Solar History

Student Objective
The student:
- will identify major events and developments in the history of solar energy
- will work cooperatively to create a poster or computer generated presentation that communicates information.

Key Words:
passive solar
photovoltaic
solar collector
solar furnace
solar still
time line

Materials:
- internet and book resources
- internet and computer presentation materials
- time line information

Time:
1 - 2 class periods for research and development
1 - 2 class periods for presentations and discussion

Procedure
1. Divide the class into seven (7) groups of students; the number of students in each group should be as even as possible.
2. **Engage:** Explain to the class that they will be working in small groups for the purpose of researching and creating a class presentation for a particular "theme" representing the historical development of solar energy and then presenting this information to their peers.
3. Assign one of the seven themes to each group; or let students select one for their group so that each group has one of the seven different themes. The seven groups are:
   - Early development and uses of solar energy from 600 B.C.E. - 1700s
   - Historical development and uses of passive solar architecture (1800 to present)
   - Historical development and uses of solar thermal (1800 to present)
   - Historical development and uses of photovoltaics (1800 to present)
   - Solar Energy Scientists - select major contributing scientists, include both achievement and personal information
   - Solar Energy milestones, 2002 to present; update EERE timeline used in this lesson
   - Future research and development in the field of solar energy
4. **Explore:** All students will research their subject area. Students should use the time line information, and at least three resources to develop a class presentation.
5. Students should have access to computers and various books for resource material. Computer presentation programs should be utilized for developing the presentations. However, if this is not possible, a poster board presentation may be prepared. The group

members should be assigned (or volunteer for) a significant and equal role in this project researching and presenting material.

6. Discuss and display the rubric so students know your expectations. Use the rubric to score group presentations.
7. **Explain and Elaborate:** Each group is to write a haiku poetic conclusion to summarize their information and to integrate science and the art of literature. (A haiku follows a 5-7-5 syllable pattern and should reflect a sensory image, in this case summarizing the beauty and importance of their segment of solar energy and history.) You may wish to print out or make available the haiku summary of the IPCC's 2013 climate change report (**http://daily.sightline.org/2013/12/16/the-entire-ipcc-report-in-19-illustrated-haiku/**) to help spark creativity in the groups.
8. Have each group present their portion of solar energy history to the class in a sequential order.

Evaluation and Student Assessment

Solar History Presentation Rubric				
Criteria	**Exemplary** **exceeds expectations**	**Above Average** **most skills mastered**	**Average** **approaching expectations with a few errors**	**Novice** **developing expectations - needs improvement**
Main theme - clear, identified title and group introduction				
Main ideas - purposeful and support the theme				
Information - sequential, logical, accurate, and interesting				
Visuals - clearly exhibited and connected to the theme				
Voice and body language - shows enthusiasm and interest				
Organization - coordinated and thoughtful				
Haiku - supports theme, is reflective and conveys emotion				
Overall - Group was prepared and full participation is evident				

Class Discussion Rubric				
Criteria	**8 Excellent**	**7 High Quality**	**6 Acceptable**	**0 Not Done**
Presents valid and reliable point of view				
Includes strategies				
Includes barriers				
Respects the opposing ideas of others				
Supports the similar ideas of others				

Suggested Overall Assessment:

40% group presentation rubric score

20% observation of students participating in the group

40% class discussion based on student participation. Students need to present and defend their ideas and plans for future implementation.

Key Words & Definitions

- **passive solar** – construction technique of using structural elements to bring in heat when needed and deflect or vent heat when it is not desired
- **photovoltaic** – the effect of producing electric current using light from the Sun
- **solar collector** – a device that collects solar energy
- **solar furnace** – a device that uses solar energy to heat , burn or melt
- **solar still** – a device that uses solar energy to distill a liquid

Related Research:

1. Have the students produce skits about their time period.
2. Write and propose a new policy to implement solar technology in a place of your choice.
3. Have students write letters to the newspaper's editor, political leaders, school board, or others in support of using more solar technology as a source of energy in schools.
4. Develop a homeowners guide to use more solar technology as a source of energy in the home.

Related Reading

- ***From Space to Earth: The Story of Solar Electricity*** by John Perlin (Aatec Publications, 1999)
  John Perlin surveys the fascinating evolution of photovoltaics from its problematic and controversial nineteenth century beginnings to its indispensable and versatile role as a power source for contemporary daily life. More than the story of a technology, From Space To Earth is also a chronicle of the individuals who persevered, took chances, bucked authority, innovated, invented, and crusaded to provide humanity with renewable energy.
- ***Let it Shine: The 6,000 Year Story of Solar Energy*** by John Perlin (New World Library, 2013)
  In this book, author John Perlin provides a historical perspective of the influence of solar energy on society throughout the ages. The book provides information relating to the scientific, societal and economic influences contributing to the development of solar technology, as well as explanations of how the various forms of solar technology function.
- ***The Return of the Solar Cat*** by Jim Augustyn (Patty Paw Press, 2003)
  "A cat sunning itself in the doorway of a barn knows all about solar energy. Why can't man learn?" (E.B.White). The Return of the Solar Cat book decisively answers this question. Jim Augustyne takes the Suessian approach to showing the reader our myopia when it comes to the nature of renewable energy, politics, and economics through the fun-house mirror of technologically advanced felines and their 'natural' instincts and behavior which are optimized for solar utilization. Augustyne has developed an alternate universe of whimsy and pointy satire where kitties rule and our human foibles and blindness to the advantages of solar energy are entertainingly exposed.

