.

After life

Waste generation lag due to life of technology
Heavy metals and toxic gases produced in breakdown.
High temperatures

Example of Progressive policy

EU "End of Life of Vehicles" Policy.

PV Industry has a pro-active approach to energy saving/ environmental benefit increase etc.

Policy can be created like ELV to encourage manufacturers to incorporate breakdown into production.

Things to consider when looking at technologies

Payback or breakeven is important (Energy produced by technology - energy used in production <per unit/ unit of time>)
Less hazardous materials.
More easily taken apart if constructed with several detachable components which could be recycled or smelted.

Solar Energy Organizations

International solar energy society (ISES)

Founded in 1954

A UN accredited non-government organization

Exists in over 50 countries

Promoting international development of solar energy

Holds a biannual solar world congress, the next will be held next year in Orlando Florida

American Solar Energy Society

The American Chapter of the International Energy Society

-Located in Boulder CO- Nation's Largest and Oldest Membership Organization for Renewable Energy

-Sponsors the National Solar Energy Conference: Held July 10-14, Portland OR

-Publishes the Bimonthly Magazine Solar Today

-Organizes the Annual National Solar Tour

-Organizes the Solar Action Network

- **Solar Energy Industries Association (SEIA)**
  - -Provides funding and research for solar advancement technologies
  - -Political group that spends much energy lobbying on behalf of solar power and other renewable resources
  - -14 state SEIA Organizations

Solar Energy Business Association of New England (SEBANE)

- -Centered in Boston, MA; services the entire New England Area

Vermont Based Solar Providers

- **Vermont Solar Businesses that are Members of SEBANE:**
- **Northern Power Systems**
  Northern Power Systems designs, builds and installs high reliability electric power systems. Northern has installed over 800 systems worldwide in the past 25 years, earning a reputation for delivering top-quality energy solutions. Northern provides photovoltaic, wind and wind/diesel hybrid power for commercial, industrial, institutional and government clients.

Vermont Based Solar Providers

- **Solar Works, Inc.**
  Since 1980, Solar Works, Inc., has provided renewable energy services and equipment to government agencies, utilities, private businesses, homeowners, and not-for-profit organizations in the United States and overseas. As a full-service renewable energy firm, Solar Works maintains sales offices in California, Connecticut, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont. Our experience includes: program development, project management, and the design and installation of Photovoltaic (Solar Electric or PV) Systems, Solar Thermal Systems (both active and passive), High-efficiency Lighting and Heating systems, and small-scale Wind Turbines.

Vermont Based Solar Companies

- **Sunnyside Solar, Inc.**
  Sunnyside Solar, Inc. is a full service photovoltaic company specializing in line-tie and stand alone photovoltaic systems. Design, & engineering, equipment sales, full service & installation capabilities. Educational programs seminars and workshops. Sunnyside Solar, Inc. The gentle electric company. We bring good things from light!

  Sunrise Solar Service
  Sunrise Solar Service installs, sells, and services domestic hot water systems, pool heating, water pumping, lighting systems, and system components and supplies.

Sources

http://www.eere.energy.gov/solar/photovoltaics.html

http://www.fsec.ucf.edu/pvt/pvbasics/index.htm45

- http://www.brookes.ac.uk/eie/elv.htm
- http://www.environmentaldefense.org/documents/894_GC_takeback.htm

Solar cells

Solar cells (or photocells) turn light energy from the Sun directly into direct current electricity.

Manufacturing solar cells is very expensive and requires the use of highly toxic materials. However, once the solar cell is built it produces no pollution and requires little maintenance.

This makes solar cells ideal for use in remote locations where maintenance is difficult and other sources of electricity would be expensive.

Efficiency of a solar cell

Solar cells suffer from a low efficiency. This is because only light with enough energy causes an electron to be released which is only about 25% of all sunlight.

The amount of electricity a solar panel can produce depends on two factors: its surface area and the light intensity.

Producing enough electricity to power a town would require a very large area of solar panels but covering the roof of a house can meet the annual electricity needs of the household.

Problems with solar cells

One obvious problem with solar cells is that they do not produce electricity at night.

If more electricity is produced during the day than is used, the excess can be used to charge a battery which can then provide power during the night.

Scientists are working to develop improved solar cells which require less polluting chemicals in their manufacture, cost less to produce and are more efficient than the current technology.

Effective use of solar cells

Solar cells can be used very effectively in the right situation.

The robust nature of solar panels can be exploited in remote areas where maintenance is difficult.

The Dangling Rope Marina on Lake Powell in Utah, USA, is only accessible by water. It previously depended on more than 246,000 litres of diesel to fuel its generators.

A photovoltaic energy system has now been installed. It will reduce the cost of providing electricity and is clean, quiet and dependable.

Effective use of solar cells

Solar cells are very useful for remote locations where supplying mains electricity would be expensive.

This solar-powered street light is in a remote part of mid-Wales with no mains electricity supply close by.

The use of solar power in this way removes the need to lay electricity cables to the light, which is another benefit to the environment.

Effective use of solar cells

Solar cells are very useful where the light intensity is highest.

These solar panels are in a remote part of Morocco where they are used by a local utility company.

Solar cells are also useful where low amounts of power are needed.

Calculators only require a small amount of electricity, so most calculators now use solar cells in place of batteries .

Solar power stations

Solar power stations use the energy from the sun to heat water to make steam, which is then used to drive a turbine.

Some solar power stations use a series of mirrors called heliostats to reflect light onto a boiler.

This solar power station in California consists of about 1800 heliostats, with an electrical output of 10 megawatts.

Effective use of solar power stations

Solar power stations are most effectively located in areas with high light intensity.

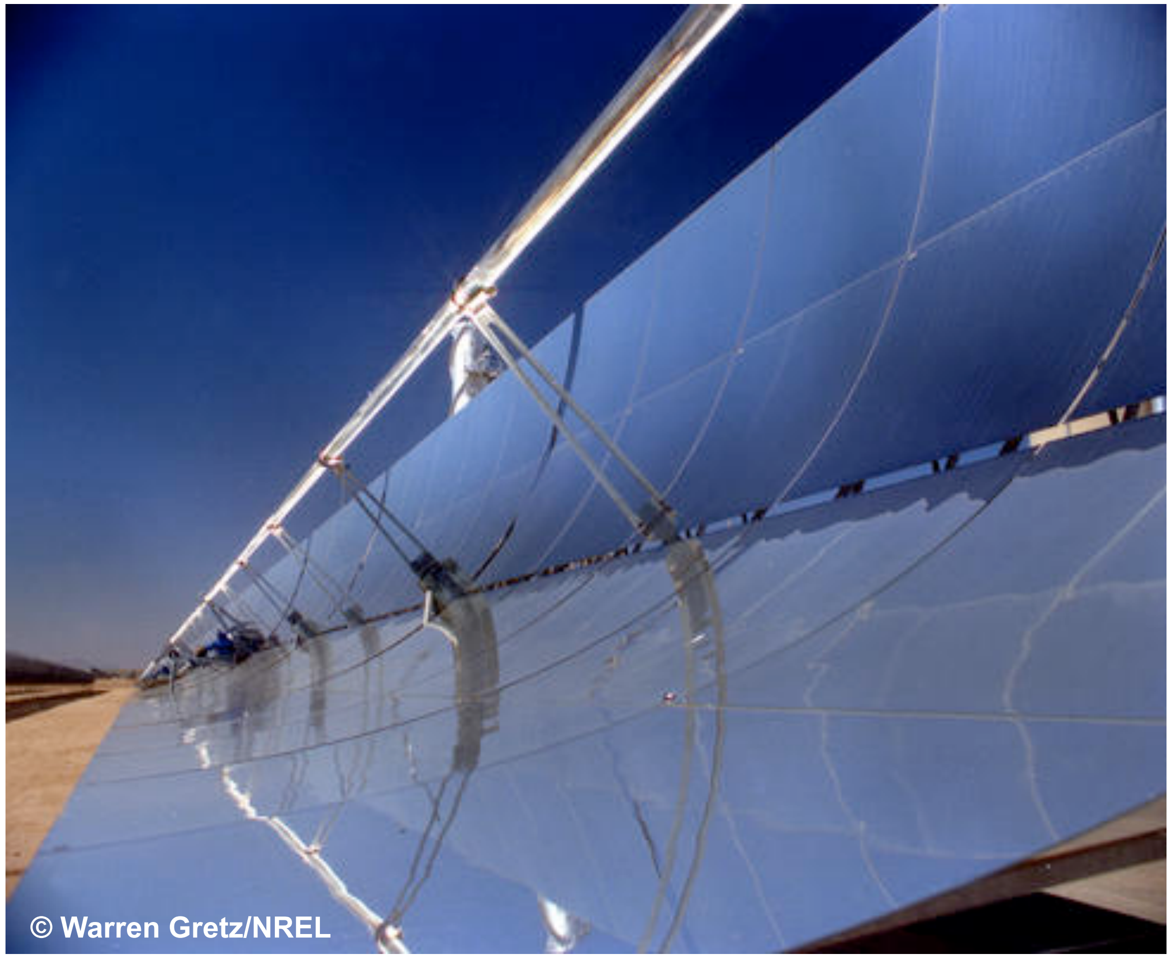
This test design is located in Arizona where the sunlight is intense and the air temperature is high.

The mirrors must track the Sun as it moves across the sky to be efficient as possible,

Would this sort of power station be effective in the UK?

More solar power stations

Some solar power stations use curved mirrors which focus the Sun's energy onto pipes containing water. This heats the water forming steam.



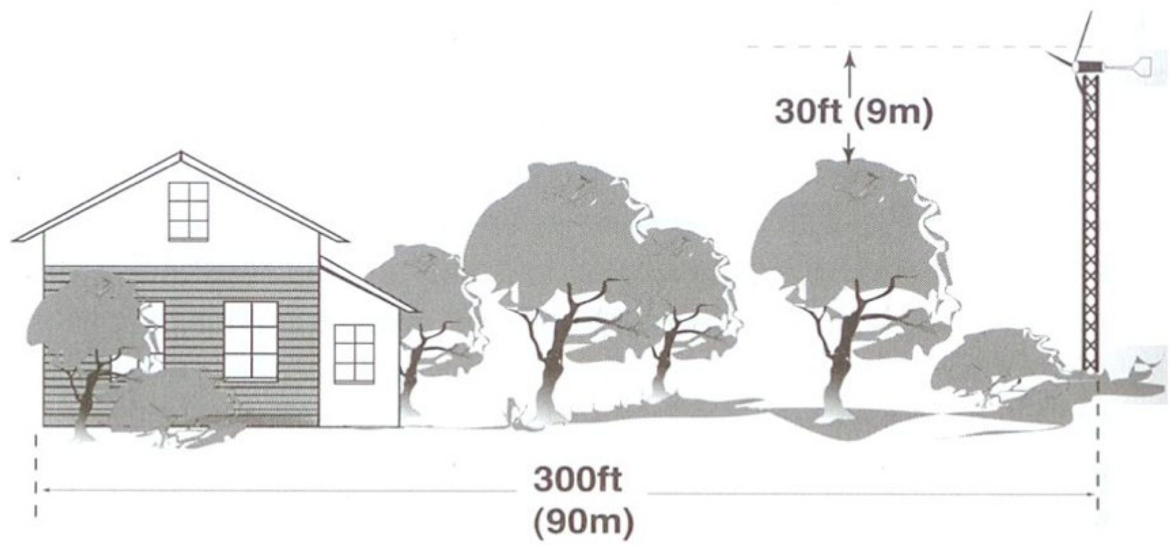
wind

Power

풍력발전

장점
풍력자원이 풍부하고 재생 가능한 에너지원으로서 많은 이점
공해물질 배출이 없어 청정성, 환경친화적 특성
풍력단지의 관광자원화가 가능
발전단가가 0.05$/㎾로 핵발전 단가와 같은 수준

단점
풍력의 에너지 밀도가 낮아 특별한 지점에만 설치 가능
바람이 있을 때만 발전을 할 수 있어 지속적 발전이 곤란하여 저장장치 필요(기존발전설비와 태양광 발전등과 병행 필요)
소음문제(대형화로 소음문제 해결)



소형발전기 설치 방법

Wind energy

$$E = \frac{1}{2}mv^2 = \frac{1}{2}(Avt\rho)v^2 = \frac{1}{2}At\rho v^3,$$

Wind energy is the kinetic energy of air in motion, also called wind. Total wind energy flowing through an imaginary area *A* during the time *t* is:

- where ρ is the air density;
- v is the wind speed;
- *Avt* is the volume of air passing through *A* (which is considered perpendicular to the direction of the wind);
- $Avt\rho$ is therefore the mass *m* passing per unit time.
  - Note that ½ ρv^2 is the kinetic energy of the moving air per unit volume.

Power is energy per unit time, so the wind power incident on *A* (e.g. equal to the rotor area of a wind turbine) is:

Wind power in an open air stream is thus *proportional* to the *third power* of the wind speed; the available power increases eightfold when the wind speed doubles. Wind turbines for grid electricity therefore need to be especially efficient at greater wind speeds.

