


# Decentralised Energy Solutions

***Investment potential in solar thermal, modern biomass energy systems for heat and decentralised electricity generation***



MAKE IN INDIA

Ministry of New and Renewable Energy
Government of India

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Empowered lives.
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RE-INVEST
1st RENEWABLE ENERGY GLOBAL
INVESTMENT PROMOTION MEET & EXPO
15 - 17 FEBRUARY 2015 • NEW DELHI, INDIA

The Ministry of New and Renewable Energy, Government of India is organising the first Renewable Energy Global Investors Meet & Expo (RE-Invest) on 15–17 February 2015 in New Delhi, as a follow-up to the 'Make in India' initiative launched by the Prime Minister of India. The central theme of RE-Invest is to attract large-scale investments for the renewable energy sector in India.

## The Objective

RE-Invest is the first major platform for investment promotion in this sector at Government of India level to signal India's commitment to the development and scaling up of renewable energy to meet its energy requirement in a sustainable manner. This will enable the global investment community to connect with renewable energy stakeholders in India. The event was attended by over 200 investors and over 1000 delegates, both domestic and international. Besides, representatives from State Government, Public Sector Enterprises, renewable power developers and manufacturers, state renewable energy nodal agencies, and other related stakeholders played important roles.

## The Indian Renewable Energy Market

Renewable energy contributes about 6.5% in the electricity mix of the country. It is proposed that this would be taken to about 12% in the next three years. Major initiatives by the Government, including accelerated depreciation, generation based incentive, feed-in-tariff and viability gap funding, are expected to add massive investments in renewable energy sector. FDI up to 100% under the automatic route is permitted in renewable energy sector.

## The Conference and Exhibition

RE-Invest saw a culmination of conference and exhibition of manufacturers, project developers, investors and other players in the renewable energy space to showcase manufacturing capabilities, latest technologies, financing options and investment opportunities. International companies from this sector had the opportunity to exhibit and showcase their services at the expo to a wide-ranging Indian audience.

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# Contents

# Message

**Dr Jaco Cilliers**
**Country Director**
**United Nations Development Programme**

The RE-INVEST conference is a welcome initiative of the MNRE in wake of the Prime Minister's 'Make in India' call. UNDP appreciates the Government's supportive policies on renewable energy and we feel this will be very beneficial to the country in the long run.

India's energy consumption has more than doubled since 1990. In spite of this, about 300 million Indians remain without access to electricity and 800 million still depend on traditional biomass burnt in inefficient cook-stoves for serving their cooking energy requirements. This is not speaking of the fact that even for most of those who do have access to energy the amount of energy available falls woefully short of meeting their complete requirements. The reasons for this could be either inadequate energy supply or unaffordability or both. The energy access situation in the country, therefore, poses a complex challenge with multiple dimensions such as resource availability, affordability, etc.

In order to put some spotlight on the energy issues confronting remote and backward areas, the UNDP considered sponsoring a session on this topic. We are happy to bring out this booklet, which documents important issues on decentralized energy and talks of eminent speakers who graced this session. I hope participants will find this booklet useful.

# Preface

Subsequent to the 'Make in India' call of the Prime Minister of India, the Government of India is gearing up all faculties under its command to attract foreign investment into the country, which would provide the necessary impetus for setting up manufacturing activities in the country thus fulfilling the 'Make in India' dream. In order to realize this important goal, the government has already started identifying potential sectors where investments could be invited. One sector that enjoys top priority in this context and is poised for major expansion and growth in the coming years is **renewable energy**.

Against this backdrop, the MNRE is organizing a **Global Renewable Energy Investment and Promotion Meet: 'RE-INVEST'** from 15 to 17 February, 2015 in New Delhi with the aim to bring together global experience and thinking on ways to encourage investments in the Renewable Energy sector. Under the aegis of this international conference, the UNDP has sponsored a dedicated session scheduled for 17 February 2015, to deliberate on investment potential decentralised or off-grid renewable energy solutions, which also happens to be one of UNDP's focus areas. Importantly so, the session is expected to draw attention of the participants towards energy availability and access issues confronting some of the most marginalized communities in the world in addition to underlining the utility of decentralized devices in grid connected areas as well, particularly for direct heat applications.

This booklet has been prepared specifically for this occasion and intended to act as a take-away reference document for persons attending this special session. The contents of this booklet are spread over two separate sections. Section A contains a set of discussion papers prepared by subject matter specialists, specifically commissioned by UNDP for the purpose. The discussion papers document the current status and corresponding investment potential in context of three important themes in the decentralised energy space. These are:

1. Solar Thermal Technologies: For direct heat applications
2. Biomass Energy Systems: For domestic and industrial applications—cooking, process heat
3. Decentralized Electricity Supply (only for off-grid photovoltaic provided): For domestic, agricultural and rural entrepreneurship applications

Section B contains compilations of articles and presentations pertaining to the talks delivered by various speakers in the session. The booklet also contains contact details of the speakers and information on the co-hosts of the conference. We hope the participants find it useful and informative.

**S N Srinivas**

**O S Sastry**

**Preeti Soni**

# Acknowledgements

UNDP is grateful to MNRE not only for providing a time slot for this session but also for their active cooperation and collaboration in the ongoing UNDP-sponsored projects. In particular, we would like to thank Mr Upendra Tripathy, Secretary; Mr Tarun Kapoor, Joint Secretary; and the staff connected to RE-INVEST event at MNRE. We would like to thank the Confederation of Indian Industry (CII) and in particular, Ms Sreya Majumder for taking personal interest in the planning and organization of this session.

We gratefully acknowledge the technical and analytical inputs provided by Dr Sameer Maithel from Greentech Knowledge Solutions and Dr Shirish Sinha from the Swiss Agency for Development Cooperation, in the form of discussion papers.

We appreciate the efforts of all speakers in providing their write-ups and presentations in a short period of time. Lastly, we thank UNDP team members, Mr S Sathis Kumar (Project Manager, Technical), Ms Manisha Sanghani (Programme Associate), Mr Sanjay Bailwal (Project Associate), Ms Varshika Singh (Project Associate) along with Mr Parimal M Sadaphal and Mr K P Eashwar (Consultants) for their efforts in the coordination of all activities including compilation of all inputs for the preparation of this booklet.

**S N Srinivas**

**O S Sastry**

**Preeti Soni**

# SECTION A
## Discussion Papers

# Solar Thermal Market in India: Potential and Investment Opportunities

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*Photo Courtesy: Sunwater Solar*

## Solar Thermal Technologies and Applications in India

### Background

An analysis of the energy consumption pattern[1] of India shows that 57% (240 million tonnes of oil equivalent) of final energy consumption is used for thermal applications. Industrial process heat, residential cooking, and water heating are the main thermal applications, accounting for more than 90% of the thermal energy requirement. Presently, the thermal energy demand in India is primarily being met through coal, biomass, and petroleum fuels.

Solar thermal technologies convert solar energy into heat, which may be further used for heating water, domestic and commercial cooking, agricultural and industrial drying, water desalination, low and medium temperature industrial process heat, space conditioning (i.e., space heating, cooling), and refrigeration.

[1] *Analysis carried out under this study used the data from The India Energy Security Scenarios 2047 (IESS 2047), by the Planning Commission, Government of India, 25 April, 2014.*

Solar thermal technologies provide an alternative and reduce the dependence on imported fuels. These technologies also enhance the energy security, improve energy access, reduces electricity demand, better environmental quality, and lays the path for socio-economic development.

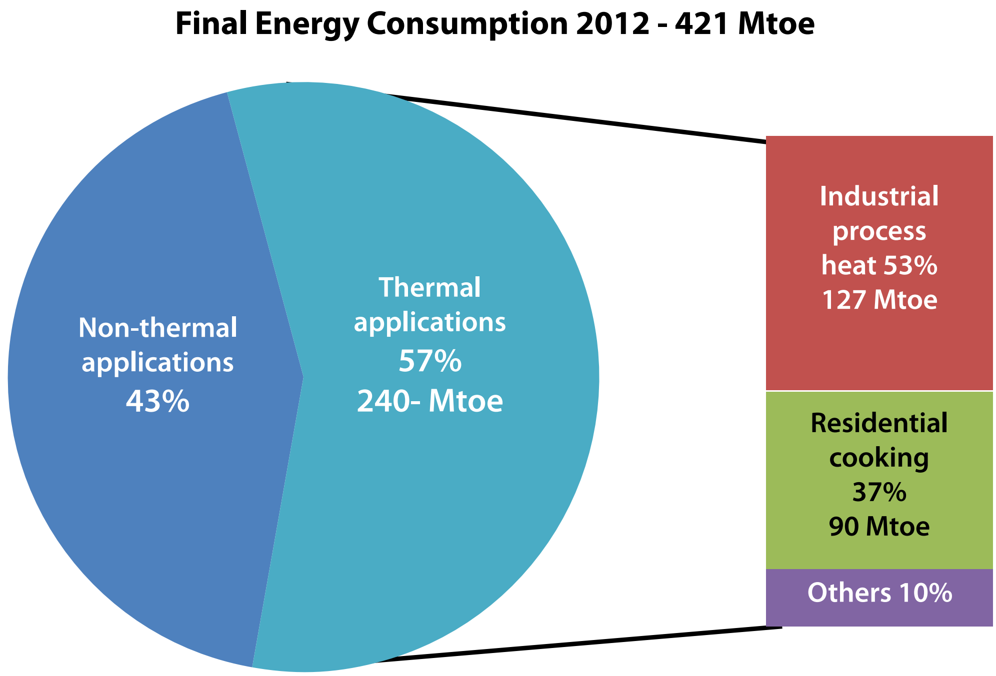


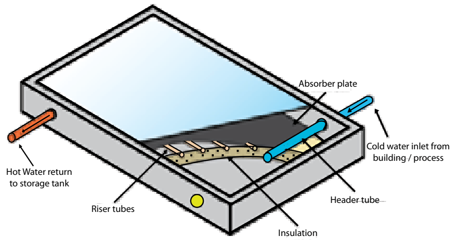

***Figure 1*** *Energy consumption pattern for India (2012)*

## Overview of solar thermal technologies and applications

### Solar Thermal Technologies

Generally, any solar thermal technology consists of a collector, which collects and absorbs the solar radiation; a heat storage unit, where the collected heat from the collector can be stored; and a heat transfer circuit to transfer the heat from the heat storage to the point of thermal application.

## Types of Solar Collector

<table>
<tr><th colspan="2">Non-concentrating Collectors: Non-concentrating collectors work on the principle of exposing a dark surface to solar radiation so that the radiation is absorbed.</th></tr>
<tr><td>Flat plate Collector: A flat plate collector consists of a metal absorber enclosed in a box, covered on the top with a glass sheet (glazing), and insulated at the back and sides.</td><td>Evacuated Tube Collector: It has two glass tubes fused together with a vacuum in between. The absorber is placed at the outer layer of the inner glass tube.</td></tr>
<tr><td>
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<table>
<tr><th colspan="2">Concentrating Collector: The concentrating collectors work on the principle of focusing the radiation falling on a large area (reflector) onto a small area (absorber) to achieve higher temperatures.</th></tr>
<tr><td>Single Axis Tracking Collector: It consists of reflectors (parabolic or plain reflectors) with a line or point focus.</td><td>Dual Axis Tracking Collector: It consists of reflectors in a shape of a paraboloid dish with moving point focus.</td></tr>
<tr><td></td><td></td></tr>
</table>

## Solar Thermal Technology Applications

<table>
<tr><th colspan="2">Building Sector</th></tr>
<tr><td>Solar Water Heating: Heats water up to 80 °C for bathing and other utilities</td><td>Solar Cooker: Converts solar radiation to heat for cooking food.</td></tr>
<tr><td>
</td><td></td></tr>
</table>

| | |
|---|---|
| **Solar Concentrator for Community Cooking** Produces steam that can be used for cooking food. | **Solar Space Conditioning:** Heating and Cooling produce heat for space heating or to operate thermal cooling machine for cooling. |
|  |   |

| 2. Industries | 3. Agriculture |
|---|---|
| **Solar Thermal for Industrial Process Heat:** Can be used to deliver medium to low temperature process heat (< 250 °C) for industrial applications. | **Solar Dryers:** Can be used for drying applications for horticulture products; also used for fish drying. |
|  Steam generation for Milk Pastuerization at Chitale Dairy, Sangli, Maharashtra |  |

## Stage of Development of Solar Thermal Technology Applications

The corresponding Figure 2 captures the stage of development of various solar thermal technology applications on Moore's technology adoption life cycle curve. [2] The stages of development are defined as:

a) development,
b) introduction,
c) growth, and
d) maturity.

[2] *Geoffrey A Moore expanded the diffusion of innovation theory to suggest that there is a chasm between early adopters of innovations and the early majority. The chasm indicates that aggressive efforts are required, particularly in aligning the technology/products to suit the needs of the mainstream market to cross the chasm.*

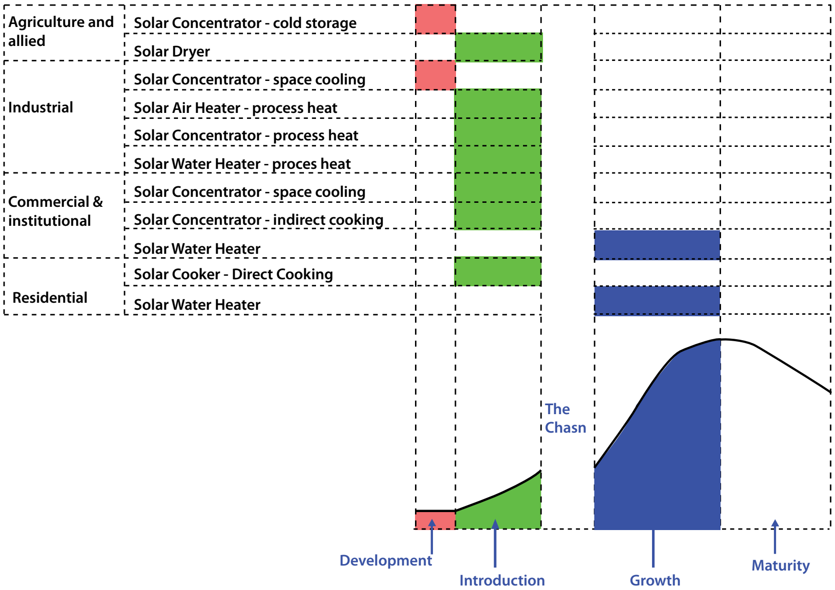


***Figure 2** Stage of development of solar thermal technology applications*

Presently, the solar water heater (SWH) technology in the buildings sector is the lone technology that has been able to reach the mainstream market (growth phase), whereas a majority of the other solar thermal technology applications, including solar-assisted cooking, solar industrial process heat, and solar dryers are still in the introductory phase. Solar thermal-based cooling is also in the developmental stage where there are a few demonstration projects being tested for field performance.

## Status of solar thermal technologies in India

### Deployment

As of March 2014, the total installed capacity of all solar thermal technologies in India was 5.67 $GW_{th}$ (~8 million $m^2$). Solar water heating accounts for 99.4% of the installed capacity (Figure 3).

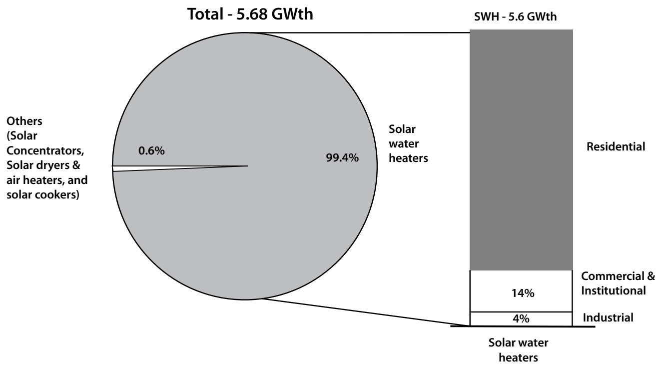


***Figure 3*** *Total installed capacity of solar thermal technologies in India*

## Market Size and Trends

The current market size of the solar thermal market is given in Table 1. The overall size of solar thermal market has been estimated at ~USD 200 million per year. Solar water heater technology constitutes 99% of the solar thermal market in India. Around 95% of the solar thermal market is in the buildings sector (residential and commercial and institutional buildings).

**Table 1. Market for solar thermal in India (2014)**

| Application sector | Solar technology | Annual sales 2014 | Market size 2014 (million USD) |
|---|---|---|---|
| Buildings | **Solar Water Heater** | **0.92 million m$^2$** | **~190** |
| | Solar concentrator | 1900 m$^2$ | ~0.8 |
| | Solar cookers | 5000 cookers | ~0.3 |
| Industries | **Solar Water Heater** | **35000 m$^2$** | **~7.3** |
| | Solar concentrator | 2200 m$^2$ | ~1 |
| | Solar air heaters | 1500 m$^2$ | ~0.12 |
| | | | |
| Agriculture | **Solar Dryer** | 320 m$^2$ | ~0.03 |
| **Total** | | | **~200 million** |

The solar water heater market has witnessed a growth rate (CAGR) of >20% in the last decade. Sales of evacuated tube collector technology have risen more than 20 times, since its introduction in Indian market in 2008. More than 85% of the solar water heater market lies in Zone I, i.e., southern and western states (Gujarat, Maharashtra, Karnataka, Tamil Nadu, Telangana and Andhra Pradesh) of India (Figure 4).

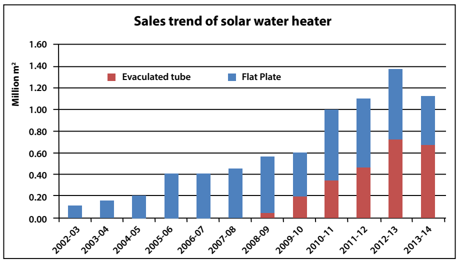


***Figure 4** Sale of solar water heaters (2002 to 2014)*

## Market Potential of Solar Thermal Technologies in India

Market potential analysis of solar thermal technologies shows that the installed capacity will reach ~ 15 $GW_{th}$ by 2022, i.e., around three times the present installed capacity, and to more than 100 $GW_{th}$ by 2032 (Figure 5). Among various solar thermal technology applications, the demand for solar water heater technology, particularly for building applications is expected to grow at a much faster pace than other solar technology applications. This is mainly because the SWH technology is already in the growth phase and has already established a significant market base.

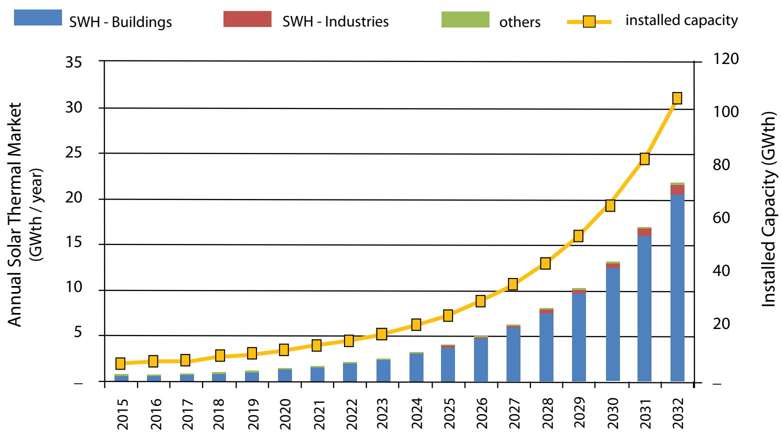


***Figure 5** Market potential of solar thermal technologies 2015–32*

It is estimated that both in 2022 and 2032, the solar water heater technology will constitute ~95% of the solar thermal market. Residential buildings will remain the largest market of solar water heaters. The economics of solar water heaters in residential buildings are influenced by factors such as hot water demand, cost of hot water generation from conventional technologies (mainly electricity- and biomass-based) and availability of solar radiation. India can be segmented into five geographical zones having distinct hot water requirements and solar radiation availability (Figure 6). A simple payback analysis shows that the payback period for solar water heaters in residential buildings varies from 4–10 years in urban areas and 10–22 years in rural areas (Figure 7). The payback periods are expected to become progressively more attractive due to the rise in the price of conventional fuels.

