Indian Solar Thermal Technology – Technology to Protect Environment and Ecology

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Abstract

Rising fuel costs and global warming are pushing the development of renewable energy supplies. Solar energy is most promising as unlike wind it is evenly and uniformly spread and more predictable. 1 % of the solar energy received on earth would meet the total energy requirements of the world. It has been calculated that even if only 2 % of Indian deserts were to be used for putting up solar concentrators that would suffice to produce all present India's power need i.e. 140,000 MW. In the near future, solar energy may become part of the total commercial energy basket with its share rising in proportion to the new challenges. This study report shall provoke readers to act in their limited "circle of influence" by using technologies that have already delivered results worldwide. India is a leader among the nations in having a special Ministry for the promotion of Renewable Energy (MNRE). Even though there is no lack of funds and ideas, the results are still not commensurate with the potential that exists in India. This paper introduces a case study for the establishment of renewable energy supplies in India. Sustainable entrepreneurship as well as potentials and challenges from a life cycle perspective are described.

Keywords:

Solar Concentrators; Sustainable Business Models; Renewable Energy

1 INTRODUCTION

In the 30 member countries of the OECD, where electricity markets are well developed and the economical situation as well as the size of populations are more or less stable, the growth of electricity generation is evidently slower than in the non-OECD countries. Considering the strong economic growth that is projected for the developing non-OECD countries such as China and India, where a high percentage of the population does not even have access to electricity yet, a substantial increase of electricity generation will be needed to meet the industrial as well as the residential demand. The World Energy Outlook 2008, published by the International Energy Agency (IEA), projects that China and India will account for more than half of the growing total energy demand until 2030, considering that India is the second largest country in the world and has a significant economic growth of about 8% with over 1 billion inhabitants [1]. Relying on existing patterns and the strong use of fossil energy carriers to cope with the resulting energy demand would unfavourably influence global climate conditions.

India's government recently presented an action plan which specifically focuses on an increasing usage of renewable energies to reduce environmental impact without disturbing economic growth. Certainly a continuous energy supply is crucial for long term economic growth. Having in mind that 60% of India's rural population are not or not sufficiently connected to electricity underlines the importance of decentralized and renewable energy supply structures. Solar energy is specifically addressed by the government and with over 300 sun days a year the country is predestined for this renewable energy source.

Therefore India has a special Ministry for New and Renewable Energy (MNRE). The Ministry has been working hard to develop renewable energy, widen the base of manufacturers and providing incentives for users to make renewable energy products affordable and accessible. Recently, the Ministry committed itself to the aim that by 2012 more than 10 % of India's power shall come from renewable energy. At present, the share is about 5 %. For the first time in Indian history, the share will be higher than that of nuclear energy.

Till now, major contribution in renewable power comes from wind energy. To promote Solar Concentrator Technology, Indian government through MNRE provides subsidy of Rs 5,000 (approx 90 Euro) per square meter of Concentrator reflecting area to NGOs and non-profit institutions as well as accelerated depreciation benefits and subsidies of Rs 3,500 (approx 55 Euro) to the industry. The only drawback of going for government support and subsidies at present is that to get subsidies the buyer has to undergo a tendering procedure. The matter with MNRE has been taken up to do away with tendering as it causes delays and forces the companies to buy from someone who may quote low but has never proven his supplying capacities. In addition to the government support, the industry can sell carbon credits under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

2 SOLAR CONCENTRATOR TECHNOLOGY

Solar Concentrators are one example for decentralized and renewable energy supply structures as they are demanded in India and have been known for centuries. Everyone knows that fires can be ignited using magnifying glasses. But only recently, technologies for its commercial use are being developed. There are various types of solar concentrators that can be broadly classified into Line Concentrators, Trough Concentrators, Heliostats, and Parabolic Solar Concentrators**.** At present, due to high costs and the complex curved mirror technology, Line Focus Concentrators are viable only in larger capacities. The same is true for Heliostats as the cost of the Central Tower is high and thus a minimum size of MW is needed. Parabolic Solar dishes can be of any size and thus having modularity can be of smaller sizes enabling its use for cooking, process heat and process cooling while they may also be scaled up to the range of a MW Power Plant. In this technology, parabolic dishes concentrate solar rays at a point achieving high temperatures. The temperature in the focus can be 500 to 2000 degree centigrade depending on the Concentration Ratio (CR). Of all solar technologies, Parabolic Dish Solar Concentrators have made maximum impact in India and have relevance and future.

