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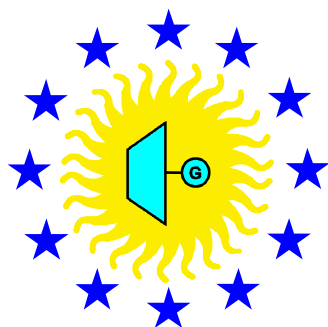
European **C**oncentrated **S**olar **T**hermal **R**oad-Mapping



Roadmap Document

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Deutsches Zentrum für Luft- und Raumfahrt e.V.





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European Concentrated Solar Thermal Road- Mapping

**Coordination action
Sustainable Energy Systems**

Deliverable No. 7 Roadmap Document

**Due date of deliverable: 1.11.2004
Actual submission date:**

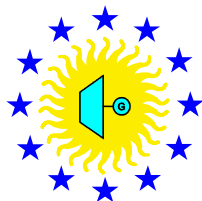
Start date of project: 01.12.2003

Duration: 15 months

Lead contractor for this deliverable: DLR

Revision: 1.0

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	PU

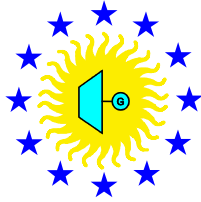


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Acknowledgement and Disclaimer

The ECOSTAR team acknowledge the financial support of the European Union under contract SES6-CT-2003-502578. We would also like to thank all reviewers for their valuable comments, particularly: Manfred Becker, Scott A. Jones, Hansjörg Lerchenmüller, Peter Heller and Peter Viebahn.

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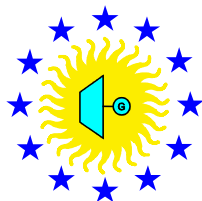
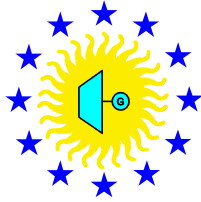


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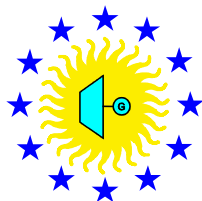
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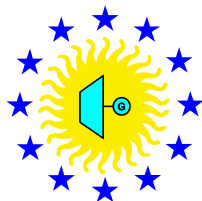
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Abbreviations

°C	Degrees Celsius
€	Euro
AA	Atmospheric Air
CIEMAT	Center for Energy, Environment and Technological Research
CNRS	French National Center for Scientific Research
CRS	Central Receiver System
CSP	Concentrating Solar Thermal Power
DLR	Deutsches Zentrum für Luft- und Raumfahrt e.V.
DNI	Direct Normal Insolation
DSG	Direct Steam Generation
E.ON	E.ON Energie AG
ETH	Eidgenössische Technische Hochschule, Zürich, Switzerland.
EU	European Union
FCR	Fixed Charge Rate
GWh	Gigawatt-hours
h	Hours
HCE	Heat Collection Elements
HTF	High Temperature Fluid
IEA	International Energy Agency
IVTAN	Institute for High Temperatures of the RAS, Ass. IVTAN, Moskau, Russia
kg	Kilograms
km ²	Square kilometre
kW	Kilowatts
kW _{el}	Kilowatts-electrical
kW _{th}	Kilowatts-thermal
LEC	Levelized Electricity Cost
m	Meter
m ²	square meter
m ³	cubic meter
MS	Molten Salt
MW	Megawatts
MW _{el}	Megawatts-electrical
MWh	Megawatt-hours
MW _{th}	Megawatts-thermal
O&M	Operating and Maintenance
PB	Power Block
PCM	Phase Changing Materials
PSA	Plataforma Solar de Almería
PURPA	U.S. Federal Public Utility Regulatory Policy Act
PV	Photo Voltaic
R&D	Research and Development
RES	Renewable Energy Source

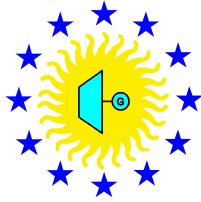


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RTILs	Room Temperature Ionic Liquids
s	Seconds
SCE	Southern California Edison
SEGS	Solar Electric Generating Station
SM	Solar Multiple
Solar PACES	Solar Power and Chemical Energy Systems
SOLGT	Solar Hybrid Gas Turbine
STEOR	Solar Thermal Enhanced Oil Recovery
t	Tons
TES	Thermal Energy Storage
TSA	Technology Program Solar Air Receiver, Germany
VGB	VGB PowerTech e.V.
WIS	Weizmann Institute of Science, Israel



1. Executive Summary

1.1. Purpose and scope

Recognising both the environmental and climatic hazards to be faced in the coming decades and the continued depletion of the world's most valuable fossil energy resources, **Concentrating Solar Thermal Power (CSP)** can provide critical solutions to global energy problems within a relatively short time frame and is capable of contributing substantially to carbon dioxide reduction efforts. Among all the renewable technologies available for large-scale power production today and for the next few decades, CSP is one with the potential to make major contributions of clean energy because of its relatively conventional technology and ease of scale-up.

Today's technology of CSP systems is implemented in the cost range of **15 - 20 cents€/kWh**. In the conventional power market, it competes with mid-load power in the range of 3 – 4 cents€/kWh. Sustainable market integration as predicted different scenarios can only be achieved, if the cost will be reduced in the next 10 to 15 years to a competitive cost level. Competitiveness is not only impacted by the cost of the technology itself but also by a potential rise of the price of fossil energy and by the internalization of associated social costs such as carbon emissions. Therefore we assume that in the medium to long-term competitiveness is achieved at a level of **5-7 cents€/kWh** for dispatchable mid-load power.

