The Commercial Path Forward for Concentrating Solar Power Technologies

A Review of Existing Treatments of Current and Future Markets

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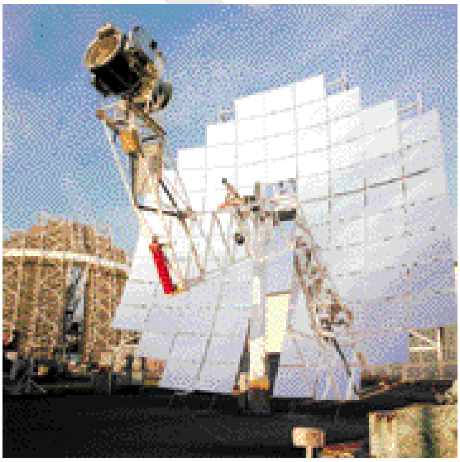

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Executive Summary

CSP Technologies - Concentrating Solar Power (CSP) technologies concentrate solar energy to produce high temperature heat, which is then converted into electricity. The three most advanced CSP technologies are Parabolic Troughs (PT), Central Receivers (CR) and Dish Engines (DE). CSP is a perfect fit with today's modern efficient power plants for which CSP can substitute solar heat for fossil fuel, fully or partially, to reduce emissions and provide additional power at peak times. DE is well suited for distributed power, from10kW to 10MW, while PT and CR are well suited for larger central power plants, 30MW to 200MW and higher. These same technologies can also provide thermal energy for commercial and industrial processes.

Attributes - In addition to producing high temperature heat, CSP has many other attributes that make it a vital part of the global and the US RET portfolio. These attributes include dispatchability, modular and rapidly deployable, and proven performance.

Context - New and powerful political and institutional forces are emerging to promote greater use of renewable energy technologies (RETs). Heat drives the world's power plants. Because they produce high temperature heat, CSP technologies are unique among the renewable energy technologies and are therefore a vital component of the worlds and the US's renewable energy portfolio. CSP, like the other RETs needs continued development and deployment support. It is generally recognized by policy makers and proponents that RETs must be helped into the growing global energy market.

Market Status - Just like many other RETs, CSP consists of a family of technologies, in different stages of development. Parabolic trough systems have entered the commercial market, with central receivers and dish engine systems still in the pilot test phase. Some consider parabolic troughs as the initial approach and central receivers as the ultimate approach in the development of large CSP power plants, but only the marketplace will provide a true test of this thesis. (Ref. Appendix A, "Cost Reduction Study for Solar Thermal Power Plants: Final Report – Executive Summary.")

Market Potential - Market expansion and market acceptance lie ahead for all CSP technologies. Structured programs with subsidies and supportive policies are needed to move CSP technologies into the market expansion phase. The market potential of CSP has been estimated in various studies to be large enough, several 100's of GW, to justify the needed subsidies. By 2010, between 2 and 8 GW are predicted, rising to between 20 and 45 GW by 2020. An installation rate of 2 GW/yr is achievable in a mature market.

Today's Costs - 354 MW of PT systems have been operating successfully in the United States for over 10 years. The cost of electricity from these plants has dropped steadily and is now down to 10-15 c/kWh making CSP the least expensive solar electricity option. Further reductions to about 8 c/kWh are required to enter the peak power market and to about 6 c/kWh to enter the intermediate power market. Central receiver systems have similar goals. Dish engine systems must reduce their electricity costs from about 50 c/kWh today to below

12 c/kWh ($2/W) to enter the distributed energy market in the US and to below 30 c/kWh ($4/W) in developing countries. The key to further reductions is additional power projects.

Projects - Because such projects are privately funded investments, they must provide the investors with attractive investment returns. Because the current capital cost is higher than for the competition, subsidies are necessary, as is typical for other RETs.

Cost Reduction Potential - Electricity costs are reduced by lower capital costs that result from technology and project learning curve improvements, and by lower debt service via better financing, subsidies and risk reduction. The three CSP technologies have predictions and/or scale-up plans that show they can reach their cost targets within 5 years assuming projects are available and can be developed. With incentives, the necessary "virtuous cycles" of *production scale-up - cost reduction- increased market share* are feasible and could be rapidly established for all CSP technologies. For example, a new 200 MW PT Rankine power plant receiving the same tax treatment as a conventional power plant and with the same production credit currently received by wind and biomass would produce electricity for about 9 c/kWh. If the same size plant were to be an integrated solar-combined cycle system (ISCCS) plant, the electricity price would drop to about 7 c/kWh. Learning curve effects will further decrease these costs. Conventional energy prices may also increase in the future, thereby closing the cost gap.

Entry Niche Markets - Many ideal entry niche markets have been identified around the world. Ideal CSP markets require good direct normal radiation, high competing energy prices, availability of subsidies, and other positive factors such as fuel price uncertainty and fluctuations, time-of-day pricing, green power premiums and a need for new capacity. Very promising markets exist in the US, Northern and Southern Africa, Middle East, Southern Europe, India, Pakistan, China, Brazil, Chile, Mexico and Australia.

Barriers - The market barriers are known, manageable and must be addressed for all CSP technologies to successfully enter commercial markets. The major market barriers, in all countries, are higher capital costs, technical risks and financial risks; a dormant CSP industry and cheaper competing fuels. Additional barriers in developing countries include uncertain policies, grid extension plans and legal structure; lack of infrastructure, regressive tax policies and numerous instabilities.

US Market Situation - In the US, new market opportunities for CSP are emerging in response to major new market forces. Many parts of the US need stable electricity prices and new capacity, some of which must be green (solar) to respond to growing customer choice. This creates new opportunities for several hundred MWs of CSP power projects in the US over the next few years.

International Market Situation - In response to Kyoto requirements, a major driving force is environmental and is expressed as a commitment to use public funds to buy-down the initial high cost of promising clean energy technologies. In response, the Global Environmental Facility (GEF), the European Union (EU) and the Governments of Spain and Italy have initiated, or plan to initiate, CSP projects. Approximately ten projects are in the feasibility study or bid process today and it is possible that 10-20 CSP power projects will be initiated in the next 5 years. Refer to Appendix B, "A Rebuttal of the National Research Council's Review of the U.S. DOE Concentrating Solar Power Program – Executive Summary."

Policies - A variety of policies are being used today around the world to invest public funds to move RETs down the cost curve. These include renewable energy portfolio standards, systems benefit charges, non-fossil fuel obligations, electricity feed laws, green pricing, grants, low interest, production/energy/emission/tax credits, and guarantees of several kinds.

Subsidies - Investments ranging from $500M to $4B are needed to bring CSP technologies into the competitive market, depending on the required market expansion take-off price. Incentives such as production credits or carbon credits could provide a major portion of this amount.

Next Steps - A variety of studies have concluded that a series of power plants, of increasing size and performance, requiring decreasing subsidies and associated supportive policies are necessary to make CSP technologies competitive. The Global Environmental Facility (GEF) and the major CSP industries and other stakeholders will attempt to design a strategic market intervention involving the next 10-20 CSP power projects to maximize their ability and rate at which they move down the cost curve.

Purpose – "To review and prepare a report on the current market status and path toward commercialization of Concentrating Solar Power technologies".

Sandia requested that the report should:

a) be a **high-level treatment** of the three CSP technologies;

b) use **prior evaluations** such as in the PCAST and NRC Reports;

c) address current and potential **markets** in the US and internationally; and

d) identify market **barriers** and recommend ways in which they may be **addressed**.

DOCUMENTS REVIEWED AND SUMMARIZED

Policy

Creating Markets for Renewables: Policy Options for Developing Countries, World Bank

Report of the President's Committee of Advisors on Science and Technology, 1997 and 1999

Dish / Engine

Status and Markets for Solar Dish Power Systems, A.D. Little

Dish/Engine Technology Roadmapping Meeting Presentations and Input Materials, Sandia
Market Analysis Summary for Dish/Engine Products, EPIC

Electric Utility Customer Dish Economic Market Potential in the Western US, DUA

Market Potential of the Cummins Dish-Stirling System in Mexico, Dyncorp Meridian

Dish-Stirling Product and Market Development Presentation, Cummins

Solar Dish/Engine System Overview, Sandia

Summary Information Memorandum on SunDish Solar Technologies, Price Waterhouse Coopers

Solar Dish/Sterling Program Cost Projections, SAIC/STM/APS

Central Receiver

Draft Final Report, Nexant

Cost Reduction Study for Solar Thermal Power Plants, Enermodal

Parabolic Trough

Parabolic –Trough Technology Roadmap, SunLab NREL

Status Report on Solar Trough Power Plants, Pilkington

Cost Reduction Study for Solar Thermal Power Plants, Enermodal

CSP Technologies

Market Penetration Study for CSP, SunLab/Sandia

Utility Company's Perspective on Solar Thermal Electric Technology, APS

1999 Annual Report on Status and Future Prospects, IEA SolarPACES

NRC Report

Rebuttal of the NRC Review of the DOE CSP Program, MAI

KEY REFERENCES

Dish/Engine	Status Markets for Solar Dish Power Systems, A.D. Little
Central Receiver	Draft Final Report, Nexant
	Cost Reduction Study for Solar Thermal Power Plants, Enermodal
Parabolic Trough	Parabolic-Trough Technology Roadmap, SunLab/NREL
	Cost Reduction Study for Solar Thermal Power Plants, Enermodal
Policy	Creating Markets for Renewables: Policy Options for Developing Countries, World Bank
	Report of the President's Committee of Advisors on Science and Technology, 1997 and 1999

Findings

- Renewables are important and CSP can and needs to play a key role.
- New and powerful political and institutional forces are emerging to promote the greater use of RETs now. It is widely recognized that RETs must be helped into the growing global energy market.
- CSP technologies are recognized (though not universally), unique enough and important enough to warrant continued development and deployment support as a vital component of the US RET portfolio.
- CSP can and should be a major resource in the US renewable energy portfolio.
- CSP is, or is close to the commercial entry market with the potential market large enough to justify the needed subsidies.
- Market expansion and market acceptance lie ahead for all CSP technologies, with troughs closer to that stage.
- Structured programs, with subsidies and policies, are needed to move CSP technologies through these last three phases.
- There is a large market potential (100's GWs) and the operating characteristics of CSP are well matched with intermediate and peak loads of target countries.
- By 2010, between 2 – 8 GW are predicted, rising to between 20 –45 GW by 2020.

- Market entry for DE requires the electricity price to fall below 12 c/kWh(US) and below 30c/kWh (DC); requires capital costs of $1-2/W (US) and $4/W (DC) and will require about 100MW installed capacity.
- Market entry for PT/CR requires the electricity price to fall below 8c/kWh, capital costs to fall by 2-4 times and will require 1-2 thousand MW installed capacity.
- The three CSP technologies can reach their take-off price points in the next 5 years with a relatively small number of projects, further technology development and subsidies (as other RETs receive).
- With incentives, the necessary "virtuous cycles" (better than Rankine) of production scale up - cost reductions – increased market share are feasible and could be rapidly established for all CSPs.
- In addition to reducing costs, all CSPs must reduce risk and improve dispatchability during peak periods.
- Other market factors can enhance success.
- CSPs must enter the market in the best places first and those have been identified around the world.
- Market barriers are known, manageable and must be addressed to successfully enter commercial markets.
- Policies make markets – look at wind in the US and Europe or PV in Germany and Japan.
- Numerous policy tools have been developed and are being used – they are an essential aspect of the commercialization path for CSP (as for any RET).
- These include RPS, SBC, NFFO, EFL, green pricing, grants, low interest loans, a variety of per kWh credits and guarantees of several kinds.

- Known and anticipated power projects, in the US and overseas, will be enough to drive the cost of CSP electricity into the competitive range.
- US needs new capacity, new green (solar) capacity and electricity price stability. Deregulation lead to RPS, SBC and customer choice. Together creates opportunities for several hundred MWs of CSP power in the next few years.
- Overseas, buy-down programs in response to Kyoto have opened several project opportunities and many more have been studied, resulting in the possibility of building 10-20 CSP projects in the next 5-10 years.
- Overseas, driving force is environmental expressed as a commitment to use public funds to buy-down promising RETs by the GEF, EU, most European countries, especially Spain and Italy for CSP.
- Many ways have been proposed into the market for CSP – primarily via 10-20 power projects, of increasing size and performance, requiring decreasing subsidies, between $0.5 and 4B and associated supporting policies.
- Need a comprehensive set of policies for the greatest chance of success.
- The time is ripe to bring projects and policies together to drive CSP into the competitive range.

CONTEXT

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Renewables are important … CSP can and needs to play a key role

- New and powerful political, policy and institutional forces are emerging to promote greater use of renewable energy technologies (RETs) now. It is recognized that RETs must be helped into the growing global energy market.

- The CSP technologies are recognized (though not universally), unique enough and important enough to warrant continued development and deployment support as a vital component of the US renewable energy technology portfolio. CSP should be a major resource in the US renewable energy portfolio.

