

H.R. 2774: The Solar Energy Research and Advancement Act of 2007

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EXECUTIVE SUMMARY

In the ongoing search for better, cleaner, less-expensive forms of energy, solar power has shown strong potential to be a significant component of the U.S. electricity profile. Solar power is renewable, environmentally friendly and completely free to harvest. While solar technology has made great strides in recent years, it has not yet reached the point of commercial viability on a national level. The Solar Energy Research and Advancement Act of 2007 (H.R.2774) seeks to bridge the gap to commercial viability and make solar power a nationwide source of electricity. Through research programs and job training, H.R.2774 aims to improve current solar technologies and establish the infrastructure necessary to incorporate solar power into our electric profile.

Currently, the vast majority of electricity in the U.S. is generated by combusting fossil fuels, the most common of which is coal. While combusting any fossil fuels carries a variety of environmental consequences, coal is especially detrimental to both the environment and human health. Both the coal extraction and combustion process have significant environmental impacts, including soil erosion, acid rain and climate change. With projected increases in population and electricity consumption, the U.S. needs to reduce its reliance on coal or risk exacerbating these environmental problems.

H.R.2774 seeks to reduce the U.S. reliance on fossil fuels by supporting further research on a variety of solar power technologies. Of all the technologies promoted in H.R.2774, Concentrated Solar Power (CSP) has the greatest potential to address our addiction to coal. CSP is a clean and renewable energy source that can be easily incorporated into the current electric grid. A U.S. Department of Energy study determined that enough solar energy could be harvested on a 92 mile x 92 mile piece of the Nevada desert to provide electricity for the entire U.S. While this scale of production is not realistic given current CSP technologies, this statistic provides an indication of the vast potential of solar power. If only a portion of the U.S. electricity profile can be converted to solar, the environmental benefits would be significant. While solar power alone may not provide the complete solution to our energy needs, it can certainly be part of the solution.

INTRODUCTION

“A bold new era awaits us – an era of clean energy independence...I firmly believe this is the Apollo mission of our generation. Our goal today, however, is not to put a man on the icy surface of the moon, but to capture the awesome power of the sun.”

– Representative Gabrielle Giffords, press release, June 21st, 2007

On June 19, 2007, Rep. Gabrielle Giffords (D-AZ), along with 19 other co-sponsors, introduced The Solar Energy Research and Advancement Act of 2007 to the House of Representatives. According to a report submitted by The Committee on Science and Technology on August 3, 2007, the purpose of this bill is “to support the research, development, and commercial application of solar energy technologies.” As a Representative of Arizona, this legislation is particularly pertinent to Rep. Giffords and her constituency. Arizona has the second fastest growing population in the country behind neighboring Nevada (Census, 2005). With a growing regional population that is located in a hot climate and has a significant air-conditioning load, the increase in electric usage seems inevitable. Rep. Giffords hopes to use solar energy to help meet these growing demands while minimizing our impact on the environment. Giffords effectively sums up the intentions of H.R.2774, by stating “The potential of solar energy is nothing short of astounding...not to tap this unlimited natural resource would be short-sighted and foolish. Solar energy stimulates business development, creates new jobs, helps protect our environment, and promotes energy independence” (Giffords, 2007). H.R.2774 is a research bill that intends to further the development of solar energy technology and to increase its commercial viability. To understand the importance of this, it is important to understand the problems associated with the current electric consumption in the United States.

PROBLEM BEING ADDRESSED

Current Electric Consumption

The United States is an energy-intensive nation. In 2006 alone, the U.S. consumed 3,653 billion kilowatt hours (kWh) of electricity (EIA, 2007). Of the total electricity consumed, 37 percent was in the residential sector, 36 percent in the commercial sector and 27 percent in the industrial sector (EIA, 2007). According to the Department of Energy, total electric consumption in the U.S. is projected to increase by 40 percent by the year 2030 (EIA, 2007). This increase encompasses both total consumption of electricity as well as the total electricity demanded. Consumption is a measurement of how much electricity is used in total across the U.S., whereas demand measures the amount of electricity needed at any one given time. An increase in consumption means that more fuel will be needed to provide enough energy for the country. An increase in demand means that more electric capacity will be needed, in the form of new power

plants. Both of these increases are relevant to H.R.2774, which seeks to make solar power a viable option in meeting this growing need for electricity.

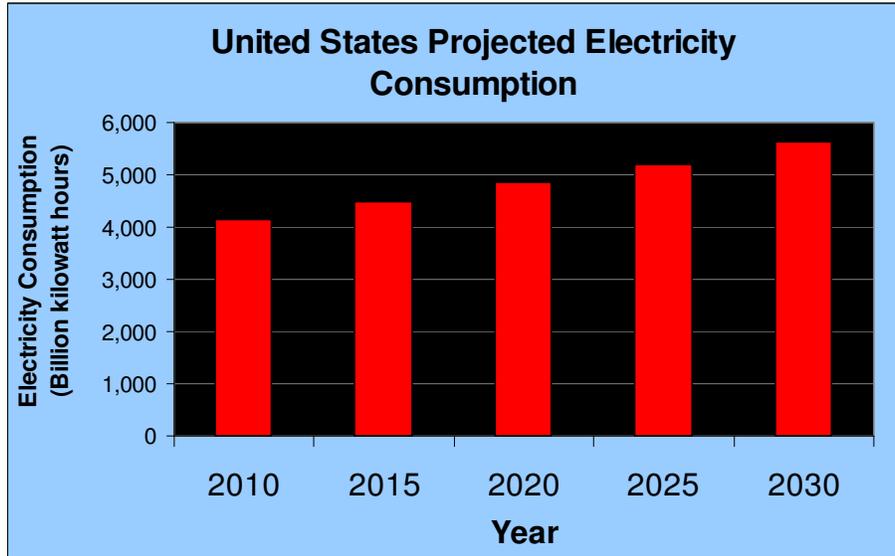


Figure 1. The projected increase in total electricity consumed in the United States from 2010 to 2030 (data source: EIA, 2007)

Electricity is such a common part of the American culture yet not many people are aware of how it is generated. In the U.S., electricity is generated using a variety of fuel sources, many of which are finite in supply. Some electricity is generated through renewable sources, such as hydroelectric, wind and biomass. However, these sources are a small part of our electric profile and account for less than 10% of total electric generation. Solar power accounts for only .07% of total electric generation. Nuclear power plays a substantial role in generating electricity for the U.S., contributing approximately 19% of net generation. However, the most dominant source of electricity is obtained through the combustion of fossil fuels. About 71% of electricity generated in the U.S. is from fossil fuel combustion. Coal is the most commonly used fossil fuel, accounting for 49% of total electric generation in the U.S. (EIA, 2007).

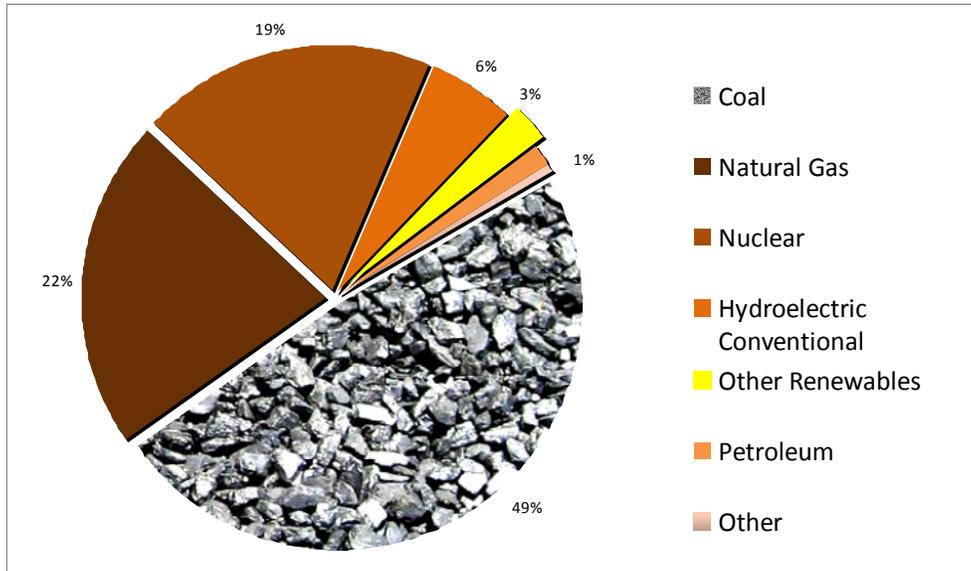


Figure 2. Fuel sources used for total electric generation in the United States for the year 2006 (data source: EIA, 2007)

Coal has been the electric fuel of choice for the U.S. for many years because of abundant domestic reserves and relatively low prices. Most of the modern amenities we enjoy today would not be possible without the widespread use of coal. As a secure and abundant domestic fuel source, coal has helped industrialize the U.S. and raise standards of living. However, there are many serious environmental issues associated with our use of coal in both the extraction and combustion processes. Although it is inexpensive and abundant, coal is a major source of pollution through both land degradation and air emissions. As our population and use of energy continues to grow, the amount of electricity produced by coal is likely to increase as well. This will have devastating consequences for our environment and all of its inhabitants.

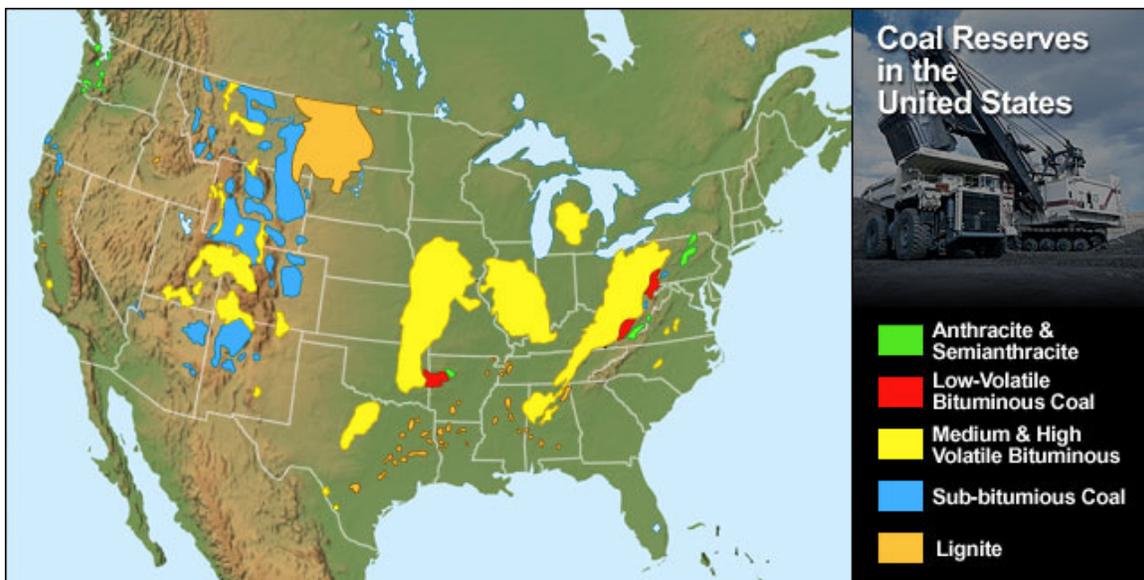


Figure 3. Coal reserves in the United States as of 2007 (source: West Virginia Coal Association: Coal Factbook 2007)

CONVERTING COAL TO ENERGY

Extraction

To extract coal from the earth, both surface and underground mining techniques are employed. Surface mining, also known as strip mining, is the typical method used when coal reserves are close to the earth's surface. Explosives are detonated to remove the land directly above the coal, at which point the coal can be extracted through drilling or blasting. Such a destructive process imposes several environmental repercussions on the mining region, including the destruction of wildlife habitat, vegetation loss, soil erosion and noise and water pollution. Underground mining is utilized when coal reserves are not close to the earth's surface. The two most common methods of underground mining are longwall and room and pillar. In both cases, large amounts of earth are excavated from below the earth's surface to retrieve the coal deposits. Like surface mining, underground mining also carries environmental consequences including soil erosion, changes to local water tables and subsidence. Subsidence occurs when surface land sinks as a result of rock strata collapsing into the space left by the mining operation. This consequence of coal mining can cause damage to buildings, roads, railroads and buried pipe lines that lay above the subsided earth.

