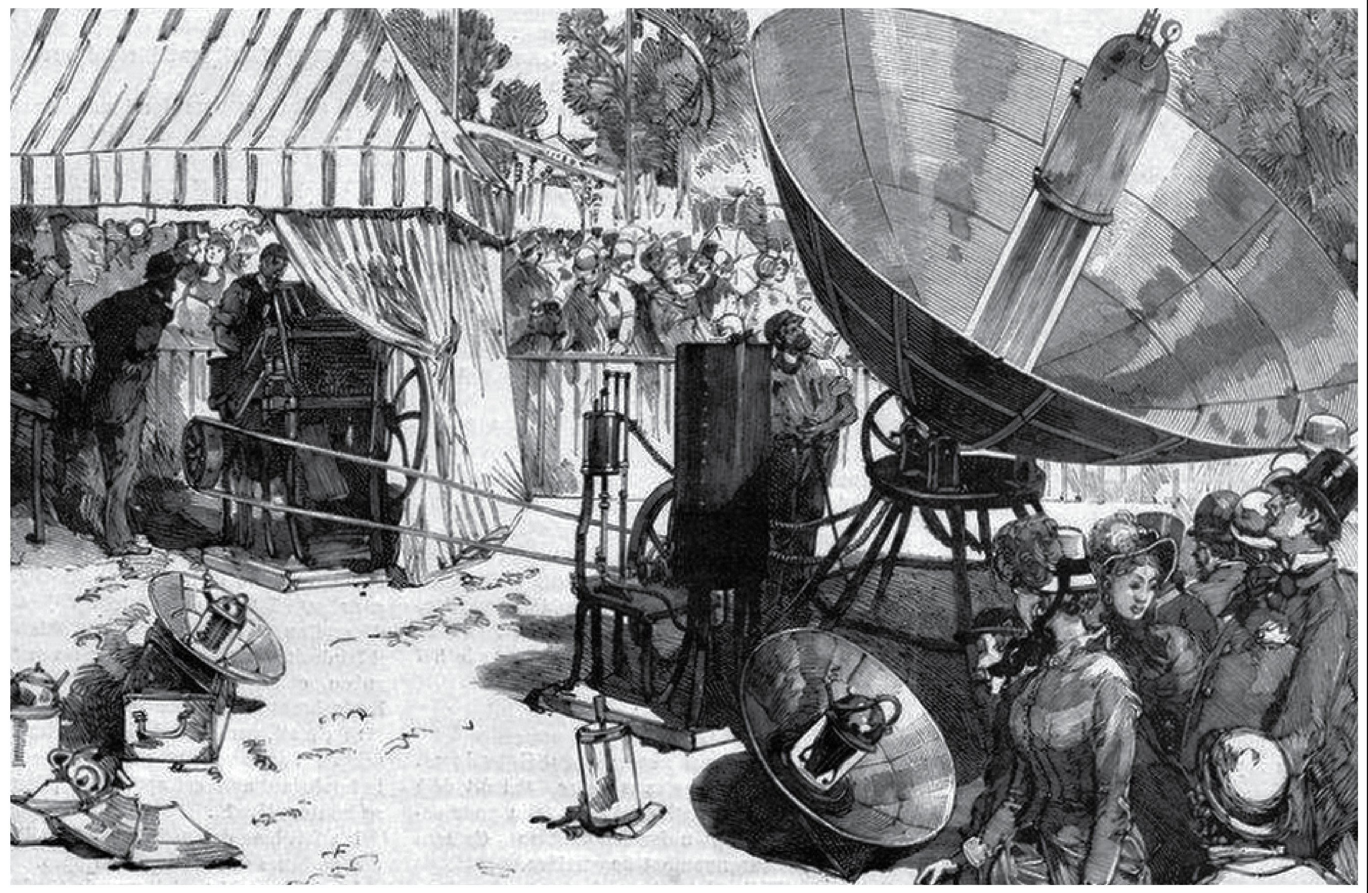
Exploring the history of sustainable energy

Coal will undoubtedly be used up. What will industry do then... ?

...One must not believe, despite the silence of modern writings, that the idea of using solar heat for mechanical operations is recent. On the contrary, one must recognize that this idea is very ancient.

