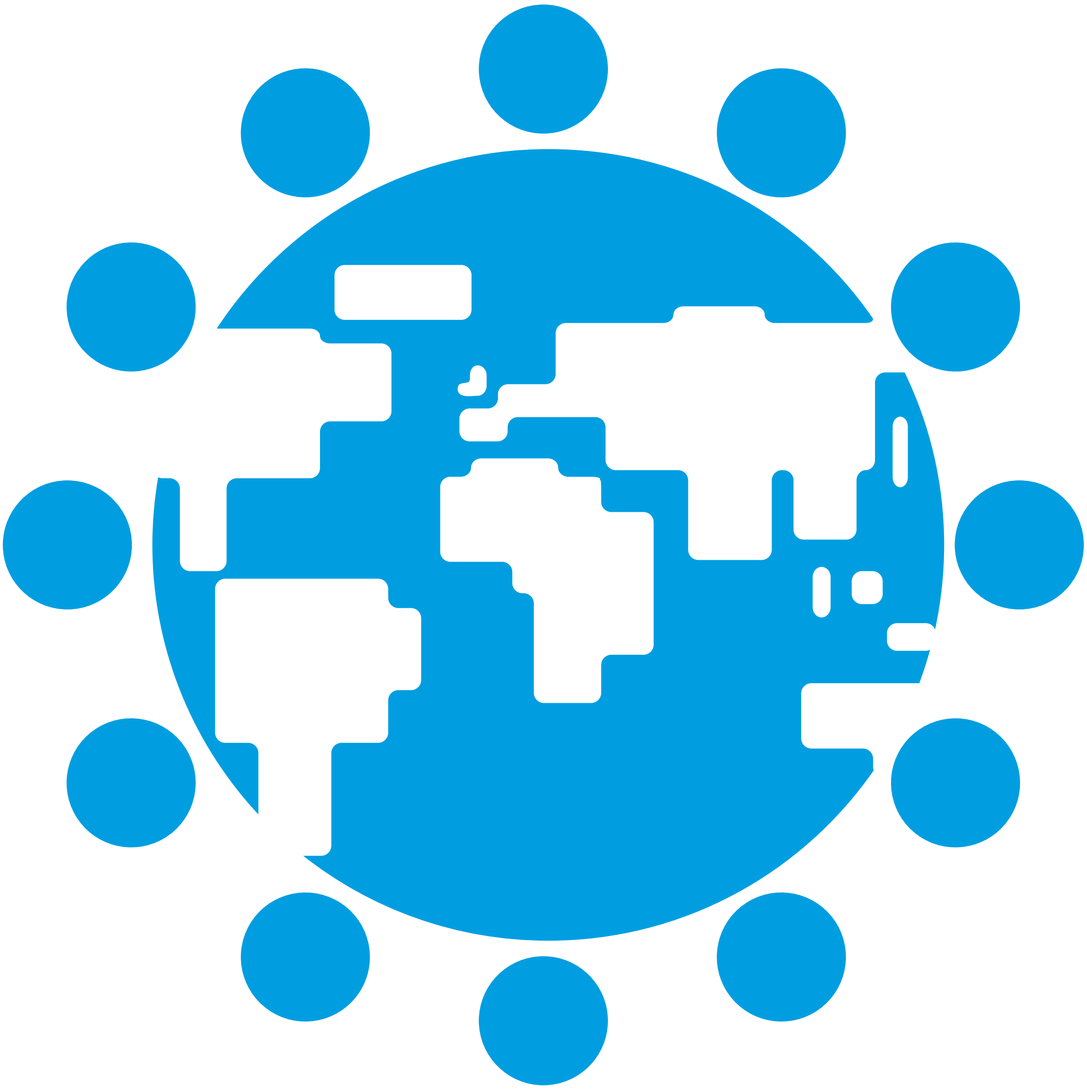

Scalable Electric Power from Solar Energy

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THE °CLIMATE GROUP

Breaking the Climate Deadlock
Briefing Paper

About the 'Breaking the Climate Deadlock' Initiative

'Breaking the Climate Deadlock' is an initiative of former UK Prime Minister Tony Blair and independent not-for-profit organisation, The Climate Group. Its objective is to build decisive political support for a post-2012 international climate change agreement in the lead up to the 2009 UN Climate Change Conference in Copenhagen. Its particular focus is on the political and business leaders from the world's largest economies, particularly the G8 and the major developing countries. The initiative builds on Mr Blair's international leadership and advocacy of climate change action while in office, and The Climate Group's expertise in building climate action programmes amongst business and political communities.

This briefing paper and its companions were commissioned by the Office of Tony Blair and The Climate Group to support the first Breaking the Climate Deadlock Report – 'A Global Deal for Our Low Carbon Future' – launched in Tokyo on June 27th 2008. Written by renowned international experts and widely reviewed, the papers' purpose is to inform the ongoing initiative itself and provide detailed but accessible overviews of the main issues and themes underpinning negotiations towards a comprehensive post-2012 international climate change agreement. They are an important and accessible resource for political and business leaders, climate change professionals, and anyone wanting to understand more fully, the key issues shaping the international climate change debate today.

The views expressed and information provided in this paper are the sole responsibility of the author. The Climate Group, the Office of Tony Blair and the staff of Breaking the Climate Deadlock Initiative accept no responsibility for any errors of fact or the opinions contained herein.