In addition, coal mining exposes rocks and minerals to air and water that would not normally be exposed. Iron pyrite is one of these substances and is found in abundance in coal mines. Exposing iron pyrite to water creates a chemical reaction that creates sulfuric acid and iron. The sulfuric acid further dissolves heavy metals such as lead and nickel into ground and/or surface water. Coal mines also tend to disrupt water tables and are therefore prone to flooding. The combination of exposed minerals and excessive flooding creates chemical runoff at the mine site, commonly referred to as acid mine drainage. This acidic runoff can infiltrate ground and surface water, lowering its pH levels and creating an environment inhospitable to aquatic life.

After coal has been successfully extracted, it must be prepared for combustion. The preparation process consists of washing the coal to remove impurities from it. This process usually occurs at a power plant where coal is washed and the wastewater, known as slurry, is discharged into a sludge pond. This water tends to be highly acidic, laden with heavy metals and can dissolve into the ground and surface water. In short, serious environmental impacts accompany all phases of the coal extraction process.

Combustion

While coal extraction and preparation poses several environmental problems, the combustion process carries additional concerns. To generate electricity using coal, the coal must be combusted. In this process, the coal, which has already been washed and crushed, is put into a boiler where it is burned. The heat generated from burning the coal is used to heat water that is housed in heat exchanging pipes running through the boiler. The water is heated to its boiling point, creating steam. The high-pressure steam is piped to a turbine where the steam's pressure is utilized to rotate the blades of the turbine. As the steam rotates the turbine blades, it is continually recovered in a

condenser which cools the steam using water from a nearby source, such as a river or stream. The steam is then converted back to its liquid state and is then either piped back to the boiler to carry out the process again (closed-loop system) or discharged into the water body from which it was taken (once-through process). It is important to note that the once-through process requires significantly more water than a closed-loop system and may not be ideal for use in water scarce regions. The shaft of the turbine that the steam is rotating is attached to a metallic coil, which is suspended in a magnetic field. This apparatus, known as an alternator, is the main component of a generator and is the mechanism for generating electricity. The movement of a metallic object within an electric field creates a flow of electrons, effectively generating an electrical current. The generator is wired to a transformer, which can capture the current and ramp it up to a higher voltage. This high voltage current is now ready to be transmitted to the electric grid and supply electricity to those who need it.

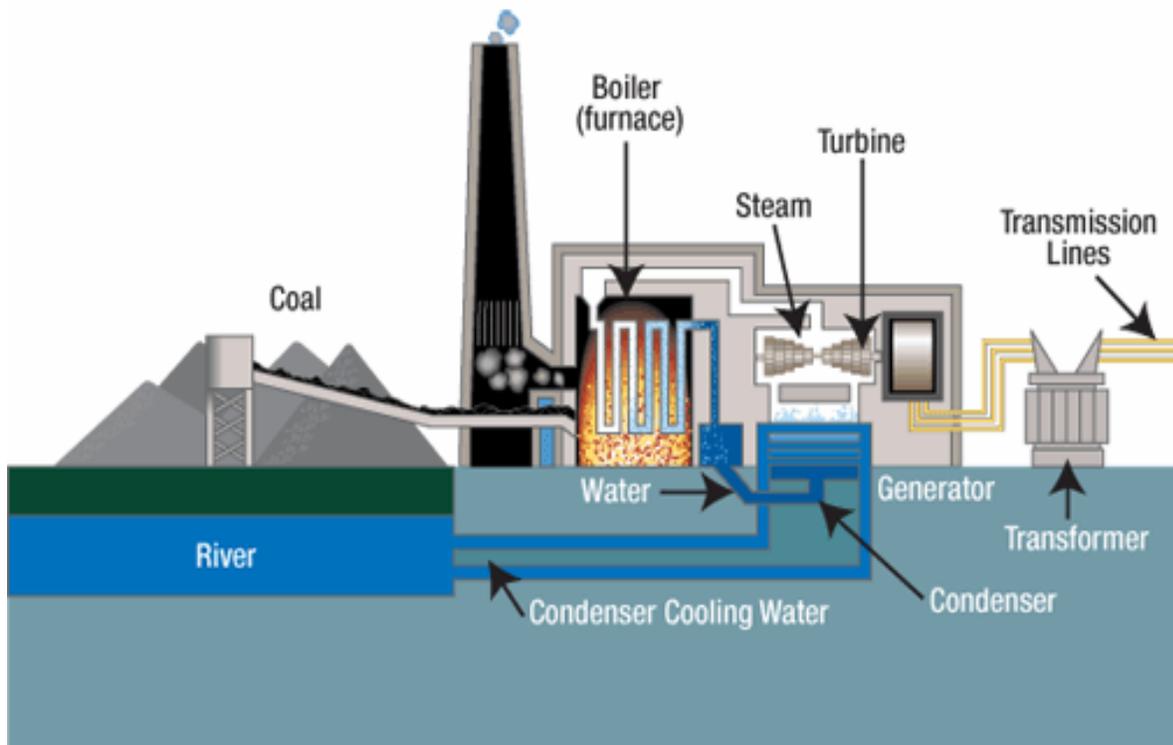


Figure 4. A traditional, coal-fired power plant utilizing a steam-powered turbine to generate electricity. Heat released from combusting coal is used to make steam, which in turn spins the blades of a turbine. The turbine generates electricity which can be transmitted to the grid (source: www.tva.gov)

This process of generating electricity through the use of a steam-powered turbine is not, in itself, an environmentally harmful process. The problem is that most of the power plants in the U.S. use coal as a fuel source; and coal combustion has several negative environmental impacts. When coal is burned, the chemical bonds within coal are broken resulting in the release of heat and the emission into the atmosphere of several chemical compounds. The coal emissions most problematic for the environment are sulfur and nitrogen oxides, carbon dioxide, and mercury.

Acid Rain and Deposition

When sulfur oxides (SO_x) and nitrous oxides (NO_x) are released into the atmosphere, they combine with water vapor to create sulfuric acid (H_2SO_4) and nitric acid (HNO_3). These suspended acids will eventually precipitate from the atmosphere and return to the Earth in the form of acid rain, which has a variety of environmental consequences. When acid rain falls into surface waters, such as lakes and streams, it can decrease the pH of the water to levels that are harmful to aquatic organisms. The average pH of fresh water is 7, while acid rain has a pH ranging from 5.6 to 4.5. When water reaches a pH of 6, snails and rainbow trout begin to die. When it reaches a pH of 5, frogs, crayfish and mayflies die. When the pH reaches 3, all fish in the water will die (Aliff, 2003).

When acid rain falls over land it causes soil acidification. This condition removes key nutrients from the soil, such as calcium and nitrogen, which can have deleterious effects on the health of vegetation. Acid rain can also damage sculptures and buildings if it falls over land. Many of these structures are made from substances containing calcium carbonate, such as marble, which acid rain erodes over time. This leads to the decay of building facades and statues. Coal combustion plays a significant role in the formation of acid rain, as it is responsible for 59% of all SO_x emissions and 18% of all NO_x emissions in the U.S (Sierra Club, 2008).

SO_x and NO_x released into the atmosphere can also return to the earth in the form of dry particulates. These particulates can be inhaled at ground level, exacerbating asthma and other respiratory ailments.

Smog

NO_x emissions at ground level lead to the creation of ground level ozone, also known as smog. When nitrogen dioxide (NO_2) absorbs sunlight it becomes photoexcited and unstable, causing disassociation to nitric oxide (NO) and oxygen (O) atoms. These O atoms combine with the nearby oxygen molecules (O_2) and form ozone (O_3), which is a main component of smog. The remaining NO molecules can react with these ozone molecules to recreate NO_2 , which can then carry out the ozone forming process again. While ozone in the upper atmosphere is beneficial, as it absorbs harmful UV rays from the sun, ground level ozone has several negative health impacts. Inhalation of ground level ozone can aggravate asthma, irritate the respiratory system and lead to permanent lung damage (Spiro, 2003). This is most problematic for humans living in more urbanized regions where an increased number of cars and buses help propagate the formation of ground level ozone (*see Q&A section for a more detailed explanation of the ozone forming process*).

Greenhouse Gas Emissions

Many of the emissions from coal plants are also considered to be greenhouse gasses. When these greenhouse gasses are released, they help trap heat in the atmosphere that would otherwise be radiated back out to space in a process known as the

greenhouse effect. The greenhouse effect is generally a positive feature of the atmosphere as it keeps our climate warm and habitable. However, by adding extra greenhouse gasses to the atmosphere, this warming effect can become magnified and lead to excessive increases in atmospheric temperature, commonly referred to as global warming. CO₂ is one of the primary compounds contributing to the greenhouse effect and is a common by-product of the coal combustion process. In fact, 38 percent of all CO₂ emissions in the atmosphere are from coal combustion (Sierra Club, 2008). While it is not entirely clear what effects global warming may have on the planet, the International Panel on Climate Change has concluded that the rise of global sea levels, disturbance to ecosystems, and an increase of infectious diseases like malaria are all likely to occur (IPCC, 2007).

