ABENGOA SOLAR

Solar Power for a Sustainable World

We Develop, Build, and Operate Solar Power Plants and Installations

Solutions to Global Climate Change

Power Tower Plants

Power Tower
Technology Plants

The Issues…

Climate Change and Sustainable Development

We have all heard of acid rain, the Ozone layer and the Greenhouse Effect, but what exactly are they and how do they affect humans?

- Acid rain is caused by high concentrations of certain gases in the atmosphere. These high concentrations are the result of the emissions from the excessive burning of fossil fuel. Acid rain can cause fatal deterioration to field and forest regions.
- The ozone layer, considered the "protective shield" of life on Earth, regulates the amount of radiation that reaches Earth's surface. Because of the actions of humans, the ozone layer is deteriorating.
- The Greenhouse Effect produces rapid and alarming warming of the lower level atmosphere. It is caused by the presence of greenhouse gases (GHG) which trap heat that would otherwise escape into space.

The conjunction of these three phenomena will increase the number and intensity of catastrophic events, such as: floods, desertification, thaw, and ecosystem destruction. Additionally, the changes in climate patterns could create a food production crisis which would lead to a social crisis.

Perhaps the most significant cause of the increased greenhouse effect and global warming is the 30% increase in atmospheric carbon dioxide (a well known GHG) since 1750. Present carbon dioxide concentrations have not been seen in 20 million years. It is estimated that ¾ of the GHG emissions in the last 20

Figure 1: Solar Thermal Technology

"According to the World Health Organization (WHO), global warming killed 150,000 people in the year 2000 and this number could double in the next decade"
Source: WHO.

Figure 2: Photovoltaic Technology

years is due to the burning of fossil fuels for human consumption and transportation.

Today, one of society's primary concerns is moving from old development methods towards sustainable development. Sustainable development methods are intended to satisfy current needs without compromising future generations.

To ensure sustainable development, the corporate sector needs to work toward the objectives of Corporate Social Responsibility (CSR) and its stakeholders. In doing so, corporations would begin to manage their activities in a cleaner and more efficient manner.

The Kyoto Protocol, written in 1997, is an effort to work toward sustainable development. Although not signed by the USA, China or India, the Kyoto Protocol was signed by more than 55% of the countries worldwide. The goal of the Kyoto Protocol is to reduce the emissions levels of 6 major greenhouse gases in 1990 by 5.2% between the years 2008 and 2012. Only developed countries have been able to quantify their commitment to emissions reduction. Each developed country must distribute its emissions rights among its companies. If companies exceed their emissions rights they could be economically penalized. In the case that a company can not viably remain under its emissions rights, flexible mechanisms have been created to help them comply with regulations.

Within renewables, the potential of solar technologies has recently caused a large increase in its development. From a commercial point of view, working toward sustainable development has created a new market for energy companies which includes:

- New tax legislation, subversion and incentives for sustainable development being established in many countries.
- Flexible fostering mechanisms divided into: emissions trading, joint projects and clean development mechanisms that allow companies to receive emissions rights for investing in renewable energy (even if it is in another country).

Although the flexible fostering mechanisms that help companies comply with their emissions rights is good, it is undoubtedly better to avoid GHG pollution through the reduction or elimination of their emission. In order to do so we must use energy in a rational and efficient way and begin to integrate renewable energy technologies into our current systems.

Proposed Solution: Renewable Energy

Renewable energy technologies are those that provide energy from a source considered inexhaustible (i.e. the sun, wind, biomass, river water, etc.). The use of renewable energy technologies is an effective way to reduce emissions. Without initiatives to develop renewable energy technologies, today's total emissions would have increased by 30% above 1990 levels. Today, installed electricity capacity from renewable energy technology is 160 GW, which is 4% of the global installed electric capacity.

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Solar Power

Benefits of Solar Energy

The characteristics of solar energy make it well suited to supply peak electricity demands. In the developed world the summer peak demands have become overwhelming and the winter peak demands are primarily due to space heating. If we analyze the solar radiation curve during the summer, it coincides very closely with the peak power demand curve. This is very convenient because solar energy technologies can produce their maximum when the demand is at its maximum.

