

## CHAPTER II

### REVIEW OF RELATED LITERATURE AND RESEARCH

This chapter explains on one hand the technical possibilities as they are discussed in the public, but also specializes on the comments of leading multipliers and scientists on the future use of CSP technologies regarding its economical advantages.

Several solar technologies are suitable for common use and basically we distinguish electrical and thermal solar power systems. Electrical systems means photovoltaic processes, while thermal power systems allow a variety of technologies.

#### **Types of solar thermal power plants**

Concentrating solar technologies work on the principle of reflecting and concentrating direct solar radiation at its focus (a point or line), thereby using the concentrated solar radiation as a high temperature thermal energy source to produce electricity, process heat, fuels and chemicals. The mirror elements used to reflect and concentrate solar radiation vary in geometry and size (but are generally referred to as a reflector or concentrator or reflective concentrator). To facilitate concentration of direct normal irradiation (DNI), the mirrors need to be continuously tracked following the path of the sun in single or two-axes. Concentrating solar technologies are appropriate and economically favourable for countries situated in the Sunbelt region where direct solar radiation is high. Worldwide research, development and demonstration (RD&D) of four concentrated solar technologies are currently promoted namely:

1. Parabolic dish systems
2. Central receiver systems (CRS)
3. Parabolic trough collectors (PTC)
4. Fresnel Technology

## 1. Parabolic dish system

Parabolic dish systems or solar dish systems use paraboloid-shaped mirrors in the form of a dish that tracks the sun in two-axes, to concentrate direct radiation either onto a receiver or motor-generator mounted at its focal point (Figure 1). Concentration ratios from 3000 to 4000 suns for electricity generation have been achieved with dishes. The concentrated energy is used to heat up the HTF that is circulated in the receiver up to about 800 °C. In case of a motor-generator unit that is based on Stirling and Brayton cycle engines, power generation up to 50 kW<sub>e</sub> and peak efficiencies up to 30% net have been achieved. Dish systems are modular in nature and can be grouped together to produce more power cumulatively. Within the European project EURODISH, a cost effective 10 kW Dish-Stirling engine for decentralised electric power generation has been developed.

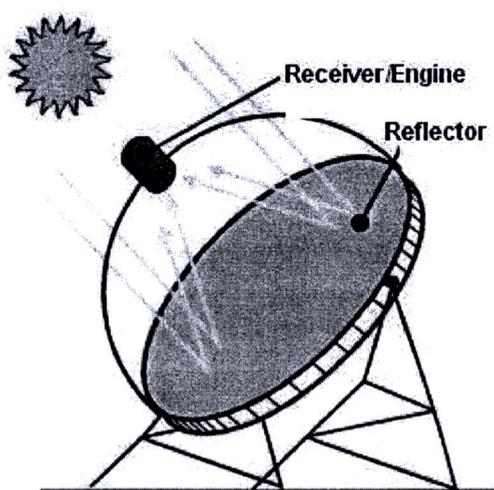
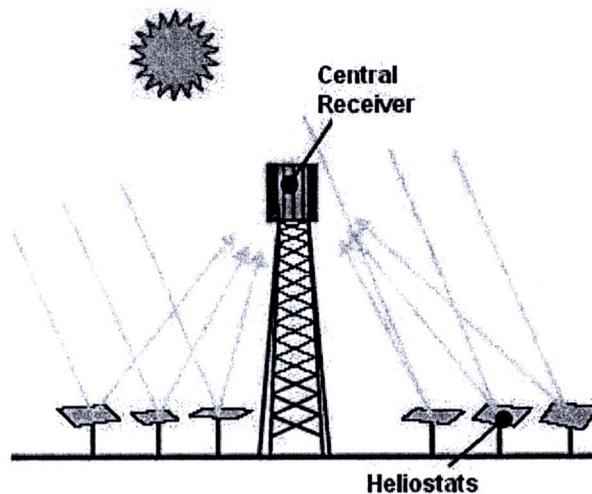


Figure 1 Schematic representation of parabolic dish technology

Source: SolarPACES, 2004

## 2. Solar tower / central receiver systems

Central receiver systems (CRS) are less mature than the PTC technology. CRS use highly reflective mirrors called heliostats to track the sun in two-axes, and reflect as well as concentrate the direct radiation to a central receiver that is placed in its focal point (Figure 2). The HTF is circulated in the central receiver, is heated and drives a turbine to produce electric power. Concentration ratios or concentration factor can be defined as the ratio of aperture area (i.e. area of the reflective surface) to the area of sun image in the focal plane (i.e. absorber area). Ideally concentration factors up to 10 000 is possible up to 3000 and heat transfer fluid (HTF) temperatures from 500 to 1000 °C are achieved in CRS. Some of the experimental plants based on CRS technology include the 10 MW<sub>e</sub> plant 'Solar Two' in the USA and 10 MW<sub>e</sub> plant 'PS10' in Sanlucar-Spain.

