

ABENGOA SOLAR

Solar Power for a **Sustainable World**

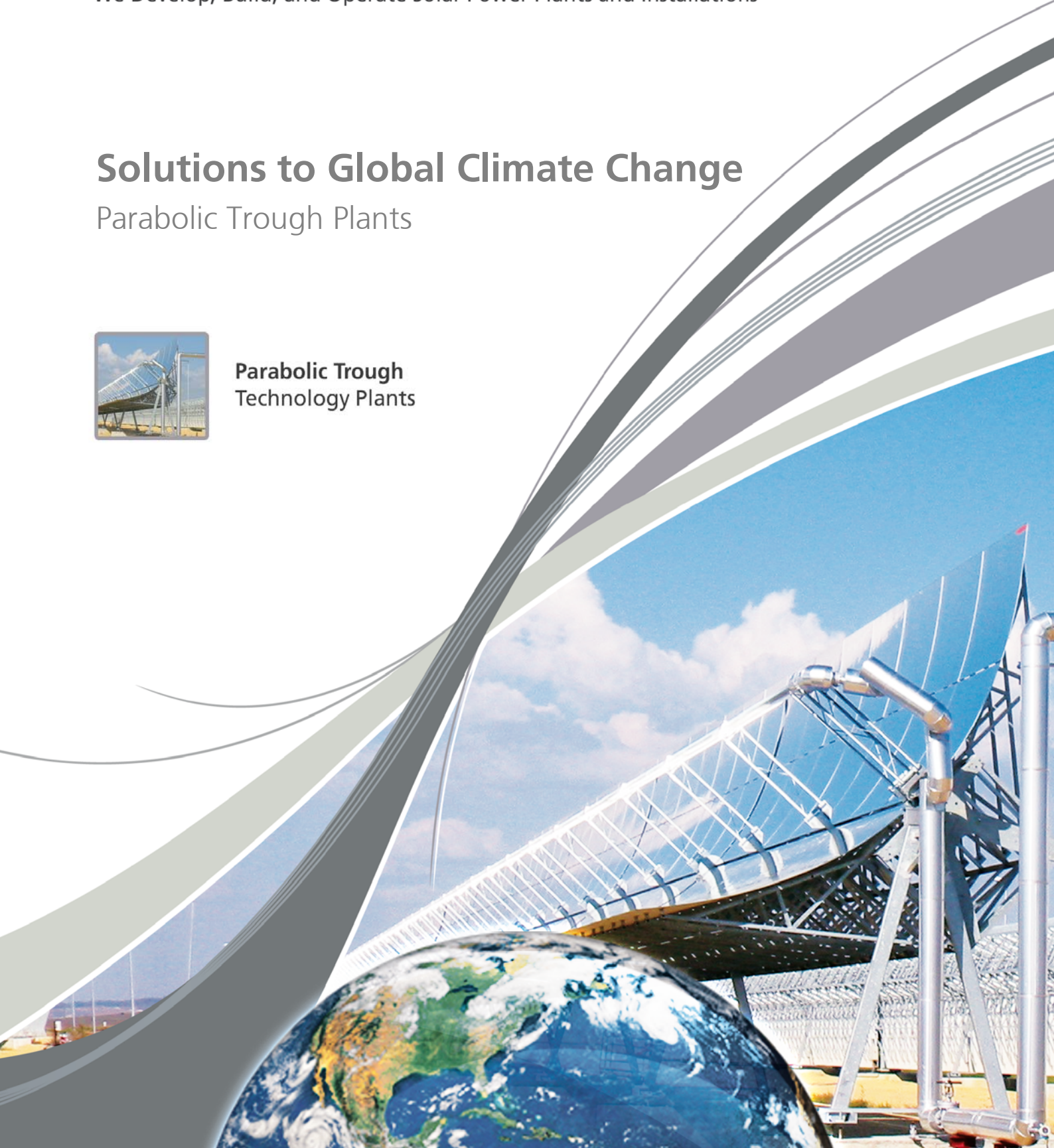
We Develop, Build, and Operate Solar Power Plants and Installations

Solutions to Global Climate Change

Parabolic Trough Plants



**Parabolic Trough
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 $\frac{3}{4}$ 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.

