LESSON PLAN

Solar Panels: A Life Story

Grade Level:
7-9

Subjects:
Science & Economics

Length:
3-4 Class Periods

Solar Panels – A Life Story

INTRODUCTION

As solar power gains popularity, solar panels are quickly becoming a part of everyday life. However, the public knows surprisingly little about these energy sources. Where do solar panels come from? How do they work? How much do they really cost? This lesson plan will guide students toward answers by exploring the many factors that influence how solar panels are manufactured.

LESSON OVERVIEW

Grade Level & Subject: 7 – 9, Science and Economics

Length: 3 – 4 class periods

Objectives:

After completing this lesson, students will be able to:
- Identify the raw materials that comprise a solar (photovoltaic, or PV) panel, where those materials come from, and how panels are manufactured.
- Identify the components of a solar panel.
- Determine the costs of manufacturing a solar panel.
- Compare and contrast solar and traditional energy costs using economic and environmental variables.

National Standards Addressed:

This lesson addresses the following National Science Education Standards from the National Academies of Science:[1]
- **Content Standard: NS.5-8.5 SCIENCE AND TECHNOLOGY**
  In grades 5 – 8, all students should develop and understanding of:
  - Technological design
  - Science and technology
- **Content Standard: NS.5-8.7 HISTORY AND NATURE OF SCIENCE**
  In grades 5 – 8, all students should develop an understanding of:
  - Science as a human endeavor
  - Nature of science
  - History of science

[1] National Science Education standards are from the National Academies of Science, 2011, http://www.nas.edu. National Science Education standards can also be found at http://www.education-world.com/standards.

- **Content Standard: NS.5-8.6 PERSONAL AND SOCIAL PERSPECTIVES**
  In grades 5 – 8, all students should develop an understanding of:
  - Populations, resources, and environments
  - Risks and benefits
  - Science and technology in society

21st Century Skills:

This lesson addresses the following 21st Century Skills from the Partnership for 21st Century Skills by asking students to:[2]

- Focus on 21st century skills, content knowledge, and expertise.
- Research real-world data, tools, and experts they will encounter in college, on the job, and in life. Students learn best when actively engaged in solving meaningful problems.
- Investigate and analyze environmental issues, and make accurate conclusions about effective solutions.
- Demonstrate knowledge and understanding of the environment and the circumstances and conditions affecting it, particularly air, climate, land, food, energy, water, and ecosystems.
- Demonstrate knowledge and understanding of society's impact on the natural world (e.g., population growth, population development, resource consumption rate).
- Develop a deep understanding rather than shallow knowledge.

Key Questions:

- Can students understand that solar power is fundamentally different than power derived from fossil fuels?
- Can students identify the basic building blocks of a solar panel?
- Can students understand that solar power involves a considerable manufacturing process?
- Can students estimate the potential savings from proper solar energy use?

Materials Needed:

- Sample of solar cell if available.
- **Reproducible #1 – What's in a Solar Panel?**
- **Reproducible #2 – What's in a Solar Panel? – Answer Key**
- **Reproducible #3 – Coal Power**
- **Reproducible #4 – Production Costs**
- **Reproducible #5 – Average Appliance Wattage Rates**
- **Reproducible #6 – Average Electricity Prices**

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[2] "P21 Framework Definitions." Partnership for 21st Century Skills, 2011. http://www.21stcenturyskills.org/documents/P21_Framework_Definitions.pdf.

Assessment:

Students will be assessed through the following activities:

- Participation in class discussion on energy sources
- Participation in group presentations
- Completion of **Reproducible #1 – What's in a Solar Panel?**
- Completion of research for **Reproducible #4 – Production Costs**
- Completion of **Reproducible #5 – Average Appliance Wattage Rates**
- Completion of **Reproducible #6 – Average Electricity Prices**

LESSON BACKGROUND

Relevant Vocabulary:

- **Amperage:** The strength of a current of electricity expressed in amperes, or amps.[3]
- **Electron:** An elementary particle of an atom that carries a negative charge.[4]
- **Emissions:** The production and discharge of something, in particular a form of gas or radiation (such as a smokestack or an automobile engine).[5]
- **Fossil Fuels:** Formed from the remains of living organisms, these fuel resources (coal, oil, and natural gas) are burned today to provide the bulk of the world's energy.[6]
- **Ingot:** A mass of metal cast into a convenient shape for storage or transportation.[7]
- **Kilowatt:** A measure of 1,000 watts of electrical power.[8]
- **Kilowatt Hour:** A measure of electrical energy equivalent to power consumption of 1,000 watts over 1 hour.[9]
- **Photovoltaics:** The direct conversion of light into electricity at the atomic level.[10]
- **Renewable Energy:** Any naturally occurring, theoretically inexhaustible source of energy, such as biomass, solar, wind, tidal, wave, and hydroelectric power, not derived from fossil or nuclear fuel.[11]

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[3] "Amperage Entry." *Merriam-Webster Online Dictionary*. June 3, 2011 from http://www.merriam-webster.com/dictionary/amperage.

[4] "Electron Entry." *Merriam-Webster Online Dictionary*. Retrieved June 3, 2011 from http://www.merriam-webster.com/dictionary/electron?show=0&t=1307133240.

[5] "Emissions Entry." *Merriam-Webster Online Dictionary*. Retrieved June 3, 2011 from http://www.merriam-webster.com/dictionary/emissions.

[6] "Fossil Fuels Entry." *Oxford University Press Online Dictionary*. Retrieved May 23, 2011 from http://oxforddictionaries.com/view/entry/m_en_us1248640#m_en_us1248640.