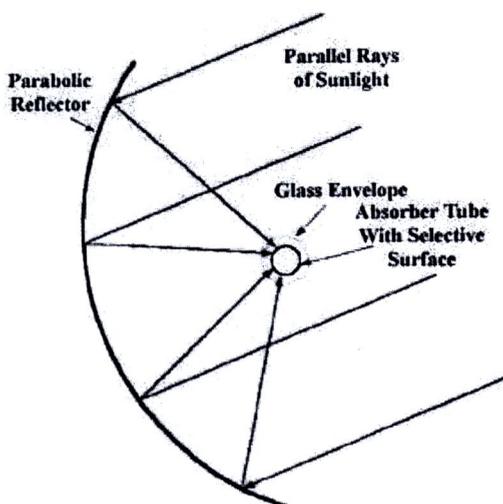


**Figure 2 Schematic representation of central receiver technology**

Source: SolarPACES, 2004

### 3. Parabolic trough collectors

PTC or simply trough technology is the most mature among the CSP technologies. The large sized PTC utilised in power plants are often referred to as solar collector assembly (SCA). SCA is a collective term for all the necessary components required to trap and convert the direct radiation into useful energy namely parabolic mirrors, the metal support structure, receivers (metal absorber pipe surrounded by glass tubes), and the tracking system that includes the drive, sensors, and controls (Figure 3). The direct radiation falling perpendicular to the parabolically curved, trough shaped mirrors is reflected and concentrated on an absorber pipe located in the length of the focal line (Figure 3). Heat from the absorber pipe is removed by circulating HTF through the pipe and is utilised to produce electricity or process heat. PTC is normally tracked in single and oriented in north-south direction for good energy yield or in east-west direction for research purposes.

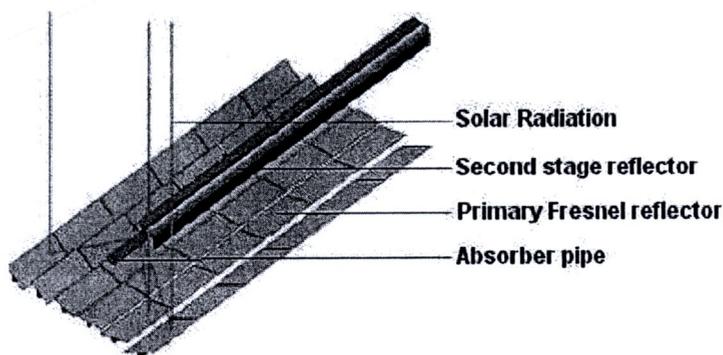


**Figure 3 Schematic representation of trough technology**

**Source:** Indian Standard Time (IST), 2005

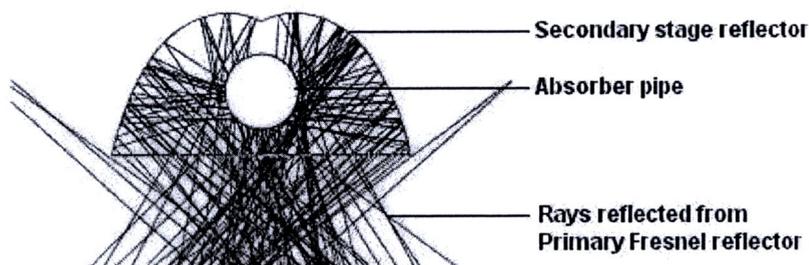
#### 4. Fresnel systems

Industrial scale application of linear concentrating Fresnel technology is relatively new. This technology, based on the principle of Fresnel, uses single or two-axes tracking segmented mirrors to concentrate direct radiation on a stationary receiver located several meters above it (Figure 4). This receiver contains a second stage reflector which further concentrates all the incoming energy on the absorber pipe located along the length of the focal point (Figure 4). A prototype plant with Fresnel collectors of area 2500 m<sup>2</sup> has been erected and operated by a Belgian company Solarmundo in Liege, Belgium.



**Figure 4 Schematic representation of linear concentrating Fresnel technology**

**Source:** Indian Standard Time (IST), 2005



**Figure 5 Second stage reflector and absorber**

## World CSP outlook

ESTIA and Greenpeace explain in their study from 2005 [13], that CSP technology is going to be used worldwide. Until 2020 21,540 MW are going to be installed and produce 54,6 TWh of electricity. Until 2040 630 GW are installed, producing 1,573 TWh electricity. This amount equals 5 % of the world electricity demand at that time.

### 1. Greenpeace outlook

<b>KEY RESULTS FROM GREENPEACE-ESTIA SCENARIO 2002-2020</b>	
Capacity of Solar Thermal Power in 2020	21,540 MW
Electricity Production in 2020	54,6 TWh
Cumulative Investment in Plant Construction	41,8 billion
Employment Generated	200,000 jobs
Carbon Emissions Avoided 2002 – 2020	154 million tonnes CO <sub>2</sub>
Carbon Emissions Avoided in 2020	32,7 million tonnes CO <sub>2</sub>
<b>Projection 2021 to 2040</b>	
Capacity of Solar Thermal Power in 2040	630,000 MW
Electricity Production in 2040	1,573 TWh
Percentage of Global Demand	5%

**Figure 6 ESTIA-Greenpeace preview for CSP global development**

Two years after this study Greenpeace-ESTIA updated their study along with SolarPACES [15]. The results from the study are given below.

<b>Key results from Greenpeace-ESTIA Scenario 2002-2025</b>	
Capacity of solar thermal power in 2025	36,850 MW
Electricity production in 2025	95.8 TWh/year
Employment generated	54,000 jobs
Investment Value	16.4 billion \$ per year
Carbon emissions avoided	362 million tonnes CO <sub>2</sub>
Annual carbon emissions avoided in 2025	57.5 million tonnes CO <sub>2</sub>
<b>Projection 2025 to 2040</b>	
Capacity of solar thermal power in 2040	600,000 MW
Electricity production	16,000 TWh
Percentage of global demand	5%

**Figure 7 Key results from Greenpeace-ESTIA scenario 2002 to 2020**

**Source:** Aringhoff, Rainer; Brakmann, Georg; Geyer, Michael and Teske, Sven, 2005

The projection shows that, by 2030, the worldwide capacity will have reached 100,000 MW and, by 2040, a level of almost 600,000 MW. The increased availability of plant resulting from the greater use of efficient storage technology will also increase the amount of electricity generated from a given installed capacity. The result is that by 2040 more than 5% of the world's electricity demand could be satisfied by solar thermal power.