CONTEXT FOR CSP

In the past two years, the importance of renewable energy sources has been acknowledged at the highest levels of government, thereby creating a context and new opportunities for CSP.

- ✓ **G8** – The importance of renewable energy sources was recently elevated by the requests of the G8 Ministers for concrete recommendations for consideration to elevate the level of renewable energy supply and distribution in developing countries. (Paragraph 66 of the G8 Press Communique, 2000).
- ✓ **EU** – The European Union Competition Commissioner Mario Monti proposed generous state aid and tax incentives to promote renewable energy technologies. These include a 40% EU grant towards capital costs, augmentable by member states for the next seven years and with subsidies for operating costs over the next five years (EU Press Release, 2000).

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- ✓ **IEA** – The Governing Board made up of the Ministers of Energy of the industrialized countries recently emphasized the need to mobilize public and private resources to deploy environmentally sound technologies, including renewable energy, globally.
- ✓ **US** – In the United States, the two most recent reports by PCAST provide a very positive and important context for the way forward for CSP technologies.
- ✓ **Spain** – Recently amended their incentives to offer a 16 ¢/kWh premium for solar-only CSP power.
- ✓ **Italy** – Recently announced important program and incentives for CSP systems.
- ✓ **Germany** – Just moved their CSP activities to focus more attention and funding in this area.
- ✓ **Conclusion – New and powerful political forces are emerging to promote greater use of renewables now.**

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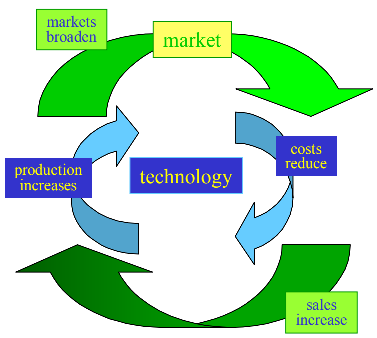
CONTEXT FOR CSP – PCAST 1999

- Global electricity demand will increase by **92%** during 1996 – 2020, with 12% in the US.
- The capital investment in energy supply technologies (fossil, nuclear and RETs) will average between $400 and $600 Billion per year between 1990 and 2020.
- US firms need adequate R&D investments to compete in that market..
- Most expansion of the energy market will take place in developing countries, and these markets represent the most significant growth opportunities for US energy firms in the coming decades.
- RETs could supply an increasing share of world energy demand with appropriate investments in technology and infrastructure.
- RET sales are and will continue to be offshore and are promising for US firms.
- However RETs face market barriers and market failures thus requiring government involvement.
- **Conclusion – RETs are vital and must be helped into the growing global energy market.**

CONTEXT FOR CSP – PCAST 1999

- Proposed a High Priority Widespread – Renewables Initiative to accelerate the deployment of renewable energy technologies (RETs), including CSP, in both developed and developing countries.
- Goal – by 2050, RET's contribution is equal to that of fossil's current contribution.
- Initiative includes buy-downs, tax credits, leveraging of IFC and WB funds and other market development supports.
- PCAST speculates that it might be feasible, over the next 5 years, to establish industries for some intermediate RETs (including CSP) in markets large enough to begin rapid "virtuous cycles".
- In these cycles, production is scaled-up, thereby driving costs down and broadening the market base, making possible further increases in production volumes and still lower costs, as a result of both learning by doing and continuing technological improvements.
- The report notes the increased bullishness about RETs by some energy companies, specifically Shell, BP Amoco and Enron. The author of this report would add Duke, Bechtel, Siemens, AES, El Paso and many others to this list.
- **Conclusion - With incentives, the necessary "virtuous cycles" are feasible and could be rapidly established for all CSP technologies.**

The Virtuous Cycle



Market opportunities lead to increased production, lowering costs. Sales increase, leading to further rises in production and opening up new market horizons.

ATTRIBUTES OF CSP

The CSP technologies are unique enough and important enough to warrant continued development and deployment support as a vital component of the U.S. renewable energy technology portfolio.

Primary Merits include:

- Elegant and effective use of optics to concentrate solar energy into high temperature fluid, which is converted into steam and then power using today's best power technology.
- Modular and thus suitable for large central facilities in the 100's of MW down to distributed generation in the 10's of kW.
- Dispatchable power can meet peaking and intermediate load.
- Proven capabilities, e.g., 354 MW trough plants in operation for 10 years, with selective demonstration of excellent performance, availability, investment cost reduction of almost 50%, and significant O&M cost reductions.

- Trough and tower technologies are solar technologies that are well suited for large scale projects; trough technologies are mature and commercially ready today.
- Adding CSP to existing of new high performance gas turbine systems, reduces CO_2 emissions with minimal cost impact.
- Large US resource with broad siting potential in the Southwest and parts of California.
- Can be rapidly deployed using entirely domestic resources and existing infrastructure.
- Lowest actual electricity costs of any solar technology based on commercial operations.

Other Merits include:

- Maximum output at peak time of day when electricity is at premium price.
- Scale can be significant enough to impact climate change targets.
- Large scale results in significant CO_2 reductions with a single facility.
- Fits IPP projects as well as turn key projects.
- Any IPP can develop CSP hybrid plant because the solar field just provides steam.
- Well suited for integration with conventional power plant design and operation and can blend output with fossil fuel, wind, biomass and geothermal resources.
- Identified potential improvements are feasible and certain as more plants are built and operated.
- Proven potential for further cost reductions including those resulting from mass production economies, i.e. for glass, steel, etc.

Conclusion – CSP's attributes are profound and therefore CSP should be a major resource in the US renewable energy portfolio.

MARKET STATUS AND POTENTIAL

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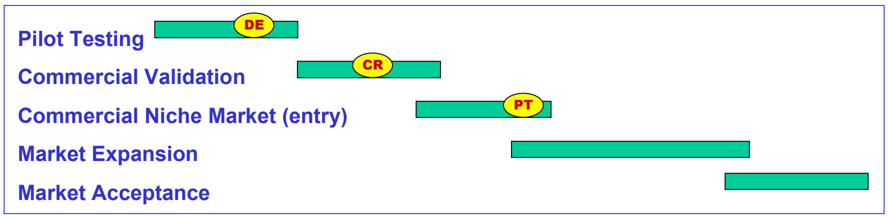
CSP is, or is close to, commercial/entry market, with the potential market large enough to justify needed subsidies.

Market expansion and market acceptance lie ahead for all CSP technologies, with troughs closer to that stage. Structured programs, with subsidies and policies, are needed to move CSP technologies through these last three phases.

There is a large market potential (100's of GW) and the operating characteristics of CSP are relatively well matched with the intermediate and peak loads in target countries. By 2010, between 2 and 8 GW are predicted, rising to between 20 and 45 GW by 2020. An installation rate of 2 GW/yr is achievable in a mature market.

MARKET STATUS

The commercialization path may be described in five phases:



Conclusion – Market expansion and market acceptance lie ahead for all CSP technologies, with troughs closer to that stage. Structured programs are needed to move CSP technologies through these last three phases.

Market Potential and Projections

Is the market potential of CSP large enough to support the increased scale of production that would be required to compete with conventional sources?

- Global potential is roughly estimated to be 100's GW by Pilkington
- While the referenced reports include projections of the market for CSP technologies, none were comprehensive, rigorous and independent
- Therefore, projections from different sources should not be compared.
- Two projections were done relatively independent of manufacturers and, therefore, were primarily used in this report:

  DE – A.D. Little Report

  PT and CR - Enermodal Report

Conclusion – There is a large enough market potential and the operating characteristics of CSP are relatively well matched with the intermediate and peak loads in target countries.

Market Projections

Estimates for installed capacity range widely from:

1,800 – 8,300 MW	by 2010
20,000 – 45,000 MW	by 2020

Today's capacity is 354 MW of commercial PT power.

Conclusion – The market potential for CSP appears to be large and worth the effort required to access it. A rigorous assessment of the global potential of each CSP technology is needed.

PT AND CR MARKET PROJECTIONS

Enermodal – Global

- ✓ 8,300 MW by 2010 could be installed of PT and/or CR globally if the levelized cost of electricity could be brought to below 6 c/k Wh.
- ✓ 30,000 MW by 2020 based on annual installation rate of 2,000 MW/yr beginning in 2010.
- ✓ This prediction was based on a planned response to a series of CSP power plants of increasing size with decreasing subsidies, primarily from the GEF.

Pilkington – Global

- ✓ 45,000 MW by 2020 installed in high value niche markets, based on capturing a small percentage of the 600,000 MW potential.

SunLab – Update of DOE-OPT Estimate – US

- ✓ 2,900 – 4,500 by 2020 if electricity price reaches 4.2 ¢/kWh and is dispatchable and wheelable to adjacent region.
- ✓ Analysis showed 3,900 MW could be built by 2020, about half resulting from price competition and the other half resulting from premiums offered in green markets.
- ✓ If interregional sales are not allowed, capacity of 3,900 MW drops to 2,900 MW.
- ✓ If CSP power plants are allowed to provide more than 10% of the power in any NEMS region, the estimated capacity increases to 4,500 MW.

US CSP Inc. – Global

- ✓ The US CSP industry proposed, <u>without critical review for consistency or connection:</u>

  1,800 MW by 2010

  20,000 MW by 2020

- ✓ These estimates were based on the following distribution for 2010 and 2020:

Hybrid PT	800 MW	6,000 MW
Solar PT	400 MW	4,000 MW
CR	600 MW	4,000 MW

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DE MARKET PROJECTIONS

EPIC

- ✓ 75 MW/yr by 2020 – based on capturing a certain part of the growth on the existing market for diesel generator replacements, rural electrification and IPP applications in developing countries.
- ✓ No information is provided on what the installed capacity might be by 2020.

SAIC/STM

- ✓ 300 MW by 2010 – assuming cost, performance and manufacturing targets are met

  200 MW installed in the US

  100 MW installed in developing countries

- ✓ 1,000 MW by 2020

  440 MW installed in the US

  560 MW installed in developing countries

US CSP Inc.

- ✓ 400 MW by 2010 proposed without critical review for consistency or connection
- ✓ 6,000 MW by 2020

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TAKE-OFF COSTS AND CAPACITIES

INITIAL TAKE-OFF COSTS AND CAPACITIES

Trough systems must cut electricity cost by 40%, tower and dish even more.

Take-off costs and market entry are very difficult to quantify using simple numbers because they depend on competing prices and availability of subsidies and credits.

Dish/Engine	Today about 50 ¢/kWh and $10/W with approximately 0.1 MW pilot units
	Below 12 ¢/kWh and $2/W in the US
	Below 30 ¢/kWh and $4/W in developing countries
	Several hundreds of MWs installed capacity
Trough/Tower	Today about 10 – 15 ¢/kWh and $2,000 – 3,000/kW with 384 MW commercial PT
	Below 8 ¢/kWh and $1,600/kW (Rankine)
	1-2 thousand MWs installed capacity

The 3 CSP technologies have predictions and/or scale-up plans that show they can reach those targets within 5 years, assuming projects are available.

COST PROJECTIONS

The market potential for CSP appears to be large – what about the energy and capital costs?

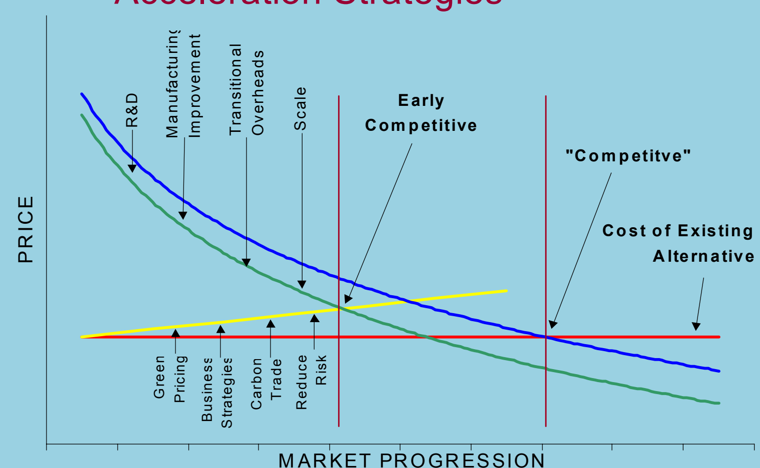
While the excellent technical progress continued in the 90's, promising this greater performance and lower costs, additional projects are now needed to drive the electricity generation prices into the competitive range.

What is that competitive price?

The IEA RET Market Initiative defines a Take-off Price (TOP) as the price of electricity from RET that equals the competing electricity price.

And that competitive price depends on many factors – it is not simply a number.

Analysis:
Acceleration Strategies



DISH/ENGINE ENERGY TAKE-OFF PRICES

TOP assumes that the required performance, reliability, service life and O&M target requirements have been met at that price.

Energy take-off prices and their associated market segments are:

12 - 30 ¢/kWh	Off-grid diesel or remote power in developing countries
6 - 12 ¢/kWh	On-site retail power in US
5 - 10 ¢/kWh	Grid-connected sub-station support in US
3 - 6 ¢/kWh	Grid-connected bus bar power in the US

Today's price, from prototype units, is around 50 ¢/kWh

Conclusion – Market entry for DE requires the electricity price to fall below 12 ¢/kWh in the US and below 30 ¢/kWh in developing countries.