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Executive Summary

- Electric power generation accounts for 40 percent of human-generated carbon emissions. Solar energy can provide a material part of global low-carbon electricity needs at costs directly competitive with fossil alternatives, and can meet "utility grade" power quality, cost and reliability requirements. In addition to significant emissions reduction and environmental benefits, solar offers sharply reduced supply and commodity risk.

- Three primary solar technologies – solar thermal electricity, photovoltaic solar (PV), and solar heating – are maturing rapidly, on a fast-declining cost curve. Solar thermal electricity offers the greatest potential for base-load, large-scale power to replace fossil fuel power plants at low technical risk. Photovoltaic solar power can help meet peak load and distributed power needs and could scale rapidly if PV efficiency and storage technology developments accelerate. Solar heating can displace fossil fuel use in residential and industrial uses as process heat.

- With the implementation of an effective carbon credit pricing mechanism or the continuation of current incentives, solar thermal technology can be competitive with electricity from today's new natural gas or Integrated Gasification Combined Cycle (IGCC) coal power plant at "risk adjusted" prices. Low cost capital for plant financing and investment in grid transmission is required to enable this. Costs of competing power sources are underestimated and will rise as costs for externalities like carbon or other pollution are included, providing incentives for scaling up solar.

- Four primary policy steps need to be taken: the adoption of a global carbon pricing scheme; the implementation of national, regional and global renewable power standards; an increased focus on regional/continental power transmission; and making available low-cost capital for low-carbon power generation. Our goal should be to increase global "optionality" to accommodate technological surprises.

Recommendations

a) Decisions required immediately:

- Expansion of technology-neutral, Renewable Portfolio Standards to encourage competitive technology development and deployment to meet decarbonisation needs at the lowest cost of energy.
- Stability of current US and European incentive schemes, along with clear mechanisms for definition and evaluation, and metrics for the new technologies. Time of day pricing will make solar more competitive.
- Formation of large-scale, low-cost capital to underwrite low-carbon energy projects, suitable in scale to finance many individual projects of $100 million-$1 billion scale, and administered so as to support accelerated market entry of newer technologies from early commercial stage to very large deployment.

b) By Copenhagen in December 2009 (COP 15):

- A commitment to build transmission infrastructure to scale solar thermal & PV technology and create "solar parks" – locations with transmission, permitting and infrastructure to support many gigawatts of solar generation each and fundamental research in PV and storage technology. Transmission infrastructure connecting high solar, wind and geothermal power production regions is required.
- Establishment of a framework for a carbon pricing scheme.

Scalable Electric Power from Solar Energy

This paper explores the opportunity for low-carbon solar energy to provide a major part of the world's electric power generation needs – at costs competitive with conventional power sources, within a short time. The paper covers:

- The potential and context for expanding solar power generation
- The current status and future prospects of solar technology
- The cost of solar power generation – understanding it, and reducing it to enable rapid scale-up
- Key policy steps required

Why solar? Potential and context

Electric power generation creates more than 40 percent of human-generated carbon dioxide (CO_2) emissions worldwide, and is the fastest growing large source of carbon emissions. A key challenge for economic decarbonisation is to transform the electrical grid towards "near zero" carbon sources and away from coal, the current mainstay of power generation.

Solar energy offers nearly unlimited potential to generate clean, carbon-free power. In theory, about 1 percent of the world's desert areas, if devoted to solar power generation and linked to demand centres by high-voltage DC (HVDC) cables, could be sufficient to meet total global electricity demand as forecast for 2030[1]. Industry estimates are that a 100 by 100 mile area in Nevada could meet the full electricity demand of the US, with each square mile replacing one 175 megawatt (MW) coal fired power plant[2]. One percent of India's land could supply all its electricity needs in 2030[3]. Elsewhere, it has been estimated that roughly 3 percent of the land area of Morocco, devoted to solar power generation, could provide all of Europe's electricity needs. Similar calculations can be made for, China, Africa and Australia. In most of these areas, the land required has little alternative agricultural or other use.

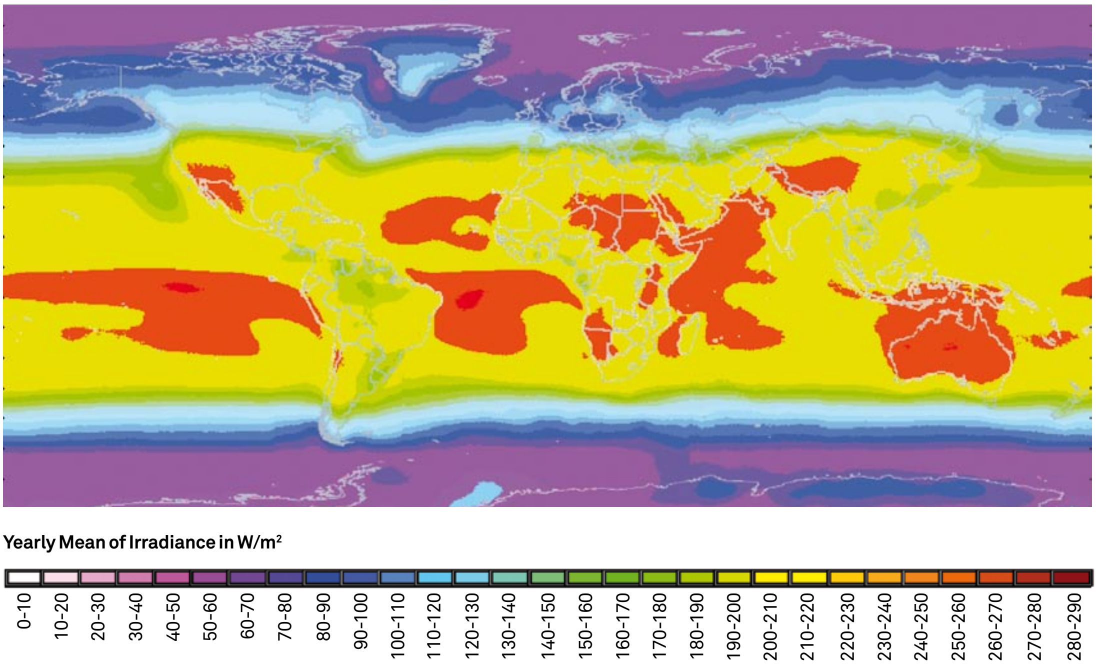
All the world's current and expected major electricity load centres are within practical transmission range of excellent solar radiation locations. Western China, parts of India, the Mediterranean region, Australia, North Africa, the Middle East and the south western US are all ideal sites for large-scale generation projects (Exhibit 1); HVDC grid transmission of power across thousands of miles is feasible from these strong solar radiation zones. In many parts of the world the solar radiation is appropriate for cost effective distributed solar PV.

