BUSINESS OPPORTUNITIES IN SOLAR THERMAL POWER PLANTS.

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Solar thermal power plants are technically proven: Nine solar thermal power plants with parabolic trough concentrating collectors and a total capacity of 354 MW have fed more than 6 000 GWh of solar based electricity into the Californian grid since 1985. That production accounts for more than 70% of solar based electricity produced per year.

Because of historically low prices for fossil fuels no further commercial solar thermal power plants have been built since 1990. This, in spite of the fact that solar thermal power plants compare very favorable on the basis of cost of CO_2 reduction measures by other strategies. However, CO_2 emission reduction is not yet considered a commercial transaction. Conventional financial analysis consider only the direct cost of electricity generation and ignore the cost and benefits of external effects. In such a conventional analysis electricity from solar thermal power plants, although being far less costly than electricity from photovoltaics, has typically a 50% higher cost than does electricity from large base load fossil power plants.

In the most cost effective strategy for global CO_2 emission reduction, solar thermal power plants will play an important role. This requires innovative means of project financing and project organizations which reward such external benefits and at the same time assure that the user of electricity pays a price which is not higher than the price of fossil generated electricity. This can be accomplished for example by international agreements and binding CO_2 emission limits which result in tradable CO_2 credits. Once such mechanisms are in place, Activities Implemented Jointly (AIJ) and the forces of the free market will assure the lowest cost options for worldwide CO_2 emission reduction. At that time a boom for solar thermal power plants can be expected.

However it is absolutely critical, that in the interim the European Union, national governments and international organizations support the European Industry not only with R&D projects but with utility scale power plants. Only thereby can European Industry keep a technological leadership.

SOLAR THERMAL POWER PLANT TECHNOLOGIES

A solar thermal power plant is basically a conventional power plant using solar radiation as its primary heat source to convert water to steam for the advanced high efficiency Rankine reheat steam cycle (Figure 1). Cogeneration of process heat and power is also possible. In order to achieve the same availability and dispatchability as a conventional fossil fuel-fired power station, the solar production can be extended beyond sunshine hours via complementary fossil back-up burning or by means of thermal energy storage.

From the different solar thermal technologies in various stages of development, only the parabolic trough technology is used today in commercial operated solar thermal power plants. It consists of long parallel rows of identical concentrated modules, typically using trough shaped glass mirrors (Figure 2). Tracking the sun from east to west by rotation of one axis, the trough collector concentrates the direct solar radiation onto a heat collection element (HCE) located along its focal line. A heat transfer medium, typically synthetic oil, at temperatures up to 400 °C is circulated through the pipes, the hot oil converts water into steam driving the steam turbine generator of the power cycle.

Figure 3 illustrates the heat collection element (HCE) used in the SEGS plants in California. It consists of a 70 mm diameter steel tube, 4 m in length, with a black chrome or cermet selective surface, surrounded by an evacuated glass tube. A glass to metal seal and a bellow at each end of the tube provide the vacuum tight enclosure while also allowing for differential thermal expansion between the glass and metal tube. The vacuum serves to protect the selective surface and to reduce heat losses; the selective surface helps to improve the absorption of solar radiation while minimizing radiation heat losses. Earlier HCE used black chrome selected surfaces. For the later SEGS plants which required temperatures up to 400 °C the company Luz developed the cermet (graded ceramic metal applied by a spattering process) selectors surface coating which could be operated at much higher temperatures. In addition, the cermet has reduced radiation losses due to a lower emittance and does not oxide or otherwise degrade if air enters the annulus. The surrounding glass tube has an anti-reflective coating on both surfaces. Inside the glass tube are getters, metallic substances which are designed to absorb hydrogen and other gases which migrate into the vacuum over time. The black chrome performs better at lower temperatures whereas the cermet performs better at higher temperatures.