Mercury

Coal combustion also releases significant amounts of mercury into the atmosphere. In fact, it is estimated that coal combustion is responsible for 30% of all mercury emissions in the U.S. (Sierra Club, 2008). This is because mercury, like SO_x and NO_x, can combine with water vapor in the atmosphere and precipitate back to earth where it is absorbed into waterways. Once in the water, bacterial conversion transforms the relatively stable mercury (Hg) into the water soluble and toxic methyl mercury (CH₃Hg₊). Once in this form, the methyl mercury can be ingested by aquatic organisms, such as fish, where it has the ability to bioaccumulate in fatty tissue, as it is a fat soluble substance (Spiro, 2003). Small fish absorb methyl mercury and are eaten by larger fish which absorb the methyl mercury present in the small fish. Since methyl mercury is fat soluble, larger fish continually accumulate it in their tissues as they eat the smaller fish. By the time the mercury reaches the top of the food chain, it has accumulated in levels significant enough to affect human health and these larger, predatory fish tend to be the ones consumed by humans. If ingested in significant quantities, mercury can have significant impacts on the central nervous system and can also cause deafness, speech difficulties and visual impairment. Even more serious are the risks mercury poses to a developing fetus. Mercury consumed by pregnant mothers has been linked to deafness, blindness, mental retardation and cerebral palsy in fetuses (Spiro, 2003).

THE SOLUTION TO THE PROBLEM

With so many environmental problems associated with coal and the projected increase in electricity consumption, a new approach must be taken to meet the growing electricity demand in the U.S. The Solar Energy Research and Advancement Act of 2007 seeks to address this problem.

H.R. 2774 promotes solar energy use through several different technologies including photovoltaic, daylighting systems, solar air conditioning and concentrated solar power. While the importance of each of these technologies is debatable, H.R. 2774 does place a large emphasis on improving CSP technology and seeks to address some of the issues that are continuing to prevent large-scale adoption of CSP. To achieve this goal, H.R. 2774 provides research and development funding for improving the efficiency of thermal energy storage technology. A second issue this bill seeks to address is water

usage for a CSP system. A CSP plant uses the same amount of water as a traditional coal-fired plant but CSP plants are best suited for areas that are water scarce, making this issue an important one to consider. A third important issue this bill seeks to address is connecting CSP plants to the regional and national electric grids. The Secretary of Energy is instructed to study this matter and make recommendations of transmission upgrades needed so as to bring electricity generated by CSP plants to areas where it is in growing demand.

In addition to CSP, this bill seeks to strengthen such other solar technologies as photovoltaic, daylighting systems and solar air conditioning. This will be achieved through both research and development programs as well as job training programs to ensuring the U.S. workforce is properly trained in solar energy technologies. In terms of appropriations, the photovoltaic demonstration program garners the most money, while appropriations for workforce training and thermal energy storage R&D are a close second and third.

The bill requires a minimum of 60 percent of the funding for the PV demonstration program to come from non-federal sources with the added qualification that at least 10 percent of total funding comes from the state. Federal funds will be allocated based on the proportion of U.S. population in each state. Figure 5 details the amount of appropriated funds in H.R.2774 and the specific technologies they are allocated to.

H.R. 2774 Solar Energy Research and Advancement Act of 2007						
(\$ in Millions)						
	Thermal Energy storage	Solar Energy Curriculum	Daylight Systems	Solar A/C	Photovoltaic	Photovoltaic incl. Matching**
2008	\$5.0	\$10.0	\$3.5	\$2.5	\$15.0	\$39.0
2009	\$7.0	\$10.0	\$3.5	\$2.5	\$30.0	\$78.0
2010	\$9.0	\$10.0	\$3.5	\$2.5	\$45.0	\$117.0
2011	\$10.0	\$10.0	\$3.5	\$2.5	\$60.0	\$156.0
2012	\$12.0	\$10.0	\$3.5	\$2.5	\$70.0	\$182.0
Total	\$43.0	\$50.0	\$17.5	\$12.5	\$220.0	\$572.0

** Grants require 60% matching source from State or Private source, minimum of 10% from State funds

Figure 5. Fund appropriations for various types of solar technologies as part of H.R.2774

H.R.2774 appropriates funds to a variety of solar energy programs, in the hope of creating a diverse solar profile in the U.S. Each of these technologies serves a particular purpose and has certain applications where they may be most effective.

Solar Technologies

Photovoltaic (PV) Cells

PV cells are one of the most common forms of solar power currently being used. The science behind PV can be seen in many applications from large arrays of rooftop panels to the small strips that power many calculators. PV cells absorb radiation from the sun and transform it into an electric current. This reaction is created by a semiconductor material, usually silicon crystal. The silicon crystal is chemically treated in such a way that one half of the crystal has an abundance of electrons, making it negatively charged, while the other half has an electron deficiency, making it positively charged (REUK, 2008). When photons of light from the sun reach the electron-rich half of the silicon crystal, some electrons are knocked loose and are free to move. These free electrons are naturally attracted to the electron-deficient portion of silicon, so they will move in that direction. The movement of electrons in a particular direction is the basic formation of an electric current. This current is harnessed from the panel and is directed through lead wires to where electricity is needed. The electricity generated is a direct current (DC), which for most practical purposes needs to be converted with a transformer to an alternating current (AC) before it can be used. Once transformed into AC, the electricity can be used to power any equipment that runs on AC, such as household appliances or electronics. The electricity also has the potential to be stored in batteries and used as needed. The generation capacity of a PV system is generally a function of how many PV panels are being used and where those panels are located. Areas that receive more sunlight, such as the southwestern U.S., can generate more electricity with PV panels throughout the year than can cloudier regions. While this doesn't mean PV will only work in sunny regions, it will be more efficient and cost effective in areas with more sun.

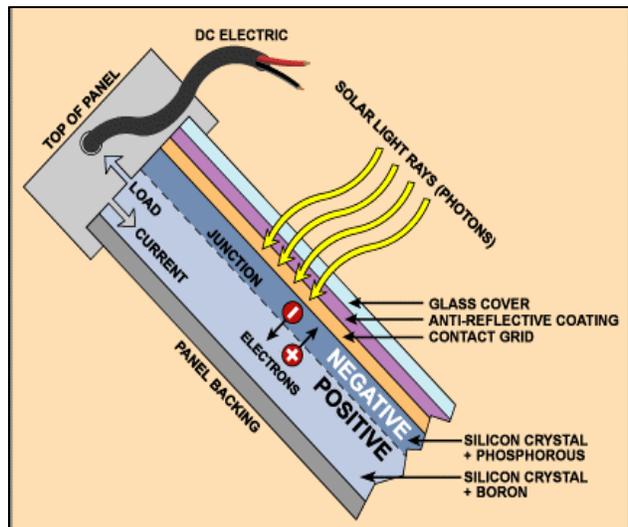


Figure 6. A side view of a solar cell and its generation process.

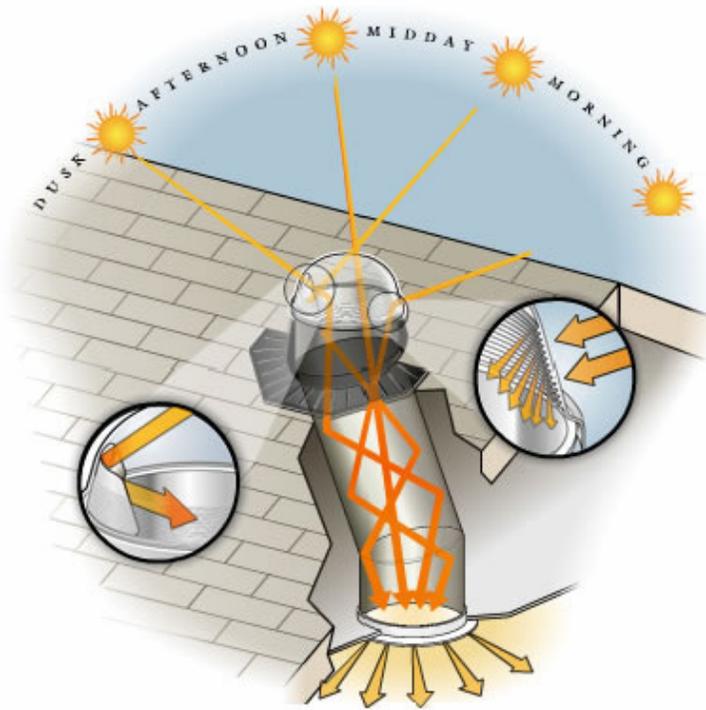


Figure 7. A typical light pipe system installed in the roof of a home. The sun can be harvested throughout the day and used for interior lighting (source: www.solatube.com)

Daylighting systems and light-pipes

Daylighting systems and light-pipes are a simple and effective way to provide lighting using direct sunlight. Light-pipe technology utilizes a solar collector, usually dome shaped, which is mounted on the roof of a building. This collector absorbs and concentrates sunlight using a series of mirrors or fiber optic cables. The concentrated light is piped down into the inhabited space and provides overhead light through what looks similar to a recessed lighting fixture. Figure 7 illustrates how the solar collector harvests sunlight throughout most of the day, though ultimately the fixture will stop providing light when the sun goes down. This system can be an effective alternative to

traditional sources of overhead lighting but has limitations on where it can be used. For example, it would not be very effective for a large apartment building with several floors and limited roof space. Light-pipe technology may be limited in scope but because interior lighting is a very common use of electricity, the widespread adoption of this technology may be able to noticeably reduce electricity consumption.

Solar Air-Conditioning

There are several types of technologies encompassed within the solar air conditioning concept. Some of the more innovative technologies utilize desiccants to remove moisture from the interior air. Desiccants are solid substances that are able to absorb moisture, effectively reducing the humidity in the surrounding air. Since moist air tends to hold heat better than cold air, removing moisture from the air effectively removes heat as well. The desiccant, after being saturated with moisture, is dried out using heat collected from solar energy. This recharges the absorptive capacity of the desiccant and restarts the cooling cycle. Other solar air conditioning technologies simply solar energy to power a traditional air conditioner, similar to one used in an automobile's cooling system. Since cooling loads generally tend to be higher during the day, when there is ample solar energy, a solar air conditioner can effectively utilize the sun's peak power output. Further, the amount of air conditioning used in the U.S. is projected to increase, which will make these technologies increasingly relevant in the coming years.

Concentrated Solar Power (CSP)

CSP generates electricity by first using mirrors to concentrate the sun's energy. In most cases, the mirrors used are of a parabolic shape in order to concentrate the sun's energy onto a focal point. The parabolic shape is advantageous when considering the properties of reflected light. When a ray of light is reflected by a flat mirror, the angle of the incoming, or incident, ray is equal to the outgoing, or reflected, ray. Utilizing this property of light, a parabola can be curved in such a way that all incident rays striking it will be reflected on to a single focal point. This makes the parabolic mirror very efficient at collecting incoming solar rays and concentrating their energy on a set point.

