Delivering on Earth's *Solar Potential*

Concentrating Solar Thermal Power as a solution to the world's energy challenges

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THE CLIMATE GROUP

PRICEWATERHOUSECOOPERS

> What if you could provide the world with an endless supply of virtually carbon-free electricity; ensure a constant source of drinkable water to the world's most vulnerable areas; avert some of the world's future humanitarian crises; and save billions of dollars in the process? Concentrating Solar Thermal Power (CSP) proponents say there is no 'could' about it - it's more a case of 'can'.
>
> CNN, 12 November 2007

Front cover | Solucar PS10 and PS20, Abengoa Solar

Back cover | BrightSource Energy

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Solar Potential

so·lar / sōōr/ adj.

- of, relating to, or determined by the sun
- solar radiation: relating to or denoting energy derived from the sun's rays

po·ten·tial (p-tnshl) / adj.

- Capable of being but not yet in existence
- Having possibility, capability, or power

Solar Potential is the name that has been given to the collaboration between The Climate Group and PricewaterhouseCoopers LLP (PwC) to research and communicate the opportunity to accelerate the development of a SuperGrid, and the uptake of renewable sources of electricity, in particular Concentrating Solar Thermal Power (CSP), globally as a direct means of tackling Climate Change and energy security. This short paper has been written to highlight the opportunity in Europe, the Middle East and North Africa (EUMENA) building on the results of a number of earlier detailed studies. It also looks to begin to provide an illustrative roadmap for how we might then deliver on Earth's ***Solar Potential*** globally in the coming years.

PricewaterhouseCoopers refers to PricewaterhouseCoopers LLP (a limited liability partnership in the UK) or, as the context requires, the PricewaterhouseCoopers global network of firms, each of which is a separate and independent legal entity.

The Climate Group is a UK registered charitable company limited by guarantee, trading as The °Climate Group.

Executive summary

The challenge

We now know that substantial climate change is unavoidable and that it poses an immense risk both to mankind's everyday lives and the world around us. There is an urgent need to take action, but progress to date has been slow and limited in its impact.

The opportunity

The world needs to identify and promote those solutions that can immediately cut global greenhouse gas emissions, and begin to address other areas of risk such as energy security and the provision of safe water for human consumption.

The solution

As part of a multi-faceted approach, Concentrating Solar Thermal Power (CSP) can play a key role in addressing this challenge. This document aims to highlight those areas that need to be accelerated to deliver a EUMENA solution in the coming years, which can then be used as a blue-print for other regions around the world.

Why CSP

- CSP produces clean electricity
- It produces no hazardous operational waste
- It can supply electricity on demand
- It is based on proven technologies, many of which are available now on a commercial scale
- It can directly and significantly contribute to GHG emission reductions
- It has the potential to support the desalination of sea water
- It has the potential to supply electricity to the EUMENA region when combined with HVDC infrastructure

> “Within 45 seconds, the surface of the Earth receives enough solar energy to fully meet the world’s entire energy needs for that day.[1]”

Key Benefits for Europe

Clean and Secure Energy

- GHG emission reductions
- Opportunity to create a more diversified source of electricity for Europe
- Production of “clean” electricity that meets the renewable directive targets
- Possibility of CDM and ROC credits

Energy Market Development

- Driving the development of a coherent energy policy across Europe
- Increased political and commercial cooperation across EUMENA

Economic Benefits

- Potential for stable and lower cost electricity over time with increasing scale of production
- Economic development/innovation

Key Benefits for the Middle East and North Africa

Access to resources

- Domestic provision of electricity to rural areas
- Improved grid infrastructure
- Increased energy security and independence
- Desalination of seawater and the provision of freshwater to areas affected by water scarcity

Economic Regeneration

- Export earnings from the sale of ‘clean’ electricity to Europe
- Availability of water and funds to support horticulture
- New investment and development opportunities
- Job creation during the construction and operation of the sites

Social Benefits

- Reduction in emigration as a result of increased jobs and earning potential
- Opportunity for transport and mobility
- Increased standards of living
- Increase in education and expertise