[7] "Ingot Entry." *Merriam-Webster Online Dictionary*. June 3 from http://www.merriam-webster.com/dictionary/ingot.

[8] "Kilowatt Entry." *Oxford University Press Online Dictionary*. Retrieved June 3, 2011 from http://oxforddictionaries.com/definition/kilowatt?region=us.

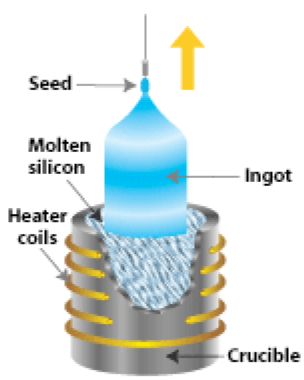
[9] "Kilowatt Hour Entry." *Oxford University Press Online Dictionary*. Retrieved June 3, 2011 from http://oxforddictionaries.com/definition/kilowatt-hour?region=us.

[10] "Photovoltaics." *How Do Photovoltaics Work?* National Aeronautics and Space Administration. Retrieved May 23rd, 2011 from http://science.nasa.gov/science-news/science-at-nasa/2002/solarcells.

- **Semiconductor:** Any of a class of solids (such as germanium or silicon) whose electrical conductivity is between that of a conductor and that of an insulator. At high heat, it is very conductive, while at low heat its conductivity is nearly absent. These materials are beneficial for electrical generation and transmission. [12]
- **Solar Cell:** A device that converts solar radiation into electricity.[13]
- **Solar Panel:** A panel designed to absorb the sun's ray as a source of energy for generating electricity or heating.[14]
- **Voltage:** Electric potential or the difference in potential expressed in volts.[15]
- **Watt:** A basic unit for measuring electrical power.[16]

Background Information:

Our modern lives are filled with many conveniences unknown to previous generations. These conveniences all depend on a massive amount of energy. Much of this energy is generated using products made from fossil fuels. For a long time, this has been an economical way to meet our power needs. However, because petroleum resources are becoming scarce and politically unstable, their costs are increasingly volatile. Additionally, the harmful environmental effects of petroleum-based emissions are becoming widely known across the world. These factors and several others have caused our society to examine alternative ways to generate our power. One of the most popular alternative energy sources harnesses the sun's energy using photovoltaic panels.



Solar panels absorb sunlight and produce an electrical current that humans are able harness and utilize in our everyday routine. They are comprised of many different components; each of these is sourced as a raw material from the earth. These materials are mined, milled, refined, and constructed to manufacture the solar panel that sits atop one's roof and creates energy for one's everyday needs. Solar power, however, does not exist in a vacuum, and when examining the materials that make up a photovoltaic cell, it is also important to keep real-life costs and benefits in mind.

The solar cell that absorbs the sunlight is made mostly of silicon. Silicon is used to create the semiconductor that transfers energy from the solar cell to the home. The silicon is

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[11] "renewable energy." *Dictionary.com Unabridged*. Random House, Inc. 06 Jun. 2011. Dictionary.com http://dictionary.reference.com/browse/renewable energy.
[12] "Semiconductor Entry." *Merriam-Webster Online Dictionary*. Retrieved June 3, 2011 from http://www.merriam-webster.com/dictionary/semiconductor.
[13] "Solar Cell Entry." *Oxford University Press Online Dictionary*. Retrieved June 3, 2011 from http://oxforddictionaries.com/definition/solar+battery?region=us.
[14] *Solar Panel Entry*. Oxford University Press Online Dictionary. Retrieved May 18th, 2011 from http://oxforddictionaries.com/view/entry/m_en_us1292196#m_en_us1292196.
[15] "Voltage Entry." *Merriam-Webster Online Dictionary*. Retrieved June 3, 2011 from http://www.merriam-webster.com/dictionary/voltage.
[16] "Watt Entry." *Oxford University Press Online Dictionary*. Retrieved June 3, 2011 from http://oxforddictionaries.com/definition/watt?region=us.

transformed into an ingot, which is sliced into a wafer that is then processed into a solar cell. Silicon is also used in some panels to create the glass sheet that covers and protects the solar panels from the weather and other destructive forces.

Aluminum is often used to create the frame, which holds the solar cells and makes a panel. Like silicon, aluminum is mined. Aluminum is generally used because of its light weight. Solar panel installations are often mounted on roofs, so lighter installations are [17] better for the structure and durability of the home.

On the back of the panel is a small plastic control box. Inside this box is a small semiconductor plate. This semiconductor transfers the energy collected by the solar panel through wires comprised of copper into an electrical service panel.

The solar industry has only recently begun to make a mark on the U.S. economy. Moving from the raw materials to a working panel to installation and then finally to electrical generation and transmission is a complex process, but gradually becoming more profitable each year. This burgeoning industry is creating a wealth of new careers. From production to sales, marketing, installation, research, maintenance, and the financing of solar panels, these career pathways are set for a likely, and possibly significant, expansion in our lifetimes. Technological advances are helping solar manufacturers lower their costs and pass the savings on to consumers. However, for the solar industry to truly gain a firm footing, it has to be economically viable.

Energy purchased from an electrical company is sold by the kilowatt hour (kWh), and costs are compared in kWh. This is the way students will find energy use represented on their parents' utility bills.

Resources:

Electric Power Monthly – *U.S. Energy Information Administration*
http://www.eia.doe.gov/cneaf/electricity/epm/epm_sum.html
Solar Photovoltaic Electricity Production –*University of California Energy Institute*
http://www.ucei.berkeley.edu/PDF/csemwp176.pdf
Special Report on Renewable Energy Resources – *Intergovernmental Panel on Climate Change*
http://srren.ipcc-wg3.de/
Flat-Plate Photovoltaic Systems – *U.S. Department of Energy*
http://www.eere.energy.gov/basics/renewable_energy/flat_plate_pv_systems.html

[17] "Types of Silicon used in Photovoltaics." *Energy Basics*. U.S. Department of Energy, 05/31/2011. Web. 6 Jun 2011. http://www.eere.energy.gov/basics/renewable_energy/types_silicon.html.