DISH/ENGINE CAPITAL COSTS TAKE-OFF POINTS

The relationship between capital cost and electricity cost depends on many factors, particularly the hours in operation, system availability, debt and depreciation time.

SunDish Solar Technologies estimates the cost of electricity from their 25 kW system to be 9 ¢/kWh when the capital cost has reached $2/W (Price Waterhouse Coopers, 1999).

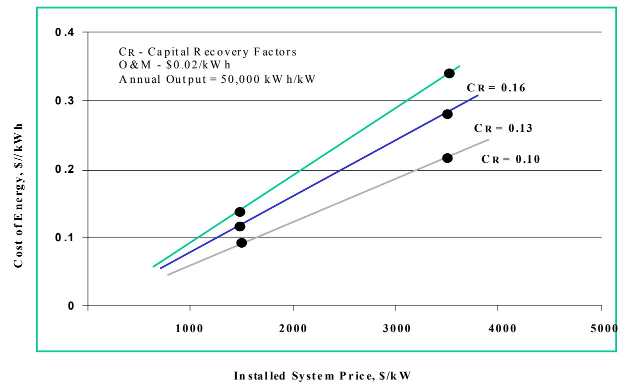
A rule of thumb, for the US, is to multiply the $/W by 5 to get the approximate ¢/kWh cost of electricity.

A.D. Little report uses same rule of thumb

Slide showing ¢/kWh vs $/kW from A.D. Little report

Dish/Stirling Systems **Integrated System Status/Performance**

At capital costs approaching $1,500/kW, solar dish/Stirling systems become cost competitive in selected utility markets.



DISH/ENGINE CAPITAL COST ASSOCIATED WITH TAKE-OFF PRICE

In the US

Reliability may not be critical unless demand charge is a large portion of benefit

- Small business load is a good match and pays the highest rates now
- Industry difficult; residential complex
- Need sophisticated market study – regions, applications, time-of use, demand charges, siting, interconnect rules.

In developing countries

- Higher reliability and lower O&M costs required.

DISH/ENGINE CAPITAL COST ASSOCIATED WITH TAKE-OFF PRICE

Two similar perspectives

Capital cost associated with take-off price

- $2/W Small high value entry markets for on-site and sub-station power in US
- $1.5/W Significant US market without subsidies, green power, set-asides, etc.
- $1/W Huge widespread on-site and sub-station support and entry to busbar power in US
- $4/W Widespread markets in developing countries

Capital cost associated with take off price

- $1.8 – 2.6/W High value in US
- $1.6 – 2.1/W Significant US
- $1.0 – 1.5/W Widespread US

Today's capital cost is about $10/W

Conclusion – Dish/engine systems require capital costs of $1 – 2/W in the US and $4/W in developing countries.

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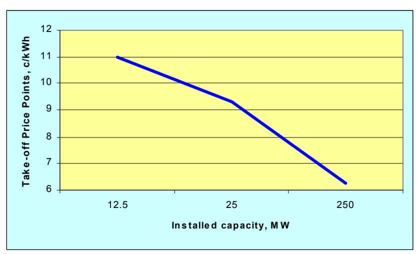
DISH/ENGINE INSTALLED CAPACITY AT TAKE-OFF PRICE

Installed capacity at Take-off Price Points:

11 ¢/kWh	at 12.5 MW
9.3 ¢/kWh	at 25 MW
6.25 ¢/kWh	at 250 MW



This installed capacity pertains to each company, e.g., must be doubled to allow two companies to each drive down learning curve. Additional cost reductions will derive from repetitive installations and product design improvements.

Conclusion – Market entry for dish/engine requires several hundreds of MWs installed capacity

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TODAY'S PARABOLIC TROUGH ENERGY PRICES

- 10 – 15 ¢/kWh is the estimated levelized electricity cost from a solar steam power plant (SEGS) built today without grant financing.
- Lower limit of about 8 ¢/kWh with ISCCS approach.

Conclusion **– These electricity prices are about 2 times more expensive than competing prices but are about 2 – 4 times more cost competitive than PV power generation**

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TODAY'S CENTRAL RECEIVER AND PARABOLIC TROUGH CAPITAL COSTS

- Range of conventional capital cost is \$330/kW (CombGas) \$1,000/kW (RankineGas)
- Range of predicted capital costs for plants built today is \$877/kW - \$4,200/kW
- \$877/kW predicted for an ISCCS plant in Morocco (Pilkington,1998)
- \$2,400 – 3,500/kW predicted for a SEGS plant in the US today
- \$2,100 – 3,100/kW predicted for a new PT/SEGS plants in developing countries
  - \$2,100/kW for Jordan (Geyer, 1997)
  - \$2,244/kW for Mexico (Spencer, 1994)
  - \$2,662/kW for Morocco (Pilkington, 1998)
  - \$3,100/kW for India (Pilkington, 1996)
- \$4,200/kW estimated for a CR plant (Enermodal,1998)
- \$6,000/kW estimated for Solar Tres in Spain (Nexant, 2000)

Conclusion **– These capital costs are about 2 – 4 times higher than the competition.**

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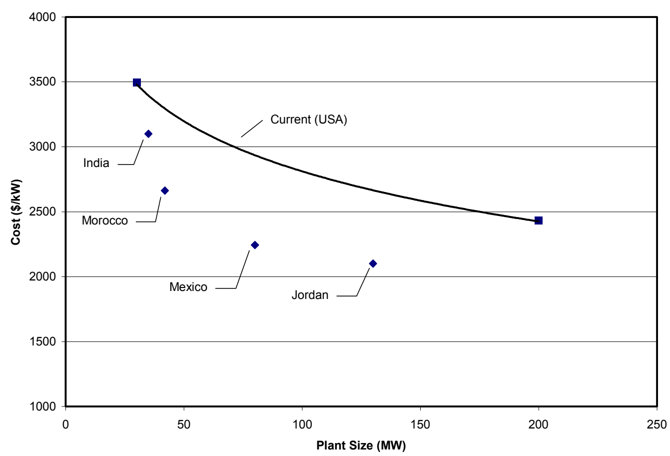
Capital Cost vs MW Capacity

For US + Four Developing Country PT Power Plants



Source: WB/Enermodal

CR AND PR ENERGY TAKE-OFF PRICE OBSERVATIONS

- The PT Roadmap Report predicts that when green markets materialize and mature, CSP power plants will compete without other incentives if they can sell dispatchable electricity at 6 – 8 ¢/kWh.
- The PT Roadmap, however, did not quantify market potential.
- At 4.2 ¢/kWh, which EPRI and DOE (1997) predicted would be reached by 2020, CSP will be nearly competitive with fossil and should be able to be sold on the green market, as it is only 1 – 2 ¢/kWh higher than prices from natural gas combined cycle plants (Kolb, 2000).
- The challenge is to find the best markets to introduce the next series of CSP power plants.
- CSP will reach DOE's goal of 20,000 MW installed and a cost of 5 ¢/kWh in 2015 at a cumulative cost of $690M. By 2035, CSP will reach half its market potential and will then produce 50 TWh.

CR AND PT ENERGY TAKE-OFF PRICES

Energy take-off prices depend on local competing electricity prices and available subsidies.

For example:

- ✓ 6 – 8 ¢/kWh — Peaking power or if fuel prices are high and green power premiums are available
- ✓ 4 – 6 ¢/kWh — Intermediate power
- ✓ 2.5 – 4 ¢/kWh — Base load power from low cost coal where infrastructure is well developed
- ✓ Today's PT electricity prices are between 8 – 15 ¢/kWh
- ✓ Today's electricity prices for intermediate and peaking are 3 ¢/kWh for Combined Cycle to 5.6 ¢/kWh for Rankine-Gas, but wide variations exist.

✓ **Conclusion – Must decrease energy prices by 2 – 4 times.**

INSTALLED CAPACITY FOR PT/CR TO REACH TOP

The additional MWs required to reach the price take-off point depends on that point, hence on competing prices and subsidies. For example, for hybrid PT, to get to the TOP:

1,620 MW	Peaking power and subsidy, hence 8.7¢/kWh
5,700 MW	Peaking power and no subsidy, hence 6.9¢/kWh
8,700 MW	Intermediate power and subsidy, hence 6.1 ¢/kWh
58,000 MW	Intermediate power and no subsidy, hence 4.3 ¢/kWh

The subsidy can be a carbon credit or a production credit of 1.8 ¢/kWh .

The Commercial Path Forward for CSP Technologies

CSP TAKE-OFF PRICES

Technology	Market Application	Take-off Prices
Dish	Grid-connected sub-station	5 – 10 ¢/kWh
	Distributed Generation	6 – 12 ¢/kWh
	Rural Generation – Diesel	12 – 30 ¢/kWh
Tower	Central Station – Intermediate	4 – 6 ¢/kWh
	Central Station – Peaking	6 – 8 ¢/kWh
Trough	Central Station – Intermediate	4 – 6 ¢/kWh
	Central Station – Peaking	6 – 8 ¢/kWh

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CSP INSTALLED CAPACITY REQUIRED TO REACH TOP

Given supportive subsidies and policies, estimates are:

- Dish 0.1 MW pilot systems today. Will require several 10 MW size plants, perhaps several hundred MWs, to reach TOP.
- Tower 10 MW validation systems today. Solar Tres will be 15 MW and will need to be followed by one or two GEF plants in the 30-40 MW size, then followed by many more in the 100 – 200 MW size for 1-2 thousand MWs
- Trough 354 MW today. Need about 5-10 more in the 100 – 200 MW size, perhaps a total of 1-2 thousand MWs.

Caution – Installed capacity to reach TOP is very difficult to estimate due to its complex dependencies.

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CSP PRICE REDUCTIONS VS. YEAR

The following are examples of price reduction plans:

- **Dish** Cummins Business Plan for 7.5 kW units (shifted to begin in 2000)

  $11/W (2000), 8 (2002), 5 (2004), 3 (2006)

- **Tower** EPRI/DOE 1997

  7.6 ¢/kWh (2005), 5.8 (2010), 4.7 (2020), 4.7 (2030)

- **Trough** DOE Roadmap

  14 ¢/kWh (2000), 10 (2005), 7 (2010), 5 (2015), 4 (2020)

  Enermodal Study

  14 ¢/kWh (2000), 10-11 (2004), 7-8 (2009), 6 (2010)

Conclusion – It is easy to draw curves that slope downward. The issue is building the projects to allow those curves to become real.

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COST REDUCTION POTENTIAL

COST REDUCTION POTENTIAL

The three CSP technologies can reach their take-off price points in next five years with a relatively small number of projects, further technology development and subsidies.

Electricity costs – must reduce capital costs via technology and project learning curve improvements and reduce debt service via better financing and subsidies and reduced risk.

- Dish/Engine — Manufacturing scale-up to 1,000 units/yr required
- Trough/Tower — Many available options identified to reach take-off costs

With incentives, the necessary "virtuous cycles" of production scale-up – cost reduction – increased market share are feasible and could be rapidly established for all CSP technologies.

DISH/ENGINE PRODUCTION SCALE-UP PLANS - CUMMINS

To reach take-off prices must reduce capital cost and debt service

Capital costs can be reduced by manufacturing scale-up technology improvements

Cummins started dish/engine work in 1988, spent $20M by 1995 and planned to invest another $45M to build the necessary manufacturing capabilities.

Their scale-up plan was:

Year	1998	1999	2000	2001	2002	2003	2004
7.5 kW units/yr	50	100	500	1,000	2,000	5,000	10,000
$/W	11	9	7.5	6	5	3.8	3
25 KW units/yr	40	200	400	400	1,000	5,000	5,000
$/W	7	2.5	2	2	2	2	2

CR/PT COST REDUCTION POTENTIAL

- To reach take-off prices must reduce capital costs and debt service costs.
- Capital costs can be reduced by manufacturing scale-up, technology improvements, clustering, cycle changes and larger plant sizes.
- Debt service costs can be reduced by grants, low interest loans and tax credits.
- The California plants have demonstrated a significant cost reduction due to investor cost reductions, O&M cost reductions and significant technology improvements

Conclusion – Build more and larger plants with improved technology and lower debt service.

The Commercial Path Forward for CSP Technologies

CR AND PT COST REDUCTION POTENTIAL

- The Enermodal report gave considerable attention to cost reduction potential for PT and CR technologies.
- Future costs were calculated via two methods:
  - Engineering approach based on known technical improvements
  - Learning curve cost reductions from increased volume due to more projects
- They gave similar results, that is, the capital cost of PT power plants will fall by 40% and from CR plants will fall by over 60% from today's values (Enermodal, 1999).