1. Trans-Mediterranean Renewable Energy Cooperation (TREC is now represented by the Desertec Foundation http://www.desertec.org)

Our global challenges

> Our climate is changing, and we are faced with many years of continuing unavoidable change. Even if we make a significant reduction in greenhouse gas emissions tomorrow, the lag in the climate system means that we will need to cope with a changing climate for the next 40 plus years, due to emissions we have already put into the atmosphere.[2]

Many reports have been issued over the past decade highlighting the increasing concentrations of atmospheric greenhouse gases (GHGs) such as CO_2 and the impact that these have on global warming. When this is combined with ongoing natural resource depletion, human populations and biodiversity around the world could be facing a bleak future.

To enable us to understand these developments and develop a coherent response, scientists and researchers have identified a number of mega-trends through which the resultant impacts will be felt. These range from likely shortages of water and energy, to changes in agriculture and biodiversity around the world. The global response to these challenges to date has been largely inconsistent with the scale of the problem. Efforts have primarily been focussed on selective mitigation measures with very little work done by way of adaptation, particularly in the developing countries that are likely to be most affected by climate change.

During 2008 and 2009, the world introduced a further self inflicted crisis – the economic crisis. This continues to impact the global economy today and has the potential to distract the attention of the world from taking steps to address the more serious and long term climate change issues.

Recently, Lord Stern outlined that the economic crisis will be shorter term and less profound, than climate change or poverty.[3] Our coordinated response to this economic crisis however has the potential to play a very important role in determining our ultimate success in addressing the risk to human existence from the impacts of climate change. He adds that if we exclude the move to a low carbon economy from the response to the economic crisis, we could instead be sowing the seeds for the next, potentially larger financial crisis.

With man-made GHG emissions acknowledged to be the primary cause of climate change[4] and with the majority of these emissions resulting from the combustion of fossil fuels for energy generation, there is a clear opportunity to link a response to the economic crisis with an active programme of investment in low carbon and renewable energy opportunities. A range of renewable energy options exist and the potential role of one type of renewable energy, CSP, is explored further in this document.

Other energy challenges

- Supply challenges resulting from population growth and economic development. Some estimates put global demand increases at 50% by 2050. Such an increase cannot be met by existing or planned infrastructure;
- GHG emission reduction targets will restrict new build and the ongoing use of fossil fuel power stations. Alternative energy represents a means of producing energy and still meeting these targets;
- Recent price volatility and concerns about security of fossil fuel e.g. gas supply, have forced governments to consider both their source of supply and their overall energy policy.

2. Firth, J and Colley, M 'The Adaptation Tipping Point: Are UK Businesses Climate Proof?' Acclimatise and UKCIP, Oxford.
3. Stern, N., "A Blueprint for a Safer Planet: How to manage Climate Change and Create a New Era of Progress and Prosperity", The Bodley Head, London
4. IPPC Fourth Assessment Report (AR4)