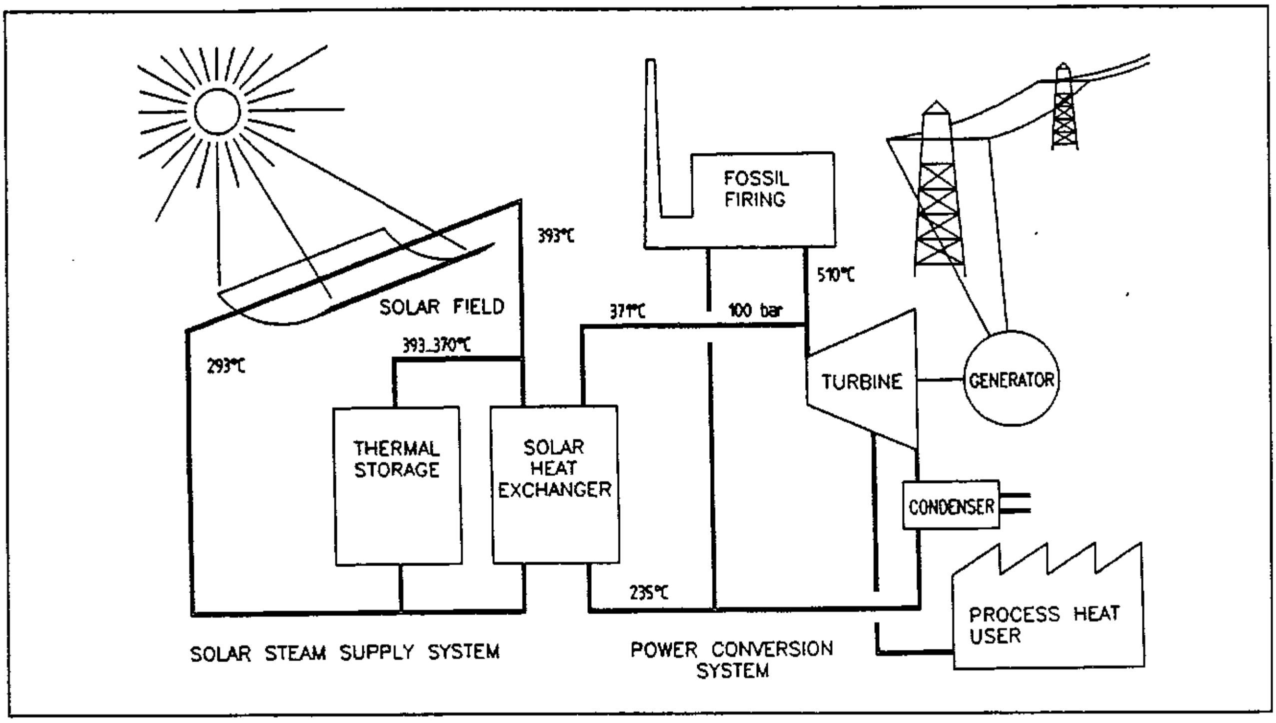

Figure 1 Concept of a solar thermal power plant

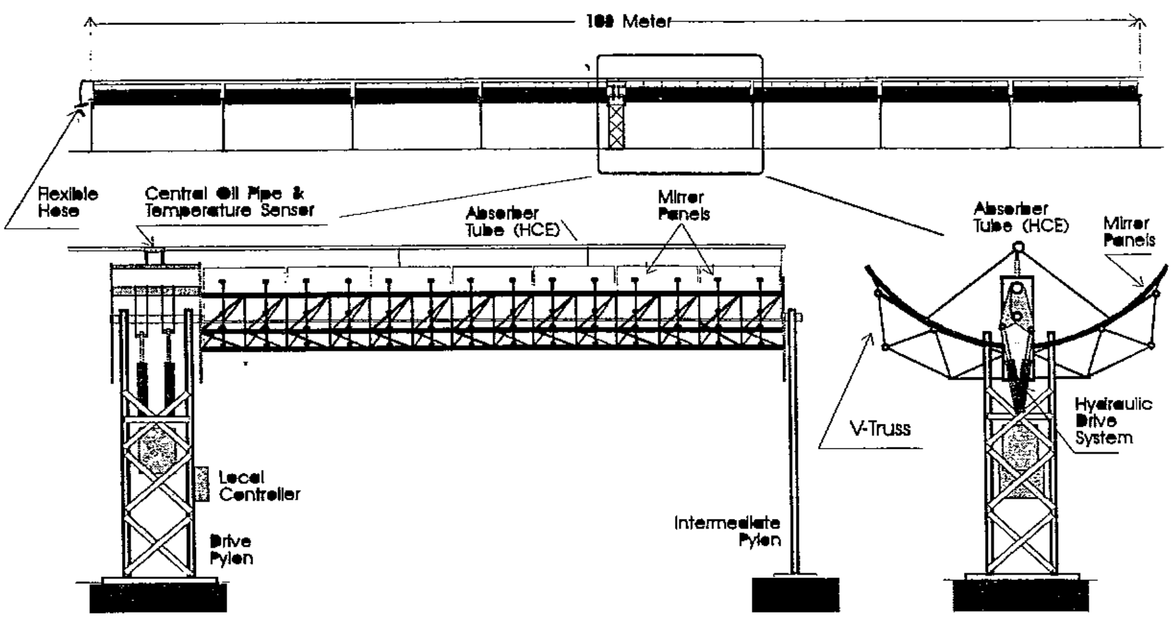

Figure 2 LS-3 Solar Collector Assembly

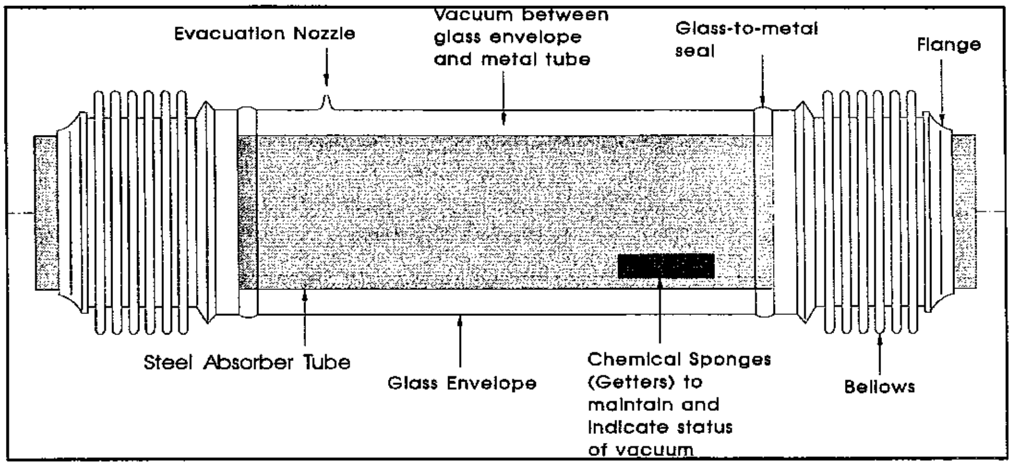

Figure 3 Heat Collection Element

POTENTIAL SOLAR THERMAL POWER PLANT PROJECTS

In a number of countries in the sun-belt of the earth solar thermal power plants are in different stages of project development. In the following some of these countries are listed in alphabetical order.

EGYPT

Egypt has extensive interests in applications of solar energy: In 1996 Fichtner has been awarded a contract by the Egyptian New and Renewable Energy Agency (NREA) for the detailed study, the analysis and the specification for solar process heat generation. The study includes the investigation of 24 Egyptian industrial companies to reduce energy consumption. The remaining process heat requirement is then to be supplied by a solar thermal energy application. The study is being financed by the African Development Fund (ADF).

Egypt has now formulated a request to the World Bank / GEF for assistance in financing first a detailed feasibility study and thereafter the implementation of a 100 MWe solar thermal power plant.

GREECE

The proposed Theseus Project to be located in the Frangokastelló area in the southern coast of western Crete in the county of Sfakia consists of a nominal 50 MWe net solar power plant with an advanced design parabolic trough collector field as a primary heat source. The power block is a high efficiency Rankine reheat steam cycle with its associated balance of plant equipment. The solar field energy source is supplemented with an oil-fired boiler to supply steam during conditions of low insolation.

The investment cost of Theseus is some 135 million ECU. Even without any subsidies this would result in electricity generation cost of some 0.085 ECU/kWh, which is lower than the current average cost from the existing power plants of Crete. Financial assistance for project implementation will be requested in order to assure, that for Greece and for the Island of Crete the electricity generation cost from this clean energy source will not be higher than from any potential other new plant. The financial assistance per ton of CO_2 emissions avoided will be lower than would be required to reach the various reduction goals by other means.

At the end of 1996 the DG XVII (Energy) of the European Commission has accepted the Thermie application of the Theseus consortium for the design phase. The Theseus consortium consists of leading European utilities, industry, engineering and research organizations with pronounced background and experience in solar thermal power plant technology. PreussenElektra, the second largest German utility proposed the Theseus Project to the German Government to be selected as one of Germany's contribution to the Pilot Phase for Activities Implemented Jointly (AIJ).