- Capital costs, which vary with local costs and insolation levels, will drop as output increases and should, in the long term, reach $800/kW and be competitive with Rankine.
  - PT costs will drop to $1,800/kW by 2005 and $1,550/kW by 2010
  - CR costs will drop to $2,440/kW by 2010 and $1,560/kW by 2015
- When these reduced costs are achieved, PT/Rankine will be competitive with conventional peaking plants. ISCCS could become competitive with conventional natural gas combined cycle plants as a result of rising natural gas prices. Emissions credit will make PT cheaper.

CR AND PT ELECTRICITY COST REDUCTION POTENTIAL

- The PT Roadmap quantified the cost reduction that could be achieved by various actions.

CAPITAL COSTS

- Plant Size – Doubling the size of the solar field reduces capital cost by 12 – 14% due to increased manufacturing volume which reduces the unit costs for power block and solar field and due to fewer people to perform the O&M.
- Power Cycle – Going to an ISCCS rather than a Rankine cycle/SEGS via a steam bottoming cycle in a 100% larger steam turbine results in higher efficiency and lower capital cost and could reduce solar power costs by 22% over blended power from a SEGS.
- Technology Improvements – Proven and expected technology improvements indicate that cost reductions of over 50% and performance improvements of up to 50% may be feasible.

The Commercial Path Forward for CSP Technologies

- Solar Power Park – Multiple plants in same location can result in lower project development costs, engineering costs, O&M, OH, better labor learning curves, multi-year manufacturing and lower unit costs. Building 5 plants in same site could reduce cost by 25 – 30% over a single project.

DEBT SERVICE COSTS

- Financing – Cost of capital and type of financing and ownership affects cost of electricity and could reduce costs between 10 – 40%.
- Tax Equity – CSP power plants would currently pay a higher percentage of taxes than expense-intensive conventional power projects. SEGS would show an 18% reduction in levelized electricity costs if it had tax equity with conventional plants.
- Low-cost Debt – If debt rate drops from 9.5% to 2%, the levelized electricity cost is reduced by more than 30%.

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COST REDUCTION POTENTIAL

Action	% Cost Reduction	¢/kWh Reduction Based on 13.8 ¢/kWh
Increase size from 50 to 160 MW	20%	-2.8
Go to ISCCS hybrid plant	22%	-3.0
Technology development	10%	-1.4
Multiple siting	25%	-3.5
GenCo financing	10%	-1.4
Tax equity	18%	-2.5
2% debt financing	30%	-4.1

It is not difficult on paper to put several of these factors together to reduce the electricity cost to the take-off point.

Conclusion – Projects and policies can cause substantial cost reductions, large enough to make PT competitive to day and CR and DE competitive soon thereafter.

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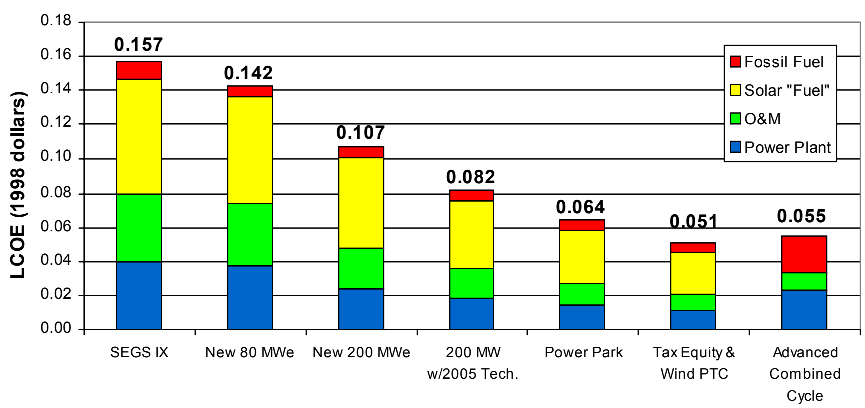
Cost Reduction Impacts on Trough Plant Electricity Costs



Source: PT Roadmap

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OTHER MARKET REQUIREMENTS AND FACTORS

OTHER MARKET REQUIREMENTS

All CSP technologies must, in addition to reduced costs, also reduce risk and improve dispatchability during peak periods.

In addition to competitive electricity prices, must reduce risks and improve dispatchability, especially during peak periods.

Risks include technical, scheduling, financial, political, exchange rates, etc.

Dispatchability improved via thermal storage and/or hybridization.

The three CSP technologies know how to address these needs.

OTHER MARKET REQUIREMENTS

- ✓ Risk –
  - Risk affects financing terms and is reflected in the investors rate of return.
- ✓ Dispatchability – If power can be delivered when it is needed to meet system peak loads, its value is much greater than if it only displaces fuel.
  - The key measure of dispatchability is the capacity factor during peak periods.
  - The SEGs plants faced a peak between 12:00 and 18:00 on summer weekdays and was required to have an 80% capacity factor during this period.

PROPOSED IMPROVEMENTS IN THE KEY MARKET REQUIREMENTS FOR PT AND CR POWER PLANTS

Factor	90	00	05	10	15	20
COST						
LEC	15 – 18	10 – 12	7 – 8	5 – 6	4 – 5	4
RISK						
Equity of IRR	18%	18%	15%	15%	15%	15%
Debt Interest	9.5%	9.5%	8%	8%	8%	8%
Perf War (yrs)	10	3	3	1	1	1
DISPATCHABILITY						
Peak CF	95%	95%	95%	90%	90%	90%
Peak Dur (hrs)	6	3	3	6	6	6
Peak Season	Summer	Annual	Annual	Annual	Annual	Annual
Time of Day	Afternoon	Evening	Evening	Evening	Evening	Evening
Technology	Hybrid	Hybrid	Hybrid	Storage	Storage	Storage
Annual CF	34%	30%	30%	40%	50%	50%

MARKET FACTORS THAT COULD FACILITATE CSP POWER PLANT OPPORTUNITIES

- Continued uncertainty and fluctuations in fuel costs
- New capacity needs create new opportunities
- Demand-based time-of-use electricity prices will move the take-off prices upward
- Restructuring – change creates opportunities
- Green power choice will move the take-off prices upward by adding a per kWh premium

Conclusion – Other market factors can enhance success.

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TARGET MARKETS

TARGET MARKETS

Many ideal markets have been identified around the world.

Ideal CSP markets require good scores for about 10 factors, such as direct normal radiation, competing energy prices, availability of subsidies, and others. Very promising markets exist in the US, Northern and Southern Africa, Middle East, Southern Europe, India, Pakistan, China, Brazil, Chile, Mexico and Australia.

TARGET REGIONS FOR MARKET ENTRY OF CSP TECHNOLOGIES

- Markets for CSP are characterized by their:
  - Direct normal solar radiation
  - Climate
  - Conventional fuel prices
  - Energy market situation
  - Policies

- Ideal CSP take-off markets require some combination of:
  - Good direct normal solar radiation
  - Arid or semi-arid climate
  - High fuel prices
  - Access to fuel is restricted or have no fossil resources
  - Vulnerability to fossil fuel price escalation and fluctuation
  - Large and economically efficient domestic energy market
  - Rapid demand growth in electricity demand
  - Load curves that match the solar output, with and without storage
  - Adequate infrastructure
  - Strong, established and supportive government policies
  - Strong national interest in becoming a leader in CSP technologies

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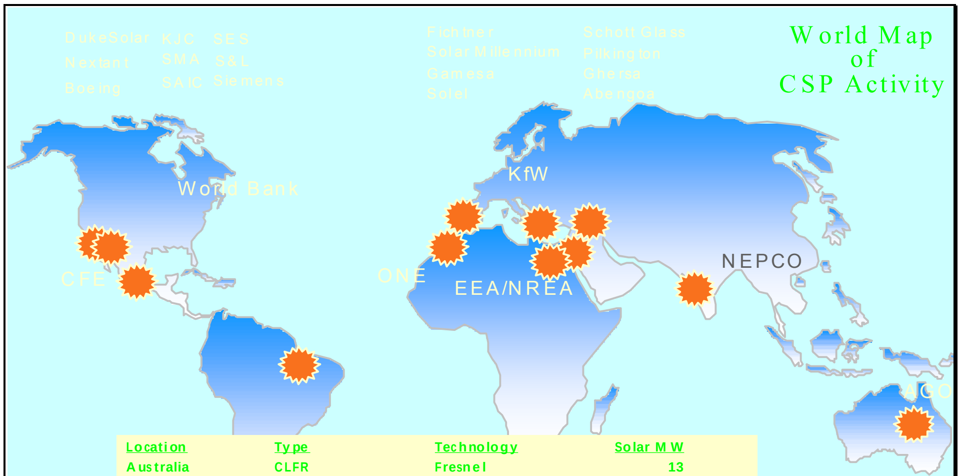
- An example is Spain:
  - Direct normal insolation is adequate
  - Semi-arid areas
  - 70% capital cost subsidy from multiple sources
  - Premium prices for output
  - Long-standing interest in CSP technologies

PROMISING TARGET REGIONS AND COUNTRIES INCLUDE

- United States
- Southern Africa
- North Africa – Morocco
- Middle East – Israel, Jordan , Egypt, Iran
- Southern Europe – Spain, Italy, Turkey, Crete
- India and Pakistan
- China
- Brazil and Chile
- Mexico
- Australia

Conclusion – Must enter market in the best places first and those have been identified.



Location	Type	Technology	Solar MW
Australia	CLFR	Fresnel	13
Brazil	ISCCS	Trough/Tower	??
Crete	SEGS	Trough	52
Egypt	ISCCS	Trough,Tower	30-80
India	ISCCS	Trough	35
Iran	ISCCS/SEGS	Trough	30-80
Jordan	PHOEBUS	Tower	30
Mexico	ISCCS	Trough	40
Morocco	ISCCS/SEGS	Trough,Tower	30-80
Spain	SEGS, SP10	Trough,Tower	10-50
USA	SEGS	Trough	354

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MARKET BARRIERS

MARKET BARRIERS

Market barriers are known, manageable and must be addressed to successfully enter commercial markets.

The major market barriers, in all countries, are higher capital costs, technical risks, financial risks; a dormant industry and cheaper competing fuels.

Additional barriers in developing countries include uncertain policies, grid extension plans, legal structure; lack of infrastructure, regressive tax policies and numerous instabilities.

BARRIERS IN ADDITION TO HIGH ENERGY PRICES

- In addition to higher energy costs, many other barriers must be overcome before CSP plants are widely accepted in the market.
- All countries
  - Higher capital cost – largest barrier
  - Higher technical risk – one time start up costs, resistance
  - Higher financial risk – due to many uncertainties
  - Higher transaction costs per project – One time start-up costs
  - Cheaper competing fuels – which are now increasing and fluctuating price
  - Dormant industry – no new construction since 1980s, need to reactivate production lines

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- Developing Countries
  - Regressive tax or financial policies – e.g., high import duties
  - Lack of infrastructure
  - Uncertain legal systems
  - Tied aid
  - Subsidized domestic markets that strengthen their industries
  - Instabilities – political, economic and currency exchange rates
  - Uncertain grid extension plans
  - Uncertain government policies
- **Conclusion – Must address all key barriers in order to successfully enter commercial markets.**

The Commercial Path Forward for CSP Technologies

POLICY TOOLS

POLICY TOOLS

Policies make markets – look at wind in the US and Europe, or PV in Japan and Europe. Numerous policy tools developed and used. They are an essential aspect of the commercialization path for CSP.

A variety of policies are being used today around the world to invest public funds to move RETs down the cost curve. These include RPS, SBC, NFFO, EFL, Green Pricing, Grants, low interest, production/energy/emission/tax credits, and guarantees of several kinds.

POLICY ELEMENTS NEEDED TO ADVANCE CSP

- ✓ **Renewable Portfolio Standards**
- ✓ **System Benefit Charges**
- ✓ **Utility Restructuring**
- ✓ **Federal Green Power Purchase Requirements**
- ✓ **Grants**
- ✓ **Emission Credits**
- ✓ **Renewable Energy Credits**
- ✓ **Production Credits**
- ✓ **Electricity Feed Laws**
- ✓ **Non-Fossil Fuel Obligations**
- ✓ **Low-Cost Capital**
- ✓ **Taxes – Investment and Production Tax Credits; Solar Property and Sales Tax Exemptions**
- ✓ **Letter of Credit**
- ✓ **Guaranteed Long Term PPAs**

Conclusion – Many effective policies are being used today to promote RETs. A comprehensive set of policies would be most effective for CSP. Must study carefully to find optimal combinations.

POLICY ELEMENTS NEEDED TO ADVANCE CSP

A variety of policy strategies are currently being employed around the world to invest public funds in support of the deployment of RETs.

- Renewable Portfolio Standards

  Requires a certain percentage of new capacity to use RETs, if a percentage of that is for solar, will create a market opportunity for CSP.

- System Benefit Charges

  Available for per kWh incentives or can be used to buy-down the difference between the actual electricity price and the market price.

- Utility Restructuring

  Customer choice can enter the market and force the building of green power supplies, hence some CSP

- Federal Green Power Purchase Requirements

  Acts like a RPS in the federal sector

- Grants

  To buy-down the capital cost of clean technologies, as GEF, EU Thermie and the Spanish Royal Decree do, thereby mitigating all or some of the technology risk.