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There are four applications (technologies) in Solar Concentrators that have found their foothold and made mark in India:

- For Domestic Cooking: Seifert Parabolic Solar Concentrator (SK 14) are small size parabolic dishes of 1 meter or 1.4 meter diameter in which blackened cooking vessels are put in its focus and due to temperatures above 250 degree centigrade food gets cooked fast, conveniently and free. There are thousands of such solar cookers being used in rural India.
- For Community Cooking: Scheffler Concentrators (Figure 1) are concentrators made out of segments of parabola with flexible curvatures to achieve a stationary focus and thus the light can be reflected in the kitchen and cooking can take place in comfort. These advantages led to their being used for community cooking preparing food for 50-100 people.
- Institutional Cooking, Process heating, and Cooling applications: With the help of the German company HTT GmbH, a solar steam generating system was developed. Now there are about 50 large systems in India that provide cooking energy at institutions for 500 to 25,000 people twice a day.
- Scheffler Concentrators have also been successfully installed and tried out by Gadhia Solar for uses like solar air-conditioning (a 100 TR= 350 KW system has been successfully installed at a Hospital by us in India), laundry and ironing, sludge drying, wastewater evaporation, incineration, food processing, desalination, and others. With this, the Solar Concentrator Systems are bound to spread and newer applications are being developed.

Figure 1: Scheffler Solar Concentrators.

3 ESTABLISHMENT OF SOLAR CONCENTRATOR TECHNOLOGY IN INDIA

After studying Process and Environmental Engineering and doing Post Graduation in Energy Consultancy and Energy Management at TU Berlin after his return to India Deepak Gadhia founded the company Gadhia Solar Energy Systems Pvt. Ltd. He discovered the potential of solar energy more by chance than by plan. Mr. Gadhia came into the field to help his wife Dr. Shirin Gadhia who runs the NGO Eco Center ICNEER and who was looking for a solution to offer to poor when she told them not to cut forest and was confronted with their question: “Than how do we cook?.” On getting in the field Deepak Gadhia realised that 50% of the world’s population cook on open fire and that pollution in the kitchen is the third largest killer. Thus he saw business opportunities and started his company that evolved and grew [2].

Figure 2: Installed Scheffler Concentrators, Project from 2001

Gadhia Solar Energy Systems is an innovative solar thermal energy company, focused on providing energy solutions by using parabolic concentrated technologies. Since its inception, Gadhia Solar has been technologically, solution focused company driven by strong passion for environmental and social contribution. Gadhia Solar has implemented some of the world's largest solar thermal systems in the last two decades (Figure 2, Figure 3). It offers cost effective, reliable hot water solutions, solutions for drinking water, water evaporation and desalination system of industrial scales, centralized solar air conditioning and heating systems, as well as complete customized solutions for industrial applications from pharmaceuticals to chemical to food processing industries [3].

Figure 3: Installed Scheffler Concentrators, Project from 2008/09

The company Gadhia Solar with the help of GTZ registered its Solar Kitchen Projects under the CDM Gold Standard and the CER (Certified Emission reduction Certificates) arising out of use of Solar kitchens would be purchased by GTZ for German Ministry to compensate for the CO_2 emission of the Solar Meet held in Bonn making it a Carbon Neutral Conference.

3.1 Products

Systems from Gadhia Solar are built up of dishes (in sizes of 9 m², 16 m² or 32 m² depending on specific application) that incorporate the basic principle and therefore the advantage of high efficiency of the parabolic dish concentrators. However there is a major difference regarding the functional principle. While parabolic dish concentrators like dish-Sterling systems have to move the absorber unit connected to the dish during sun tracking, the Gadhia system can use stationary mounted receiver units. That means that receiver constructions and piping systems are significantly easier to design and the linking of several dishes for efficient energy generation systems is enabled [3].