Wind energy

$$P = \frac{E}{t} = \frac{1}{2} A \rho v^3.$$

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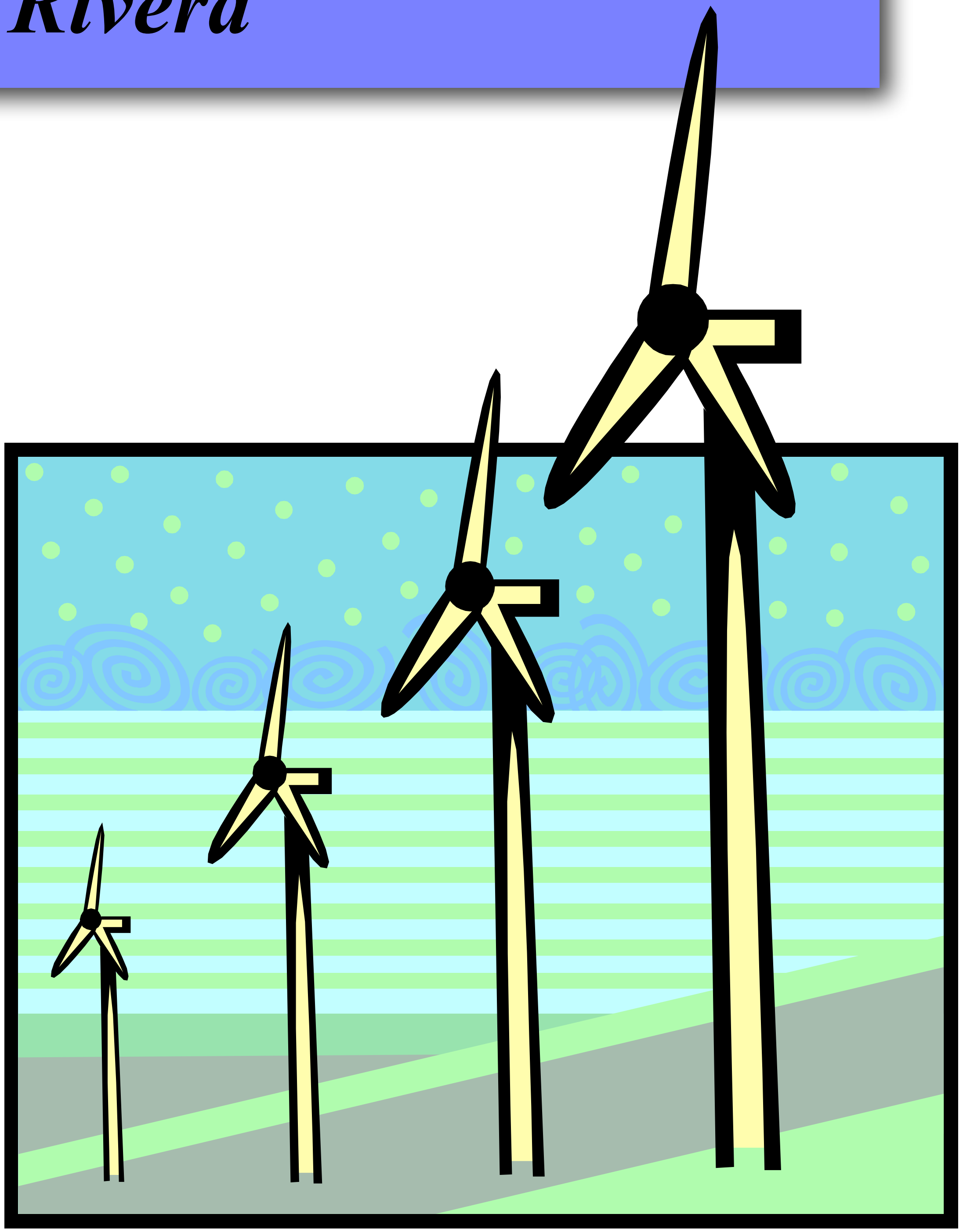
WIND POWER

By: *Roger Rivera*

What is it?
How does it work?
Efficiency
U.S. Stats and Examples



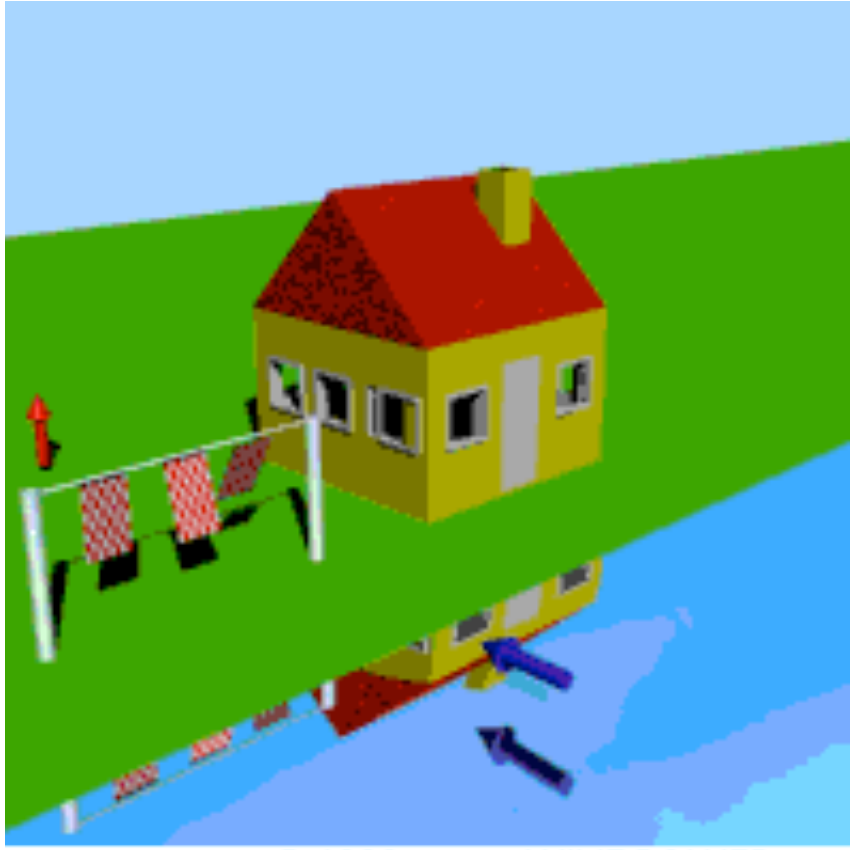
WIND POWER - What is it?

All renewable energy (except tidal and geothermal power), ultimately comes from the sun

The earth receives 1.74 x 10^{17} watts of power (per hour) from the sun

About one or 2 percent of this energy is converted to wind energy (which is about 50-100 times more than the energy converted to biomass by all plants on earth

Differential heating of the earth's surface
and atmosphere induces vertical and horizontal air currents that are affected by the earth's rotation and contours of the land → WIND.
~ e.g.: Land Sea Breeze Cycle



Winds are influenced by the ground surface at altitudes up to 100 meters.

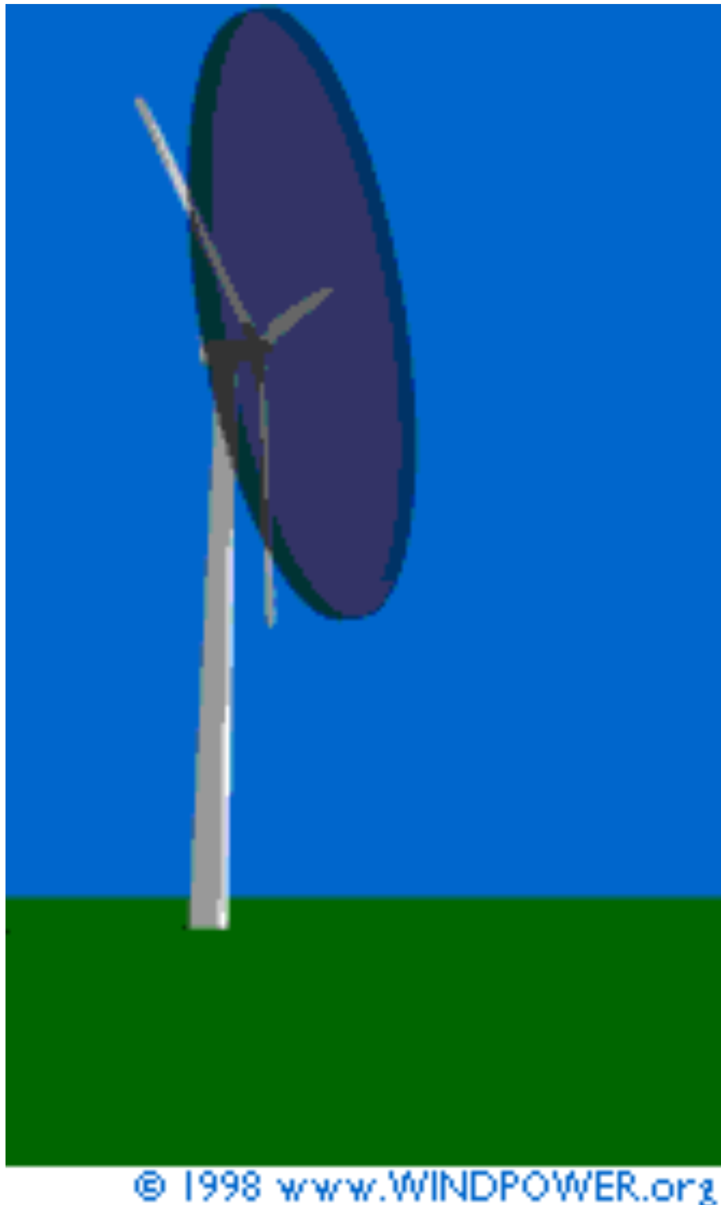
Wind is slowed by the surface roughness and obstacles.

When dealing with wind energy, we are concerned with surface winds.

A wind turbine obtains its power input by converting the force of the wind into a torque (turning force) acting on the rotor blades.

The amount of energy which the wind transfers to the rotor depends on the density of the air, the rotor area, and the wind speed.

The kinetic energy of a moving body is proportional to its mass (or weight). The kinetic energy in the wind thus depends on the density of the air, i.e. its mass per unit of volume. In other words, the "heavier" the air, the more energy is received by the turbine.



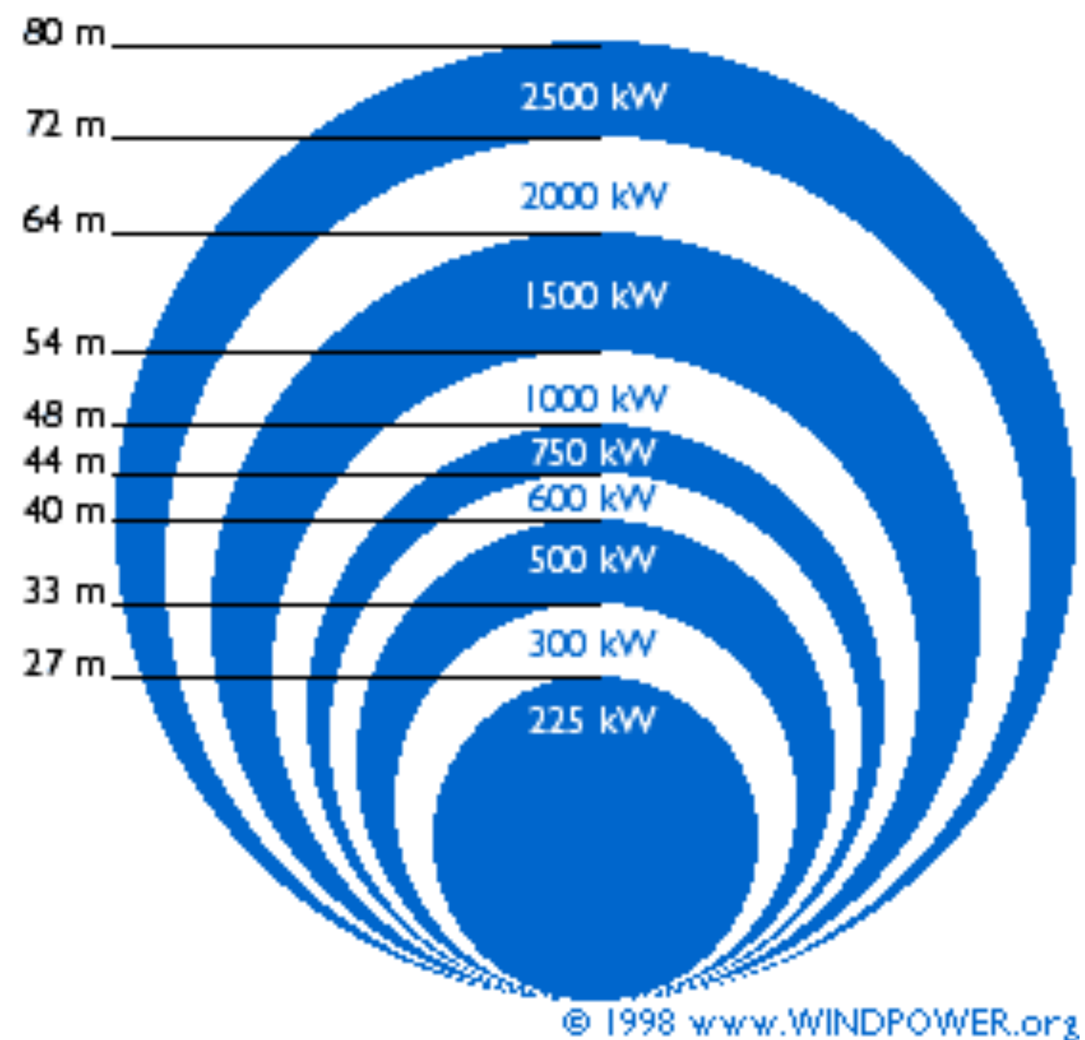
at 15° Celsius air weighs about 1.225 kg per cubic meter, but the density decreases slightly with increasing humidity.