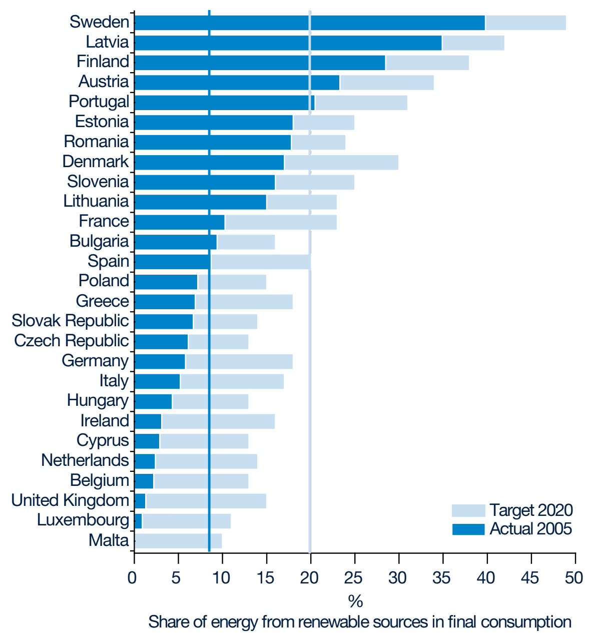
The EU policy response

Globally, faced with increasing awareness of the consequences of climate change, governments have come together over the past decade to agree on measures aimed at reducing emissions of GHG. The Kyoto Protocol required ratifying countries to curb emissions by 5.2% (compared to their 1990 level) by 2012 and work is now underway to define the post 2012 regime. The endorsement of secondary targets by world leaders will play a key part in determining whether a concerted response is possible. In December of this year governments will again assemble, this time at COP15 in Copenhagen, in an effort to agree a new set of post-Kyoto targets and measures.

Several countries have adopted ambitious national emission reduction targets. In the EU governments such as the UK have set targets to reduce national GHG emissions by at least 10% and 20% (compared to 1990 levels) by 2010 and 2020, and EU MEPs have recently voted in favour of long term reduction targets of 60 - 80% by 2050. These figures mirror those favoured by the US, where President Obama has also made significant investment available for the development of renewables, clean technology and smart grids.

Directives have also been issued in recent years to restructure the EC framework for the taxation of energy products and energy generation by allowing partial exemptions or reductions in the level of taxation on renewable sources. The hope is that this legislation will act as a driver for industry and consumers to become more efficient and reduce their carbon footprint whilst also encouraging the use of more electricity from renewable sources.

Although electricity only represents approximately 20% of EU energy consumption, looking at the current state of play, it is clear that very few countries are in a position to come close to achieving their EU reduction targets. Further actions both nationally and across the EU will be required to substantially increase the use of renewable energy to enable these targets to be met.



> Europe needs to work harder to diversify its sources of energy, something it must do anyway if it is to meet its ambitious climate change targets…a fully liberalised energy market with better linkages between countries, offers Europe not only a more efficient energy future, but also a more secure one.[5]

5. The Economist, 10th January 2009

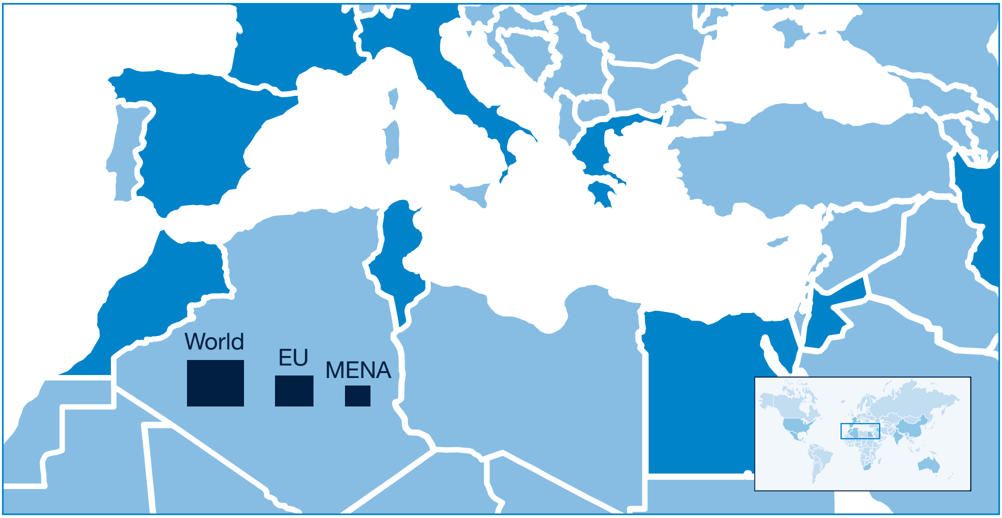
The role of renewable energy technologies

Positioning CSP to help meet our energy needs

With higher fossil fuel prices and increasing concerns over energy security likely in the coming years, we expect governments to increase their encouragement for the development of renewable energy for electricity production through measures such as policy mechanisms that will impact renewable technologies more generally.