The design bases on the idea of the Scheffler dish, which was invented by Mr. Wolfgang Scheffler in Kenya in 1983. The basic idea that did lead to the development of the Schefflerreflectors was to make solar cooking as comfortable as possible [4] [5]. At the same time the device should be build in a way that allows it to be manufactured in any rural welding workshop in southern countries after a certain period of training with locally available materials. To make cooking simple and comfortable the cooking-place should not have to be moved, even better: it should be inside the house and the concentrating reflector outside in the sun [5]. The technology to achieve these desired requirements is based on changing the shape of the parabolic dish concentrator and led to the term fix-focus principle which shall be explained hereafter (see also Figure 4).

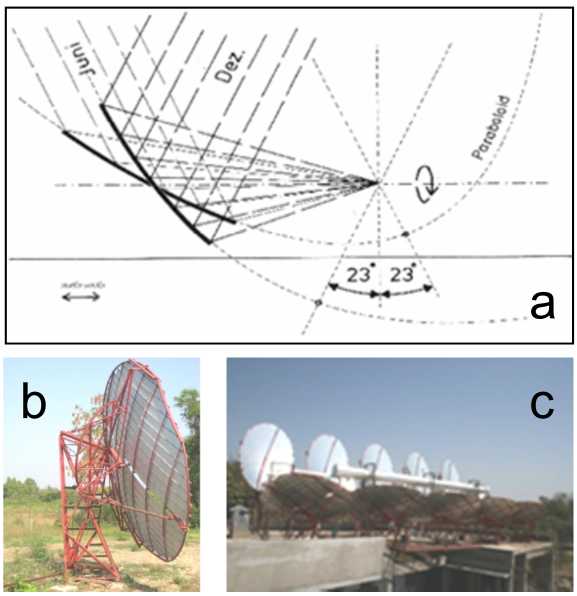

Figure 4: Gadhia Solar concentrator - functional principle (a), concentrator (b) and system with several dishes (c) [3].

The reflector is a small lateral section of a much larger paraboloid. The inclined cut produces the typical elliptical shape of the Scheffler-Reflector. The direct beam radiation falling onto this section of the paraboloid is reflected sideways to the focus located at some distance of the reflector. The concentrator system is tracking the suns' daily movement one the one hand and the seasonal movement on the other hand. The axis of daily rotation is located exactly in north-south-direction, parallel to earth axis and runs through the centre of gravity of the reflector. The focus is located on the axis of rotation to prevent it from moving when the reflector rotates. The distance between focus and centre of the reflector depends on the selected parabola. During the day the concentrated light will only rotate around its own centre but not move sideways in any direction. That way the focal area or hot spot stays fixed and is therefore called fix focus. After sunset the system has to be set back into morning position. As previously mentioned, the unique feature of the concentrator system is the fixed hot spot near the ground. The adjustable paraboloid dish can concentrate the radiation onto a defined target area for all positions of the daily and seasonal sun movement. Adjustment of the dish shape is necessary because in the course of the seasons the incident angle of the solar radiation varies in relation with the perpendicular to earth-axis. The paraboloid has to perform the same change of inclination in order to stay directed at the sun. Changing only the inclination of the dish is not sufficient to obtain a sharp focal point. Even though the position of the focus stays fixed the focal length is differing and has to be adjusted as well for a sharp and small focal area. This is only possible by shaping the reflector after another parabola for each seasonal inclination-angle of the sun, i.e. for each day of the year. This means the reflector has to change its shape at regular intervals. The reflector-frame is build for equinox. By inclining and elastically deforming the reflector-frame all other parabolas can be achieved with sufficient accuracy [5].