LESSON STEPS

Warm-Up: ***What's in a Solar Panel?***

1. Ask students to think about what they know about a solar panel and then, as a class, answer the following questions:
   a. Where have you seen solar energy being used?
      Calculators, solar panels on roofs, gardens and food (photosynthesis), on highway signs, etc.
   b. What is a solar panel?
      A solar panel is the device that allows us to turn sunlight into electricity.
   c. What do you think a solar panel is made up of? Why?
      Answers will vary, but encourage students to give a reason for their response.

Activity One: ***What Is Solar Power?***

In this activity, students will compare common sources of energy and their environmental impacts.

1. Explain to students that solar energy is a type of renewable energy, meaning that the sun's rays are a natural energy source; they do not need to be mined, extracted, or otherwise taken from the earth. Many researchers and scientists are developing solar technologies to make them even more cost-effective, energy-efficient, and environmentally friendly. Solar energy is converted into electricity through solar panels.
2. Hand out **Reproducible #1 – What's in a Solar Panel?** Allow students time to study the handout and answer the questions. These concepts are fairly complicated so set aside 10 – 20 minutes to review the answers as a class.
3. Lead students through the questions using **Reproducible #2 – What's in a Solar Panel? – Answer Key** to further illustrate the different materials that are used to make solar panels.

Activity Two: ***Comparative Energy and the Environment?***

1. Ask students to name common forms of non-renewable energy and record their answers on the board.
   Oil, coal, natural gas, etc.
2. Now ask students to name common forms of renewable energy and record their answers on the board.
   Solar, wind, geothermal, biomass, hydropower, tidal energy.
3. Explain to students that they will be learning about how several forms of renewable energy are made and from where the materials originate.
4. Ask students to brainstorm about methods of extraction (the process of taking materials from the earth) and refinement (the process of removing impurities or unwanted elements) for the fossil fuels listed on the board. Ask them to consider the tools, jobs, materials, and steps required for each process.

Encourage students to use their imaginations, but be prepared to limit the discussion as these lists can become exhaustive.

5. Using coal as an example, hand out **Reproducible #3 – Coal Power**, which includes a diagram on coal power, and fill out **Reproducible #4 – Production Costs** as a class. This activity will later be assigned as homework for other methods of energy production. Therefore, it will be useful for students to be familiar with this example. Be sure to note for students that this activity involves only the environmental impacts associated with the sourcing, refinement, and manufacture of coal, and not the burning of it. Burning fossil fuels has additional environmental impacts. To complete **Reproducible #4 – Production Costs**, it may be useful to ask students leading questions, such as:
    a. Where is coal found in the U.S.?
    Mining is prevalent in Appalachia – West Virginia, Kentucky, Virginia, and Pennsylvania – and in specific areas of the West such as Montana, but it can be found in places all over the country. Mark these areas on the map.
    b. How does coal get to a power plant? How does that travel affect coal's environmental impact?
    Methods and tools for extraction include mining, large digging machinery, water, and human power. Trucks and trains are often used for transportation, and they burn oil, which contributes to air pollution and global warming. The environmental impact of using fossil fuels to move the coal may be quite large depending on how far the coal has to travel to the nearest power plant. To calculate the precise environmental impact would be quite a lengthy process; the objective here is to have students get a general sense about the impacts beyond just burning fossil fuels in a power plant.
    c. What materials are necessary to turn coal into energy?
    Reproducible #3 – Coal Power provides a diagram. However, the materials necessary to burn coal in a power plant include all the materials needed to build the power plant as well: concrete, steel, machinery etc. The origin of those materials should be marked on the map as well.
6. Break students into 5 groups. Ask each group to examine the environmental impacts of one of the following 5 energy options:
    a. Solar
    b. Oil
    c. Wind
    d. Hydroelectric
    e. Natural gas
7. Hand out **Reproducible #4 – Production Costs** and instruct students to brainstorm within their groups about the production and manufacturing processes required for their assigned energy source.
8. As a homework assignment, have students fill out the worksheet by using the Internet or the library to research the environmental impact of each step used in the process of creating the energy. They should use the map to help them

remember where the source materials originate and how they are transported to different areas.

9. Ask students to complete their work for homework and be ready to present the next day as a group.
10. Using the maps and student research, lead a discussion centered on the overall environmental impact of our energy choices.
    a. Is it viable to cut back on the use of fossil fuels and switch to renewable sources of energy?
    Answers will vary.
    b. What is the "cleanest" type of energy?
    Answers will vary.
    c. Are there other forms of alternative energy that students are familiar with. Are they more or less environmentally friendly?
    Answers will vary.

Activity Three: *Economics and the Use of Solar Energy*

In this activity, students will explore the economics of solar energy by researching real-world applications and their associated costs.