Today, several scenarios exist describing the potential deployment of CSP systems. A typical example is the Athene Study (www.dlr.de/socrates) that uses a scenario technique to quantify the world-wide deployment of CSP through 2025 (see Figure 1-1). Based on this analysis and taking into account learning and scaling effects, the overall investment cost and the average levelized electricity cost are estimated. This approach predicts a cost reduction down to 5 cents/kWh at a total installed capacity of 40 GW achieved between 2020 and 2025 (see **Figure 1-2**). The European Union has adopted the potential of this technology and currently supports the implementation of three pilot solar thermal power plants in Europe (PS10, ANDASOL, SOLAR TRES).

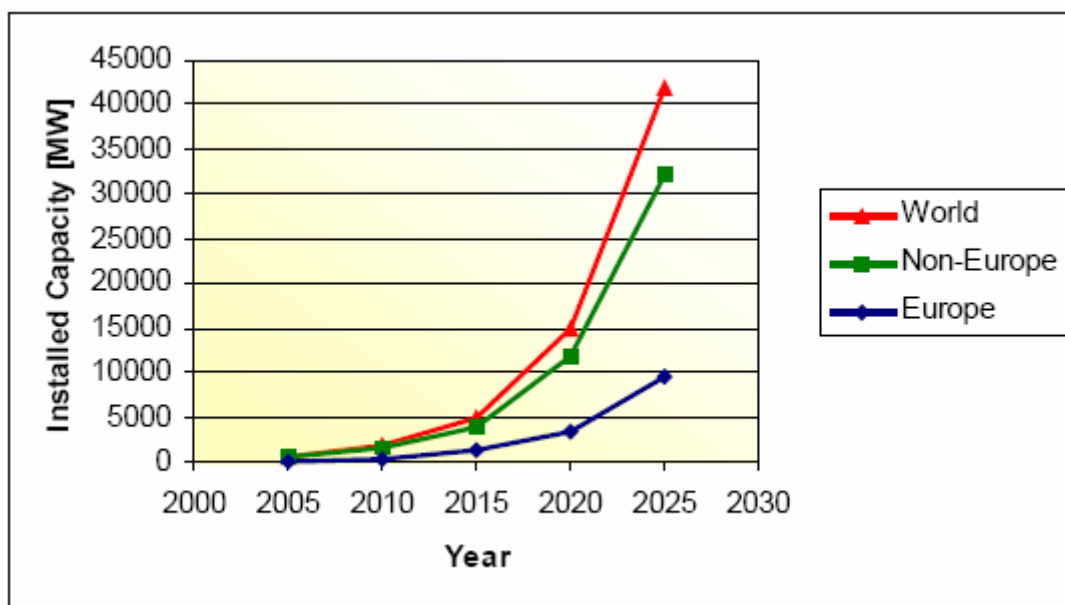


Figure 1-1: Athene scenario on the deployment of concentrated solar power systems (www.dlr.de/socrates)

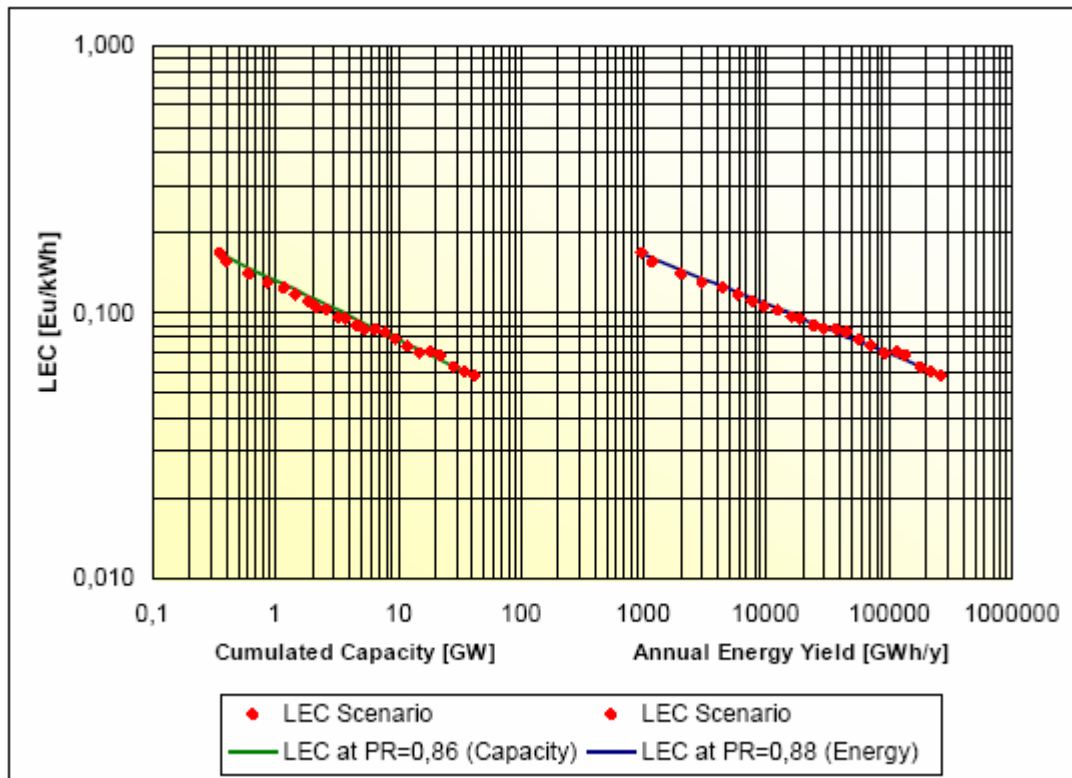
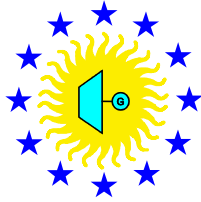