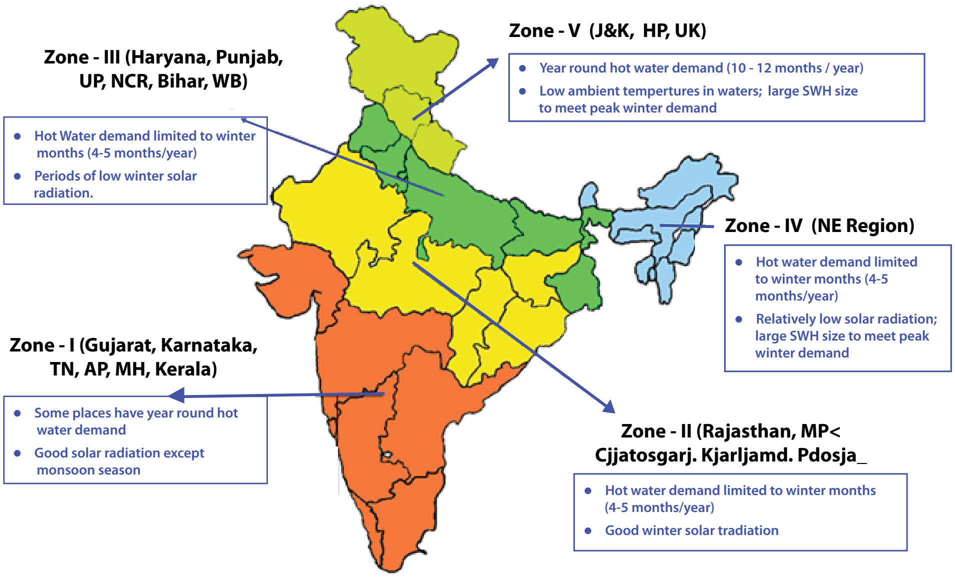


*Figure 6: Segmentation of India in five zones on the basis of hot water demand and solar radiation*

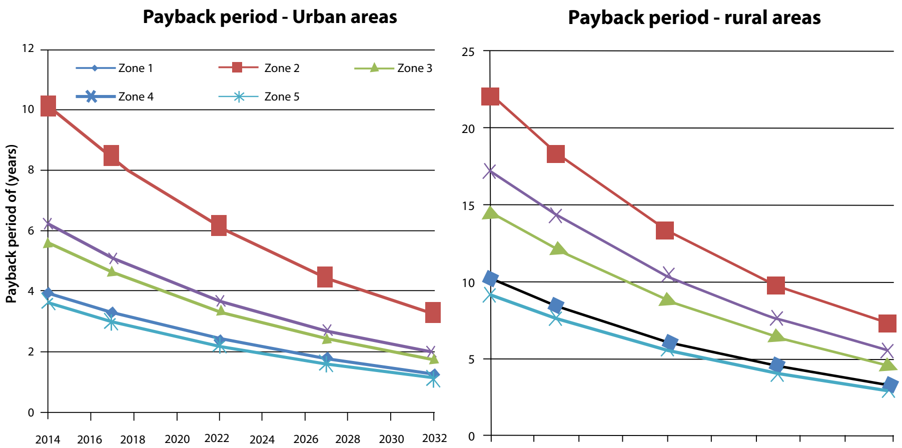


***Figure 7*** *Projected payback period of solar water heaters in urban and rural areas (residential sector)*

The annual market for solar water heaters is expected to quadruple to reach 3.25 million $m^2$/ year by 2022 and to 31 million $m^2$/ year by 2032 (Figure 8). While at present, urban areas are the main market for solar water heaters, progressively the rural market will start picking-up. From a market share of around 12% in 2022, the rural market is accepted to account for ~50% of the market potential by 2032. In terms of technology, the evacuated tube is expected to gain further market share—the annual market of evacuated tube system is expected to grow from 0.6 million $m^2$ in 2014 to 2.5 million $m^2$ and 28 million $m^2$ by 2022 and 2032, respectively. In terms of geography, around 84% of the market potential of Solar water heater in 2032 will be accounted by Zone I and Zone III (Figure 8).

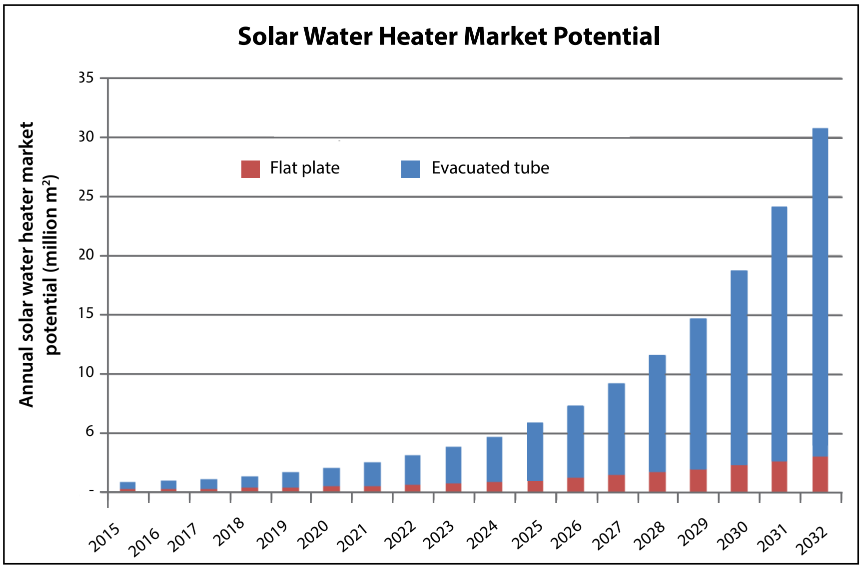


***Figure 8** Market potential of solar water heater*

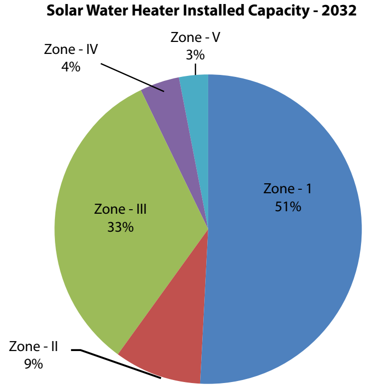


***Figure 9** Zonal distribution of solar water heater market potential (2032)*

# Investment Opportunities in Solar Thermal

## Total investment

It is estimated that the total investment required in the period 2015–32 to achieve the market potential in solar thermal sector is of the order of USD 30 billion. More than 98% of the investment would be required in solar water heater technology.

**Table 2. Total estimated investment in solar thermal (2015-32)**

| Solar investment (million USD) | 2015–22 | 2022–32 |
|---|---|---|
| 1. Solar water heater | 2800 | 26700 |
| 2. Solar concentrator | 35 | 380 |
| 3. Others (solar cookers, solar dryers, solar air heaters) | 5 | 60 |
| Cumulative investment | 2840 | 27140 |
| **Total estimated investment during 2015–32** | **~30000** | |

## Investment in manufacturing and supply and service network

Presently, there are no manufacturing facilities for evacuated tube collectors in India and most of the evacuated tubes are imported from China. The market potential of solar water heater indicates that evacuated tube collectors would constitute 90% of the 31 million $m^2$/year (~USD 6.5 billion/year) solar water heater market by 2032. The realisation of such a large potential will entail investing in manufacturing of solar thermal technologies, particularly in evacuated tube collectors and setting up supply and service network across the country. Investments required in setting up of manufacturing and assembly unit for meeting 100% of the demand through domestic production is estimated to be of the order of USD 500 million during the period 2015–32. It is estimated that an investment of around USD 3 million would be required from 2015–32 to build supply and service network.

**Table 3. Investment in manufacturing and assembly**

| Manufacturing and Assembly (million USD) | 2015–22 | 2022–32 |
|---|---|---|
| 1. Solar Water Heater | 46 | 442 |
| Evacuated tube collector | 30 | 250 |
| Flat plate collector | 4 | 24 |
| Tanks and other ancillary | 12 | 168 |
| 2. Others (solar concentrators, solar cookers, solar dryers, solar air heaters) | 0.7 | 7 |
| Cumulative Investment | 46.7 | 449 |
| **Investment in manufacturing and assembly (2015–32)** | **~500** | |

## Acknowledgement

This paper draws substantially from the report titled "Accelerating the Deployment of Decentralised Solar Thermal Technologies in India", prepared by Greentech Knowledge Solutions with support from Shakti Sustainable Energy Foundation. Greentech would like to thank Shakti for its support towards this research.

# Biomass Energy Thermal Gasifiers: Clean and Cost-Effective Solution for Energy Needs of Micro, Small and Medium Enterprises Sector

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*Apoorva Jain, Albert Trevor, Sunil Dhingra*
*The Energy and Resources Institute (TERI), New Delhi*
*<shirishsinha@eda.admin>*

## Introduction

In India, the growing concerns about long-term energy security, depleting fossil fuel reserves and their environmental impact have created a greater stimulus to promoting renewable energy, particularly in sectors where larger gains are possible. Quality energy services resulting in improved productivity are seen as a harbinger driving economies and societies. In light of the energy security challenge, it becomes imperative to adopt strategies for an energy mix that lead towards a low-carbon development pathway. The strategies should include development or modification of energy systems that reduce greenhouse gas emissions. India needs a mix of both large-scale grid-connected and off-grid decentralised renewable energy to meet its electricity and energy deficits.[1] In the recent policy formulation there has been a significant emphasis on large-scale renewable, which is rightly placed. However, the decentralised renewable energy systems based on sustainable use of resources such as biomass have the potential to provide solutions for developing low-carbon development pathways in some of India's energy-intensive sectors such as the Micro, Small and Medium Enterprises (MSME) sector.[2]

Referred to as the engines of growth, the MSME sector in India plays a critical role in industrial output, exports, and employment generation. In fact, this sector provides the largest share of employment after the agriculture sector. Around 36.2 million MSMEs, spread over 180 clusters, provide employment to approximately 80.5 million people.[3] Together, they account for 45% of the total manufacturing output, and 40% of the total exports of the country. With a substantial contribution of 8% to the country's gross domestic product

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[1] *Sinha S (2012). In Pursuit of a Light Bulb and a Smokeless Kitchen. Enschede: University of Twente*

[2] *Sinha S, Dhingra S and Ziegerer D (2014). Large scale diffusion of thermal gasifier in India's Micro, Small and Medium Enterprises: Experience and Opportunities. Paper presented at Technology 4 Development 2014, June 4-6, Lausanne.*

[3] *Government of India (2013). Annual Report 2012-13, Ministry of Micro, Small and Medium Enterprises, New Delhi.*

(GDP), the sector also forms the backbone of the economy. Further, this sector has consistently registered a higher growth rate than the rest of the industrial sector. There are over 6000 products, ranging from traditional to futuristic, which are currently being manufactured by the MSMEs in India. Owing to the sector's enormous contribution towards the growth of the economy, the ready availability of and access to clean forms of energy at affordable prices is particularly crucial.

Despite its enormous contribution to the growth and development of the economy, the MSME sector is going through a turbulent phase. This is primarily due to the overall sluggishness in the economy, and the rising input energy costs. In the recent years, the prices of all forms of energy, especially fossil fuels used by MSMEs have witnessed a steep increase. There are many energy-intensive industries among MSMEs that still use commercial fuels like coal, oil and gas or biomass inefficiently. In most of these industries, energy costs account for nearly 30%–50% of the total production cost. Further, these MSMEs use a wide range of locally available cheaper fuels, which together with inefficient processes and technologies have adverse environmental impacts, especially at the local level. For this reason, energy efficiency / fuel switching is at the centre stage for improving the competitiveness of the sector and reducing carbon emissions. Biomass is one such important source of renewable energy in India which can generate considerable energy savings in the sector. It has been estimated that about 500 million tonnes of biomass, including woody biomass and agro-residues, is produced annually in the country. Out of this, more than 150 million tonnes is estimated to be surplus. The surplus, if used effectively in a cleaner energy form, can contribute significantly to meeting the overall energy needs of the country in a sustainable manner.

## Biomass Gasifier

The Government of India through a combination of national policies and schemes has put considerable emphasis on the use of renewable energy systems such as the biomass-based clean energy solutions. These policies and plans have also identified the importance of cleaner technologies in the MSME sector for improving energy efficiency, reducing transaction cost, ensuring environmental sustainability, and for making them competitive in a liberalised economy. With the changing energy sector policies and increase in energy prices, especially of fossil fuels, many MSMEs are exploring ways to switch to cleaner energy options, which adhere to the stringent environmental / pollution regulations.[4] Biomass-based clean energy systems based on gasification technology (Box 1) is one

[4] *Soni, P (2009). Small-scale Industries: Small yet Significant in Climate Change – Perspectives from India, UNDP. New Delhi.*

such option that has the potential to transform energy use in MSMEs in India. Although biomass-based energy solutions have demonstrated huge potential in addressing the growing energy concerns of the MSME sector; going forward, they have the potential to integrate and mainstream renewable energy at a much larger and wider scale.

## Biomass energy programme of the Swiss Agency for Development and Cooperation: A journey of two decades[5]

In 1994, the Swiss Agency for Development and Cooperation (SDC) initiated a project by involving The Energy and Resources Institute (TERI) to support MSMEs as low-capacity end-users, and enable them to improve their technologies / processes and undertake measures that lessen the impact on the environment, reduce energy costs and improve their competitiveness in the market. One specific low-capacity end-use application was biomass energy-based technology solutions for thermal / heat applications in the MSMEs. Although the basic science of gasification was well established in India, it was not until 1994 that efforts to develop technology and integrate biomass gasifier with industrial furnaces and ovens for thermal energy generation were undertaken. In the initial years of the partnership, the focus was on developing low cost technological solutions. The solutions were achieved by first understanding the actual process of gasification, by obtaining end-user feedback, and then by translating this experience in technology design. As a result of the continuous interaction with end users, process experts and consultants, TERI was able to develop a gasifier for a variety of thermal energy applications for different MSMEs in different clusters. Consequently, the biomass gasifier for thermal use could be successfully demonstrated in enterprises such as silk reeling, textile dyeing, magnesium chloride production, brick drying, spices drying, wax melting, aluminium billet heating, puffed rice making, sand drying, cardamom curing, natural rubber processing, chemical extraction, metal smelting, and mineral processing. After the successful demonstration of technology development and implementation in MSMEs, the focus shifted to accelerate the use of biomass-based energy systems that can help small enterprises secure access to clean energy services.

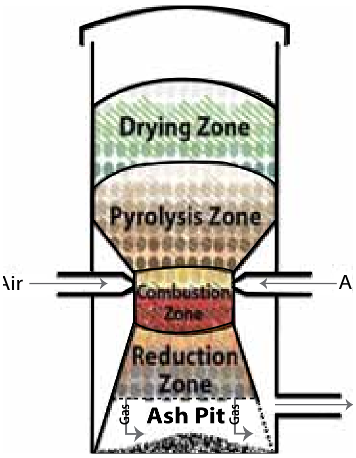
The innovative approach to the dissemination of biomass gasifiers for thermal applications in MSME clusters involves local delivery mechanism, which also facilitates the process of commercialization in the target sector. The dissemination approach has also addressed the implementation process, building human capacities and providing local employment opportunities. The highlights of the approach include identification of local gasifier manufacturers, creation of local

[5] *Sinha S, Dhingra S and Ziegerer D (2014). Large scale diffusion of thermal gasifier in India's Micro, Small and Medium Enterprises: Experience and Opportunities. Paper presented at Technology 4 Development 2014, June 4-6, Lausanne.*

delivery system through an entrepreneur, capacity building of the manufacturer, entrepreneur and MSMEs, and providing processed biomass linkages along with maintenance backup facilities. As an implementing partner, TERI focused on awareness generation, demand creation, technology development and customisation, capacity building, establishing local supply chain for biomass, and capacity building of manufacturers, local service providers and operators in selected industrial clusters.

**Box 1. Biomass Gasification Technology**

**In a biomass gasifier, solid biomass fuels (wood, agriculture residues, briquettes, etc.) are converted into gaseous fuel (producer gas) by a series of thermo-chemical processes. The producer gas has calorific value of about 1000–1200 kcal/$Nm^3$ and consists mainly of carbon monoxide, hydrogen, and nitrogen. One kilogram of biomass produces about 2.5 $Nm^3$ of producer gas. The producer gas can be used as fuel in burner for producing heat energy or in IC engine for mechanical power and electricity generation. The schematic diagram shows the general scheme of a biomass explaining the working arrangement. A biomass gasifier has four different temperature zones consisting of drying, pyrolysis, combustion and reduction zone that converts the solid fuel into combustible gas.**




Under the SDC–TERI partnership, over 650 biomass gasifiers have been installed for meeting the thermal energy needs of MSME clusters in the country. These replications, which are demand driven, have established biomass gasifiers as a cost-effective energy delivery system. They have also resulted in generating positive spin-off effects within and across clusters. The experience has demonstrated the financial viability of biomass gasifiers. The payback period for an MSME unit using different types of fossil fuels is anywhere between six to nine months. This payback period, however, increases to around two years if the fuel is replaced with biomass. The experience also shows that there is a significant reduction in cost per unit of useful energy through gasification. In case a fossil fuel is replaced, the reduction is as much as 60%–80%, while for biomass fuels, it is 50%. For example, for thermal applications like water heating, hot air generation, drying, cooking and steam generation, the cost per unit of useful energy through gasification is 60% cheaper than furnace oil / diesel option, and 80% cheaper than the electricity option at current prices of diesel, electricity, and biomass fuels. Another key economic benefit is improved productivity of MSMEs, and the subsequent improvement in quality of end products as a result of better processes and uniform heat control.

Further, the interventions have created local manufacturing and delivery services in a few MSME clusters, thus providing employment and establishing clean energy entrepreneurs. The recent energy pricing and implementation of pollution norms for MSMEs have also created a favourable environment for rapid acceptance of this technology. Finally, the enforcement of stringent environmental and pollution norms has emerged as a new driver to encourage use of biomass thermal gasifiers.

## Investment Potential for Biomass Gasifiers

The experience of scaling-up has shown that there are continuing challenges. However, these continuing challenges open up multiple entry points for investment potential in biomass gasifiers to meet thermal energy needs in India's MSME sector. The market size is large and very little of it has been tapped. Then there is a potential for investing in technology upgradation to meet the demands of MSME sector. Since the energy requirements of MSMEs vary, this creates potential for employment creation through local manufacturing and cluster level service delivery systems.

The experience from the dissemination efforts show that the current installation is just a small fraction of the potential and opportunity that exists. In other words, there exists huge untapped potential. Biomass gasifier systems can meet thermal energy capacity needs ranging from 25 $kW_{th}$ (kilo watt thermal) to three $MW_{th}$, and fulfil the temperature requirements of MSME units ranging from 60 °C to 1000 °C. For example, of the 26 million MSMEs operational in the country, 6.78% manufacture textile items, 14.26% cater to food products and beverages, and 3.77% account for other non-metallic mineral products. Together these sectors account for 25% of the total MSME units in India. From the sector-wise distribution above, it is known that the textiles, food products and beverages and other non-metallic mineral products are considered to be low heat applications. The temperature requirement in these sectors varies from 150 °C to 600 °C, which can be easily met by thermal biomass gasifiers. Therefore, there lies a vast potential (approximately 6.5 million units) for the use of biomass-based clean energy solutions (such as biomass gasifiers) in the sectors mentioned above.

This, in turn, opens up opportunities for applications in other units such as silk reeling, textile dyeing, hot water / steam generation, food processing, non-ferrous metal recycling (aluminium and lead), powder coating, chemicals, foundries (allied core baking operations), glass melting, charcoal and brick making and ceramics. Box 2 provides a quick snapshot of high potential MSME clusters with varied application.

**Box 2. Examples of High Potential Clusters**

Under the SDC biomass energy programme, a market research was conducted by Indian Market Research Bureau (IMRB) to gain a better understanding of the potential of the thermal biomass gasifier market in India, This exercise was primarily undertaken to identify the energy requirements of certain MSME clusters and determine the suitability of the biomass gasifier technology for intervention in such clusters. Twelve clusters were covered by this study and were classified as low, medium and high potential markets for thermal biomass gasifiers based on the findings from the study. Some of the high potential clusters identified from this study demonstrate the overall potential that exists.

**Chemical Units, Ankleshwar, Gujarat**

The chemical units cluster in Ankleshwar has about 610 units. The small-scale chemical units in Ankleshwar used 4.6 million kg of natural gas on an annual basis. Additionally, medium- and large-scale units consumed 168.72 million kg and 644.41 million kg of natural gas annually. Therefore, the use of a total of 817.73 million kg of natural gas could be abated by use of biomass gasifiers and result in substantial savings on fuel cost in this cluster.

**Snack Units, Indore, Madhya Pradesh**

In Indore, about 1100 snack manufacturing were identified as high potential cluster for gasifier intervention. As per the study, the small-scale, medium-scale and large-scale units in this cluster used 8.2 million kg of wood, 5.47 million litres of diesel, and 9.3 million kg of natural gas on an annual basis to meet its process heat requirement. This, if replaced by biomass-based clean energy solutions, can result in huge energy savings on a large scale and contribute towards making a positive environmental impact.