We believe that solar power, in particular CSP, has the potential to represent a significant part of this production increase globally, as the technology is currently already available to support large scale electric generation. Locations where incentives and commercial CSP pilot plants are already underway, e.g. Spain and the US are expected to show particularly large increases in production.[6]

As a natural resource, the sun's energy is more abundant and more geographically spread compared to other renewable resources. The IEA also forecasts that CSP will (with biomass and geothermal sources) contribute up to 7% of a total of 23% of global electricity generation from renewable sources by 2030. With about 10% of the global solar renewable energy capacity present in the Mediterranean and Middle Eastern region, it makes sense to begin here.[7] Other high potential areas include the South West US, China, Australia and South Africa.



The diagram above indicates the size of the area of desert that theoretically would be sufficient for CSP plants to generate as much electricity as is currently consumed annually by the world, Europe (EU-27) and Middle East and North Africa (MENA) respectively.[1]

Less than 1% of the area of the world's deserts, if covered with CSP plants, could produce as much electricity as the world currently uses.

6. International Energy Agency, World Energy outlook 2008, OECD,IEA
7. Observatoire Mediterraneen de l'Energie, Mediterranean Energy Perspectives, 2008

Positioning CSP to help address GHG emissions

CSP can also help directly with efforts to reduce CO_2 emissions. For example, research has suggested that each single square kilometre of desert can potentially generate 50MWhrs of electricity and avoid 200,000 tons of CO_2 emissions. Estimates have been made that indicate if it were deployed globally to achieve its full maximum potential, CSP electricity could avoid up to 35Mt/year of CO_2 by 2020 and 130Mt/year of CO_2 by 2030[8]. With energy related CO_2 emissions accounting for 61% of global GHG emissions, we believe that CSP should be at the heart of government and business efforts to stabilise CO_2 levels in the coming years.

Introduction to HVDC and Smart Grids

High Voltage Direct Current (HVDC) technology has been in use for many years for transmission of electricity over large distances with minimal losses, or for subterranean and submarine powercables. Combining this technology with the concept of a Smart Grid or SuperSmart Grid[9], would allow electricity from renewable sources in North Africa to be transmitted around the Mediterranean and across Europe with minimal loss of power. Through projects like MEDRING and individual EU country initiatives, work is already underway today to begin the development of a Europe-wide HVDC grid.

8. An overview of CSP in Europe and MENA, CSP Today, 2008
9. European Climate Forum, see http://www.supersmartgrid.net

The time is right for CSP

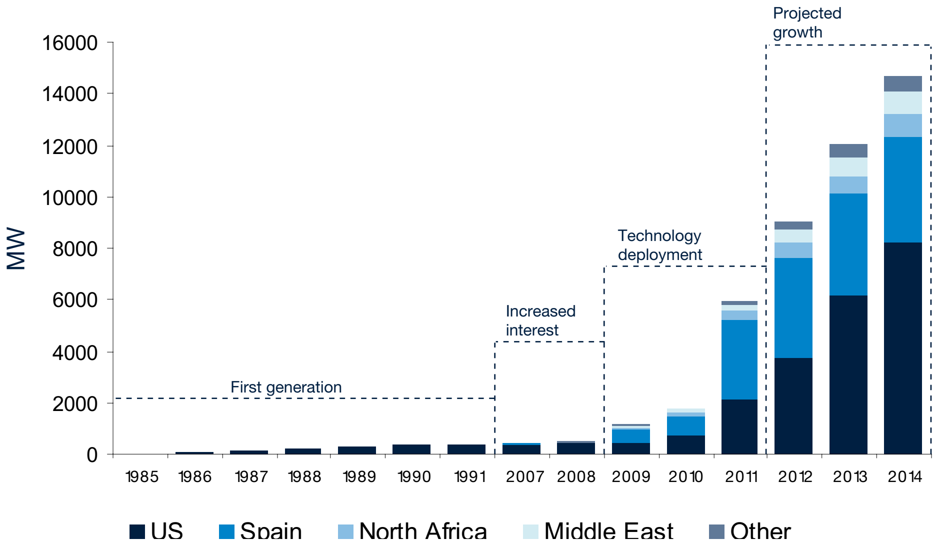
The time is right and the opportunity exists for governments and business to demonstrate leadership by actively supporting and encouraging the large scale rollout of CSP not only as a response to climate change commitments, and as a way of addressing concerns about energy security, but also as a way of encouraging economic and social development in less developed countries.