-- Augustine Mouchot, 1878



Solar energy demonstration, Paris, August 6, 1882, -- With coal shortages looming and forests unable to keep up with energy demand, Augustin Mouchot and Abel Pifre demonstrate a 3.3 meter silver plated conical solar steam generator. The steam feeds into a Rankine engine and then runs a printing press inside the tent. A variety of solar cookers showed more ways to use solar power. (Le Monde Illustré, Aug. 12, 1882).

Energy transitions were envisioned many times in the past

History, as H.G. Wells once said, is "a race between education and catastrophe." Nothing could better illustrate that idea than the modern race to transition away from fossil fuels and to renewable energy in time to prevent highly destructive climate change. But this kind of race was anticipated, for various reasons, many times in the past.

That's why we neeed to understand the history of this idea. History involves focused thinking about the past in order to understand the present and the prospects for the future. History allows us to ask basic questions about the nature, direction and control of technology and the social and ethical issues surrounding its development.

Possibly the biggest surprise in the history of sustainable energy is that a subject so interesting has been neglected for so long. Sustainable energy's past is full of heroic characters, insights into the human prospect and hope for the future.

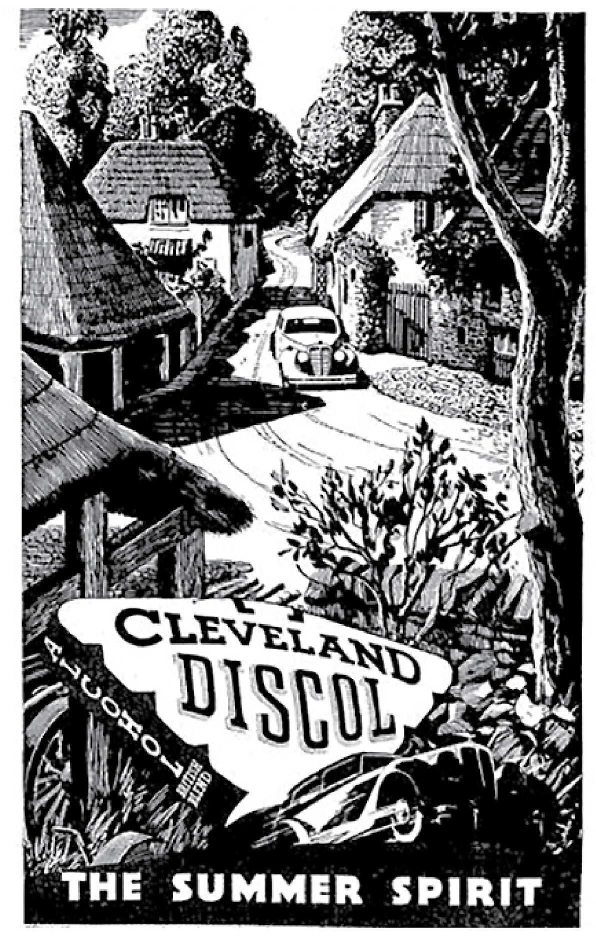
Augustin Mouchot, a French physics professor, felt so strongly about the prospects for solar energy replacing coal that he and his students powered a printing press with a concentrating solar collector in Paris in 1882 (left). UN naval architect John Ericsson, designer of the USS Monitor in 1862, devoted much of his life to making solar energy practical. Frank Shuman said a century ago: "After our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the sun."

Henry Ford and others saw the future in sustainable agriculture and hoped to challenge the oil industry with farm fuels in the 1920s and 30s. Wind energy pioneers like students at the Tvind school in 1975 hoped to show that nuclear power was not needed in Denmark.

These and many other people pioneered the future for sustainable / renewable energy technologies. Now more than ever, their work needs to be understood.

Motivations for sustainable energy:

- Guard against shortages of coal or oil (1870s - present)
- Put the sun "into service" for humankind (1880s)
- Help farmers find new markets (1890s - present)
- Help civilization live within energy "income" instead of drawing down energy "capital" (1920s - 30s)
- Provide fuels & chemicals for WWII (1940s)
- Alternative to coal and oil political power (1890s- present);
- Provide an alternative to nuclear energy (1950s - present);
- Promote national energy independence (from 1970s);
- Increase employment with green jobs (1990s);
- Decrease pollution from fossil fuels (from 1980s);
- Avert climate catastrophe by replacing fossil fuels with sustainable sources of energy (from 2000s)



The fuel of the future is going to come from fruit like that sumach out by the road, or from apples, weeds, sawdust—almost anything. There is fuel in every bit of vegetable matter that can be fermented. There's enough alcohol in one year's yield of an acre of potatoes to drive the machinery necessary to cultivate the fields for a hundred years.