Solar energy's most significant advantage over traditional energy sources is environmental. Concentrated solar plants (CSP) produce no CO_2 or other emissions during operation; by contrast, the average 500 MW coal plant produces 3.7 million tons of CO_2 annually, along with major releases of other greenhouse gases (GHG). Further, the construction carbon costs of solar plants, relative to the carbon savings, are not material over their lifetime.

Exhibit 1

Global Solar Irradiance Map

Source
Ecole des Mines de Paris / Armines 2006



However, if solar energy is to meet its potential and provide a significant proportion of the world's electric power, it must meet three key thresholds – for cost, availability and reliability:

- The cost of energy must be directly competitive with new fossil fuel or nuclear powered generation – no more than $0.10-0.12/kilowatt-hours (kWh) at equal cost of capital, roughly the cost of new combined cycle natural gas plants today in the US (2007 prices) or just above new Integrated Gasification Combined Cycle (IGCC) coal plants without sequestration.
- Generation must be "dispatchable": power must be available when utility customers need it, not when it is convenient to produce. Energy storage will therefore be required for intermittent resources such as the sun for utility needs, except when matched to local peak load conditions. For solar thermal, storage is relatively easy and can actually reduce the cost of providing power overall. Significant potential exists to develop flow cell or other technologies for power storage but cost effectiveness is critical.
- To achieve "utility grade" power generation, reliability and uptime of the power source, by itself or in combination with other sources, should be on par with that of current coal based power plants. This can be achieved by aggregation of distributed sources or hybridization of multiple sources like solar, enhanced geothermal, wind and natural gas, though it adds complexity to the management of the grid.

As this paper seeks to show, the rapid maturing of solar thermal technology puts it in a strong position to meet all three of these thresholds beyond 2013. With many companies across many countries investing in large-scale centralized solar projects, solar power is likely to be competitive against fossil fuel based generation in the developed world within a few years, though developing world competitiveness may take longer. With significant technology improvement and cost declines, solar photovoltaics used in distributed fashion could provide substantial power generation too in the appropriate geographies. Diverse technology approaches are making rapid progress. The massive scalability and declining cost curves of the technologies mean that solar could displace fossil based power generation quite rapidly, especially if carbon sequestration becomes a requirement and adequate transmission capacity is built. (A new 200 MW solar power plant can be built in two years after permitting. Distributed PV can be installed very rapidly).

Such a transition to solar power would bring significant advantages beyond the environmental benefits already outlined. Notably, it would contribute to regional and international security and stability, avoiding many of the challenges posed by fossil fuel supply and nuclear fuel cycles. As the sun is a reliable, free source of power, solar energy does not bear significant price variability, commodity or transportation risk, and would allow economic growth without "energy shocks". Risks such as terrorist attacks or natural catastrophes could be mitigated through the wide distribution of power projects throughout sunny regions and the availability of diverse backup fuel sources, including natural gas. Further advantages of solar power include its potential complementarities with water desalination, which would reduce the costs of both technologies.

Solar power has the potential to achieve unsubsidised market competitiveness at scale in the developed world; and potentially also in the developing world, provided cost of capital is sufficiently low. There are several steps that policymakers need to take to allow solar to achieve this potential. A key one is to set a reliable long-term carbon price, without which many of the required solar infrastructure investments will remain unacceptably risky. And to promote the required scale and speed of technology development and investment, governments and institutions will need to set standards for renewable power generation, and facilitate the availability of low-cost project capital.

To preserve maximum 'optionality' given the critical and urgent need for carbon reduction, policy should allow for a fair balance between allowing for surprising new technology developments in solar, wind, storage, enhanced geothermal, carbon sequestration, and other areas, while reinforcing the developments that are most likely to succeed based on current "best knowledge" of cost and adoption risks or that offer superior future technology trajectory. Essentially, the role of policy makers should be to set an initial market through the usage of Renewable Power Standards and carbon pricing mechanisms, and then let the best available technologies (that meet requisite environmental standards) to compete, though consideration of future technology trajectory may warrant additional consideration.