Internet Sites:

http://inventors.about.com/library/inventors/blsolar2.htm

Time line of photovoltaics listing major inventors and scientists**.**

http://www.energy.gov/about/timeline.htm

Department of Energy’s Energy Timeline.

Solar History

Florida NGSS Standards & Related Subject Common Core

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 4	**SC.912.N.4**		X																		
Earth and Space																					
Standard 6	**SC.912.E.6.**						X														
Life Science																					
Standard 17	**SC.912.L.17.**											X		X			X	X		X	X
Language Arts Standards		**Grades 9 & 10:** LAFS.910.W.3.7, LAFS.910.W.3.8, LAFS.910.SL.2.4, LAFS.910.SL.2.5, LAFS.910.L.3.6 **Grades 11 & 12:** LAFS.1112..W.3.7, LAFS.1112.W.3.8, LAFS.1112.SL.2.4, LAFS.1112.SL.2.5, LAFS.1112.3.6																			
Social Studies Standards		SS.912.A.1.3, SS.912.A.1.5, SS.912.A.3.4, SS.912.G.5.3, SS.912.W.1.1																			

Science–Standard 4: Science and Society
- SC.912.N.4.2 - Weigh the merits of alternative strategies for solving a specific societal problem by comparing a number of different costs and benefits, such as human, economic, and environmental.

Science–Standard 6: Earth Structures
- SC.912.E 6.6 - Analyze past, present, and potential future consequences to the environment resulting from various energy production technologies.

Science–Standard 17: Interdependence
- SC.912.L.17.11 - Evaluate the costs and benefits of renewable and nonrenewable resources, such as water, energy, fossil fuels, wildlife, and forests.
- SC.912.L.17.13 - Discuss the need for adequate monitoring of environmental parameters when making policy decisions.
- SC.912.L.17.16 - Discuss the large-scale environmental impacts resulting from human activity, including waste spills, oil spills, runoff, greenhouse gases, ozone depletion, and surface and groundwater pollution.
- SC.912.L.17.17 - Assess the effectiveness of innovative methods of protecting the environment.
- SC.912.L.17.19 - Describe how different natural resources are produced and how their rates of use and renewal limit availability.

- SC.912.L.17.20 - Predict the impact of individuals on environmental systems and examine how human lifestyles affect sustainability.

Language Arts–Writing Standards

- LAFS.910.W.3.7 & LAFS.1112.W.3.7 - Conduct short as well as more sustained research projects to answer a question or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
- LAFS.910.W.3.8 & LAFS.1112.W.3.8 - Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Language Arts–Standards for Speaking and Listening

- LAFS.910.SL.2.4 & LAFS.1112.SL.2.4 - Present information, findings, and supporting evidence, conveying a clear and distinct perspective, such that listeners can follow the line of reasoning, alternative or opposing perspectives are addressed, and the organization, development, substance, and style are appropriate to purpose, audience, and a range of formal and informal tasks.
- LAFS.910.SL.2.5 & LAFS.1112.SL.2.5 - Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence and to add interest.

Language Arts–Language Standards

- LAFS.910.L.3.6 & LAFS.1112.L.3.6 - Acquire and use accurately general academic and domain-specific words and phrases, sufficient for reading, writing, speaking, and listening at the college and career readiness level.

Social Studies–American History

- SS.912.A.1.3 - Utilize timelines to identify the time sequence of historical data.
- SS.912.A.1.5 - Evaluate the validity, reliability, bias, and authenticity of current events and internet resources.
- SS.912.A.3.4 - Determine how the development of steel, oil, transportation, communication, and business practices affected the United States economy.

Social Studies–Geography

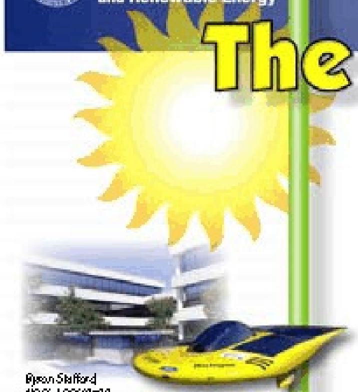
- SS.912.G.5.3 - Analyze case studies of the effects of human use of technology on the environment of places.

Social Studies–World History

- SS.912.W.1.1 - Use timelines to establish cause and effect relationships of historical events.

U.S. Department of Energy
Energy Efficiency
and Renewable Energy

The History of Solar



Byron Stafford
NREL / PIX10730

Byron Stafford,
NREL / PIX05320

Solar technology isn't new. Its history spans from the 7th Century B.C. to today. We started out concentrating the sun's heat with glass and mirrors to light fires. Today, we have everything from solar-powered buildings to solar-powered vehicles.