-- Henry Ford, 1925

Solar energy

Passive solar energy has used in many cultures since the earliest times. For most cultures in the pre-industrial world, buildings were built to be shielded from sunlight in the warm seasons and to trap solar heat in the cold seasons. Knowledge of the sun was so important in ancient Greece that, in Aeschylus' 456 BCE play, Prometheus uses knowledge of solar energy to distinguish civilized people from barbarians.

Solar architecture was more or less forgotten until the industrial age. American architect George Fred Keck's House of Tomorrow for the 1933 Chicago World Fair Century of Progress Exposition saw the beginning of a comeback. The exhibition house had twelve sides made almost completely out of glass. When Keck noticed that workers were comfortable in just shirts inside the House of Tomorrow, lacking a heating system, on a below freezing day, he found that sunlight passing through glass could be used to heat homes. After this discovery, Keck continued to design other solar houses with south-facing windows.

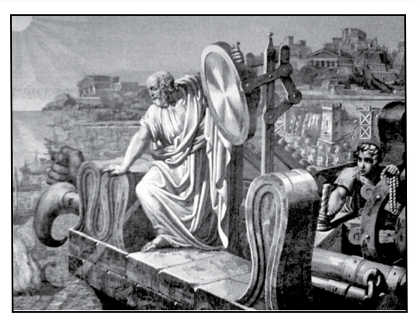
The Massachusetts Institute of Technology led the way in experimenting with passive solar architecture in the United States. In 1939, Solar One, the first of six solar houses built by MIT, was completed. In Europe, the concept of energy efficiency building standards came to fruition by Bo Adamson and Wolfgang Feist starting in 1988 under the name of Passive House, or Passivhaus.

Solar photovoltaics Edmond Becquerel and Charles Fritts were the first to develop a photovoltaic cell in the mid 1800's. Gerald Pearson, Daryl Chapin and Cslvin Fuller of Bell Labs made the first working PV device i 1954 (left). Solar PV was widely used in the space race between the United States and the Soviet Union. Hanz Zeigler, a German scientist working for the U.S., advocated for the use of solar PV on the first U.S. satellite, the Vanguard 1. The satellite was launched into orbit powered by chemical batteries and solar energy and within two weeks the chemical batteries had died and the solar PV continued to function for 60 years or more.

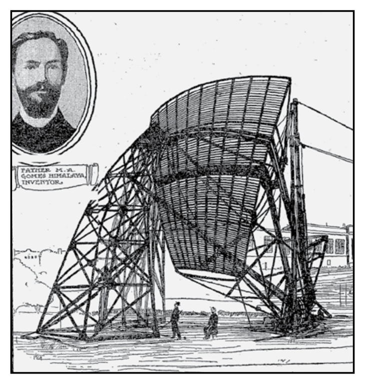
The high early price of solar cells resulted in the technology being used for remote applications, such as to power lighthouses, buoys, and warning lights on oil refineries. in the 1970s, Elliot Berman was able to reduce the price of solar using thin-film technology. This led to a rapid expansion of the technology.

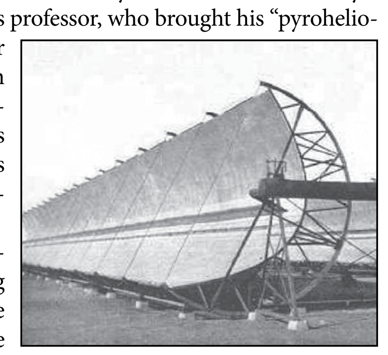
Solar PV technology is now a large commercial market with an array installed every four minutes in the United States. It is the fastest growing energy source in the market.

Solar thermal energy, sometimes called "active" solar, has been used since ancient times. For example, in ancient Rome around the 7th century BCE, polished brass mirrors focused solar heat on torches that started the Vestal fires every year. In 212 BCE, legend has it that brass mirrors were used by the mathematician Archemedes to defend the city of Syracuse (right).



