



**RENEWABLES**  
**BEYOND ELECTRICITY**

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# Renewables

## Beyond Electricity

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## Acronyms & Abbreviations

AC	Alternating Current
AFPRO	Action For Food Production
AHU	Air Handling Units
ALRI	Acute Lower Respiratory Infection
ASHRAE	American Society of Heating, Refrigerating & Air-Conditioning Engineers
BARC	Bhabha Atomic Research Centre
BEE	Bureau of Energy Efficiency
BGFP	Biogas-Fertilizer Plants
BIS	Bureau of Indian Standards
BTU	British Thermal Units
CAGR	Compound Annual Growth Rate
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CERC	Central Electricity Regulatory Commission
CFA	Central Financial Assistance
CMSCRI	Central Salt & Marine Chemical Research Institute
COD	Chemical Oxygen Demand
COP	Coefficient of Performance
COPD	Chronic Obstructive Pulmonary Disease
CPSC	Concentrated Parabolic Solar Cooking
CSP	Concentrated Solar Power
CSR	Corporate Social Responsibility
DC	Direct Current
DNES	Department of Non-Conventional Energy Sources
DNI	Direct Normal Irradiation
DO	Dissolved Oxygen
DST	Department of Science & Technology
ECBC	Energy Conservation Building Code
ED	Electrodialysis
EER	Energy Efficiency Ratio
ETC	Evacuated Tube Collectors System
ETHP	Evacuated Tube Heat Pipe System
FPC	Flat Plate Collector
FRP	Fibre Reinforced Plastic
GHG	Greenhouse Gas
GIAN W	Gujarat Grassroots Innovations Augmentation Network - West
GoI	Government of India
GRIHA	Green Rating for Integrated Habitat Assessment

GSHP	Ground Source Heat Pump
GW	Gigawatt
GWP	Global Warming Potential
HDPE	High Density Polyethylene
HP	Horsepower
HVAC	Heating, Ventilation, and Air Conditioning
ICVIT	Indo-Canadian Village Improvement Trust
IFC	International Finance Corporation
IGBC	Indian Green Building Council
IIT	Indian Institute of Technology
INCCA	Indian Network on Climate Change Assessment
INR	Indian Rupees
IPCC	International Panel on Climate Change
JNNSM	Jawaharlal Nehru National Solar Mission
Kg	Kilogram
kPa	Kilopascal
KVIC	Khadi & Village Industries Commission
kW	Kilo Watt
LEED	Leadership in Energy & Environmental Design
Lpd	Litres Per Day
LPG	Liquefied Petroleum Gas
MDMP	Mid Day Meal Programme
MED	Multi-Effect Distillation
MEH	Multi-effect Humidification
MNRE	Ministry of New and Renewable Energy
MoEF	Ministry of Environment & Forests
MoSPI	Ministry of Statistics and Programme Implementation
MSF	Multi-Stage Flash Distillation
MT	Million Tonnes
MVC	Mechanical Vapour Compression
MW	Megawatt
MYT	Multi-Year Tariff
NABARD	National Bank for Agriculture and Rural Development
NAP	National Afforestation Programme
NAPCC	National Action Plan on Climate Change
NATCOM	National Communication
NBC	National Building Code
NBMMP	National Biogas and Manure Management Programme
NGRI	National Geophysical Research Institute
NIF	National Innovation Foundation



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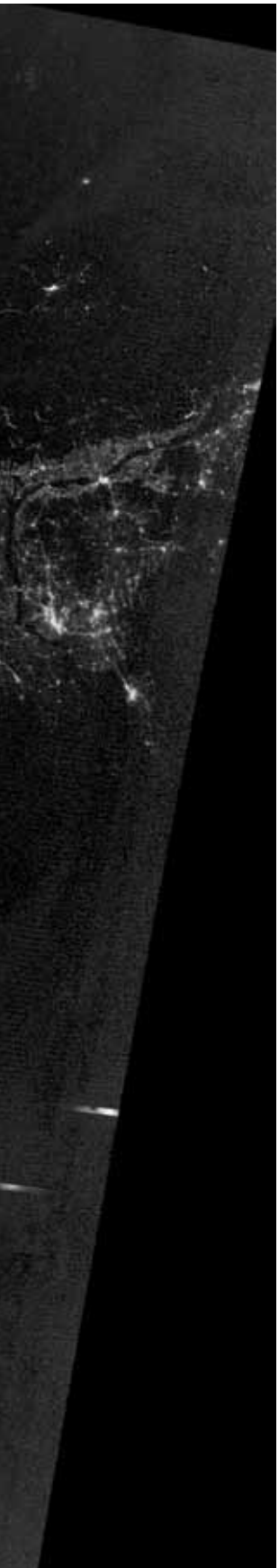
NPBD	National Program on Biogas Development
NPIC	National Programme on Improved Chulhas
NSSO	National Sample Survey Organization
NZEB	Net-Zero Emission Buildings
O&M	Operation & Maintenance
ORP	Operational Research Programme
PV	Photovoltaic
R&D	Research and Development
RCC	Reinforced Cement Concrete
RE	Renewable Energy
REEEP	Renewable Energy and Energy Efficiency Partnership
RO	Reverse Osmosis
RPM	Revolutions Per Minute
SD	Solar Distillation
SODIS	Solar Water Disinfection
SRI	System of Rice Intensification
SVNIT	Sardar Vallabhbhai National Institute of Technology
TDS	Total Dissolved Solids
TERI	The Energy & Resources Institute
TR	Tons Refrigeration
TVC	Thermal Vapour Compression
USA	United States of America
VAM	Vapour Absorption Machines
VC	Vapour Compression
VRF	Variable Refrigerant Flow
WWF	World Wide Fund for Nature



# Background

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Energy has been unanimously acknowledged as one of the most important building blocks for economic growth and human development of a nation. Energy security and accessibility has become a major issue globally; especially in developing countries. Internationally, efforts have been made by respective governments and international aid agencies to improve the conditions through devoted programmes, schemes and financial aids. Yet, nearly 2.7 billion people all over the world are dependent on traditional biomass energy sources (wood, straw, charcoal, dung) for satisfying their energy needs.