A typical 600 kW wind turbine has a rotor diameter of 43-44 meters, i.e. a rotor area of some 1,500 square meters.

The rotor area determines how much energy a wind turbine is able to harvest from the wind.

Since the rotor area increases with the square of the rotor diameter, a turbine which is twice as large will receive $2^2 = 2 \times 2 =$ four times as much energy.

To be considered a good location for wind energy, an area needs to have average annual wind speeds of at least 12 miles per hour.



WINDMILL DESIGN

A Windmill captures wind energy and then uses a generator to convert it to electrical energy.

The design of a windmill is an integral part of how efficient it will be.

When designing a windmill, one must decide on the size of the turbine, and the size of the generator.

LARGE TURBINES:

- Able to deliver electricity at lower cost than smaller turbines, because foundation costs, planning costs, etc. are independent of size.
- Well-suited for offshore wind plants.
- In areas where it is difficult to find sites, one large turbine on a tall tower uses the wind extremely efficiently.

Wind Turbines

SMALL TURBINES:

Local electrical grids may not be able to handle the large electrical output from a large turbine, so smaller turbines may be more suitable.

High costs for foundations for large turbines may not be economical in some areas.

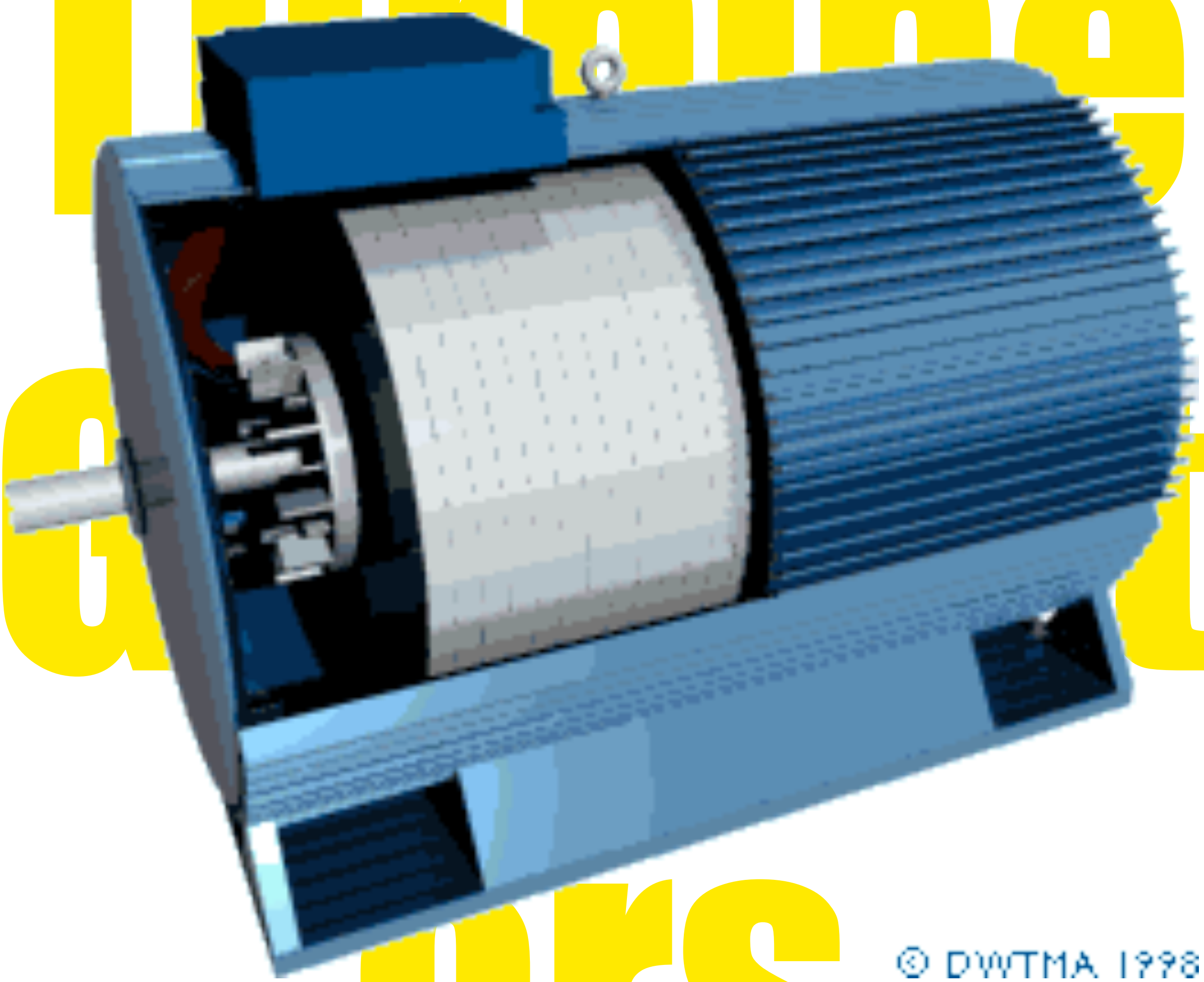
Landscape considerations

Wind Turbines: Number of Blades

Most common design is the three-bladed turbine. The most important reason is the **stability** of the turbine. A rotor with an odd number of rotor blades (and at least three blades) can be considered to be similar to a disc when calculating the dynamic properties of the machine.

A rotor with an even number of blades will give stability problems for a machine with a stiff structure. The reason is that at the very moment when the uppermost blade bends backwards, because it gets the maximum power from the wind, the lowermost blade passes into the wind shade in front of the tower.

Wind Turbine Generators



Wind power generators convert wind energy (mechanical energy) to electrical energy.

The generator is attached at one end to the wind turbine, which provides the mechanical energy.

At the other end, the generator is connected to the electrical grid.

The generator needs to have a cooling system to make sure there is no overheating.

SMALL GENERATORS:

Require less force to turn than a larger ones, but give much lower power output.

Less efficient

i.e.. If you fit a large wind turbine rotor with a small generator it will be producing electricity during many hours of the year, but it will capture only a small part of the energy content of the wind at high wind speeds.

LARGE GENERATORS:

Very efficient at high wind speeds, but unable to turn at low wind speeds.

i.e.. If the generator has larger coils, and/or a stronger internal magnet, it will require more force (mechanical) to start in motion.

Other Design Considerations

- **A windmill built so that it too severely interrupts the airflow through its cross section will reduce the effective wind velocity at its location and divert much of the airflow around itself, thus not extracting the maximum power from the wind.**

- **At the other extreme, a windmill that intercepts a small fraction of the wind passing through its cross section will reduce the wind's velocity by only a small amount, thus extracting only a small fraction of the power from the wind traversing the windmill disk.**

- **Modern Windmills can attain an efficiency of about 60 % of the theoretical maximum.**

Power of Wind

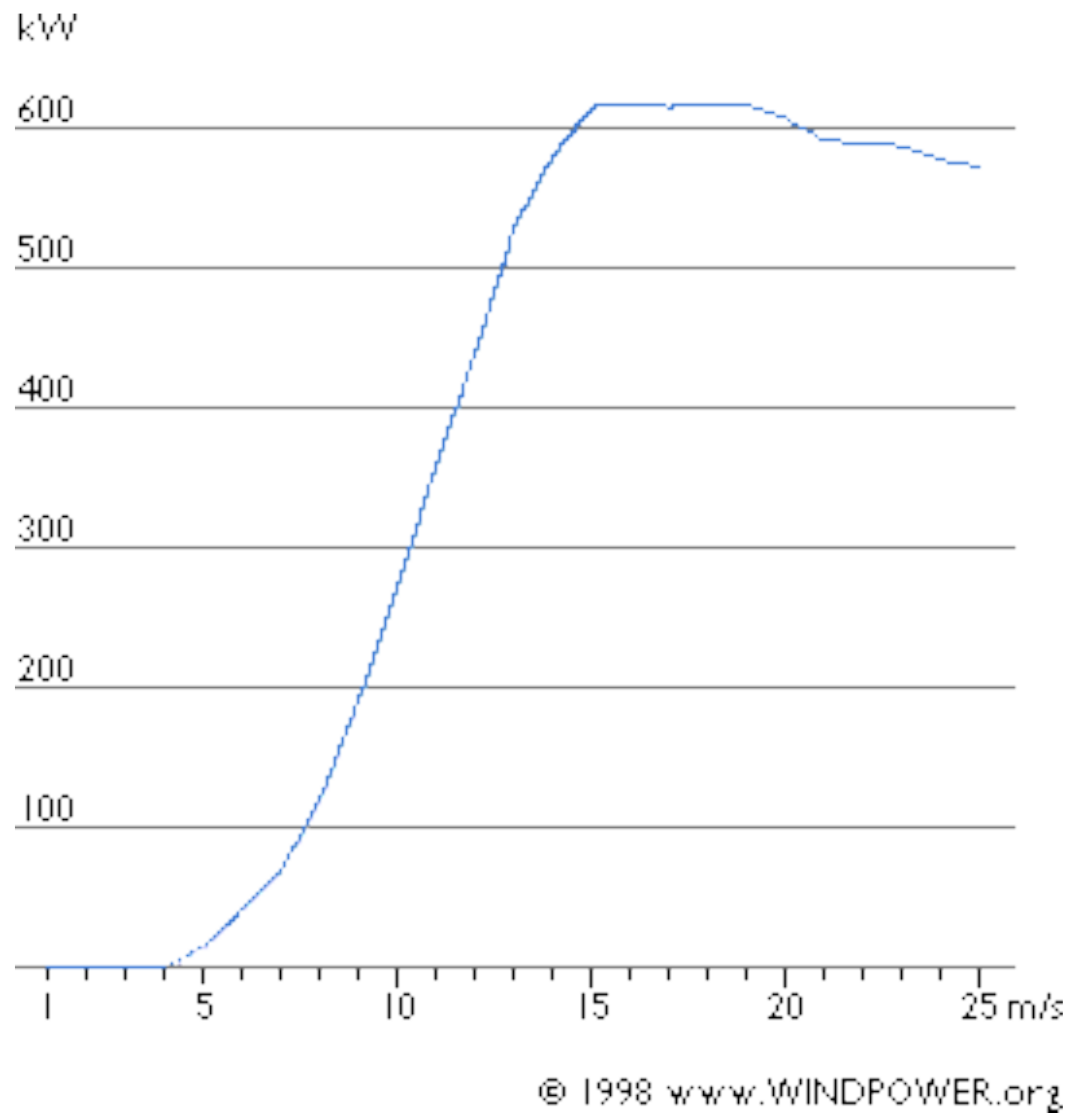
P/m^2 = 6.1 x 10^-4 v^3

*The power in wind is proportional to the cubic wind speed (v^3).

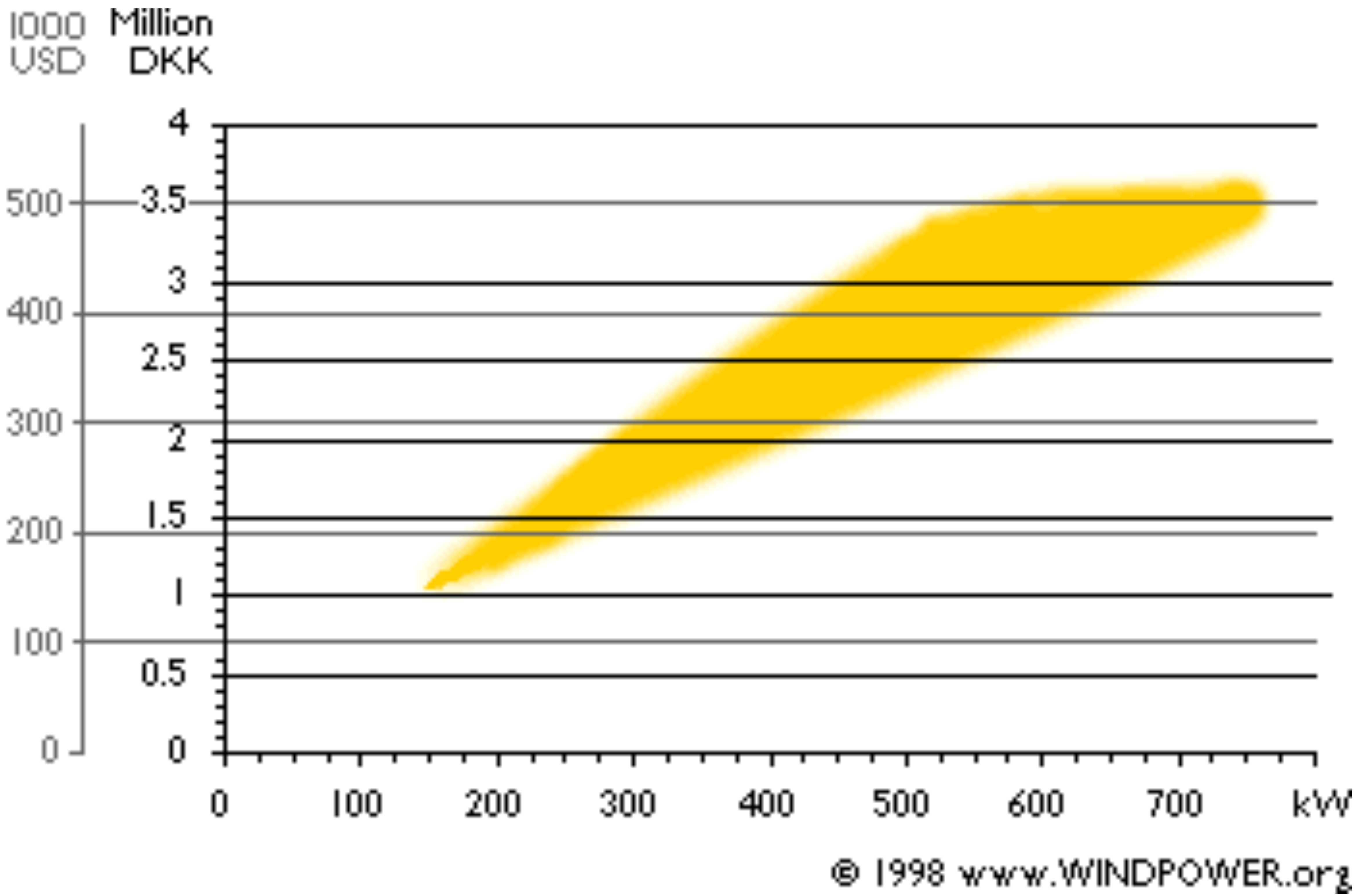
WHY?