## **2. DLR Analysis on SEGS plants**

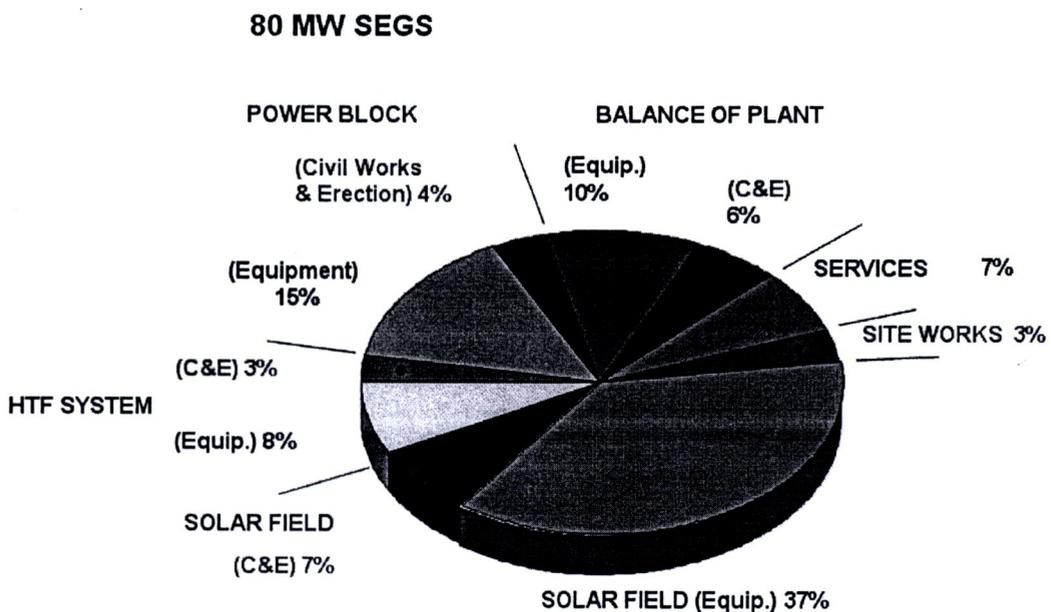
A more general approach comes from the analysis of the SEGS stations by DLR. A close look at the erection shows that the civil works and erection part is taking quite an important share of the total investment cost. The following table gives us an idea and leads directly to the definition of factors:

**Table 1 key results from DLR analysis**

<b>System</b>	<b>Civil works &amp; erection</b>	<b>Equipment</b>
Power block	4 %	15 %
Balance of plant	6 %	10 %
Services	3 %	7 %
HTF System	3 %	8 %
Solar field	7 %	37 %

Civil engineering and erection take nearly 25 % share in their specific investment cost, when we look at power block or solar field. Looking at bop or other services this share goes up to more than 50 %.

The material share shows properly the majority of the solar field in the total investment. This differs in some projects, where other turbine systems are in use.

**Figure 8 Key results from DLR analysis in graphic detail**

Emerging Energy Research (EER) announced in their market study for CSP in November 2007 [21], that until 2012 already 5,800 MW are going to be online. For the Asean market they foresee an installed capacity of 2,350 MW until 2020. Today nearly 500 MW are in operation worldwide.

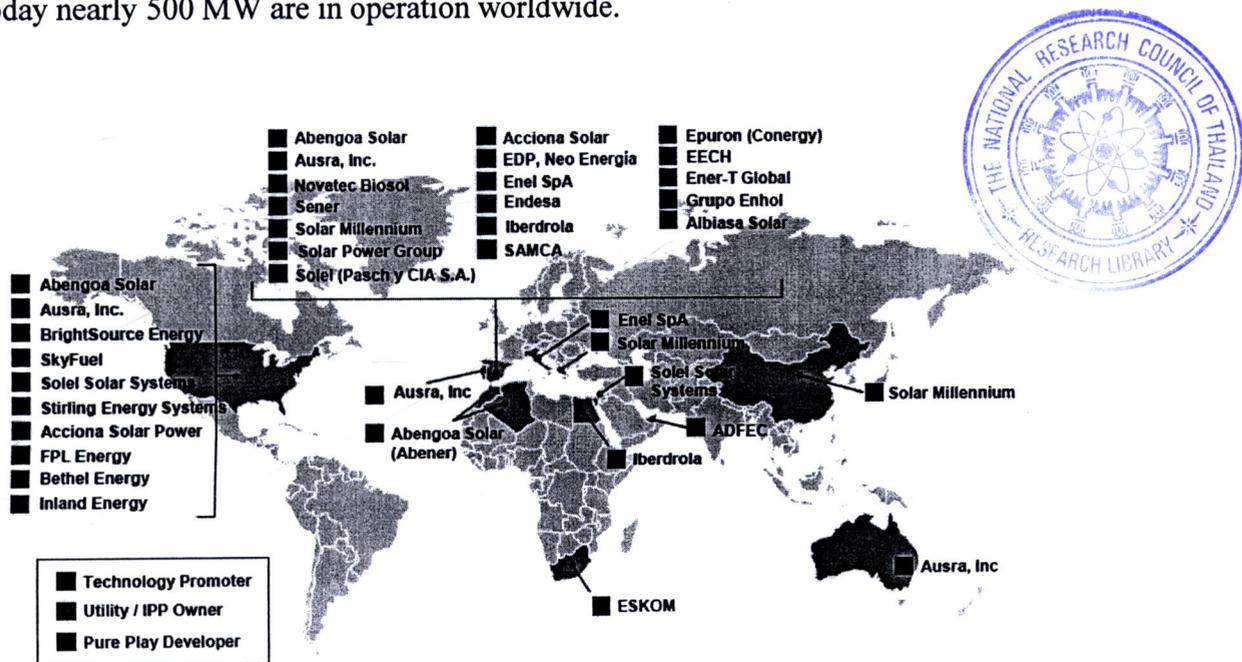
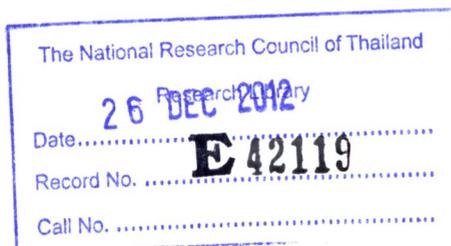