- **Emission Credits**

  A per kWh credit associated with a carbon emission reduction by a renewable energy technology. Reduces the ¢/kWh thereby reducing the capital cost subsidy required to compete.

- **Renewable Energy Credits**

  Certificate of proof that 1 kWh has been generated from a renewable source and sold to an end user.

- **Production Credits**

  Provides a per kWh credit for electricity produced from certain renewable energy technologies

- **Electricity Feed Laws**

  Sets a minimum price on electricity from certain RETs as a percentage of the average market price.

- **Non-Fossil Fuel Obligations**

  Provides a premium payment for a certain percentage of electricity from a non-fossil source.

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- **Low-cost Capital**

  Currently pay a risk premium on equity and debt over rates available for conventional power.

- **Taxes**

  US taxes favor expense-intensive projects and penalize capital-intensive projects. This inequity results in restraining new beneficial technologies.

  - Investment and Production Tax Credits – Fed and State Investment Tax credits provided 55% to the SEGs at the start. Could switch to production credit as for wind.
  - Solar Property Tax Exemption – Property tax is now like tax on 30 years of fuel and is a significant cost penalty for PT. California exempted SEGS from paying property tax on solar property – land and equipment for the solar field and also the conventional plant as it was needed for solar operation. Should be solar field only.
  - Sales Tax Exemption – Fossil fuel plants do not pay sales tax so neither should solar equipment

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- Letters of Credit

  To guarantee performance – Need performance guarantee via letter of credit to cover potential warranty payments. Need other approach to ensure investor confidence in the PT. Will be performance warranty with suitable backing such as a fund.

- Guaranteed Long Term PPAs

  An agreement to purchase a specified amount of electricity at a specific price for a specified (long) period of time and guaranteed by a governmental agency.

Conclusion – Many effective policies are being used today to promote RETs. A comprehensive set of policies would be most effective for CSP.

MARKET SITUATION IN US AND OVERSEAS

MARKET SITUATION

US Market Situation

New market opportunities emerging from major new market forces.

US needs new capacity, new green (solar) capacity and electricity price stability. Deregulation leads to RPS, SBC and customer choice. Together create new opportunities for several hundred MWs of CSP power projects in the next few years.

International Market Situation

Buy-down programs in response to Kyoto have opened several project opportunities and many more have been studied, resulting in the possibility of building 10 – 20 projects in the next 5 years.

Driving force is environmental expressed as a commitment to use public funds to buy-down promising clean energy technologies, e.g. by the GEF, the EU and the Governments of Spain and Italy. Ten projects are in the feasibility study or bid process today.

CURRENT MARKET SITUATION IN THE US

The US is facing a need for new capacity and a need for new green capacity. As utilities compete for customers, more and more customers are choosing green power. New market forces have emerged in the power sector.

- **Restructuring**
- **Deregulation**
- **New Capacity**
- **RPS**
- **SBC**
- **Green Power**
- **Credits**
- **FEMP**
- **Cities**
- **Ownership**
- **Prices**

Conclusion – Numerous opportunities now exist for CSP in the US that can be used more towards the price take-off points. A comprehensive analysis to find optimal combinations is required.

The Commercial Path Forward for CSP Technologies

CURRENT MARKET SITUATION IN THE US

- The US is facing a need for new capacity and a need for new green capacity. As utilities compete from customers, more and more customers are choosing green power. New market forces have emerged in the power sector.
  - Restructuring – Rapidly changing the energy market
  - Deregulation – Least-cost power making it hard for CSP to compete
  - New Capacity – New capacity is needed in SW US. Power needs in northern Mexico might be met with CSP hybrid plants located on US side of border.
  - RPS – Renewable Portfolio Standards will open new opportunities for CSP, especially if a portion is designated for solar – as they are in Arizona, California and Nevada. CSP technologies could target this 100 MW-sized market over the next 5 years.
  - New Capacity – New capacity is needed in SW US. Power needs in northern Mexico might be met with CSO hybrid plants located on US side of border.
  - SBC – Opens possibilities for needed subsidies. Eleven states currently have over $1.5B available.
  - Green power – marketer, such as GreenMountain.com, seek solar to add to mix and only current option is relatively expensive PV power.

The Commercial Path Forward for CSP Technologies

- Credits – Renewable energy credits and/or carbon emissions trading could help open and expand US market for CSP.
- FEMP – DOE commitment to 3% and recent Executive Order for green power opens new opportunities for CSP.
- Cities – More and more cities across the country are going 100% green, which opens new market opportunities to sell power from CSP plants.
- Ownership – Innovative schemes for ownership of green power facilities open new opportunities for CSP plants.
- Prices – Continued movement towards market-based electricity prices creates an optimistic market outlook for US CSP industry.

➢ Noting these market forces and the opportunities they create, Duke Solar is leading a consortium of major energy companies to build, in the near future, one or more CSP plants, blended with wind, biomass, and/or geothermal in the southwest US.

➢ Such hybrid systems have huge market potential because a relatively small addition of solar to a gas plant yields large benefits in premium time of day situations for a small overall increase in generation cost.

➢ **Conclusion – Numerous opportunities now exist for CSP in the US that can be used towards the price take-off points.**

US MARKET SITUATION AS PERCEIVED BY THE NRC

The NRC report presents a bleak and negatively biased market outlook for the CSP technologies, as noted in the following quotations:

"The absence of buyers for a U.S. solar thermal facility speaks for itself, and there is no reason to believe the situation to change in the next 10-20 years",

"Overall, the commercial prospects for CSP technologies are not very promising."

"No private market has been identified for power-tower or solar-trough technologies",

"Significant deployment is still years away".

What does the NRC believe to be *"significant"* and what is wrong with *"years away"?* The NRC report expresses strong support for other RETs for which significant deployment is still years away.

"Small, village power or distributed power-generation schemes appear to be the only possible domestic applications (for CSP)…"

That is incorrect because the first domestic applications were, and for sometime will be, large grid-connected hybrid power systems.

The Commercial Path Forward for CSP Technologies

CURRENT INTERNATIONAL MARKET SITUATION

The following points characterize the overseas market for CSP technologies today:

- ✓ GEF committed $200M to 4 CSP plants in Egypt, Mexico, Morocco and India and is currently considering subsidizing additional CSP plants in Brazil, South Africa and China
- ✓ Spain's Royal Decree may open significant markets in that country. The official objective for the year 2005 is for a minimum of 5 CSP plants for a total installed power of 200 MW. Investment subsidies of up to $300M are projected for CSP in that period.
- ✓ Italy announced a new 3 year program to support CSP systems at the $100M level
- ✓ Studies, varying from preliminary to project development have been completed for CSP power plants in Australia, Turkey, Crete and Israel.
- ✓ Kyoto agreement creating interest in developing countries to meet some of their growth in capacity with renewables.
- ✓ Activities Implemented Jointly, AJI, opens opportunities overseas.
- ✓ Carbon trading, if and when it arrives, will open more opportunities for large scale power like CSP.

We live in a global economy where US companies seek foreign markets for the same reason they seek domestic markets – to make money.

- ✓ They make money by selling services and products.
- ✓ And what they develop for an overseas market they use in their domestic market, and vice versa.
- ✓ Bechtel and Duke Solar, to name two, are pursuing the CSP projects in Spain, Egypt, Morocco, India and/or Mexico to make money

Conclusion – Many new project opportunities exist in international markets which are crucially important for PT and CR.

INTERNATIONAL MARKET SITUATION

AS PERCEIVED BY THE NRC

While stressing the importance of overseas markets for the other renewable energy technologies the NRC Review Committee was even more critical of overseas markets for CSP than it was of the domestic markets.

The NRC report states that *"Project viability may be more likely in foreign markets, but those projects would also require significant intervention by a financial institution".*

The reality is that all power plant financing needs *"significant intervention by a financial institution"*

That is how debt financing is done and all power plants require some debt financing.

The NRC report states that *"U.S. companies, however, would be at a disadvantage (in foreign markets) because host nations will want to derive the economic benefits of construction and operation locally".*

That is true for all IPP projects

Yet US IPP companies are not at any disadvantage because of that

They compete vigorously for those opportunities and do so in order to make money

That is just the nature of the power project business

And finally the NRC report states that *"the international markets for CSP technologies is (are) limited…".*

Probably all markets for anything are limited.

Conclusion – The known and anticipated international power projects, for some reason unknown to the NRC Review Committee, will be enough to drive the cost of CSP electricity into the competitive range in many parts of the world.

FUTURE MARKETS FOR CSP - SUMMARY

- Market entry opportunities will be in the US, other OECD countries and in many developing countries.
  - Driven by restructuring, customer choice and supported by various policies, opportunities for CSP exist in the US.
  - Driven by host country energy programs and encouraged by the positive attitudes of the GEF, the WB, the IEA and the EU, opportunities for CSP power plants exist in developing countries.
  - These opportunities are strongly influenced, positively and negatively, by bureaucratic snags, shifting internal politics, broader energy issues and other factors. But they exist.
- Central Receiver
  - The outlook for building CR power plants is improving.
  - CR has the best chance today for taking a step forward with the design and construction of Solar Tres in Spain.
    - The size will be 1.5 times Solar Two and provides the next scale-up toward commercial and competitive CR plants.
    - If successful, Solar Tres might lead to CR plants in Egypt and Morocco

- Parabolic Trough
  - Due to expanding global power markets, interest in reducing greenhouse gas emissions, and growing interest in green power, a number of PT project opportunities may soon be realized.
  - Based on the excellent ten-year performance record of the Kramer Junction SEGS plants, PT may be the only CSP technology that has low enough risk to attract financial community and IPPs.
- CR and PT
  - The four GEF-subsidized projects plus many others around the world are emerging project opportunities. Only 2 of the 4 are open to CR at present.
- Dish/Engine
  - In the US, the growing interest in distributed generation and RPS and SBC and the urgency of providing electricity services to unserved populations in developing countries should create specific project opportunities.

The Commercial Path Forward for CSP Technologies

TODAY'S CSP OPPORTUNITIES AROUND THE WORLD

Country/State	Plant Configuration	Next Step	Subsidy
India	140MW ISCCS/35MW solar	RFP issue	$45M GEF grant + 150M KfW soft-loan
Egypt	137MW ISCCS/36MW solar	RFP prep	$50M GEF grant
Morocco	180MW ISCCS /26MW solar	RFP prep	$50M GEF grant
Mexico	291MW ISCCS/40MW solar	CFE planning / RFP prep	$50M GEF grant
Greece	50MW SEGS		EU grant, IPP dev
Jordan	ISCCS or SEGS	Inactive	
Iran	60MW ISCCS	GEF application	
Spain	2x50MW SEGS + 2x10MW CR + 2x25kw DE demo	In process	
Arizona	10 – 30MW ISCCS	Possibility	
Nevada	SEGS	Feasible	Unknown, green pricing

Conclusion – Many real new project opportunities exist today and more are anticipated.

CASE STUDY – MARKET POTENTIAL FOR DISH/ENGINE IN MEXICO

In 1994, Dyncorp Meridian performed a detailed study of the market potential in Mexico for the 7.5 kW and 25 kW Cummins dish/engine units.

- ✓ Mexico was selected because of its high direct normal insolation, large regions that lacked the grid and the many needs that could be met by these dish/engine units.
- ✓ Five states in two regions were studied but decided to focus on the north-western region of Mexico only.
- ✓ Off-grid applications were studies for the 7.5 kW unit while grid-connected applications were studies for the 25 kW unit.
- ✓ The findings were livestock water pumping was the largest market with 10,000 units followed by water pumping and electricity for villages with 1,200 units.

CASE STUDY – POLICY RECOMMENDATIONS IN SPAIN

On 30 December 1999, the Ministry of Industry and Energy and IDEA, the Institute for the Conservation and Diversification of Energy in Spain published their plan to reach their Kyoto Accord Targets.

- ✓ They offer a combination of grants for the capital cost plus subsidies for the cost of electricity generated from renewable resources.
- ✓ This offer is to last 20 years.
- ✓ CSP power plants are specifically identified in that plan as deserving of grants of up to 70% of the estimated $100M capital cost for the first plant.
- ✓ The remaining funds are to come from 20% private investment and 10% bank debt.
- ✓ Additional benefits are reduced taxes, including reduced social taxes, accelerated depreciation, low cost construction loans and a premium on the sale of the electricity of about 16 ¢/kWh.

CASE STUDY – POLICY RECOMMENDATIONS IN SPAIN

- ✓ The plan has two CSP top priority items, which are:
  - Build two solar-only 10 – 20 MW CR demonstration plants, one using air and the other using molten salt technology.
  - Build 1 – 2 PT demonstration plants.
- ✓ Solar Tres can be profitable with the 6 ¢/kWh premium, the reduction in social taxes and half the offered grants.
- ✓ If the premium goes to 21 ¢/kWh, the plant will be profitable without any grants, as will any follow-on plants. (Subsequently, a premium of 15 ¢/kWh was approved)

Conclusion – The objective of such buy-down programs is commercial competitiveness with conventional sources in Spain.