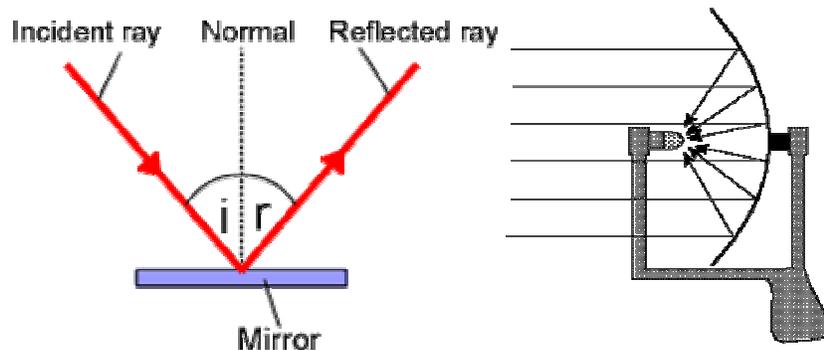


Figure 8. On a flat mirror, the reflection angle of an incident ray is equal to the angle of the reflected ray. A parabolic mirror can reflect several rays on to a focal point. (source: www.library.thinkquest.org, www.scienceprog.com)

The focal point onto which the sun's energy is concentrated contains some form of heat exchange liquid. The liquid traditionally used have been oils with the characteristic of being easily heated to high temperatures. The efficiency of the heat exchange process is dependent on the heat capacity of this liquid. The less solar radiation needed to super-heat the liquid, the more efficient this heat exchange process will be. Once this liquid becomes super-heated, it is pumped through heat exchange pipes located in a tank of water. The heat is transferred from the super-heated oil to the water in the tanks, which creates steam. The steam is routed to a turbine, where its high pressure is used to spin the turbine blades. Like a coal plant, the turbine shaft is attached to a metallic coil suspended in a magnetic field, which creates an electric current as it spins. The electricity is then stepped up in voltage to be transmitted through the electric grid, just as it is in a coal plant. In fact, the entire electricity generation process for CSP is essentially identical to the generation process for a coal plant. The major difference is that a CSP plant utilizes heat from the sun, while a coal plant relies on combustion as a source of heat.

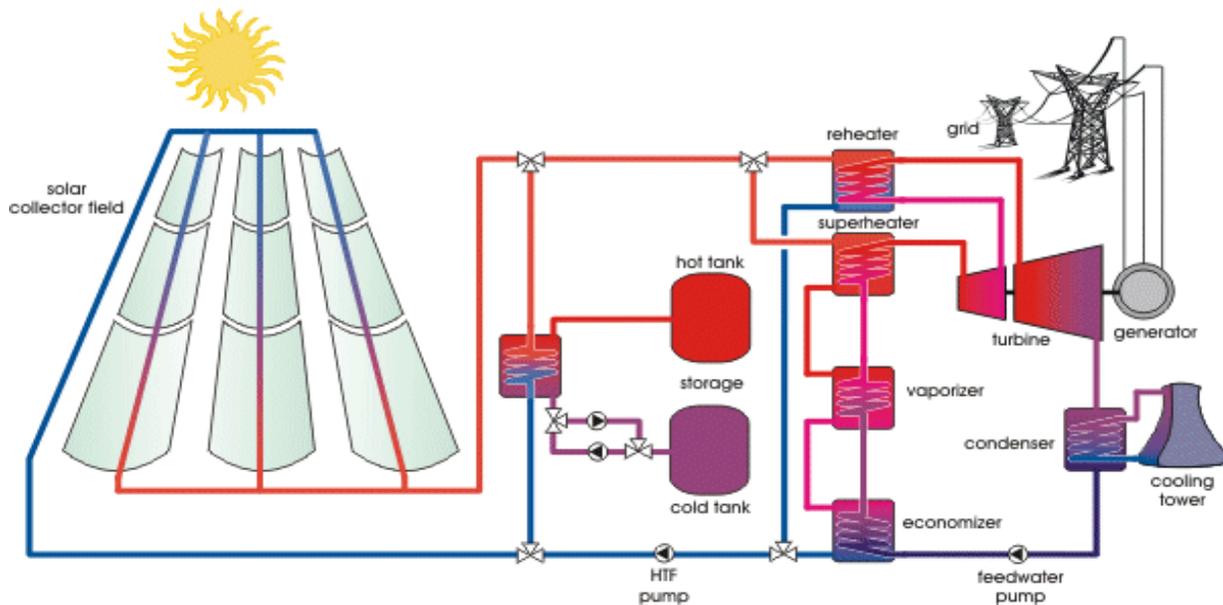


Figure 9. A schematic of a parabolic trough concentrated solar power plant. (source: www.volker-quaschnig.de)

This is the basic concept behind a CSP system, however there are some variations to CSP systems depending on the specific technology. Currently, CSP has three demonstrated technologies that are being employed in both experimental and operational situations.



Figure 10. The three main types of Concentrated Solar Power currently being used or researched. These are the Dish System, the Trough System and the Power Tower System (picture sources: www.thefraserdomain.typepad.com, www.cleanmpg.com and www.abengoasolar.com)

The Dish System

Dish-shaped, parabolic mirrors track the sun and concentrate energy on a receiver located at the focal point. Hydrogen gas is pumped through this receiver as a heat exchange medium and can reach temperatures of 480-1300°F (Abengoa, 2008). As it is heated, the hydrogen expands and drives pistons in a high-efficiency Stirling engine. The engine spins an electric motor and creates electricity. Since the hydrogen gas is contained in a closed-loop system, each dish is highly efficient and very little, if any, gas is lost. To achieve higher electricity outputs, dish system arrays can be scaled up by adding additional dishes as needed. This technology does not offer a method of storage and is therefore only operational during sunny daylight hours.

The Trough System

Elongated parabolic mirrors focus sunlight on a central receiver tube through which a heat transfer fluid is pumped. When it is heated to 300-660°F, the fluid is transferred to a heat exchanger where its thermal energy is used to heat water and create steam (Abengoa, 2008). This steam drives a turbine that generates electricity to be transmitted to the grid. This technology is currently used for immediate power production, but it offers the potential to store thermal energy. The present technology utilizes synthetic oil as a heat exchange fluid, which is an effective heat exchanger but has little heat storage capacity. Using a different heat exchange fluid could make the heat exchange process more efficient and could potentially provide the ability to store heat.

The Power Tower System

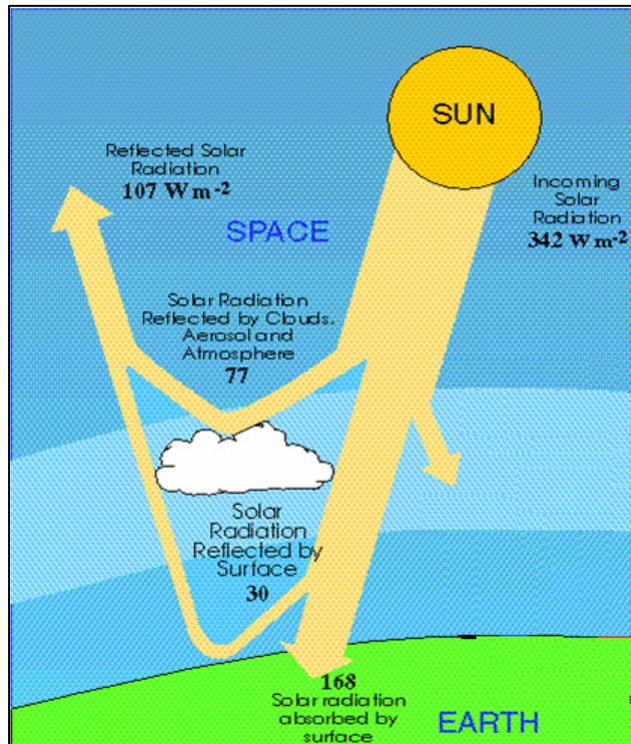
A circular field of computer-controlled flat mirrors is oriented to reflect solar radiation at the upper part of a collection tower located at the center of the circle. Solar energy is concentrated here to over 600 times its initial energy (Abengoa, 2008). The thermal energy is transferred to a molten salt, which is then pumped to a heat exchanger to vaporize water and power electricity-generating turbines. Under current technologies, the molten salt can attain a temperature of 1800°F and can retain this temperature in a storage tank for six to ten hours (Sandia, 2006). During dark or cloudy hours, the power plant can access the stored thermal energy to power turbines instead of relying on traditional fossil fuels. When the stored power is depleted, the plant can return to traditional means of energy production, such as natural gas, until the sun is shining once again.

WHY CONCENTRATED SOLAR POWER?

While all the solar technologies being researched H.R.2774 can help in reducing our dependence on coal, CSP is the technology most likely to help mitigate the problems associated with our current energy consumption. There are several reasons why CSP can have the most significant impact in reducing our nationwide reliance on fossil fuels and why it can combat the negative environmental impacts associated with fossil fuel combustion.

Renewable and Free

A major benefit of a CSP plant is that its fuel comes directly from the sun. This is a renewable energy source that has the added benefit of being completely free to harvest. Earth is constantly being bombarded with energy from the sun, receiving about 198



watts per square meter at its surface. This is a significant amount of energy that is consistently available for us to harvest. The sun is also accessible in all parts of the country, albeit in varied intensities. While the greatest amount of sunlight falls on the southwestern U.S., certain solar technologies, such as PV cells, have proved to be effective in places like New Jersey, where sun does not shine as often. Currently, CSP technology needs intense sunlight to function however it's possible that future technologies may be able to operate in areas with less sun.

Figure 11. Earth's incoming solar radiation. 168 watts per square meter are absorbed by the Earth's surface and another 30 watts per square meter are reflected off the surface. The total of 198 watts per square meter would be available for solar power. (source: <http://www.atmos.washington.edu>)

Clean

The generation of electricity through CSP produces few, if any, harmful atmospheric emissions. Since the energy source comes directly from the sun, there is no destructive extraction process. There is also no combustion process when generating power with CSP, which eliminates the issue of hazardous emissions. In most electric generation systems, the fuel must be combusted to release heat for use in generation. With CSP, energy from the sun is directly utilized for the heat used in the electricity generation process. This lack of a conversion step is a key component of what makes CSP such a clean energy source.

Grid Ready

The majority of power plants in the U.S. utilize steam-powered turbines to generate electricity. Since CSP is designed to power these types of turbines, existing power plants can be retrofitted with CSP systems. Much of the electric infrastructure currently in place, i.e. power plants and transmission lines, would be compatible with CSP systems, making it easier to tie CSP into the existing electric grid. This will avoid the costs associated with a dramatic grid overhaul. Further, CSP can be used in

conjunction with other traditional fuels, such as natural gas, at a power plant. In this scenario, CSP would be used to generate electricity during hours with abundant sunlight. When the sun goes down, natural gas can be used to generate electricity. Figure 12 illustrates what this hybrid system may look like. This type of combined fuel system may be a good stepping stone on the path to plants that run entirely on CSP.