Solar technology – current status and future prospects

Solar energy is available in three different forms:

- **Solar thermal power,** which uses solar energy to generate steam in very large configurations to run electricity generation turbines of equivalent size to coal power plants.
- **Photovoltaic panels,** which directly convert solar radiation into electricity. This technology could help meet peak load and distributed power needs, supporting small power plants of below 50 MW
- **Solar heaters,** which convert solar radiation into hot water or air to be used for heat or for other applications. This technology could displace fossil fuels in residential and industrial uses.

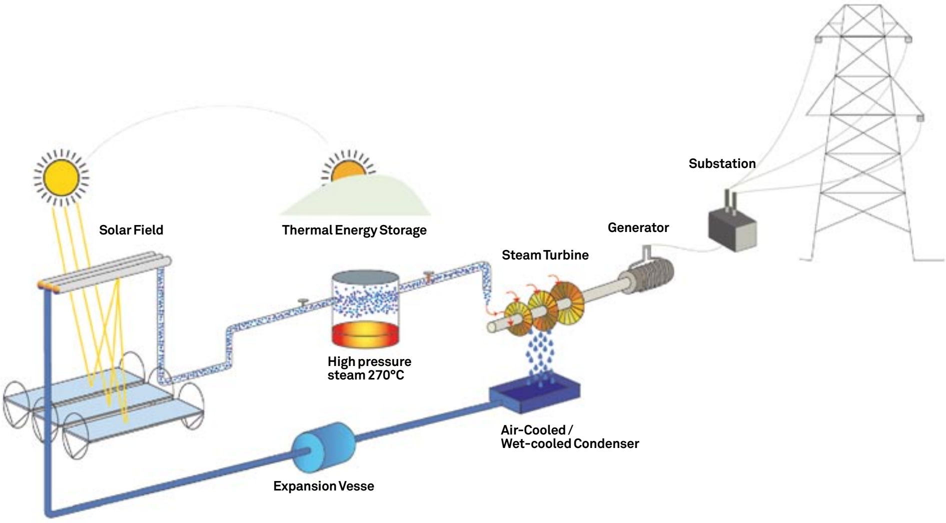
Solar thermal power technology offers the greatest potential to produce base-load, large-scale power that could replace fossil power plants (presently principally coal based) at low technical risk and with characteristics similar to coal, thus reducing adoption risk. The technology is maturing rapidly, amid aggressive competition amongst suppliers. The key advantage of this technology is its capacity to store heat energy at low cost, making "utility grade" solar power reliable and available around the clock (see Exhibit 2). The development of new forms of heat storage is key to making solar thermal power dispatchable at low cost; multiple thermal storage technologies are now at or near commercial deployment, including systems using concrete, molten salt, and pressurised water as the heat-storage element. Thermal storage systems with up to 12 to 15 hours are "free" – adding storage either reduces or leaves constant the cost per kWh of energy while increasing the "capacity factor" and reliability of power generation (because plant and capital utilization, the principal cost in solar technologies, increases). Spain currently has two power stations with large-scale energy storage coming on line, with five more in development.

Companies across many countries are investing in large-scale projects to advance the design of solar mirror fields, which are used to gather sunlight and to heat steam for solar thermal power. These designs are expected to be validated in full-scale commercial operations of between 50 and 200 MW by 2010/11. The principal risk remaining is one of cost per kilowatt of installed capacity; however, continued optimization of manufacturing techniques and designs, with sufficient scale, will significantly reduce costs and improve output efficiency. Many new kinds of cost effective storage technologies also seem likely.

Further experimentation and research is likely to deliver greater sophistication in solar thermal technology over the next decade or two. For example, hybridisation of solar thermal plants with natural gas plants would allow for backup power to cater for rare weather events, as well as supplementary power to enhance output and efficiency. Two other hybridisation technologies are under research, one melding solar with wind based generation; the other linking solar with enhanced geothermal technologies, which could significantly reduce costs. Other configurations in concentrated solar thermal like dish concentration with Stirling engine power generation are also innovating rapidly.

Exhibit 2

Illustrative Solar Thermal Plant



Photovoltaic panels and solar heaters, have an important role to play for distributed generation especially with the development of low-cost power storage, where technical development is being pursued with technologies like flow cells, hybridization with plug-in automotive technologies, distributed aggregation and averaging and other approaches. Their role currently is principally in distributed or remote power generation and they are ideal in locations where peak power demand often coincides with maximum solar radiation. Applications could expand dramatically as storage technology is developed and costs decline. Current costs for wholesale power, central station installations are about twice those of solar thermal technologies under the same financing assumptions. On the other hand, distributed photovoltaic power has the potential to be broadly cost effective in the near future in higher power cost OECD markets, or where air conditioning is a big need, as in the south western US, India or the Middle East. High efficiency and lower cost PV technologies are in development.

Photovoltaic cell technology is following a rapidly declining cost curve. The price of solar modules is expected to fall from around $2 per watt today to $1 in the near future, with the price per watt installed likely to fall from $6-8 to $3 per watt. However, "balance of plant" costs, including power electronics and installation, are declining more slowly and may become the dominant costs unless low cost high efficiency cells are developed. Active research in this area is underway. Concentrated solar PV provides additional area for innovation and cost reduction. Low cost tracking mechanisms including passive tracking are also being tried to improve the output of each PV cell.

The development of effective storage mechanisms, such as flow cells, could make photovoltaics a significantly more valuable base-load power source, and significant research is warranted in this area. Hydrogen as a storage medium is also possible further in the future, although efficiencies are currently low and costs high. Other possibilities exist in combination with solar based hydrogen production and use for "storage" via fuel cells. An important development would be to get acceptance of large scale distributed generation and management among utilities.