INDIA

Fichtner has followed the potential solar power project in India from as early as 1988 and in 1990/91 has performed on behalf of the KfW a detailed feasibility study for Solin-1, a 30 to 80 MWe solar Rankine steam cycle plant, to be located 5 km from the city of Mathania which is some 25 km from Jodhpur in Rajasthan, India. A feasibility supplement to include an integrated solar combined cycle system (ISCCS, Solingas) was completed in conjunction with Engineers India Ltd. in January 1996. This feasibility supplement concentrated on a 128 MWe combined cycle plant to be operated as a base load plant for some 7 000 h/a. The integrated solar field of parabolic trough design and total aperture area of 219 000 m^2 will supply steam for the generation of about 35 MWe for 2 000 equivalent full load hours. The annual net electricity to be supplied to the grid amounts to some 850 GWh/a and the fossil fuel consumption will be in the order of 150 000 t/a of light distillate. A similar solar power plant without solar enhancement would require an additional 12 000 t/a of light distillate in order to supply the same amount of electricity to the grid. On this basis of allocations of energy input and annual electricity generation the solar contribution is 7.4 %. A simplified schematic diagram of the plant is shown in Figure 4. Subsequent to the study it has been decided to increase the size of the plant to some 140 MWe and the solar field to some 40 MWe. A request for proposal for the project is expected soon.