~ Kinetic energy of an air mass is proportional to v^2

~ Amount of air mass moving past a given point is proportional to wind velocity (v)

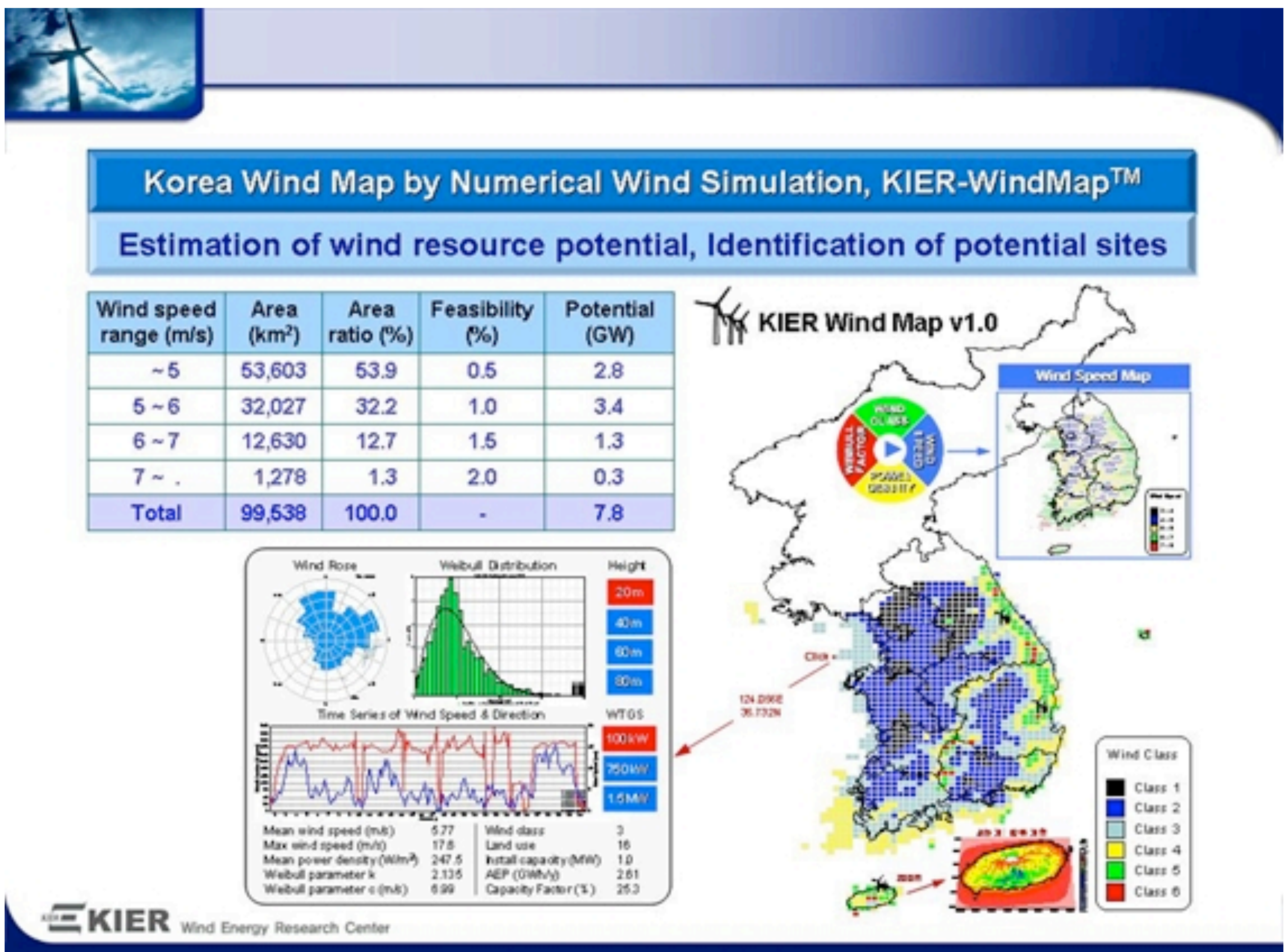


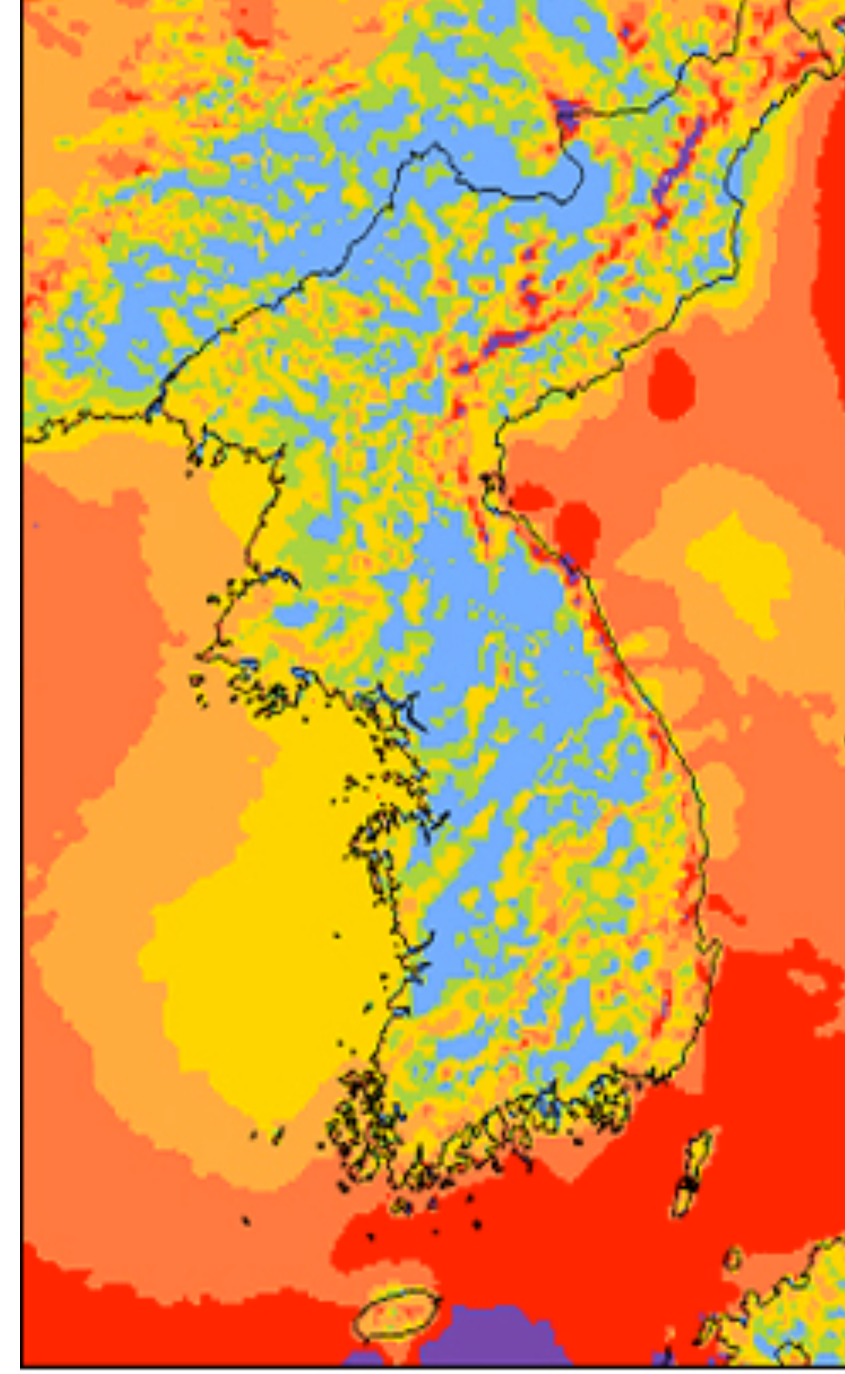
Costs of a Wind Turbine



*** An extra meter of tower will cost roughly 1,500 USD.**

Wind Map





Wind Speed Class	Land	Land (> 500m)	Sea
1	~ 4.0	~ 5.0	~ 5.5
2	~ 4.5	~ 6.0	~ 6.5
3	~ 5.5	~ 7.0	~ 7.5
4	~ 6.5	~ 8.0	~ 8.0
5	~ 7.5	~ 9.0	~ 9.0
6	~ 8.5	~ 10.0	~ 10.0
7	8.5 ~	10.0 ~	10.0 ~

(units : ms^{-1})

Advantages of Wind Power

- The wind blows day and night, which allows windmills to produce electricity throughout the day. (Faster during the day)
- Energy output from a wind turbine will vary as the wind varies, although the most rapid variations will to some extent be compensated for by the inertia of the wind turbine rotor.
- Wind energy is a domestic, renewable source of energy that generates no pollution and has little environmental impact. Up to 95 percent of land used for wind farms can also be used for other profitable activities including ranching, farming and forestry.
- The decreasing cost of wind power and the growing interest in renewable energy sources should ensure that wind power will become a viable energy source in the United States and worldwide.

Wind Power and the Environment

Wind Turbines and the Landscape

- Large turbines don't turn as fast → attract less attention

- City dwellers "dwell" on the attention attracted by windmills

Sound from Wind Turbines

- Increasing tip speed → less sound

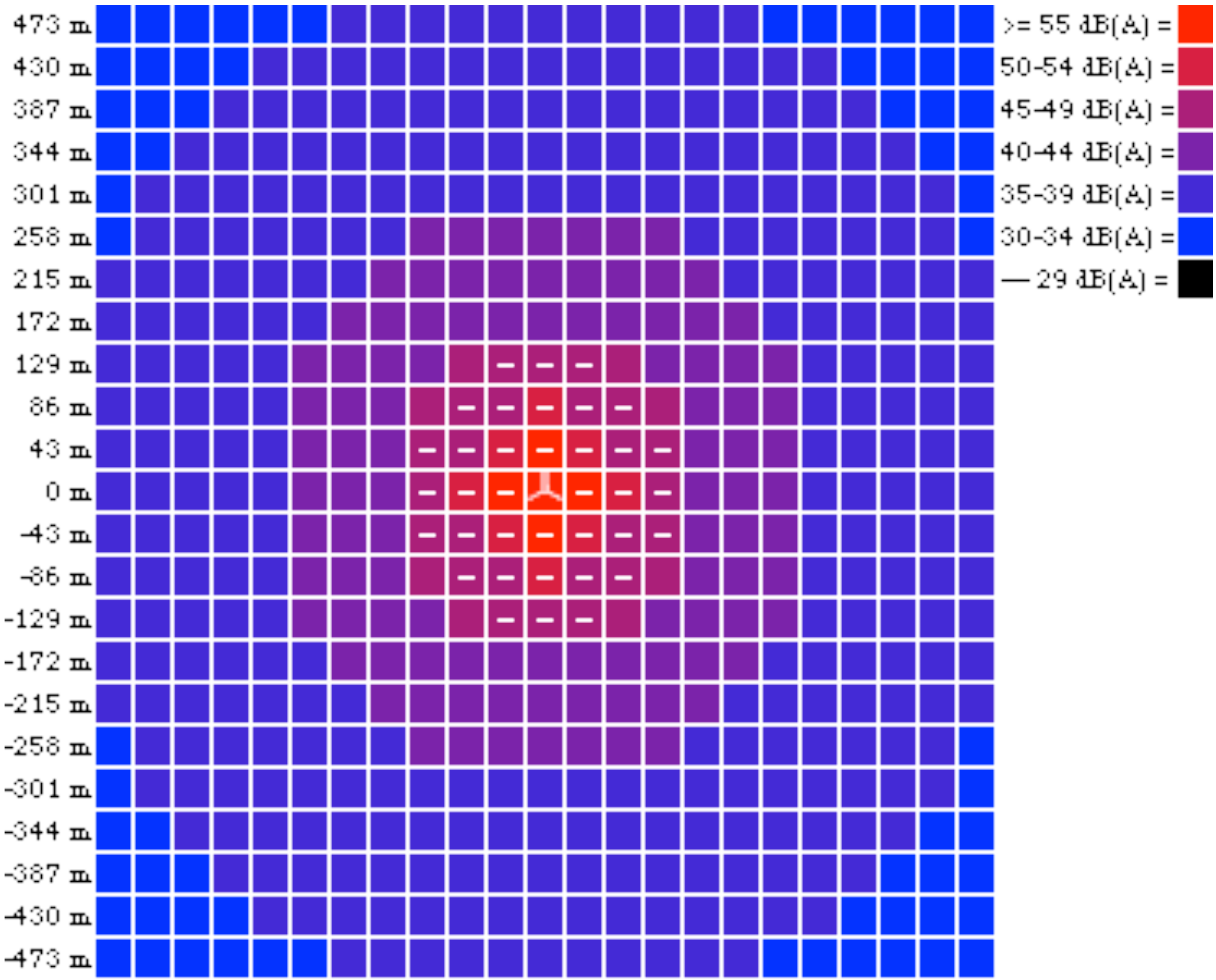
- The closest neighbor is usually 300 m → experiences almost no noise

Birds often collide with high voltage overhead lines, masts, poles, and windows of buildings. They are also killed by cars in traffic. However, birds are seldom bothered by wind turbines.