WAYS INTO THE MARKET

WAYS INTO THE MARKET

Many ways proposed – primarily via a series of 10 – 20 power plants, of increasing size and performance, requiring decreasing subsidies, between $0.5-3B and associated supportive policies.

PCAST – For the US, proposed market aggregation via long-term concessions in areas of high DN insolation. PPAs with specific MWs at specified prices auctioned periodically. Augmented by green price premiums, SBCs and the GEF in developing countries.

Enermodal – A series of PT/CR power plants, of increasing size, would be built between now and 2010 using decreasing subsidies. Depending on the cost of competing electricity and the subsidy available (location), up to 8,300 MW would be required to reach the associated range of take-off prices. Between $1 – 3B in subsidies would be required, 60% of which the GEF would provide.

PT Roadmap – A series of PT/CR power plants, of increasing size, would be built between now and 2010 , taking advantage of various subsidies and market factors. Neither the installed capacity required nor the total cost of the subsidies are provided.

CR Strategy – A series of CR power plants, of increasing size and performance, would be built overseas, the majority in Spain. Between 8,000 and 20,000 MW would be required to reach prices competitive in the US. Subsidies in Spain will come from grants and price premiums; the total required subsidy was not provided.

IEA Strategy – Under development, but will seek to aggregate the leading/target markets to increase financing levels.

WB Strategy – Will promote the use of EFL and NFFO in target developing countries. Will use GEF to provide the required subsidies.

Major Aspects of Different Approaches

	Grants	Premium Prices	CETO/ NFFO	Mkt. Aggregation	PPAs vis Auctions
PCAST	✔	✔	✔	✔	✔
Enermodal	✔	✔			
PT Roadmap	✔	✔			
CR Plan	✔	✔			
IEA				✔	
WB		✔	✔		

APPROACHES TO DEVELOP THE MARKET POTENTIAL FOR CSP

- Considering both the US and foreign markets, today's market prospects for CSP technologies look very good.
- There are numerous new project opportunities in the US and overseas that could provide the framework for major cost reductions for the three CSP technologies.
- There are numerous policies that could play a major role in making these project opportunities feasible.
- Several approaches have been proposed to create a policy and project framework to allow CSP to move down the cost curve:
  - Enermodal / GEF
  - World Bank
  - PT Roadmap
  - PCAST
  - IEA

The Commercial Path Forward for CSP Technologies

- The GEF and the CSP industry have just started work on a CSP Global Market initiative.
- This initiative will seek a way to aggregate the next series of CSP projects around the world and associated policies to maximize the opportunity to bring costs into competitive range as soon as possible.

Conclusion – Must raise the awareness, image and potential of CSP to meet and help solve today's energy and environmental problems.

The Commercial Path Forward for CSP Technologies

APPROACH TO REACH CR AND PT TAKE-OFF PRICE - ENERMODAL

- Enermodal proposed a series of subsidized CSP power plant projects between now and 2010.
  - The phases are envisioned to bring CSP technology to the price take-off point.
  - Under this proposed series, 55 – 65 CSP power plants, ranging in size from 80 – 200 MW, would be built with decreasing subsidies as their cost of electricity decreased to below 6 ¢/kWh.
  - A total of 8,300 MW would be built requiring a subsidy of between $1 – 3B, 60% of which would be provided by the GEF and the balance by participating countries and/or donors.
  - It is assumed that taxes and other items do not penalize CSP and that favorable financing terms are available

- The GMI will explore that possibility.

ENERMODAL STRATEGY - PHASES

Required Investment in STPPs by Phase[1]

Phase	Time Frame	Solar LEC Target (c/kWh)	Additonal Installed Capacity	Est. Total Incremental Investment ($ million)	Est. GEF Investment ($ million)
Phase 1	2000 – 2004	10 to 11	750 MW	440 to 750	350 to 700
Phase 2	2005 – 2009	7 to 8	3000 MW	500 to 1,800	250 to 900
Phase 3	2010 +	Under 6	4600 MW	0 to 330[1]	0 to 150[1]
Total			**8300 MW**	**940 to 2,955**	**600 to 1,750**

[1] – assumes a carbon market develops by Phase 3

PHASE 1 – COMMERCIAL NICHE MARKETS

Industry interest is re-established, start-up production and evaluate new concepts

- ✓ Focus on markets where the conditions are most favorable for CSP
  - High solar resource
  - High fossil fuel prices
  - Daytime peaking load
  - Inefficient conventional power plants
  - Local support-subsidies
  - Access to water and the grid
- ✓ These plants will be capable of selling electricity at 10 – 11 ¢/kWh.
- ✓ Between 2000 and 2004, 9 additional CSP plants of approximately 80 MW each will be built, adding 750 MW of installed capacity.
- ✓ These will likely be smaller than the 200 MW optimal size.
- ✓ The total incremental investment cost will be between $550 - $1,000/kW with the GEF providing $350 – 700M in subsidies out of the total $440 – 750M subsidy required.
- ✓ These funds are required to deal with the high risks and start-up costs.

The Commercial Path Forward for CSP Technologies

PHASE 2 – MARKET EXPANSION

Scale-up plant size, decrease costs and increase performance to take advantage of Renewable Energy Portfolio Standards and Green Power.

- ✓ These plants will be capable of selling electricity at 7 – 8 ¢/kWh.
- ✓ Between 2005 and 2009, 15 – 30 additional CSP plants of 100 – 200 MW solar field size will be built, adding 3,000 MW of installed capacity.
- ✓ These plants will realize cost reductions due to increased size, decreased costs and increased performance as a result of moving down the learning curve and standardized system designs.
- ✓ The total incremental investment cost will be between $350 - $750/kW with the GEF providing half of the total $500 - $1,800M subsidy required.
- ✓ The other half would come from national governments, other donors, etc.

The Commercial Path Forward for CSP Technologies

PHASE 3 – MARKET ACCEPTANCE

Sustainable global markets – cost competitive

- ✓ After 2010, 20 – 25 additional CSP plants of 200 MW each will be built, adding 4,600 MW of installed capacity.
- ✓ These new plants will be capable of selling electricity below 6 ¢/kWh and, therefore, compete for intermediate loads without subsidies.
- ✓ The total incremental investment cost will be between $0 - $70/kW with the GEF providing between zero and half of the maximum $330M subsidy required.
- ✓ GEF must push for carbon credits in this phase.

Figure 11.1 Scenario 1 – Low conventional electricity cost and no credit for carbon reductions

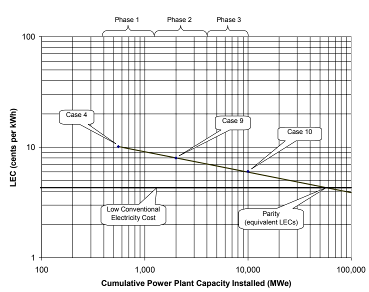


Figure 11.2 Scenario 2 – Low conventional electricity cost with credit given for carbon reductions

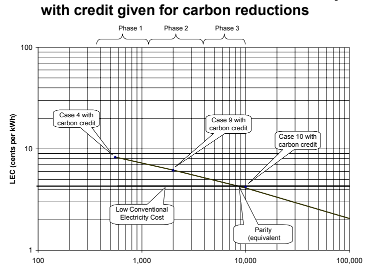


Figure 11.3 Scenario 3 – High conventional electricity cost and no credit for carbon reductions

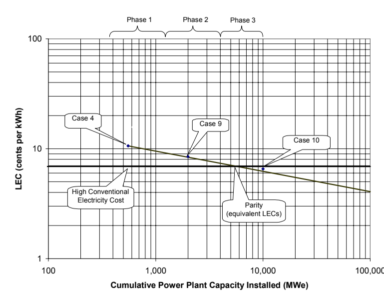
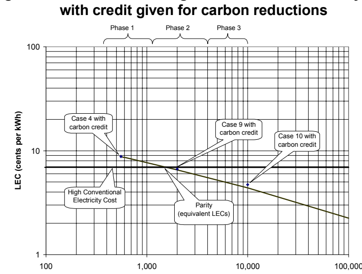


Figure 11.4 Scenario 4 – High conventional electricity cost with credit given for carbon reductions



Source: WB/Enermodal

APPROACH TO REACH PT TAKE-OFF PRICE – PT ROADMAP

The PT Roadmap envisioned a series of steps, not too different from Enermodal's phases

The main difference is the rage of take-off prices considered

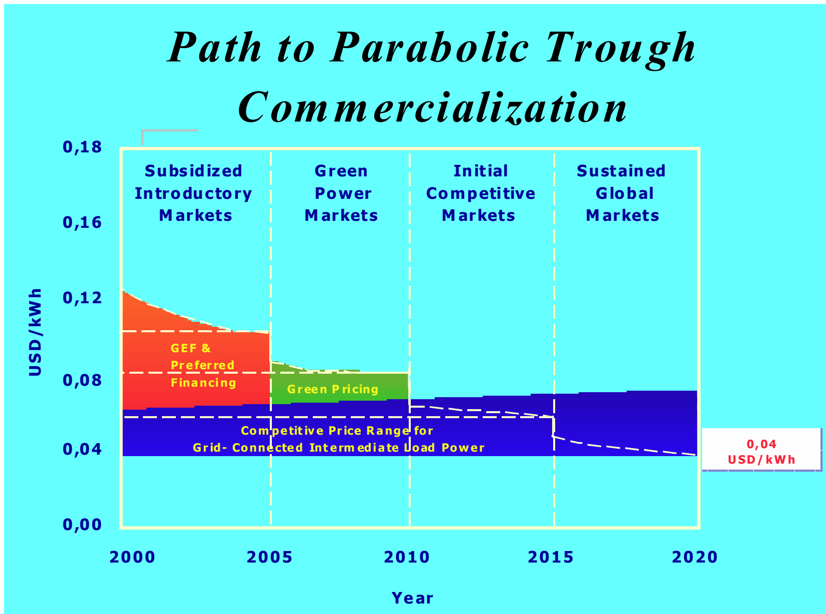
- Step 1 – Subsidized Introductory Market
- Step 2 – Green Power Market Price Take-off Point
- Step 3 – Initial Competitive Markets Price Take-off Point
- Step 4 – Sustained Global Markets Price Take-off Point

PT ROADMAP STEPS

Step	Years	LEC		Tech Dev	Market Situation
		Start	End		
0	90-00	14	14		
1	00-05	14	10	State of the art PT ISCCS optimal des (-2)	GEF market aggregation, low cost financing and grants (-2)
2	05-10	10	7	Several (-2)	Green market development, tax equity, standard financing packages (-1)
3	10-15	7	5	Several (1.5)	Solar parks, investment funds (-.5)
4	15-20	5	4	Several (-.5)	Nothing more (-.5)

The numbers in the brackets are the cost reductions, in ¢/kWh, from the technology developments or market changes in each step.

Steps are relevant for CR and DE as well.



The Commercial Path Forward for CSP Technologies

APPROACH TO REACH CR TAKE-OFF PRICE – NEXANT

➢ Parabolic Trough systems benefited greatly from the nine SEGS plants built s sequentially by Luz in one location.

- Central Receivers need a similar sequence of plants to bring them into the commercial validation phase.
- The next likely CR power plant will be Solar Tres, a 15 MW plant to be built in Spain.
- The size of the receiver is the same as what will be bid for the GEF subsidized plant in Egypt.
    - The Egypt plant will use an exact replica of the receiver, tower, thermal Storage and steam generation systems and the same heliostat design.
    - Only the collector field will vary to match the local insolation.
    - Solar Tres will allow the cost of the CR for Egypt to be lower by covering the non-recurring engineering, manufacturing and tool development costs.
    - If Egypt can be won, CR's will have a good chance of success in Morocco where both the solar and conventional portions of the power plant could be replicated.

The Commercial Path Forward for CSP Technologies

- It may be possible to build 5 or 6 CR plants in Spain during the next 10 years.
- Planning will begin on Solar Quattro before Solar Tres has finished its first year of operation, but construction will begin only after the performance of Solar Tres has been proven.
- Economics of scale will drive the size up past 50 MW to the optimum of between 100 and 200 MW. Plants will be sited in the best solar area because profit increases by several million dollars for each 5% increase in insolation.
- CR may need another 8 – 10 plants abroad before the costs, capital and O&M, have been reduced to compete in markets defined by the RPS and green power premiums.

➢ **Conclusion – The key is subsidies – GEF, EU, KfW, Kingdom of Spain and any other who have the ability and will support CSP.**

DISH/ENGINE PATH OF LEAST RESISTANCE

Insert page 1 of Butler presentation here – shows LEC vs mean time to service and the markets that open along that path, and their predicted year.