**Powder Coating Units, Surat, Gujarat**

In Surat, there are about 80 powder coating units in the cluster, which are suitable for gasifier intervention. The market study indicates that the large- and medium-scale sized units operating in this cluster use 0.42 million kg of natural gas on an annual basis. The small-scale units in Surat at present use 0.13 million kg of LPG annually to meet their process heat requirements. Biomass gasifiers would be an economical and viable alternative for replacing these conventional fuels.

**Namkeen and Bakery Units, Nagpur, Maharashtra**

Nagpur has about 200 namkeen making units using wood and LPG and 350 bakery units, which uses diesel and wood. The study showed that 23.8 million kg of wood and 1.08 million kg of LPG used in these namkeen making units could be replaced by biomass gasification based systems. Additionally, 0.72 million litres of diesel and 72 million kg of wood could be substituted through use of biomass gasifiers.

The second area of investment potential is in technology upgradation. In addition to these MSMEs, the gasifier can also meet energy needs of other industries where precision heating is required. However, this would require further technology upgradation including system automation in order to make gasifier systems more robust and user-friendly.

The third area of investment potential is in the creation of local service delivery mechanisms through a combination of local manufacturing, biomass energy supply chain and job creation for skilled manpower. The diversity of energy requirements of MSMEs means that the gasifier systems need to be customised or tailor-made to suit each end-use application (Box 2). This requires that the technology is manufactured locally and thus creating pockets for local employment creation through setting-up appropriate local support services in the form of local manufacturing, supply, and maintenance and a pool of skilled human resources. Unlike other energy carriers, organisation of biomass supply chain and fuel supply linkages is of critical importance. Experience shows that MSMEs are reluctant to stock biomass as it requires more space, and therefore, a local biomass supply chain and delivery mechanisms are needed to ensure sustained availability of biomass.

## Way Forward

The paper by drawing on the experience of a long cooperation for promoting biomass gasifier for thermal applications in MSME units has identified some potential investment opportunities. As the experience of SDC's partnership with TERI has shown, biomass thermal gasifier, as a renewable energy option, is economically viable and likely to remain so in the future. The past and on-going efforts have resulted in a significant improvement in the understanding of the technology, in the uptake and diffusion of the gasifier in MSMEs, and in the identification of key barriers and opportunities with respect to accelerated dissemination. However, to move forward, there is a need to address the following challenges.

### Framework providing holistic energy policy for MSME sector

While there is a policy-level commitment for renewable energy in general, and for integration of renewable energy and energy efficiency in large industries, the MSME sector in itself does not have a holistic energy policy. Other energy-intensive sectors, which have developed some frameworks for energy conservation including increasing the share of renewable energy, have given impetus to these sectors. A similar framework or policy / regulation is needed for the MSME sector as a whole. Such a framework could have a target in terms of increasing the share of renewable energy or regulations, which mandate the use of renewable energy as the main source of energy for certain levels of thermal energy use in MSMEs.

## Strengthening and mobilisation of stakeholders

An enabling framework will assist in mobilising industry association to shift towards renewable energy solutions and district industry centres, which play a key role in supporting MSMEs to provide awareness and demonstration of these solutions. These associations and district centres can play a critical role in strengthening institutional structures to facilitate gasifier deployment. Technical institutions are needed for skills development and training. Similarly, the financial institutions need to develop innovative financial products for MSME clusters.

## Cluster service approach

In order to scale up, there is a need to undertake a cluster approach with the objective of saturation with renewable energy solutions directly or integrated with energy efficiency measures. A cluster service approach with involvement of a local manufacturer/local service provider, which offers multiple services of technology supply, biomass supply, maintenance and awareness creation, can be a potential model for accelerated diffusion.

In conclusion, to enable leapfrogging of biomass energy technologies in the MSME sector, it is important to move the solutions out from research and technology demonstration (supported by bilateral agencies and the government) to commercialisation with involvement of private sector and industries. This will result in economies of scale and technology upgradation to compete with other energy or renewable energy options.

# All in One Pot: Improved Cookstoves for Better Health and Environment

## *Towards an 'Energy Plus' Approach for the Poor: A Review of Good Practices and Lessons Learned from the Asia and the Pacific*

*Aprovecho Research Center**
*79093 Highway 99 PO Box 1175 Cottage Grove Oregon 97424, USA*

## Background

In Asia-Pacific, almost two billion people are dependent on the traditional use of biomass and almost 800 million have no access to electricity[1]. The resulting emissions present a range of problems.

### Fourth-highest health risk in developing countries

Indoor air pollution from burning biomass fuels ranks as the fourth highest health risk in developing countries. According to the World Health Organization (WHO), more people in the developing world die from indoor air pollution than from malaria. Globally, about 1.6 million people—mostly women and children under the age of five – die every year of pneumococcal pneumonia, meningitis and sepsis caused by indoor air pollution.[2]

### Climate change, deforestation and gender issues

Incomplete combustion of biomass produces greenhouse gas (GHG) emissions that contribute to climate change. However, the clean burning of biomass can provide a readily available carbon neutral cooking method when the fuel is sustainably harvested. The use of wood often exacerbates deforestation, and its collection is a demanding, sometimes dangerous chore, usually undertaken by women and young girls.

### Challenges to producing improved cookstoves

For decades, individuals and institutions have been working on developing and disseminating improved cookstoves (ICSs). But these efforts face multiple challenges: an ICS has to minimize adverse impacts on health, fuel use and climate change, while also making cooking an easier, cleaner and more pleasant task.

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* *This paper has been reproduced here with permission.*

1 *IEA, UNDP and UNIDO, 2010.*

2 *WHO, 2005.*

Years of hard work have produced ICS models that meet the various needs of cooks in different cultures. In general, ICSs are easier to manufacture on a large scale when charcoal is the fuel used. Burning woody biomass cleanly requires materials that are more difficult to procure and techniques that are more difficult to apply in mass production.

### Challenges to disseminating ICSs

The commonly used dissemination model is the artisanal approach, where local artisans are trained to build and sell ICSs as an add-on activity to their existing pottery work. However, it can be difficult to bring small artisanal units up to speed in the methods needed to make high-quality components, such as abrasion-resistant refractory ceramics, high-quality stove bodies and long-lasting stove tops with tolerances measured in millimetres. Lack of materials and security can also hamper successful local production. As a result, the numbers and quality of stoves produced have fallen short of need, and the majority of users of traditional biomass cookstoves have not yet been reached.

### Newly defined and codified ICS

The definition of an ICS has been expanded and codified in recently proposed performance standards now used by the United States Environmental Protection Agency (USEPA), the World Bank and the Shell Foundation (see Box 2 in Section 3.4).

## Overview

The Aprovecho Research Center (ARC) is a not-for-profit USA corporation involved in the design of efficient stoves. Shengzhou Stove Manufacturers (SSM) in Zhejiang Province, China, is the largest manufacturer of domestic coal stoves in China, selling 3 million combustion chambers and 500,000 ceramic coal stoves annually.

Since late 2007, the two companies have worked together to design and produce a new range of high-quality ICSs that meet the Shell Foundation benchmarks for fuel use reduction and lowered emissions. Production began in 2008, and in the first year SSM shipped about 90,000 factory-built stoves to projects worldwide.

In 2008, ARC started StoveTec, a for-profit corporation in the United States, to oversee the business development, marketing and promotional aspects of this new partnership. Today, StoveTec is one of the few companies selling ICSs that meet both international performance benchmarks and are sold at close-to-cost prices. SSM's commitment to the partnership has been substantial: in addition to investing over USD 1 million in new production facilities, it has recruited 20 additional workers to manufacture the StoveTec stoves.

## Implementation strategy

### Business model

StoveTec is responsible for ICS design, testing, marketing and sales, while SSM oversees production and shipping. Stoves are manufactured at a single centralized production facility with a capacity of more than 1 million stoves per year, and are distributed worldwide.

At the local level, StoveTec partners with existing distributors – including companies, government programmes and non-governmental organizations (NGOs) – who use various approaches including commercial sales, subsidies and micro-credit (see Box 1). StoveTec derives its income from the sale of stoves and emissions equipment used to test stove performance. On humanitarian grounds, stoves have been provided to users in refugee camps free of charge.

**Box 1. Examples of local distribution of ICS**

Micro Energy International (MEI) group in the Republic of Uganda uses microfinance to promote sustainable energy products. MEI is planning a two-year project with FINCA Uganda (Foundation for International Community Assistance), a large microfinance institution. FINCA Uganda has more than 45,000 clients, to whom MEI hopes to sell about 10,000 StoveTec stoves in the first two years of the project. MEI also plans to target small entrepreneurs and retailers who can help distribute more ICSs.

In Kenya, Food for the Hungry and World Vision, a joint venture between the Paradigm Project and Impact Carbon, is planning to distribute 200,000 stoves for carbon credits over a four-year period.

Envirofit, an Indian NGO, has sold more than 100,000 biomass stoves in four states in southern India. The stoves are sold through a multi-tier distribution strategy, involving dealers, distributors, village entrepreneurs, NGOs and self-help groups. Envirofit has over 500 channel partners with roughly 1,500 outlets throughout southern India.

#### Low-profit, high-volume production and sales

The business model used is one of low-profit and high-volume production and sales (traditionally used to established distribution chains). In developed markets such as the USA, StoveTec sells stoves directly to individual consumers and wholesale to retailers. Sales in the USA market are largely through an e-commerce website designed for this purpose. In the USA and European markets, the stoves are appreciated by outdoor sporting enthusiasts, campers and preparedness advocates working with communities in natural disaster recovery. StoveTec also uses its presence in developed markets to raise awareness about the need for efficient stoves: recently, a programme was launched for customers in developed markets to purchase ICSs for cooks in developing countries.

#### Cross-subsidization of sales in developing countries

StoveTec's sales in developed countries generate profits that help to fund stove projects in developing countries. In developing markets, StoveTec only sells stoves wholesale to distributors and retailers. StoveTec offers pre-sales support, providing connections to partners that can help arrange project financing and microcredit. It also offers pre- and post-sales marketing and advertising support, and helps identify stove transportation options from arrival port to the local warehouse and distribution centres. StoveTec also sends ICS samples to local consumers, giving them the opportunity to assess the suitability of the stove in the local context. More information on distribution and marketing is provided below.

## Product design and production process

As described in Figure 1, three models of StoveTec stoves have been developed based on feedback from users through focus groups worldwide.

**Box 1. Examples of local distribution of ICS**

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| | |
|---|---|
| **StoveTec Wood Stove** can be used with wood and other biomass fuel types, including dried corn cobs, fronds and grass.<br>Two models:<br>24 cm diameter top, weight: 7.3 kg<br>26 cm diameter top, weight: 8.2 kg |  |
| **StoveTec Wood-Charcoal Stove** can be used with the same variety of fuel types<br>as the Wood Stove, while providing the additional option of using charcoal.<br>One model:<br>26 cm diameter top, weight: 8.6 kg |  |

***Figure 1.** StoveTec wood stove and wood-charcoal stove*

## Product design and production process

As described in Figure 1, three models of StoveTec stoves have been developed based on feedback from users through focus groups worldwide.

All stoves are based on the 'rocket' design developed by Dr Larry Winiarski, using an engineered USD 2 lightweight refractory ceramic combustion chamber. The StoveTec Wood Stove burns only wood, and has a single door for adding the fuel. A StoveTec Wood-Charcoal Stove has two doors, with a lower door for controlling primary air and an upper door for fuel entry.

The stove combustion chambers are made from a unique lightweight clay that, when fired, produces a light yet durable insulating ceramic material that is resistant to abrasion. Combustion chambers are weighed to ensure uniformity. Stoves are also tested for emissions in the laboratory at the factory. Lab and field tests have demonstrated that StoveTec stoves last at least two years when used three times a day, with little deterioration in performance. Centralized production reduces per-unit production costs, and improves quality control so that every stove meets performance standards.

Stove finishing and packaging are adapted and branded according to customer requirements, and instruction manuals are provided in the local languages where the stoves are used. An adjustable pot skirt which improves heat transfer to the cooking pot (hence increasing stove efficiency) is also included.

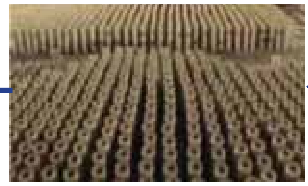
In response to feedback from the German Agency for International Cooperation (GIZ), StoveTec also offers the ceramic combustion chamber as a very low-cost all-ceramic stove. Moulds are provided that can be used to make attractive cement bodies for finishing the stove in-country. Purchasing parts for assembly in-country provides local manufacturing jobs while reducing duties. A new version of the stove that can last five years under the same conditions is being developed for participation in carbon financing programmes.

The stove production process is described in Figure 2.

The clay is bought from a local mine, about 2 km away from the factory.

The clay is sorted and mixed with sawdust, other materials and water to form damp clay.

SSM uses an innovative technique to extrude the clay through a mould, cut it into sections, trim it, cut the door opening and shape the top.



The combustion chambers dry under cover at ambient temperature for a few days before being moved into the 45,000-stove capacity drying sheds for up to a week. Here they are dried by waste heat that is pumped through vents in the floor from the large ceramic kiln.

Stoves are moved into the low-smoke ceramic kilns, which are fueled by coal (about 25%) and sawdust (75%).

The chambers are fitted into the stove bodies, made from locally purchased, galvanized, enamel-coated steel sheets, painted to give an attractive finish to the product

The f ired, ceramic combustion chambers thus produced are tough and resistant to abrasion. They are then ground to precise dimensions and finished.

The chambers and the stove bodies are taken to the new assembly and shipping facility, a short distance from the factory.

The cast iron tops (designed by ARC/SSM and produced by a local manufacturer) are added, and handles are fixed in place. The refractory cement floor is then cast inside the stove.

After testing, the stoves are packaged, loaded into shipping containers and transported to the port of Ningbo for shipping..

***Figure 2*** *Production flow chart for Stovetec stoves in Shengzhou, China*

## Distribution and marketing

### Adapting established production facilities

Clear advantages follow from finding an existing factory and adapting it to manufacture new products, as was the case with SSM.

### Collaborating with established distributors

Rather than trying to create large-scale distribution chains from the ground up, StoveTec identifies existing distributors with knowledge of local tastes and preferences, and collaborates with established distribution chains to deliver stoves to cooks who need them. Distributors use a variety of financing mechanisms (depending on their market and their mission), which has helped gain acceptance from users in the market. As discussed in Box 1, the NGO Envirofit had developed a multi-tier distribution network of 500 channel partners comprising dealers, village entrepreneurs and community groups to disseminate SSM stoves in southern India

### Partnering in regional distribution hubs

StoveTec is currently working to establish regional distribution hubs with partners in India, the Republic of Haiti, the Republic of Kenya, the Marshall Islands, the United Mexican States, the Republic of Nicaragua, the Federal Republic of Nigeria, South Africa and Uganda.[3]

GIZ is a key StoveTec partner. GIZ manages two programmes in southern Africa that are disseminating stoves for both rural and urban markets. These are the Basic Energy Climate Change Alleviation Project (BECCAP) and the Programme for Basic Energy Conservation (ProBEC). BECCAP has located existing distribution chains in South Africa, and is creating an on-the-ground affiliation of StoveTec stove distributors for further scaling-up. A series of 40 energy stores in South Africa now offer the stoves for sale. ProBEC, in turn, has distributed about 2,600 stoves for market testing in nine southern Africa countries. The long-term goal of the partnership is to create a successful distribution system that can be replicated in other areas.

## User needs vs. emission benchmarks

To succeed in the marketplace, ICSs must fulfill user needs. Consequently, StoveTec stoves have been developed in consultation with design committees, including local women in Africa, Asia and Central America.

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[3] *Photovoltaic stores in Nicaragua have recently begun selling ICS stoves. A utility in the Republic of Botswana is also offering StoveTec stoves. A large manufacturer of treadle pumps in India is considering adding stoves to its product range. In Nigeria, Kadsol Ltd., a logistics company, is a StoveTec partner.*

In India, for example, cooks in more than 10 villages participated in week-long design sessions where engineering principles were explained and prototype rocket-type stoves were built. The stoves had to be satisfactory to cooks whilst meeting fuel-use and emission performance benchmarks developed by the Shell Foundation (see Box 2). The prototype stoves were tested in the field using the 'controlled cooking test', and were then subject to a standard water-boiling test under an emissions hood at the ARC lab.

**Box 2. Efficiency and emission performance benchmarks for ICSs**

The Shell Foundation has developed the following performance benchmarks for ICSs:

- **Fuel use.** Using the 'international testing pot' from a cold start, a wood-burning stove without a chimney should use less than 850 grams of wood to bring 5 litres of 25°C water to a boil and then simmer it for 45 minutes. This is known as the water boiling test (WBT); and
- **GHG and particulate emissions.** The same process should produce less than 20 grams of carbon monoxide and less than 1,500 milligrams of particulate matter (2.5 microns or smaller).

Independent third-party market tests of the StoveTec stoves conducted in the Republic of Bolivia, the Republic of Peru, Tanzania and Uganda showed that cooks appreciate these stoves largely because of their fuel efficiency and reduced cooking time. Both lab and field tests show reductions in fuel use and emissions.[4]

Field performance of ICSs varies with on-the-ground conditions.[5] ARC has also conducted standardized testing of its stoves under an emissions testing hood. The results are provided below.

### Fuel efficiency

The three StoveTec models use roughly the same amount of wood to complete the WBT. They use about 33 percent less fuel than the laboratory three-stone fire, whilst the use of a pot skirt saves approximately 25 percent more. The StoveTec Wood-Charcoal stove uses 40 percent less charcoal than the traditional charcoal-burning Jiko stove.

### Particulate emissions

StoveTec Wood Stoves reduce particulate matter by 50%–75% when compared to the three-stone fire. The stoves meet the Shell Foundation particulate benchmarks of performance (with or without a pot skirt).

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4 *StoveTec, 2010.*

5 *For further information regarding international field studies, refer to the India Field Report (MacCarty et al., 2008b), the Uganda Controlled Cooking Test (Tyler, 2009) and the Marshall Island Field Report (Trevor, 2009).*

### GHG emissions

StoveTec Wood Stoves (with or without the pot skirt) produce less than half of the carbon dioxide emissions of a three-stone fire.

### Safety

Using a safety analysis based on the protocol developed at Iowa State University, StoveTec stoves obtain a score between 33-36 out of 40, depending on the size and model of the stove (see Table 1).

**Table 1. StoveTec Stove Safety Performance**

| Safety Evaluation | Score/4 | Comments |
|---|---|---|
| Sharp Edges/Points | **3** | **Metal around door is slightly sharp** |
| Cookstove Tipping | 3-4 | The wider stoves models are more stable |
| Containment of Combustion | 3-4 | The two-door stove has better containment |
| Expulsion of Fuel | **4** | |
| Obstructions Near Cooking Surface | 3-4 | Greater obstruction if a skirt is used |
| Surface Temperature | 2 | The stove body does get hot |
| Heat Transfer to Surroundings | 4 | |
| Cookstove Handle Temperature | 4 | Wooden handle remains cool |
| Flames/Heat Surrounding Cookpot | 3 | |
| Flames/Heat Exiting Fuel Chamber | 4 | |
| **Total Score (out of 40)** | **33-36/40** | |

## Production capacity and product development

### Recruitment and training

SSM is responsible for manufacturing the stoves, and trains all production workers in-house. Only qualified people are recruited for skilled positions such as welders, mechanics and electricians. For general production, SSM looks for people with experience in ceramic making.

### Expanded production capacity

SSM has greatly expanded production capacity by constructing four new factories and making production more automated. As a result, 18 combustion chambers can be made by the company every minute.

### Design development and quality control

ARC is responsible for continuing design development. In response to customer feedback from GIZ experience in the field, a door liner was added for the two-door model. ARC staff visit the SSM factory every four months to check on production quality and to give technical advice. SSM quality checks a sample of each batch of stoves, and has won government quality awards following regular inspections by the central and local governments. ISO 2001 certification is in process.

### Standards and monitoring

ARC has helped SSM to set up a new laboratory at the factory to test stoves for emissions and fuel efficiency using internationally approved standard testing protocols. The firewood use is measured, along with carbon monoxide, carbon dioxide and particulate matter emissions. Durability tests are also carried out in nearby villages and at the factory

### Project costs

Over the past two years, SSM has invested roughly RMB 8 million (USD 1.2 million) in the new stove production line, mainly using accumulated profits. ARC has invested USD 145,000, bringing the total investment to USD 1.35 million.

## Impacts

In the first year of distribution, over 90,000 stoves were sent to stove projects in Argentina, Chile, Ethiopia, India, Madagascar, Marshall Islands, South Africa and Tanzania. About 350,000 people have been reached.

StoveTec's contribution to the attainment of Millennium Development Goals (MDGs) is outlined below.