Understanding, and reducing, the cost of solar power

How, then, does the cost of solar power technology compare to that of other technologies? And, how can solar power rapidly become sufficiently cost-competitive to provide a major part of the world's electricity needs?

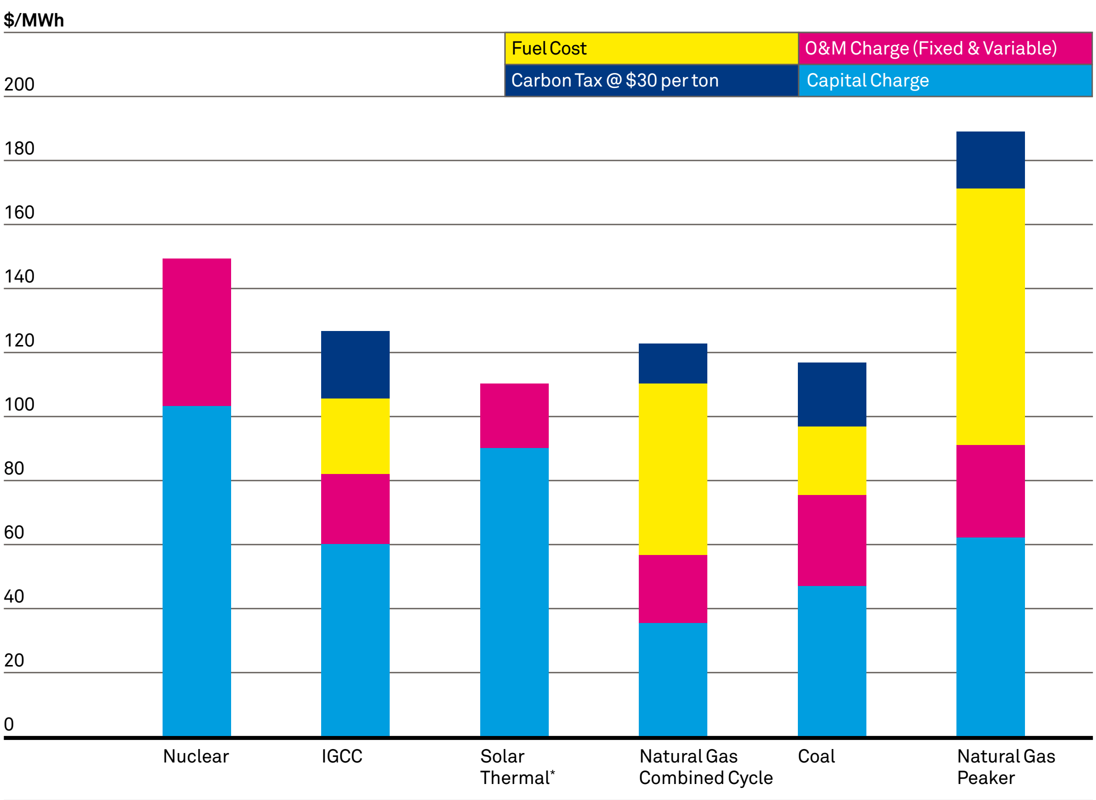
Current and projected costs of solar power

At the outset it is important to note that when renewable, developing technologies are compared with older, stable technologies, there are multiple cost curves at play. One is the cost escalation curve for raw materials like steel, which applies across the board; the other is a technology improvement curve of various components that varies significantly between technologies and components, making the greatest impact on nascent technologies. Finally there is an "experience learning curve" as production gets more efficient with scale and experience. This is particularly relevant to solar thermal technology, which is on a rapidly declining technology and experience cost curve, especially when it approaches scale. The "module" component of solar PV has a similar fast improving technology and experience cost curve.

With current incentives in place in the US and in many European countries, solar thermal power generation is approaching cost parity with, or is cheaper than, natural gas or oil based power generation. The solar thermal power generation cost[4] in California is approximately US$0.14-0.15/kWh for new "best in class" construction starting today (including US incentives), and is expected to fall to US$0.10-12 by 2013 (including either current incentives or carbon credits), provided plants are built at scale and in high solar radiation zones. This compares with today's US power generation cost from next generation coal plants – $0.08-0.10 in the USA from new IGCC coal plants without sequestration, and $0.10-0.12 per kWh for new natural gas combined cycle plants without carbon sequestration. Costs depend materially on the year of "construction" and "fuel pricing" and 2007 construction/materials cost is used as a base year in the above estimates. Carbon credits costs at $30/ton would add roughly $0.03/kWh to coal plants but sequestration costs could be substantially higher for the next decade or two. Financing premium for unproven technologies or companies can add $0.02-0.03/kWh in costs today which is expected to be eliminated for new construction starting in 2013.

Exhibit 3

Solar Thermal vs. Conventional Technologies – 2013



Note
Data provided by Ausra for US plants of at least 175 MW; older CSP data has generally been for small, uneconomic plants and without factoring improvements in technology. Additionally, here are many solar thermal competitors with varying cost profiles.

Exhibit 3 provides an overview of the expected costs in 2013 of solar thermal relative to other power technologies; these are broken down by fuel, operations and maintenance, capital charges and carbon tax. As these figures demonstrate, capital is by far the largest factor in the cost of solar power today. This makes the cost of capital crucial to solar energy's viability. With access to the kind of low-cost capital that has historically financed large-scale power projects such as nuclear, solar thermal technology could produce electricity significantly more competitively[5]. Exhibit 4 provides a representative cost estimate for wholesale solar power production, including producers' margins; it demonstrates the major impact of the cost of capital on the price of electricity produced. Exhibit 5 shows the estimated variation in costs in other locations around the world.