Storage Potential

One of the most problematic aspects of current solar technology is its inability to provide energy when the sun goes down. While power storage systems do exist, such as batteries in PV systems, their capabilities are limited. CSP systems have demonstrated the potential to store significant amounts of heat through the use of molten salts. These salts are used as the system's heat exchange fluid but they can also be stored and later used to generate electricity. If a CSP plant is producing more electricity than the grid demands, some of the molten salt can be diverted from the electricity generation process and placed into a storage tank. The tank essentially acts as a giant Thermos, allowing the molten salt to retain the heat it has absorbed from the sun. When this reserve heat is needed, for instance if cloud cover reduces the plant's ability to generate electricity directly from the sun, the stored molten salts can be piped back into the generation process to produce electricity. Currently, molten salts used in this capacity have a demonstrated storage capability of about six hours.

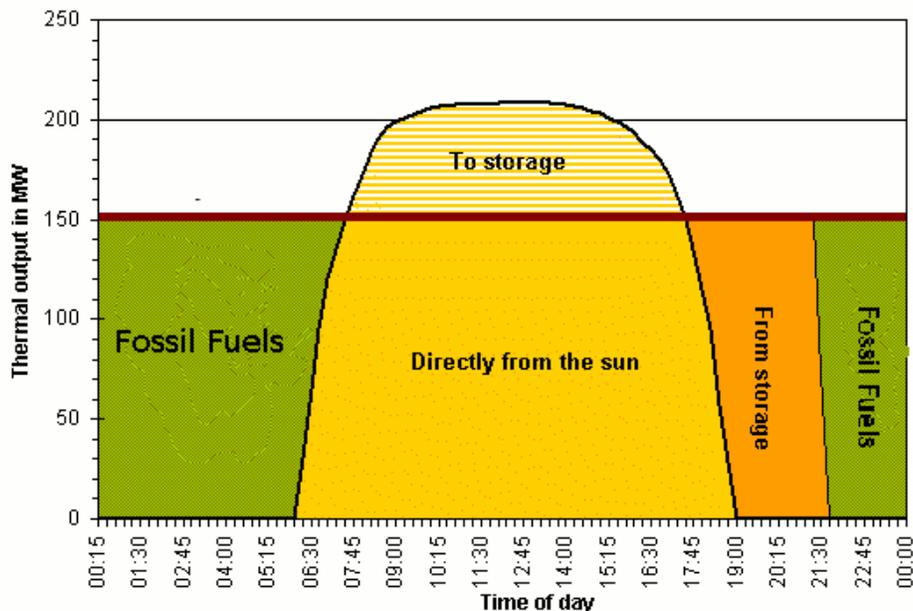


Figure 12. The load pattern of a plant utilizing both CSP and a fossil fuel source to generate electricity. During daytime hours, sunlight directly generates all electricity demanded with any excess heat stored for later use. When the sun goes down, either stored heat or fossil fuel combustion can be used to generate electricity. (source: www.volker-quaschnig.de)

CASE STUDIES

While CSP is still a nascent technology, operational and experimental plants have demonstrated functionality in a variety of locations. There are also several plants currently being built, many of which have significant electricity generation capacity.

Southern California Edison Plant

Outside of Los Angeles, California, Southern California Edison is building one of the world's largest solar power plants. This CSP dish system plant will span seven square miles and will be capable of producing more electricity than all U.S. solar plants combined. Utilizing efficient Stirling engines at the receivers, this plant is estimated to have a capacity of about 250 MW and is scheduled for completion in 2010 (TheirEarth, 2007). To put the size of this plant into perspective, it takes about 1 MW to power 800 average homes in the U.S. This project is the most ambitious CSP plant planned in the U.S. and will be a boon to the widespread adoption of CSP if it proves successful.

Nevada Solar One

Located near Boulder City, Nevada, about 40 miles southeast of Las Vegas, the Solar One plant was completed in 1991 and has a maximum generation capacity of 75 MW. Encompassing 400 acres, about the size of 270 football fields, this parabolic trough system is the third largest CSP plant in the world. Solar One represents a total investment of \$266 million USD, and has created 28 permanent, operations-related jobs. On June 7, 2007, Solar One began supplying the Nevada grid with electricity and is still operational today (Acciona, 2007). This illustrates how current CSP technologies can prove to be commercially viable today.



Figure 13. Rows of parabolic troughs at the Solar One plant, in Boulder City, NV (source:www.nevadasolarone.net/)

Solar Tres

Slated to be the first commercial power tower system in the world, Solar Tres is currently under construction near Seville, Spain. Part of a larger, 300 MW solar power plant, Solar Tres is scheduled for completion in 2013 and will be capable of generating about 11MW (SENER, 2007). The plant will be the first to utilize molten salt as a heat transfer liquid in commercial electric generation. Further, the system is said to have a storage capacity of 15 hours, which is nearly three times higher than current demonstrated storage capacities. If Solar Tres can meet these goals and is successful as a commercial electricity source, it will represent a huge advance in CSP technology and a big step towards commercial viability in the U.S.

CSP CHALLENGES

With all the great benefits of solar energy, why does solar power currently only make up less than 0.1 percent of the total electric generation in the U.S. (EIA, 2007). The basic answer to this is that there are still significant issues regarding the generation and distribution of solar power. This is especially true for CSP, which still has several challenges that must be addressed before it can become a commercially viable source of electricity.

Intermittent Supply

The intermittent nature of CSP is one of the major issues that need to be addressed if it can become a commercially viable power source. Continuous generation of electricity is essential to maintain baseload level of power. A consistent level of electricity must be supplied to power the basic needs of consumers. However, the output of solar power is limited by the cycle of the sun, achieving its maximum output to Earth in the middle of the day and providing no power during the nighttime hours. While high incident solar energy follows similar daily patterns as high electricity demand, they are not perfectly correlated. The demand for electricity peaks during the warmest, sunniest time of the day but high electricity demand continues after the sun has already begun to descend. Additionally, electricity demand can still be high at night and on cloudy days when there is little or no incoming solar radiation. While CSP can work on cloudy days, it is much less efficient and may not be able to supply the electricity needed by the grid. For CSP to become a practical source of baseload electricity, plants will have to be able to operate when the sun is not shining or during periods of inclement weather.

Costs

Utilities are naturally attracted to the lowest cost solution to meet electricity demand. Currently electricity costs for CSP generation are between \$0.15 and \$0.17 per kWh compared to \$0.05 cents per kWh for coal (CNet.com). Investors predict that \$0.10 per kWh will be the crucial threshold to reach for widespread adoption of CSP to be realized (CNet.com). There are two main factors behind the high cost of CSP. Due to its unique land requirements, the distance between CSP installations and consumers tends to be higher than other power plants. As the current cost for building high voltage power lines is \$1.5 million per mile (CNet.com), significant costs can accrue when developing infrastructure to connect a CSP plant to the grid. Another factor leading to high costs is that CSP lacks proven generating capacities. One potential way to bring the price of CSP would be to increase the scale of CSP plants. Pacific Gas and Electric (PG&E) believes that upgrading a 300 MW plant to 600 MW would bring the cost down from \$0.17 per kWh to around \$0.11 per kWh, which will be a more competitive price.

Price of electricity generation per kWh by fuel source

Power Plant	Low Range	Average Range	High Range
Gas	\$0.039	\$0.042	\$0.044
Coal	\$0.048	\$0.052	\$0.055
Nuclear	\$0.111	\$0.128	\$0.145
Hydro	\$0.051	\$0.082	\$0.113
Solar(all types)	\$0.150	\$0.225	\$0.300
CSP	\$0.150	\$0.160	\$0.170

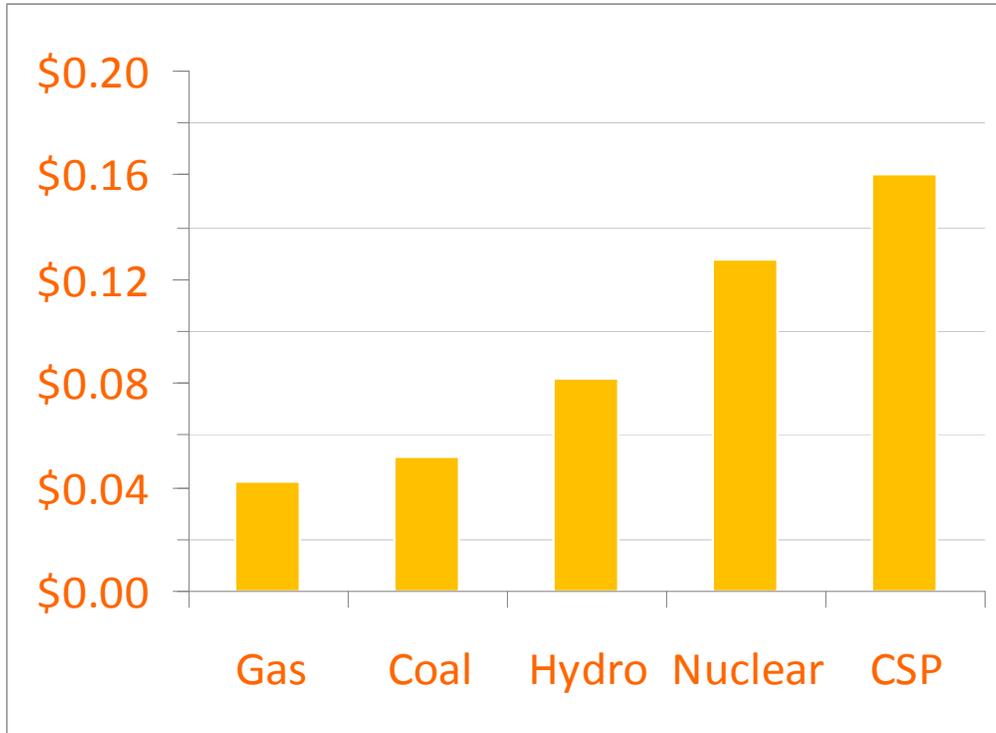


Figure 14. Price of electricity generation per kWh for common fossil fuel and renewable energy sources as of July, 2008 (data source: PESWiki, 2008)

Land Usage

There are many limiting factors to where CSP plants can be built. CSP is most efficient when built on land with a 1 percent or lower grade and where constant solar input is most intense. This means that regions with extensive cloud cover are not acceptable for construction, nor are areas with significant pitches. In the U.S., the region best suited for CSP plants is the desert area of the southwest. The amount of land needed for a large scale CSP plant is significant but highly dependant on the specific CSP technology and the area where the plant is located. It is difficult to give a precise number but the land requirements for CSP are likely greater than or equal to the land needed for a traditional coal plant. Another issue to consider is the disruption of animal habitat that may occur from the establishment of an expansive CSP plant. Fragmentation of animal habitat caused by manmade barriers can have severely detrimental effects on animal populations.