The only known site with bird collision problems is located in the Altamont Pass in California.

Danish Ministry of the Environment study revealed that power lines are a much greater danger to birds than the wind turbines.

Some birds even nest on cages on Wind Towers.


473 m
430 m
387 m
344 m
301 m
258 m
215 m
172 m
129 m
86 m
43 m
0 m
-43 m
-86 m
-129 m
-172 m
-215 m
-258 m
-301 m
-344 m
-387 m
-430 m
-473 m
>= 55 dB(A) =
50-54 dB(A) =
45-49 dB(A) =
40-44 dB(A) =
35-39 dB(A) =
30-34 dB(A) =
— 29 dB(A) =

Wind power

Wind is the result of the Sun heating the Earth and creating convection currents in the Earth's atmosphere.

Using the wind as a source of energy is not a new idea.

Sailing ships, powered by the wind, have been around for thousands of years.

Windmills which used the wind's power to grind corn were once a common landmark across Britain.

Wind farms

A wind farm is a group of wind turbines in the same location used for production of electricity. A large wind farm may consist of several hundred individual wind turbines, and cover an extended area of hundreds of square miles, but the land between the turbines may be used for agricultural or other purposes. A wind farm may also be located offshore.

Offshore wind power

Offshore wind power refers to the construction of wind farms in large bodies of water to generate electricity. These installations can utilise the more frequent and powerful winds that are available in these locations and have less aesthetic impact on the landscape than land based projects. However, the construction and the maintenance costs are considerably higher. As of 2011, offshore wind farms were at least 3 times more expensive than onshore wind farms of the same nominal power but these costs are expected to fall as the industry matures.

Wind turbines

Wind turbines (or aero-generators) use large blades to capture the kinetic energy of the wind. This kinetic energy is used to directly turn a turbine and produce electricity.

Wind turbines do not produce any polluting waste, however, some people consider them to be an noisy and an eyesore. There is also concern that, if poorly located, they could kill migrating birds.

Wind farms

One problem with wind turbines is that individually they do not generate a lot of electricity. They are usually needed in large numbers to have an impact on electricity production. A group of wind turbines is called a **wind farm**.

Wind farms require large amounts of space in open areas, but the land can also be used for farming at the same time.

Offshore wind farms are located at sea. This wind farm is located 10 kilometres from the south-east coast of Ireland.

Effective use of wind turbines

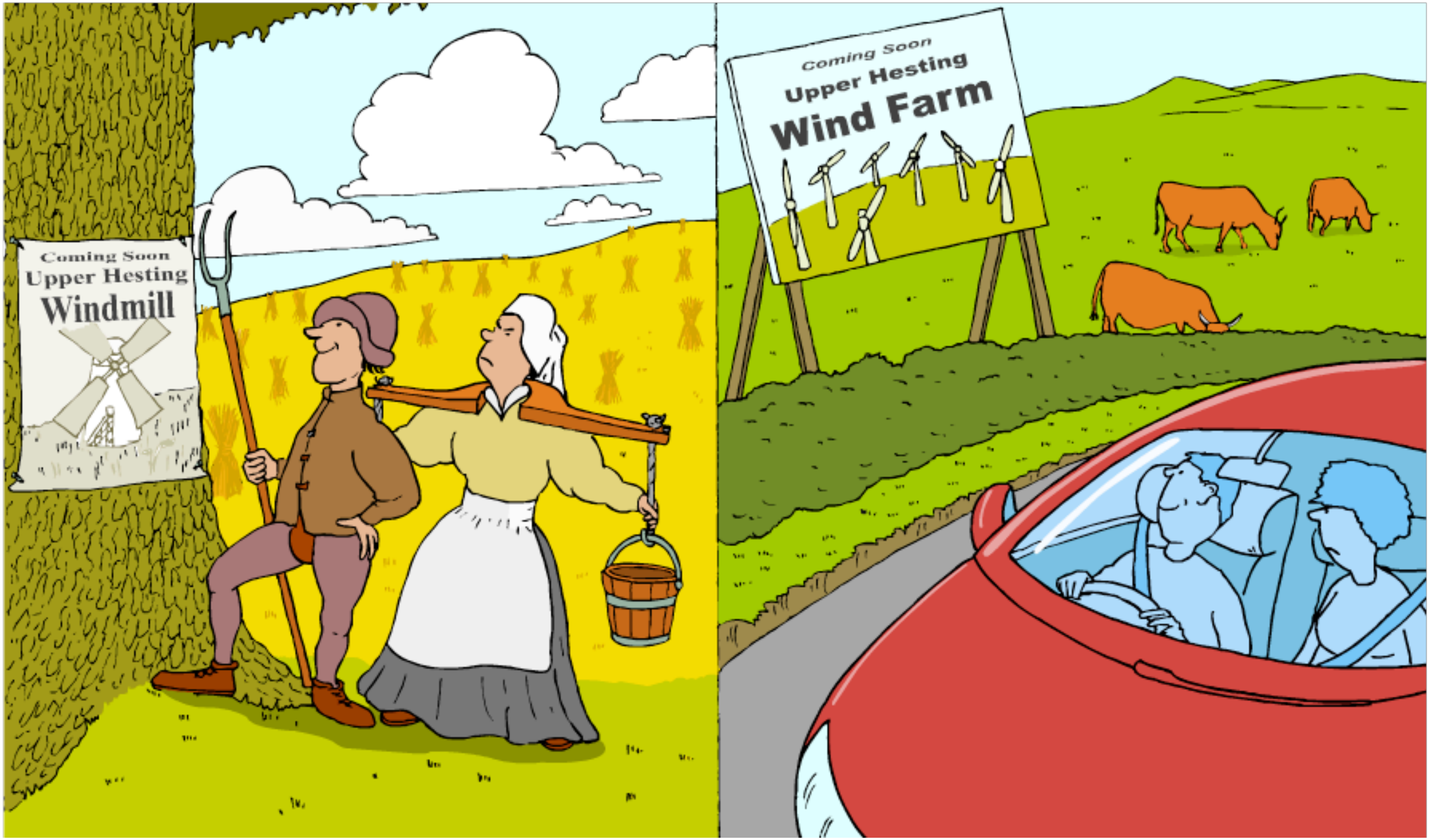
The energy produced by a wind turbine depends on the wind speed. If it is not windy, electricity is not produced, so wind turbines are not a reliable source of electricity.

To be effective, wind turbines need to be located in windy areas. Unfortunately, these are usually upland areas of natural beauty and some people object to the building of wind farms in these areas.

Wind power can be used effectively in remote locations to charge batteries which can then be used to provide a constant supply of electricity.

The then and now guide to wind power

How has the use of wind power changed over time?



Water
Power

Hydropower

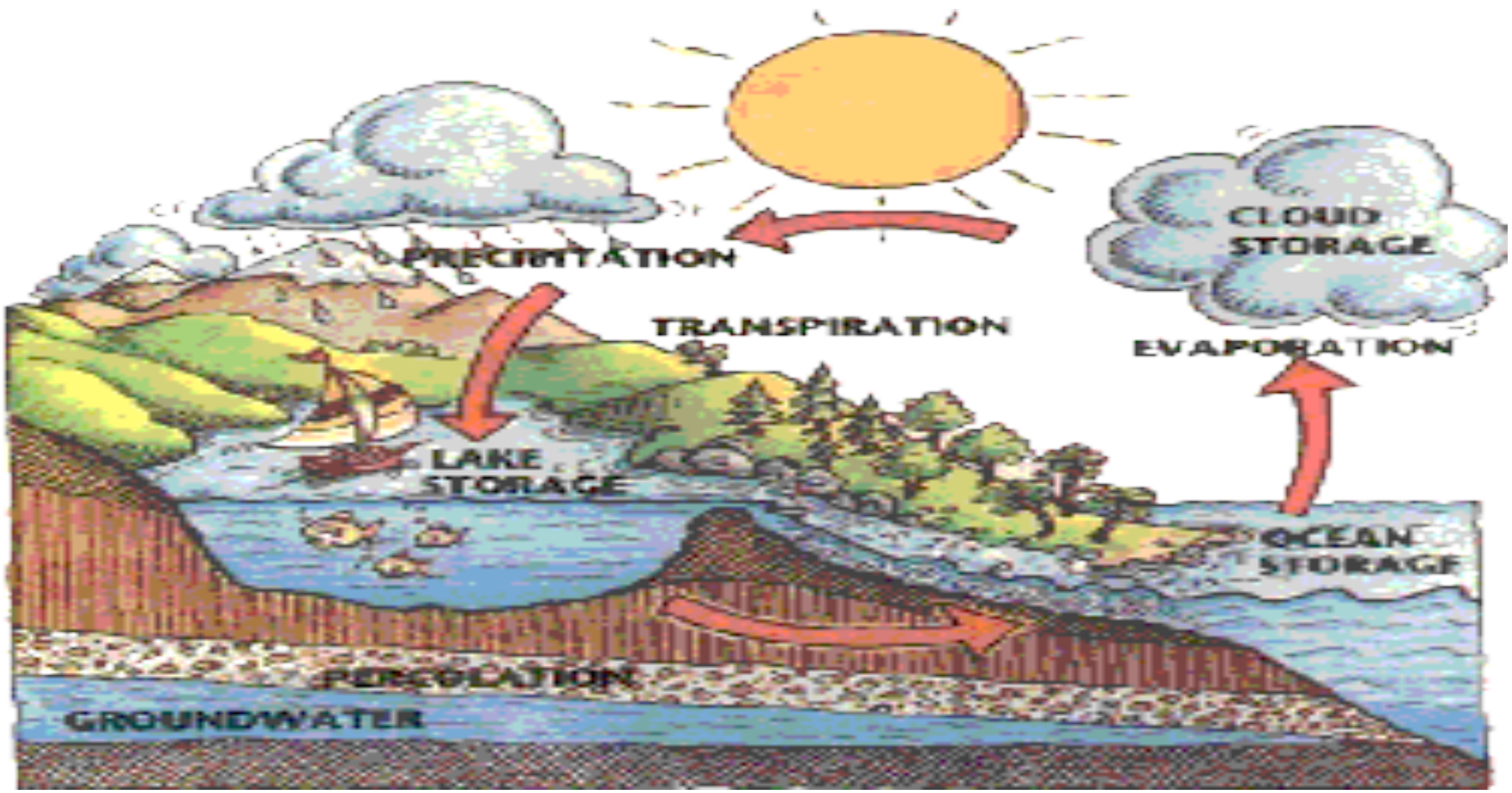
Energy in water can be harnessed and used. Since water is about 800 times denser than air, even a slow flowing stream of water, or moderate sea swell, can yield considerable amounts of energy. There are many forms of water energy:

- Hydroelectric energy is a term usually reserved for large-scale hydroelectric dams. Examples are the Grand Coulee Dam in Washington State and the Akosombo Dam in Ghana.
- Micro hydro systems are hydroelectric power installations that typically produce up to 100 kW of power. They are often used in water rich areas as a remote-area power supply (RAPS).
- Run-of-the-river hydroelectricity systems derive kinetic energy from rivers and oceans without the creation of a large reservoir.