Figure 1-2 Athene scenario of the reduction of LEC predicted by the learning curve approach (see www.dlr.de/sokrates)

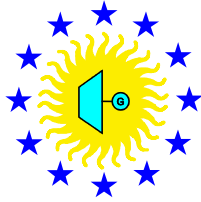
While scenario approaches estimate cost reduction potential and the total market incentives needed to achieve full competitiveness with conventional choices, they do not help to identify specific innovations that may enable these reductions. Other recent cost reduction studies [1] have already pointed out that approximately half of the cost reduction potential for CSP can be attributed to scale-up to larger plant sizes and volume production effects, whereas the other half is attributed to technology R&D efforts.

The focus of this document is to show the essential technology innovations that may contribute significantly to the R&D-driven cost-reduction potential.

Three **major objectives** of the proposed ECOSTAR co-ordinating action are followed:

- to **identify the potential European technical innovations** with the highest impact on CSP-cost reduction.
- to **focus the European research activities and the national research programs** of the partners involved on **common goals and priorities**.
- and to **broaden the basis of industrial and research excellence**, capable to solve the multidisciplinary CSP specific problems.

In this context we understand the word “innovation” as something that is new compared to the current status of technology. Many of the considered innovations have been subject of R&D projects in the past, and due to the limited resources in the project, we have only included those



where sufficient information on potential performance and costs are available from previous investigations. The list of innovations handled here is certainly not complete and should not discourage consideration of other advanced concepts. However, the major objective of this investigation is to show which of the ongoing work is most appropriate to achieve a significant cost reduction in CSP technologies. This is considered to be a pre-requisite to agree on R&D priorities in national and European programs.

1.2. Methodology

Today several CSP technologies (like parabolic troughs and central receiver using different heat transfer media) are at the phase of a first commercial deployment for bulk power production in Europe. In addition to those technologies, several others are also included in this investigation if they have had a successful proof-of-concept demonstration, have undergone comprehensive engineering studies, and if industry is promoting a commercial plant.

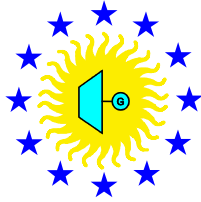
The approach is to analyze the impact on cost of different innovations applied to a reference system in order to identify those with the highest impacts. Cost and performance information of the reference systems are currently at a different level of maturity. Therefore, the evaluation will focus on the identification of the major cost reduction drivers for each of the considered reference systems and identify the impact of technical innovation approaches. This will lead to recommendation on R&D priorities as well as on recommendation on changes in the political framework needed to achieve a successful deployment. These findings should serve as input for the definition of future R&D and demonstration programs also support the adaptation of a political framework on the national and European level to accelerate commercial deployments.

The methodology for the cost study is depicted in Figure 1-3. The essential figure of merit is the levelized electricity cost (LEC) which is calculated according to a simplified IEA Method [2] using current euros (see the grey box next page, where the common assumptions for the financial parameters are listed). The goal of this study is the comparison of different technical innovations, therefore any project specific data (e.g. tax influences, or financing conditions) are neglected. The approach is kept simple, but it appears to be appropriate to perform the relative comparison necessary to quantify the impact of different innovations. For each reference system a detailed performance and cost model has been established in Microsoft Excel. The model uses common assumptions for the site¹, meteorological data² and load curve³. It calculates the annual electricity production hour by hour, taking into account the instant solar radiation, load curve, part load performance of all components (depending on load fraction and ambient temperature), operation of thermal energy storage, and parasitic energy requirements. The reference size of all systems is assumed to be 50 MW_{el} net.

¹ Seville, Spain 5.9 ° W, 37.2° N, 20 m above sea level, land costs 2,000,000 €/km²

² Seville, Spain, hourly data of direct normal insolation and ambient temperature from measurements; DNI 2014 kWh/m²a ;average Temp 19,5C°, Min = 4,1°C, Max = 41,4°C

³ Free-load operation or in hybrid operation 100% load between 9:00 a.m. and 11 p.m. every day, average availability of 96% to account for forced and scheduled outages resulting in a capacity factor of 55%