APPROACH TO REACH CSP TAKE-OFF PRICES – PCAST99

- PCAST proposes market aggregation via concession which offer exclusive market development rights in an area for a specified time to a single supplier. PPAs will also be used.
- This will increase the scale of the projects and attract capital.
- Buy downs would be available to decrease the costs until they reach the take-off point.
- Concession model applied to CSP:
  - The government would offer, via competition, concessions to companies to develop direct solar in a region for a specified period.
  - To transmit this energy to major markets, need to fully load high capacity transmission lines (>1GW). So need multi-GW plants, possibly with storage, or geothermal or other hybrid.
  - Government sets the framework, PPAs, maybe set price via auctions in a CETO.

CLEAN ENERGY TECHNOLOGY OBLIGATION

- **Fixed period** of time, say 5 – 10 years (longer may be needed)
- Guarantee sufficiently **large markets** that CSP manufacturers will expand production to realize those economics and also realize learning curve cost reductions
- **Bid prices** must not exceed specified ceiling prices
- Target markets should be of **high value** to minimize required buy-down subsidies plus have good potential for sustainability
- Series of **auctions** of specified MW levels at specified ceiling prices
- Some of the **buy-down funds** come from increased payments by customers (green price premiums), some from climate-change funds (GEF) and rest from government (SBC, EFL, tax credits, etc.)
- CETO must be carefully designed to encourage innovation and **fastest cost reductions**

APPROACH TO REACH CSP TAKE-OFF PRICES IEA

- Will design an acceleration strategy on a large scale, for a long enough duration and with supportive policies and incentives that manufacturers and financial institutions will invest sufficiently to bring RETs into a competitive market position for widespread use.
- Approach will:
  - Integrate the leading (target) markets to include all relevant RETs
  - Improve multi-lateral coordination – WB, GEF, ENEP, WEC, etc.
  - Increase private-sector engagement
  - Increased financing
  - Raise awareness of value of RETs
- Seeks to use the IEA's position to add value by coordination of multiple approaches.

APPROACH TO REACH CSP TAKE-OFF PRICES – WORLD BANK AND GEF

- Based on an analysis of the RPS, SBC, NFFO and EFL mechanisms, the following was proposed for developing countries, and presented for CSP technologies:
  - EFL policy will be used to set an initial price for electricity from a CSP project, perhaps different for different CSP technologies
  - This should minimize the risk for companies entering this market by eliminating the threat of being under-bid for projects
  - Once a market is established and a number of companies are in it, move to a competitive bidding process like the NFFO
  - The GEF would cover the incremental cost of the electricity in the participating LDCs (should meet the target country criteria)
  - GEF involvement would provide the resources and assurance needed by the private sector – companies and investors – to participate in that market

REQUIRED LEARNING INVESTMENTS

INVESTMENT COST FO RPT/CR TO REACH TOP

The additional MWs required to reach the price take-off point depends on that point, hence on competing prices and subsidies. For example, for hybrid PT, to get to the TOP:

1,620 MW	8 plants (200 MW)	Costing $0.5B	If HC/Yes
5,700 MW	27 plants	Costing $1.2B	If HC/None
8,700 MW	42 plants	Costing $4.1B	If LC/Yes
58,000 MW	280 plants	Costing $9.7B	If LC/None

Parameters are:

Cost of conventional fuel – LC is 4.3 ¢/kWh (intermediate), HC is 6.9 (peak)

Availability of carbon or production credits – Yes is 2 ¢/kWh, None is 0

Investment costs range from $500M to $9.7B depending on the required take-off price and the availability of incentives. $4.1B is more realistic upper limit because if carbon credits do not exist by 2020, will renewables really be promoted?

THE LONG-TERM MARKET IMPACTS OF RENEWABLE LEARNING INVESTMENTS

- The viability of commercial scale CSP technologies has been demonstrated for PT. CR and DE are following behind.
- There now remains a long process of building a series of such systems to scale up equipment manufacturing facilities for the solar field components and to learn how to reduce manufacturing, installation and O&M costs to competitive levels
- The initially higher costs must be covered – this is the buy-down cost or learning investment.
- Because of the substantial public benefits that CSP offers, the government should provide these buy-down investments.

The Commercial Path Forward for CSP Technologies

LEARNING INVESTMENTS

- Learning investments (LIs), commonly known as buy-down costs, are those needed to reach target price point.
  - This is accomplished by driving costs down the learning curve
  - LIs range from $500M to $4B (Enermodal) with PCAST proposing $690M
  - Amount depends on the situation, especially cost of competing fuel and existence of carbon credit (or production credit)
- Conclusion **– Need to develop better estimates of these investments for the different approaches.**

The Commercial Path Forward for CSP Technologies

MARKET IMPACT OF LEARNING INVESTMENTS

- Result of the LI is to arrive at a competitive technology
- That will allow CSP to be an option
- Given the environmental advantages, as well as the other benefits of CSP, the long term impact should be continued market share growth
- Energy system costs, $/MW, should continue to fall as technological improvements continue to be made
- The environmental impact will scale with the MW of solar field installed
- Even if a new technology appears fully competitive on paper, i.e., reaches the price take-off point, there are still significant barriers to its widespread use. These barriers include:
  - Overcoming residual concerns about its risks
  - Need for feasibility studies
  - Building distribution and service networks
  - Providing adequate financing

The Commercial Path Forward for CSP Technologies

THE CSP COMMERCIALIZATION PATH

THE CSP COMMERCIALIZATION PATH

The GEF and the major PT/CR industry and other stakeholders, will attempt to design a strategic market intervention with the next 10 – 20 CSP power projects to maximize their ability to drive down the cost curve. Should be expanded to include, or repeated with different stakeholders to address DE.

The Commercial Path Forward for CSP Technologies

SUMMARY RET APPROACHES

Bottom Line – WB, GEF, IEA and PCAST see importance of deploying RETs and each proposed some innovative ways. CSP fits well in their approaches.

- A combination of international and national policies would have the greatest impact on accelerating the arrival of CSP at the TOP
- Different countries and markets will require a carefully designed policy structure, that may include any or all of the following policy instruments
- International policies might include:
  - Participation in an aggregated market program such as a Clean Energy Technology Obligation (CETO) to buy-down costs
  - Emissions trading and/or credits
  - A combination of electricity feed laws and a non-fossil fuel obligation

- National policies might include:
  - Low-interest loans, grants
  - Government Letters of Credit to guarantee performance
  - Production Credits or Green Power premium prices
  - Favorable Taxes, e.g. property and sales tax exemptions on solar field, investment credits
  - System Benefits Charges available to subsidize CSP
  - Renewable Energy Portfolio Standards with specific CSP set-asides
  - Market-based prices
  - Guaranteed Long Term PPAs

Conclusion – Need a comprehensive set of policies for greatest chance of fastest success.

GEF COMPREHENSIVE GLOBAL MARKET INITIATIVE

- A structured global initiative is required to accelerate CSP markets by driving the cost of CSP generated electricity into the competitive range.
  - As one possible example, the solar fields for various planned CSP projects could be aggregated and bid together.
    - This would allow and require the winning consortium to make the necessary investments to lower the capital cost of the solar field to an agreed-to level.
    - On the other hand, the complete CSP power projects could be subject to open competition among interested developers/IPPs, thereby encouraging the lowest electricity prices.
    - Interested governments could be encouraged to play a facilitating role by establishing supporting policies and incentives, such as the CETO, EFL, NFFO, etc.
  - Strategic Alliance – the creation of a global CSP network that could lead to a strategic alliance of principal public and private stockholders.

  - Develop Approaches – through personal communications and workshop to identify joint interests and establish a common perspective that could form the premise for a global CSP market initiative, based on the most promising and feasible approach.
  - Commitments – The operational development of the initiative would rely on explicit commitments of key stakeholders which would be defined and secured through the network and verified at an international executive level conference, brining together the highest ranking decision makers of all interested entities.
  - Result – a strategic market intervention leveraging an unprecedented volume of venture capital for CSP investments through an alliance of public and private technology sponsors that would help to pull the market through aggregation and economies of scale.
  - Cost – The GEF is offering to share the development costs of the initiative, provided that members of the international CSP industry, interested utilities, IPP developers and financial institutions supply at least half of the required fund.s.
- **Conclusion – The time is ripe to bring together the projects with the policies to drive CSP into the competitive markets.**

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APPENDIX A

Cost Reduction Study for Solar Thermal Power Plants

Final Report

Executive Summary

April 20, 1999

Report prepared for:
The World Bank
Washington, D.C.

COST REDUCTION STUDY FOR SOLAR THERMAL POWER PLANTS

FINAL REPORT

April 20, 1999

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EXECUTIVE SUMMARY

Recent concern over the problem of climate change has generated renewed interest in Solar Thermal Power Plants (STPP) as a means of generating electricity. STPPs, although more expensive than conventional fossil-fuel power plants, release much less carbon dioxide and other pollutants. There are several applications for World Bank/GEF funding for STPPs in developing countries. The purpose of this report is:

- to assess the current and future cost competitiveness of STPPs with conventional power systems,
- to determine the market potential for STPP with particular emphasis on developing countries, and
- to identify an overall strategy for promoting accelerated development of STPP, including recommended roles for the key players (in particular the GEF).

The market for STPP is large and could reach an annual installation rate of 2000 MW. The best regions for STPP are Southern Africa, Mediterranean countries (including North Africa, Middle East and Southern Europe), India, parts of South America, Southwest U.S./northern Mexico and Australia. The operating characteristics of STPPs are relatively well matched with the intermediate and peak electricity load requirements in these regions.

Two types of collectors have been used in STPPs: parabolic trough and central receiver. Electricity is generated by incorporating the solar collectors with a Rankine cycle power plant or as an add-on to a natural gas combined cycle (referred to as an ISCCS). STPPs in southern California, with a total output of 354 MW, have operated reliably over the past 15 years.

New parabolic trough STPPs are estimated to have a capital cost (in developing countries) that is $2,000 to $3,000 per kilowatt or 2.5 to 3.5 times that of conventional Rankine-cycle plants. Central receiver STPPs are less mature than parabolic trough and will require several successful projects to scale up to reasonable sizes. The current costs of central receiver STPPs are close to $4,200 per kilowatt or five times that of conventional Rankine-cycle plants.

At the current state of technology development, the cost of solar-generated electricity is between 10 and 15 cents per kWh (at a 10% discount rate). This is two to four times more expensive than power from conventional power plants. Although solar power from ISCCS is 10% to 20% less expensive than for a similar sized Rankine-cycle STPP, it is competing against a much lower cost conventional power plant (combined-cycle).

Two approaches were used to predict the future cost performance of STPP: an engineering approach based on known technical improvements and cost reductions from commercialization and an experience curve approach. The two approaches yielded similar results. The cost-per-kilowatt of trough plants are expected to fall by 40% and central receiver systems are expected to fall by over 60%. The cost of electricity from conventional power plants is expected to stay constant over the next twenty years.

The solar Levelized Energy Cost (LEC) is expected to fall to less than half current values as a result of performance improvements and cost reductions. At these costs, the potential for STPPs to compete with Rankine cycle plants (coal, gas or oil fired) is promising. In the long-term, the LEC for Trough Rankine plants is expected to be within the cost range for conventional peaking plants. If a credit for reduced carbon emissions is included, all STPPs have a lower LEC than coal-fired Rankine plants. ISCCS plants are not expected to produce power that is less expensive than a gas-fired combined-cycle plant.

Given the promising results, a three-phase development plan is recommended to commercialize STPPs as summarized below. The three phases are market awareness, market expansion and market acceptance. GEF support is critical to the success of this plan.

Required Investment in STPPs by Phase[1]

Phase	Time Frame	Solar LEC Target (c/kWh)	Additonal Installed Capacity	Est. Total Incremental Investment ($ million)	Est. GEF Investment ($ million)
Phase 1	2000 – 2004	10 to 11	750 MW	440 to 750	350 to 700
Phase 2	2005 – 2009	7 to 8	3000 MW	500 to 1,800	250 to 900
Phase 3	2010 +	Under 6	4600 MW	0 to 330[1]	0 to 150[1]
Total			**8300 MW**	**940 to 2,955**	**600 to 1,750**

1 – assumes a carbon market develops by Phase 3

In Phase 1, the GEF would need to provide financial support in the order of $350 to 700 million to fund approximately nine projects. The support would be in the range of $550 to $1000/kW.

In Phase 2, a further 3,000 MW of installed capacity would be supported. The total support cost is estimated at $500 million to $1.8 billion ($350 to 750/kW). Additional financial partners are expected to emerge, so that GEF support would only be a portion of these values.

In Phase 3, the emergence of carbon credits could mean that STPPs are cost effective and only modest financial support is required (under $330 million). The total support required to commercialize STPPs is estimated at between $1 and $3 billion; approximately 60% of which would need to come from the GEF. The annual GEF investment is estimated at between $60 and $160 million.

The success of the commercialization will depend on several factors. First and most importantly is whether the cost and performance goals for STPPs are met. The goals are 10 to 11 cents/kWh at the end of Phase 1, 7 to 8 cents/kWh at the end of Phase 2 and under 6 cents in Phase 3. Second, cost parity is based on a financial credit for reduced carbon emissions. If there is no carbon trading, carbon credits or carbon tax, the adoption of STPPs will be reduced or slowed. Third, trade, tax and other economic barriers must not penalize the solar option. Real-life financing issues can have a major impact on the adoption of any technology. The study was performed as an economic analysis, not a financial analysis.