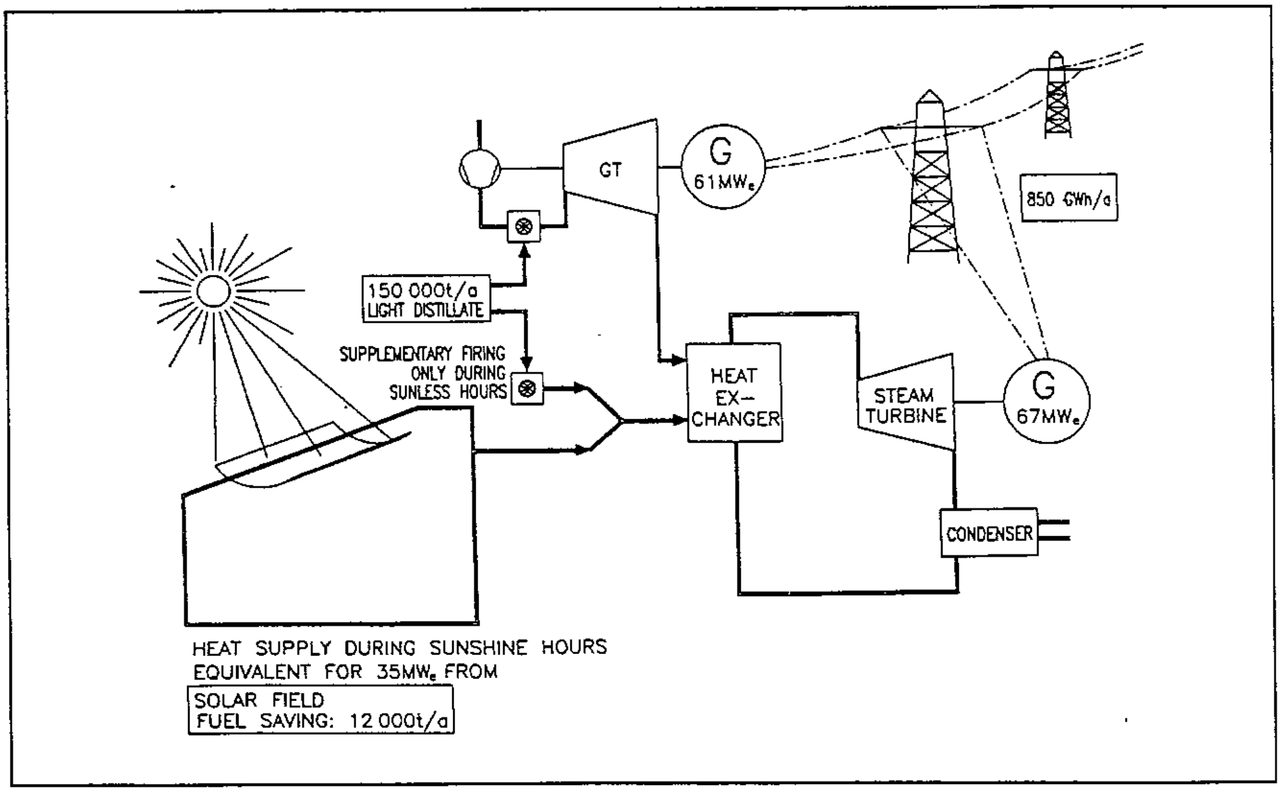

Figure 4 Simplified Schematic diagram of the Solingas project, India

IRAN

In 1993 / 94 on behalf of the German Federal Ministry of Environment and the Iranian Ministry of Power a joint German-Iranian Expert Group developed a project definition for a 100 MWe Rankine cycle solar power plant with a parabolic through collector field of some 600 000 m^2. The location will be in the area of Yazd in central Iran with a direct normal solar radiation of 2 400 kWh/ m^2/a. Backup fuel will be gas for up to 30 % of the production. Preliminary estimated electricity production will be 220 GWhe/a (solar) plus additional up to 95 GWhe/a from the fossil backup. In early 1997 the Electric Power Research Center (MATN) of Iran made a contract agreement with Fichtner of Stuttgart and Pilkington Solar International of Cologne for consultancy services for a feasibility study of the first solar power plant in Iran. This feasibility study is financed by the Government of Iran and will be a sound basis for a request to the GEF for financing assistance for the implementation of the plant.

ISRAEL

The company Solel (Israel) has developed project plans for an 85 MWe integrated solar combined cycle system (ISCCS) to be located in the Negev Desert. The solar field of 196 000 m^2, is designed for solar contribution during sunshine hours of about 35 MWe. As a next step the Israel Electric Company (IEC) will call for bids for the design and operation under the BOO/IPP concept of a solar thermal hybrid plant of 80-100 MWe net capacity.

JORDAN

An international consortium under the leadership of Fichtner performed a detailed feasibility study for Phoebus, a commercial demonstration 30 MW_e solar power plant of the central receiver technology (solar tower). The purpose of the study was to determine the final technical concept, the basic parameters, the site, the organizational concept for building as well as for operating the solar tower plant. Upon completion of the feasibility study two technical concepts were developed further: US companies selected the molten salt concept and are rehabilitating the 10 MWe Solar One test facility in Barstow, California. A German consortium also under the leadership of Fichtner performed successful tests of a 3 MWth volumetric air receiver at the Plataforma Solar de Almeria. A large number of potential host countries had initially been considered, thereafter the project evaluation was done for a site location in Wadi Rum in Jordan. In early 1997 the Jordanian Government reiterated its interest in a solar power plant, the selection of the technology will be left to the discretion of the project developer. Other countries like Brazil and Iran have indicated interest in the solar tower technology.

MEXICO

With financial support from the Rockefeller Foundation, the US Electric Power Research Institute and several member utilities, the national laboratories, Sandia and NREL and from Bechtel Enterprises, the California based project developer Spencer Management Associates performed a feasibility study for a number of integrated solar combined cycle system (ISCCS) to be located in northern Mexico and Baja California. The study focused on a 312 MWe plant to be located in Mexicali with a solar share of about 8 %. The World Bank and GEF will consider financial assistance upon request by the Mexican Government. A GEF grant could buy down the higher electricity generation cost of this project to the cost of a competitive non-solar combined cycle power plant.

MOROCCO

A detailed feasibility study had been performed by Flagsol (now Pilkington Solar International) in cooperation with Endesa, Spain largest utility company and CER, Morocco's renewable energy center in 1993/94 under contract of DG I (External Relations) of the European Union. This study centered around 80 MWe Rankine cycle parabolic trough solar power plants at various site locations. The solar field size is about 470 000 m^2 for a net electricity production of 338 GWhe/a, thereof 51% solar and 49% from fossil additions. In 1996 a supplemental study was performed in order to consider an ISCCS (integrated solar combined cycle system) in proximity to the Euro-Maghreb gas pipeline which is under construction in northern Morocco. Final results will be the basis for a request for financing assistance to the GEF and the European Union.

NEVADA, USA

The California based project developer Spencer Management Associates performed a feasibility study for a 135 MWe integrated solar combined cycle system (ISCCS) to be located in the solar development area (the former federal nuclear test site) of southern Nevada. The solar share is around 8%. This project is selected for further review by the Corporation for Solar Technology and Renewable Resources (CSTRR). The project will be financially feasible by receiving premium electricity rates for green power generated in premium demand periods from WAPA, the Western Area Power Administration.