Exhibit 4

Representative 2013 cost estimate for US wholesale concentrated solar power production, including producers' margins
Assumptions: 80% debt, Return On Equity (ROE) 12% in Arizona, USA, wholesale prices including producer margins)[6]

Interest rate on debt	3%	6%	8%
United States Electricity costs US$/MWh (no investment tax credit-ITC)	136	155	169
United States Electricity costs US$/MWh (30% ITC, 35% income tax)	88	105	117

*** With 100% debt @ 3% for municipal utilities, no tax credits, current cost = US$115 MWH*

Exhibit 5

Price variation estimates due to location (solar radiation differences and local costs)

Location	Cost variation relative to US
Brazil	between -10% and +10%
Western China	between -10% and -20%
Spain	between +10% and +20%
Morocco	between -0% and -10%

Solar PV Cost Projections

Solar PV cost projections also show a rapidly declining cost curve – in the US, the President's Solar America Initiative (working with the Department of Energy) has targeted grid parity for photovoltaics by 2015 (assuming no "cost" to adding dispatchability to the power). The Solar Energy Industry Association roadmap targets costs reaching about $4 per watt installed by 2015[7]. Active research is underway using a wide variety of technical approaches and significant cost reductions are likely. They key issue with distributed PV power is locations where people live may not broadly meet the optimal solar conditions assumed below in Exhibit 6.

Exhibit 6

Projected future costs of Solar PV[8]

2015 System Price ($/W)	$4.00
2015 Electricity Costs ($/kWh) -- with tracking (25% capacity factor)	0.125 (without storage & dispatchability)
2015 Electricity Costs ($/kWh) -- without tracking (18% capacity factor)	0.168 (without storage & dispatchability)

Though costs for concentrated solar PV are very design dependent and hard to estimate without a specific design, they have the potential to significantly reduce cost per kWh.

Reducing the cost of solar power and achieving rapid scale-up

The establishment of clear, long-term price signals for carbon emissions will have significant impact on the rate of investment and construction in the renewable energy sector, including making solar power more competitive against fossil energy power sources. Historically, concerns about swings in fossil fuel prices have dampened investor enthusiasm in fixed-cost power options; market signals which result in CO_2 costs of $30 a ton would establish a firmer base for solar power investments, and such widespread deployment would in turn strengthen the price competitiveness of all solar technologies. Even without a clear carbon price, non-carbon related environmental regulations, such as restrictions on sulphur oxides and nitrous oxides, have increased the cost of coal power plants and contributed to solar energy's greater viability. The volatility of fossil fuel prices has further strengthened solar power's attractiveness.

With an appropriate cost of capital, supportive policies and sufficient transmission capacity, solar power generation can scale very rapidly in the developed world as soon as next generation plant designs are proven; a number of ventures with new solar thermal plant designs are expected to come on line in 2010-11. A wide variety of solar PV technologies are getting significant venture and research funding. In the developing world, though, solar power faces a more challenging trajectory, given the high cost of capital, limited electric grid capability, and limited pollution control requirements on traditional coal power plants. With poor grid infrastructure photovoltaic solar may get faster acceptance as costs decline.

Globally, solar thermal power capacity can grow by at least 30 percent per year from 2011/12 for the following 10-20 years; potentially up to 200 GW of new plant capacity can be added each year, starting at a conservative 1-2 GW per year in 2012. These figures are based on the growth rates observed in solar photovoltaic (which is also expected to grow 30% per year) and wind capacity and the relative simplicity of the solar technologies. This growth will be subject only to the limitations and build-out of the power transmission grid, and the availability of low-cost capital. Demand for both solar thermal and PV will depend on the cost of power production, though for scalability of the technologies worldwide and especially in India and China, unsubsidized market competitiveness will be key.

In the US, the National Renewable Energy Laboratory has identified the potential for more than 6,000 GW of solar thermal power in the south western US.[9] Large scale expansion would result in more competitive power generation than most fossil sources, including natural gas, oil and new generation coal power plants, even at modest prices of carbon.

Key policy steps required

The primary goal of public policy should be to set the rules under which the market can operate, and to ensure that decision-making takes account of externalities such as environmental impact, health costs, volatility of cost and supply, and energy security. Policy towards solar power generation should therefore be directed at enabling the technology to compete in the market, with full accounting for the cost of carbon and other pollutants. There are four main policy steps required:

- Adoption of a global carbon pricing scheme
- Implementation of national, regional and global renewable power standards
- Increased focus on regional/continental power transmission for all renewable technologies
- Making low-cost project capital available for low-carbon power generation

Each of these steps is outlined in turn.

Adoption of a global carbon pricing scheme
As discussed above, carbon price signals could drive a reduction in the cost of solar power generation, but suitable frameworks have not yet been put in place. Carbon "cap-and-trade" systems have thus far been inadequately administered, and political tradeoffs have weakened these systems, allowing generous transitional concessions to existing power producers. Without a reliable long-term carbon price floor, many needed solar power infrastructure investments will remain unacceptably risky. The implementation of an effective carbon-pricing mechanism is therefore an essential policy step.

Implementation of national, regional and global renewable power standards
With the right policies, renewable electricity standards can play a significant role in transforming the power generation sector.