The GEF can play a major role in all three of these factors, ensuring that a cost-effective technology is developed, a program of carbon credits or trading is implemented and financial barriers are limited.

ACKNOWLEDGEMENTS

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DISCLAIMER

APPENDIX B

A Rebuttal of the National Research Council's Review of the U.S. DOE Concentrating Solar Power Program

Executive Summary

June 2000

A REBUTTAL OF THE NATIONAL RESEARCH COUNCIL'S REVIEW OF THE U.S. DOE CONCENTRATING SOLAR POWER PROGRAM

Executive Summary[1]

June 2000

from the

U.S. Concentrating Solar Power Industry Review Panel

INTRODUCTION

In April 2000, the National Research Council (NRC) issued a report "Renewable Power Pathways", which presented the results of their programmatic review of the U.S. Department of Energy's Office of Power Technologies (OPT) and its R&D programs. It has become apparent that this report has become a serious threat not only to the DOE CSP Program but also to the very viability of the concentrating solar technologies. Therefore, the Concentrating Solar Power (CSP) Industry Panel ("Panel") was formed to provide a fair balance to this damaging review. The Panel considers this matter to be of the utmost importance, in that the NRC report attacks the very substance of our industrial endeavors with few substantive facts and conclusions. The CSP Industry Panel is comprised of representatives of major U.S. industrial firms in power, solar engineering and marketing technologies, such as Duke, Bechtel, SAIC and Boeing, as well as key experts from solar plant operating companies, national lab staff, and technology developers.

The CSP industry takes strong exception to elements of that report regarding the status and commercial viability of CSP technology. We assert that the NRC Review Committee conclusions are based on inconsistent analysis and misconstrued data, as well as oversight of critical input and current market circumstances. The experienced and knowledgeable view of the Panel is significantly different than that of the NRC report.

We further assert that:

- **There is a strong U.S. industry interest in CSP technologies.**
- **There is a U.S. market today for trough technology**

[1] Full rebuttal report available on request. Contact Mr. John Myles, Duke Solar, (919) 776-2000. (Ver5)

- **There is an overseas market today for trough and tower technologies.**
- **CSP is by far the cheapest current source of solar electricity**
- **Further improvements in performance and reductions in cost will come from additional CSP power plants and supporting R&D.**

It is very important to our industrial and environmental goals and to the interests of the U.S. taxpayer that the DOE CSP Program support the U.S. CSP industry's interests. Lack of program support will send a damaging message to our potential customers, and undermines the considerable investment and advances of this important technology **at a most critical time of its development**. A reduction or elimination of the CSP Program at DOE will undermine the U.S. industry's efforts to raise private capital for the U.S. and overseas markets. The CSP industry is moving forward, and there is no logic in the loss of meaningful DOE support to recognize CSP as a vital part of the renewable energy portfolio. It is clearly worthy of the same incentives and support as other renewable electric technologies. Lack of recognition and support at this critical time is viewed by the Panel as a strategic mistake, and counter to both our goals and those of DOE program. With such support, **the CSP industry itself will develop its market and continue to drive the technology and system costs down**. For several reasons, **now** is the most opportune and critical time in the last 10 years to advance the commercial deployment of the CSP technology.

INDUSTRY CONCERNS

A FLAWED ANALYSIS SHOULD NOT BE A BASIS FOR EITHER JUDGEMENTS ON TECHNOLOGY WORTHINESS OR BUDGET REDUCTIONS.

The CSP Industry Review Panel noted serious inconsistencies in the treatment of CSP relative to the other renewable energy power-generation technologies. We found that many of the favorable findings and recommendations made for other renewable energy technologies are just as applicable to CSP technologies. In addition, a careful review of the entire report raised questions about the process used by the NRC review committee to arrive at a consensus. It is our considered opinion that the NRC treatment of CSP is inconsistent, inaccurate and reaches unjustified conclusions.

More specifically, it is apparent that the NRC did not contact key members of the CSP industry and other well-qualified CSP experts, did not take into account credible relevant studies done by organizations in the U.S. and abroad, and did not arrive at a true consensus.

The CSP Industry Review Panel is well qualified to rebut the NRC evaluation and comment on this technology. Collectively the Panel represents major U.S. energy companies with markets around the world. Members have operated CSP power plants successfully for over a decade, have conducted R&D and field testing for decades, and have considerable private investment at stake. Collectively Panel members have decades of research and development experience in solar troughs, power towers and dish technologies. From our industry perspective we see things quite differently than the NRC Review Committee.

THE MERITS

We believe that the CSP technologies are a vital component of the U.S. renewable energy technology portfolio. Critical merits include:

- **CSP capabilities are well proven with 354 MW in operation for 10 years, with excellent performance and availability, and documented cost reductions by a factor of 3. In addition all of these plants continue to operate today, a feat that no other renewable technology has achieved.**
- **At present, trough and tower technologies are the only viable solar technologies for large-scale projects.**
- **Dispatchable power via thermal storage or hybrid operation can meet peaking and intermediate loads. Therefore, unlike most renewables, CSP can provide power whenever it is needed – not only at the moment that the sun or wind resource is available.**
- **This ability of CSP plants to meet peak demand – the most valuable electricity in the U.S. market – makes them attractive to power marketers**

MARKET OPPORTUNITIES

United States: **The NRC report clearly misrepresents the domestic power market.** Given the power sector restructuring that has been occurring over the last 10 years, very few power plants of any kind (fossil or renewable) have been built. To fault CSP for a lack of market penetration during this period is unreasonable. While well aware of the potential impacts of the restructuring of the power-generation industry, the report seems to ignore the importance of recent changes in the energy market that affect CSP technologies.

Now that the market is stabilizing we are beginning to see a resurgent customer-driven interest in renewables. Wind, a technology that currently has larger cost subsidies available than solar, is just now beginning to make significant penetration in the market. The CSP circumstance would be greatly improved with similar subsidies in view of current opportunities.

The rapidly changing Renewable Portfolio Standards situation at the state level will open new opportunities for CSP, especially if a portion is designated for solar - as they are in Arizona, California and soon Nevada. CSP technologies will target half of this 100 MW market over the next 5 years. A similar portfolio standard for wind has resulted in thousands of Megawatts for installation in Texas and Minnesota.

Duke Solar is a major player in a consortium of major energy companies working to build one or more large CSP plants in the Southwest, blended with wind, biomass, and/or geothermal. Such a hybrid system has very large market potential because a relatively small addition of a solar CSP component to a natural gas power plant yields large benefits in premium time of day supply for a small overall increase in generation cost.

Integration of CSP solar technologies with power cycle technologies developed for geothermal resources will allow smaller modular CSP thermal plants (approximately 1-10 MW capacity) to be deployed cost effectively for distributed and remote power

applications. Many of the industrial players in the geothermal industry are moving forward on the development of modular CSP systems (ORMAT, Exergy, Bib & Associates, and Barber Nichols). The CSP dish program also continues to move forward aggressively developing even smaller kW-scale engine systems for distributed applications.

Continued movement towards market-based electricity prices and continued reduction in cost of CSP power creates an attractive market outlook for U.S. CSP industry. Polls of U.S. electricity customers have indicated a strong preference for renewable power. In the dozens of studies conducted for more than a decade, solar is always the preferred form of renewable power, and the public indicates a willingness to pay more for solar power than any other conventional or renewable power source**. CSP technology provides the lowest cost solar power generation option. This in and of itself qualifies CSP for maximum support, not the minimum accorded by the NRC report.**

***International**:* **The overseas market for CSP is absolutely essential, desirable and a dynamic catalyst for the U.S. CSP industry. The NRC position, downplaying this critical market, is totally inconsistent with current global market activity.** We cite two examples to emphasize the crucial significance of this market:

First, the Global Environmental Facility (GEF) and the World Bank have committed $200 million to four CSP plants in Egypt, Mexico, Morocco and India and is currently considering subsidizing additional CSP plants, e.g., in Brazil, South Africa and China. **This commitment is a dramatic endorsement of the CSP technology. From the GEF perspective, CSP is the leading renewable technology to achieve significant carbon emissions abatement on a global scale.**

U.S. companies have been involved in all four of these projects to date. In a May 2000 pre-qualification of bidders for the upcoming Egyptian RFP five major U.S. companies have applied and are confident of approval.

FURTHERMORE, IN DIRECT CONFLICT WITH THE NRC REPORT, A KNOWLEDGEABLE INDEPENDENT EVALUATOR AND WB/GEF PANEL ASSESSED IN 1999 THE POTENTIAL FOR CSP TO REACH ITS COST GOALS IN A FUTURE COMMERCIAL MARKET, AND CONCLUDED THAT THE $200M GEF COMMITMENT TO CSP TECHNOLOGY WAS WELL FOUNDED[2].

Second, Spain's recent Royal Decree may open significant CSP markets in that country. The official objective for the year 2005 is for a minimum of five CSP plants for a total installed power of 200 MW. Investment subsidies of up to $300M are projected for CSP in the same period.

Considering both the U.S. and foreign activity, the CSP Industry Review Panel concludes that today's market prospects for CSP technologies are exciting, worthy of substantial private investments, and critically important to the industry and the investment to date by the U.S. taxpayer

[2] Carpenter, Stephen, Entermodal Engineering Ltd., Cost Reduction Study for Solar Thermal Power Plants, prepared for the World Bank/Global Environment Facility, June 1999.

PRIVATE SECTOR INTEREST IN CSP DEPLOYMENT AND DEVELOPMENT

In contrast to the NRC conclusion that the industry support for CSP is weak, the contributors to this rebuttal – major energy companies such as Duke Solar, Bechtel, Boeing, Siemens, Sargent & Lundy, ABB, El Paso Electric, ASE and SAIC – are fully committed to this technology. These companies have the ability to deliver major energy projects. They are able to guarantee performance, back warrantees, build on fixed price contracts, and bring equity financing and arrange for debt at reasonable risk.

The CSP Industry Review Panel expects that the next 300-400 MW of solar fields, trough or tower, will markedly reduce the technology cost, bringing electricity costs from CSP plants closer to the competitive range. Contrary to a NRC conclusion, we argue that incremental, evolutionary improvements - significant in scope - are the paths to success for CSP. There is absolutely no evidence that R&D investments will not be commensurate with the potential payoff, and in fact the opposite can be shown by myriad examples. We consider the need for R&D to support our efforts to reach competitive costs to be a valid and justified goal.

Furthermore, government incentives and government purchase of electricity from CSP plants are as important for CSP technology as they are for the other renewable energy technologies. Thus, the GEF commitment to the technology in these early commercialization stages is very important. For example, most of the wind power that is currently being installed in the U.S. is a result of legislated minimum requirements rather than economic competitiveness.

The Industry has worked with the DOE CSP program to develop a joint technology roadmap for the development of trough technology. We believe this roadmap shows significant near-term and future opportunity for trough and other CSP technologies. The roadmap clearly identifies the need for both market deployment of the technologies in early niche markets (such as the GEF projects, Spain, Arizona, etc.) as well as continued R&D to enable future cost reductions necessary to enable introduction of the technology into more competitive markets. The DOE CSP R&D program is based on the trough roadmap and has helped make significant contributions to the advancement of trough technology in the last year. The roadmap has clear sequential metrics that are being met or exceeded through current programmatic activities. For example, in the last year the DOE CSP program has made significant advances in the development of thermal storage for troughs and optimization of the integration of trough technology into combined cycle plants.

It is not clear to the CSP industry how DOE is assessing the relative merits of different renewable technologies. We have seen no clear technology roadmaps for other renewable technologies that set out performance metrics to evaluate the progress of the technologies. From our perspective, as well as that of the GEF, **large scale CSP technologies clearly provide the greatest environmental benefit at the lowest cost today and are likely to remain that way for a long time into the future.** PV, for example, requires $5000 per kW_{peak} subsidies with net metering (another form of subsidy) and still provides only half the environmental benefits of large-scale CSP plants per consumer dollar invested. This PV investment subsidy alone is 2 to 4 times higher than the full capital cost of a CSP plant. From this standpoint how does DOE justify continued investment in PV while cutting back on an already superior technology? PV deserves support, but our Panel believes that commitments to both CSP and PV are justified in their own right.

We who endorse this document have worked in the CSP field or the energy industry for the past 20 years. Our companies are leaders in the power field and our companies have collectively built hundreds of power plants, and are willing to invest significant equity in the upcoming CSP plants, an investment that dwarfs the DOE budgets we are concerned about protecting.

The CSP Industry Review Panel offers the following alternate recommendation:

The Office of Power Technologies should continue its research and development on CSP because further refinements are at hand and guaranteed to achieve significant cost reductions leading to increased deployment, which will strengthen the ability of industry to capture segments of both current and future renewable markets in large blocks. The U.S. taxpayer, the DOE and industry will all benefit from this support.