Here you can learn more about the milestones in the historical development of solar technology, century by century, and year by year. You can also glimpse the future.

This timeline lists the milestones in the historical development of solar technology from the 7th Century B.C. to the 1200s A.D.

7th Century B.C. — 1200s A.D.

Courtesy of New Vision Technologies, Inc./ Images ©2000 NVTech.com

7th Century B.C.

Magnifying glass used to concentrate sun's rays to make fire and to burn ants.

3rd Century B.C.

Greeks and Romans use burning mirrors to light torches for religious purposes.

2nd Century B.C.

As early as 212 BC, the Greek scientist, Archimedes, used the reflective properties of bronze shields to focus sunlight and to set fire to wooden ships from the Roman Empire which were besieging Syracuse. (Although no proof of such a feat exists, the Greek navy recreated the experiment in 1973 and successfully set fire to a wooden boat at a distance of 50 meters.)

20 A.D.

Chinese document use of burning mirrors to light torches for religious purposes.

1st to 4th Century A.D.

The famous Roman bathhouses in the first to fourth centuries A.D. had large south facing windows to let in the sun's warmth. For an example, see information on the http://www.hum.huji.ac.il/archaeology/zippori/RomanSeph.htm Zippori in the Roman Period from the Hebrew University of Jerusalem.

Courtesy of Susan Sczepanski, NREL

6th Century A.D.

Sunrooms on houses and public buildings were so common that the Justinian Code initiated "sun rights" to ensure individual access to the sun.

1200s A.D.

Ancestors of Pueblo people called Anasazi in North America live in south-facing cliff dwellings that capture the winter sun.

The Anasazi cliff dwellings demonstrate passive solar design. (John Thornton, NREL / PIX 02510)

1

1767-1891

This timeline lists the milestones in the historical development of solar technology from 1767 to 1891.

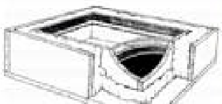


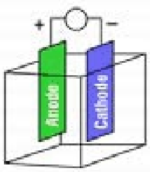
Illustration courtesy of Kevin Porter Solar Cookers, International

1767

Swiss scientist Horace de Saussure was credited with building the world's first solar collector, later used by Sir John Herschel to cook food during his South Africa expedition in the 1830s. See the Solar Cooking Archive for more information on http://solarcooking.org/saussure.htm Sassure and His Hot Boxes of the 1700s.

1816

On September 27, 1816, Robert Stirling applied for a patent for his economiser at the Chancery in Edinburgh, Scotland. By trade, Robert Stirling was actually a minister in the Church of Scotland and he continued to give services until he was eighty-six years old! But, in his spare time, he built heat engines in his home workshop. Lord Kelvin used one of the working models during some of his university classes. This engine was later used in the dish/Stirling system, a solar thermal electric technology that concentrates the sun's thermal energy in order to produce power.



1839

French scientist Edmond Becquerel discovers the photovoltaic effect while experimenting with an electrolytic cell made up of two metal electrodes placed in an electricity-conducting solution—electricity-generation increased when exposed to light.

1860s

French mathematician August Mouchet proposed an idea for solar-powered steam engines. In the following two decades, he and his assistant, Abel Pifre, constructed the first solar powered engines and used them for a variety of applications. These engines became the predecessors of modern parabolic dish collectors.

1873

Willoughby Smith discovered the photoconductivity of selenium.

William Grylls Adams, Courtesy of John Perlin 2002 From Space to Earth The Story of Solar Electricity

1876

1876 William Grylls Adams and Richard Evans Day discover that selenium produces electricity when exposed to light. Although selenium solar cells failed to convert enough sunlight to power electrical equipment, they proved that a solid material could change light into electricity without heat or moving parts.

Samuel P. Langley, Courtesy of NASA

Bolometer, Courtesy of NASA

1880

Samuel P. Langley, invents the bolometer, which is used to measure light from the faintest stars and the sun's heat rays. It consists of a fine wire connected to an electric circuit. When radiation falls on the wire, it becomes very slightly warmer. This increases the electrical resistance of the wire.

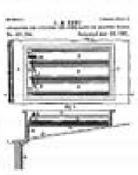
Heinrich Hertz, Courtesy of NASA/ Goddard Space Flight Center

1883

Charles Fritts, an American inventor, described the first solar cells made from selenium wafers.

1887

Heinrich Hertz discovered that ultraviolet light altered the lowest voltage capable of causing a spark to jump between two metal electrodes.



Solar Water Heater Courtesy of John Perlin/ Butti Solar Archives

1891

Baltimore inventor Clarence Kemp patented the first commercial solar water heater. For more information on the water heater, see the http://www.californiasolarcenter.org/history_solarthermal.html California Solar Center.