A number of initiatives have developed and promoted this idea over the past 5-10 years. One of these, the Trans-Mediterranean Renewable Energy Cooperation (TREC)[1], has, for many years, looked to promote a cooperation and sharing of benefits amongst the countries of Europe, the Middle East and North Africa for the generation and supply of electricity to all these countries. Detailed studies have shown that CSP offers huge opportunities e.g. one study concluded that it could realistically provide 15% of Europe's electricity needs by 2050, however given the scale of investment and effort required to achieve this, progress has been slow.

Such ambitious concepts also require significant political will to enable, amongst other things, the appropriate legislation and regulation to be devised at national and regional levels. Once in place, this can then pave the way for an energy market structure that sensibly acknowledges the role of a variety of renewable energy sources and provides a planning and development environment that will encourage potential investors.

If in turn the business community is then able to adopt some flexibility in the way business cases for investment are developed (e.g. accepting non-standard financing models, and longer time horizons for returns on investments), capital is made available and risks are shared, rapid expansion of installed CSP capacity could then be achieved to support a wider global energy security strategy.

Historic and projected global CSP pipeline[10]



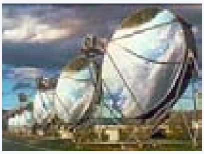
10. Global Concentrated Solar Power Markets and Strategies 2009-2020, Emerging Energy Research, 2009

Introduction to CSP

In simple terms, CSP technology uses mirrors or solar collectors to track the sun and focus the light onto a central point containing a heat transfer fluid. This fluid then passes through a steam generator where the heat boils water to create superheated steam. The steam drives a turbine, which drives a generator and this feeds electricity into a transmission grid. Storage of solar heat is also possible, and the use of gas or biofuels as a back up source of heat means that electricity may be generated at night and on cloudy days.

Types of CSP technology


Fresnel Mirrors


Dish Engine


Parabolic Trough


Power Tower

Key benefits of CSP

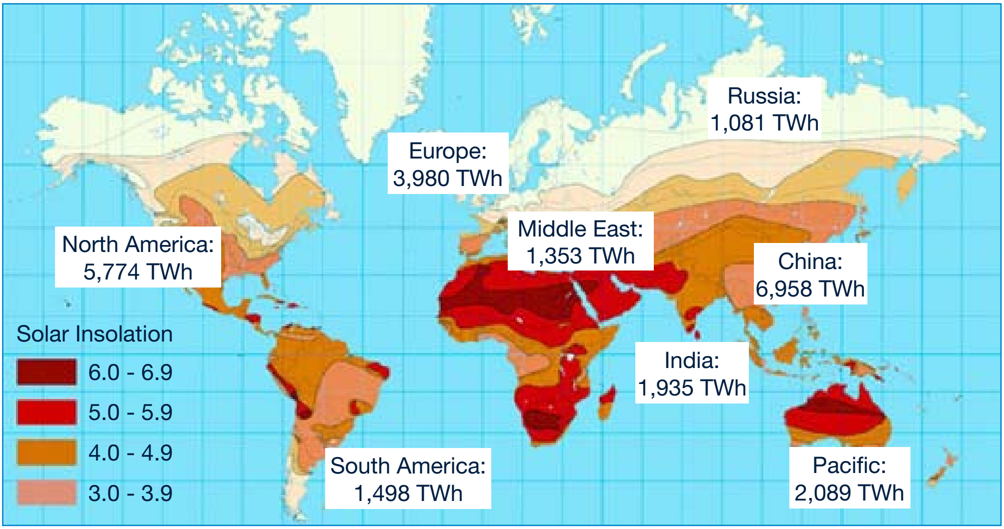
Low carbon	CSP produces clean electricity and utilises the largest, technically accessible source of energy (the sun).
Low operating costs and increased energy security	Large-scale CSP offers stable and decreasing costs of electricity generation. Already competitive against fossil fuels and nuclear power when environmental costs and other externalities are properly accounted for, it has the potential to be much cheaper than established sources of power (especially when technologies such as Carbon Capture and Storage become mandatory).
Proven technology	There are a range of technologies that have evolved over the years. Some of these are proven and have been operating on a commercial scale since the early 1980s, and some still in development, however, each of these offers increased efficiency and capacity with increases in scale.
Desalination	Sustainable and carbon free desalination of seawater is possible, with the water produced then being used for human consumption and agriculture.