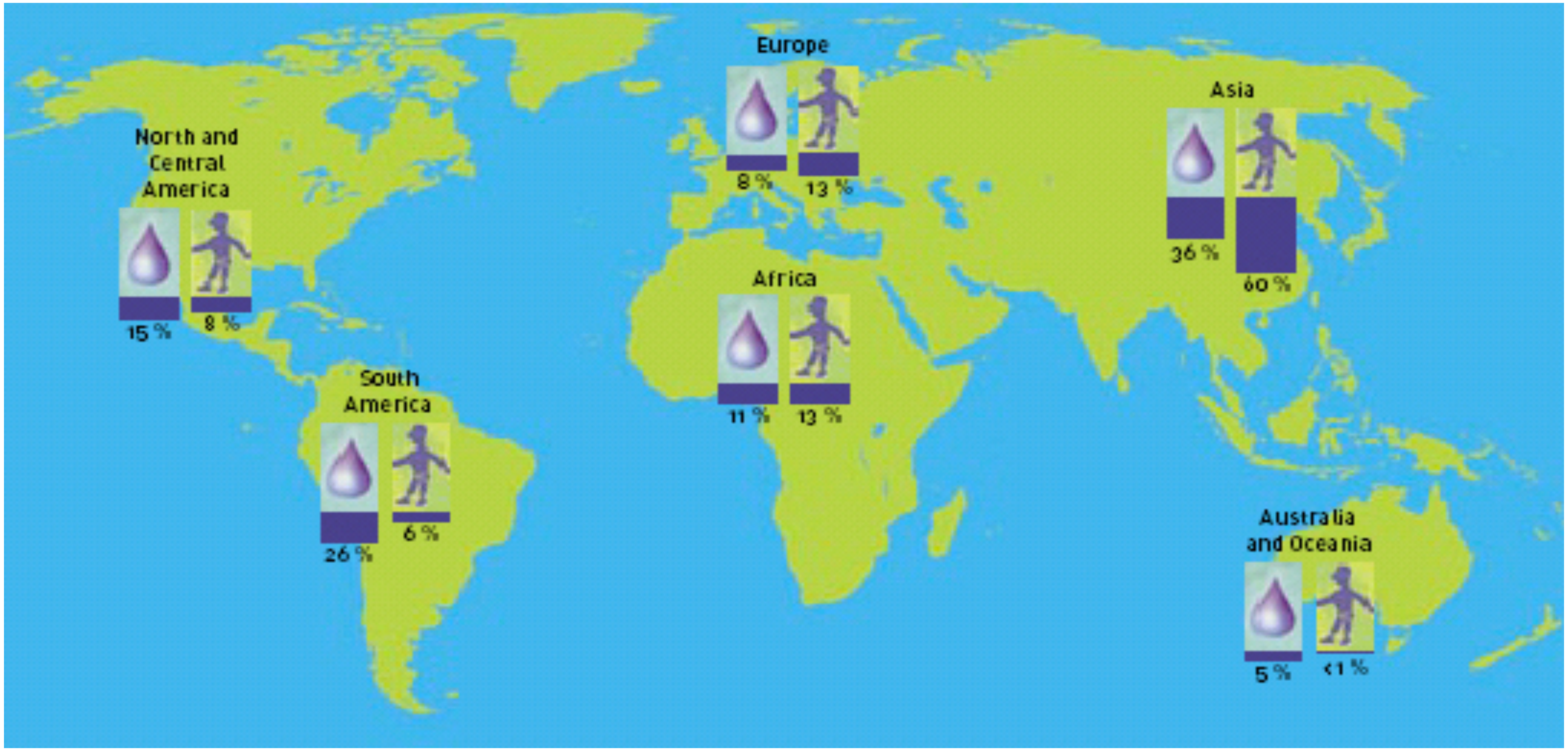
Water resource

What is water resource
Distribution of water resource

Cycle of water resource



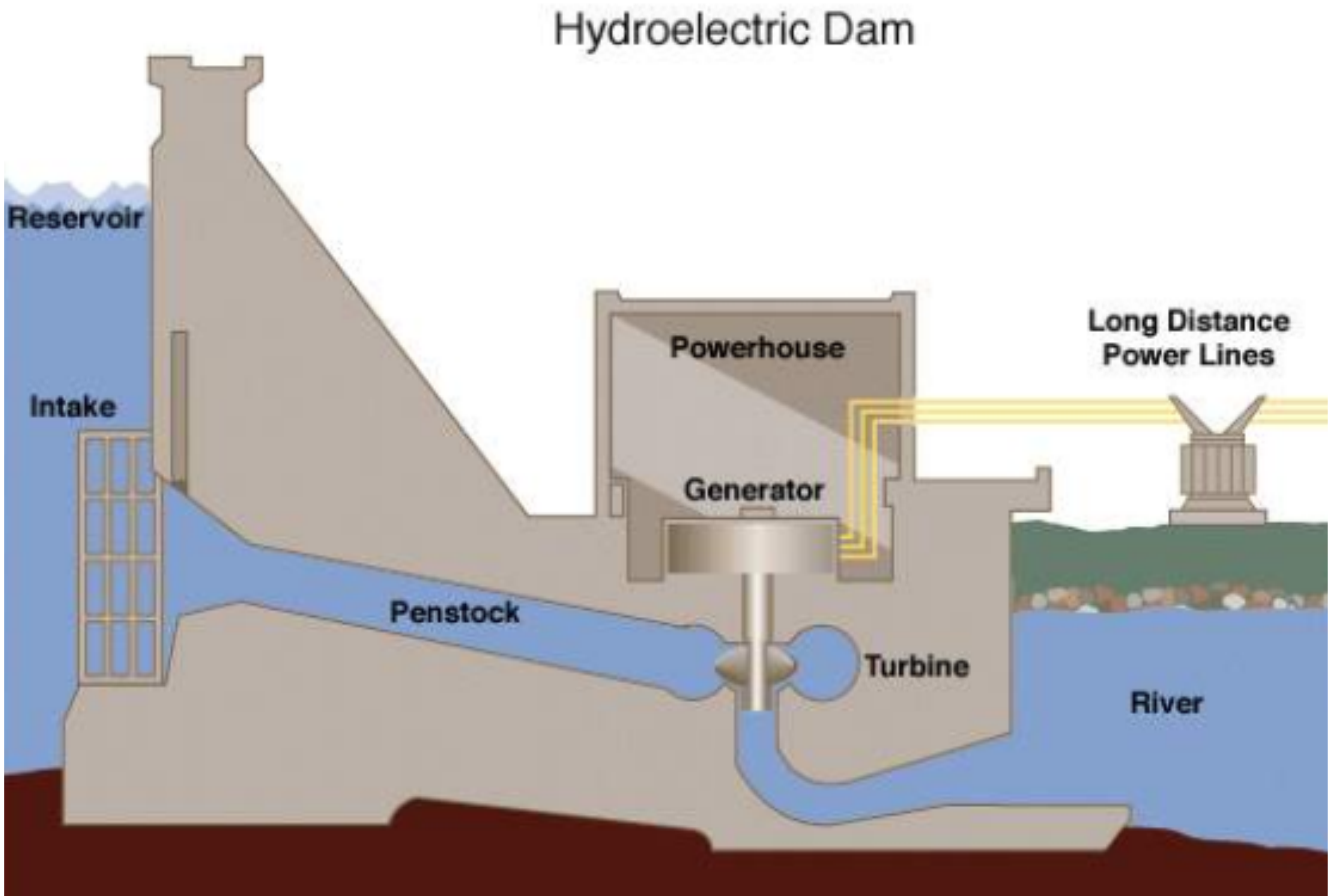
Condition of water resource in world



Introduction of Hydroelectric Power production:

The marshes that there are to construct suppose an important impact.
In the environment, marshes also have positive impact

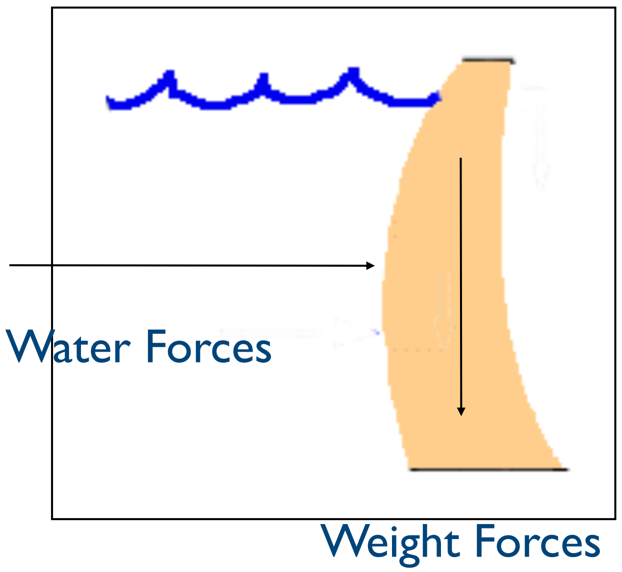
Hydro Power Plants

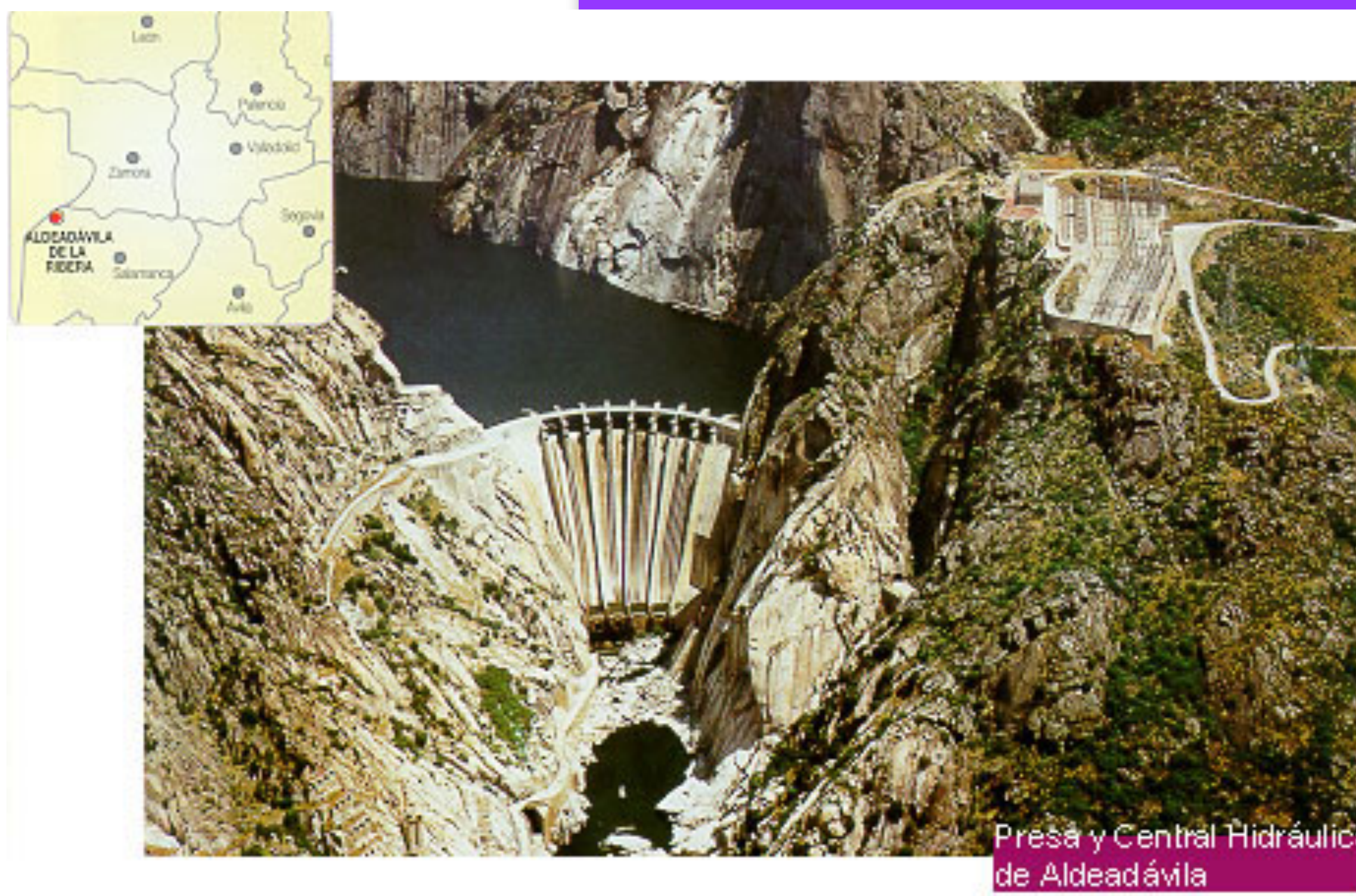


Different kind of Dams

Arch Dams
Gravity Dams
Arch-gravity Dams

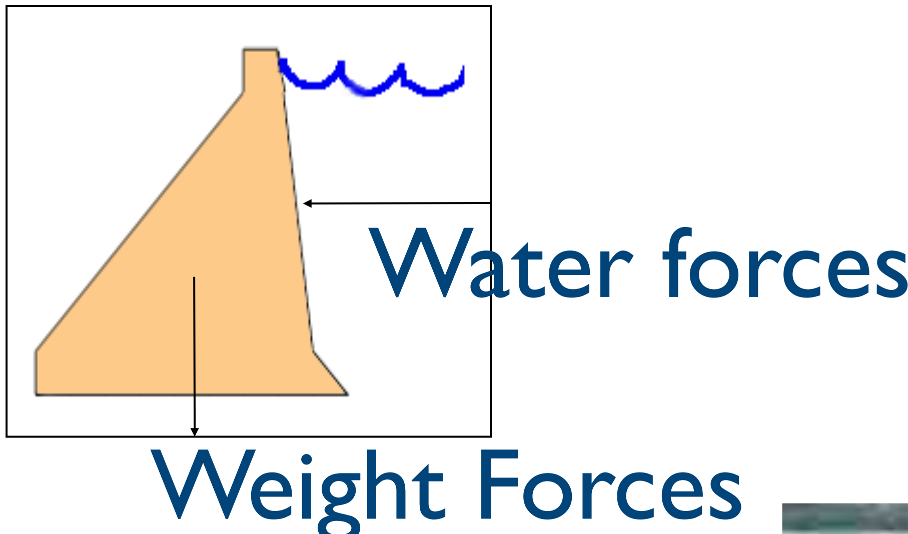
Arch Dams





Aldeadávila Dam (in Spain)

Gravity Dams



Guri Dam (in Venezuela)

Arch-Gravity dams

Hoover Dam (between the U.S. States of Arizona and Nevada)

Water power 1: hydroelectric power

The power of flowing water has been used for hundreds of years to operate machinery. This power can also be used to generate electricity.

Hydroelectric power

Large scale hydroelectric schemes involve building a dam across the end of a river valley to create a reservoir. This is done high up in a mountainous area.