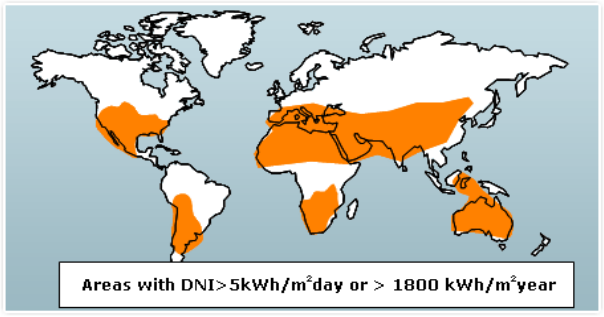
Although they produce the most power during peak daylight hours, solar technologies can also be used to provide electricity throughout the day. By storing heat from solar radiation in storage tanks and hybridizing with fossil fuels solar plants are able to provide clean and reliable electricity throughout the day.

Because they can provide base and peak demand electricity, solar technologies could become one of the foremost power sources worldwide.

The installation of solar plants is ideal in locations known as the "solar belt" (see picture). These locations in much of the world and receive high solar radiation.

Over the last century, the financial investment in solar technology development has coincided with oil shortages. Due to increasing power consumption worldwide, the life expectancy of fossil fuels is dramatically shrinking. Experts forecast a substantial increase in solar technology development due to increasing investment and an ever growing experience with the technology.

"If only 2% of the solar radiation from the world's deserts were used it would be enough to supply the worlds power demands."



Source: Abengoa Solar

Figure 3: Irradiation map

Abengoa Solar

Abengoa Solar as part of Abengoa

Abengoa is an international company with the mission of applying innovative solutions for sustainable development in the infrastructure, environmental and power sectors.

Abengoa Solar offers deep know how, technology, and experience in building both CSP and PV plants. Internationally it has the backing of a large corporation that can offer financial support, an EPC company that builds our plants, and other companies with expertise in key areas like control systems and water management.

Global Expertise with Solar Support since the 1980's

With installations in several different countries and offices in Spain and the USA, Abengoa Solar has established a team of experts with vast solar knowledge and a globally respected reputation.
Abengoa Solar's industry leadership is based on a well established, but still growing, engineering team. More than 20 years of experience and collaboration with prominent research institutes (NREL, Ciemat, DLR, Fraunhofer ISE, and others) have allowed Abengoa Solar to build a wealth of solar energy knowledge and experience.

This wealth of knowledge and experience is devoted to all forms of solar energy technology. Research teams are focused on parabolic troughs, dish Stirling systems, thermal storage, solar hybridization and PV concentration. As evidence of the commitment to all of these technologies, demonstration facilities have been constructed to test and develop trough, dish Stirling, power tower, storage and PV technologies.

Source: Abengoa Solar

Figure 7: Abengoa Solar International Presence

Abengoa Solar Activities

Abengoa Solar provides solar thermal technology for all levels of use including: power plants for large-scale electric needs, customized industrial/commercial installations for thermal needs, and residential installations for thermal needs.

Abengoa Solar also provides PV technology for various levels of use, including: large-scale electricity generation from concentrated PV with two-axis tracking, smaller PV installations for independent projects, and integration of thin-film PV technology with buildings to achieve "off the grid" housing.

Abengoa Solar manufactures its own components for concentrated solar power installations (heliostats, structures and mirrors) as well as PV installations (solar trackers and concentrators). In doing so, Abengoa Solar becomes a technology vendor for its own plants and installations.

Examples of technological knowledge and experience are Abengoa Solar' plants and installations:

- **PS10** – The first commercially operating power tower in the world with PS20, which is under construction, becoming the second.
- **Solnova 1 and 3** – Of 80 MWs each that are the first of 5 parabolic trough installations.
- **Sevilla PV Plant** – The largest low-concentration plant in the world (1 MW).
- Construction of the first **hybrid plant** with an Integrated Solar Combined Cycle (ISCC) in Algeria.
- **Customized solar thermal** projects for industries in California, Arizona and Texas in the USA.

Photovoltaic

Figure 8: Low Concentration PV

Concentrated Solar Power

Figure 9: Trough Plants

Figure 10: PS10 Tower

PS10: The First Commercial Tower Worldwide

1.- Concentrated Solar Power Technology

One of the primary components of concentrated solar power (CSP) technology is the solar collector. The receiver is a device in which a working fluid flows and absorbs the solar energy that is concentrated at the collector. There are many different CSP technologies that use different types of collectors. Currently, the most common and most important CSP technologies are parabolic trough systems, power tower systems, parabolic dish systems and hybridized combined cycles.