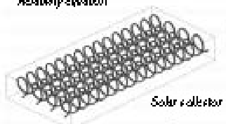
2

Early 1900s

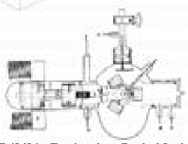
Albert Einstein, courtesy of the Lotte Jacobi Archives, University of Hampshire

$$a = \frac{F}{M}(1-\frac{v^2}{c^2})^{3/2}$$

Theory of Relativity equation

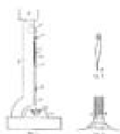


Solar collector



©1916 by The American Physical Society

Jan Czochralski, courtesy of Debra Kaiser, AACG newsletter



Single-crystal silicon

Mid 1950s

Bell Labs scientists, Daryl Chapin, Calvin Fuller, and Gerald Pearson, courtesy of John Perlin

Bell Labs silicon solar cell

This timeline lists the milestones in the historical development of solar technology in the 1900s.

1904
Wilhelm Hallwachs discovered that a combination of copper and cuprous oxide is photosensitive.

1905
Albert Einstein published his paper on the photoelectric effect (along with a paper on his theory of relativity).

1908
1908 William J. Bailley of the Carnegie Steel Company invents a solar collector with copper coils and an insulated box—roughly, it's present design.

1914
The existence of a barrier layer in photovoltaic devices was noted.

1916
Robert Millikan provided experimental proof of the photoelectric effect.

1918
Polish scientist Jan Czochralski developed a way to grow single-crystal silicon. For more information on Czochralski, see the article http://rekt.pol.lublin.pl/users/ptwk/art2.htm Professor Jan Czolchralski (1885-1953) and His Contribution to the Art and Science of Crystal Growth.

1921
Albert Einstein wins the Nobel Prize for his theories (1904 research and technical paper) explaining the photoelectric effect.

1932
Audobert and Stora discover the photovoltaic effect in cadmium sulfide (CdS).

1947
1947 Passive solar buildings in the United States were in such demand, as a result of scarce energy during the prolonged W.W.II, that Libbey-Owens-Ford Glass Company published a book entitled Your Solar House, which profiled forty-nine of the nation's greatest solar architects.
http://www.californiasolarcenter.org/history_solarthermal.html.

1953
Dr. Dan Trivich, Wayne State University, makes the first theoretical calculations of the efficiencies of various materials of different band gap widths based on the spectrum of the sun.

1954
1954 Photovoltaic technology is born in the United States when Daryl Chapin, Calvin Fuller, and Gerald Pearson develop the silicon photovoltaic (PV) cell at Bell Labs—the first solar cell capable of converting enough of the sun's energy into power to run everyday electrical equipment. Bell Telephone Laboratories produced a silicon solar cell with 4% efficiency and later achieved 11% efficiency. See the http://www.californiasolarcenter.org/history_pv.html for more information.

1955
Western Electric began to sell commercial licenses for silicon photovoltaic (PV) technologies. Early successful products included PV-powered dollar bill changers and devices that decoded computer punch cards and tape.

3

Mid 1950s (cont.)

William Cherry
courtesy of
Mark Fitzgerald

Mid-1950s

Architect Frank Bridgers designed the world's first commercial office building using solar water heating and passive design. This solar system has been continuously operating since that time and the Bridgers-Paxton Building, is now in the National Historic Register as the world's first solar heated office building.

1956

William Cherry, U.S. Signal Corps Laboratories, approaches RCA Labs' Paul Rappaport and Joseph Loferski about developing photovoltaic cells for proposed orbiting Earth satellites.

1957

Hoffman Electronics achieved 8% efficient photovoltaic cells.

1958

T. Mandelkorn, U.S. Signal Corps Laboratories, fabricates n-on-p silicon photovoltaic cells (critically important for space cells; more resistant to radiation).

1958

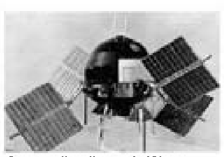
Hoffman Electronics achieves 9% efficient photovoltaic cells.

1958

The Vanguard I space satellite used a small (less than one watt) array to power its radios. Later that year, Explorer III, Vanguard II, and Sputnik-3 were launched with PV-powered systems on board. Despite faltering attempts to commercialize the silicon solar cell in the 1950s and 60s, it was used successfully in powering satellites. It became the accepted energy source for space applications and remains so today. For more information, see the Smithsonian National Air and Space Museum's information on http://www.nasm.si.edu/nasm/dsh/artifacts/SS-vanguard.htm "Vanguard 1".

1959

Hoffman Electronics achieves 10% efficient, commercially available photovoltaic cells. Hoffman also learns to use a grid contact, reducing the series resistance significantly.



Courtesy of http://www.solar101.com

1959

On August 7, the Explorer VI satellite is launched with a photovoltaic array of 9600 cells (1 cm x 2 cm each). Then, on October 13, the Explorer VII satellite is launched.

1960s

1960

Hoffman Electronics achieves 14% efficient photovoltaic cells.

1960

Silicon Sensors, Inc., of Dodgeville, Wisconsin, is founded. It starts producing selenium and silicon photovoltaic cells.