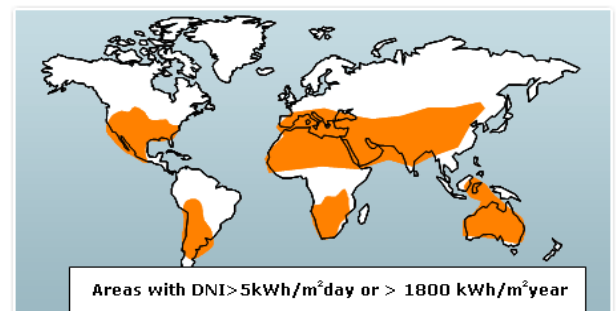
Because they can provide base and peak demand electricity, solar technologies could become one of the foremost power sources worldwide.

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

Although energy from fossil fuels currently costs less than energy from renewables, concentrated solar power and photovoltaic technologies are predicted to cost less in the near future.

Future power costs from fossil fuels will tend to increase due to increased demand and economic sanctions imposed on CO₂ emissions.

Types of Solar Technology

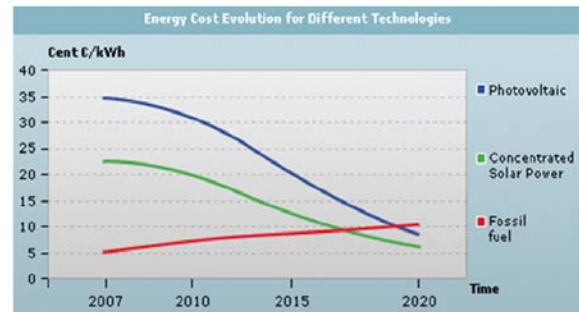
As briefly mentioned above, there are two general branches within solar technology:

- 1.) Photovoltaic (PV) technology directly converts solar radiation into electricity through the use of semiconductors and the photovoltaic effect.
- 2.) Concentrated solar power (CSP) technology stores the energy from solar radiation in a working fluid in the form of heat. This heat can then be used to run a conventional power cycle.

In both cases the electricity produced can be used locally or supplied to the grid at a specially set price.

Both PV and CSP technologies are highly matured technologies. Worldwide, conventional silicon PV has an installed capacity of 6 GW and CSP trough plants have been installed in the USA since the 1980s.

Abengoa Solar has become a pioneer in the solar market, developing and installing systems globally.



Source: Abengoa Solar

Figure 4: Cost Trend for different technologies



Figure 5: Photovoltaic Technology



Figure 6: Photovoltaic Technology

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

Solnova 1: Abengoa Solar' 50 MW Parabolic Trough Plant

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.- Parabolic Trough Technology: Components and Advantages

A parabolic trough system is composed of a parabolic concentrator that reflects direct solar radiation onto a receiver, located at the parabola's focal point. The primary components of a trough system are:

- The **parabolic trough concentrator**: The parabolic trough concentrator reflects direct solar radiation and concentrates it onto the focal point. The reflective surface, often silver or aluminum films, is deposited on some type of rigid support. Currently, the most commonly used support structures are metallic, glass or plastic plates.
- The **absorber tube**: Being that it has a large influence on temperature and overall efficiency, the absorber tube is one of the most important components of a trough system. The absorber tube is made of two concentric tubes that lie along the parabolic trough's focal point. The outer tube (made of glass) is separated from the inner tube (made of metal) by a vacuum layer. This reduces heat loss and increases the overall efficiency. A working fluid is circulated through the inner tube and absorbs solar radiation energy as heat.
- The **working fluid**: Depending on the trough technology, the working fluid varies. For lower temperature applications, less than 329° F (200° C) demineralized water with an ethylene-glycol mixture is often used as the working fluid. For higher temperatures, 392° F – 842° F (200° C – 450° C) synthetic oil is often used as the working fluid. Newer technologies are using molten salts as the working fluid, or are capable of withstanding the high pressures of direct steam generation.
- The **solar tracking system**: The most common tracking systems track the sun about the long axis of the trough.
- The **support structure**: The entire parabolic trough system must be supported by a rigid metallic support structure.

A large benefit of parabolic trough systems compared to other solar technologies is its maturity as a technology for being installed at a commercial level. The first trough plants were installed in the USA in the 1980's and have since undergone vast improvement both to cost and efficiency. Worldwide, parabolic trough systems currently have an installed capacity of 400 MW, with 350 MW under construction and 7 GW in development.