Power tower systems use a centralized receiver as the collector. Solar radiation from a field of heliostats is concentrated onto the centralized receiver, which is located in a tower. The centralized receiver transfers solar radiation energy to a working fluid which is used to run a conventional power cycle.

Parabolic trough systems use an absorber tube as the collector. Solar radiation is reflected from the parabolic trough to the focal point of the parabola. The absorber tube is located at the focal point and it transfers the solar radiation energy to the working fluid. This energy is then used to run a conventional power cycle.

Figure 11: Abengoa Solar´Trough

Dish Stirling: Systems use various types of reflector designs to concentrate solar radiation onto a collector. Typically, the collector is the "hot" side of a Stirling engine or the inlet of a Brayton turbine. The collector transfers solar radiation energy to the working fluid within the engine/turbine, which is then used to generate electricity. One of the greatest advantages to parabolic trough systems is that their thermoelectric conversion efficiency is higher than other technologies. However, these systems are typically only used for small-scale applications.

Figure 12: Abengoa Solar Dish Stirling

In order to mitigate the problems that arise with varying electricity demand and varying solar radiation, it is possible to build solar combined cycle plants. Such plants use fossil fuels or some other renewable source (like biogas) to supply power when there is insufficient sunlight. The world's first solar combined cycle plant, which Abengoa Solar is involved in, is under construction in Algeria and is planned to be finished by 2009.

2.- Tower Technology: Operation and Main Advantages

Tower technology operation is based on two primary components: heliostats and the receiver

- A **field of heliostats** works to reflect and concentrate solar radiation on the central receiver. Each heliostat is composed of a flat reflective surface, a supporting structure and a solar tracking mechanism. Currently, the most commonly used reflective surfaces are glass mirrors.
- The **receiver** works to transfer solar radiation energy reflected by the heliostats to the working fluid. Heat from the working fluid is used to run a conventional power cycle.

Solar tower technology has many advantages. Like all solar technologies, towers generate electricity with drastically reduced emissions and have an inexhaustible fuel source. Towers also have the potential to achieve higher efficiencies than many other CSP technologies.

The world's first commercially operating solar tower, PS10, was developed by Abengoa Solar in Sanlúcar la Mayor (discussed below).

3.- PS10 at the Solúcar Platform

The PS10 solar tower plant was built by Abengoa Solar after several years of research and development and began operation on March 30th, 2007. It is located in the Spanish province of Sevilla, in Sanlúcar la Mayor, and sits on 150 acres (60 ha). It is the first tower in the world commercially delivering electricity. As seen in the operating schematic (Figure 13), the plant generates pressurized steam to run a conventional power cycle with an 11 MW capacity.

Along with the electricity generated, the plant brings social benefit to the area. The plant has created many new jobs to support its operation and the scientific tourism associated with it. For all of their installations, Abengoa Solar educates their personnel so that they can add value to the location