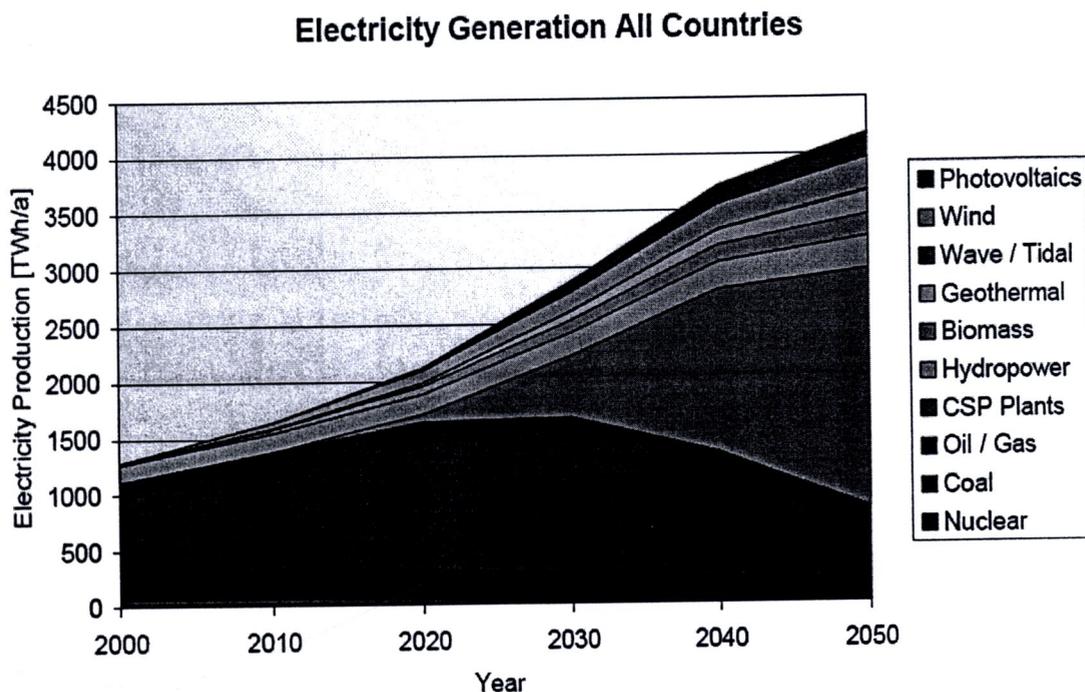
Figure 9 CSP Industry’s global focus; Market study 2007; EER.

**Europe CSP outlook**

The MED-CSP study by the German Aerospace Center, institute of technical thermodynamics commissioned by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety of Germany [22] shows the potential just for the Mediterranean region – this potential can of course be transferred to other parts of the world as well. Dr. Trieb explains that until 2050 CSP technology is generating more electricity than the crude oil and gas power plants of today are generating.

He also points out that the renewable energy produced by CSP technology is able to reach production costs per kWh of today’s large scale power plants with fossil resources. This main criterion is often published in the opposite way. Though trough technology is not the youngest – it is still younger than other renewable energies and net yet fully explored. There is still a large potential to make advantage of economies of scale in later production.



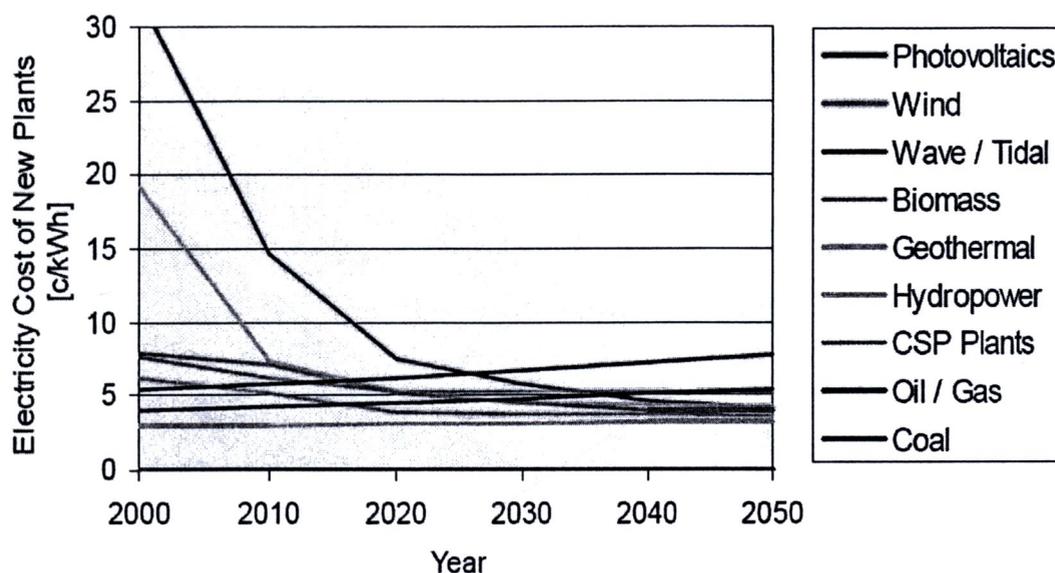


**Figure 10 Electricity generation in the Mediterranean until 2050 and CSP potential**

**Source:** Trieb, Franz and MED-CSP study, Final report, 2005

Larger production quantities and more suppliers will reduce the prices for CSP power plants. Bottle neck for mirrors and receivers still allow high price policy of certain producers. This leads to the fact that the overall kWh price is today between 12 and 20 ct/€. This price is dropping below 10 ct/€ already in the actual projects in Spain and will reach 5 ct/€ for new projects in northern Africa. Photovoltaics are also dropping to this price level, but more on the long-term.