Water Usage

Electric power plants that use steam-powered turbines for generating electricity are inherently water intensive. CSP plants are no different from coal plants in this way and

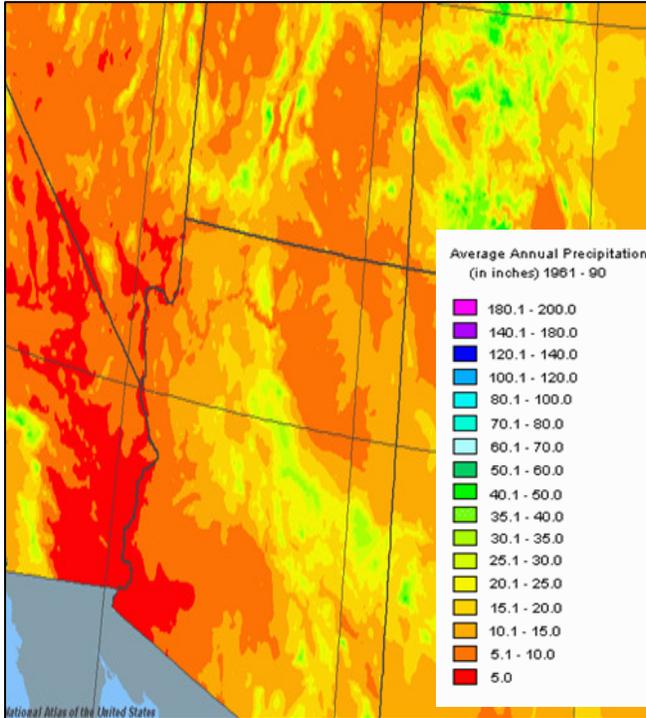


Figure 15. Average annual precipitation levels for the southwestern United States.

(source: www.nationalatlas.gov)

use just about the same amount of water (Mancini, 2008). The problem is that CSP plants are most effective in areas that experience water scarcity. As stated before, CSP plants will only be commercially viable in the southwestern U.S. at present. This hot, arid region already contends with issues of water scarcity, so the addition of CSP plants could be problematic. The annual precipitation in this region is exceptionally low, as evidenced in Figure 15. Compare these rates of precipitation, in some areas less than 5” inches per year, to that of the New York City region, which receives around 40” of precipitation per year (Hypertextbook, 2005). Nearly all power plants built in the Southwest today use closed-loop cooling systems which are very water efficient compared to single use, or ‘once-through’, systems. A closed-loop system uses about 23 gallons per MWh for cooling and generation, thus a 300 MW CSP plant would consume about 69,000 gallons per hour. This uses considerably less water than a traditional, ‘once-through’ plant which requires 7,500–2,000 gallons per MWh (Baum, 2003). However, even in a closed-loop system water usage is an issue as about 5% of the total water used will be lost to evaporation (NETL, 2007). In areas with water scarcity issues, addressing the water usage associated with CSP will be crucial to making it a viable energy solution.

Grid Issues

While CSP technology is currently able to supply the grid with electricity, the inefficiencies inherent to the grid itself make it difficult for CSP plants to provide power for the entire nation. To get electricity from the southwestern U.S. to high-use areas on the east coast, it would have to be transmitted nearly the length of the country through the electric grid. There are significant losses associated with this transmission process that are amplified the further the electricity must travel. This makes it difficult for CSP to provide power for the entire U.S. since generation takes place in a small, specific region. While CSP could supply local power needs, grid inefficiencies make it difficult for CSP plants to supply electricity nationwide.

MEASURES OF SUCCESS:

CSP is a promising technology, but some major hurdles must be overcome for it to be an effective source of electricity. Ultimately, the success of H.R.2774 will be based on making CSP a commercially viable source of electricity. This does not mean that CSP occupies a niche as a clean, but expensive alternative. Rather, commercial viability and success are defined as getting CSP to the point where it is competitive with and even preferred to other traditional energy sources, such as coal. Elevating CSP to such a level will make the Solar Research and Advancement Act of 2007 a success. The question now is what needs to happen in order for CSP to achieve commercial viability and what positive environmental benefits would be expected if success were achieved?

Increased Efficiency

To help reduce costs, CSP technology needs to become more efficient at turning the energy from the sun into energy that can be used. Currently, a standard CSP plant can convert 15% of the incoming solar energy it receives into electricity (ECER, 2008). Compare this with coal plants, which have efficiency levels of 37-40% (Torrens, 1997). This efficiency measure accounts only for the conversion from fuel source to electricity rather than transmission, so it's the electric generation process that is of highest concern. To increase its efficiency, CSP plants should focus on several factors. Mirrors must be made more effective at concentrating the sun's rays so that more energy can be generated per watt of sunlight received. Another improvement would be to find a heat exchange fluid with a higher heat capacity. This would allow more heat to be absorbed in the fluid and ultimately make more energy available to generate electricity. Any energy losses in the generation process should be accounted for and minimized. Waste heat could potentially be utilized in the plant to power other functions. Finally, energy efficient technologies should be employed wherever possible in order to help minimize any operational energy losses.

Increased Storage

While storage capability is one of the main reasons CSP can potentially be an effective source of power, the storage technology needs to advance further to make CSP commercially viable. The current proven storage capacity for a CSP plant is about six hours, that is, the plant can provide six hours of electricity after the sun goes down. For a CSP plant to operate independently of any fossil fuel supplements, this storage capacity needs to increase to a point where it can generate power throughout all of the nighttime hours and during periods of inclement weather. The exact degree of storage necessary is unclear, but getting it up to 16 hours of capacity would likely be a minimum level. One way of achieving increased storage capacity would be to simply increase the size of the storage tanks containing the molten salts. For small scale CSP projects (<100 MW) this may be viable, however considering that four hours of capacity requires a tank that is 80 feet in diameter and 30 feet in height, increasing the tank size on a large-scale CSP plant (>400 MW) is likely not a viable option (Sandia, 2006). The most practical way to increase storage capacity would be to develop a storage medium with a

higher heat capacity. This may mean a different type of molten salt, or a different substance altogether, but the goal is more heat storage over a longer period of time.

Decreased Water Use

To address the pressing concerns of water scarcity in areas where CSP plants will be located, the water used by CSP plants must be decreased. While CSP only use about 5% more water than a coal or natural gas plant (Mancini, 2008), the difference may be enough that CSP plants would not be a preferred choice to build. To reduce water use in CSP plants, modifications must be made to the processes that use water. For the steam generation and condensation processes, closed-loop systems must be employed to reduce the amount of water lost. These systems are already in use for other power plants, so applying them to CSP plants is feasible. To further reduce water use, a dry cooling system could be employed, in which condensation can be achieved without using any water. While the process of dry cooling is costly, it can add 1.5-2 cents/kWh to the cost of generation (Mancini, 2008), it may have the most potential at addressing the issue of water usage. Finally, selectively locating a CSP plant will help mitigate the water issue to an extent. Through diligent study, the areas with maximum water sensitivity can be found and avoided in choosing construction locations, thus mitigating the water usage issue.

Environmental Metrics

If these technological improvements can be made, and CSP can become competitive with coal, there will be a significant reduction in environmental emissions and human health will be increased. By having solar power generate 10% of the total electricity in the U.S., by the year 2030, there will be a significant reduction in environmental pollutants.

- NO_x reductions of 220,000 tons/ year
- SO_x reductions of 370,000 tons/year
- CO₂ reductions of 860,000,000 tons/year
- Mercury reductions of 1.53 million tons/year

Achieving these reductions will enhance environmental and human health by lowering the levels of smog, acid rain and lessening the effect of global warming. While the immediate aim of H.R.2774 is to make CSP a viable electricity option, the ultimate goal is to minimize these environmental harms. Both are important goals to consider in this legislation and ultimately are what will determine its success.

CONCLUSION

As energy use and population increase in the United States, it is imperative to find new ways of generating electricity. While fossil fuels will likely be part of our electricity profile for many years to come, the percentage of electricity they produce needs to decrease

substantially. The environmental impacts associated with harvesting and combusting fossil fuels are too significant to continue using them in their current quantities. This is an unsustainable way of powering the U.S. since fossil fuel reserves are finite and some environmental degradation may be irreversible. It is also vital to diversify our electricity profile to help hedge against the price swings of fossil fuels, which will likely intensify as global demand increases and fossil fuel reserves are depleted. Concentrated solar power shows great potential as a viable, nationwide source for electricity. Improvements to the technology still need to be made to make CSP commercially viable. This is a goal that can be realized and should be strongly pursued as CSP can be a nationwide source of clean, renewable energy. While CSP may not be the only solution to our current energy predicament, it can certainly be part of the solution.

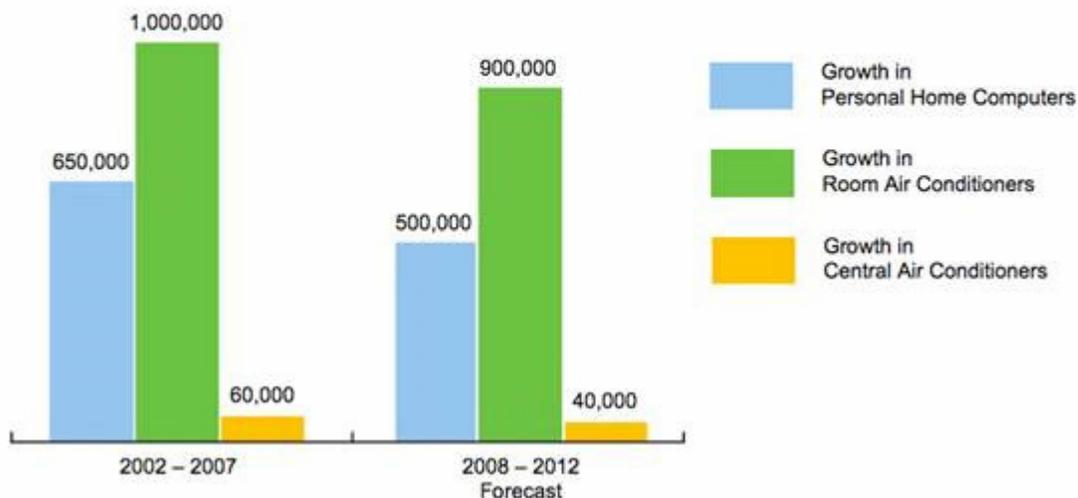
FREQUENTLY ASKED QUESTIONS

What is the cause of energy increase in the last 10 years?

The proliferation of personal use computers, cell phones and small electronics, as well as an increase in home air conditioning are all major contributors to the increase in U.S. electricity consumption over the last ten years. If climate change projections prove true, we can expect hotter temperatures, especially in the arid regions of the southwest, which will increase demand for home air conditioners.

As an example, the below graph demonstrates the increase in amount of personal computers and domestic air conditioners in New York between 2002 and 2007, as well as the expected increase from 2008 to 2012.

Proliferation of Electric Devices is Driving Higher Usage in Homes



What is the current cost of coal power vs. solar power?

Coal: 8.4 cents/kWh in 2007

Solar: 20-50 cents/kWh depending on type of system and location—about 30 cents/kwh average.