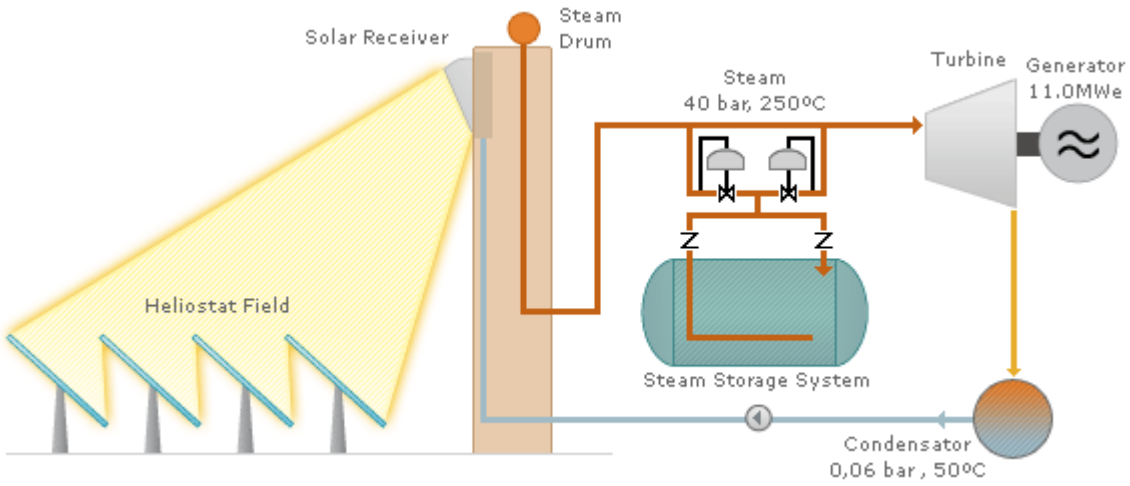


Figure 13: PS10 Schematic

4.- PS10 Infrastructure

The PS10 plant has 624 heliostats that are 1,300 ft^2 each (120 m^2), which is a total surface area of 18.5 acres (75,000 m^2). Each heliostat has an independent solar tracking mechanism that directs solar radiation toward the receiver.

As seen in Figure 15, the heliostat field does not completely surround the receiver tower. In the northern hemisphere, the heliostat field is located on the north side of the tower to optimize the amount of solar radiation collected while minimizing heat loss.

The receiver is located in the upper section of the tower. The receiver is a "cavity" receiver and is comprised of four vertical panes that are 18 ft (5.5 m) wide and 39 ft (12 m) tall. The panels are arranged in a semi-cylindrical configuration and housed in a square opening 11 m per side.

Under normal conditions, the receiver is capable of operating at 92% thermal efficiency and delivering 55 MWt of saturated steam at 500º F (250º C) and 40 bars.

Figure 16. PS10 Plant Tower

5.- PS10 Functioning and Operation

One of the foremost difficulties is controlling the heliostat field. If there are problems with heliostat control it could be very dangerous. For example, if a group of heliostats was not proper focused, the receiver could end up damaged as a matter of the hot points that may appear. In order to function properly, heliostats must be cleaned. Dirty heliostats can greatly reduce the efficiency of the entire system. Wind poses another difficult for heliostats. In winds greater than 22.5 mph (36 km/h) the heliostats are set vertically to avoid structural damage. If winds exceed 87 mph (140 km/h) it could result in the loss of structural integrity.

Although the operation of PS10 is not easy, it must be remembered that it is a unique installation with significantly higher generation capability than many other CSP technologies. That being said, it is important to realize PS10 great advantages.

- With an installed capacity of 11 MW, and the local solar resource, PS10 is capable of generating 24.3 GWh of clean energy annually. This is enough to supply approximately 5,500 homes and avoid more than 6,700 tons of CO_2 emissions every year.
- PS10 has the capability to store 1 hour worth of steam for electricity generation. Additionally, under low radiation conditions it is capable of supplying 12-15% of its capacity via natural gas.
- The total efficiency, from solar radiation to electricity, is approximately 17%. This is a fairly high number considering that the efficiency of the steam cycle is approximately 27%.

Figure 17: Storage Tanks

6.- Future CSP Developments

Abengoa Solar is committed to facing the great challenges of solar energy. Currently, PS20 is under construction, a new solar tower, at the Solúcar Platform. PS20 will operate similarly to PS10, but with almost twice the capacity (20 MW). It will have 1,255 heliostats, each 1,300 ft^2 (120 m^2), the tower will be 525 ft (160 m) tall and it should produce enough power for 12,000 homes.

Along with PS20, our R&D department is working on the development and construction of several other installations. One such installation is the 50 MW Solnova 1 parabolic trough plant, which will be the first of 5 trough plants.

Development and construction are also being done on demonstration plants for Dish Stirling, solar tower and parabolic trough technologies.

Figure 18. PS20 Plant under construction beside PS10

7.- Conclusions

Solar energy technologies are one of the renewable with the most potential for growth in the near future. The technology has been proven to be feasible and reliable, which is often untrue about many other renewable sources. Solar energy technologies' promising future is can be forecast through the incredible technical advances and research that is currently being done. It is easily affirmed that solar energy technology is one of the best solutions for future energy production. It is clean, storable and will eventually be less expensive than fossil fuel.[9].

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