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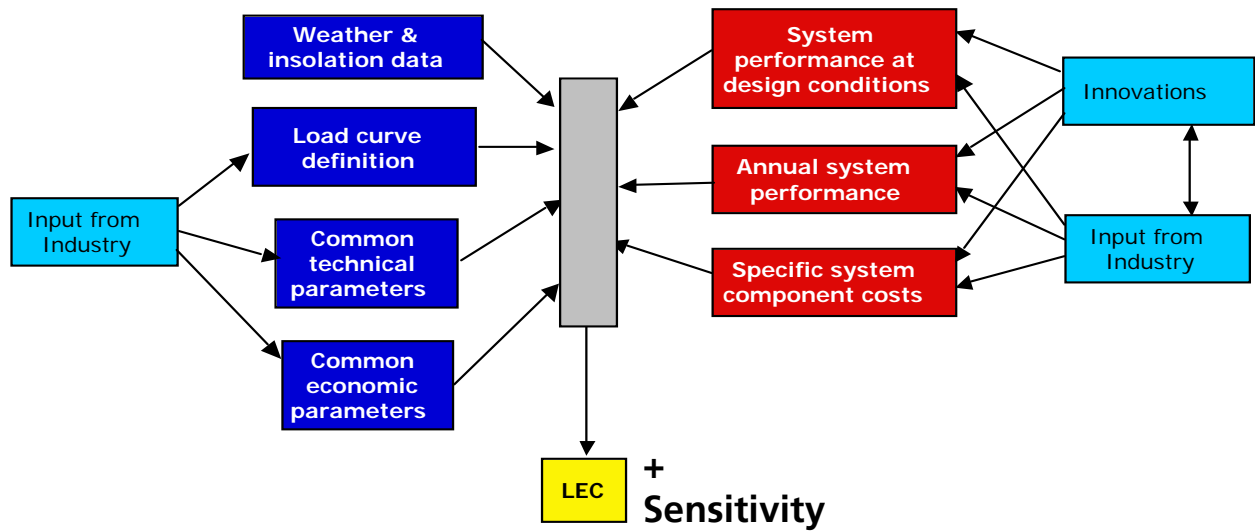


Figure 1-3: Methodology for the cost studies.

Definition of “Levelized Electricity Costs” (LEC)

$$LEC = \frac{crf \cdot K_{invest} + K_{O\&M} + K_{fuel}}{E_{net}}$$

with

$$crf = \frac{k_d (1 + k_d)^n}{(1 + k_d)^n - 1} + k_{insurance} = 9,88\%$$

k_d real debt interest rate = 8%

$k_{insurance}$ annual insurance rate = 1%

n depreciation period in years = 30 years

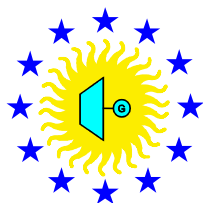
K_{invest} total investment of the plant

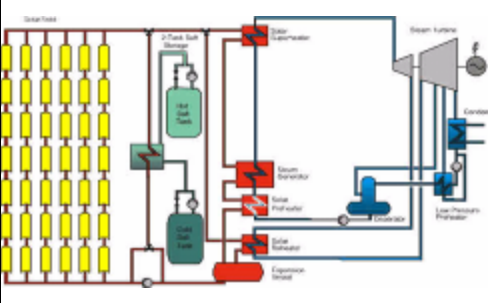
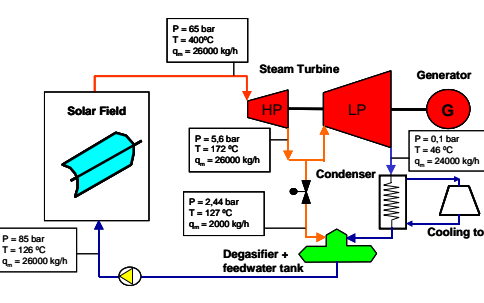
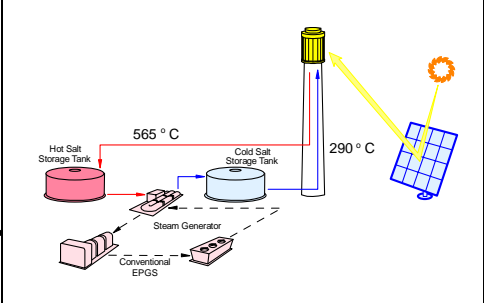
$K_{O\&M}$ annual operation and maintenance costs

K_{Fuel} annual fuel costs

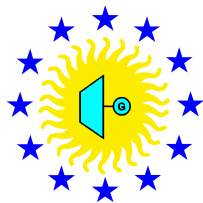
E_{net} annual net electricity

Seven different CSP technologies are considered in this study:



Technology	Parabolic trough / HTF	Parabolic trough DSG ⁴	Molten salt Central receiver system
			
Technical design parameter:			
Collector	Parabolic trough	Parabolic trough	Heliostat field
Receiver	Linear receiver (tubes)	Linear receiver (tubes)	Molten salt receiver
Storage system	2-tank-molten-salt storage	No storage system available up to date	2-tank-molten-salt storage
Cycle	Rankine steam cycle	Rankine steam cycle	Rankine cycle
Planned / built power size			
	50 MW Andasol I & II, under preparation, Spain	4.7 MW INDITEP study	Solar Tres (17MW), planned, Spain
Maturity	Several commercial units up to 80 MW _e are in operation in southern USA	Single row experimental plant in Spain	Solar 2 (11 MW) experimental plant in California in the 1990ies
Temperature	393°C	411°C	565°C
Size of the reference system	50 MW _e	10 × 4.7 MW _e	3 × 17 MW _e
Solar capacity factor	29 %	22 %	33 %
LEC for a single ECOSTAR reference system, solar-only			
	0.172 €/kWh _e	0.187 €/kWh _e	0.183 €/kWh _e
LEC for power plant park consisting of several reference systems with total capacity of 50 MW, solar-only			
	0.172 €/kWh _e	0.162 €/kWh _e	0.155 €/kWh _e

⁴ The linear Fresnel collector has been considered as innovation for the parabolic trough DSG system in the subsequent analysis.