### Fuelwood savings, incomes and livelihood impacts (MDG 1)

#### Fuelwood savings

Worldwide, almost 2 billion people use traditional biomass (e.g. wood, dung, crop residues) and coal for household cooking and heating. In many regions, wood is a purchased resource (for many, an expensive one). More efficient cooking stoves, therefore, can reduce household expenditure. Laboratory and field tests of StoveTec stoves show 40% of fuelwood saved (50% if a pot skirt is used), and a 20-40% reduction in cooking time. Saved income can be spent on alternative needs, including education, food, clothing, shelter and medical treatment.

### Promoting local businesses

By using local distribution channels, StoveTec supports existing businesses, provides a high-quality product that enhances the distributors' image and thereby creates potential for expanded employment by the distributors.[6]

## Health and gender impacts (MDGs 3, 4, 5 and 6)

| | |
|---|---|
| Using ICSs offers multiple health benefits, particularly for women and children: | … In most societies, women are in charge of cooking and – depending on the demands of the local cuisine – they spend between three and seven hours per day near the stove, preparing food. 59% of all indoor air pollution-attributable deaths thus fall on females. Young children are often carried on their mother's back or kept close to the warm hearth. Consequently, infants spend many hours breathing indoor smoke during their first year of life when their developing airways make them particularly vulnerable to hazardous pollutants. As a result, 56% of all indoor air pollution-attributable deaths occur in children under five years of age. **WHO, 2005** |
| ▪ reduced indoor and neighborhood air pollution results in less respiratory diseases (including pneumonia) and eye diseases. Children and women are the primary beneficiaries | |
| ▪ improved health results in a lower expenditure on medications and lowers mortality rates; | |
| ▪ reduced particulate matter and lower carbon monoxide emissions help to alleviate neighbourhood and indoor air pollution, including personal exposure levels to cooks and their families; | |
| ▪ a safer way to cook prevents injuries and accidents that are common when cooking over open fires; and | |
| ▪ reduction in cooking time allows cooks more time to participate in other family or social activities. | |

## 4.3 Environmental impacts (MDG 7)

Use of biomass fuels for cooking and heating contributes to deforestation and global warming. StoveTec stoves require less fuel than other traditional stove cooking methods and emit far fewer pollutants, reducing the pressure on forests and decreasing the volume of GHG and particulate emissions. A single StoveTec stove reduces GHG emissions by an estimated 1.5 tonnes every year.

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6 *In addition to fuelwood, these stoves can burn biomass such as agricultural waste, grasses, palm fronds and corn husks.*

## Project Sustainability

Various factors contribute to the sustainability of the StoveTec dissemination model:

- stoves are sold in markets where distributors profit from sales;
- microfinance, bank loans and government assistance, among other measures, make stoves affordable to the user;
- if developed, a vertically integrated carbon credit programme can make large-scale distribution possible. Such programmes can put stoves in the hands of humanitarian aid and development organizations, providing structure and expertise to facilitate carbon-credit rebates; and
- StoveTec locates strategic partners who can act as project implementers in addition to aiding with financing, logistics, warehousing, monitoring and tracking.

### Experience with expansion

First year sales figures and increasing interest in the StoveTec stove suggests vast potential for expansion. SSM now produces 10 times as many stoves as StoveTec distributed in its first year. As distribution expands, increased opportunities for local transportation, sales and service enterprises will follow.

StoveTec is now working with a variety of partner organizations to replicate the distribution model and to mainstream distribution of ICSs to countries where traditional cook stoves are predominant. The partners include: the World Bank; Shell Foundation; Philips Corporation; Bosch Siemens; GIZ; ProBEC; the WHO; the World Food Programme; Trees, Water & People; AidAfrica; Asia Regional Cookstove Program (ARECOP); and the Nature Conservancy.

## Lessons Learned and Good Practices in Expansion of Energy Services for the Poor

The ARC/SSM partnership won the 2009 International Ashden Energy Champion Award for their production of “cheap, robust and efficient stove for mass production to developing countries”.[7]

### A robust, high-quality product

StoveTec stoves consistently meet established benchmarks for ICS performance, due to the following factors:

- production of components in a centralized production unit under strict quality control;

7 *The Ashden Awards for Sustainable Energy, 2009.*

- low costs, in part through large-scale manufacture and transport by sea freight; and
- continuous product improvement through field tests by real-world cooks and product development facilities.

### Leveraging comparative advantages of partners

ARC specializes in stove research, development and testing, whilst SSM is a mature industrial partner with decades of manufacturing experience. In bringing together the skills and expertise of these complementary organizations, StoveTec stoves have created a win-win situation. Specifically, StoveTec is leveraging its relationship with SSM to bring quality ICSs to the world in large quantities, while SSM is using this relationship to expand its market to regions outside China. StoveTec, meanwhile, utilizes ARC's relationships with international partner organizations to scale up distribution.

### StoveTec's business model

StoveTec's business model is to make a narrow profit through sales slightly above production cost. Thus StoveTec is not an obvious choice for investors seeking large returns. Therefore, whilst StoveTec's role in distributing the stoves could be replicated, it is unlikely that most commercial parties would be interested.

Instead, StoveTec seeks to help development and aid organizations meet the needs of their constituents for ICSs worldwide. StoveTec is currently investigating the possibility of carbon credit financing with the aim of using carbon credits to reduce the sale price.

### Continuous focus on developing knowledge and dissemination

ARC has contributed significantly to an extensive network of partners in the ICS community.[8] It has produced a number of ICS publications, including eight cooking and heating technology manuals and journal papers on lab and field stove performance, and global warming impacts.[9]

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8 *The network includes: the Partnership for Clean Indoor Air; the USEPA; the World Bank; Shell Foundation; Philips Corporation; Bosch Siemens; GIZ; ProBEC; the WHO; the World Food Programme; University of California at Berkeley/Center for Entrepreneurship in International Health and Development/Berkeley Air; University of Illinois; Colorado State University; Iowa State University; University of Oregon; United States Agency for International Development; Trees, Water & People; AidAfrica; ARECOP; and the Nature Conservancy.*

9 *Bryden et al., 2005; Winiarski, 2005; Still and MacCarty, 2006; ARC, 2007; 2008; MacCarty et al., 2008a; Still and MacCarty, 2009.*

## Conclusions

The ARC/SSM partnership capitalizes on the relative strengths of both companies. The business model, which is based on low-profit and high-volume production and sales, offers several innovative practices, including:

- involving users in stove design process, backed by world class research;
- capitalizing on the strengths of existing distribution channels, including dealers, distributors, village entrepreneurs and not for profit organizations; and
- cross-subsidization of stoves in developing countries through sale of stoves (at market price) to developed countries.

More than 90,000 stove users around the world today use stoves manufactured by SSM, and are experiencing multiple MDG impacts in terms of improved health through reduced indoor air pollution, improved local environment, freeing time for women and fuel (and monetary) savings.

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# Off-Grid Solar Photovoltaic Market in India: Potential and Investment Opportunities*

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## Off-Grid Solar Photovoltaic Products and Applications in India

### Background

Nearly 80 million[1] households in India (i.e., around one-third of India's population) do not have access to electricity. Additionally, around another 50–60 million households have access to unreliable and intermittent electricity supply. In the absence of grid electricity, petroleum fuels like kerosene and diesel are widely used for meeting the requirements for lighting, operation of appliances, pumping water, motive power, etc. Around 180 million households[2] are using kerosene for lighting purpose and spending around 2.2 billion USD annually on kerosene which is subsidised by the Indian government. The poor access to electricity is also adversely affecting the livelihood activities and productivity of hundreds of millions of people both in rural and urban areas. Additionally, the use of costly and polluting fuels such as diesel for generating electricity is affecting the economic growth of the country as well as the environment.

India is endowed with abundant solar radiation – 4 to 7 kWh/m$^2$/day – in most parts of the country for about 270–300 days in a year. In recent years, a wide range of off-grid solar photovoltaic (PV) products have been introduced in the market for various applications and are becoming popular in areas having no access or poor quality grid electricity supply.

### Introduction to solar photovoltaic technology

Solar photovoltaic (SPV) technology enables direct conversion of sunlight into electricity. PV cells, commonly known as solar cells, are used to convert light (photon) into electricity. The commercially available solar cells are usually made up of monocrystalline or polycrystalline silicon, or are thin film PV cells such as cadmium telluride (CdTe) and copper indium gallium selenide (CIS).

* *This paper does not include grid-connected rooftop solar PV, grid-connected or off-grid micro / mini grid for village electrification and solar PV power systems for captive use in commercial, institutional and industrial premises.*

1 *Census of India, 2011*

2 *Report on 'Lighting Asia: Solar Of-Grid Lighting', by International Finance Corporation, 2012.*

***Figure 1*** *Solar photovoltaic modules*

A number of solar cells are joined together to make an SPV module (Figure). The electrical output of a solar cell / PV module is rated in terms of peak watt ($W_p$), which is the maximum power output that the PV module could deliver under standard test conditions.

The output power from an SPV module is in the form of direct current. Depending upon the end use requirement, solar modules are used directly or in combination with inverters to convert the direct current output from SPV into indirect current. Storage batteries are also used to store the electrical power for later use when power is not available directly from the sun (Figure 2). A PV system can be used to provide electricity for lighting, water pumping, and battery charging as well as for feeding power to the grid, etc. Some of the advantages of SPV systems are its long-life, reliability, and no recurring requirement of fuel, low maintenance and no pollution. The PV technology is one of the most promising ways to generate electricity in a decentralised manner at the point of use for providing electricity.

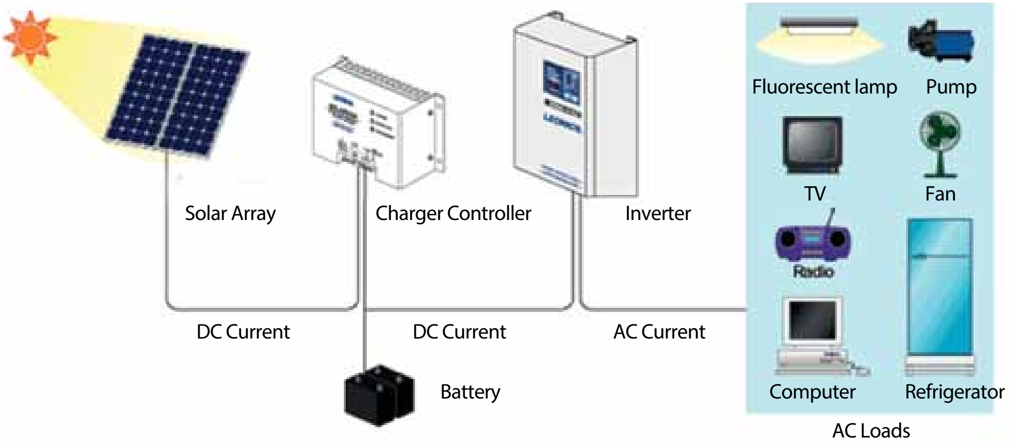


***Figure 2*** *Schematic of solar photovoltaic technology application*
***Source.*** *www.leonics.com*

## Off-grid SPV products and potential applications

A wide range of off-grid SPV products are available in India to cater to the diverse market with capacities ranging from, as low as, below one Watt to, as large as, a few kilowatt. The off-grid SPV products and their potential applications are described below.

### Off-grid SPV products for household applications

For household applications such as lighting or powering other appliances, large range off-grid SPV products are available in the market depending upon the requirements and purchasing power of a household.

#### *Solar lanterns/lamps*

Solar lanterns/lamps are portable standalone products used for lighting purpose (Figure 3). It mainly comprises a small PV module, battery and lighting device (which can be an LED bulb or a CFL, with LED bulbs being preferred more these days). Generally, a point for mobile charging is also provided in the lanterns. The typical capacity of a solar lantern varies from 0.5 $W_p$ to around 10 $W_p$. In some of the smaller lanterns, the solar module is usually mounted on the lantern itself, however, for higher capacity lanterns, the module is provided separately. Kerosene lamps are the main source of lighting in un-electrified regions where majority of the inhabitants are poor families. Apart from other applications, solar lanterns can be the direct replacement for kerosene lamps in these regions.

***Figure 3*** *Solar lanterns*

#### *Solar home systems*

Solar home systems have PV modules and batteries of higher capacities as compared to solar lanterns. Typical capacities of solar home systems usually vary from 10 $W_p$ to 25 $W_p$. Most of the solar home systems can power 2–3 lighting points and a mobile charging point; several of them can also power small fans. Some of the higher capacity models are also capable of powering a small television set. However, solar home systems usually do not have inverters and can power only those appliances that operate on direct current (DC) power (Figure 4).

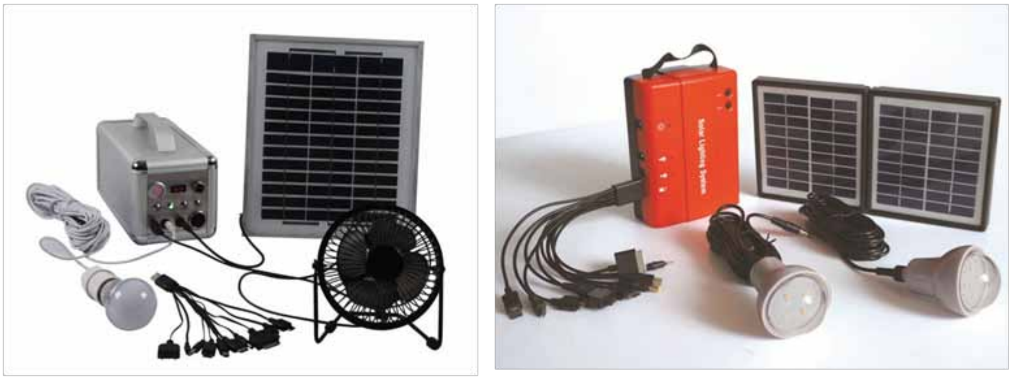

***Figure 4*** *Solar home system*

### *Rooftop solar power packs*

Rooftop solar power packs mainly comprise a solar module, battery, inverter and control system. It provides output power in the form of alternating current (AC) and can power lights, fan, and other household appliances. Generally, the capacity of a typical off-grid rooftop solar power pack for household applications varies from 50 $W_p$ to 2 $kW_p$. These can be used as the main power source in un-electrified areas and as a back-up source in regions of unreliable electricity supply. A typical schematic of a solar power pack is as shown in Figure 5.


***Figure 5*** *Schematic of solar home system*
***Source.*** *www.jjsolar.in*

### Solar-powered water pumps for irrigation and water supply schemes

Solar-powered pumps are widely used to draw water from underground or from other surface source for irrigation purpose as well as for rural water supply schemes. A large range of solar-powered pumps—surface and submersible pumps, and DC-powered and AC-powered pumps—are now available in the Indian market. The capacities of solar pumps can vary from as low as 200 $W_p$ to as high as 7.5 $kW_p$ or even more (Figure 6).

***Figure 6*** *Solar pump*
***Source.*** *www.hbl.in*

### Solar power packs for various services in villages and peri-urban areas

Solar power packs may be best used for essential services and in centres like banks, petrol stations, telecom towers, post offices, community services in villages, etc., that are located in regions with unreliable electricity supply (Figures 7 and 8). These centres mostly rely on diesel generators for their operation. Solar power packs can be a potential alternative power source for their requirements and some of these centres are already using solar power packs. These solar power packs comprise SPV modules, inverter, and electronic controls, and may be battery for storage depending upon the requirement.


***Figure 7*** *Solar powered petrol station*
***Source.*** *www.su-kam.com*

***Figure 8*** *Solar power pack for a telecom tower*

### Solar power packs for livelihood activities in villages and peri-urban areas

Majority of the population in villages and peri-urban areas are dependent on livelihoods such as horticulture, dairy, fisheries, poultry, and village/cottage industries. And, many of these livelihood activities require reliable power source to enhance their productivity like cold rooms for preservation of fruits and vegetables, pump sets/aerators in fisheries, milk collection centres and micro milk chilling facilities in dairy, equipment in village/cottage industries, etc. Solar power packs in various configurations and capacities have been tried and are being used to support these livelihood activities. However, these applications are relatively new and at present the penetration is low. The configuration and capacity of the solar power packs vary with specific requirements and characteristics of the power use. A few examples of these solar power packs being used for livelihood activities are as shown in Figure 9 and 10.

***Figure 9*** *Solar-powered milk chiller (operates on thermal energy storage concept where solar power is used for charging the thermal battery for milk chilling)*
***Source.*** *Promethean power systems*

***Figure 10*** *Solar-powered multi-utility centre to support livelihood activities in a village*
***Source.*** *Sambandh, Odisha*

### Solar-powered outdoor, street, and highway lighting

Street, campus, and highway lights are usually powered by grid electricity. To reduce the load on grid or in the regions with poor electricity supply, solar-powered lights are being used to illuminate outdoors (villages, factories, residential, and institutional campuses), streets, and highways (Figure 11). Usually the module is mounted on the lighting pole itself and is also provided with a battery of 1–3 days of storage capacity. The capacities of the module generally lie between 15–75 $W_p$.

***Figure 11*** *Solar streetlights*
***Source.*** *http://longmansuntech.co.in*

## Potential Market Segments for Off-Grid SPV Products in India

The potential market segments for off-grid SPV products and applications in India are briefly mentioned below.

### Household applications

Around 180 million households in India have either no access or have access to unreliable and poor grid electricity and are using kerosene lamps for lighting purpose. Kerosene oil is subsidised by the Government of India and the cost incurred by the Centre for subsidising kerosene oil was around 5.1 billion USD[3] in 2013/14. Apart from lighting, there is huge requirement of reliable power for household appliances. The total sales of off-grid SPV products for lighting and other household applications are quite low as compared to the huge market available. The cumulative sales of solar lanterns and solar home systems were estimated to be 2.3–3.2 million and 1.0–1.2 million, respectively till 2012.[4]

[3] *Report on "Kerosene Subsidies in India", by International Institute of Sustainable Development, 2014*

[4] *Report on "Lighting Asia: Solar Off-Grid Lighting", by International Finance Corporation, 2012*

In 2010, the International Energy Agency[5] projected that despite the policy measures taken, around 300 million people in India would still be without access to electricity in 2030. The additional off-grid energy that needs to be generated to provide electricity access to all the households by 2030 is estimated to be 48 TWh per year.[6] This means addition of 32–40 GW of off-grid power generation capacity 2030.[7]

## Solar-powered water pumps for irrigation

In 2012, there were around 10 million diesel pumps in operation for irrigation in India with a total capacity of around 30 GW. The market for diesel pumps was estimated at 1.3 billion USD with annual sales of around 2 million units.[8] Apart from diesel-operated pumps, almost an equivalent number of electric pumps are also being operated in India. The electricity tariff for water pumping in agriculture is highly subsidised and if the subsidy is continued, by 2021/22 the annual budget for this subsidy would be around 50 billion USD.[9] The annual sale of solar-powered pumps was around 12,000 units[10] in 2012, which indicates that there is enormous untapped potential for solar pumps.

## Service segment such as banks, petrol stations, post offices, telecom towers, and community services in villages

Majority of the service segment units/centres such as banks, petrol stations, telecom towers, etc. are located in the regions with irregular and poor quality of electricity supply. The use of diesel and other fuels for power requirement significantly increases the operational cost.

In 2011, there were around 3.6 lakh telecom towers in India, which are likely to grow to 5.5 lakh by 2015 and to 7 lakh by 2020. In addition to grid electricity, these telecom towers are consuming around 2 billion litres of diesel per annum which is expected to increase to 3.5 billion litres per annum by 2020. Assuming that 30% of the diesel consumption would be gradually replaced by 2020, the market potential for solar-powered telecom towers would be around 3 GW.[11]

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5 *Report on "World Energy Outlook", 2010, International Energy Agency*

6 *Assuming the average energy requirement of 250 kWh/year for a rural household and 500 kWh/year for an urban household.*

7 *Assuming that 1 $kW_p$ solar PV module would generate 1200–1500 kWh/year.*

8 *Article on "The Market for Solar Irrigation Pumps in India" by Bridge to India, 2014, available at http://www.bridgetoindia.com/blog/the-market-for-solar-irrigation-pumps-in-india/*

9 *Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

10 *Article on "The Market for Solar Irrigation Pumps in India" by Bridge to India, 2014, available at http://www.bridgetoindia.com/blog/the-market-for-solar-irrigation-pumps-in-india/*

11 *Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

There more than 50,000 petrol stations in India and a large number of these stations operate on costly power from diesel generators. And, with reducing gap between the costs of power from solar and grid electricity, solar power is emerging as an attractive alternative even against the grid power. Indian Oil Corporation Ltd (IOCL), which operates the highest number of petrol stations (~24,000) in India, has equipped 2000 of its outlets with solar power. The company has set a target of increasing the number of solar-powered petrol stations to 10,000 from existing 2000 by 2017.[12]

There are a large number of these service segment centres/units, located in power-deficient regions, to cater to the needs of around 6 lakh villages in India. This market segment offers enormous opportunities for off-grid SPV applications.