1. Explain to students that they will be investigating the costs of solar energy. Although renewable energy sources are better for the environment, one must consider their economic viability as well.
2. Have students name appliances and electronics in their homes that use energy, such as refrigerators, computers, and televisions. Write them on the board and have students rank them in the order of how much energy they use.
3. Ask students to use **Reproducible #5 - Average Appliance Wattage Rates** to generate answers.
4. Once the actual wattage is established, have students compile a list of the appliances and electronics in their own homes and then calculate, using **Reproducible #5 Average Appliance Wattage Rates**, how many watts they will use in a year. This calculation involves estimating the hours per day as well as the days per year that appliances are in use: (appliance wattage x hours used/day x days used/year)
    - For example, if a window fan runs at 200 watts and is used 4 hours per day, 120 days per year, it will consume 96,000 watt-hours/year.
      200 x 4 x 120 = 96,000
        i. If the timing allows, this lesson can be made more personal by involving parents in an investigation of exactly how much energy they use in their homes by examining their electric bills.
5. Ask students how much money they think it takes to power their homes every year. Explain that energy is sold not in watts, but in kilowatt hours. There are 1,000 kilowatts in each watt; therefore, divide the previous number by 1,000 to find the kilowatt hours that each appliance is running each year. Guess how much utility companies typically charge for a kilowatt hour. Then, use **Reproducible #6 - Average Electricity Prices** to find the average price of electricity in your region. Multiply that number by students' kilowatt hours to find the total price for a year of electricity in their homes.

6. Begin a discussion of the pros and cons of installing solar energy. Students likely will not know the answers to the following questions, but the discussion will set the stage for further investigation to be completed as homework.
   a. How large a system might they install?
      Answers will vary.
   b. How much might it cost?
      Answers will vary.
   c. Is there a price tag that is too much?
      Answers will vary.
   d. Are there tax rebates from the government? Have students research federal, state, and local rebates.
      Answers will vary.
   e. Would they like to cover all of their energy usage or just some of it with solar power?
      Answers will vary.
2. Tell students that they must find their own answers to the discussion questions. As a homework assignment, choose a handful of motivated students to research local solar installation companies.[18] Ask them to call the companies to get estimates on the prices for three different sized arrays (based on a consensus of their answers to the questions above). Students chosen to complete the assignment should come to class prepared to explain the cost, timeline, necessary permits, and potential rebates based on their discussions with the solar companies. This activity will likely take students more than one night to complete, so schedule the deadline for at least two nights after the assignment is given.
   a. When calling, students should be sure to identify themselves as students doing research for a class project. Most solar companies are likely to be willing to help, as they are generally excited to share their solar knowledge. Students should ask their parents' permission before making the calls. If possible, bring in a representative from a solar company to speak with the class.
3. Students who are not assigned to call solar installers should research potential jobs in the solar industry and be prepared to share which job they found most interesting and why. They should be able to explain the pros and cons of that job.

Wrap Up:

As a final wrap-up activity, lead a discussion based on the student presentations. Through the questions below, gauge students' knowledge of solar power, and engage their critical thinking skills in applying this new technology toward a society they will inherit.

- A useful instrument to use during this discussion is the PV Watts Calculator.[19] This tool takes into account local electricity prices and estimate how much money will be saved based on the size of a solar array.
  a. How long might it take to recoup the initial solar investment?
     Answers will vary.

[18] North American Board of Certified Energy Practitioners http://www.nabcep.org.
[19] PV Watts Calculator: http://mapserve3.nrel.gov/PVWatts_Viewer/index.html.

b. Do you anticipate rising costs of electricity? How might this affect the solar industry?
   Answers will vary.
c. What accounts for any differences in estimates from different companies?
   Answers will vary.
d. Where do you see the solar industry heading in the future?
   Answers will vary.

CONCLUSION

This lesson focused on one of the most popular alternative energy sources in use today. Students researched and discussed the development and use of solar panels. Students also examined how solar panels work and their cost. They investigated the complexity of the solar industry, from moving the raw materials to the installation and production of power in a home. They found that production, sales, marketing, installation, research, maintenance, and financing of solar panels are all possible careers. Finally, they learned why it is important for consumers to examine cost savings in order to justify the purchase of a solar array.

LESSON PLAN CREDITS

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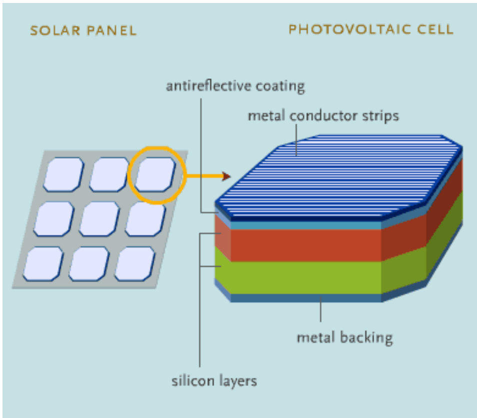
REPRODUCIBLES FOR CLASSROOM USE

This lesson plan contains the following reproducible documents for classroom use:

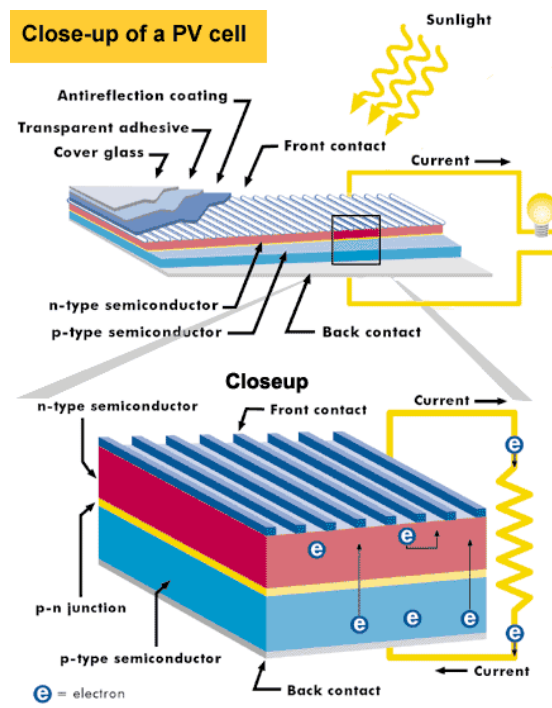
- **Reproducible #1 – What's in a Solar Panel?**
- **Reproducible #2 – What's in a Solar Panel? – Answer Key**
- **Reproducible #3 – Coal Power**
- **Reproducible #4 – Production Costs**
- **Reproducible #5 – Average Appliance Wattage Rates**
- **Reproducible #6 – Average Electricity Prices**

What's in a Solar Panel?