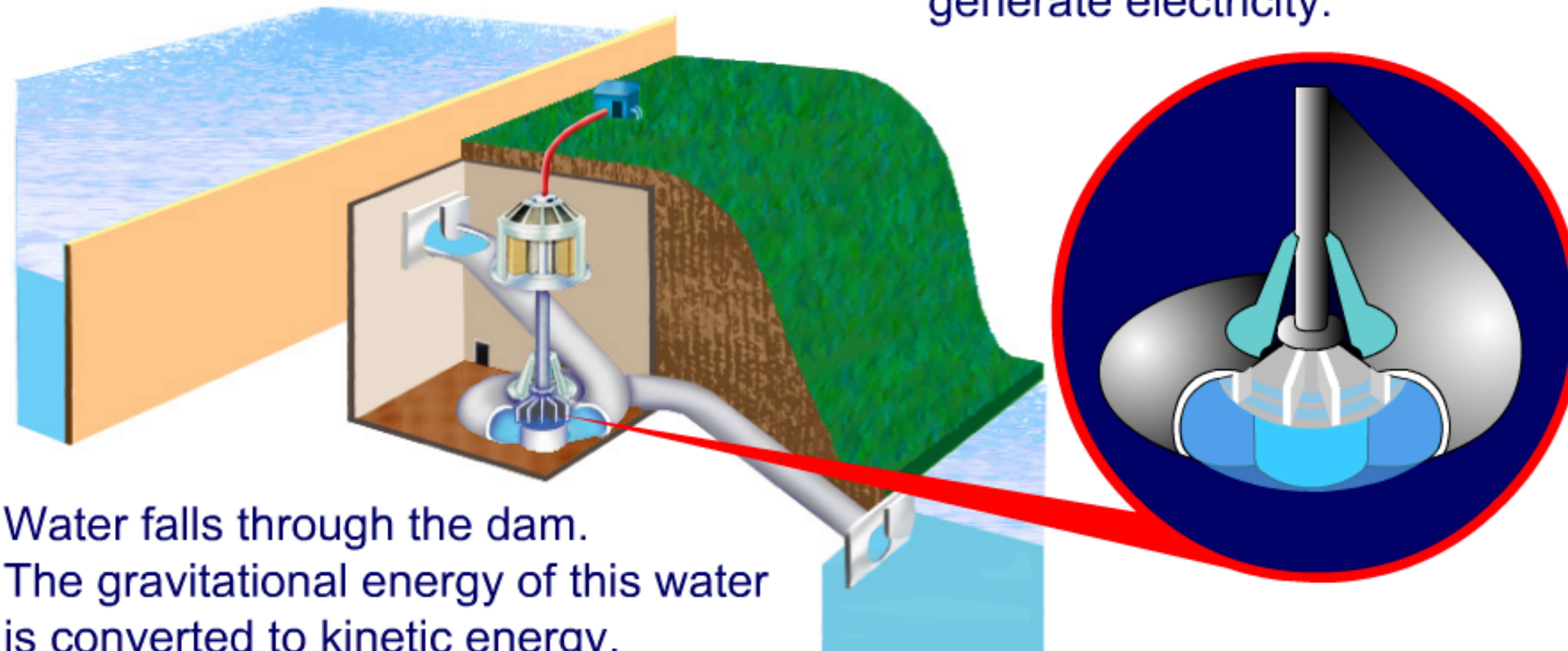
Hydroelectric power stations are able to start up electricity production quickly.

Hydroelectric power is also very reliable.

Hydroelectric power station

A dam is built across a valley, causing it to flood.

The kinetic energy of the water is used to turn a turbine and generate electricity.



Water falls through the dam.
The gravitational energy of this water is converted to kinetic energy.

?

Effective use of hydroelectric power

Hydroelectric power stations need to be situated in high mountainous areas such as North Wales or Scotland.

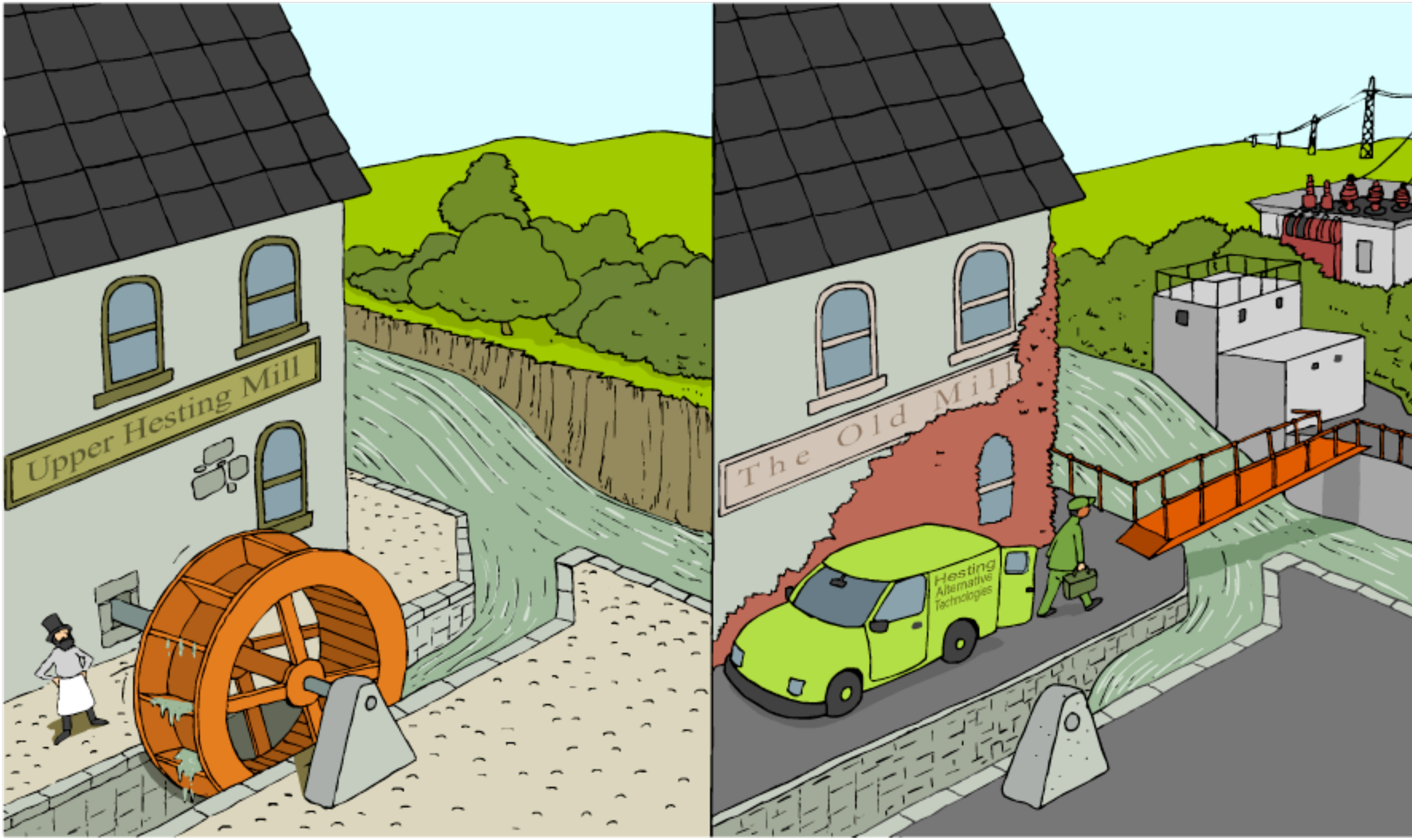
Damming the river causes the river valley to flood which could mean that houses and villages are destroyed.

Hydroelectric power schemes also cost a lot of money and take a long time to build. However, they do last a long time and they are able to produce large amounts of electricity.

Once they are built, hydroelectric schemes provide a cheap and reliable source of electricity.

The then and now guide to water power

How has the use of water power changed over time?



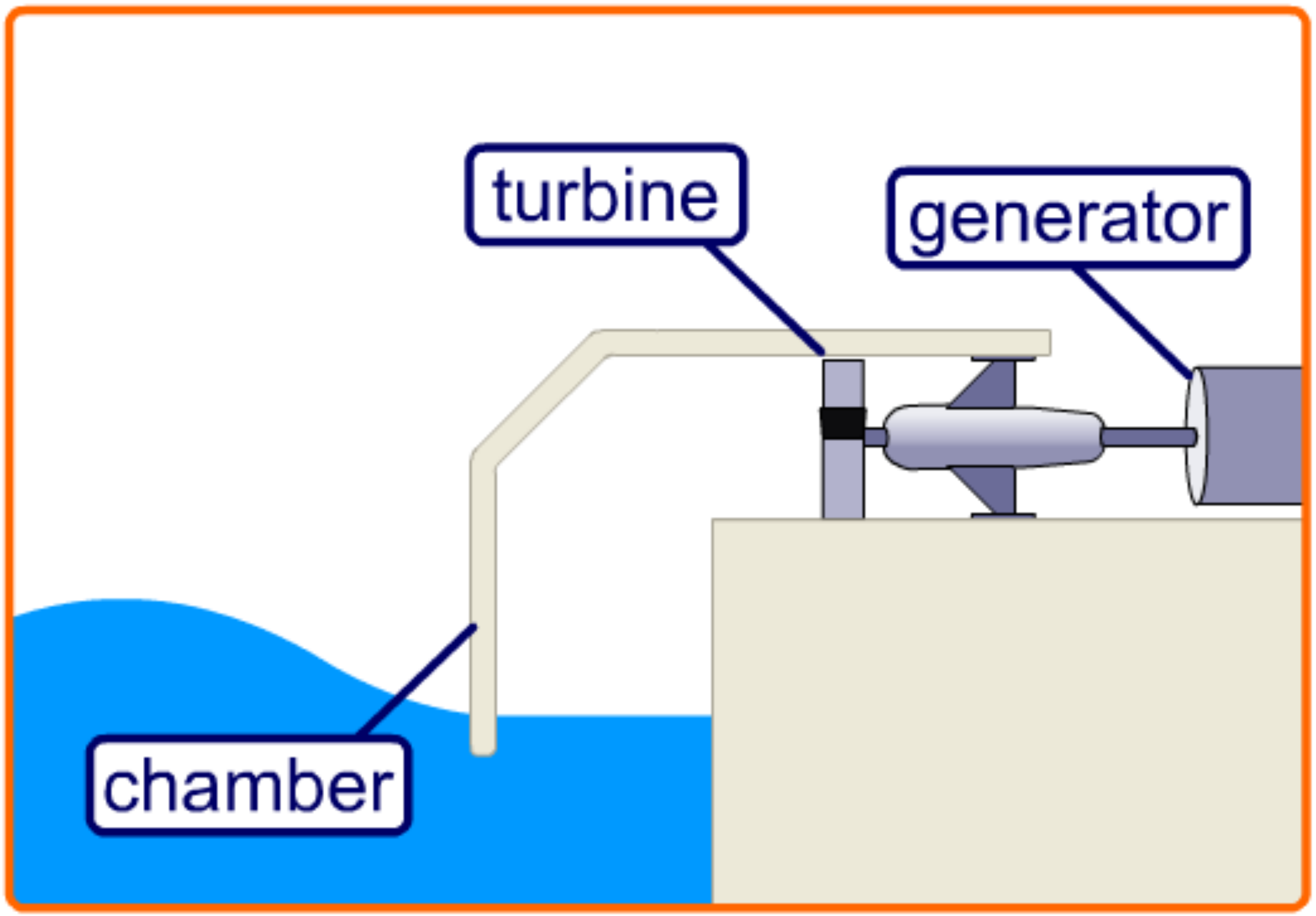
Water power 2: wave power

The rise and fall of waves is a renewable source of energy. Effective sites for harnessing wave energy need to have strong waves most of the time, to ensure that enough electricity will be produced.

The “Limpet” (land-installed marine-powered energy transformer) on Islay, Scotland, is the world’s first commercial wave energy device. Its low profile is designed so that it does not effect coastal views.

How does wave power work?

How does wave power work?



A "Limpet" is a Land Installed Marine Powered Energy Transformer.

Click "play" to find out it uses the up and down motion of the waves to turn a turbine and produce electricity.

Water power 3: tidal power

Tidal power involves building a dam across a river estuary.