Bell Labs

1962

Bell Telephone Laboratories launches the first telecommunications satellite, the Telstar (initial power 14 watts).

SHARP

1963

Sharp Corporation succeeds in producing practical silicon photovoltaic modules.

1963

Japan installs a 242-watt, photovoltaic array on a lighthouse, the world's largest array at that time.

4

1980s (cont.)

1982

Volkswagen of Germany begins testing photovoltaic arrays mounted on the roofs of Dasher station wagons, generating 160 watts for the ignition system.

1982

The Florida Solar Energy Center's http://www.fsec.ucf.edu/About/quals/index.htm#recentcon "Southeast Residential Experiment Station" begins supporting the U.S. Department of Energy's photovoltaics program in the application of systems engineering.

1982

Worldwide photovoltaic production exceeds 9.3 megawatts.

1983

ARCO Solar dedicates a 6-megawatt photovoltaic substation in central California. The 120-acre, unmanned facility supplies the Pacific Gas & Electric Company's utility grid with enough power for 2,000-2,500 homes.

1983

Solar Design Associates completes a stand-alone, 4-kilowatt powered home in the Hudson River Valley.

1983

Worldwide photovoltaic production exceeds 21.3 megawatts, with sales of more than $250 million.

1984

The Sacramento Municipal Utility District commissions its first 1-megawatt photovoltaic electricity generating facility.

1985

The University of South Wales breaks the 20% efficiency barrier for silicon solar cells under 1-sun conditions.

Warren Gretz, NREL / PIX01224

1986

1986 The world's largest solar thermal facility, located in Kramer Junction, California, was commissioned. The solar field contained rows of mirrors that concentrated the sun's energy onto a system of pipes circulating a heat transfer fluid. The heat transfer fluid was used to produce steam, which powered a conventional turbine to generate electricity.

– Photo Caption: This solar power plant located in Kramer Junction, California, is the largest of nine such plants built in the 1980's. During operation, oil in the receiver tubes collects the concentrated solar energy as heat and is pumped to a power block located at the power plant for generating electricity. (Warren Gretz, NREL / PIX01224)

1986

ARCO Solar releases the G-4000—the world's first commercial thin-film power module.

1988

Dr. Alvin Marks receives patents for two solar power technologies he developed: Lepcon and Lumeloid. Lepcon consists of glass panels covered with a vast array of millions of aluminum or copper strips, each less than a micron or thousandth of a millimeter wide. As sunlight hits the metal strips, the energy in the light is transferred to electrons in the metal, which escape at one end in the form of electricity. Lumeloid uses a similar approach but substitutes cheaper, film-like sheets of plastic for the glass panels and covers the plastic with conductive polymers, long chains of molecular plastic units.

1990s

Warren Gretz, NREL / PIX03541

1991

President George Bush redesignates the U.S. Department of Energy's Solar Energy Research Institute as the National Renewable Energy Laboratory.

1992

1992 University of South Florida develops a 15.9% efficient thin-film photovoltaic cell made of cadmium telluride, breaking the 15% barrier for the first time for this technology.

– Photo caption: Thin-film modules, such as this one made with amorphous silicon, can be deposited on a variety of low-cost substrates, including glass and flexible plastic sheets. (Warren Gretz, NREL / PIX03541)

Sandia National Labs / PIX01728

1992

A 7.5-kilowatt prototype dish system using an advanced stretched-membrane concentrator becomes operational.

Terry O'Rourke / PIX00253

1993

1993 Pacific Gas & Electric completes installation of the first grid-supported photovoltaic system in Kerman, California. The 500-kilowatt system was the first "distributed power" effort.

– Photo caption: Pacific Gas and Electric Company (PG&E) installed a 500-kilowatt photovoltaic system at its Kerman substation to reinforce a weak feeder. PG&E found that distributed systems like this have measurable benefits such as increased system reliability and peak-shaving capabilities. (Terry O'Rourke / PIX00253)

Dave Parsons / PIX06995

1994

The National Renewable Energy Laboratory (formerly the Solar Energy Research Institute) completes construction of its http://www.nrel.gov/buildings/highperformance/serf.html "Solar Energy Research Facility", which was recognized as the most energy-efficient of all U.S. government buildings worldwide. It features not only solar electric system, but also a passive solar design.

1994

First solar dish generator using a free-piston Stirling engine is tied to a utility grid.

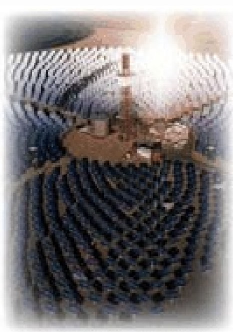
Warren Gretz, NREL / PIX03302

1994

The National Renewable Energy Laboratory develops a solar cell—made from gallium indium phosphide and gallium arsenide—that becomes the first one to exceed 30% conversion efficiency.