The process of manufacturing a photovoltaic cell begins with very pure polysilicon, a material processed from **quartz** (a mineral) and used extensively throughout the electronics industry. To form the polysilicon into a semiconductor, the polysilicon is heated until it melts.

Trace amounts of **boron** (an element) are added to the melted silicon to create a "P-type" semiconductor material that is used as a layer in the photovoltaic cell. Boron is typically extracted from [20] mines. In fact, the town of Boron, California is home to one of the world's largest boron mines.

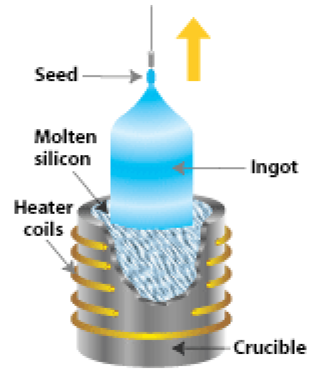


Next, an ingot, or block of silicon, is formed, commonly using one of two methods: 1) growing a pure crystalline silicon ingot from a very small crystal, like a seed, drawn from the molten polysilicon, or 2) casting the molten polysilicon in a block, creating a polycrystalline silicon material. Individual wafers are then sliced from the ingots using wire saws and subjected to surface etching. After the wafers are cleaned, they are placed in a phosphorus diffusion furnace, creating a thin "N-type" semiconductor layer around the entire outer surface of the cell. [21]

Phosphorus is also mined. It can be found in many areas of the world.

20 "Anatomy of a Solar Cell." Inside a Solar Cell. Web. 5 Aug 2011. http://www.pbs.org/wgbh/nova/solar/insi-nf.html.
21 "Close Up of a PV Cell." Solar Energy Technologies. Web. 5 Aug 2011. http://is.njit.edu/competition/2009/Cat2_2_Winner_Group142.

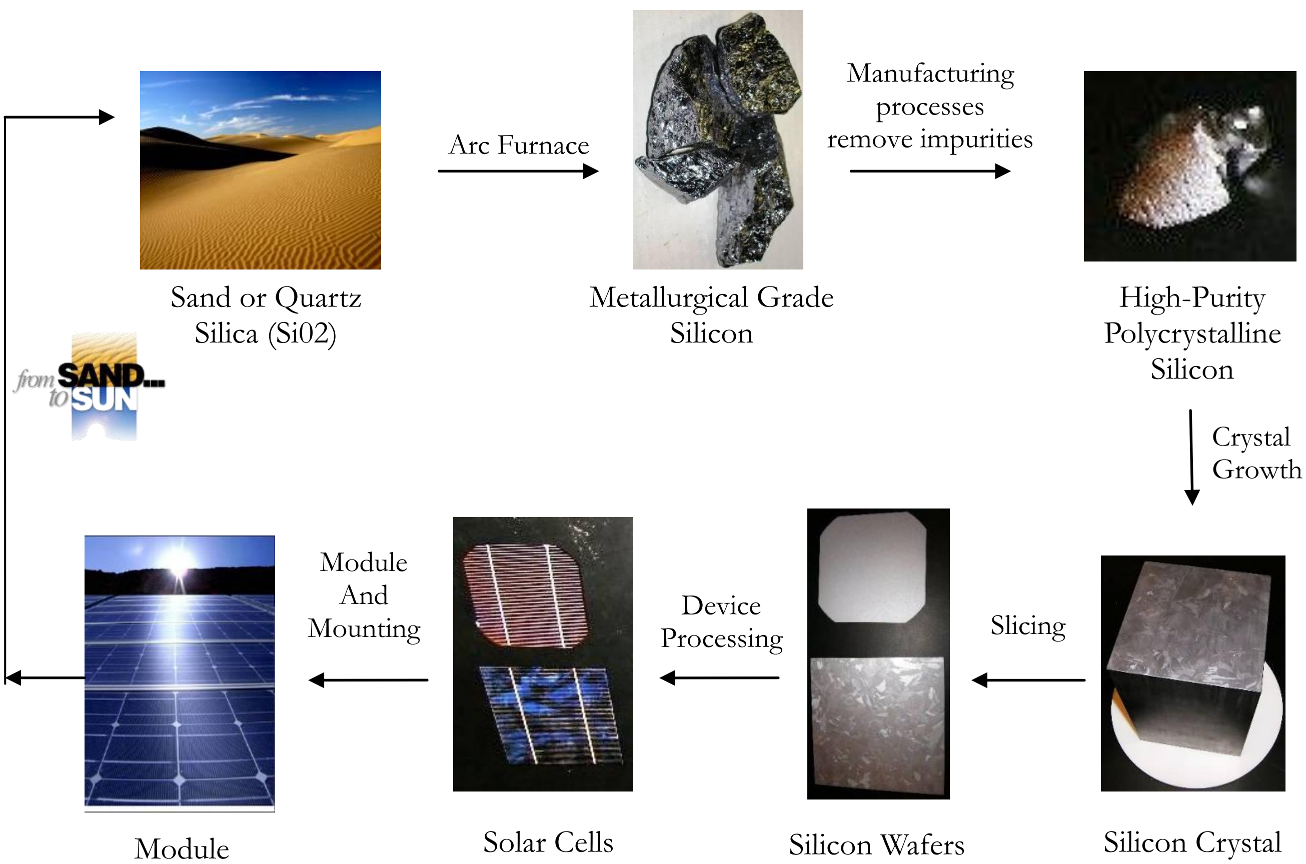
Next, an anti-reflective coating is applied to the top surface of the cell to make photons more easily absorbed, and electrically conductive contacts are imprinted on the top surface of the cell. An aluminized conductive material is deposited on the back surface of each cell. Each cell is then electrically tested, sorted based on current output, and electrically connected to other cells to form cell circuits for assembly in photovoltaic modules.[22]



Aluminum is commonly used in the frame of the solar panel. Aluminum is another element that is found in the earth's crust and needs to be mined. It is typically refined from bauxite ore.