Our role: facilitating the growth of CSP in a low carbon future

PricewaterhouseCoopers and The Climate Group believe that CSP is one of a few currently available low carbon technologies which can be considered for a globally dominant role in the electricity sector over the next 40 years delivering energy security and helping to directly address GHG emissions in both developed and developing countries.

This conclusion has been drawn by looking at the maturity of the technology and the established performance record from the US and Spanish CSP plants. In the short to medium term, we see greater grid connectivity emerging in both Europe and the US. This will serve to support an increasing role for renewable energy and act as a pilot for similar schemes that will eventually emerge in other parts of the world. The anticipated growth in CSP capacity will come from solar technology companies with experience gained in California and Spain, and an increase in the number of commercial pilot projects being established with the support of development banks. This will help to reduce risk perceptions associated with this technology, and enable CSP to play a key role in meeting energy needs of developing countries.

Estimated global electricity consumption by Region by 2030[11]



11. International Energy Agency, World Energy outlook 2008, OECD,IEA

However a number of challenges remain, and our combined focus in the coming years will be on the successful achievement of the following challenges:

Political activities

There is a need for political will to create the right legal and financial framework to govern the actions and activities of a large scale CSP programme. This would also include further regional bilateral agreements to ensure widespread political support.

Market structure

Creating a single market for electricity throughout EUMENA or Europe, and developing a reliable framework for the market introduction of renewable energy technologies. It is important that a proper price is paid for emissions of CO_2, and that a reliable carbon market is established that encourages investment in alternatives to Fossil Fuels. This includes removing overt or hidden subsidies for non-renewable sources of energy.

Renewables

In Europe, political and business support will be required for the implementation of the EU Renewables Directive. This will ensure that there is continued focus on **how** Europe will deliver on its commitments to promote renewable energy and **where** it should be coupled with further national and EU wide regulation to promote renewable energy.

Certainty

Providing the right framework of incentives will be important. This includes long term power purchasing guarantees and removing Government imposed restrictions on the total renewable capacity that can be built. Countries that provide the most certainty will attract the most investment and/or supplies of electricity from CSP plants.

Financing and finance structures

The development of greater grid connectivity between Europe and North Africa will require large investments within an adequate financial framework. This will require careful governance, management and support from a range of stakeholders.

Costs of energy

Electricity production costs will play a key role in determining whether CSP is adopted on a large scale. Convergence of costs with other renewable sources and fossil fuels is expected in the coming years and will need to be supported by continued technological innovation, decreasing component costs, economies of scale and innovative financing arrangements.

Infrastructure

Realisation of CSP's potential and the resulting reduction in GHG emissions will only be achieved if it is possible to finance and develop the associated transmission infrastructure. Once in place this will also promote economic development in North Africa, and support the growth of other renewable sources of electricity.

Utilities

These organisations will need to engage with governments and businesses in the renewables debate, consider changes to their business models, support renewable energy pilot projects and do more to inform their customers about the costs and benefits of renewable energy.