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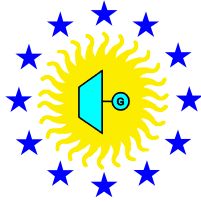
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Technology	Saturated steam central receiver system	Atmospheric air central receiver system	Pressurized air central receiver system	Dish engine System
Technical design parameter:				
Collector	Heliostat field	Heliostat field	Heliostat field	Parabolic dish
Receiver	Saturated steam receiver	Volumetric atmospheric air-cooled receiver	Pressurized air receiver	Cavity receiver with tube bundle
Storage system	Water/steam buffer storage	Ceramic thermocline thermal storage	No storage system available up to date	No storage system available up to date
Cycle	Rankine cycle	Rankine cycle	Combined cycle	Stirling engine
Planned / built power size				
	PS 10 (11MW), under construction, Spain	PS 10 conceptual design study	Solgate study 14.6 MW _e	22 kW _e
Maturity	Several experimental plants up to 2 MW _{th} have been tested	2.5 MW _{th} experimental plant tested in Spain in 1993	2 × 200 kW _e under construction in Italy	About 30 units up to 25 kW _e are in operation at different sites
Temperature	250°C	750°C	800°C	800°C
Size of the reference system	5 × 11 MW _e	10 × 4.7 MW _e	4 × 14.6 MW _e	2907 × 25 kW _e
Solar capacity factor	26%	33 %	11 % (55%) ^b	22%
LEC for a single ECOSTAR reference system, solar-only				
	0.241 €/kWh _e	0.234 €/kWh _e	0.147 €/kWh _e (0.1 €/kWh _e)	0.281 €/kWh _e
LEC for a power plant park consisting of several reference systems with total capacity of 50 MW, solar-only				
	0.169 €/kWh _e	0.179 €/kWh _e	0.139 €/kWh _e (0.082 €/kWh _e)	0.193 €/kWh _e

^b Values in brackets are for hybrid operation



Classes of innovations

The innovations considered within this study may be divided into several groups:

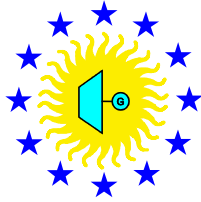
- Scale up of of plant size to 50 MW_{el}: This measure is required because only the parabolic trough HTF system has been demonstrated at a 50 MWe size. All other technologies considered here are planned at a scale of 15 MWe or smaller for initial commercial demonstrations.
For these technologies, it is assumed that several smaller plants are co-located at one site to reach the 50 MWe reference size and provide a common basis for computing O&M costs. Increasing plant scale to 50 MWe for those systems would provide a significant efficiency increase and cost reduction.
- Modification of structures, application of new materials and simplification of the concentrator system are measures of the second group of innovations.
- Integration of thermal storage for several full load hours, together with new storage materials and advanced charging/discharging concepts allow for increased solar electricity production without changing the power block size. Provided that the storage is sufficiently inexpensive, this would lower the LEC, and additionally increase the dispatch ability of the electricity generation.
- Further development of the cycle with increased temperatures, or additional superheating for the CRS saturated steam plant are considered. These measures provide higher efficiencies and solar fractions.
- For all CSP reference systems the most promising innovations are combined (as far as possible) and the cost reduction potential for this combination of selected measures has been calculated.

One has to keep in mind that the innovations have different probabilities of success and are in different stages of development; some of are already conceptually proven and some are only a concept. This uncertainty is addressed by providing optimistic and pessimistic bounds on the input data for the performance and cost model, resulting in appropriate bounds for the LEC values and cost reduction percentages presented here.

1.3. Summary of findings

Today's costs and cost reduction potential

Many of the systems considered here are planned for commercial deployment in Spain, which recently enacted an incentive of around **21 cents€/kWh** for solar thermal electricity. The most mature technology today is the parabolic trough system that uses thermal oil as a heat transfer medium. Several **50 MW_{el}** units using thermal energy storage based on molten salt are currently planned in Spain. The present ECOSTAR evaluation estimates levelized electricity cost of **17-18 cents€/kWh** for these initial systems, assuming a load demand between 9:00 a.m. and 11:00 p.m. These cost estimates may deviate from electricity revenues needed for the first commercial plants in Spain because they were evaluated using a simplified methodology including the financing assumptions recommended by the IEA for comparative studies like this. The other technologies analyzed are currently planned in significantly smaller pilot scale of up to **15 MW_{el}**. The LEC is significantly higher for these small systems ranging from **19 to 28 cents/kWh**. Assuming that several of the smaller systems are built at the same site to achieve a power level of 50 MW and take benefit of a similar O&M effort as the larger plants, LEC estimates of all of the systems also range between 15 and 20 cents/kWh. The systems achieve a **solar capacity factor of up to 30%** under these conditions (depending on the availability of storage). One significant exception is the integration of solar energy into a gas turbine /



combined cycle, which at the current status of technology can only provide a solar capacity factor of 11% and needs significant fossil fuel (20% -25 % annual solar share depending on load curve) but offers **LEC of below 9 cents/kWh for the hybrid operation**⁶ (equivalent to 14 cents/kWh for the solar LEC). Due to the low specific investment cost of the gas turbine / combined cycle together with a high efficiency, the system is specifically attractive for hybrid operation. Further development of the receiver technology can increase the solar share significantly in the future.

Since the absolute cost data for each of the reference systems are relatively close and are based on a different level of maturity, **choosing technologies for R&D prioritization** (e.g. troughs vs. towers) **doesn't appear feasible**. This competition between technologies will be left to industrial entrepreneurship and market forces. However, the evaluation has identified the major cost reduction drivers for each of the considered reference systems and has identified the impact of technical innovation approaches.