By 2050 oil, gas and coal are going to be more expensive per kWh than the renewables. Renewables will produce more than 80 % of our electricity demand. To reach this situation and to declare this aim, a tremendous task is set up and needs all our strength to bring this into reality.



**Figure 11 Electricity cost in the Mediterranean until 2050 for CSP and other RE**

**Source:** Trieb, Franz and MED-CSP study, Final report, 2005

### **Small CSP in Europe**

Small scale CSP in Europe is mainly understood as practical for process heat or in hybrid systems as solar-cogeneration devices. Several units are already installed; the capacities reach from 50 kW<sub>therm</sub> to 1 MWe. Some installations are purely working on solar cooling; others are trial for decentralized power generation. The potential as shown in table below is enormous – more than 250 PJ are demanded by small scale solar thermal heat processes at medium temperature level.

In Germany, there are some small scales of CSP as well, used in agricultural application as a co-generating hybrid system combined with a biomass steam boiler.

Country	Industrial final energy consumption	Industrial heat demand (Final energy to heat demand conversion factor: 0.75)	Solar process heat potential at low & medium temperature	Solar process heat/ Industrial heat demand	Potential in terms of capacity	Potential in terms of collector area	Source of the data used for calculation (*)
	[PJ/year]	[PJ/year]	[PJ/year]		[GW <sub>th</sub> ]	[Mio m <sup>2</sup> ]	
Austria	264*	137	5.4	3.9%	3	4.3	Eurostat energy balances, year 1999; PROMISE project
Spain	-	493*	17.0	3.4%	5.5 - 7	8 - 10	POSHIP project
Portugal	-	90*	4.0	4.4%	1.3 - 1.7	1.9 - 2.5	POSHIP project
Italy	1,653*	857	31.8	3.7%	10	14.3	Eurostat energy balances, year 2000
Netherlands	89*	46	1.95	3.2%	0.5 - 0.7	0.8 - 1	Onderzoek naar het potentieel van zonthermische energie in de industrie. (FEC for 12 branches only)
<i>EU 25</i>	<i>12,994*</i>	<i>6,881</i>	<i>258.2</i>	<i>3.8%</i>	<i>100 - 125</i>	<i>143 - 180</i>	Eurostat energy balances, year 2002

**Figure 12 IEA preview for small scale CSP process heat station development in Europe**

**Source:** Vannoni, Claudia; Battisti, Riccardo and Drigo, Serena, 2008

### **Southeast Asia CSP outlook**

The interest in CSP technology in Thailand and the neighbouring countries is growing. Especially decentralized power plants in the rural areas seem to be of great interest. Official figures regarding the potential sizing of CSP installations in the coming years are not available yet. Assumptions may reach a capacity of 400 to 600 MW for very small power plants (VSPP) being installed until 2020.

#### **Small CSP in Southeast Asia**

In Thailand we find the first applications of small scale CSP. Naresuan University and ECC Chonburi present demonstration units to introduce this technology to interested multipliers and researchers. Both units are designed as co-generating hybrid systems with a biomass steam boiler. Results of these stations are not presented yet. Malaysia and China also inquire for this technology. China has signed a 1000 MW CSP contract for Inner Mongolia province. Yunnan province approaches German institutions for mutual project development.

### **General statements on CSP worldwide**

The Sarasin Bank, an important consultant and financing institution for renewable energies announces in their press release on November 17<sup>th</sup>, 2008 by Harald Melzer:

...CSP technology is established as a cost-effective solution for centralized energy production. Until 2012 5.5 GWe are going to be installed – this equals a growth rate of 44 % per year

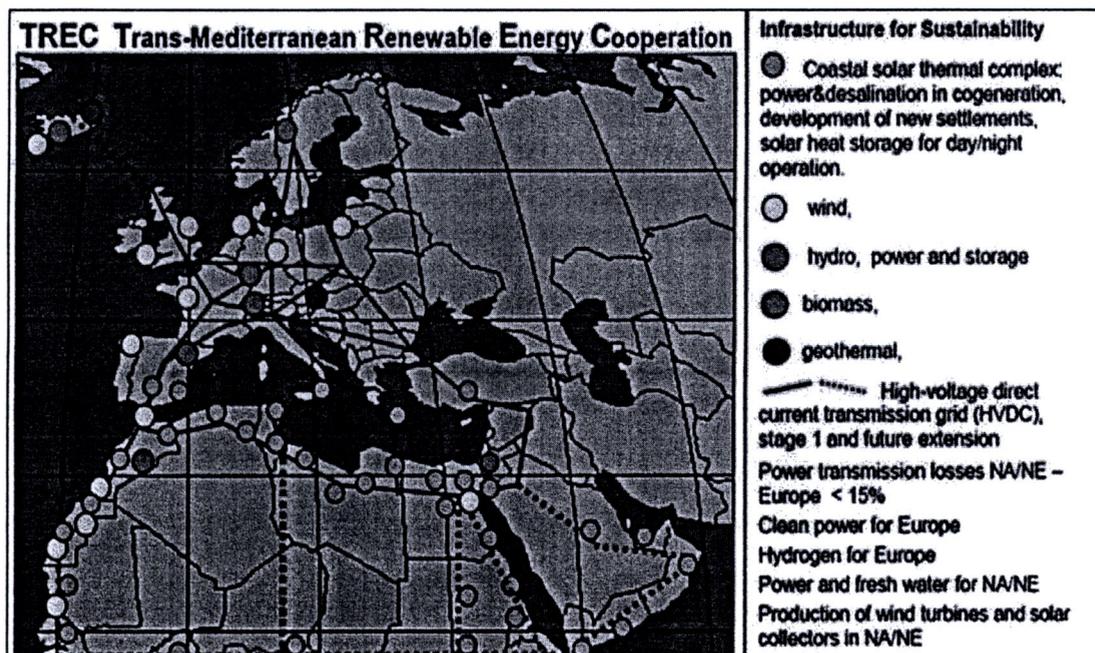
(Press release, Sarasin Bank, Zürich, 2008)