### Livelihood activities in villages and peri-urban areas

Many of the livelihood activities in rural and peri-urban areas require adequate power supply and at the appropriate time. Some examples listed below.

- Preservation of fruits and vegetables in small cold rooms
- Regular aeration of ponds during fish farming
- Lighting and ventilation of poultry farms
- Milk chilling

In the absence of a reliable power source, people are adversely affected due to lower productivity and hence lesser incomes. For example, it was estimated that around INR 133 billion worth of fruits and vegetables is wasted in India per year due to inadequate cold storage and non-availability of refrigerated transport facilities.[13]

### Street and highway lighting

The power requirement for street lighting in towns and cities is likely to increase to 3500 MW by 2020 from the existing requirement of 1600 MW.

Table 1 summarises, the potential market segment for the off-grid SPV products. Suitable SPV products for each market segments are also listed in Table 1.

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[12] *Article on "Indian Oil Corporation Targets 10,000 Solar-Powered Fuel Stations" by CleanTechnica, 2015, available at http://cleantechnica.com/2015/01/12/indian-oil-corporation-targets-10000-solar-powered-fuel-stations/*

[13] *Report on "The Food Wastage & Cold Storage Infrastructure Relationship in India" by Emerson Climate Technologies, 2013*

**Table 1.** Potential market segment and respective market size for off-grid SPV product/application

| Potential market segment | Market potential | Appropriate off-grid SPV products/ applications |
|---|---|---|
| Household applications | 180 million households have no access or have access to unreliable electricity supply[1] | Solar Lanterns<br>Solar home systems<br>Solar Power pack |
| Water pumping for irrigation and water supply schemes | Around 10 million diesel pumps are in operation having cumulative capacity of around 30 GW[2] | Solar powered water pumps |
| Services segment such as banks, ATMs, post-offices, petrol stations, telecom towers, and other community services in villages | Around 5 lakh telecom towers, and a large number of these operate on diesel generators[3]<br>Around 50,000 petrol stations; a large number of these are located in power-deficient areas<br>A large number of other service segment units | Solar power packs |
| Livelihood sectors such as horticulture, dairy, poultry, fisheries and village/cottage industries | 24 million hectare of land is being used for horticulture<br>70 million farmers are involved in dairy services<br>3 million families are involved in poultry and fisheries | Solar power packs to power: Cold rooms in horticulture<br>Milk collection centres and micro milk chilling facilities<br>Lights and fan in poultry farms<br>Pump sets and aerators in fisheries<br>Lights, fan and other equipment in village/cottage industries |
| Street and highway lighting | Around 1600 MW power is required for street lighting in towns and cities[4] | Solar-powered street and highway lights |

## Potential and Investment Opportunities in Off-grid SPV Market in India

The potential market is large and can bring in enormous economic and social benefits. According to the Off-grid Business Indicator (OBIN) Report, released by the Solar Energy Foundation in April 2014, India stands as the biggest off-grid SPV market in the world.

Various studies have tried to estimate the potential for some of the off-grid SPV products and the corresponding investment opportunities in India. Some of the estimates for the year 2022 are as provided in Table 2.

| **Table 2.** Potential and investment opportunities in off-grid SPV market in India by 2022 | | |
|---|---|---|
| Off-grid SPV product/application | Potential and investment opportunities | |
| | $GW_p$ | Billion USD |
| Potential - kerosene lamp replacement in households | 0.9[14] | 5.3[15] |
| Market potential for solar pumps | 16.2[16] | 33–40[17] |
| Market potential for solar-powered telecom towers[18] | 3.5 | 12.5 |
| Potential for street lighting | 3.5[19] | 15–26[20] |
| Total investment required for small-scale off-grid SPV market[21] | – | 69 |

If we analyse the trend of the contribution of off-grid SPV systems in the total installed capacity of solar power systems in recent years, we can assume that the contribution of off-grid SPV systems will be 5%–10% in the 100 GW target for solar power installation by 2022.

| Table 3: Contribution of off-grid solar PV systems in total solar power installed capacity[22] | | | | |
|---|---|---|---|---|
| Year | Year wise installed capacity of solar power systems ($MW_p$) | | | % contribution of off-grid PV systems |
| | Grid connected | Off-grid | Total | |
| 2012-13 | 234.97 | 16.12 | 251.09 | 6.4% |
| 2013-14 | 495.13 | 19.7 | 514.83 | 3.8% |
| 2014-15 | 430.67 | 52.77 | 483.44 | 10.9 % |
| | | | | |

[14] *Assuming each of the household using kerosene lamps will be provided a solar lantern of 5 Wp capacity.*

[15] *Report on "Off-grid Business Indicator (OBIN)" released by Solar Energy Foundation, 2014*

[16] *Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

[17] *Assuming that the cost of solar water pumps, by the year 2021-22, would decrease by 25% as compared to the existing prices because of bigger sales volume and reduced module prices*

[18] *Assuming that, 30% of the diesel consumption would be gradually replaced by solar power by 2021-22. Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

[19] *Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

[20] *Considering the benchmark cost for solar street light specified by MNRE (INR 270-450 per Wp).*

[21] *Small scale off-grid solar PV market includes market for rooftops, agriculture pump-sets, telecom towers, street lights, etc. Report on "The Rising Sun: Point of View on Solar Energy Sector in India", by KPMG, 2011*

[22] *Data gathered from MNRE website (www.mnre.gov.in).*

Investment opportunities in the off-grid solar PV market, estimated for two scenarios – (i) 5 GW installed capacity by 2022 and (ii) 10 GW installed capacity by 2022; is provided in the table below:

| Table 4: Investment opportunity in off-grid solar PV market in India by 2022 | | |
|---|---|---|
| Total installed capacity of off-grid solar PV systems (in $GW_p$) | 5 | 10 |
| Investment required in off-grid solar PV systems (in billion USD)[23] | 25-33 | 50-67 |

To conclude, the India market has huge potential for off-grid solar PV products and can bring in enormous social and economic benefits. However, the market is diverse and dispersed; and significant efforts in terms of customising and developing products for specific needs, establishing widespread sales and supply network and ensuring quality products, providing access to finance to end-users, would be required to capitalise the market potential.

[23] *Assuming the cost of small off-grid solar PV systems at INR 300-400 per Wp.*

# SECTION B

## Papers/presentations by Speakers

# Opening Remarks

*Rohit Kansal, Co-Chair*

Dr Cilliers, distinguished speakers on dais, and participants

I am pleased to welcome you all to this session on Decentralised Energy Solutions being hosted by UNDP as part of the RE-INVEST. The idea of organising the RE-INVEST was conceived by the Ministry of New and Renewable Energy (MNRE), as a follow-through to the 'Make in India' initiative of the Prime Minister of India.

As you know, the primary mandate of this Ministry is to contribute increasingly to meeting the country's growing energy demand through renewables. To achieve this, the scale of investments in the RE sector has to grow to levels that are several times higher than present.

As a consequence of the Government's emphasis on renewable energy, considerable progress is underway as far as renewable energy for large grid connected applications is concerned. Therefore, it is most relevant and appropriate that this session focuses on some of the less prominent applications of renewable energy: decentralised power supply and direct heat applications. These applications may have lesser prominence but certainly not lesser relevance.

The UNDP has been focusing on decentralised applications of renewables and supporting several interventions on this overall theme in India over two decades.

MNRE also has been providing a thrust to decentralised power production and supply. Some of the main focus areas are:

a. Biomass-based heat and power projects and industrial waste-to-energy projects for meeting captive needs.
b. Biomass gasifiers for rural and industrial energy applications.
c. Watermills/micro hydro projects—for meeting electricity requirement of remote villages.
d. Small wind energy & hybrid systems—for mechanical and electrical applications, mainly where grid electricity is not available.
e. Solar PV roof-top systems for abatement of diesel for power generation in urban areas.

We are also promoting stand-alone renewable energy devices such as:

f. Family-size biogas plants

g. Solar street lighting systems

h. Solar lanterns and solar home lighting systems

i. Solar water heating systems

j. Solar cookers

k. Standalone solar/ biomass based power generators

l. Wind pumps

Many of these systems have been found to be useful in urban and semi-urban areas to conserve the use of electricity and other fossil fuels. Solar water heating systems have helped in demand side management of electricity in various cities and towns during peak hours. Standalone roof top SPV systems are getting popular for day time diesel abatement in areas where incidence of power cuts is very high.

Despite several well-intentioned efforts by national and state governments and international development partners to expand energy access, current estimates indicate that about 2.4 billion people worldwide [800 million of them Indians] still depend on traditional biomass burnt in inefficient stoves for satisfying their cooking energy needs

The installed capacity of renewables in India has grown at an annual rate of 25% over the past decade. It has touched 32,000 MW as of March 2014 and currently accounts for about 13% of the total electricity generation capacity [232,000 MW], contributing to about 6% of the electricity produced in the country.

Interestingly enough, today the amount of power produced through renewables is more than twice of that produced by all nuclear power plants in the country put together. As of today, more than a million households in the country derive their basic electricity needs solely from solar energy!

Nevertheless, these achievements are only indicative of a good beginning: there is substantial ground to be covered before a certain amount of progress can be considered to have been made towards energy self-sufficiency and sustainability.

The Government of India has set new targets for it to achieve 100,000 MW of electricity through renewable sources of energy and to provide 24 x 7 electric supplies to unserved villages through conventional and renewable sources of energy.

In this session, we also intend to brainstorm on the following issues:

- How solar thermal technology can help meeting thermal energy demands for water heating, high temperature requirements such as steam, hot air, and cooking?
- How biomass/ biogas devices can meet thermal energy requirements such as large scale cooking, energy required in processing industries, enterprises, etc?
- How different renewable energy technologies such as solar, micro-hydro, biogas, biomass gasifiers, and small wind generators can provide electricity?

This session is going to focus on the potential, best practices and the investment required. We are indeed very fortunate to have some of the most knowledgeable and experienced speakers on these topics who are familiar with the best practices demonstrated in India as well as other countries.

Their insights will be very useful in identifying areas that are ready for sizeable investments and have potential for multiplication. Again, I welcome all participants to this important session and hope the deliberations herein are useful in identifying as well as attracting investments for decentralised renewable energy solutions in the country.

# UNDP Remarks

*Dr Jaco Cilliers, Country Director*
*United Nations Development Programme, India*

Dear  Mr Kansal, distinguished speakers on dais, and participants

It gives me great pleasure to welcome the speakers, investors, eminent experts, development practitioners, Government officials and international delegates to this extremely important session.

India has now entered into a phase of positive development orientation wherein emphasis is being put on a close and continuous dialogue with the nation's citizens and addressing their priorities. The new Government has come out with its expansive economic vision outlining how it plans to usher in reforms that lead to inclusive development. Needless to say, since energy happens to be an important pre-requisite for development, strengthening and augmentation of energy infrastructure in the country constitutes a major thrust area of the new Government. It is also heartening to note that renewable energy features very prominently in Government's plans of boosting, strengthening and revamping the energy infrastructure in the country. This will also bode well for the entire world by way of fostering long term sustainability.

This vision of the Government of India very much compliments the 'Sustainable Energy for All' or SEFA initiative of the United Nations Secretary General, which is aimed at facilitating access to energy for the entire world and also double the use of renewable energy by 2030.

Promoting low carbon, climate resilient and inclusive development has always been UNDP's commitment. Within the UNDP, there is a dedicated unit focusing on Energy and Environment. We continue to support the Government of India in meeting their national development objectives and its commitments under important multilateral environment agreements.

Which brings us to the theme, constituting the main focus of this session? Although India has made considerable progress in energy access, it is estimated that nearly:

- 300 million people do not have access to electricity. This is one-third the global population without access to electricity.
- 800 million people depend primarily on biomass as a source of energy for cooking, which of course, is done in a rather inefficient manner.

- A large segment of the available potential for undertaking farming and other economic activities in rural areas remains untapped due to lack of energy access. For instance, there exists over 9 million diesel pump-sets in the country, many of them grossly inefficient and polluting, simply because of unavailability of electricity or unreliability of power supply services in certain areas. Similarly, as many as 800,000 telecom towers in India make use of diesel-based electricity, again due to unavailability or unreliability of power supply services.
- When we look at urban and semi-urban areas, it is amply clear that fossil-based energy sources such as LPG, petroleum fractions, coal, etc., continue to be the predominant fuel options for domestic chores such as cooking, water heating and industrial applications.

This session envisions pooling of experiences from around the world and bringing them together to evolve sustainable solutions involving use of renewable energy.

Renewable energy has travelled a long way from the times when the costs were very high and only a very high level of subsidy could accord some dimension of affordability. Over the past decades, considerable degree of technological and economic feasibility has been achieved by improving on aspects like energy conversion efficiency, optimization of materials, scales of economy, etc.

UNDP has supported several pilot initiatives in this area showcasing sustainable and economical solutions in last two decades with the Government of India, specifically, the Ministry of New and Renewable Energy. I would like to cite a few examples:

- Demonstration installations that serve to establish practical utility of micro-hydro power plants for electrification of remote rural areas, were undertaken, followed up by development of a master plan for decentralised electrification of remote areas of Himalayan states. A micro-hydro simulator has been installed at IIT Roorkee, which is serving as a training platform for different categories of personnel. Trainings are being conducted by the Institute on self-sustaining basis and experts are providing policy inputs on micro-hydro even after project closure.
- Practicability of bio-methanation technology for power generation based on different substrates was demonstrated; capacities of the demos varied from ½ to 2 MW. On a parallel note, assessment of waste generation in about 80 cities was carried out.
- The market demand for solar water heaters for domestic and industrial uses has tripled due to a UNDP supported demonstration project.
- An ongoing project on use of solar concentrators for direct heat applications

is generating very interesting results – it has already increased the market for solar concentrators by about three times in comparison with that in the baseline year 2011. India has largest population of solar concentrators for heat applications both in terms of number of installations and collector area. The project has established two state-of-the-art test centers for solar concentrators at the National Institute of Solar Energy, Gurgaon and University of Pune. These are perhaps only of its kind in Asia, the handful of others being located in the United States, such as NREL.

- Pilot efforts of market development for renewable energy products such as solar PV products have helped household business, provided employment and five banks have started providing loans for RE products in Rajnandgaon.
- Building on these experiences, UNDP in collaboration with MNRE with funding support from GEF has launched a project to develop market for renewable energy-based rural enterprises. The new project aims to set up 30,000 enterprises in 15 districts in the states of Assam, Madhya Pradesh and Odisha. Khadi and Village Industries Commission, National Thermal Power Corporation, Climate Group, Local State Nodal Agencies, NGOs, and service providers are expected to support us in implementing the project.

To address the various dimensions of decentralised energy requirements, this technical session aims to cover three key aspects, which are:

- ***First:*** Decentralised thermal energy solutions through heat derived from the sun. India has enormous potential for solar energy with more than 300 clear sunny days. There is significant energy demand for meeting cooking, hot water and process steam requirements in urban as well as rural areas. For a city like Bengaluru, almost 15% of its domestic hot water requirement is met by solar water heaters. Many cities in India and perhaps in other countries can replicate this and increase the penetration of solar energy further. One estimate indicates that the market potential for solar water heaters stands at about 350 $m^2$. India has over 5 million small enterprises which require process heat, presently met by burning fossil fuels. Solar concentrators can be valuable clean energy solution.
- ***Second:*** Decentralised thermal energy solution through biomass based technologies. Over 80% of Indian household's burn biomass in very inefficient cookstoves leading to inordinate deforestation as well as causing dangerous levels of indoor air pollution. Efficient cookstoves, biogas, biomass gasifier based devices; alternative fuels can address these issues. In addition, there is considerable need for heat in industrial applications for which coal, kerosene oil / diesel, woody biomass, crop residue and even electricity are used as

fuel. Biomass gasifiers can be a viable alternative that reduce the biomass consumption by half or replace the use of fossil fuels.

- ***Third:*** There is enormous potential to make use of renewable energy to meet decentralised electricity requirement. Depending on the resources available, micro-hydro, solar, biogas, biomass and even small wind generators can be viable options. According to an estimate of the International Energy Agency (IEA), by the year 2050 the potential for decentralised energy systems in India is in between 92 and 115 GW. The Government of India aims to connect all villages with 24 x 7 electricity supply and also achieve a target of 100,000 MW of solar electricity by 2022. In order to achieve this ambitious target, decentralised renewable energy solutions can play a significant role.

To increase the energy access and fully realize the potential of renewable energy, it is essential to catalyze the experiences so that one can choose most robust options and also require huge investments. The speakers will provide us with their expertise on delivery mechanisms both financial and technology. They will also deliberate on the need for policy environment, investments required and experiences of how it can be mobilised. I am sure addressing these aspects will also strengthen India's response to global commitments when the countries meet in Paris during end of this year.

I am sure today we will be able to benefit substantially from the vast experience of our distinguished speakers and make use of the discussion generated herein for making pertinent plans for promoting decentralised energy solutions in India and other countries. Again, while welcoming all distinguished participants, I eagerly look forward to looking at the outputs of this session and subsequent new and innovative ideas that emerge subsequently.

# Experiences in Solar Water Heater Markets in Europe and Scope for Collaboration with India for Accelerating

*Gerhard Stryi-Hipp*
*Head of Energy Policy, Coordinator, Smart Energy Cities*
*Fraunhofer Institute for Solar Energy Systems*
*ISE President European Technology Platform on Renewable Heating and Cooling*

## Solar Water Heating in Europe

**MARKET 2013** (EU-27 + Switzerland)

- Newly Installed: 3.1 Mio $m^2$ / 2.1 $GW_{th}$
- In operation: 43 Mio $m^2$ / 30 $GW_{th}$

**CHARACTERISTICS**

- Solar radiation: for free and everywhere
- Daily and seasonal solar variation
  *Storage and auxiliary heating source needed*

**CHALLENGES**

- Enlarge the type of applications
  *Large systems, district heating, process heat, higher temperature, solar assisted cooling*
- Increase the solar fraction per building
  *From hot water to Solar-Active-Houses*
- Ease operation and reduction of costs

**APPLICATIONS**

**Domestic hot water & space heating**

- One/two/multi family homes
- Hotels, hospitals, residential homes,…
- District heating
- Multifunctional façades
- PV-Thermal (PV-T) hybrid collectors

**Process heat**

- Low up to 100°C
- Medium up to 250°C
- Solar assisted cooling and refrigeration

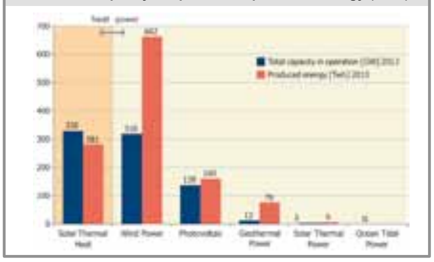
RHC Renewable Heating & Cooling European Technology Platform

Fraunhofer ISE

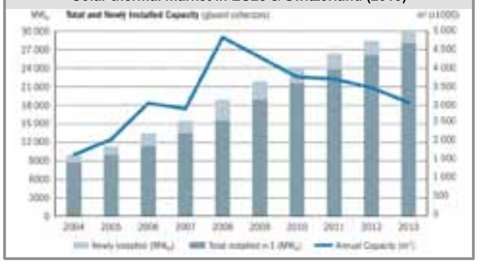
## Solar Water Heating Market in Europe and Global

- Solar thermal heat (SWH) is the Renewable Energy Source (RES) with the highest capacity and second highest energy generation globally
- The European Solar Thermal (ST) market is dropping since 2009
- China is by far the biggest ST market worldwide, India No 3, Germany No 5

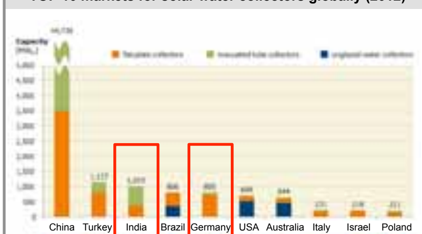
**Total RES capacity in operation & produced energy (2013)**



**Solar thermal market in EU28 & Switzerland (2013)**



**TOP 10 markets for solar water collectors globally (2012)**




Sources: ESTIF (left): Market statistics and IEA SHC (right): Solar Heat Worldwide, 2014 Edition

RHC Renewable Heating & Cooling European Technology Platform

Fraunhofer ISE

## European Technology Platform on Renewable Heating and Cooling developed Vision, Strategy and Roadmaps

*Download: www.rhc-platform.org*

**Common Vision** 2020 - 2050

**Strategic Research Priorities** of Solar thermal, Biomass, Geothermal and Cross-cutting
→ **Strategic Research & Innovation Agenda**

**Technology Roadmaps** of Solar thermal, Biomass, Geothermal and Cross-cutting
→ **Common Implementation Roadmap**

2011 2012 2013 2014

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## Collaboration Europe – India on Solar Water Heating

Most interesting market segment in India:
**SWH for industrial processes**

- Rather small market yet, but **high potential**
- **General barriers**
  - **Lack of awareness**
  - **Concerns on reliability of SWH systems**
  - **No sufficient data on performance and cost savings** of SWH systems
  - Available **roof space** is limited

**Opportunities for collaboration**

Within the GIZ-project »SoPro India« first steps of cooperation are established:

- **Monitoring of SWH systems to gain reliable data on the energy yield of SWH systems**
- **Development of a concept for cheap and robust monitoring systems**
- **Recommendations for an optimized system design are under development**

SoPro India
Solar Water Heating for Industrial Processes in India

www.soproindia.in

Renewable Heating & Cooling
European Technology Platform

Fraunhofer ISE

## Thank you very much for your attention!

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Renewable Heating & Cooling
European Technology Platform

Fraunhofer ISE

# Best Practices, Business Models for Marketing Biomass Cookstoves and Scope for India

*Dean Still (CEO) and Ronal W Larson (Adjunct Faculty)*
*Aprovecho Research Center, Cottage Grove, Oregon*

## Introduction

Introduction: The following is presented in the form of frequently asked questions (FAQs) - all related to investment opportunities for biomass cook-stove improvements in India. The authors have been involved with cookstove development for more than 20 years, and believe there are many opportunities for entrepreneurs in India. We do not address heating stoves, biomass for small industries, nor fossil fuel or electric cooking alternatives. We briefly discuss other biomass alternatives to fossil fuels.