For all systems considered technical innovations were identified and translated into component cost and performance estimates to calculate the LEC. For example the utilisation of thin glass mirrors in parabolic trough collectors impacts the following:

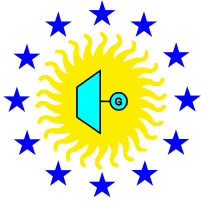
- the mean reflectivity is left unchanged at 0.88 / increases to 0.89,
- the specific investment costs are reduced to 95% / 90% of the reference value,
- the O&M equipment cost percentage is increased to 1.1% / left unchanged at 1.0%.

The first of the above mentioned parameter values is the pessimistic estimate and the second one is the optimistic one. Using these boundary values within the annual calculation model results in the boundary values for the LEC reduction shown in Figure 1-4.

The most promising options were combined to evaluate the overall cost reduction potential. Based on the limited number of approaches suggested in the scope of this study, **cost reductions of 25 - 35%** due to technical innovations and scaling up to 50 MW_e are feasible for most of the technologies. These figures do not include effects of **volume production** or **scaling of the power size of the plants beyond 50 MW unit size, which** would result in further cost reductions.

For parabolic trough technology the Sargent & Lundy study [1] estimated a cost reduction of 14 % from larger power blocks (400 MW) and 17% by volume production effects when installing 600 MW per year. Assuming similar figures also for the other technologies, an **overall cost reduction of 55 – 65%** can be estimated in the next 15 years. Figure 1-5 illustrates this accumulated potential for the parabolic trough / HTF system, but very similar figures appear feasible for the other six systems investigated here.

⁶ At a fuel price of 15 €/MWh



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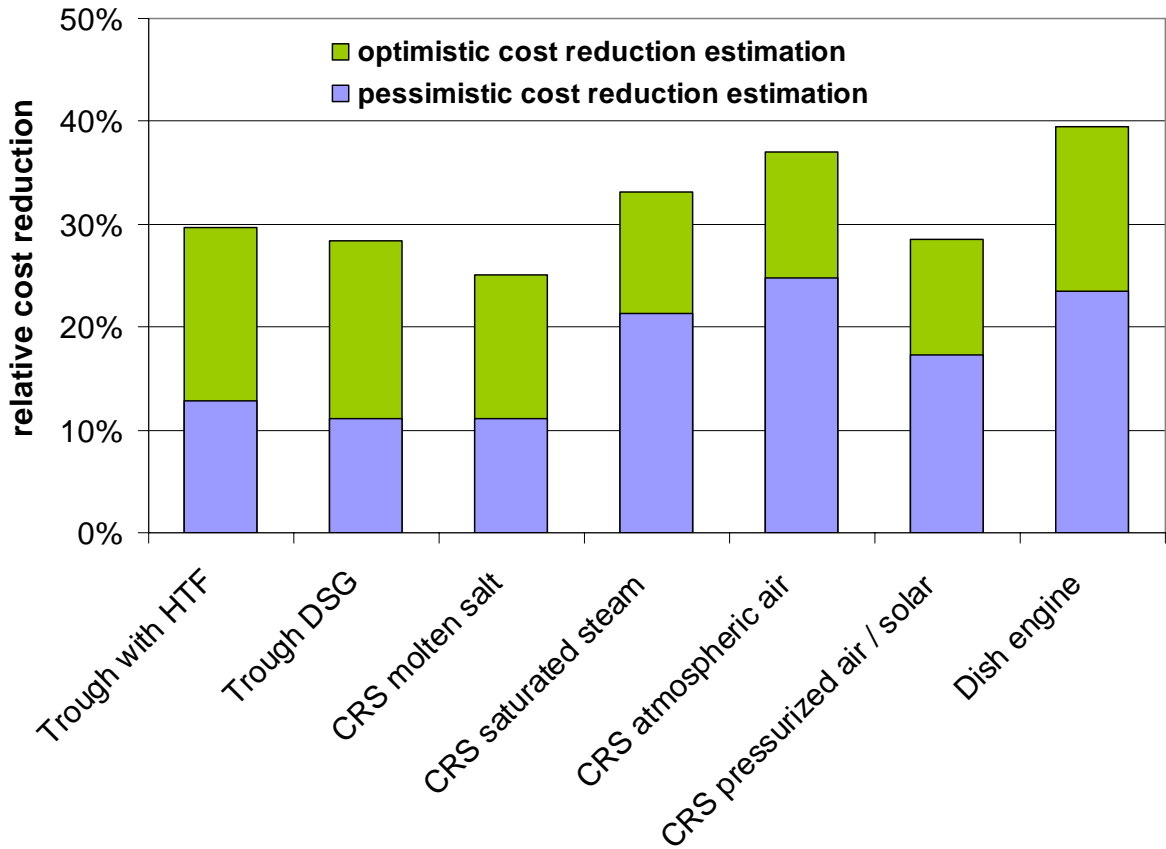


Figure 1-4: Innovation driven cost reduction potential for the 7 CSP technologies investigated in this study based on the LEC for the 50 MW_e reference system and assuming a combination of selected innovations for each system.