...Mindful also of its responsibility toward future generations, the state shall protect the natural bases of life

(German Basic Law, Article 20 A, 2008)

The sun-belt and the technology belt can become very powerful when they begin to understand themselves as a community: a community of energy, water and climate security; a community for their common future (H.R.H. Prince El Hassan Bin Talal, President of the Club of Rome, 2006, Address for World Energy Dialogue, Hannover Messe, Germany)

This statement shows the great importance of the CSP technology in the sun belt regions. It seems to be viable to have this technology as basis for electricity export to Europe or other northern hemisphere areas like USA, Canada. The new renewable energy agency IRENA promotes the ideas of TREC as an example how renewable energy with CSP technology can increase the living standard of many in northern Africa and the Arabian world.



**Figure 13 Electricity supply network for Europe, Northern Africa, Near East and Arabia**

**Source:** Trans-Mediterranean Renewable Energy Cooperation (TREC), 2005

The above mentioned ideas and concepts are subject of the MED-CSP and TRANS-CSP studies supported by the European Commission and German Ministry of Environment.

A report in Business Week (2006-02-14) quotes the CEO of Solel as saying “Our [CSP] technology is already competitive with electricity produced at natural-gas power plants in California”. Similar claims are being made by others in the industry. Speaking about CSP at the Solar Power 2006 conference in California, the US venture capitalist Vinod Khosla said “we are poised for breakaway growth - for explosive growth - not because we are cleaner [than coal-fired electricity] but because we are cheaper. We happen to be cleaner incidentally.” This opinion is common in the group of solar thermal power plant producers. Nevertheless more improvement and reduction of production costs is possible – alternatives have to be developed and checked.

Pablo Fernandez Ruiz, Directorate General for Energy Research at the European Commission states “Pilot and demonstration projects are needed in order to prove the quality of the newly developed technological options. And there is still a need for further research and development if the electricity production costs are to be reduced to 0.05 Euro per kilowatt-hour in order to be able to compete with current from fossil or nuclear sources in the medium term. Apart from electricity, it will also be necessary to produce fuels from renewable sources of energy at reasonable prices in the long term.”

At the “Renewables 2004” international conference on renewable sources of energy in Bonn in June, Jürgen Trittin, the Federal Minister for the Environment (BMU) said: About 80 per cent of global energy consumption is based on fossil fuels. There is therefore a close link between climate protection and a transformation of energy systems. Only by means of a sustainable energy policy can we slow down climate change. Key elements here are firstly energy conservation and energy efficiency and secondly increasing the use of renewable sources of energy. Solar thermal power plants will play a major role in the future provision of energy. Jürgen Trittin was the Federal Minister for the Environment, Nature Conservation and Nuclear Safety (BMU) until 2005.

### **Advantages and disadvantages of solar thermal power plants**

Numerous points are relevant to figure out advantages and disadvantages of different power plant technologies. As stated above CSP offers a lot of economical advantages, but there are also critical parameters that have to be taken into consideration before selecting CSP technology. Beside the advantages of robust, proven technology with a high content of local production and low investment cost, we find disadvantages that may influence investment decisions as there are large surface demand, dependence on sun radiation and the necessity of creating storage device to operate 24 hours 7 days.

The following critical parameters need to be checked before a decision pro CSP can be made. Although other technologies may have the same critical or some similar critical points, that need to be solved.

### **Critical parameters for economical use**

In general we have to distinguish two groups of critical parameters – on one hand their the obvious critical parameters like climate, radiation and water situation. On the other hand we find critical parameters regarding economical erection, design, material and competition with other technologies. Beside the selection of the best suitable technology, critical climate parameters have to be taken into consideration at first. The impact of climate conditions, solar radiation and the access to resources for operation play an important role. The location on the planet must be useful to consider solar thermal power plants as the best possible economical solution to generate energy from the sun's radiation. Installations above the planets sun belt around the equator become critical from the investors point of view as the operating times and amount of radiation is reduced, but the investment also has to be increased by necessary larger solar fields.