SUPPORT FROM THE EU AND FROM NATIONAL GOVERNMENTS

Electricity from solar thermal power plants, although being far less costly than from photovoltaics, has typically an up to 50% higher cost for its solar share than does electricity from large base load fossil power plants. Therefore such plants will only be realized if there will be some financial support from a sponsor, the EU, a national government or international organization. However such financial support only makes sense if it is motivated in countervalue for the EU and the national member countries. In case of requested financial support for large scale solar thermal power plant projects such **countervalue for the EU and for the national governments will be low cost CO_2 emission reduction, additional tax revenues, employment creation, technological leadership and creation of future large export opportunities for the European industry.**

CO_2 EMISSION REDUCTION

Emissions per unit of electricity generated depends on the type of fuel and on the conversion efficiency. For example as shown in Figure 5 the current Cretan average emissions are 1.06 t/MWh; because of better efficiency plants projected, it will drop to 0.89 t/MWh for future plants. Solar thermal power plants will have zero emissions when operating in the solar-only mode and will have emissions like conventional power plants when operating in the fossil mode. The projected Theseus plant with 55% solar contribution will emit CO_2 at an average of 0.4 t/MWh, thus some 0.5 t/MWh less the average of the future Cretan power plant park. Hence the total reduction in CO_2 emissions will be some 2.2 million tons during the 25 years projected technical life time of the Theseus project.