One way to ensure real carbon reductions is to mandate 'hard renewable technologies' such as solar, wind and geothermal energy, for which the cradle-to-grave carbon cycle can be clearly calculated. In the US, Renewable Portfolio Standards (RPS) at the state level have had outstanding success: utilities have met their RPS requirements and have deployed substantial amounts of wind power in doing so. Resulting production volumes and associated learning curves have dropped the cost of US wind energy 20 times over two decades; and electric utilities have become major owner/operators of wind generation systems. Today more than half of US states have RPS in place[10], and a national RPS scheme seems plausible. Solar technologies have dropped in cost to the point that they are now being taken up aggressively by utilities as part of meeting their RPS mandates, with 4,000 MW of projects now in contract in the US.

A key advantage of RPS policies is that they leave market power in the hands of utilities, rather than picking winning companies or technologies. As a result, fierce price competition is the order of the day; new technologies which can disruptively reduce costs are able to enter against more established alternatives; and cost reductions more commonly associated with computer systems than energy systems have resulted. As a result, typical kWh pricings for new solar thermal electric plants in the US under RPS (US$0.13-0.15 for new bids in California) are less than half the current feed-in law rates in Spain (€0.27 as of 2007), in part because larger scale power plants are being planned in the US.[11]

There is wide support amongst electricity end-users for standards such as RPS: a 2007 poll found that clean electric power standards are by far the most popular and acceptable approach to decarbonisation among Americans, even if they result in higher costs for electric power.[12]

For the next two decades, until low-carbon alternatives such as solar mature and decline in cost, it will helpful to put in place escalating renewable electricity generation standards for "utility grade power" in each country. This will provide guaranteed markets for the most cost competitive low-carbon technologies, assisting them to move further down the cost curve. The implementation of renewable power standards will make it feasible for immature technologies such as solar to compete with highly cost reduced and optimised older fossil technologies which currently enjoy a range of advantages – including scale, previous subsidies, fully amortised infrastructure, lack of accounting for externalities like health and pollution costs, and in many cases help from subsidised or protected industries such as railroads and coal mining. A standards-based approach is preferable to uneconomic feed-in tariffs, unless the tariff has a declining premium over fossil electricity over time and scale. The renewable electricity standard can include "escape valves", which would kick in if the price of renewable electricity were more than an 'X' percent premium over fossil electricity, where 'X' should be a declining number over time.

Increased focus on regional/continental power transmission
Achieving large-scale renewable generation at low cost depends on establishing plants at the lowest-cost, high solar radiation sites; this will be made possible by the development of transmission corridors to move energy from those sites to where the loads are required. Technology is not a significant barrier to improved transmission: long distance transmission technologies are commercially available from a wide range of suppliers, and make it economically feasible to move electrical energy many thousands of miles.

The major challenge in transmission is in policy and co-ordination. In the US, for example, long distance power transmission has been the major barrier to the success of RPS implementation in certain regions: challenges in financing, permitting and pricing transmission systems have created nearly insurmountable obstacles. In the US today, thousands of MW of wind projects are stalled, awaiting transmission across state lines, while many solar power deployments are experiencing similar challenges, with parochial regulators blocking transmission projects. In Europe, where excellent and complementary renewable resources are located thousands of miles apart, coordination of generation presents a major challenge and opportunity for policymakers. Interconnection and strong transmission grids will help all renewable, and fossil, technologies.

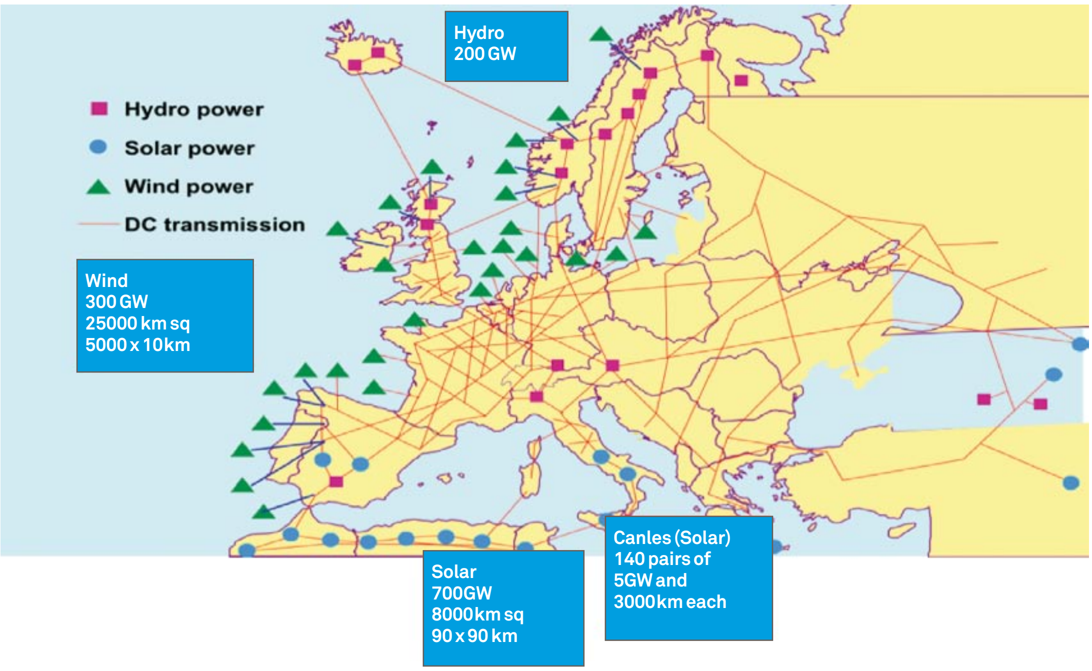
A major step which can be taken in the developed world is the creation of large (potentially continent-wide) "solar park regions", with a staged plan for 1-20 GW of transmission into the countries' or continent's major grid; this would allow rapid development of solar projects by private industry in each country. The DESERTEC proposal, for example, would tie European countries into a "supergrid" – bringing Norwegian hydro power, North Sea wind and Mediterranean solar power to every country. Such an integrated approach would result in the lowest costs and highest reliability for large-scale clean power. How would a continental approach of this kind impact a country like the UK, which is distant from the high solar radiation locations of Southern Europe and North Africa and thus faces challenges in taking advantage of the world's solar energy opportunity? Exhibit 7 shows one company's view (ABB) of how distant solar sources can be mingled with UK wind and other resources in an advanced European high voltage electricity grid[13].