#### **Direct solar radiation**

The technical feasibility and economical operation of these technologies at a specific location depends on the available solar radiation or solar resource. Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one "spot" on the Earth's surface varies according to these factors:

1. Geographic location
2. Time of day
3. Season
4. Local landscape
5. Local weather

Because the Earth is round, the Sun strikes the surface at different angles ranging from  $0^\circ$  (just above the horizon) to  $90^\circ$  (directly overhead). When the Sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the Sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid polar regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year. The Earth revolves around the Sun in an elliptical orbit and is closer to the Sun during part of the year. When the Sun is nearer the Earth, the Earth's surface

receives a little more solar energy. The Earth is nearer the Sun when it's summer in the southern hemisphere and winter in the northern hemisphere. However the presence of vast oceans moderates the hotter summers and colder winters one would expect to see in the southern hemisphere as a result of this difference. The  $23.5^\circ$  tilt in the Earth's axis of rotation is a more significant factor in determining the amount of sunlight striking the Earth at a particular location. Tilting results in longer days in the northern hemisphere from the spring (vernal) equinox to the fall (autumnal) equinox and longer days in the southern hemisphere during the other six months. Days and nights are both exactly 12 hours long on the equinoxes, which occur each year on or around March 23 and September 22. The rotation of the Earth is responsible for hourly variations in sunlight. In the early morning and late afternoon, the Sun is low in the sky. Its rays travel further through the atmosphere than at noon when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar collector around solar noon.

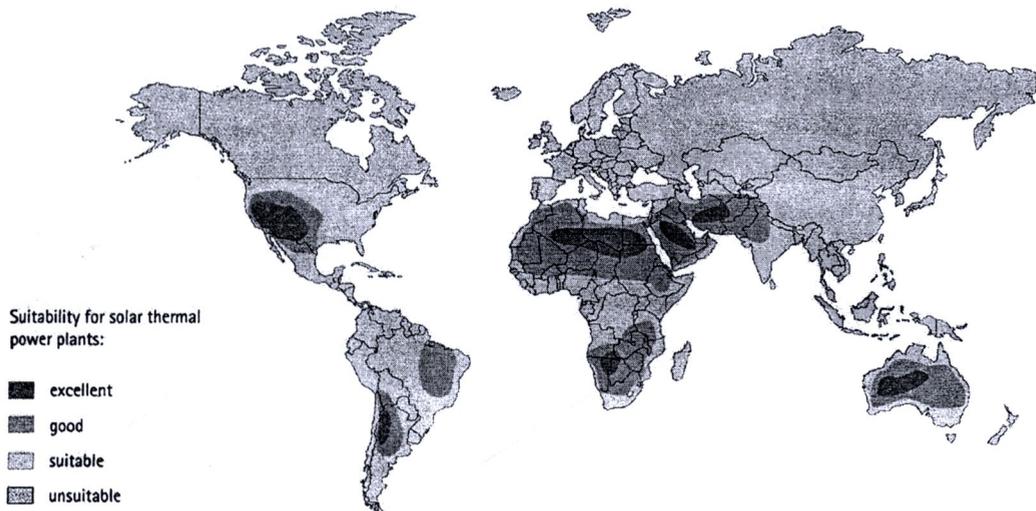
As sunlight passes through the atmosphere, some of it is absorbed, scattered, and reflected by the following:

1. Air molecules
2. Water vapor
3. Clouds
4. Dust
5. Pollutants
6. Forest fires
7. Volcanoes



This is called diffuse solar radiation or diffuse insolation. The solar radiation that reaches the Earth's surface without being diffused is called direct solar radiation or direct insolation. The sum of the diffuse and direct solar radiation is called global insolation. Atmospheric conditions can reduce direct beam radiation by 10% on clear, dry days and by 100% during thick, cloudy days.

To operate CSP station at their very best, the location should offer highest possible direct radiation. High temperature CSP plants need more than  $1500 \text{ kWh/m}^2$ , while small scale units on low temperature can already be operated at  $1200 \text{ kWh/m}^2$ .



**Figure 14 Location suitability and economical potential for solar thermal power Plants**

**Source:** Voltwerk, AG, 2007

### **Climate conditions**

The climate plays the most important role regarding the selection of technology, but also regarding the economical use of CSP of course. Climate and location have to fit to the technology – a solar power plant at the northpole is obviously not the best economical solution.

If the steady rain or clouding has to be considered, then solar systems should not be favorized. Tropical regions offer rainy seasons or monsoon seasons – this has an impact on the productivity of a solar system. The operating hours are lower in comparism with stations in dry arid areas like the Arabian peninsula. Nevertheless the amount of radiation over the year might be enough to operate a solar system economically even under tropical, rainy conditions.

The surrounding temperature is not of major impact, as long as the direct radiation is high enough. Some locations of CSP stations are at high altitude with clear skies and highest amounts of direct radiation, but the temperatures are lower. If direct steam generating systems are selected, than anti-freeze security devices may have to be integrated.

Some CSP stations are erected in areas with high wind speed. This has an impact on static and stability of your CSP station. Maybe the structural elements need to be reinforced – another major impact on the economies as you have to increase your investment.

### **Water resources**

To operate CSP stations or another steam or thermal energy using technology, it is essential to have cooling devices integrated to keep certain efficiencies. Even the use of dry cooling devices includes the use of minimal water quantities during operation. If no water supply can be arranged, then it may cause a situation that the power plant can not be operated. The total water consumption of a solar thermal power plant with wet cooling system can be split as follows:

- 8 % steam cycle
- 2 % cleaning purposes
- 90 % wet cooling device

If a dry cooling system can be used, than these amounts can be reduced by factor 10.

Nevada One, a 64 MW solar trough station in the US and in operation since 2007 has a water consumption of 800 gallons or 3 m<sup>3</sup> per MWh. On a 6 hours operation day this leads to a consumption of up to 1,451 m<sup>3</sup>/d and 529,615 m<sup>3</sup> per year. All power plants based on thermal processes need it, but it has to be taken into consideration, if you plan to install a solar power plant as well.