Mining and processing boron, phosphorus, and aluminum are pollution-intensive activities.

PV Module Manufacturing Sequence[23]



22 "How PV Cells are Made." Florida Solar Energy Center. University of Central Florida, n.d. Web. 5 Aug 2011. http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/how_cells_made.htm.

23 Images Courtesy of Dow Corning Corporation, Copyright 2011

1. What are the components of a solar panel?

2. What are the raw materials that comprise a solar panel?

3. How are the raw materials gathered and refined to be used in solar panel production?

4. What is silicon?

5. What is an ingot?

6. How are ingots made into solar cells?

7. How are the solar cell, the semiconductor, and the panel components assembled to create a solar panel?

What's in a Solar Panel? – Answer Key

1. What are the components of a solar panel?
   A solar panel is comprised of solar cells that are sliced from an ingot of crystalline silicon. (An ingot is silicon that has gone through the manufacturing process and creates a large crystal.) The solar cells are connected to each other and then to a semiconductor. The entire assembly is covered with a glass coating and then put in an aluminum frame for mounting on a roof.

2. What are the raw materials that comprise a solar panel?
   Silicon is the main raw material and is derived from quartz or sand, the second most abundant substance on earth. The silicon is transformed in the manufacturing plant into an ingot. Aluminum is also a raw material used in solar panel production. The wire that connects the solar panels is often made of copper, which is an excellent conductor of electricity and also a raw material.

3. How are the raw materials gathered and refined to be used in solar panel production?
   a. ***Quartz is mined and then processed to make high-purity silicon. The silicon is then sold to a manufacturer with sophisticated equipment to transform the silicon into an ingot. Silicon is also made into glass for the panel.***
   b. ***Aluminum is mined. However, recycled aluminum now accounts for most of the aluminum that is used in the solar frame.***
   c. ***Copper is mined, although recycled copper now accounts for the majority of copper in use.***
   d. ***Boron and phosphorous are also mined.***

4. What is silicon?
   Silicon is most commonly found in nature as sand or quartz. It is used as the base material for a semiconductor. It is also used to manufacture glass.

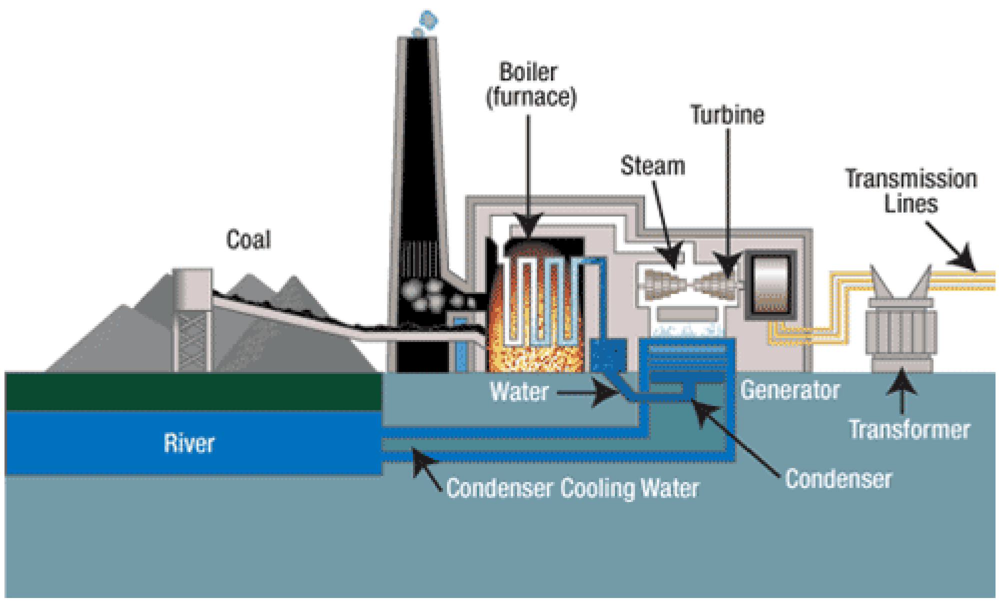
5. What is an ingot?
   An ingot is silicon that has gone through the manufacturing process and creates a large crystal. This crystal is an ingot.

6. How is silicon manufactured into an ingot?
   Many manufacturers keep this process secret. Moreover, they have patented machines to create the cells and make ribbons from this material. Essentially, the silicon is crystallized into the ingot using heat and pressure.

7. How are ingots made into solar cells?
   The ingots are then sliced into very thin wafers. These wafers are then imbedded with circuitry that is connected together. The process of slicing the ingots into wafers is another highly guarded secret from manufacturer to manufacturer.

8. How are the solar cell, the semiconductor and the panel components assembled to create a solar panel?
   Solar cells are manufactured in sterile clean rooms at the manufacturing plant.