The dishes were already used in diverse applications in the context of decentralized cooking (with just one dish), water treatment or steam generation in systems with more than 100 dishes e.g. for cooking in pilgrim shelters or women's refugees. Besides basically a wide range of promising fields of applications is possible which typically involve larger amounts of solar concentrators to run the system efficiently, e.g. steam generation for process heat (for industrial purposes), co-generation of steam (process heat) and electricity (approx. 1 MW), and generation of electricity (power plant with at least 5MW) [3].

3.2 Potentials and Challenges from a Life Cycle perspective

As the previous chapters show the current and predicted economic background in context to solar thermal electricity generation is quite positive in India as well as worldwide. Gadhia Solar as leading and well known company for solar thermal solutions in India naturally wants to take part in these developments. Their products are characterized by unique technological properties like the fixed focus dishes which may give them technological advantages in terms of efficiency. However, until now Gadhia Solar has not installed power plants for large scale electricity generation yet. Quite obviously there are some challenges that have to be solved when establishing business with large scale solar power plants. Based on previous statements two critical success factors can be derived [6]:

- **be able to cope with high production volumes** to face capacity increase and upscaling of systems
- **reducing costs of electricity generation** to encounter high cost pressure in competition with other energy sources

Considering economies of scale and scope it is obvious that both factors are closely connected to each other. Against this background the following paragraphs shall give a more detailed look on challenges along the life cycle of a solar thermal power plant based on Gadhia Solar concentrators (Figure 4). Thereby, while India being the home country and also primary market of Gadhia Solar it is absolutely crucial to consider the specific conditions there.

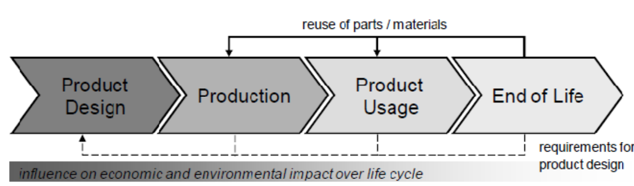

Figure 4: Life cycle of solar concentrator systems [6].

Product Design

Whereas the influence on costs is mainly given in the design phase, in the sense of a "Design for X" it is naturally necessary to consciously consider all other life cycle phases already here. In order to cope with high production volumes and cost pressure specifically design for manufacturing and assembly (DFMA) is of major relevance. In this context it is important to take a look at improving the product structure, increasing the amount of common parts and the careful definition of interfaces with appropriate selection of subassemblies and joining technologies. Main objectives of DFMA are the reduction of product costs assembly time (enables faster product throughput/higher capacity) and the amount of parts (e.g. fewer parts in stock) both resulting in lower product costs (labor and material). Studies underline that reductions of about 50% in all categories compared to the initial state are realistic [7]. Hereby it is crucial to take certain specific critical conditions or restrictions regarding transportation (e.g. road conditions, space on trucks), qualification of personnel (e.g. easy activities, safety issues) and usable technologies (e.g. no electricity on installation site) into account. Critical points in mechanical and electrical system design in the considered system of Gadhia Solar include parts like the steam pipeline (design of all components for optimizing the system to produce superheated steam for power generation), the mirror surfaces (foils, adhesive bonding of reflective coated glass, improvement of the long time behaviour of the mirror surfaces, cleaning, weather proof coatings), the frame (redesign for light weight and carbon foot print, using of space frame, computation and optimization of the welded structure), the day time sun tracking and the seasoning adjustment (e.g. design for automatical use in power plants). [6]

Production

As described above the proposed fields of applications using the Scheffler solar concentrator involve a very significant increase (factor 5-10 of current production capacity per year) of the necessary number of concentrators. This larger production volume is a totally new requirement for the whole production process chain which consists of the rather manual manufacturing of parts and subassemblies in a production plant (in Valsad, Gujarat) and their final assembly on the actual installation site. Significantly higher production volumes need a redesign of the production system. However, connected technical (e.g. production system design /material flow, selection and dimensioning of specific production processes / machines) and organisational (e.g. planning and control of production, organisational structures, qualification) measures to adapt the production system will lead to economies of scale with positive effect on product costs. Again, while being quite different compared to e.g. European countries Indian specific conditions and requirements (e.g. qualification of employees, given infrastructure, cost structure/ prices for machinery and raw materials, integration of local content) need to be considered. As a final result the production process chain based in India shall be able to timely deliver as many qualitatively sound solar concentrators as needed for the proposed fields of application – under consideration of additional targets like competitive costs and also low environmental impact. [6]