The following questions do not always repeat the term "Indian cook-stoves", but that term should be understood throughout. This paper is not pertinent to business practices related to cooking in developed countries, nor for the wealthy in developing countries.

The initial questions are designed to amplify key words in the presentation title (best practices, business models, marketing, scope).

FAQ1 (Best stove type?). Is there an obvious best biomass cook-stove for India? Briefly the answer is no. This is a very complex topic - and we start with this question since so many new options are becoming available - and are likely to influence all the subsequent topics covered.

India is a big country with many possibilities for both urban and rural families. Different stove types are needed for different cooking tasks. The availability of biomass fuels at low cost will be a strong determinant of stove type. Many questions below will fur-ther explain the rationales for different stove choices - such as cost, time-savings, health, climate change, etc.

It now seems necessary to consider more than doing a better job with traditional approaches to cooking. An example may turn out to be the use of fans/blowers - which are cheap and essential components of widely used and out-of-date computers. Another possible desirable advance is with stoves supplying electricity for cell phone recharging.

Life cycle analysis must accompany low first cost.

Processed fuels may prove to be attractive - especially if a stove can then produce rather than consume charcoal.

Climate issues may bring forth previously unavailable subsidies.

FAQ2 (Optimum business model?) For the different biomass cook-stove types, is there a single optimum business model? Again, the brief answer is no - it is likely that many different business models can work successfully. Cooking with three-stones is essentially cost-free - but only for the initial cost; they are not as efficient as we can make them. In lab testing with skilled operators, three-stone approaches have beaten some claimed-to-be improved stoves. Going one step higher: artisanal production of stoves has many favorable attributes, but greater lifetime, improved safety, reduced harmful emissions, possible income generation, greater attractiveness leave plenty of room for new business models. These can include longer lifetime with improved materials, designs with electronic controls, etc. - as further detailed below.

FAQ3 (Optimum marketing?). Do different business models require different marketing strategies? Briefly, yes and no. Marketing is key when attempting to change habits developed over millennia. And there is growing sophistication in marketing. So certain aspects of marketing are likely important for all new stove approaches. But on the other hand, a different marketing strategy is probably needed when the focus is a) on health rather than b) one focused on climate issues rather than c) one on saving money. There are plenty of reasons for entrepreneurs to look closely at present cooking practices in India and plan their marketing around changes - for understandable reasons.

One should not minimize the problems that will be associated with the marketing of im-proved stoves.

FAQ4 (Importance) Why are improved cooking systems so important?

Health is first for most well-known stove people (Example Prof. Kirk Smith of Berkeley) but for Prof. Tami Bond (University of Illinois) improved stoves are important to reducing atmospheric black carbon. For others the driving force is now carbon dioxide removal. For others, it is forest degradation. For almost all, there is a recognition that improved efficiency can save money and time.

The UNDP perspective summarizes much of the above; Improved cooking stoves address at least 5 of the 8 United Nations' Millennium Development Goals: [1] ending poverty and hunger; [2] gender equity; [3] child health; [4] maternal health; and [5] environmental sustainability (e.g. smoke polluting the skies over Asia and accelerating glacial melting from traditional cooking fires.)

FAQ5 (Scale of biomass use) What is the magnitude of present biomass consumption?

This can be expressed in many ways (tonnes, EJ, cubic meters, %), with good data available from GACC (Global Alliance for Clean Cookstoves). Examples of their reports for India are at:

http://cleancookstoves.org/country-profiles/focus-countries/5-india.html

http://cleancookstoves.org/about/news/12-17-2014-india-clean-cookstove-forum-2014.html

Biomass is more than half of all renewable energy (RE), which itself is a fairly small part (about 15%?) of total annual energy consumption - approaching 100 exajoules (EJ) out of a total of more than 500 EJ.

We should also include in these totals the roughly 20% of annual excess carbon dioxide ($CO_2$) coming from human farm and forestry practices. Fortunately, this is less of a problem in India than in many countries.

FAQ6 (Sustainability) How unsustainable is the harvest of biomass?

There have been many horrible examples of the unsustainable harvesting of biomass - not only for cookstoves but for large scale biofuel and biopower systems. Of particular concern is the common practice of producing charcoal illegally. Use of the same wood in improved stoves, rather than charcoal, is estimated to be able to provide nine times as many meals.

But unsustainability need not be. It is imperative that policies (see FAQ12) be established to ensure the sustainable harvesting of biomass (typically wood) for cooking everywhere - but especially India.

FAQ7 (Health) What are the current statistics on indoor air pollution deaths? WHO has stated, and GACC uses, a value in excess of 4 million/yr globally, with about 25% of those in India (or about 1 million annual deaths attributable to indoor air pollution (IAP) of cooking stove use). Data is also provided for DALYs (Disability-Adjusted Life Years). The seriousness of these numbers is a prime reason for the growing interest in cookstove improvements. During the 10 minute Ppt presentation accompanying these FAQs, about 20 deaths (on an annual average basis) will occur in India.

FAQ8 (Scale of Investments) What has been the investment worldwide on cookstove development and dissemination so far? The first, not very helpful, answer is "Not Enough!" But this is changing. Two USA agencies (DoE - Department of Energy and EPA - Environmental Protection Agency) currently have, in the last few years, established first-ever stove funding for about 8 multi-organizational teams each (Universities predominating). The three-year funding for these is less than $25 million in total - and they seem to be the most aggressive stove research programs to date. No significant final results yet.

The Philips company put an extensive effort into developing a much-admired stove, but felt they had not developed a product that could compete with the much lower cost, but much less efficient and dirtier stoves whose low (or even zero) cost stoves the global stove community is now striving to eliminate.

It is likely that the greatest national funding for improved cookstoves has been by China - but much of this has been for heating stoves. Only a small amount has been for modern trends towards fan and charcoal-making stoves. Their excellent stove manufactur-ing programs are today essentially self-supporting. Much the same can be expected in India.

The best place to keep track of investments like these is the GACC (Global Alliance for Clean Cookstoves), who have in the last year raised more than $400 million, a large increase over their previous budgets. GACC's (web-acccesable) data base is now the best for keeping track of stove developments.

FAQ9 (Needed Investments?) What investments are required to bring the change in terms of cookstove development?

It is the opinion of Aprovecho that total investments in stove development should be at least several dollars per stove-using individual - hence several billion dollars. This will be cheap in climate and carbon abatement terms. But the vast majority of this can be through thousands of (small and large) firms - with individual firm (recoupable) investments being the majority of this. As emphasized elsewhere, these can be existing manufacturers. One should not expect most such firms to disclose data that could help competitors. But on the other hand, stove improvements in other countries can and should be followed.

The GACC has been remarkably successful in raising funds. These need to be matched now through the several responsible UN agencies, including the UNDP, UNEP, WHO, etc with existing responsibilities in these areas. The IPCC can assist greatly as well.

FAQ10 (Likely future changes?) What are the changes in cooking systems sought by experts in this subject and why?

Professors Kirk Smith and Tami Bond have argued for (fossil) LPG and electricity. Their reason is primarily health and/or black carbon improvements. Most everyone is striving for ISO Tier 4 (see below) - with the main improvements needed in efficiency, CO, and particulates metrics. Char-making stove proponents are arguing of course for a major switch for both carbon sequestering and soil-improvement reasons. Somewhat the same for fan stoves.

The benchmarks (presently eight in number) for good cookstoves tested in the la-boratory are undergoing development through the International Standards Organization (ISO). There is also development of in-the-field real-world testing. GACC is keeping track of these test results.

Since it is quite possible that LPG can be produced in India (and everywhere) from biomass resources (and with a charcoal-co-product), preferences for these much cleaner fuels need not be supportive of $CO_2$-emitting fossil fuels.

FAQ11 (Future Industry Scale?) What is the projected market, both worldwide and in India?

We can talk about these numbers in rough terms using GACC fund raising rationales. Billions of US dollars are needed globally, with an annual sales amount a factor of five or so lower. India is probably the world's largest future stove market.

FAQ12 (Policy Support?) What different policy and financing mechanisms have been attempted in different countries?

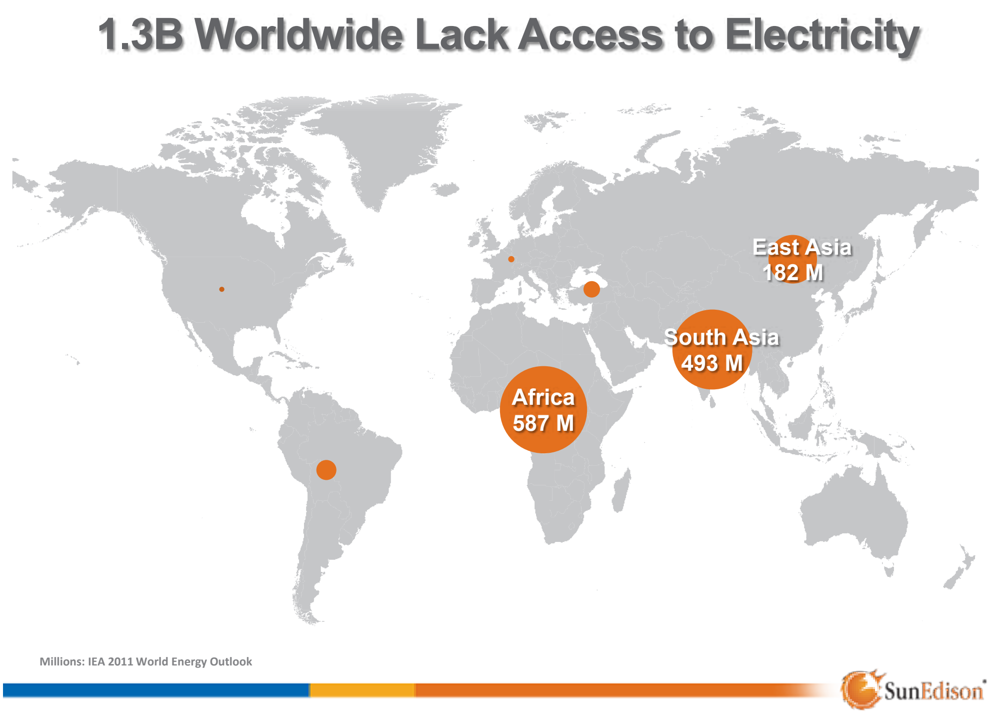
The GACC web site covers policies and financing well. China has a good reputation on these topics for stoves. Stove developers in India will undoubtedly be aware of local options that already exist or that can/should be introduced.

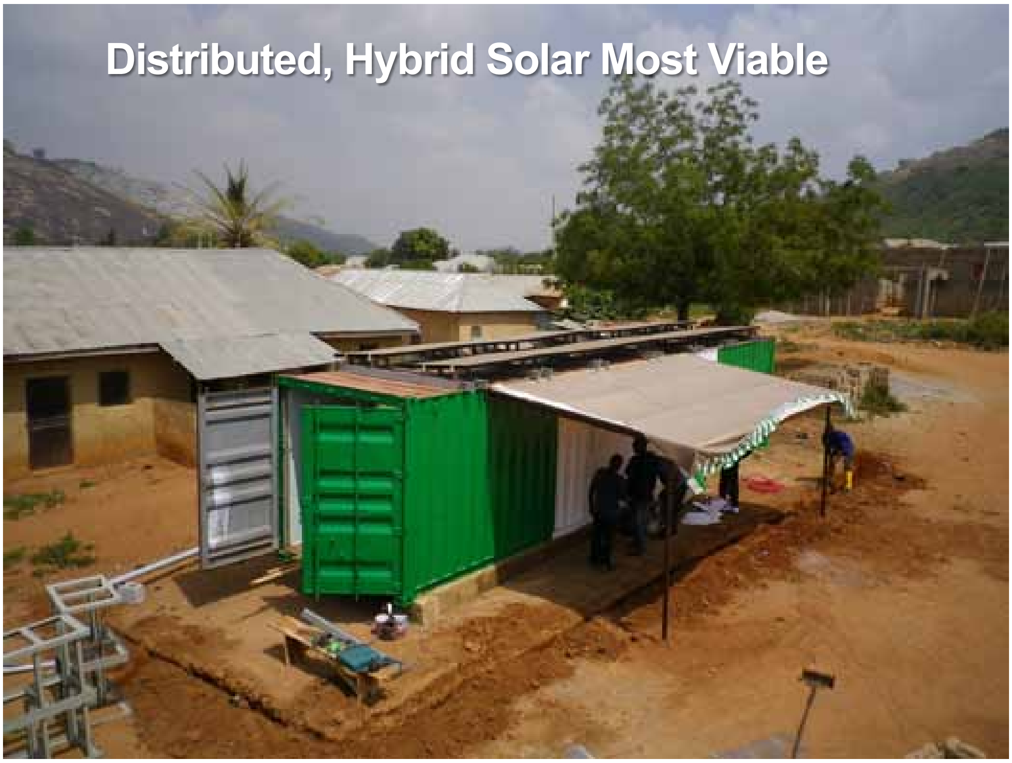
Most impressive in biomass policy development have been innovations in the Scandinavian countries. But this not so much in cookstoves - more in power plants and CHP.

One rapidly growing policy option is "Fee and dividend". In this option growing fees (really a tax) will progressively cause fossil fuels to be displaced. All of the funds are intended to be rebated equally to all citizens.

# Market for Solar Energy Solutions for Off-grid Electricity: Scope, Experiences and Constraints in Various Countries

*Alakesh Chetia*
*President, Social Innovations*




Distributed, Hybrid Solar Most Viable


Outdoor Microstations in Africa
SunEdison

## Experiences – Africa

- **Communities move up the energy ladder in steps**
  - Nothing > kerosene lamp > pico-PV > SHS > Outdoor Microstation > Mini-grid (24/7)
- **Regulatory framework is key**
  - Private operators allowed to sell electricity at a certain approved tariff in Senegal, Tanzania, Uganda, Kenya (and others will come)
- **Local skilled labor is scarce**
  - Solution must require minimum skilled labor
  - Must include all needed material as local procurement is difficult

## Experiences – Nepal

| Observation | Lesson learned |
|---|---|
| 100+ solar companies with mix of inferior or poorly designed solar systems | Customer education is needed about total cost of ownership over a long period of time |
| Direct subsidy programs from government have distorted the market | Local companies have focused on lucrative subsidy programs that pay ~75% of upfront project costs with many of these projects poorly installed and unmonitored |
| Customers are price sensitive | Gov't and donor programs are highly impactful in making solar affordable (e.g., VAT exemption, low cost financing, grants to cover "soft costs") |
| Difficult to find local contractors that can properly execute on projects | Need to be hands-on with project design, execution, and maintenance |
| Net metering policies are needed to make solar more competitive | Off-grid solar systems are still more expensive than the electric grid. Policies that allow solar to tie to the electric grid will allow solar to compete with hydro and traditional energy |

SunFarmer
powered by SunEdison Rural Energy

## Experiences – India DDG

- **Need empanelment of credible players**
  - MNRE channel partners (Genuine players)
  - Companies with at least 5MW of solar experience at National level (Assuring Quality)
  - Companies with at least 1MW of solar PPA (government) at state level (Risk mitigation)

- **Improvement in Payment terms**
  - Progressive payment milestone will lead to capital cost reduction

- **Increased Project term to 10 years**
  - Improve sustainability, given that balance of plant except battery bank has life of 10 to 30 years
  - 10 years is a more sustainable horizon, will allow for experimenting with improved and clean technologies for battery bank (e.g. Flow batteries)

- **SQR (Standard Qualifying Requirement) and SBD (Standard Bidding Document) needs to be followed by SNA (State Nodal Agency)**

# Waste to Biogas – CBG / Fertilizer Benefits

*A V Mohan Rao, Chairman, Spectrum Renewable Energy Private Limited*

## SREL plant offers environmental and socio-economic gains to rural populations

As a nation dominated by agricultural activities, India has massive potential for the utilization of agricultural products and waste-to-energy (gas) generation, particularly in rural areas. These processes allow the rural population to take care of their own energy needs and also facilitate job creation among the local youth. Within the bio-energy segment, biogas, which is produced by the biological breakdown of organic matter under anaerobic conditions, is one of the most efficient ways of energy conversion. Moreover, the setting up of biogas plants entails several socio-economic and environmental benefits.

Apart from promoting employment generation in rural areas, the setting up of biogas plants can also act as an effective means of improving sanitation and hygiene. Biogas generation provides a way to dispose of household waste and bio-waste in a useful and healthy manner. It also saves women and children from the drudgery of collecting and carrying firewood, and reduces kitchen smoke exposure and the time taken for cooking and cleaning utensils. In addition, anaerobic digestion inactivates pathogens and parasites, and is quite effective in preventing waterborne diseases.

The technology for biogas is cheaper and much simpler than that of other bio-energy fuels, particularly since any biodegradable matter can be used as substrate. Biogas has a calorific value of around 6 kWh per cubic metre, which is equivalent to half a litre of diesel. It is advantageous because it can be used as a fuel substitute for vehicles at local levels or as fuel to generate electrical and thermal energy. While larger biogas plants can generate and feed electricity into mainstream power grids, small-scale ones are a source for decentralized power generation. The digested sludge is high quality organic manure, completely natural and free from harmful chemicals. It can supplement or even replace chemical fertilizers. The diluted organic waste material (2-10 per cent solids) can be used as feed material.

Given this backdrop, Spectrum Renewable Energy Private Limited (SREL), a company owned by US-based **Akula Energy Ventures**, has developed a large-scale biogas generation and bottling project at Kodoli, near Kolhapur, Maharashtra. The demonstration project converts sugarcane waste into compressed biogas and produces organic fertilizer as a by-product.

## SREL's Commercial demonstration plant

India is the second largest producer of sugarcane in the world, with Uttar Pradesh, Maharashtra and Karnataka being the leading states in its production. About 202 sugar factories exist in Maharashtra.

India's sugar industry and farmers can benefit greatly from biomethanation, a technology with economic, social and environmental benefits. Press-mud, the waste by-product obtained during the process of making sugar from sugarcane, is an ideal feedstock for biomethanation. Its conversion into biogas also produces high quality organic fertilizer, which can be used as a soil enriched and nutrient.

The plant developed by SREL handles 100 tonnes of press-mud per day, converting it to biogas, and then blending this biogas with 12,000 cubic metres of biogas obtained from spent wash digestion, which is cleaned and scrubbed for the removal of $H_2S$ and $CO_2$. This produces about 8,000 kg of compressed biogas with high methane content and 30 tonnes of organic manure on a daily basis. The compressed biogas thus produced is a CNG-grade fuel and can be used in vehicles (permission for this is awaited from the Ministry of Road and Transport and Petroleum and Explosives Safety Organization and the Motor Vehicle Department). It also has heating applications in heat treatment facilities as a replacement for LPG, diesel or other fossil fuels in the area where the plant is located. Part of the gas generated on a daily basis is also used for running a gas engine to supply in-house power and hot water for circulation in the digesters as shown below in our site picture. The key features of this plant are as follows:



## Fuel logistics

The fuel supply chain for this project is fairly secure. Supply of press-mud and spent wash gas has been guaranteed from the Tatya Saheb Kore Sugar Cooperative for the life of the project. Sugarcane is harvested from the fields and sent to the factory for sugar recovery while the feedstock – press–mud – is stored and used during the off-peak season. The holding capacity of the storage yard is 18,000 tonnes and it consists of six open compartments made of concrete.