<http://www.solarbuzz.com/StatsCosts.htm>

Where is the bill now?

H.R.2774 was introduced by Representative Gabrielle Giffords (D-AZ) on June 19, 2007. The Subcommittee on Energy and Environment held a hearing on June 19, 2007 and has recommended it be considered by the entire House of Representatives. Although it has been placed on a calendar of business, it has not yet come up for

consideration. You can check the bill's current status here:
<http://www.govtrack.us/congress/bill.xpd?bill=h110-2774>

How will the Bureau of Land Management (BLM) allocation of land for solar energy affect your bill or will it have an effect?

It will have a positive effect, as allocated land will be used to develop solar power generation plant projects.

In smog formation, if it takes an O₃ molecule to regenerate NO₂, how can there be a net O₃ increase based on this reaction alone?

Since an ozone molecule is needed to recreate a NO₂ molecule, there will not be a net increase in ozone based on NO₂ reactions alone. Hydrocarbons are needed to propagate an increase in ground level ozone because they produce peroxy radicals when combusted. These hydrocarbons are found in the form of gasoline when it is burned in the engine of an automobile. The peroxy radicals are a by-product of the gasoline combusting process and are highly reactive. These radicals can react with NO before the ozone can, effectively recreating NO₂ without depleting the ozone levels. This creates a net increase in ground level ozone, which is problematic for organisms breathing the air.

How efficient is the grid at accepting the CSP?

The grid can accept solar power just as well as it can accept power from any source that utilizes steam-powered turbines.

Could you create as much energy with CSP as coal in the same footprint area?

This is a debatable topic based on the current state of research and development. Although CSP requires large, flat plots of land to maximize efficiency, it promises to generate more electricity per acre than either coal (based on the impact of surface and strip mining) or hydro (based on the size of the dammed lake) when all factors are accounted for.

Can you how traditional power generation can be paired with solar when the stored solar energy runs out?

In the southwestern United States, power generation is currently based largely on natural gas power plants. If CSP arrays are installed in tandem with these facilities, startup costs can be minimized and the operators can switch between the energy sources to maintain peak load demand; when the sun is shining thermal energy from CSP would be used for electricity production and thermal storage, immediately after the sun set this storage would power the turbines, and natural gas would be used only after the storage capabilities have been depleted (such as cloudy days).

Where is water being used in a Concentrated Solar Power system?

Thermal heat captured from the sun is stored in the thermal transport fluid and transferred to water to vaporize it. This steam turns turbines that generate electricity. Although closed-loop systems are more efficient than one-through cooling systems,

they still waste 5 percent due to evaporation. In addition, a small amount of water is necessary to clean the mirrors periodically.

Are there any controversies with molten salt?

No. Molten salts are just melted salts. Salt compounds have been used for hundreds of years, with no signs of environmental or human health impacts. Salts are stable compounds which are very abundant and used in all manner of applications. They melt at very high temperatures, thus they have high capacity for heat storage. Currently, molten salt is used as a coolant in nuclear reactors.

Where is CSP currently being used? Where is it viable?

Solar One and Two were demonstration power towers in California that have since been dismantled. Solar Tres is the only current commercial system of this type in the world and had proven very viable and capable of being scaled up. Nevada Solar One is an example of a trough system currently operating successfully in the United States and is a prototype for future planned CSP systems. For a complete list of global CSP installations visit: http://www.earthpolicy.org/Updates/2008/Update73_data.htm#table1

How much does a CSP plant cost to build?

Nevada Solar One, which was completed in 2007 and generates enough electricity to power 14,000 homes, took an investment of \$266 million. Keep in mind that costs will be mitigated by the lack of need for fossil fuel inputs once the plant is running. For more information on Nevada Solar One, see here: <http://www.nevadasolarone.net/>.

Is a pairing of solar with wind turbines being considered?

A great idea! New Jersey has already a solar-wind power plant and these technologies seem to pair nicely, however CSP generates electricity by capturing thermal energy whereas wind turbines turn kinetic energy into mechanical energy so more research and development is warranted.

Would the solar generation plants be located within coal plants since its being integrated into the grid? Is building as a hybrid a viable solution?

CSP plants would not be placed with coal plants specifically because natural coal stores are not located in locations of high solar intensity and flat, barren lands. CSP plants hybridize more naturally with natural gas plants that are already viable in the southwestern United States.

You made it sound like PV was a bad thing, in that it is not a widespread solution. How dare you!

Not at all! Photovoltaics are a viable alternative electricity generation technology and H.R. 2774 encourages research and development to make them more widespread and efficient. CSP, however, has been demonstrated to be a national commercial solution that generates electricity with traditional steam turbines, ties into the national distribution grid, and offers potential for thermal energy storage so it can continue to generate electricity after the sun has set.

Is cost a true factor? Can't consumers just pay a premium if they want to buy solar power?

There are other renewable energy sources that are available now for less. In order to make solar power a viable and widely-used option, cost will have to become more competitive.

What about clean coal?

Although clean coal addresses some of the emissions issues related to combustion, coal must still be mined from the earth. Coal mining has many negative environmental effects. Mining disturbs wildlife habitats, causes soil erosion, contaminates local water tables, and causes subsidence. The initial washing of coal results in slurry runoff. The runoff is highly acidic and laden with heavy metals which contaminate ground and surface water, causing harmful effects to local communities as well as plants and animals.

The various types of clean coal plants have environmental repercussions, and still emit CO₂ and other harmful chemicals. Carbon capture and storage, which some clean coal plants use, has its own disadvantages. First, it requires substantially greater amounts of energy. Therefore, more fuel must be burned to keep the system running, increasing usage of fossil fuels. Second, once CO₂ is captured, it must be transported. According to the CRS Report for Congress, there are still questions regarding pipeline requirements, regulatory classification of CO₂, and safety. Third, CO₂ must be stored in such places as underground geological formations and the deep ocean. It is unknown what effects large amounts of CO₂ will have on the locations where it is stored. It is still unknown how storage and potential leakage will affect the possible mitigation of climate change.

http://assets.opencrs.com/rpts/RL34307_20080415.pdf

http://www.netl.doe.gov/publications/brochures/pdfs/Gasification_Brochure.pdf

How long would it take for a CSP system to pay for itself? Specifically using a full impact evaluation?

If passed, HR 2774, which is a research bill, should answer this question. Since CSP technology is still developing, it's hard to get an accurate assessment for the exact dollar per MWh costs for a CSP plant. With further research, this number should become clearer. However, we know that CSP will have significantly lower environmental impacts than traditional forms of fossil fuel based power. When these externalities are taken into consideration, the cost of CSP generation would appear lower.

GLOSSARY

Acid mine drainage: This refers to water pollution that results when sulfur-bearing minerals associated with coal are exposed to air and water and form sulfuric acid and ferrous sulfate. The ferrous sulfate can further react to form ferric hydroxide, or yellowboy, a yellow-orange iron precipitate found in streams and rivers polluted by acid mine drainage.

Acid Rain: Also called acid precipitation or acid deposition, acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by nitrogen oxides and sulfur oxides released into the atmosphere when fossil fuels are burned. It can be wet precipitation (rain, snow, or fog) or dry precipitation (absorbed gaseous and particulate matter, aerosol particles or dust). Acid rain has a pH below 5.6. Normal rain has a pH of about 5.6, which is slightly acidic. The term pH is a measure of acidity or alkalinity and ranges from 0 to 14. A pH measurement of 7 is regarded as neutral. Measurements below 7 indicate increased acidity, while those above indicate increased alkalinity.

Baseload: The minimum amount of electric power delivered or required over a given period of time at a steady rate.

Baseload Capacity: The generating equipment normally operated to serve loads on an around-the-clock basis

Baseload Plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Bioaccumulation: occurs when an organism absorbs a toxic substance at a rate greater than that at which the substance is lost; hence the toxin accumulates in the body.

Biomagnification: also known as bioamplification or biological magnification, it is the increase in the concentration of a substance that occurs in a food chain.

Btu (British Thermal Unit): A standard unit for measuring the quantity of heat energy equal to the quantity of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

Capacity: The amount of electric power delivered or required for which a generator, turbine, transformer, transmission circuit, station, or system is rated by the manufacturer.

Carbon dioxide (CO₂): A colorless, odorless, non-poisonous gas that is a normal part of Earth's atmosphere. Carbon dioxide is a product of fossil-fuel combustion as well as other processes. It is considered a greenhouse gas as it traps heat (infrared energy) radiated by the Earth into the atmosphere and thereby contributes to the potential for global warming. The global warming potential (GWP) of other greenhouse gases is measured in relation to that of carbon dioxide, which by international scientific convention is assigned a value of one (1). Also see Global warming potential (GWP) and Greenhouse gases.

Clean Coal: a term used to describe methods and technologies intended to reduce the environmental impact of using coal as an energy source. These efforts can include chemically washing minerals and impurities from the coal, Gasification, treating the flue gases with steam to remove sulfur dioxide, and other proposed technologies to capture the carbon dioxide from the flue gas. The coal industry uses the term "clean coal" to describe technologies designed to enhance both the efficiency and the environmental acceptability of coal extraction, preparation and use, with no specific quantitative limits on any emissions, particularly carbon dioxide.

Coal: A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time.

Cogenerator: A generating facility that produces electricity and another form of useful thermal energy (such as heat or steam), used for industrial, commercial, heating, or cooling purposes. To receive status as a qualifying facility (QF) under the Public Utility Regulatory Policies Act (PURPA), the facility must produce electric energy and "another form of useful thermal energy through the sequential use of energy," and meet certain ownership, operating, and efficiency criteria established by the Federal Energy Regulatory Commission (FERC). (See the Code of Federal Regulations, Title 18, Part 292.)

Collection tower: A tall "thermos" located at the focus of a field of flat mirrors arranged in a parabolic array (CSP power tower) that collects and concentrates solar radiation in a thermal heat transfer fluid. Depending on the fluid used, the thermal energy can be concentrated up to 600 times in an efficient system.

Commercial: The commercial sector is generally defined as nonmanufacturing business establishments, including hotels, motels, restaurants, wholesale businesses, retail stores, and health, social, and educational institutions. The utility may classify commercial service as all consumers whose demand or annual use exceeds some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Concentrated Solar Power: Any solar technology that uses mirrors to concentrate solar energy and convert it into thermal or heat energy. This thermal energy is then used to generate electricity.

Consumption (Fuel): The amount of fuel used for gross generation, providing standby service, start-up and/or flame stabilization.

Current (Electric): A flow of electrons in an electrical conductor. The strength or rate of movement of the electricity is measured in amperes

Demand (Electric): The rate at which electric energy is delivered to or by a system, part of a system, or piece of equipment, at a given instant or averaged over any designated period of time.

Dish engine systems: Similar to how a satellite dish concentrates a signal, these dishes instead concentrate sunlight with a heat engine located at the focal point to generate electricity. These power generators are small, mobile units that can be operated individually or in clusters, in urban or remote locations.