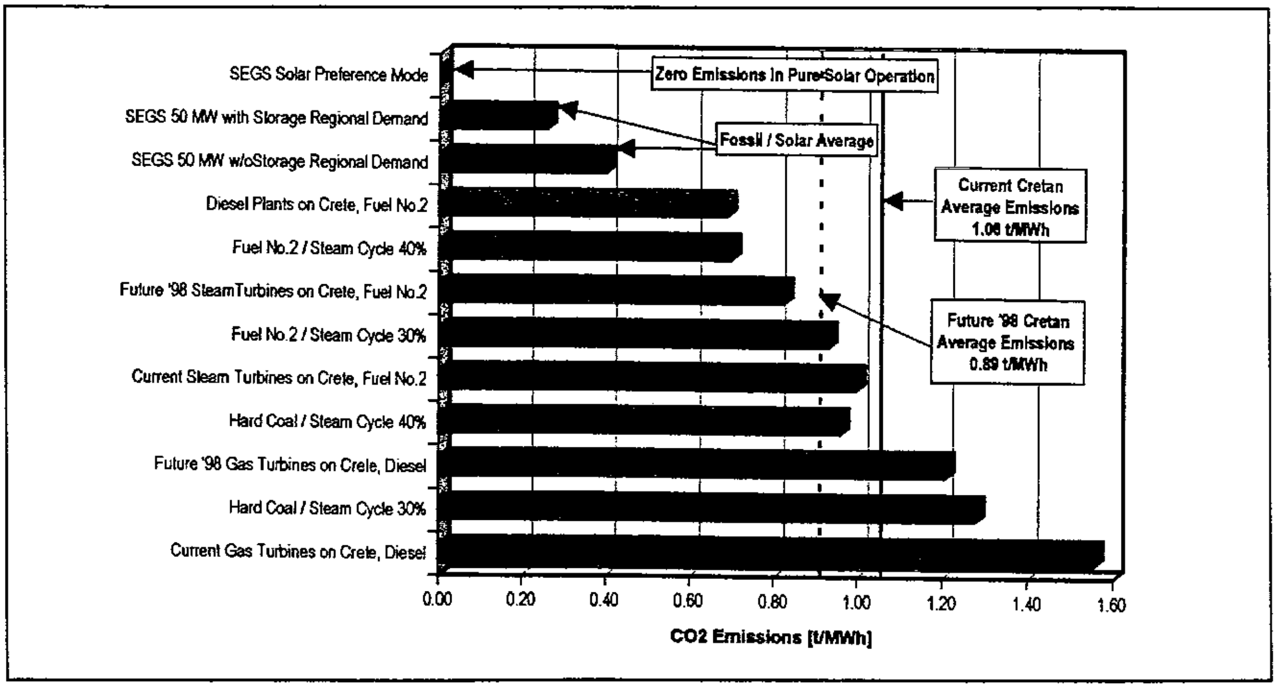

Figure 5 CO_2 emissions from various powerplants

The German Government has formulated the goal of reducing CO_2 emissions in Germany by 25% until the year 2005. The authors of a recent study, commissioned by the German Ministry of Economics, came to the conclusion that even to reach only part of this goal will result in 160 000 less jobs for a CO_2 emission reduction of 86 million tons/a. (RWI/IFO: Gesamtwirtschaftliche Beurteilung von CO_2 - Minderungsstrategien, Feb. 1997). Hence in order to obtain the 2.2 million t/a CO_2 emission reduction of Theseus by other means within Germany would cost the German economy some 4 000 man-years of employment. Assuming a low value of only 35 000 ECU for the average wealth creation per man-year of employment, one can calculate a value of 140 million ECU. For other countries similar cost can be assumed, once the low cost options have been used up. Such low cost options still exist today for example in India or in China for some lignite fired power plants with efficiencies in the order of 20 %. However these low cost options should be considered against the background that India and China have an extremely low per capita primary energy consumption, which is increasing at a rate of more than 7 % p.a., i.e. doubling in less than 10 years. It becomes evident that the low cost options will be used up very fast just for limiting the increase in CO_2 emissions which is due to the growth of these economies.

The required financial support in order to bring the electricity generation cost of solar thermal power plants below the cost from the conventional power plants is far less than what it will cost to obtain the required CO_2 emission reductions by other means. Financial support to solar thermal power plant projects is a low cost option to reduce CO_2 emissions.

EFFECTS ON THE LABOUR MARKET

Construction of a typical 50 MW plant requires a peak labour force of about 600 people. Another 40 permanent skilled jobs will be created to maintain and operate the plant. Subsequent solar projects of comparable size will secure 300 - 400 highly qualified positions, both in the European manufacturing countries and the project host countries. In total it can be said that 2 000 qualified jobs (man-years) will be created by a single 50 MWe solar thermal power plant project.

EFFECT ON BALANCE OF PAYMENT

The Theseus project will reduce the Greek energy import bill by about 4 million ECU/a as the solar field replaces approximately 28 000 tons of heavy fuel oil. Even more important, however, the solar power station will replace some 2 700 day time peak to mid load hours of costly gas turbine operation, whose fuel-related power generations costs are today as high as 0.0135 ECU/kWh. The pronounced day time peak stems basically from increasingly strong growing tourism.

EFFECT OF TAXATION

Today's taxation laws in the European Union and for that matter also in many other countries are focused more on production and less on consumption. For example income from employment and income from interest on capital is taxed and subject to social contribution at much higher rates than is the import of fossil fuel for electricity generation. In comparison the electricity generation cost from a fossil power plant is about two thirds due to the fuel, whereas the cost of solar generated electricity is mainly due to capital cost (which stems largely from manpower cost) and from interest on capital. This results in a much higher tax per unit of electricity production to be paid by a solar thermal power project than will be paid by fossil power plants.

Removal of this higher tax burden of solar thermal power plants against fossil-fired power plants would further remove burdens which the introduction of solar energy is experiencing.

EXPORT OPPORTUNITIES FOR EUROPEAN INDUSTRIES

As European companies had already supplied some 40 % of the 1 000 million ECU worth of supplies and services to the existing solar power plants in California, they will also be potential suppliers of these future projects, provided the necessary political and financial support from the European Union and the national governments will be granted. Failing this support the technology will be lost either completely or to non-European organizations.

INSTITUTIONAL SET-UP AND JOINT IMPLEMENTATION ASPECTS

There are two options for the ownership structure which will influence the implementation and operation of a power plant significantly. In the traditional approach, a utility company as owner and distributor of the electricity will take the entire economic risk of the project and give contracts to the various components and service suppliers. The IPP/BOO model has lately gained more importance when implementing large infrastructure projects. It involves a private consortium which will build, own and operate the solar plant as an independent power producer (IPP) and sell electricity to the public grid or directly to the users of the electricity.

The organizational structure to build and operate a solar thermal power plant is basically the same as for a conventional thermal power plant. However the source of the additional financing must be considered. Once the proper mechanism for joint implementation are in place with binding international agreements regarding CO_2 emission reductions and the possibility of trading credits for such CO_2 emission reductions, then such additional financing will be easily available. Before this is institutionalized it is necessary that the additional financing will be furnished by the EU, by a national government or by an international institution.