Cost and funding

SREL set up this project, which involved the procurement of a three-day supply of cascades for transporting the compressed biogas, at a cost of Rs 340 million.

The project cost was funded through a total foreign equity, debt from the Bank of Baroda, and a subsidy of Rs 35.8 million from the Ministry of New and Renewable Energy (MNRE). With competitive funding in terms of the interest rate on debt (9 to 10 per cent) and a reasonable level of subsidy (15/20 per cent of the project cost) from the MNRE, more projects across different states can come and provide substantial quantity of renewable source.

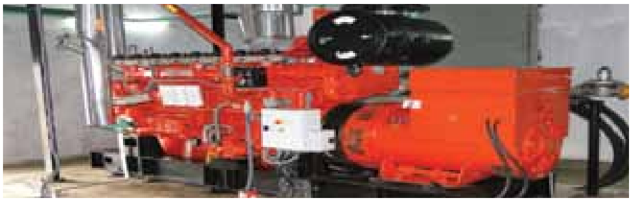
## Technical features and processes

The plant operations are 90 per cent mechanical and 10 per cent manual. It makes use of **three reactors** with an active culture volume of 9,000 cubic metres. These are continuous flow stirred-tank reactors which operate at mesophillic temperatures. The press-mud is fed into the feed tank via a conveyor belt that is fitted with a mixer for making uniform feed slurry. The slurry is then pumped (using a Wangen pump) into digesters through an underground pipeline.

Each digester is fitted with hot water pipes for maintaining temperatures at about 38 ± 1 degree Celsius; four agitators whose directions are changed manually for mixing the digester contents; and a gas-capturing system to hold about 950 cubic metres of biogas. All the digesters are interconnected through pipes in the upper gas storage area to ensure equal gas pressure. The biogas generated is continuously sucked in by a blower and supplied to the gas-cleaning system for $H_2S$ and $CO_2$ removal.


As part of the **cleaning process**, the composition of $H_2S$ is reduced from 200 parts per million (ppm) to 5 ppm, and then the $CO_2$ concentration is reduced to less than 5 per cent. After that is complete, the biogas is passed through a two-vessel molecular sieve heatless dryer. Here, the moisture is removed to ppm level. From the drying unit, the biogas is sent to the buffer vessel and then the high pressure compressor. All the above units are operated through a programmable logic controller system installed in the control room. The gas-compressing system works on the purified biogas to bring it from 7 bar to 200 bar pressure. This is then bottled into a cascade of cylinders. The excess biogas released during a plant breakdown or any other case of emergency is burnt by the flare unit.

A **gas generator** of 340 kW capacity is installed at the site. It operates completely on $H_2S$ free biogas and generates power for meeting the plant's auxiliary consumption. It generates approximately 2.5 units of electricity per cubic metre of gas. Meanwhile, a heat recovery system extracts heat from the engine jacket water, lubricating oil and exhaust gas to maintain the required temperature inside the digesters.



## The way forward

SREL is awaiting approvals from the Ministry of Road Transport and Highways and other related entities on the use of compressed biogas as a transportation fuel. If such approvals are granted, SREL and other such companies can develop at least 10 projects within the next 24 months, with a generating capacity of close to 100,000 kg (of gas) on a daily basis. This would help address the challenges associated with fossil fuel transportation. Simultaneously, it would facilitate the creation of local jobs, making rural areas independent. Moreover, nearly 300 tons of organic manure would be produced on a daily basis.

A lot of research and development work is being carried out at various Indian research centers to bring about further improvements in the performance of biogas generation plants.

A. It is a first attempt, at this scale, to generate renewable energy within the rural economy. Renewable Electricity has been generated elsewhere using Solar and Wind energy but it is the first time that agro-industry waste on this scale has been converted into fuel energy substituting fossil fuels that are imported from outside the rural economy and the money goes out of the agriculture sector in an irreversible manner. In this project right from locally available material to employment to distribution and sale, every stage is rooted within the rural economy.

B. The project is pro-poor as the use of compressed biogas would replace LPG as cooking fuel bringing down the cost and for those who are unable to afford LPG, an improvement in the overall quality of life. The availability of Compressed Biogas as vehicular fuel would reduce the transportation cost by at least 20% adding to the margin of the local farmers. For the purposes of easy storage, transporting and handling the biogas under high pressure, we compressed the biogas collected from digestion tank into high-pressure gas cylinders by means of a compressor. It thus becomes high-pressure biogas with less volume. Through experiments and analysis, it is further proved that the compression of biogas is possible and the application of biogas as a fuel for dual-fuel diesel-biogas engines is feasible and economical.

C. The promoter, energy scientist, has brought in world class technology to the rural economy at no outflow in terms of technology transfer or IPR cost in a transparent manner. All inputs are locally available and all costs are auditable at every stage. The project is done on a BOOT basis and IRR is fixed. All costs are insulated from macro-economic factors including foreign exchange fluctuations or technology upgrade/ part-replacements.

   An integrated approach has been made to fine-tune the production cycle spreading the Pressmud generated during crushing season to be available throughout the year and also dispensing of fertilizer with the seasonal demand. There will be no backlogs or accumulation in the supply chain. Methane is a component of the gas. Biogas is fully capable of replacing other rural energy sources like wood, hard coal, kerosene, plant residues, and propane.

D. The project is truly **sustainable**. Every single input is taken from within the rural economy and output is used within it. Besides savings of cost, the local availability of renewable energy will have intangible benefits, particularly reducing use of chemical fertilizers. The fertilizer obtained is rich in nitrogen. It has been analyzed, that, fertilizer made by conventional processes. It is completely nitrogen content 3 times more than the product made by conventional processes. It is completely natural and free from harmful synthetic chemicals.

The project is **participatory**. There would be considerable workload reduction in rural areas. This is particularly true for rural women engaged in day to day household work. Availability of CBG in a cylinder will relieve her of the tiring / tedious job of collecting / ferrying firewood. Since, CBG burns cleanly, the rural homes will not suffer smoke and consequently rural denizens will suffer less from physical problems like bronchial complications. Cooking is also easier with a gas stove and takes less time. Right from production/ distribution/consumption, local people are involved.

As agriculture is main occupation in rural areas, industries related with agricultural produce such as food processing (Fruits, Chilies, Tomato sauce, Jam, Vegetable drying etc.), flour and spice mill, mini oil expeller etc. are more successful in these areas. They are not only based on local produce, but also provide employment to people when they need it most.

Thus, application of bottled CBG to energize rural industries is not only economical, but also ensures uninterrupted energy supply. It would be advantageous in terms of local resource utilization, decentralization energy generation, diversified rural activities, environmental friendliness and employment generation etc. Large CBG plant will also produce enriched organic manure high in nitrogen, phosphorus and potash content in good quantity. The spirit of the whole process is to develop self sustained rural enterprises and decentralized energy system based on CBG to make rural areas economically developed /competitive in all respects.

# Financing New Business Models to Expand Energy Access in Emerging Markets: Recommendations for Development Finance Institutions

*Paul Needham, CEO & Co-Founder, Simpa Networks and Simpa Energy India*

## Abstract

Over 1.5 billion people worldwide lack access to electricity. Perhaps a billion more have unreliable connections, receiving between only 4 to 12 hours of power per day. The energy-poor often spend 20% or more of their incomes just to meet their essential needs for lighting. Globally, they spend over $50 b per year on very poor solutions, such as kerosene fuel for small lanterns, which are dangerous, dirty, and dim.

The good news is that effective decentralized energy solutions already exist. Small-scale solar home lighting systems, for example, can meet the essential energy requirements of a household or small business. Small solar PV systems can provide multi-room lighting, mobile-phone charging, and power for small DC appliances such as electric fans for cooling and mosquito control. Similarly, solar microgrids can provide affordable energy service to clusters of households and entire villages.

The problem is that because these clean energy technologies always involve significant up-front costs and are therefore not immediately affordable to the energy-poor. Studies show that consumers are willing to pay for reliable energy service but few can afford the high up-front costs associated with the installation of electricity infrastructure.

In several markets around the world new companies and new business models are emerging to tackle the development challenge of expanding access to clean, reliable electricity. These companies are pioneering for-profit business models that promise to advance the development objective of improving energy access.

A key barrier to the expansion of these innovative models is the lack of availability of appropriate working capital.

The paper identifies a critical opportunity for development finance institutions to make timely investments into the energy access sector, to demonstrate the commercial viability of new energy-as-a-service business models, and to catalyze the mainstream commercial capital that is required to achieve sustainable energy for all.

## The Transformative Role of Development Finance

Development finance institutions have a tremendously valuable role to play right now to promote the development and maturation of sustainable business models that expand access to modern energy. To succeed, this capital must be catalytic, mission-driven, patient and committed.

### Capital must be Catalytic

There are many young social enterprises that are developing quite promising approaches to expanding access to energy. Whether they are microgrids, battery rentals, or pay-as-you-go solutions, in every case there is a need for financing the up-front costs – or working capital – of the solar equipment. This is an unavoidable fact because, on the one hand, the technologies involve a high, up-front cost, and, on the other, the energy-poor are unable to make these investments themselves. So, to expand energy access, finance has to enter the ecosystem.

The scale of the problem is so large that only solutions that attract commercial capital can hope to make a significant impact. Ultimately, to expand access to energy, the sector must mobilize mainstream commercial capital and offer appropriate risk-adjusted returns.

However, to do so, businesses must be able to demonstrate, with real data and historical experience, the underlying cash flows and economics. Mainstream commercial lenders look for 2-4 years of payment histories and healthy customer portfolios. Actors such as commercial banks, private equity groups, and traditional debt funders will invest, but only once businesses can show track records with enough customers, over enough time.

Development finance institutions have an important role to play right now to catalyze the sector with working capital. Many companies have piloted and are beginning to scale very interesting approaches to expanding access to energy. Each is currently backed by equity investments from social impact investors. These funds are limited, however, and these companies now need to replicate their proven models and to build track records, with enough customers over enough time.

Development finance institutions can provide working capital to be used to help these companies build their track records, to fund the initial investments in clean energy technologies, and to provide energy services to enough customers over enough time to prove their models at modest scale. Doing so will enable those companies to transition to mainstream investors and begin to unlock private capital for massive scale.

### Mission-driven

Not only can capital be deployed in ways that are catalytic, but it can also be deployed in ways that achieve direct social impact today with magnified impact tomorrow. Mission-driven development finance institutions should seek to maximize the development outcomes that matter to them.

When used to finance only the hard costs of delivering energy solutions to identifiable end-users, funders can be assured that their funds are having the intended direct social impact.

Since energy access enterprises are committed to building sustainable models, customers pay over time for their energy services. This means that customer payments can be recycled and redeployed to finance more equipment for even more customers. This represents an attractive opportunity for funders and energy access companies to partner to maximize impact over time.

### Patient and Committed

The sector now requires large, but contingent, commitments of working capital to fund expansion.

Impact investors have previously stepped up to invest in very early stage companies, to pilot new approaches, and to take risks on entirely new business models. While some of these experiments have failed, many are showing great promise.

The successful enterprises have created "impact machines": business models that deploy working capital to create positive social impact while returning the invested capital to be recycled create even more social impact. This is the hallmark of a sustainable enterprise.

These models are today being proven on a small scale, with thousands of end-users. Development finance institutions are uniquely placed to provide patient and committed working capital to help scale these approaches.

## Conclusions and Recommendations

Access to energy is recognized as being critical to the achievement of many important development objectives. Yet to provide universal energy access through the traditional approach of large-scale, coal-burning, centralized generation is at best unviable, and at worse a false promise.

There is today an historic opportunity to provide access to clean, distributed electricity to hundreds of millions of energy-poor customers in emerging markets. The opportunity exists now because of three types of recent innovations: technological, financial, and entrepreneurial. First, technological and manufacturing innovations have resulted in improved efficiencies and rapidly declining costs for solar panels, batteries, and LED lighting. Second, innovative entrepreneurial companies are pioneering promising new business models that deliver energy-as-a-service to energy-poor households and SMEs in rural areas of Asia, Africa, and Latin America. Third, a new breed of impact investors – both angel and institutional – are identifying, funding, and supporting early-stage social enterprises with seed capital. These factors have converged to create a set of successful and promising new business models that have achieved proof-of-concept, are demonstrating market acceptance, and are beginning to scale well beyond their initial pilots.

Working capital is now required to help the sector transition from pilots and early success to mass scale. There is an opportunity for development finance institutions to have direct social impact, to have that impact magnified as funds are recycled, and to ultimately catalyze commercial capital to truly scale the delivery of sustainable business models to end energy poverty.

## Recommendations: Development Finance to Accelerate Energy Access

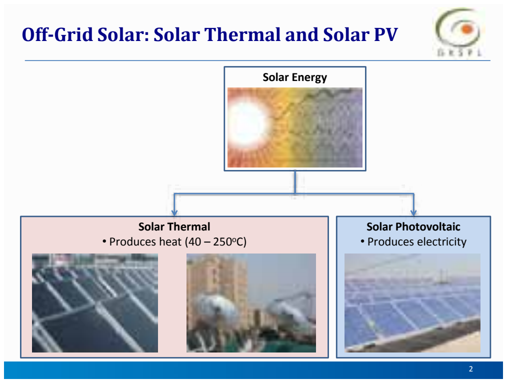
- Partner: In some cases development finance institutions may feel that they lack the capacity to evaluate the commercial viability of individual companies and their business models. In these cases, funders should partner with institutional impact investors to identify promising social enterprises that have real scale potential. In partnership with sophisticated investors, funders will look for companies that have completed successful pilots and demonstrated consumer demand for their products and services. The partnerships will also help identify companies that have the many other ingredients for commercial success such as capable and experienced management teams, favorable regulatory environments, reliable supply chains, and well-developed sales and distribution channels to reach their target customers.
- Be Creative: Development finance institutions should consider models of finance that are specifically targeted to catalyze commercial capital to scale new solutions. These financial instruments may vary depending on the nature of the business model and company, but could include pay-for-performance, loan guarantees, first loss guarantees, low-cost and longer-term debt or sub-debt instruments. By working closely with impact-oriented investors and portfolio companies, funders will have an opportunity to structure their support in ways that achieve their development objectives while responding to the needs of specific business models.
- Pay-for-Performance: In particular, development finance Institutions should consider offering funds in a pay-for-performance model. Funds could be pledged, but released only as evidence is produced that end-users have been provided with the promised services. Development finance Institutions could

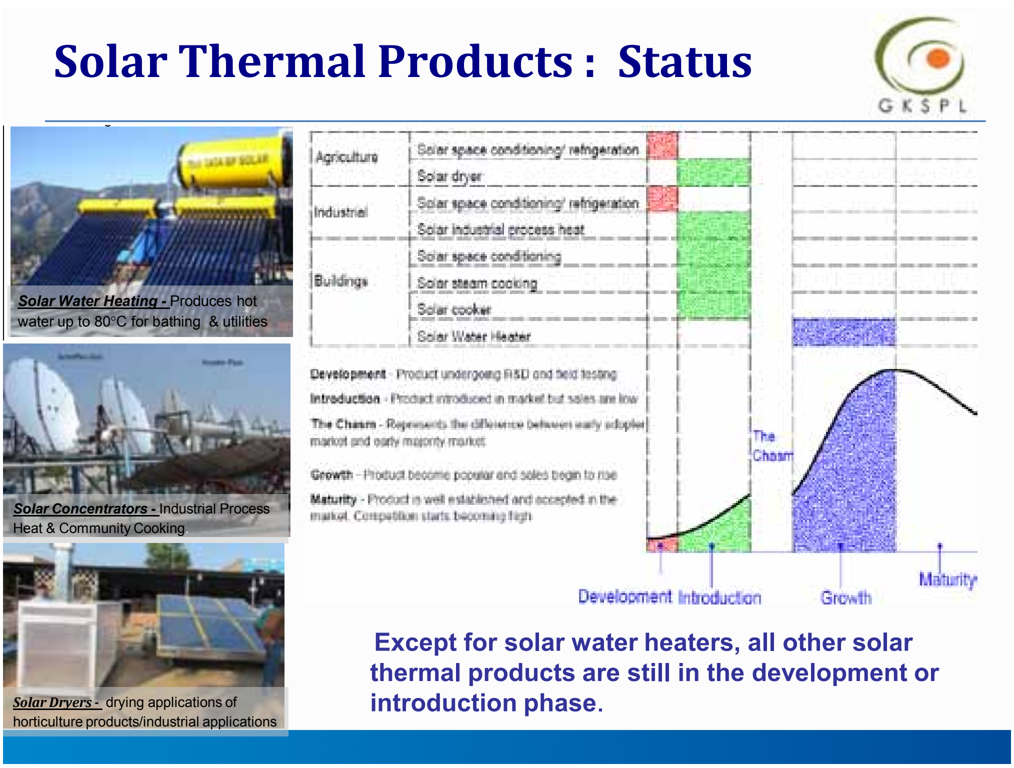
enter such relationships with clear performance metrics and agreed criteria for release of tranches of funds. A structure such as this could be highly effective at catalyzing commercial capital while also ensuring that funds generate the desired social impact. For energy access companies, having these conditional commitments of working capital in place would allow them to mobilize complementary equity and debt capital, invest in the growth of their businesses, expand operations, and build out into new areas.

- Recycle: Development finance Institutions should require that their funds be recycled to multiply the impact. As consumers pay for energy service, or pay down their loans, the recovered funds should be set aside and used again to finance new solutions for the next set of customers. This provides the right incentives to the energy access companies to deploy the funds wisely and to preserve the capital base. If structured well, this can ensure that funds are used to scale solutions for the energy-poor, and not be taken out as profits for equity investors in the energy companies.

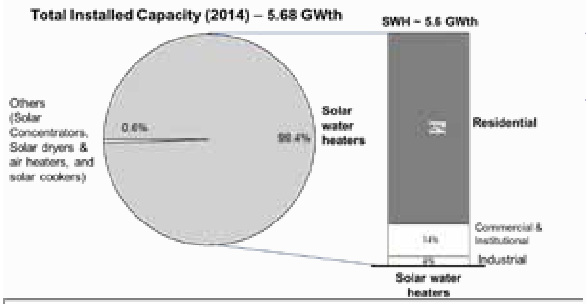
# Off-Grid Solar: Potential and Investment Opportunities

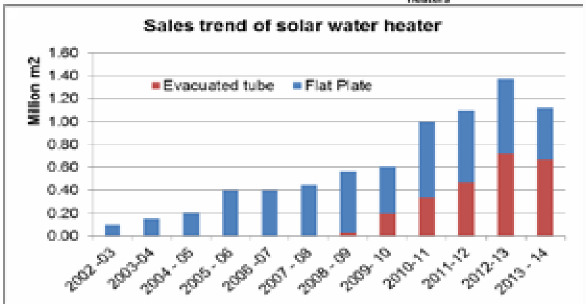
*Sameer Maithel*
*Director, Greentech Knowledge Solutions*



# Solar Thermal : Market




- Overall size of solar thermal market~ USD 200 million/year.
- Solar water heaters constitutes 99% of the solar thermal market in India.
  - Average annual growth of > 20 % (CAGR) in SWH sales during last 10 yrs.
  - Residential, commercial & Institutional buildings are the major market segments ( 95% of the market)
  - SWH with evacuated tube collectors now constitutes around 60% of the market.
  - Southern & Western states are the largest market ( 85% of the market)

**Source: Greentech Knowledge Solutions Analysis**

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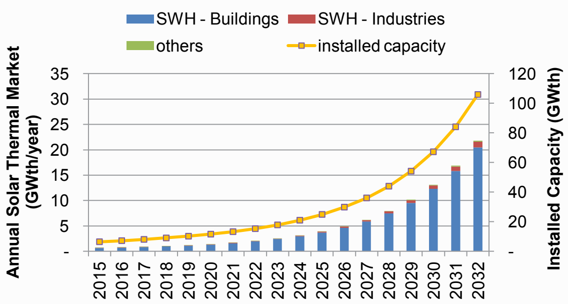
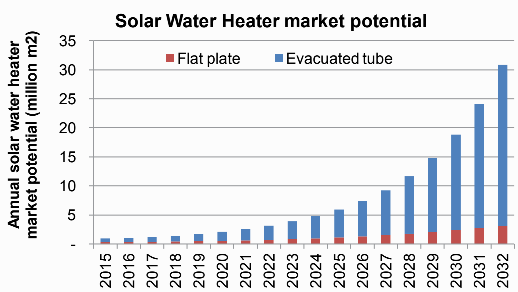
# Solar Thermal : Potential (2015-2032)




- The installed capacity of solar thermal products is expected to increase by 10 x and annual sales by 30 x by 2032
- Installed capacity expected to reach ~ 15GW$_{th}$ by 2022 and 100 GW$_{th}$ by 2032
- Annual sales of solar water heaters expected to reach 3.25 million m$^2$/ year by 2022 and 31 million m$^2$/ year by 2032.
  - Residential sector will remain the main market segment for solar water heaters,
  - The market for solar water heaters is expected to expand considerably in small towns and rural areas. Rural market share expected to reach ~50% by 2032.