1996

The world's most advanced solar-powered airplane, the Icare, flew over Germany. The wings and tail surfaces of the Icare are covered by 3,000 super-efficient solar cells, with a total area of 21 m2. See http://www.ifb.uni-stuttgart.de/icare/pictures/ica-fl2.jpg "Solar Aircraft of the University of Stuttgart" for more information about Icare.



Sandia National Laboratories / PIX01701

1996

The U.S. Department of Energy, along with an industry consortium, begins operating Solar Two—an upgrade of its Solar One concentrating solar power tower project. Operated until 1999, Solar Two demonstrated how solar energy can be stored efficiently and economically so that power can be produced even when the sun isn't shining. It also fostered commercial interest in power towers. See http://www.energylan.sandia.gov/sunlab/Snapshot/STFUTURE.htm "Solar Two Demonstrates Clean Power for the Future" for more information.

– Photo Caption: The Solar Two project will improve the 10-megawatt Solar One central receiver plant in Daggett, CA. A field of mirrored heliostats focuses sunlight on a 300-foot (91 meter) tower, which will be filled with molten nitrate salt. The salt flows like water and can be heated to 1050 degrees F. The salt is pumped through a steam generator to produce the steam to power a conventional, high-efficiency steam turbine to produce electricity. (566 degrees C). (Sandia National Laboratories / PIX01701)

8

1990s

United Solar Systems Corporation / PIX03636

Kiss + Cathcart - Architects / PIX06456

Warren Gretz, NREL / PIX00183

1998

The remote-controlled, solar-powered aircraft, "Pathfinder" sets an altitude record, 80,000 feet, on its 39th consecutive flight on August 6, in Monrovia, California. This altitude is higher than any prop-driven aircraft thus far.

1998

Subhendu Guha, a noted scientist for his pioneering work in amorphous silicon, led the invention of flexible solar shingles, a roofing material and state-of-the-art technology for converting sunlight to electricity.

– Photo caption: The PV shingles mount directly on to the roof and take the place of asphalt shingles. The system is connected to the utility grid through an inverter and produces electricity on customer's side of the meter. United Solar Systems Corporation / PIX03636)

1999

1999 Construction was completed on 4 Times Square, the tallest skyscraper built in the 1990s in New York City. It incorporates more energy-efficient building techniques than any other commercial skyscraper and also includes building-integrated photovoltaic (BIPV) panels on the 37th through 43rd floors on the south- and west-facing facades that produce a portion of the buildings power.

– Photo Caption: 4 Times Squares most advanced feature is the photovoltaic skin, a system that uses thin-film PV panels to replace traditional glass cladding material. The PV curtain wall extends from the 35th to the 48th floor on the south and east walls of the building, making it a highly visible part of the midtown New York skyline. The developer, the Durst Organization, has implemented a wide variety of healthy building and energy efficiency strategies. Kiss + Cathcart Architects designed the building's PV system in collaboration with Fox and Fowle, the base building architects. Energy Photovoltaics of Princeton, NJ, developed the custom PV modules. (Kiss + Cathcon - Architects / PIX06456)

1999

Spectrolab, Inc. and the National Renewable Energy Laboratory develop a photovoltaic solar cell that converts 32.3 percent of the sunlight that hits it into electricity. The high conversion efficiency was achieved by combining three layers of photovoltaic materials into a single solar cell. The cell performed most efficiently when it received sunlight concentrated to 50 times normal. To use such cells in practical applications, the cell is mounted in a device that uses lenses or mirrors to concentrate sunlight onto the cell. Such "concentrator" systems are mounted on tracking systems that keep them pointed toward the sun.

1999

The National Renewable Energy Laboratory achieves a new efficiency record for thin-film photovoltaic solar cells. The measurement of 18.8 percent efficiency for the prototype solar cell topped the previous record by more than 1 percent.

1999

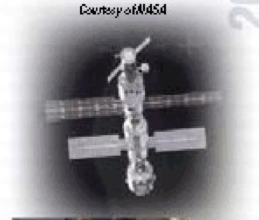
Cumulative worldwide installed photovoltaic capacity reaches 1000 megawatts.

9

2000s

This timeline lists the milestones in the historical development of solar technology in the 2000s.

Courtesy of NASA



Sandia National Labs, PIX10809

2000

First Solar begins production in Perrysburg, Ohio, at the world's largest photovoltaic manufacturing plant with an estimated capacity of producing enough solar panels each year to generate 100 megawatts of power.

2000

At the International Space Station, astronauts begin installing solar panels on what will be the largest solar power array deployed in space. Each "wing" of the array consists of 32,800 solar cells.

2000

Sandia National Laboratories develops a new inverter for solar electric systems that will increase the safety of the systems during a power outage. Inverters convert the direct current (DC) electrical output from solar systems into alternating current (AC), which is the standard current for household wiring and for the power lines that supply electricity to homes.

2000

Two new thin-film solar modules, developed by BP Solarex, break previous performance records. The company's 0.5-square-meter module achieves 10.8 % conversion efficiency—the highest in the world for thin-film modules of its kind. And its 0.9-square-meter module achieved 10.6% conversion efficiency and a power output of 91.5 watts — the highest power output for any thin-film module in the world.