A possible organizational structure under the IPP/BOO model is shown in Figure 6. Here the additional financing is foreseen to be provided by a CO_2-avoidance fund.

In case of the Theseus project, PreussenElektra, Germany's second largest utility company proposed to the German Government this project to be selected as one of Germany's contribution to the Pilot Phase for Activities Implemented Jointly (AIJ). PreussenElektra have a specific interest in getting first-hand experience in solar thermal technology as a basis for a potential investment of a Cretan solar power plant and future plans for Activities Implemented Jointly. The first European utility scale solar thermal power plant can be replicated in many locations in the Mediterranean area and in other countries of the sunbelt regions of the earth, it would be a show case for technology transfer and responsible energy and climate policy.

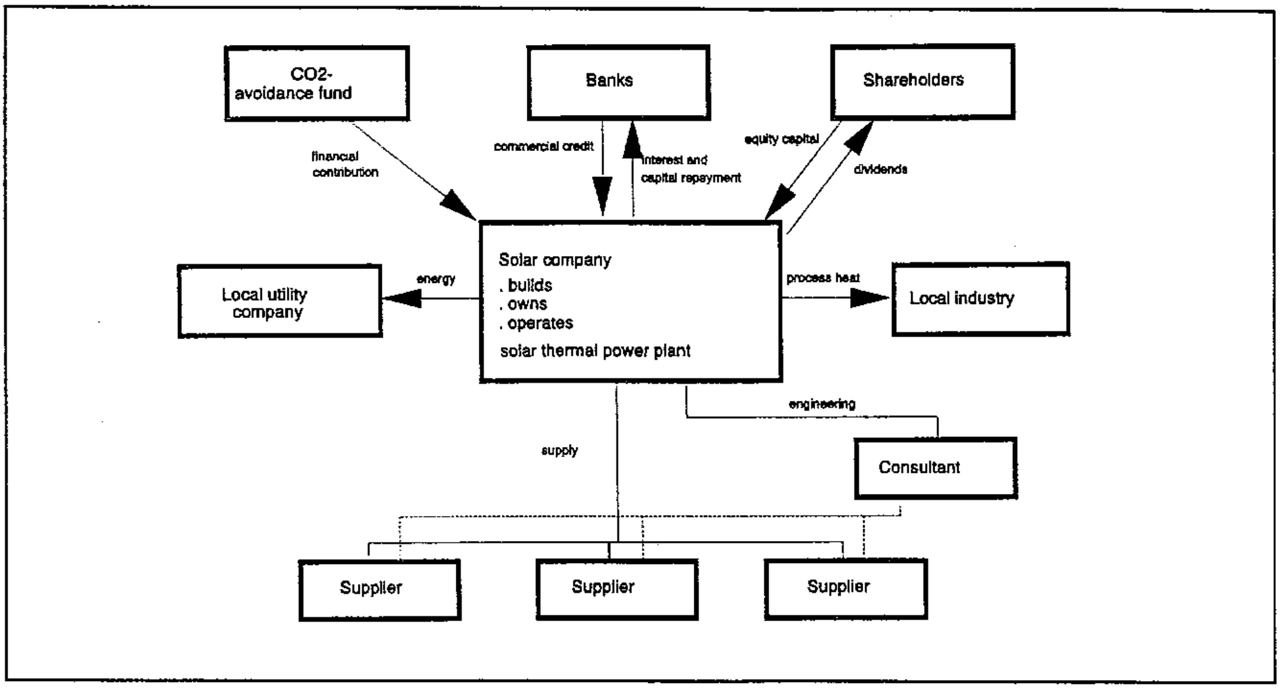

Figure 6 Possible Organizational Structure of a Solar Thermal Power Plant Project under the IPP/BOO model

CONCLUSIONS

There are opportunities for solar thermal power plant projects in a number of countries. The European industry is highly qualified to participate in these projects.

However solar thermal power plants are not competitive when considering only the financial cost of electricity generation. The benefits of solar thermal power plants are

- **low cost CO_2 emission reduction**
- **employment creation**
- **technological leadership and export opportunities for European Industries**
- **higher tax revenues for supplier's and host's countries**

Free market forces do not yet reward these advantages. This is why the Solar Industry is looking for the European Union, national governments and international organizations to assist in the financing of such projects. Such financing assistance for solar projects must not compete with development assistance for other also urgently needed projects since then it will not be requested from the receiver organization.