In the early modern era, scientists Horace de Sassure, John Hirschel and Claude Pouillet began experiments to find the solar constant. Much of their work comes together around experiments of Augustin Mouchot, a French physics teacher who started making solar cookers and devices in the 1860 - 1880s, such as the solar printing press (above). Another 19th century pioneer was John Ericsson, a Swedish naval engineer who moved to America in the 1840s. Erisson designed the USS Monitor during the Civil War, and spent the next 25 years working on solar engines in New York City. Some of Mouchot's work was carried on by Father Gomez Himalaya, a Portuguese priest and physics professor, who brought his "pyroheliopher" to the 1904 St. Louis fair (above left). Similar solar steam engines were also pumping water in the arid west around this same time, where Aubrey Enias and Frank Willsie faced competition from cheap oil.





American inventor Frank Schuman created one of the largest solar thermal installations in history around 1912 in Maadi, Egypt, using parabolic trough collectors (right). They powered a 60–70 hp engine that pumped more than 22,000 litres of water per minute from the Nile River to irrigate nearby cotton fields. World War I and cheap oil interrupted the development of solar thermal energy. Even so, Shuman said: "We have proved the commercial profit of sun power in the tropics and have more particularly proved that after our stores of oil and coal are exhausted the human race can receive unlimited power from the rays of the sun."

A solar furnace, built in Odeillo France in 1970, reaches temperatures up to 3,500 °C (6,330 °F). And solar "power towers," which collect solar energy from arrays of mirrors, have been built in Germany, Spain, France and California in recent decades. Because the mirrors often have to be computerized for solar tracking, these units tend to be more expensive than parabolic thermal units (like Shuman's, above) or distributed roof-mounted solar photovoltaic systems.

Bioenergy

Wood is the oldest energy, and possible instances of controlled fire are dated to 1.5 million years ago. Today, wood fuels account for two thirds of all energy use in Africa, nearly one third in Asia, and one fifth in Latin America. Rural areas are almost totally dependent on wood and other biomass fuels.

Some of the first improvements in the use of wood include Benjamin Franklin's cast iron stove, introduced in 1741, and another Benjamin Thompson (Count Rumford) introduced in the 1790s. Low-cost cook stoves for developing countries are now being used for efficiency and cutting pollution, and are often a better cultural fit than solar cookers. The growing need for wood energy and for conservation of forest resources has led to the Arbor Day movement in the US, the Chipko and Van Mahotsav movemenst in India, the Green Belt movement in Africa.

Biogas is widely used in Germany and Denmark to provide peaking power or fill in electric needs when wind speeds are low and wind farms produce less electricity. The white dome (right) is one of the gas storage units at the Hashøj biogas plant managed by Erik Lundsgaard in Dalmose, Denmark. The plant treats agricultural waste. Similar small-scale biogas plants have been used in China and India to treat human waste in a way that both sterilizes and produces cooking gas for villages.

Biodiesel and ethanol are the main liquid biofuels in use today. Biodiesel is made from vegetable oils. Ethanol can be made from starchy or sugary food crops, although there is controversy over competition between food and fuel. Second generation ethanol plants make fuel from plant fibers (cellulose) through a process that is somewhat more expensive but environmentally better than corn ethanol. Vegetable oils can be used in diesel engines, as Rudolph Diesel demonstrated in 1900, but they need to be treated to blend with petroleum diesel. Ethanol can be blended with gasoline and is useful in boosting octane, as Henry Ford and many other automotive pioneers found in the early 1900s. Alexander Graham Bell called ethanol a "wonderfully clean burning fuel," in a 1917 National Geographic article. Other possible biofuels fuels include jatropha, a desert shrub that produces berries that can be used in biodiesel and sustainable aviation fuels.

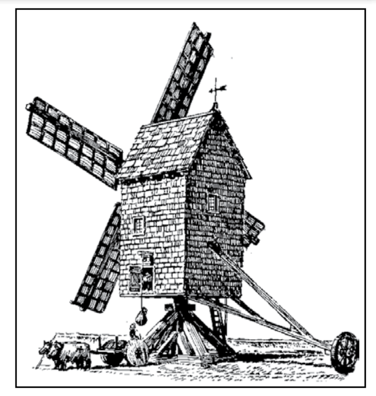
Wind energy

This Danish smock mill, originally built in 1842, was taken apart and re-assembled in Elk Horn, Iowa, in the 1980s. It is an advanced type of mill; notice the louvered sails that can be easily controlled from the deck at the bottom of the mill. Also there is a wind vane at the back that turns a gear to hold the sails steadily into the wind.