2000

A family in Morrison, Colorado, installs a 12-kilowatt solar electric system on its home—the largest residential installation in the United States to be registered with the U.S. Department of Energy's http://www.millionsolarroofs.com/ "Million Solar Roofs" program. The system provides most of the electricity for the 6,000-square-foot home and family of eight.

2001

Home Depot begins selling residential solar power systems in three of its stores in San Diego, California. A year later it expands sales to include 61 stores nationwide.

Courtesy of NASA, Dryden Flight Research Center Photo Collection

2001

NASA's solar-powered aircraft—Helios sets a new world record for non-rocket-powered aircraft: 96,863 feet, more than 18 miles high.

– Photo caption: The Helios Prototype flying wing is shown near the Hawaiian Islands during its first test flight on solar power. (Photo Courtesy of NASA, Dryden Flight Research Center Photo Collection)

2001

The National Space Development Agency of Japan, or NASDA, announces plans to develop a satellite-based solar power system that would beam energy back to Earth. A satellite carrying large solar panels would use a laser to transmit the power to an airship at an altitude of about 12 miles, which would then transmit the power to Earth.

2001

TerraSun LLC develops a unique method of using holographic films to concentrate sunlight onto a solar cell. Concentrating solar cells typically use Fresnel lenses or mirrors to concentrate sunlight. TerraSun claims that the use of holographic optics allows more selective use of the sunlight, allowing light not needed for power production to pass through the transparent modules. This capability allows the modules to be integrated into buildings as skylights.

2000s

PowerLight Corporation / PIX08431

Warren Gretz
NREL / PIX11979

Courtesy of NASA
Dryden Flight
Research Center
Photo Collection

Courtesy of
[illegible]

2001

PowerLight Corporation places online in Hawaii the world's largest hybrid system that combines the power from both wind and solar energy. The grid-connected system is unusual in that its solar energy capacity—175 kilowatts—is actually larger than its wind energy capacity of 50 kilowatts. Such hybrid power systems combine the strengths of both energy systems to maximize the available power.

2001

British Petroleum (BP) and BP Solar announce the opening of a service station in Indianapolis that features a solar-electric canopy. The Indianapolis station is the first U.S. "BP Connect" store, a model that BP intends to use for all new or significantly revamped BP service stations. The canopy is built using translucent photovoltaic modules made of thin films of silicon deposited onto glass.

– Photo Caption: The PowerView Semi-Transparent Photovoltaic Module, developed by NREL and BP Solar, is a novel system that serves as a roof or window while creating power for a building. BP has to date incorporated the system in more that 150 of its service stations and the panels are envisioned to become a functional replacement for conventional glass in walls, canopies, atriums, entrances and facades in commercial and residential architecture. (Warren Gretz, NREL / PIX 11979)

2002

NASA successfully conducts two tests of a solar-powered, remote-controlled aircraft called Pathfinder Plus. In the first test in July, researchers demonstrated the aircraft's use as a high-altitude platform for tele-communications technologies. Then, in September, a test demonstrated its use as an aerial imaging system for coffee growers.

– Photo Caption: The Pathfinder Plus is a lightweight, solar-powered, remotely piloted flying wing aircraft that is demonstrating the technology of applying solar power for long-duration, high-altitude flight. This solar-powered aircraft could stay airborne for weeks or months on scientific sampling and imaging missions. Solar arrays covering most of the upper wing surface provide power for the aircraft's electric motors, avionics, communications and other electronic systems. It also has a backup battery system that can provide power for between two and five hours to allow limited-duration flight after dark. (Photo Courtesy of NASA, Dryden Flight Research Center Photo Collection)

2002

Union Pacific Railroad installs 350 blue-signal rail yard lanterns, which incorporate energy saving light-emitting diode (LED) technology with solar cells, at its North Platt, Nebraska, rail yard—the largest rail yard in the United States.

2002

ATS Automation Tooling Systems Inc. in Canada starts to commercialize an innovative method of producing solar cells, called Spheral Solar technology. The technology—based on tiny silicon beads bonded between two sheets of aluminum foil—promises lower costs due to its greatly reduced use of silicon relative to conventional multicrystalline silicon solar cells. The technology is not new. It was championed by Texas Instruments (TI) in the early 1990s. But despite U.S. Department of Energy (DOE) funding, TI dropped the initiative. See the DOE http://www.nrel.gov/pvmat/ti.html "Photovoltaic Manufacturing Technology" Web site.

2002

The largest solar power facility in the Northwest—the 38.7-kilowatt White Bluffs Solar Station—goes online in Richland, Washington.

2000s

Solar History: The Future

Courtesy of PowerLight Corporation / PIX12398

POWERLIGHT SOLAR ELECTRIC SYSTEMS

2001

Powerlight Corporation installs the largest rooftop solar power system in the United States—a 1.18 megawatt system—at the Santa Rita Jail in Dublin, California.