Coal Power[24]



24 Coal-Fired Power Plant. Web. 5 Aug 2011. http://www.tva.gov/power/coalart.htm.

Production Costs[25]

Type of Energy: ____

Steps Included in Extraction/Manufacturing/Refinement	Potential Environmental Impact

25 "Blank World Map." Wikimedia Commons. Web. 5 Aug 2011.
http://commons.wikimedia.org/wiki/File:BlankMap-World-v5.png.

Average Appliance Wattage Rates[26]

- Aquarium = 50–1210 watts
- Clock radio = 10
- Coffee maker = 900–1200
- Clothes washer = 350–500
- Clothes dryer = 1800–5000
- Dishwasher = 1200–2400 (using the drying feature greatly increases energy consumption)
- Dehumidifier = 785
- Electric blanket, s*ingle/double bed* = 60/100
- Fans
    - Ceiling = 65–175
    - Window = 55–250
    - Furnace = 750
    - Whole house = 240–750
- Hair dryer = 1200–1875
- Heater *(portable)* = 750–1500
- Clothes iron = 1000–1800
- Microwave oven = 750–1100
- Personal computer
    - CPU – awake/asleep = 120/30 or less
    - Monitor – awake/asleep = 150/30 or less
    - Laptop = 50
- Radio *(stereo)* = 70–400
- Refrigerator *(frost-free, 16 cubic feet)* = 725
- Televisions (color)
    - 19" = 65–110
    - 27" = 113
    - 36" = 133
    - 53"-61" Projection = 170
    - Flat screen = 120
- Toaster = 800–1400
- Toaster oven = 1225
- VCR/DVD = 17–21/20–25
- Vacuum cleaner = 1000–1440
- Water heater *(40 gallon)* = 4500–5500
- Water pump *(deep well)* = 250–1100
- Water bed *(with heater, no cover)* = 120–380

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26 "Estimating Appliance and Home Electronic Energy Use." Energy Savers. U.S. Department of Energy, 02.09.2011. Web. 5 Aug 2011.
http://www.energysavers.gov/your_home/appliances/index.cfm/mytopic=10040.

Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State[27]
Cents per kWh

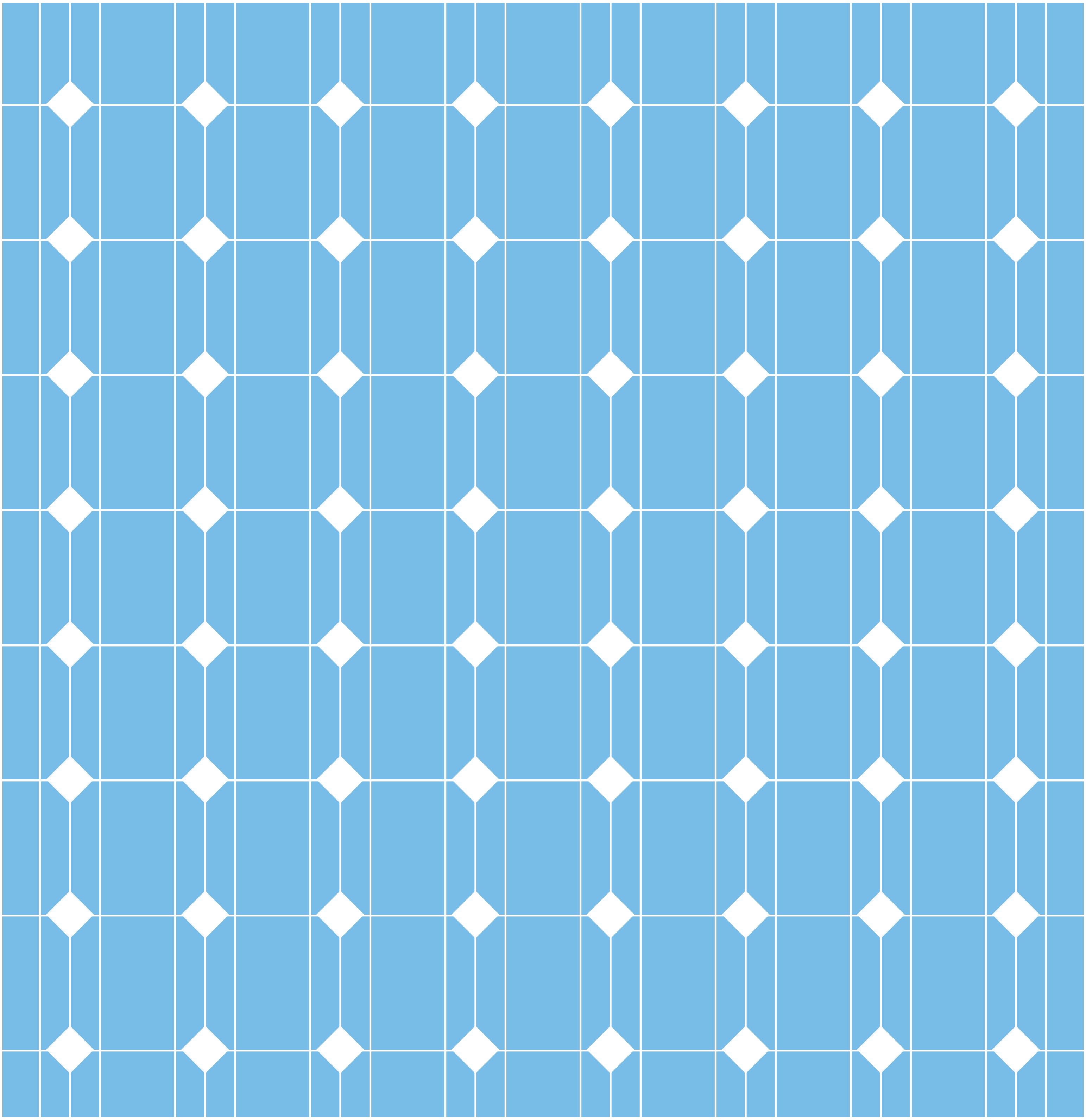
Electric Power Monthly with data for January 2011
Report Released: April 14, 2011