### **Advantages of small scale CSP (< 50 MW)**

So far this report presented the economical benefits and potential in LCOE reduction due to increasing power plant capacities. By now, the readers have been convinced that higher the capacities better the economics of the plant. But the sole purpose of this report is somewhat far from the above claims. Why anyone would like to build smaller and medium scale power plants (< 50 MWe net)? The reason simply lies in the range of applications – centralized and decentralized applications. The 50 MWe up to 400 MWe or further capacities are aimed to compete directly or replace the intermediate or base load conventional power plants. But in the same time, it is worthwhile to contemplate the decentralised applications that use expensive small scale conventional power plants. The higher capacity CSP plants are simply not applicable in these situations.

Few of the decentralised applications are:

1. Island power solutions – Land availability and maximum demand constraints limits the allowable net electricity capacity from mid kW to MW range.
2. Isolated communities in Desert and other sunny regions – centralised higher capacity STPPs are possible but higher Transmission and Distribution losses is inevitable.
3. Small communities supplied by unreliable and non continuous public grids – smaller and medium STPPs can act as backup power supply during sunny hours which incidentally happen to be the peak hours of public grid

Apart from the above mentioned applications one other unusual situation but critical is the technical constraint in the electricity feed-in points of the public grid. From the personal communication with several “Independent Power Producers” (IPP), it has been realised that there are hundreds of Feed-in points that limits the feed-in net capacities in between 1 and 14 MWe just in Spain alone. To analyse whether this is the same case for other countries, feed-in-tariff (FIT) laws from different countries are analysed [3].

Feed-in Tariff	Capacity	Tariff	Duration Years	Inflation Adjustment	Restrictions	Hybrid
Algeria	ISCCS	100-200%	life time			
France	max 12MW	0.30€/kWh	20+	no	max 12MW, max 1500h/a	no
Germany		0,46€/kWh	lifetime	no		no
	up to 5MW	0,23-0,25€/kWh	10+10	no		yes
Greece	over 5MW	0,25-0,27€/kWh	10+10	no		yes
	up to 20MW	0.20USD/kWh	20+10	yes		max 30%
Israel	over 20MW	0,16USD/kWh	20+10	yes		max 30%
	up to 10MW	0.21€/kWh	15	no		no
Portugal	over 10MW	0,16€/kWh	15	no		no
Spain	up to 50MW	0.27€/kWh	25+	yes	max 50MW	max 15%

**Figure 15 Feed-in Tariff details of different countries around the world**

**Source:** Aringhoff, Rainer; Brakmann, Georg; Geyer, Michael and Teske, Sven, 2005

Besides the above mentioned countries, Thailand and Italy also introduced Feed-in-Tariff (FIT) laws in 2006 limiting the net feed-in electricity to 10 and 30 MWe respectively. While carefully analysing the details in the above table, it is evident that

1. the energy policy makers prefer to begin with smaller and medium capacities simply to verify the functionality and reliability of the CSP technologies
2. the net electricity feed-in does not affect the stability of the public grid and saturation limit for a given location

France for instance only allows a maximum of 12 MWe [16] per installed capacity due to grid connection constraints for larger plants. The tariff only concerns the produced energy equivalent to the production of 1500 hours (Capacity factor  $\approx$  17%) annually at design power. Over this limit, the tariff drops down to 6 cts/kWh. This would mean that even with reasonable radiation ( $> 2100 \text{ kWh/m}^2/\text{year}$ ) in the southern France, higher capacity CSP plants can simply not be developed. Smaller and medium capacity STPP are the only feasible solution for France.

Considering Feed-in-Tariff in Thailand [17] and in Italy [18], the maximum limitation of 10 and 30 MWe encourages the concept of smaller and medium STPPs in the immediate future. Recently India announced its FIT in 2008. The law limits the total capacity 50 MWe with individual capacities not exceeding more than 5 MWe each.

All these recent development in FITs explains the necessity for the rapid deployment of smaller and medium STPPs at least as a Market Initiative.

Although the need for smaller and medium STPPs is justified, one most critical issue might be “At what energy costs can this be achieved?”

LCOE for the island communities where no public grids are available can easily vary from 2 to 15 times the conventional base load LCOE prices (~ \$ 4 cts/kWhe) depending on the type of fossil fuel used, capacity of the power generators and several other factors. It has already been described in the previous chapters that a LCOE of \$14 to 20 cts/kWhe is achievable for 16 to 30 MWe capacities based on SEGS experience. When scaling down further up to 0.5 MWe the LCOE costs can significantly increase if the existing collector concepts are adopted. This fact leads to the design, development and deployment of a new kind of collectors which should be scalable for any capacities and needs very little on-site assembling time. Another issue is that the new collector design should not be dependent on steel structure design for concentrators like the existing collectors.

In course of this report, the following points will be deeply analysed to formulate the most feasible methodology to realise small or medium STPPs with LCOE comparable to peaking conventional power plants (min \$ 7.5 cts/kWhe) [9].

1. Alternate structural design materials.
2. DSG concept that has potential to reduce 10 to 15% of LCOE by eliminating the usage of expensive thermal oil and oil to water heat exchangers [20]
3. Use of innovative prime movers that are highly efficient in the smaller capacities like steam screw concepts
4. Solar co-generation or multi-generation options to supply the community's electricity, heating, cooling and/or drinking water needs.

As result of the common understanding about sizing of solar thermal power plants, the following assumption is considered: small scale solar thermal power plants rely on the availability of small turbines and generator sets. The smallest, economical useful units have a size of 500 kWe. Smaller units than this, are still under development and in testing phase, they have not reached market ability yet. Above 30 MWe large scale units can be produced by globally acting industries – they supply mainly electricity producing companies directly. Industrial companies are not understood to be small scale enterprise (SME), therefore the maximum sizing for small scale solar thermal power plants are defined as being smaller than 30 MWe.