Wind power was developed in Europe starting around the 11th century, accoding to one theory by returning Crusaders who had seen windmills in Persia. Windmills were used for grinding grain, pumping water, sawing wood, fulling cloth and other early modern industrial uses.

The earliest windmills were the post mill type (right), so called because they sat on a post so they could be easily turned into the wind or moved to other locations. Later mills included the "smock" mill because the moveable cap at the top looks like a farmer's smock (shirt); the "polder" mill which pumped water in the Netherlands; and "tower" mills which used brick and mortar towers and moveable caps like smock mills.

Windmills loom large in history. Edward III rallied English troops around the windmill at the Battle of Crecy in 1345. Miguel de Cervantes had his mad knight, Don Quixote, fight them . Longfellow wrote poems about windmills. And the Moulon Rouge, the most famous dance hall of Paris, is of course the "red windmill."



Wind electric The idea of using wind to generate electricity occurred to many people in the late 19th century, including British mathematician and physicist William Thompson (Lord Kelvin). Like the solar pioneers, Thompson worried about the finite nature of coal reserves. Once coal began to run out, wind power would be "utilized everywhere as the servant of man, free for every one, working silently as a great force while the world sleeps," he said.

Electrical inventor Charles Brush built a large multi-vaned wind electric turbine (left) in Cleveland, Ohio, in 1888. It was the world's first automatically operated wind turbine generator which charged the home's batteries and lasted 20 years.

Another wind electric pioneer was Paul la Cour of Denmark, who built his first experimental wind turbine in 1891 at the Askov Folk High School. La Cour was motived by the need to to promote self-sufficiency, decentralization and cooperative work in rural areas. He also worked on ways to store up wind energy through hydrogen electrolysis and made improvements to small wind systems that would late become part of the development of large scale wind turbines in Denmark. Another important milestone in wind power engineering was the 1941 Smith Putnam turbine built on Grandpa's Knob in Vermont.

Water power & hydroelectric energy

Water mills were well known in the ancient world from at least as early as 200 BCE. They were used in China as well as Greece and Rome. First century Roman engineer Vitruvius was among the first to write a full description of the water mill. Greek writer Antipater of Thessalonica noted an early water mill in a poem written around 20 BCE. Vitruvius was a Roman engineer who lived during the first century BC. In 31 AD a Chinese engineer, Du Shi, invented water powered bellows. It was a complex machine that was used to help forge cast iron.

The two basic types of water mills are: small horizontal wheels, also called "Norse" mills; and larger, vertical mills, used for collecting grain taxes during feudal period in Northern Europe. Vertical water mills were common in the Middle Ages, and by the Domesday Book census of 1086, over 6,000 mills had been built in England alone.

In the Islamic world, watermills were used industrially since the 7th century. By the 9th century vertical and horizontal wheeled mills were used commonly. Several different types of mills were used including gristmills, hullers, paper mills, saw mills, steel mills, stamp mills and sugar mills. In the 11th century every province in the area was running water mills. There were two methods created by Muslim engineers to make waterwheels more efficient. They built the wheels onto bridges to harness a more heavy water flow. They also put waterwheels on the sides of ships. Mills became increasingly popular in Europe during the 11th century, in part due to a change in climate, which allowed more grain to be grown, and more mills were needed.

Hydroelectric power begins in the United States in Appleton, Wisconsin in 1882. Within 10 years, there were 200 hydroelectric plants in the United States alone, and by 1920 40% of the electricity in the US was hydroelectric. Many hydro dams were constructed throughout this time; most notably the Hoover Dam (originally known as the Boulder Dam). At the time of construction, the Hoover Dam employed more than 20,000 workers during the great depression and produced more electricity than any other hydroelectric source, but it was outdone 6 years later by the Grand Coulee Dam and by several other dams since.

In the 1940's hydropower provided about 75 percent of all the electricity consumed in the West and Pacific Northwest, and about one third of the total United States' electrical energy. Today, the United States has over 2500 hydroelectric power plants regulated by FERC or the federal government, which supply 49% of its renewable energy.

Although hydropower has no air quality impacts, construction and operation of hydropower dams can significantly affect indiginous peoples, natural river systems and fish and wildlife populations. Often, water at the bottom of the lake created by a dam is inhospitable to fish because it is much colder and oxygen-poor compared with water at the top.