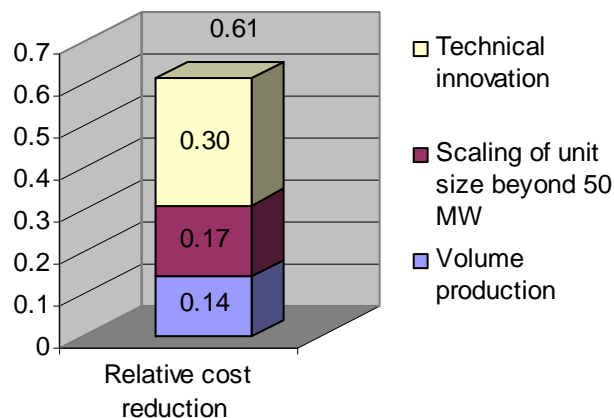
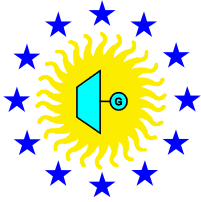


Figure 1-5: Potential relative reduction of LEC by innovations, scaling and series production through 2020 for the parabolic trough/HTF system compared to today's LEC



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This would lead to levelized cost of electricity in **Southern Spain of around 6.7 cents/kWh** and down to **5 cents/kWh in high solar resource areas** (see Figure 1-6) like those at the southern shore of the Mediterranean sea and would represent competitive cost for mid-load power (without CO₂ emissions).

CSP cost reduction

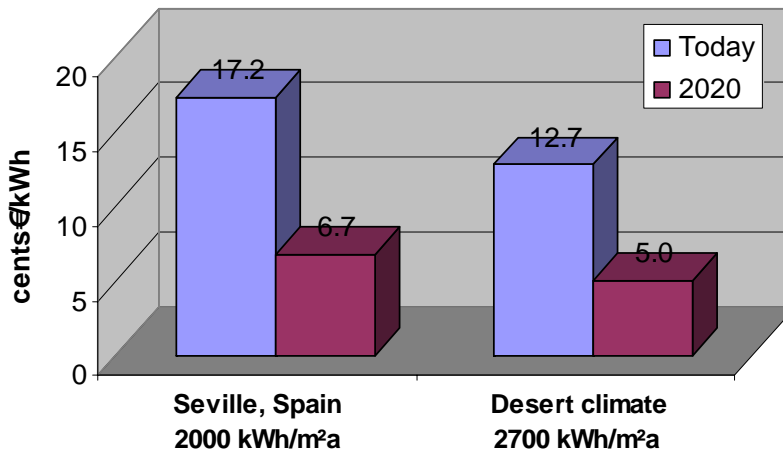
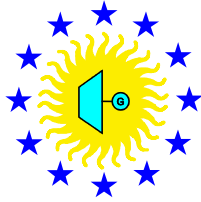


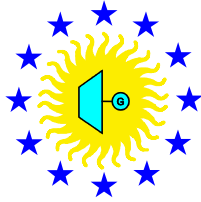
Figure 1-6: Predicted LEC today and in 2020 in cents/kWh for CSP technology for two different climate conditions. Shown for the parabolic trough / HTF system.



1.4. Research Priorities

The various innovations aspects have different impact for on the LEC reduction of the 7 systems investigated. The **innovation potential** with the highest impact on CSP-cost reduction is presented for each of the technologies in the following table

Technology	Priority A	ΔLEC	Priority B	ΔLEC	Priority C	ΔLEC
Trough using oil	concentrator structure and assembly	7-11%	Low cost storage system	3-6 %	increase HTF Temp	1 - 3 %
			advanced reflectors and absorber	2-6%	reduce parasitics	2 – 3 %
Trough DSG	scale increased to 50 MW system	14 %	Advanced Storage	3-6%	Increase HTF Temp	1 - 3 %
	Concentrator structure, and assembly	7-11%	advanced reflectors and absorber	2-6%	reduce parasitics	2 – 3 %
SCR Salt	scale increased to 50 MW	3 -11%	Advanced mirrors	2 -6%	advanced storage	0 -1 %
	heliostat size, structure,	7 -11%				
SCR Steam	scale increased to 50 MW	6-11%	superheated steam	6 -10%	advanced mirrors	2 -6%
	heliostat size, structure,	7 -11%	advanced storage	5-7%		
SCR Atmosph. Air	scale increased to 50 MW	8 -14%	advanced storage	4-9%	advanced mirrors	2 -6%
	heliostat size, structure,	7 -11%	increased receiver performance	3-7%		
SCR Hybrid GT	Heliostat size, structure,	7 -11 %	scale increased to 50 MW	3- 9%	advanced mirrors	2 -6%
	Include Thermal Storage	7 –10%			increased rec. performance.	1- 2%
Dish	mass production for 50 MW	38 %	improve availab and red. O&M.	8-11%	increased engine eff.	2-6%
			Brayton instead of Stirling	6-12%	reduced engine cost	2-6%
			Increased unit size	5-9%	advanced mirror and tracking	0-1%



Summarizing the detailed findings for the individual systems we may see that improvements in the **concentrator** performance and cost most drastically impact the LEC figures. Since the concentrator is a modular component, development of prototypes and benchmarks of these innovations in real solar power plant operation condition in parallel with state of the art technology is a straight forward strategy. New reflector materials should be low cost and have the following traits:

- good outdoor durability,
- high solar reflectivity (>92%) for wave lengths within the range: 300 nm - 2500 nm,
- good mechanical resistance to withstand periodical washing,
- low soiling coefficient (<0.15%, similar to that of the back-silvered glass mirrors).