Exhibit 7

Potential European Transmission Grid Scenario

Source
ABB (Personal Communication)

Europe 20XX Scenario



Making low-cost project capital available for low-carbon power generation
On the financial side, governments and institutions can facilitate the availability of low-cost capital for project debt or distributed solar implementation, which will reduce the cost of power generation from solar and other low-carbon technologies that have high capital costs, low operating costs, and low externalities. This can help such technologies to achieve unsubsidised market competitiveness over a short timeframe. Low cost capital can be justified on the basis of low externalities and hence lower social costs.

For the developing world, a very low cost of capital for renewable electricity projects – combined with investment in the transmission grid – would significantly change the balance in favour of low-carbon technologies. India and China, for example, can scale domestic solar thermal power production rapidly to meet all their incremental power needs, given sufficient investment in power transmission; in their case, though, the cost of capital will need to be extremely low to compete with low-cost coal power, which faces limited environmental regulations. At a 3-5 percent interest rate and with substantial capital loans, solar thermal may well become more economic than coal power plants in many other parts of the world. Low capital costs will also help to make solar photovoltaics competitive for distributed or remote rural power generations.

Other financial approaches are possible. Policies such as the German feed-in tariff, which significantly raise the price of renewable energy, are useful in the early stages of technology market introduction when new industries are weak and market development is immature. However, the prices must be reduced relatively quickly in order to avoid a distortion of the economy, in which mature but uneconomical technologies are rewarded.

Glossary of Terms

CSP:	Concentrated Solar Power
GHG:	Greenhouse gas
GW:	Gigawatts
IGCC:	Integrated Gasification Combined Cycle
HVDC:	High voltage DC
kW:	Kilowatt
kWh:	Kilowatt-hour
MW:	Megawatts
MWH:	Megawatt hour
O&M:	Operation and maintenance costs
PV:	Photovoltaic
RPS:	Renewable Portfolio Standards

Endnotes

[1] *Philibert, C: Barriers to the diffusion of solar thermal technologies. OECD and IEA Information Paper, International Energy Agency, Paris, 2006; World energy outlook 2006. International Energy Agency, OECD Publication Service, OECD, Paris. <www.iea.org>*

[2] *www.ausra.com/pdfs/SolarThermal101_final.pdf*

[3] *"National Action Plan on Climate Change", Government of India – Prime Minister's Council on Climate Change, June 2008*

[4] *Note that solar thermal cost estimates are based on current "average" bids received by electricity utilities for "100 MW+ scale" next generation plants in California form a myriad of private companies, and projections of their expected costs in 2013 and beyond.*

[5] *"Economic, Energy, and Environmental Benefits of Concentrating Solar Power in California", Black and Veatch, April 2006*

[6] *Carbon credits not included; Data provides averages based on Ausra's solar thermal power plant designs and actual cost estimates for 175 MW plant starting construction in 2009 and extrapolated to 2013 plants with known technology development expectations; current average bids from multiple suppliers in California to utilities for long term power contracts are about US$0.14/kWh.*

[7] *"Our Solar Power Future: The US Photovoltaics Industry Roadmap through 2030 and Beyond", SEIA, September 2004,*

[8] *Baseline costs are projected based on tax credits (in the US), Cost calculation assumptions: costs included tracking designs; accelerated depreciation; 8% real discount rate; operation and maintenance (O&M) cost per inverter manufacturers' recommendations (roughly half of solar thermal O&M costs).*

[9] *Mark S. Mehos and David W. Kearney, "Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Concentrating Solar Power by 2030," in Charles F. Kutscher, ed., American Solar Energy Society, Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions from Energy Efficiency and Renewable Energy by 2030, 2007.*

[10] *United States Department of Energy - http://www.eere.energy.gov/states/maps/renewable_portfolio_states.cfm#map*

[11] *United States rates – http://www.iht.com/articles/2007/07/25/business/solar.php*

Spanish rates (Royal Decree 661) - http://www.environmental-finance.com/onlinews/0605con.html

Original Spanish legislation: http://www.solarpaces.org/Library/Legislation/docs/RD6612007.pdf

[12] *New Scientist - http://environment.newscientist.com/channel/earth/mg19426091.500*

[13] *This depiction was original conceived in 1992 but its application remains valid.*

Acknowledgements

The views expressed in this paper are those of the author and do not necessarily reflect the position or views of the Breaking the Deadlock Project, The Climate Group, or the Office of Tony Blair. Any factual errors are the sole responsibility of the author.