Census Division/ State	**Residential**		**Commercial**[1]		**Industrial**[1]	
	Jan-11	Jan-10	Jan-11	Jan-10	Jan-11	Jan-10
New England	16.09	16.55	14.61	14.8	12.92	13.08
Connecticut	18.03	19.14	16.02	16.54	14.11	15.12
Maine	15.78	15.44	13.16	12.9	9.8	10.86
Massachusetts	14.8	15.56	14.35	14.47	13.58	13.4
New Hampshire	16.34	15.79	14.31	14.18	12.85	12.79
Rhode Island	16.21	15.42	13.25	13.51	11.98	12.39
Vermont	15.79	14.77	13.75	12.99	9.97	9.48
Middle Atlantic	15.06	14.46	13.35	13.31	8.81	7.89
New Jersey	16.14	15.88	13.29	14.01	12.04	9.78
New York	17.4	17.08	15.59	15.22	9.56	9.3
Pennsylvania	12.62	11.72	9.82	9.77	8.15	7.13
East North Central	10.63	10.2	9.03	9.01	6.37	6.41
Illinois	10.41	9.93	8.08	8.49	6.33	6.85
Indiana	9.35	8.48	8.55	7.98	6.14	5.71
Michigan	12.16	11.41	9.62	9.41	7.11	7.15
Ohio	10.13	10.24	9.32	9.56	5.9	6.22
Wisconsin	12.4	11.86	10.11	9.55	7.03	6.45
West North Central	8.83	8.04	7.42	6.86	5.67	5.36
Iowa	9.45	8.67	7.29	6.9	5.03	4.78

27 "Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State." Electricity. U.S. Energy Information Administration, 11.03.2011. Web. 5 Aug 2011. http://www.eia.gov/cneaf/electricity/epm/table5_6_a.html.

Census Division/ State	Residential		Commercial[1]		Industrial[1]	
	Jan-11	Jan-10	Jan-11	Jan-10	Jan-11	Jan-10
Kansas	9.35	8.61	7.94	7.3	6.33	5.76
Minnesota	10.35	9.51	8.08	7.62	6.22	6.22
Missouri	8.16	7.17	6.93	6.15	5.26	4.82
Nebraska	7.72	7.22	7.32	6.86	5.53	5.06
North Dakota	6.92	6.81	6.59	6.35	5.57	5.2
South Dakota	8.24	7.72	7.29	6.88	6.31	5.56
South Atlantic	10.55	9.92	9.35	8.57	6.58	6.54
Delaware	13	12.68	10.99	11.29	10.05	9.44
District of Columbia	13.62	13.29	13.18	13.19	8.09	9.4
Florida	11.57	9.48	9.96	7.59	8.94	7.84
Georgia	9.8	9.12	9.68	8.9	6.34	6.24
Maryland	13.39	14.16	11.62	11.59	8.84	9.74
North Carolina	9.48	9.49	7.75	7.9	5.77	5.94
South Carolina	10.23	10.07	9.12	8.81	5.71	5.69
Virginia	9.64	10.01	7.51	7.76	6.59	6.91
West Virginia	8.78	8.19	7.75	7.25	5.74	5.72
East South Central	9.57	8.7	9.55	8.78	5.91	5.44
Alabama	10.44	10.02	10.31	10.07	6.03	5.64
Kentucky	8.65	7.75	7.96	7.18	5.09	4.85
Mississippi	9.71	9.01	9.64	9.06	6.35	5.93
Tennessee	9.49	8.19	10	8.74	6.87	5.95
West South Central	9.81	10.09	8.41	8.77	5.59	6.05
Arkansas	7.77	8.42	6.84	7.59	5.05	5.8
Louisiana	7.94	8.11	7.99	8.11	5.08	5.92
Oklahoma	8.06	7.54	7.11	6.82	5	4.68
Texas	10.96	11.27	8.85	9.31	5.93	6.36
Mountain	9.63	9.5	8.09	7.99	5.43	5.63

Census Division/ State	Residential		Commercial[1]		Industrial[1]	
	Jan-11	Jan-10	Jan-11	Jan-10	Jan-11	Jan-10
Arizona	9.84	9.58	8.6	8.43	5.94	5.98
Colorado	10.4	10.3	8.31	8.13	6.28	6.47
Idaho	7.83	7.75	6.45	6.54	4.5	4.73
Montana	9.08	8.45	8.74	7.98	5.56	5.68
Nevada	11.61	12.05	9.17	9.92	5.57	6.29
New Mexico	9.77	9.65	8.21	8.09	5.45	5.8
Utah	8.17	8.07	6.56	6.41	4.44	4.4
Wyoming	8.33	8.03	7.28	7.1	4.99	4.9
Pacific Contiguous	12.16	12.14	10.81	10.68	8.88	7.16
California	15.3	15.69	12.26	12.18	9.42	9.5
Oregon	9.19	8.35	7.97	7.35	5.31	5.72
Washington	8.02	7.63	7.47	7.13	9.51	4.21
Pacific Noncontiguous	23.78	21.77	21.44	19.22	21.41	18.7
Alaska	16.61	16.01	14.69	13.4	15.25	14.3
Hawaii	30.13	26.71	28	24.73	23.8	20.36



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