**Source: Greentech Knowledge Solutions Analysis**

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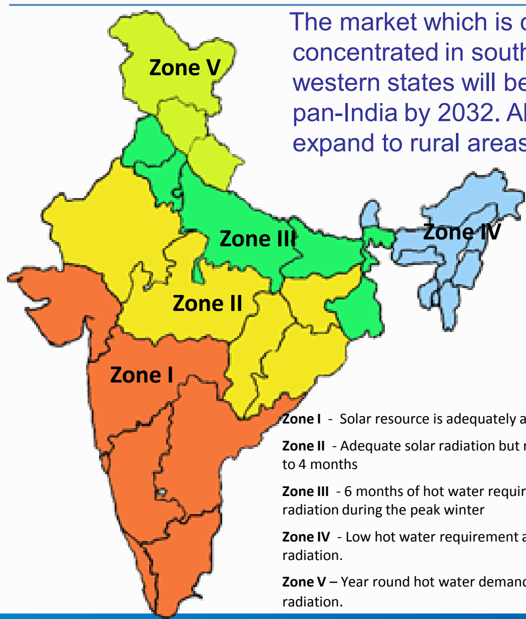
# Solar Thermal: Market (2014 & 2032)




The market which is currently concentrated in southern and western states will become pan-India by 2032. Also, it will expand to rural areas.

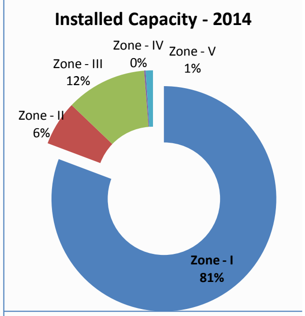
**Zone I** - Solar resource is adequately available year round.

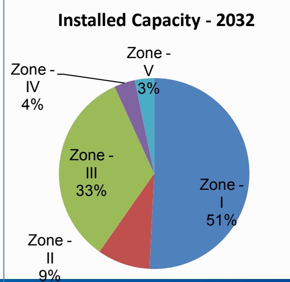
**Zone II** - Adequate solar radiation but requirement limited to 4 months

**Zone III** - 6 months of hot water requirement but poor solar radiation during the peak winter

**Zone IV** - Low hot water requirement and poor solar radiation.

**Zone V** – Year round hot water demand and adequate solar radiation.




Source: Greentech Knowledge Solutions Analysis

# Solar Thermal: Investment Opportunities

| Solar Investment (million USD) | 2015 – 2022 | 2022 – 2032 |
|---|---|---|
| Solar Water Heater | 2,800 | 26,700 |
| Solar Concentrator | 35 | 380 |
| Others (Solar Cookers, Solar Dryers, Solar Air heaters) | 5 | 60 |
| Cumulative investment | 2,840 | 27,140 |
| **Total estimated investment during 2015 – 2032** | **~30,000** | |

| Manufacturing and Assembly (million USD) | 2015 – 2022 | 2022 – 2032 |
|---|---|---|
| 1. Solar Water Heater | 46 | 442 |
| - Evacuated tube collector | 30 | 250 |
| - Flat Plate Collector | 4 | 24 |
| - Tanks and other ancillary | 12 | 168 |
| 2. Others (Solar Concentrators, Solar Cookers, Solar Dryers, Solar Air heaters) | 0.7 | 7 |
| Cumulative investment | 46.7 | 449 |
| **Investment in manufacturing and assembly (2015 – 2032)** | **~500** | |

- Total investment required between 2015 – 2032 to achieve market potential in solar thermal sector is ~USD 30 billion.
- Investment of USD 500 million required in manufacturing and assembly during 2015 – 32, to meet 100% of the market potential through domestic production
- Investment would also be required to build supply and service network.

Source: Greentech Knowledge Solutions Analysis

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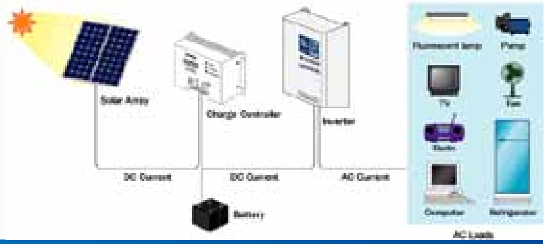
# Off-grid Solar PV Products

GKSPL

| Applications | Products |
|---|---|
| Household Application<br>– Lighting, mobile charging, fans, TV, radio and other household appliances | Solar lanterns/lamps<br>Solar home systems<br>Rooftop solar power packs |
| Water pumping for irrigation and water supply schemes | Solar pumps |

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# Solar PV Products

GKSPL

| Applications | Products |
|---|---|
| Power supply to banks, petrol stations, telecom towers and other services | Solar power packs |
| Outdoor, street and Highway lighting | Solar street lights |
| Power supply to various rural livelihood activities | Solar power packs |

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## Solar PV products: Potential Market Segments

- Household Applications
  - 180 million households have poor access to electricity
  - Govt. is spending USD 5.1 billion on kerosene subsidy which is the main source for lighting for many
- Water pumps for irrigation
  - 10 million diesel pumps and 10-12 million electric pumps are in operation
  - Electricity is highly subsidized for water pumping and the subsidy is expected to reach USD 50 billion by 2021-22

**Source: IFC, 2012; Bridge to India, 2014**

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## Solar PV Products: Potential Market Segments

- Service segment such as banks, petrol stations, telecom towers, post offices and other community services in villages
  - Around 0.5 million telecom towers in India consuming 2 billion liters of diesel/year, which is likely to increase to 3.5 billion liters by 2020
  - 50,000 petrol stations in India; Indian Oil Corporation is targeting to equip 10,000 of its petro station with solar power by 2017.
- Livelihood activities in villages and peri-urban areas
  - Small cold rooms for fruits and vegetables: 24 million hectare of land is being used for horticulture
  - Aeration of ponds during fish farming: 3 million families involved in fisheries
  - Lighting and ventilation of poultry farms: 3 million families involved in fisheries
  - Milk collection centres and micro milk chilling facilities: 70 million farmers involved in dairy

**Source: KPMG, 2011; Greentech Knowledge Solutions,2014**

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## Solar PV: Market Status & Characteristics

- Total installed off-grid solar PV capacity (31 Dec 2014) : 227 MWp which is about 7% of the total solar power installed capacity of 3062 MWp.

| Year | Year wise installed capacity of solar power systems (MWp) | | | % contribution of off-grid PV systems |
|---|---|---|---|---|
| | Grid connected | Off-grid | Total | |
| 2012-13 | 234.97 | 16.12 | 251.09 | 6.4% |
| 2013-14 | 495.13 | 19.7 | 514.83 | 3.8% |
| 2014-15* | 430.67 | 52.77 | 483.44 | 10.9 % |

Source: MNRE data; for 2014-15, the data is till 31st December 2014

- Market Characteristics
  - Dispersed market with diverse needs
    - Solar lanterns/lamps ; Solar home systems; Solar pumps; Solar installation for mobile towers, other commercial applications
  - A large number of end users are in lower income groups

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## Solar PV Products: Investment Opportunities

- Based on past trends, if we assume that 10 % of the 100 GW target set by MNRE would be contributed by off-grid solar PV systems, the investment requirement in off-grid solar PV system is estimated at around 50-70 billion US$ by 2022.
- Various studies on specific potential of solar PV products have projected following potential and investment requirements

| Off-grid solar PV product/application | Potential and investment opportunities (2022) | |
|---|---|---|
| | GWp | Billion USD |
| Potential - kerosene lamp replacement in households | 0.9 | 5.3 |
| Market Potential for solar pumps | 16.2 | 33 - 40 |
| Market potential for solar powered telecom towers | 3.5 | 12.5 |
| Potential for street lighting | 3.5 | 15-26 |

Source: KPMG, 2011; Solar Energy Foundation, 2014

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## Conclusions

GKSPL

- Wide-scale application of solar thermal and off-grid solar PV products could have enormous social and economic benefits for India.
- The Indian market has huge potential for solar thermal and off-grid solar PV products.
  - Solar thermal installed capacity expected to reach ~ 15GW$_{th}$ by 2022 and 100 GW$_{th}$ by 2032.
  - Off-grid solar PV installed capacity could reach around 10 GWp by 2022
- The estimated investment requirements are
  - Solar thermal: 30 billion US$ by 2032
  - Off-grid solar PV: 50-70 billion US$ by 2022.
- The market is diverse and dispersed; and significant efforts in terms of customising and developing products for specific needs, establishing widespread sales and supply network and ensuring quality products, making available access to finance to end-users would be required to capitalise the market potential.

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GKSPL

## Thank You !

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**www.gkspl.in**

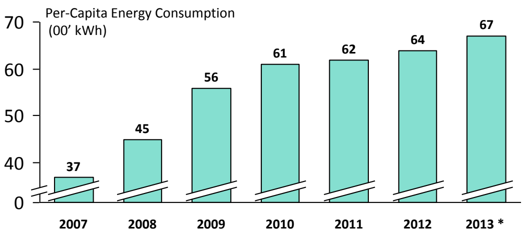
# Advantages of Roof Top Power Generation


*Anand Kumar*
*Vice President – KW & MW Sales*
*Waaree Energies Ltd.*

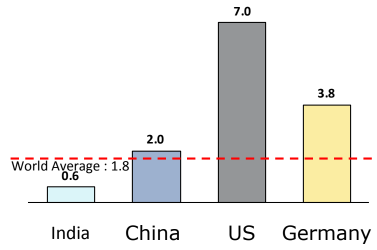

WAAREE

## Energy Scenario in India

**Rising Energy Consumption in India**

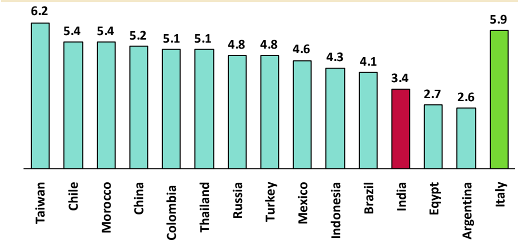



**Primary Energy Consumption per million people (TOE)**




**Quality of Electricity Supply : India Ranks low among EMEs**

1= Highly unreliable 7 = Highly Reliable




- **Per capita energy consumption in India is very low compared to developed nations.**
- **Energy consumption is low due to insufficient supply of electricity**
- **400 Million without access to electricity , distributed energy provides faster access**
- **70% of population without access to reliable and continuous source of power**

Source: CEA, India, Global Competitiveness Report -2014, * Waaree Estimates

2

WAAREE

## Advantage – Roof Utilization

| **Client** | **Surat Municipality Corp.** |
|---|---|
| Place | Gujarat |
| Size | 100 KW On Grid |

| **Client** | **VVP Engineering College** |
|---|---|
| Place | Rajkot, India |
| Size | 100 KW Off Grid |

Sites of WAAREE

## Advantage – Roof Utilization

**Self Sustaining Power Generation & Utilization**

- On an average , Each of the Metro Cities of India can have roofs that can generate almost 4000 MW of power .
- Atleast 10% - 30% of the power requirements can be generated through the idle roofs of each metro.
- Each roof that is u-utilized can become a power production house
- The roof can become an Revenue Generator by selling generated power

**Savings - $$$$$**

- The transmission lines that wind the city can be nullified or reduced
- Power Losses reduced
- The money spent on infrastructure of laying of cables can instead be used to invest on solar roof tops.
- Decentralized Power the best choice for smart grid management

MNRE: Ministry of New and Renewable Energy
SECI: Solar Energy Corporation of India

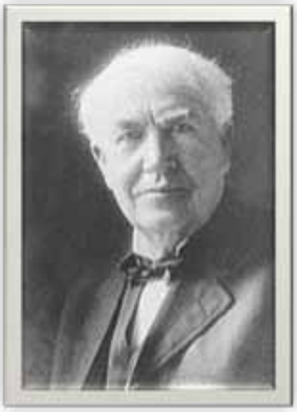
## Advantage – Roof Utilization



| **Client** | **Urja Vikas Bhavan** |
|---|---|
| Place | Uttrakhand, India |
| Size | 25 Kw w/ battery backup |

**Waaree Sites**

## Thank You



Thomas Edison (1847 – 1931)

*"I'd put my money on the sun and solar energy"*

*"I hope we don't have to wait 'till oil and coal run out before we tackle that"*

www.waaree.com

**THANK YOU**

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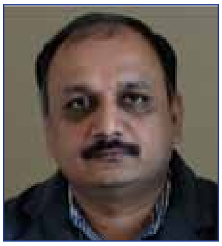
# SECTION C
# Annexures

## Profiles of Coordinators
## Contact Details of Speakers

# COORDINATOR



**S N Srinivas**

Dr Srinivas is working as Programme Analyst with United Nations Development Programme since 2007. His role involves [i] providing strategic inputs to programme formulation and leading resource mobilisation, [ii] providing oversight and compliance to projects anchored at different ministries, [iii] providing advisory support to implementation and policy formulation and [iv] leading development of knowledge products and sharing them. He has edited and published over 100 books, papers, and research reports. He was awarded 'India's one of the best energy conservationist 2014' for his contribution to energy efficiency in small-scale steel industry by HITEC, a think-tank NGO. He has also contributed to South–South cooperation. He leads the pilot demonstration of 100 biogas plants in the villages of Fayoum and Assuit provinces in Egypt. He has also provided support to development of proposals and publications at UNDP's Bangkok Regional Hub.

Srinivas obtained his Bachelor's Degree in Mechanical Engineering from the National Institute of Technology, Surathkal in 1989 and his Ph.D in Mechanical Engineering in 2010 from Vishwesharaiah Technological University, Karnataka.

Dr Srinivas worked as a lecturer for a brief period and then as project engineer at Combustion, Gasification and Propulsion Laboratory, Indian Institute of Science, Bangalore from 1990 to 1993. He worked on demonstrating decentralised electricity generation and supply to an un-electrified village through biomass gasification system and supported the design and development of different versions of small-scale gasifiers for power generation. He was awarded First prize from the Ministry of Non-conventional Energy Sources for paper "Techno-Economic Improvements to Rural Service System–Case Study of Hosahalli"

Dr Srinivas worked in The Energy and Resources Institute (TERI) from 1993 till 2007 as Research Associate and Fellow. He built and led the Rural and Renewable Energy Group in TERI, Bangalore. He worked on various aspects of renewable energy from design-development to demonstration to technology transfer, assessments to policy support. He was a member of the core team that was awarded "Energy Globe 2001 – The World Award for Sustainable Energy, Best 50 – Energy Globe 2001" for the project "Introducing Biomass Gasification Technology in Silk Industry" instituted by Government of Austria. He was also a member of the team that was awarded patent for "A cooking/heat recovery device for the cooking of cocoons".

# COORDINATOR

**O S Sastry**

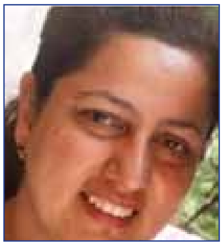
Dr O S Sastry is working as senior scientist at the Solar Energy Centre (SEC) under the Ministry of New and Renewable Energy (MNRE), Government of India. He obtained his degree of Doctor of Philosophy (Ph.D.) in physics from the prestigious Indian Institute of Technology, New Delhi. During the initial period of his career, he joined Defence Research Development Organization at Visakhapatnam. In 1989, he joined MNRE as a senior scientific officer, and was involved in country's Solar Energy Programme execution.

In 1992, he joined the SEC as in-charge of the National Photovoltaic Test Facility. He is solely responsible for design, establishment and accreditation of the PVTF of SEC as per IS 17025, quality system of NABL. He is also responsible for setting up, development and up-gradation of the PV module and system testing facilities in the country. He also established SPV modules outdoor test beds for long-term performance evaluation of PV modules in the country. As a part of long-term performance of PV modules, he also executed joint collaborative projects with NREL (USA) and AIST (Japan).

He is an accomplished technical expert for technical auditing testing laboratories for PV modules and systems. He is also the technical member of the BISET-28 committee for development of Indian SPV standards. At present, he is reviewing the IEC standards for their suitability in Indian conditions. Dr Sastry is responsible for all testing and certification activities in SPV in the country.

He has executed a number of prestigious international projects as well as consultancy projects. He has published over 40 research publications and compiled a few books. He also guided more than 25 students for their M.Tech. and B.Tech. major projects.

# COORDINATOR



**Preeti Soni**

Preeti Soni is the Adviser on Climate Change at the UNDP Country Office in India. She has over 19 years of experience in the area of policy, research and programme work related to climate change, energy and environment, and sustainable development. She has authored several papers, articles and books.

Prior to her current position, Ms Soni was the Assistant Country Director and Head of the Energy and Environment Programme at UNDP India. She has also served as the Resource Person (Environment) for UN Solution Exchange – the Knowledge Management Initiative of the UN in India. Earlier in her career, she worked as the Area Convenor and Research Associate at the Tata Energy Research Institute (TERI, now The Energy and Resources Institute).

Ms Soni has a Master's Degree in Economics from the Delhi School of Economics, Delhi University, and a PhD from the Institute for Environmental Studies, Virje University, The Netherlands.

Ms Soni has received the prestigious Netherlands Foundation for the Advancement of Tropical Research Netherlands – Netherlands Organisation for Scientific Research Fellowship for Researchers from Developing Countries (July 2002-June 2004), the UNU-INTECH Fellowship for the PhD programme in Economics and Policy Studies of Technical Change (September 1999–September 2001), and the UNEP-Tufts Fellowship for the Post-graduate Intensive Programme in Environmental Management (September–October 1996).

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## Ministry of New and Renewable Energy
## Government of India

The Ministry of New and Renewable Energy (MNRE) is the nodal ministry of the Government of India to look after all the aspects relating to the development of new and renewable energy in India. The major sectors being covered by MNRE are solar energy, wind energy, bio-energy, tidal energy, geothermal energy, and hydrogen energy. MNRE is allocated with R&D of these renewable sources of energy along with their development, production and its applications and programmes relating thereto. The National Institute of Solar Energy (NISE), the Centre for Wind Energy Technology (C-WET), the Sardar Swarn Singh National Institute of Renewable Energy (SSS-NIRE), the Indian Renewable Energy Development Agency Ltd (IREDA), and the Solar Energy Corporation of India (SECI) function under MNRE.

## United Nations Development Programme in India

India's economic growth continues to remain an impressive achievement. However, work remains to be done, and UNDP continues to be a committed partner of the Government of India in fulfilling its objective of inclusive growth. UNDP is committed to help India achieve the global Millennium Development Goals (MDGs) as well as the national objectives articulated in consecutive Five-Year Plans.

The goal of the organization is to help improve the lives of the poorest women and men, the marginalized and the disadvantaged in India. UNDP works in the following areas: Poverty Reduction, Democratic Governance, Crisis Prevention and Recovery, Energy and Environment, HIV and Development, Women's Empowerment and Inclusion and Human Development.

The booklet titled, '*Decentralised Energy Solutions: investment potential in solar thermal, modern biomass energy systems for heat and decentralised electricity generation*', is prepared as a reference document for those interested in the subject. The motivation behind publishing this booklet is the 'Make in India' call of the Hon'ble Prime Minister of India, Shri Narendra Modi, and the subsequent **Global Renewable Energy Investment and Promotion Meet:** 'RE-INVEST' convened by the Ministry of New and Renewable Energy (MNRE), Government of India, from 15 to17 February 2015 in New Delhi.

In India, current estimates indicate that about 800 million people still depend on traditional biomass burnt in inefficient stoves for satisfying their cooking energy needs and about 300 million people without access to electricity. Reaching out to these deprived sections of the society with efficient energy solutions presents both challenges and opportunities. In addition, decentralised energy solutions can be very valuable interventions that can replace conventional fuels in urban as well as in rural locations.

*Decentralised Energy Solutions* highlights the enormous potential that technologies such as solar thermal, modern biomass energy systems, and other decentralised electricity supply systems (only solar photovoltaic) carry with them. Considering the huge market size and some of the proven decentralized technologies, India looks a fertile ground for large-scale investments in these areas. The discussion papers in this booklet touch upon what it takes to reach out to this market with solutions. They include potential and investment scope in (i) solar thermal solutions, (ii) biomass based solutions for meeting heat requirements, and (iii) renewable energy solutions for decentralised electricity generation. The booklet also carries the papers/presentations of eminent speakers at the event organised by the United Nations Development Programme (UNDP) on this very subject.

This booklet should be of interest not only to those working in the renewable energy sector but also to the global investor community.

**United Nations Development Programme**

**Energy and Environment Unit**

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