Product usage and End of Life

As a long term investment good with a desired life span of at least 10-15 years the use phase naturally has a major impact regarding the ecological and economical performance of solar concentrators over the life cycle. Whereas current solutions considering systems with approximately 100-200 mirrors totally different approaches are needed to cope with the desired shift to power plant system with several hundred dishes. Critical aspects in this context are the significant effort needed to ensure efficient functionality of the whole system through adjusting / control (e.g. daytime and seasonal adjustment of the mirrors, control of system regarding heat usage / storage et cetera) or maintenance measures (e.g. ensuring high availability, cleaning of mirrors, strategy for monitoring and controlling of the system states) despite being strongly exposed to the elements. While large amounts of concentrators are in use, it is important to be able to appropriately dispose them after use (e.g. no hazardous materials). Additionally, aspects like reuse or material recycling should be considered in product design (e.g. common parts as spare parts) to gain advantages over the life cycle. [6]

4 MOTIVATION FOR FURTHER ACTIVITIES

Like all countries, India too has rolled out a very ambitious 20 GW Solar Energy Mission. This will fuel the demand but also create an increased demand for engineers, skilled workers, technicians, installers, after sales service providers, marketeers, and consultants. To overcome the shortage that will emerge Green Academies must be developed with the support of the International Labour Organisation (ILO). Muni Seva Ashram, an Indian NGO in India in which Deepak Gadhia is a trustee, plans to start a Green Academy called ASPIRE (Academy for Sustainable Practices, Innovations in Renewable Energy) to meet that demand.

Green Industries and Green Jobs are the future. They offer great opportunities to Entrepreneurs who are willing to enter into fields like solar energy, biogas etc. Besides the incentives of subsidies and carbon credits for renewable energy and of saving fuel many industries and institutions are purchasing renewable energy systems with the aim to “Go Green” and contribute to the protection of the environment and to reducing the problems of global warming. They understand the need to act. While some time ago all the decisions were taken considering economics only people are now willing to pay a bit more if that helps to protect the environment and the ecology. For the survival of mankind, it is imperative that economy and ecology go hand in hand.

5 SUMMARY AND ACKNOWLEDGEMENTS

The paper presents a case study for the establishment of renewable energy supplies in India and its underlying and enabling sustainable entrepreneurship. While being a promising approach for the future, probable developments demand manufacturers of solar thermal systems to be able to cope with high production volumes and significant cost pressure. This was underlined by the case study of Gadhia Solar where additional influencing parameters were also presented. This paper was developed in context of a cooperation between Gadhia Solar Energy Systems Pvt. Ltd. And the Technische Universität Braunschweig.

6 REFERENCES

[1] World Energy Outlook, 2008, International Energy Agency (IEA), **www.worldenergyoutlook.org**.

[2] Gadhia, D. (2010): Solar Concentrators in India - Technology to Protect Environment and Ecology, in: TU INTERNATIONAL, No. 66, pp. 12-13, Berlin, Germany

[3] Gadhia Solar Energy Systems Pvt. Ltd., 2009, company information, e.g. **www.gadhia-solar.com.**

[4] Tyroller, M., 2004, Solarsterilisator für Entwicklungsländer, München.

[5] Scheffler, W., 2009, Solare Brücke - Die Scheffler Reflektoren, **www.solare-bruecke.org**.

[6] Herrmann, C., Thiede, S., Kuntzky, K., Böhm, S., Frauenhofer, M., Gadhia, D. (2009): Indian Solar Thermal Technology: Potentials and Challenges, in: Proceedings of the 7th Global Conference on Sustainable Manufacturing, pp.169-174, Chennai, India.

[7] Boothroyd Dewhurst Inc., 2009, Design for Manufacture and Assembly (DFMA), **www.dfma.com**.