– Photo Caption: In Spring 2002, Alameda County, CA successfully completed the fourth largest solar electric system in the world atop the Santa Rita Jail in Dublin, California. This solar installation, the United States' largest rooftop system, was commissioned to help Alameda County reduce and stabilize future energy costs. This smart energy project reduces the jail's use of utility-generated electricity by 30% through solar power generation and energy conservation. Clean energy is generated by a 1.18 Megawatt system consisting of three acres of solar electric or photovoltaic (PV) panels. (Courtesy of PowerLight Corporation / PIX12398)

Here's a look at the expected future direction of solar technology.

Chris Gunn Photography / PIX12165

All buildings will be built to combine energy-efficient design and construction practices and renewable energy technologies for a net-zero energy building. In effect, the building will conserve enough and produce its own energy supply to create a new generation of cost-effective buildings that have zero net annual need for non-renewable energy.

– Photo Caption: This home was built by students from the University of Colorado (CU) for the first Solar Decathlon, a competition sponsored by the U.S. Department of Energy (DOE). Student teams are challenged to integrate aesthetics and modern conveniences with maximum energy production and optimal efficiency. Each collegiate team will build a uniquely designed 500-ft2 -- 800-ft2 house. Decathletes will transported their houses to the National Mall in Washington D.C. for the competition in the fall of 2002. The CU team took first prize in the competition overall. (Chris Gunn Photography / PIX12165)

Photovoltaics research and development will continue intense interest in new materials, cell designs, and novel approaches to solar material and product development. It is a future where the clothes you wear and your mode of transportation can produce power that is clean and safe.

Technology roadmaps for the future outline the research and development path to full competitiveness of concentrating solar power (CSP) with conventional power generation technologies within a decade. The potential of solar power in the Southwest United States is comparable in scale to the hydropower resource of the Northwest. A desert area 10 miles by 15 miles could provide 20,000 megawatts of power, while the electricity needs of the entire United States could theoretically be met by a photovoltaic array within an area 100 miles on a side. Concentrating solar power, or solar thermal electricity, could harness the sun's heat energy to provide large-scale, domestically secure, and environmentally friendly electricity.

Kramer Junction Company / PIX11070

– Photo Caption: This is the world's largest solar power facility, located near Kramer Junction, CA. The facility consists of five Solar Electric Generating Stations (SEGS), with a combined capacity of 150 megawatts. At capacity, that is enough power for 150,000 homes. The facility covers more than 1000 acres, with over 1 million square meters of collector surface. (Kramer Junction Company / PIX11070)

The price of photovoltaic power will be competitive with traditional sources of electricity within 10 years.

Solar electricity will be used to electrolyze water, producing hydrogen for fuel cells for transportation and buildings.

Richard Parish / PIX10732

– Photo Caption: SunLine, a California transit agency, is being evaluated as they add state-of-the-art hydrogen fuel cell buses to their fleets and set up infrastructure facilities for fueling and maintenance. The hydrogen is produced at the site using solar-powered electrolysis and natural gas reforming. Because fuel cell buses aren't yet commercially available, these demonstration projects are used to better understand the technology and plan for the future. (Richard Parish / PIX10732)

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Solar History

Solar History Timeline Project

1. In your group select (or receive from your instructor) one of the seven topics for further research. The topics are:
   - Early development and use of solar energy from 600 B.C.E. - 1700s
   - Historical development and use of passive solar architecture (1800 to present)
   - Historical development and use of solar thermal (1800 to present)
   - Historical development and use of photovoltaics (1800 to present)
   - Solar Energy Scientists - select major contributing scientists, include both achievement and personal information
   - Solar Energy milestones, 2002 to present; update EERE timeline used in this lesson
   - Future research and development in the field of solar energy.
3. Research your topic using the Department of Energy's timeline at **http://www1.eere.energy.gov/solar/pdfs/solar_timeline.pdf** Focus your information to your topic only.
4. Use a minimum of three more sources of your choice to gather information with the purpose of developing a class presentation covering your solar energy topic.
5. For the conclusion of your presentation, write a haiki (a poetic form with a 5-7-5 syllable pattern). As an example, here is a verse from the haiku summary of the IPCC's 2013 climate change report written by scientist Greg Johnson:

   Forty years from now
   children will live in a world
   shaped by our choices.
6. Your group's expectations and goals should be based on meeting the criteria in the presentation rubric.

Class Discussion Preparation

1. Decide on one or more features of using solar energy in our society that you believe would be the most effective with the least environmental impact.
2. Develop an action plan to increase its use as a non-polluting, greener, energy source in our society using the historical development and use that you learned during your class' presentations.
3. Defend your plan and its need for future political support as a way to supplement our society's future energy needs and reduce the use of other polluting energy sources. Be ready to answer the following questions:
   - What is your reasoning for selecting this aspect of solar energy? How was this aspect of solar energy used in the past? Why should we increase its future use?

- What strategies or conditions are needed to implement its use?
- What barriers or restrictions need to be considered?
- When should we begin implementing this plan?