Desiccant: Any substance that removes moisture.

Energy: The capacity for doing work as measured by the capability of doing work (potential energy) or the conversion of this capability to motion (kinetic energy). Energy has several forms, some of which are easily convertible and can be changed to another form useful for work. Most of the world's convertible energy comes from fossil fuels that are burned to produce heat that is then used as a transfer medium to mechanical or other means in order to accomplish tasks. Electrical energy is usually measured in kilowatt hours, while heat energy is usually measured in British thermal units.

Energy Efficiency: Refers to programs that are aimed at reducing the energy used by specific end-use devices and systems, typically without affecting the services provided. These programs reduce overall electricity consumption (reported in megawatt hours), often without explicit consideration for the timing of program-induced savings. Such savings are generally achieved by substituting technically more advanced equipment to produce the same level of end-use services (e.g. lighting, heating, motor drive) with less electricity. Examples include high-efficiency appliances, efficient lighting programs, high-efficiency heating, ventilating and air conditioning (HVAC) systems or control modifications, efficient building design, advanced electric motor drives, and heat recovery systems.

Fossil Fuel: Any naturally occurring organic fuel found in the Earth's surface, such as petroleum, coal, and natural gas. Fossil fuels are formed from long-buried plants and animals.

Fuel: Any substance that can be burned to produce heat; also, materials that can be fissioned in a chain reaction to produce heat.

Gas: A fuel burned under boilers and by internal combustion engines for electric generation. These include natural, manufactured and waste gas.

Gas Turbine Plant: A plant in which the prime mover is a gas turbine. A gas turbine consists typically of an axial-flow air compressor, one or more combustion chambers, where liquid or gaseous fuel is burned and the hot gases are passed to the turbine and where the hot gases expand to drive the generator and are then used to run the compressor.

Generator: A machine that converts mechanical energy into electrical energy.

Gigawatt (GW): One billion watts.

Gigawatt hour (GWh): One billion watthours.

Greenhouse gas (GHGs): the gases present in the earth's atmosphere which warm near-surface global temperatures through the greenhouse effect.

Greenhouse Effect: The increasing mean global surface temperature of the earth caused by gases in the atmosphere (including carbon dioxide, methane, nitrous oxide, ozone, and chlorofluorocarbon). The greenhouse effect allows solar radiation to penetrate but absorbs the infrared radiation returning to space.

Grid: The layout of an electrical distribution system.

Hydroelectric Plant: A plant in which the turbine generators are driven by falling water.

Industrial: The industrial sector is generally defined as manufacturing, construction, mining agriculture, fishing and forestry establishments Standard Industrial Classification (SIC) codes 01-39. The utility may classify industrial service using the SIC codes, or based on demand or annual usage exceeding some specified limit. The limit may be set by the utility based on the rate schedule of the utility.

Kilowatt (kW): One thousand watts.

Kilowatt hour (kWh): One thousand watt hours.

Load (Electric): The amount of electric power delivered or required at any specific point or points on a system. The requirement originates at the energy-consuming equipment of the consumers.

Longwall mining: A form of underground coal mining where a long wall (typically about 250-400 m long) of coal is mined in a single slice (typically 1-2 m thick).

Megawatt (MW): One million watts.

Megawatt hour (MWh): One million watt hours.

Methyl Mercury (CH₃Hg⁺): an organometallic cation and a bioaccumulative environmental toxin. Its anthropogenic sources are the burning of wastes containing inorganic mercury and the burning of fossil fuels, particularly coal.

Net Metering: An electricity policy that allows consumers who own wind or solar generation facilities to tie into the electricity grid. This eliminates the need for large battery backup systems and inputs energy into the grid during bright, sunny days (when energy demand is high) for a profit and purchases it back at night and during cloudy or windless days (when electricity demand is generally lower). Although this has potential to supplement the power grid during times of maximum load, it puts the burden of implementation and maintenance on fragmented consumers and can have dangerous consequences when utilities need to shut down the grid locally for maintenance.

Nitric Oxide (NO): A colorless, poisonous gas, NO is formed by the oxidation of Nitrogen or ammonia.

Nitrogen Dioxide (NO₂): A highly poisonous brown gas often present in smog and automobile exhaust.

Nitrous Oxide (N₂O): A major greenhouse gas, N₂O is emitted by bacteria in soils and oceans. Agriculture is the main anthropogenic source.

Nuclear Fuel: Fissionable materials that have been enriched to such a composition that, when placed in a nuclear reactor, will support a self-sustaining fission chain reaction, producing heat in a controlled manner for process use.

Nuclear Power Plant: A facility in which heat produced in a reactor by the fissioning of nuclear fuel is used to drive a steam turbine.

Ozone (O₃): An almost colorless gaseous form of oxygen that is abundant in the stratosphere. Ozone can also occur at ground level (see Smog).

Parabolic mirror: A reflective symmetrically curved object designed to capture incoming radiation and concentrates the sunlight onto a pipe located at the focus (single central point). A fluid circulating inside the pipe collects the energy and transfers it to a heat exchanger which, in turn, produces steam to drive a conventional turbine.

Peak Demand: The maximum load during a specified period of time.

Peak Load Plant: A plant usually housing old, low-efficiency steam units; gas turbines; diesels; or pumped-storage hydroelectric equipment normally used during the peak-load periods.

Petroleum: A mixture of hydrocarbons existing in the liquid state found in natural underground reservoirs, often associated with gas. Petroleum includes fuel oil No. 2, No. 4, No. 5, No. 6; topped crude; Kerosene; and jet fuel.

Petroleum (Crude Oil): A naturally occurring, flammable liquid composed principally of hydrocarbons. Crude oil is occasionally found in springs or pools but usually is drilled from wells beneath the earth's surface.

pH: The potential hydrogen of a given substance. The pH level is a measure of the acidity or alkalinity of a solution.

Photovoltaics (PV): the field of technology and research related to the use of solar cells or semiconductors for the conversion of sunlight directly into electricity.

Plant: A facility at which are located prime movers, electric generators, and auxiliary equipment for converting mechanical, chemical, and/or nuclear energy into electric energy. A plant may contain more than one type of prime mover. Electric utility plants exclude facilities that satisfy the definition of a qualifying facility under the Public Utility Regulatory Policies Act of 1978.

Power: The rate at which energy is transferred. Electrical energy is usually measured in watts. Also, used for a measurement of capacity.

Power tower systems: a system that uses a large field of rotating mirrors to track the sun and focus the sunlight onto a heat-receiving panel on top of a tall tower. The fluid in the panel collects the heat and either uses it to generate electricity or stores it for future use.

Redundancy: The national electricity transmission grid is a network of power stations and transmission circuits that allow areas of high demand to purchase power from areas of cheaper production, often located far away. The web of interconnections between power producers and consumers allows for multiple distribution paths to insure that inoperative links can be bypassed.

Residential: The residential sector is defined as private household establishments which consume energy primarily for space heating, water heating, air conditioning, lighting, refrigeration, cooking and clothes drying. The classification of an individual consumer's account, where the use is both residential and commercial, is based on principal use. For the residential class, do not duplicate consumer accounts due to multiple metering for special services (water, heating, etc.). Apartment houses are also included.

Retail: Sales covering electrical energy supplied for residential, commercial, and industrial end-use purposes. Other small classes, such as agriculture and street lighting, also are included in this category.

Retail Market: A market in which electricity and other energy services are sold directly to the end-use customer.

Room and pillar mining: a mining system in which the mined material is extracted across a horizontal plane while leaving "pillars" of untouched material to support the overburden and, in turn, creating open areas or "rooms" underground. It is usually used for relatively flat-lying deposits, such as those that follow a particular stratum.

Silica Gel: Gelatinous silica in a form that readily absorbs water from the air.

Smog: Smog is comprised mostly of ground level ozone and can have detrimental effects on human health. For a further description of smog formation see the Q&A section.

Solar Air Conditioning: Any system that uses solar energy to cool the air.

Solar daylighting technology: Any system which utilizes natural light as a source of interior lighting. One example are solar tubes which have an aperture and a reflective inner surface to direct sunlight. Another example is optical fiber which is simply a small cable that can carry focused sunlight and direct it where needed throughout a building.

Stirling Engine: A closed-cycle regenerative heat engine with a gaseous working fluid. "Closed-cycle" means the working fluid, the gas which pushes on the piston, is permanently contained within the engine's system. This also categorizes it as an external heat engine which means it can be driven by any convenient source of heat. "Regenerative" refers to the use of an internal heat exchanger called a 'regenerator' which increases the engine's thermal efficiency compared to the similar but simpler hot air engine.

Steam-Electric Plant (Conventional): A plant in which the prime mover is a steam turbine. The steam used to drive the turbine is produced in a boiler where fossil fuels are burned.

Subsidence: The motion of a surface (usually, the Earth's surface) as it shifts downward relative to a datum such as sea-level.

Sulfur: One of the elements present in varying quantities in coal which contributes to environmental degradation when coal is burned. In terms of sulfur content by weight, coal is generally classified as low (less than or equal to 1 percent), medium (greater than 1 percent and less than or equal to 3 percent), and high (greater than 3 percent). Sulfur content is measured as a percent by weight of coal on an "as received" or a "dry" (moisture-free, usually part of a laboratory analysis) basis.

Sulfur Dioxide (SO₂): A heavy, pungent toxic gas that is a major air pollutant emission released from the burning of fossil fuels.

Sulfuric Acid (H₂SO₄): A strong mineral acid that is soluble in water at all concentrations. Sulfuric acid is a component of acid rain, which is formed by atmospheric oxidation of sulfur dioxide in the presence of water. Sulfur dioxide is produced when sulfur-containing fuels such as coal or oil are burnt. Sulfuric acid is formed naturally by the oxidation of sulfide minerals, such as iron sulfide. The resulting water can be highly acidic and is called Acid Mine Drainage (AMD).

Super-heated: Superheating is when a liquid is heated to a temperature higher than its standard boiling point, without actually boiling. Superheated liquids can be stable above their usual boiling point if their pressure is higher than atmospheric pressure.

Thermal Energy Storage Systems: Any system that stores thermal energy for future use.

Transformer: An electrical device for changing the voltage of alternating current.

Transmission: The movement or transfer of electric energy over an interconnected group of lines and associated equipment between points of supply and points at which it is transformed for delivery to consumers, or is delivered to other electric systems. Transmission is considered to end when the energy is transformed for distribution to the consumer.

Transmission System (Electric): An interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers, or is delivered to other electric systems.

Turbine: A machine for generating rotary mechanical power from the energy of a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic energy of fluids to mechanical energy through the principles of impulse and reaction, or a mixture of the two.

Watt: The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.

Watt-hour (Wh): An electrical energy unit of measure equal to 1 watt of power supplied to, or taken from, an electric circuit steadily for 1 hour.

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