Environmental and social considerations

Environmental and social impacts must be evaluated carefully in order to avoid harmful results. As early projects get underway, environmental impacts from both the CSP plants and the HVDC transmission lines need to be carefully considered and addressed both to avoid mental harm and to avoid possible public resistance to future projects.

A roadmap for success

The diagram below provides a roadmap with five-year intervals from the present day to 2025 and provides a potential vision of the future progression/growth of CSP taking into account factors such as technological developments, planned projects and recent/upcoming government legislation.

	Technology Development	2010 · Technology Establishment	2015 · Market Development	2020 · Market Expansion	2025
Market Development	Individual country incentives/feed in tariffs, limits on installed capacity, public private partnerships	Broader based incentives, demand led purchase agreements, limits on capacity removed, long term purchase agreements	Harmonisation of cross border legislative, commercial and market conditions, insurance and guarantee arrangements	Creation of an open and competitive market for renewable and fossil fuel energy	
Policy Requirements	UNFCC Copenhagen 2009, EU Directives on CO_2 storage and emissions	Increasing National and Local Policy, use of CDM, 2nd phase of ETS, potential for higher carbon prices in later years	REN Directive and GO introduced, 3rd phase of ETS, widespread CO_2 auctioning, other GHG control mechanisms e.g. Kyoto2	Implementation of a European strategic energy technology plan	
Stakeholder Engagement	Niche interest, small but increasing number of technology providers and financing organisations Ongoing engagement with national and regional governments	Support from utilities and improved coordination with other renewables Alignment of business interests and broad financial support for new ventures	High levels of cooperation, establishment of joint governance arrangements for regional initiatives		

Key hurdles and barriers to overcome to deliver CSP

Political

- A lack of political EU leadership and will
- Suitable legislative and commercial arrangements across the EU
- Lobbying by organisations with vested interests

Social

- Western concerns about locating energy generation in North Africa and Middle East
- Impact of development on local communities
- Greater interaction and linkages between countries in North Africa and the Middle East

- Investment costs
- Certainty and incentives for investors
- Lack of a developed market structure for renewable energy (feed in tariffs, regulation, caps)
- Costs and timescales to build necessary infrastructure

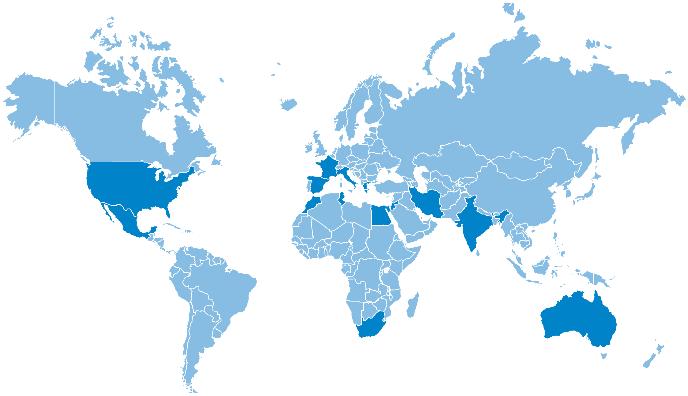
Economic

- Which CSP technology?
- Proof that the chosen technology can be scaled up to commercial levels
- Maintenance and operating requirements

Technology

Global distribution of CSP projects

A number of countries around the world most notably Spain and the US, already have a number of CSP plants in operation, with grid connections allowing local towns to derive most of their electricity requirements from clean sources. The map below illustrates some of the countries with existing and/or planned CSP installations in the coming years.



Algeria
Australia
China
Cyprus
Egypt
France
Greece
Iran
Israel
India
Italy
Jordan
Mexico
Morocco
South Africa
Spain
Tunisia
USA

Countries in bold are home to operational CSP sites. The remaining countries are at various stages of the CSP planning and development process.

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Additional sources of information

A number of organisations around the world have carried out work in recent years to examine and test the opportunity that CSP coupled with the development of a HVDC smart grid can play in meeting local, regional and global energy needs. Further information on these studies can be obtained from the relevant organisations and websites listed in this document.

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