Solnova 1 (50 MW) is the first of 5 trough plants to be installed on the Solúcar Platform. At this platform, Abengoa Solar has also installed the first commercially operating solar tower (PS10) and the largest low-concentration PV plant (Sevilla PV). A second solar tower system (PS20) is currently being constructed there as well.

3.- Solnova 1 at the Solúcar Platform

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 about how they can add value to the location.

As seen in the diagram in Figure 13, the Solnova 1 trough system uses synthetic oil to generate high temperature steam and run a conventional power cycle. The electricity generating capacity of the system is 50 MW.

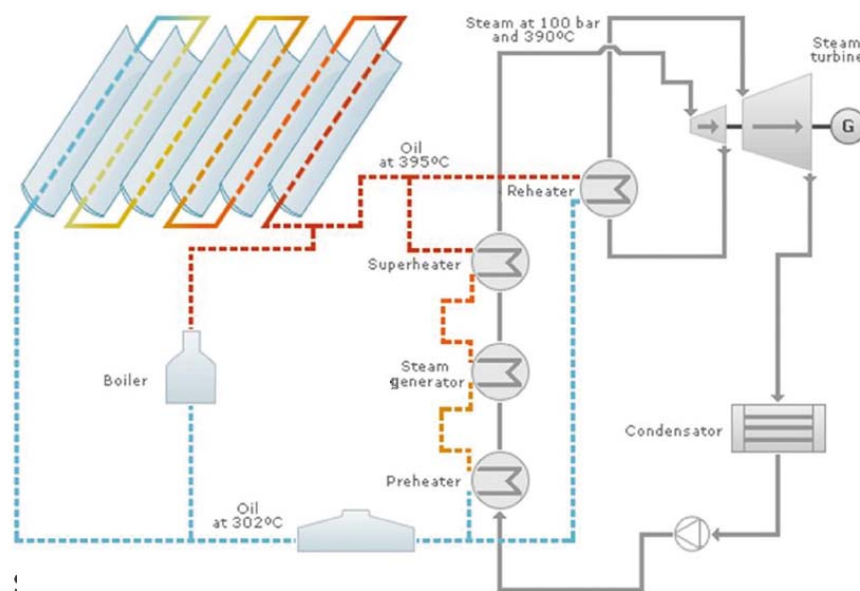


Figure 13: Solnova 1 Schematic

4.- Solnova 1 Infrastructure

Solnova 1 is comprised of 90 rows of collectors oriented north-south. Every row has four trough modules that are each 41.01 ft (12.5 m) long and 18.9 ft (5.76 m) wide. Each module rotates about its long axis to track the sun. Enough space is left between the rows to reduce losses from shading and allow for easy operation and maintenance.

The reflective surface is composed of approximately 74.13 acres (300,000 m²) of mirrors. The mirrors are manufactured by Abengoa Solar's subsidiary, Rioglass Solar. The new Rioglass Solar manufacturing plant produces approximately 5,000,000 mirrors per year and considerably reduces the cost of a trough system. Thanks to cooperation

Solutions to Climate Change: Parabolic Troughs

between mirror manufacturing and the “lean manufacturing” design for assembly, Abengoa Solar is capable of installing one finished module every 30 minutes.



Figure 14: Solnova 1 under construction



Figure 15: Abengoa Solar Trough

5.- Solnova 1. Operation and Maintenance

Plant maintenance is fairly simple, consisting mostly of mirror and tube cleaning. To perform cleaning, Abengoa Solar has designed a system that uses demineralized water to wash the mirrors and tubes. The cleaning system runs regularly on an automated schedule so soiling does not reduce plant efficiency.

Some of the most notable highlights of Solnova 1 are:

- With the local solar resource and an installed capacity of 50 MW, Solnova 1 is capable of generating 114.6 GWh of clean energy annually. This is enough to supply 25,700 homes and avoid more than 31,200 tons of CO₂ emissions every year.
- In low solar radiation conditions, the plant is capable of supplying 12-15% of its capacity through natural gas.