The supporting structure of the concentrators also needs improvement. New structures should fulfil the following requisites:

- lower weight
- higher stiffness
- More accurate tracking
- Simplified assembly

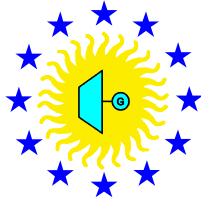
Scaling to larger power cycles is an essential step for all technologies except for parabolic trough systems using thermal oil, which have already gone through the scaling in the nine SEFS installations in California starting at 14 MWe and ending at 80 MWe. Scaling reduces unit investment cost, unit operation and maintenance costs, and increases performance. The integration into larger cycles specifically for power tower systems means a significant challenge due to the less modular design. Here the development of low-risk scale-up concepts is still lacking.

Storage Systems are a second key factor for cost reduction of solar power plants. Development needs are very much linked to the specific requirements of the systems in terms of the used heat transfer medium and the required temperature. In general storage development needs several scale-up steps generally linked to an extended development time before a market acceptance can be reached. Requirements for storage systems are

- Efficient in terms of energy and exergy losses
- Low cost
- Long service life
- Low parasitic power requirements

Especially challenging is the development of storage systems for high pressure steam and pressurized, high temperature air that would lead to a significant drop in electricity costs.

Higher temperatures also lead in many cases to higher system performance. The current status of receiver technology however, does not exploit the full performance potential. Significant improvements in the performance of high temperature receivers are possible, whereas the room for performance improvements in the temperature range below 400° is relatively small (cost improvements are possible).



1.5. How to reach the CSP Vision

The detailed analysis has identified a number of innovations most relevant for cost reduction. In order to transfer this knowledge first into products, then into a continuous deployment of CSP technology a number of key issues must be addressed:

Increasing RTD efforts

The amount of RTD funds by the European Union dedicated to CSP was small compared to other technologies like wind, photovoltaics and biomass. However, they have been sufficient to support a new start-up of CSP technology in Europe (specifically in Spain and Italy). Several hundred MWs of installed capacity appear likely to be installed by 2010. If the predicted cost reductions triggered by technical innovations shall play off its full potential in the next 15 years a significant increase in RTD efforts is required to be introduced in the 7th Framework Programme. This money appears to be well invested in a low cost solar technology providing dispatch-able bulk electricity.

Alignment of RTD strategies and goals

ECOSTAR aims to initialize a much stronger long-term European integration effect than can be achieved by co-operation on a project-by-project basis. It will initiate the process to agree on common goals and priorities and utilize national and European resources most effectively to achieve them. All European Research centers involved in ECOSTAR manage a significant institutional (or sometimes even national) budget for CSP research. A joint European roadmap shall be the starting point to adjust their individual program goals and priorities in order to achieve the highest impact with their limited resources. This will be the basis to implement the existing European facilities of various powers and concentration factors, the existing tools and human resources most efficiently in future projects and to streamline the national development activities by setting common priorities and goals. One important result is the formation of the SOLLAB alliance formed by CIEMAT, CNRS, DLR and ETH to reach this goal. It is recommended to support the extension of such an R&D platform as a European network of excellence.

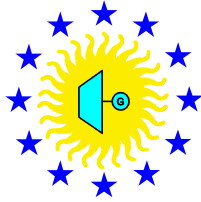
Involving further excellence

Further expertise is needed. Until now only a small number of companies with specific expertise and a variety of research institutions were involved in European R&D projects in this field. Further expertise is required:

- Large companies capable and used to lead EPC contracts of several hundred Million Euro from the power sector could bring a better market knowledge and cover the question of integration of the solar system with the power cycle more thoroughly,
- Companies specialized in glass, reflectors, light weight structures, drives, outdoor plastic etc. could provide expertise in concentrators,
- Chemical industry could support the development of improved HTF or storage media,
- Large construction companies capable of designing and building storage containers which are able to handle and transport hot fluids,
- Companies specialized in mass production and logistics (like car manufacturers) could optimize the production process and minimize manufacturing cost,
- Technical supervising companies to achieve a high quality control to reduce risks specifically in the scaling process.

Building a global market

CSP is currently emerging in many countries of the World; in Spain the situation is one of the most far developed. **A key to success is to build a sustainable market situation.** In many of



the countries, the progress is slow in part due to non-technical barriers. In order to generate a global market, it is important to take the lessons learned in the countries where CSP deployment is successful and transfer them to other countries. Such a market would have faster growth, would attract larger global companies, and would lead to costs increasingly competitive with conventional sources. The CSP global market initiative (GMI; www.solarpaces.org/gmi.htm) is an essential step that needs support of the European Union.

Setting the political framework

- CSP is inadequately considered in most European renewable electricity incentive schemes. Countries like Portugal, Greece, Malta and Italy having a significant solar resource may consider opening their incentive schemes to CSP technologies.
- Consider opening the European market for the import of solar electric from Northern Africa. Higher solar resource levels may over-compensate the additional transport cost and the deployment of the technology would help to support the political stability in this region.
- Hybrid operation of CSP systems is of high benefit for both the cost of the solar electricity as well as for the stability of the electrical grid. The legal frameworks should be more flexible to allow this option.
- Scaling up CSP to larger power block sizes is an essential step to reduce electricity costs. Incentive schemes should not limit the upper power level to fully exploit the cost reduction potential.

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- [1] Sargent & Lundy, "Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts" SL-5641, Chicago, IL, USA, May 2003.
- [2] International Energy Agency (IEA), Guidelines for the economic analysis of renewable energy technology applications, 1991.