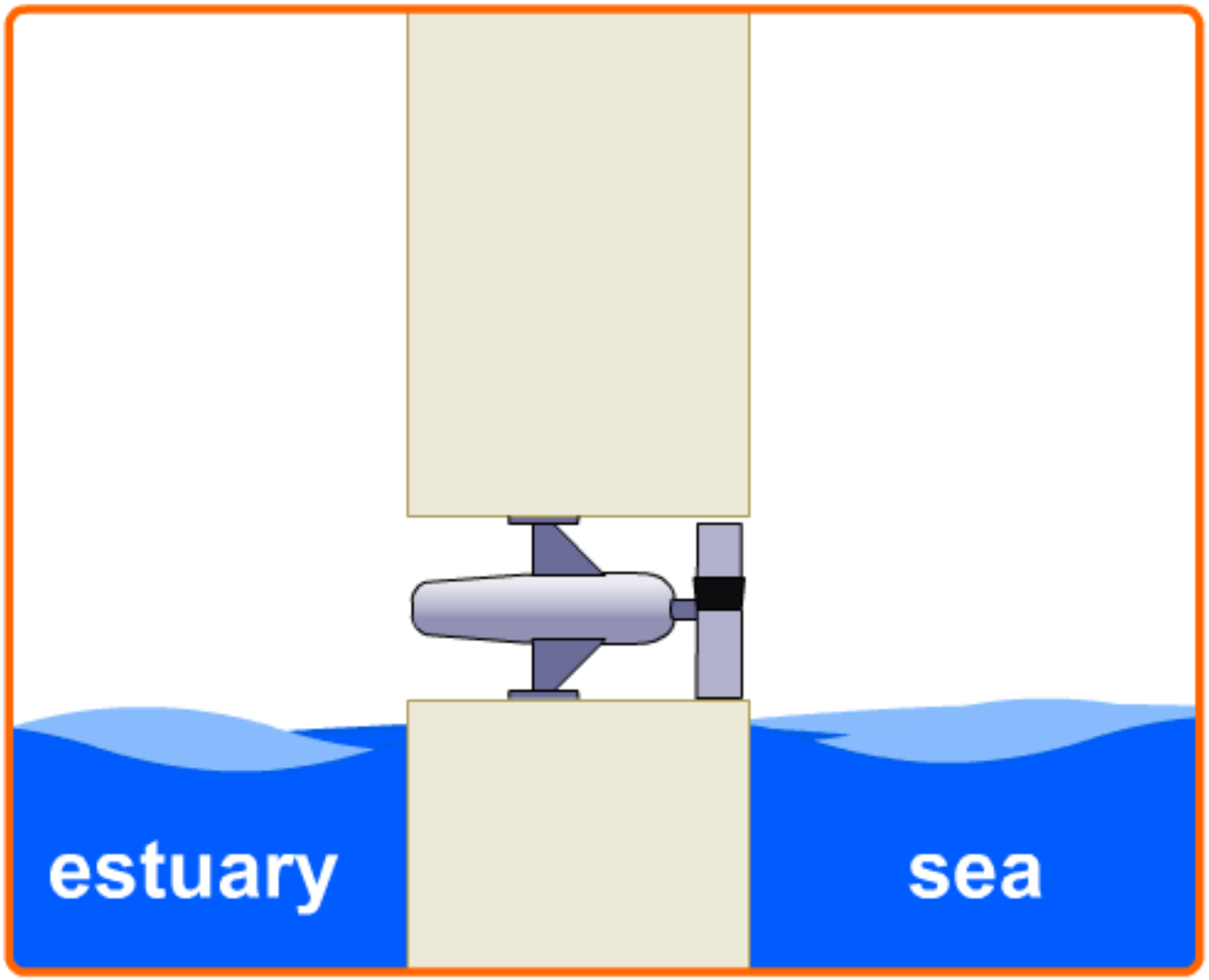
Water can only flow in and out of the estuary through turbines in the dam, which harness the tidal energy.

Tidal power is able to provide a lot of electricity, however building a tidal barrage is very expensive.

When a tidal barrage is built, it results in some of the estuary being flooded. This can mean the loss of important habits for wading birds.

How does tidal power work?

How does tidal power work?



The flow of the tide moves a huge amount of water twice a day.

Click "play" to find out how the flow of the regular rise and fall of the sea level can be used to generate electricity.

Effective use of tidal power

Tidal power provides a regular source of electricity. Exactly when this electricity will be produced is governed by the tides, which depend on the Moon.

Monthly variations in the tidal range will also affect how much electricity can be produced.

The passage of ships past the tidal barrier and the effect on wildlife also complicate the construction of tidal barrage schemes.

Thermal Power

Biomass

Biomass (plant material) is a renewable energy source because the energy it contains comes from the sun. Through the process of photosynthesis, plants capture the sun's energy. When the plants are burnt, they release the sun's energy they contain. In this way, biomass functions as a sort of natural battery for storing solar energy. As long as biomass is produced sustainably, with only as much used as is grown, the battery will last indefinitely.[*unreliable source?*] In general there are two main approaches to using plants for energy production: growing plants specifically for energy use (known as first and third-generation biomass), and using the residues (known as second-generation biomass) from plants that are used for other things. See biobased economy. The best approaches vary from region to region according to climate, soils and geography.

Biofuel

Biofuels include a wide range of fuels which are derived from biomass. The term covers solid biomass,liquid fuels and various biogases. Liquid biofuels include bioalcohols, such as bioethanol, and oils, such as biodiesel. Gaseous biofuels include biogas, landfill gas and synthetic gas.

- Bioethanol is an alcohol made by fermenting the sugar components of plant materials and it is made mostly from sugar and starch crops. With advanced technology being developed, cellulosic biomass, such as trees and grasses, are also used as feedstocks for ethanol production. Ethanol can be used as a fuel for vehicles in its pure form, but it is usually used as a gasoline additive to increase octane and improve vehicle emissions. Bioethanol is widely used in the USA and in Brazil. However, according to the European Environment Agency, biofuels do not address global warming concerns.
- Biodiesel is made from vegetable oils, animal fats or recycled greases. Biodiesel can be used as a fuel for vehicles in its pure form, but it is usually used as a diesel additive to reduce levels of particulates, carbon monoxide, and hydrocarbons from diesel-powered vehicles. Biodiesel is produced from oils or fats using transesterification and is the most common biofuel in Europe.

Geothermal energy

Geothermal energy is from thermal energy generated and stored in the Earth. Thermal energy is the energy that determines the temperature of matter. Earth's geothermal energy originates from the original formation of the planet (20%) and from radioactive decay of minerals (80%). The geothermal gradient, which is the difference in temperature between the core of the planet and its surface, drives a continuous conduction of thermal energy in the form of heat from the core to the surface. The adjective *geothermal* originates from the Greek roots *geo*, meaning earth, and *thermos*, meaning heat.

- The heat that is used for geothermal energy can be from deep within the Earth, all the way down to Earth's core – 4,000 miles (6,400 km) down. At the core, temperatures may reach over 9,000 °F (5,000 °C). Heat conducts from the core to surrounding rock. Extremely high temperature and pressure cause some rock to melt, which is commonly known as magma. Magma convects upward since it is lighter than the solid rock. This magma then heats rock and water in the crust, sometimes up to 700 °F (371 °C).

Biomass

Biomass is material from living sources. The simplest biomass energy sources are plants which can be burnt to produce steam to turn a turbine.

Traditionally, wood is burnt to give heat but trees grow slowly and require a lot of land. Other materials such as the waste from chicken farms can also be burnt.

Biomass fuels are renewable as more plants can be grown, producing yet more biomass.

Biomass fuels do not contribute to global warming as the carbon dioxide released when they are burnt is absorbed by the plants grown to replace them.

Biofuels

Some sources of biomass energy are further processed to produce more valuable biofuels.

Some plants can be fermented to give ethanol, a biofuel, which can be used instead of petrol or even aviation fuel, as in this plane!

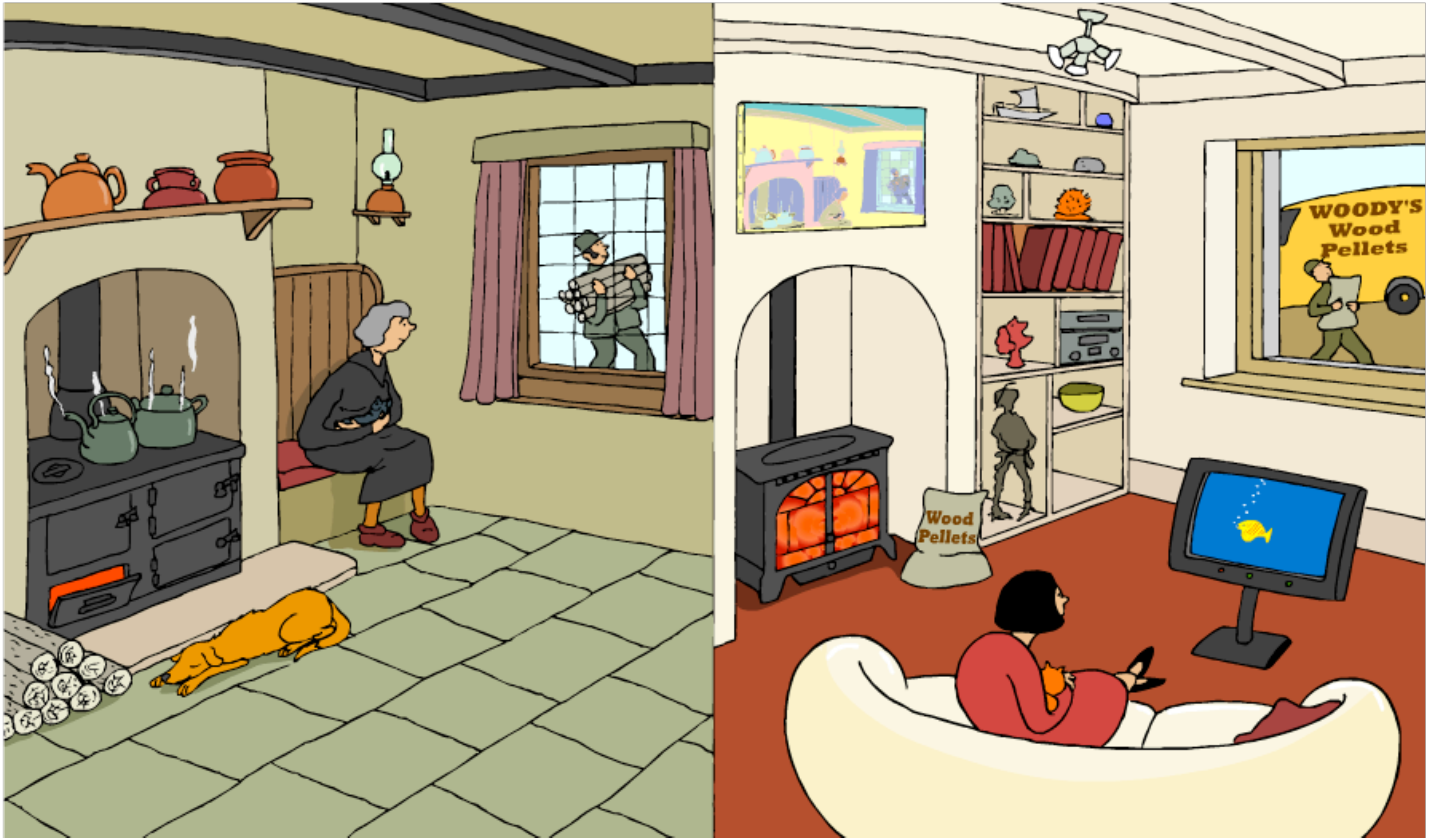
© Laurent Simon - Aviation & Pilot/NREL

© California Polytechnic State University/NREL

Methane is biogas which can be used a replacement for natural gas. It is produced in anaerobic digesters by rotting animal waste and often found on remote farms, such as this digester on a pig farm.

The then and now guide to biomass

How has the use of biomass changed over time?



Geothermal energy

In rocks under the ground, radioactive decay of elements, such as uranium, releases heat energy that warm the rocks.

In some areas, hot water and steam rise to the surface.

The steam and hot water which rises naturally to the surface can be harnessed to generate electricity.

The largest geothermal power plant is in California and has an output of 750 megawatts.

Geothermal energy

In some areas, the warm rocks are very deep underground.

Where this occurs, wells are drilled down to the hot rocks and cold water is pumped down. The water is heated by the rocks and returns to the surface as steam.

This geothermal power plant in California has 57 wells and produces 52 MW of electricity.

Summary

Glossary

- **biomass energy –** Energy from living matter, which can used as fuels.
- **geothermal energy –** Heat from radioactive decay in rocks deep below the Earth's surface.
- **hydroelectric energy –** The gravitational potential energy of falling water, which is used to generate electricity.
- **solar energy –** Energy from the Sun, which is converted into thermal or electrical energy.
- **tidal energy –** Energy from the rise and fall of the tides, which can be used to generate electricity.
- **wave energy –** Energy from the up and down motion of waves, which can be used to generate electricity.
- **wind energy –** Energy from the movement of air, which is transferred to wind turbine and used to generate electricity.

발전단가

전원		적용설비 용량기준	구 분		기존 (원/kWh)	기준가격(원/kWh)		비고
						고정요금	변동요금	
태양광		3kW이상	30kW이상		716.40	677.38	–	감소율 4% (3년 이후)
			30kW미만			711.25	–	
풍 력		10kW이상	–		107.66	107.29	–	감소율 2% (3년 이후)
수 력		5MW이하	일반	1MW이상	73.69	86.04	SMP+15	
				1MW미만		94.64	SMP+20	
			기타	1MW이상		66.18	SMP+ 5	
				1MW미만		72.80	SMP+10	
폐기물 소각 (RDF 포함)		20MW이하	–		SMP+CP	–	SMP+ 5	화석연료 투입비율 : 30%미만
바이오 에너지	LFG	50MW이하	20MW 이상		61.80	68.07	SMP+ 5	
			20MW 미만		65.20	74.99	SMP+10	
	바이오 가스	50MW이하	150kW 이상		–	72.73	SMP+10	
			150kW 미만			85.71	SMP+15	
	바이오 매스	50MW이하	목질계 바이오			68.99	SMP+5	
해양 에너지	조력	50MW이상	최대조차 8.5m이상	방조제유	62.81	62.81	–	
				방조제무		76.63	–	
			최대조차 8.5m미만	방조제유	–	75.59	–	
				방조제무		90.50	–	
연료전지		200kW이상	바이오가스 이용		–	234.53	–	감소율 3% (2년 이후)
			기타연료 이용			282.54	–	

* 개정고시(2006.8.30), 시행(2006.10.11), 부록 참고