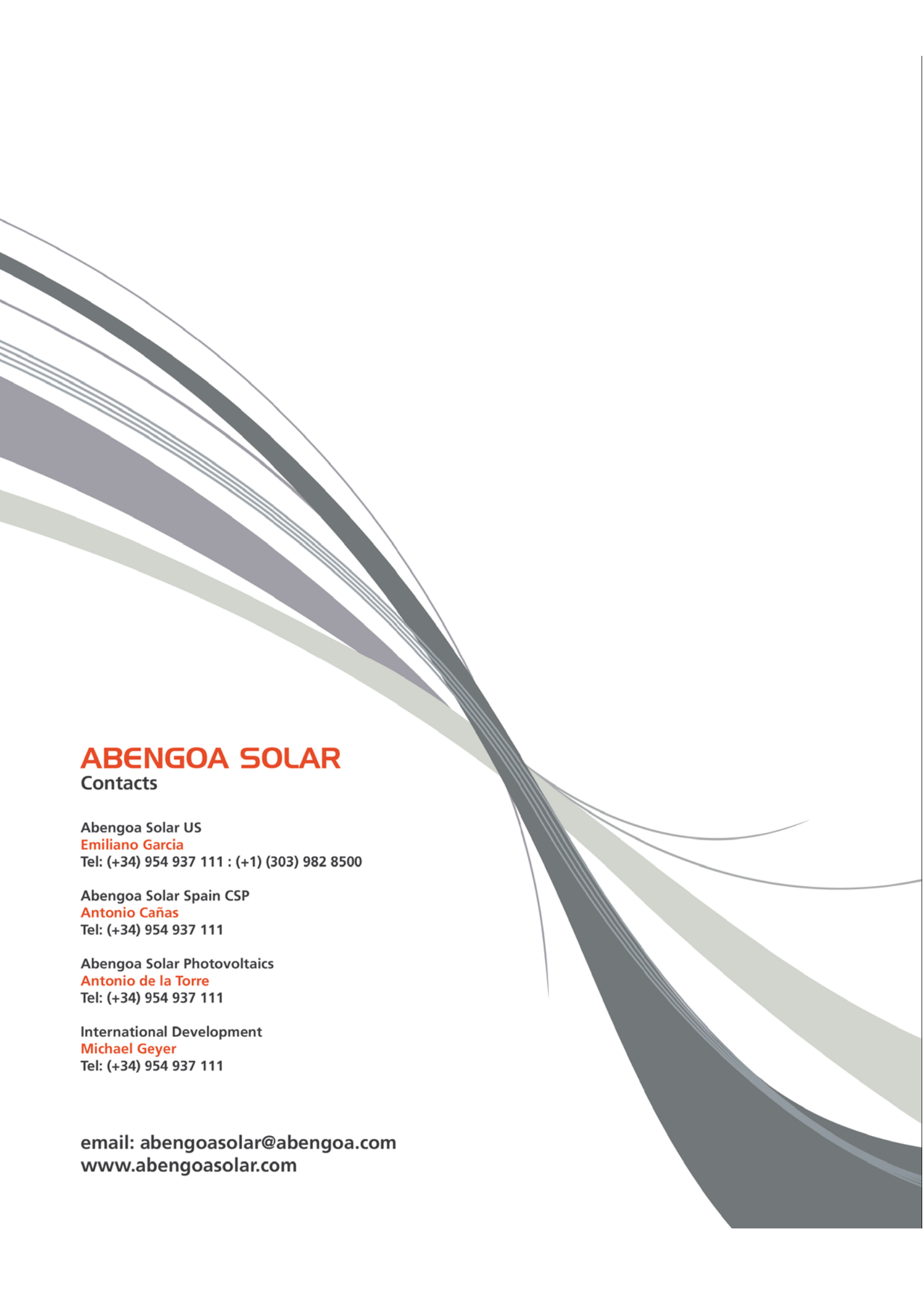
6.- Future CSP Developments

Abengoa Solar is committed to facing the great challenges of solar energy. Currently, a trough demonstration plant is under construction to test various working fluids to increase solar trough efficiency. This technology can not only be applied to electricity generation applications, but also industrial heat and residential applications. The Solucar TR, which is the support structure for the parabolic trough plants, is under continuous improvement to reduce cost, improve installation and maintain performance.

Besides Solnova 1 and its R&D projects, Abengoa Solar is involved with the research and development of many other solar thermal technologies, including: construction of a 25 kW dish Stirling demonstration plant and high temperature solar tower demonstration plants.

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 fuels



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