When this colder, oxygen-poor water is released into the river, it can kill fish living downstream that are accustomed to warmer, oxygen-rich water. Also, some dams withhold water and then release it all at once, causing the river downstream to suddenly flood. This action can disrupt plant and wildlife habitats and affect drinking water supplies. Dams can also localize disease and distrupt indiginous cultures. Today most development experts argue for smaller scale hydro projects that work more in harmony with nature and cultural resources.

A tale of two wind turbines reflects the way social factors and political will influence sustainable energy development. Both turbines were one-megawatt grid-tied structures. The two-bladed turbine (smaller, to the right) was built by NASA and Department of Energy in Boone, N.C., at a cost of $50 million in 1979. The red and white checkered turbine (large, center) was built by volunteers at the Tvind school in Denmark in 1975 at a cost of $500,000. Tvind students and teachers hoped to show an alternative to nuclear power. They tied their own reinforcing steel, mixed their own concrete, and created their own factory to cast fiberglass blades. This sort of project is not unusual in the Danish "handverk" tradition, and has contributed to the current succss of Denmark's wind industry. The NASA turbine was noisy and unbalanced, and could only be run at low power. After only a few months of operation, its aluminum blades cracked. The NASA wind turbine was deemed a failure and was dismantled in 1981, although other wind projects continued in the MOD program. The cheaper Tvind turbine has had some problems -- at one point its blades had to be replaced -- but it is still running and can be located on Google Earth.

For more information see www.environmentalhistory.org

Sustainable Energy Timeline

400,000	First controlled fire
4,000	Solar-oriented homes
2,000	Wood shortages shift civilization westward
1,000	Water mills common in Asia, Mediterrenian
750	Sun lights Rome's Vestal fires
212	Archemedes solar ray defends Syracuse
BCE - ACE	Wood shortages lead to more solar in Rome
500s - 1100s	Water mills support feudal system
1100	Wind mills begin to appear in Europe
1400s	Wind & water mills show rapid improvements, dawn of industrial era
1600s	Coal widely used in England, accelerating industrial revolution
1605	Cervantes writes Don Quixote
1741	Franklin stove invented
1790s	de Saussure solar experiments begin search for the solar constant
1799	Wood gas lights Paris hotel; British begin use of coal gas
1826	First internal combustion engine uses biofuel blend in Connecticut
1839	Edmond Becquerel discovers photovoltaic (PV) effect
1860s	Augustin Mouchot begins solar energy experiments & development in France
1866	John Ericsson begins solar engine experiments in New York City
1881	First hydroelectric light, Niagara Falls
1882	Solar printing press demonstration in Paris, Augustin Mouchot, Abel Pifre
1888	Aermoter wind engine company founded, Chicago
1891	Wind electric experiments begin in Denmark with Paul La Cour
1891	Solar water heaters go on sale in California, Florida
1900	Rudolph Diesel shows vegetable oils can run diesel engine at Paris exhibit
1904	Aubrey Eneas' Solar Motor Co. sells first water pumping engine, California
1904	Henry Willsie develops thermal storage system for solar in Arizona
1906	US Congress repeals tax on ethanol as fuel to help competition against oil
1914	Frank Schuman builds solar power plant in Egypt
1935	Henry Ford backs renewable energy farm movement (Chemurgy)
1937	Agrol ethanol plant built in Kansas; makes synthetic rubber in WWII
1939	MIT Solar House #1 built
1941	Putnam wind turbine built in VT
1954	Solar PV cells - Bell Labs
1960s	Satellites use solar PV power
1969	Solar furnace, Odiello, France
1973	First embargo ends cheap oil
1977	Green Belt movement, Kenya
1978	Tvind wind turbine built, Denmark
1979	Solar panels installed at White House
1981	First US wind farms, Vermont, Texas
1982	Solar panels removed from White House
1980s	Solar pv now effective for remote uses
1988	Bruntland Commission backs sustainable development
1991	First offshore wind farm, Denmark
1992	Earth Summit @ Rio: Sustainable development needed for earth's future
1992	White House solar collectors to Unity
2002	Energiewende begins in Germany
2000s	UN focus is on Sustainable development
2007	Court says EPA has to regulate CO2
2015	Solar PV power cheaper than nuclear; Wind power cheaper than coal