India's case is not too different. Nearly 81 million (32.8 per cent) households do not have access to electricity (Census of India, 2011). Around 74 million rural households lack access to modern lighting services (TERI, 2013) and a larger proportion of the population (around 840 million) continue to be dependent on traditional biomass energy sources (IEA, 2011).

The risk of climate change impacts due to increasing atmospheric GHG concentrations further compounds the issue. Thus, there is an urgent demand for nations to move towards low carbon development. This transition is bound to have a significant influence on the energy planning of the country.

Evidently, sustainable energy has become one of the most important developmental challenges for India. In recent years, renewable energy has increasingly attracted the attention of the public and policy-makers, particularly with regard to providing clean and modern energy access to the population and at the same time mitigating GHG emissions. Towards this end, India has embarked on various ambitious renewable energy programmes. One such programme, the National Action Plan on Climate Change (NAPCC), was launched by the Government of India in 2008. NAPCC suggested that starting 2009-10, a target 5 per cent renewable-based electricity injection be set in the national grid, to be increased by 1 per cent each year for 10 years thereby setting a cumulative goal of 15 per cent to the total national energy mix generated from renewable energy sources by 2020. This clearly indicates that renewable energy is now no longer an "alternate" to conventional energy, but is integral to the nation's energy issues.

In the last 10 years, the installed capacity of grid-connected renewable energy-based power generation has increased from just 3475 MW i.e. 2 per cent in 2002 of the total installed capacity in the country to 12.3 per cent (27541 MW) as on 31 April 2013, with wind power contributing nearly 70 per cent (19,051 MW). Apart from wind-based energy, since the inception of JNNSM solar-based energy production has witnessed tremendous growth. India's cumulative installed solar (on grid and off grid) capacity has crossed the 2 GW milestone.

Thus, it is evident that renewable energy is being explored extensively as a potential source for reliable and secure power supply, although there is urgent need for a more robust financing ecosystem to channel more investments in grid-connected projects (CEEW and NRDC 2012).

While the current policies and activities are focusing on power generation through renewables, there is a need to look at potential applications of renewable energy beyond electricity generation. The potential of renewables, particularly for heating, cooling, cooking and mechanical applications would greatly enhance the acceptance of renewables amongst the masses. There is substantial scope for use of renewables in providing energy to people both on a small-scale as well as on a larger scale.

Decentralised and distributed models of energy are being experimented with across India. Recent research reveals that there are more than 250 firms operating across the country offering a range of decentralised energy solutions (CEEW 2013). These firms sell products, integrated systems, set up mini grids for electricity generation, or develop technologies for other productive activities. It is important to recognise that the huge unmet needs of energy services are driving a surge of innovation in technologies, delivery systems, investment and revenue models, and most importantly community involvement. These trends are encouraging for two reasons: first, they demonstrate that market-based solutions can be developed to fulfil the energy needs of the poor; and secondly, they empower individual households and communities to take control of their energy destinies.

The report “RE+: Renewables beyond electricity” is a compendium comprising innovative renewable energy applications, pilot projects and novelty in technologies and business models. These 14 innovative cases bring out the experiences of different stakeholders such as entrepreneurs, developmental agencies and non-governmental agencies in exploring the diverse applications to which renewable energy can be utilized at the rural, urban and industrial levels.

The applications documented in this report cover four sources of renewable energy —biomass, wind, geothermal, and solar energy. The report documents a wide variety of renewable energy applications and technologies, such as improved biomass cook stoves, biogas digesters, solar space heating and cooling system, solar photovoltaic water pump, solar pasteurizer, solar desalinators, wind water pumps and so forth from different parts of the country, which have been successfully installed.

Using the descriptive analysis, the authors have examined these 14 different renewable energy applications. This analysis looks at each application with respect to different parameters such as technology, cost, market potential and policy scenario. Furthermore, the report dwells on the issue of various bottlenecks/gaps that need to be overcome for replication of these applications on a larger scale. Lastly, this report documents case studies of actual applications on ground that helps for a better understanding of renewable energy applications. These case studies have been compiled from various organizations and open source documents.

# Renewable Energy Technologies and Applications: **Heating**

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## SOLAR THERMAL - WATER HEATER

Heated water finds its application in bathing, cooking, cleaning, as boiler feed water, laundry and so forth. Solar thermal – water heaters are one of the most commonly used applications of solar energy in day-to-day life which can heat water up to 80°C on a sunny day (MNRE)<sup>1</sup>. It has very minimal maintenance costs and can help reduce the recurring cost of electricity incurred by an electrical geyser. In fact, a solar thermal- water heater can potentially provide heated water free of cost and pay the initial investment back in few years.

It is estimated that India has a gross potential of 140 million m<sup>2</sup> of collector area and a reliable techno-economic potential of 35-40 million m<sup>2</sup> of collector area (MNRE)<sup>2</sup>. The Ministry of New and Renewable Energy is aggressively promoting solar thermal – water heaters through many financial incentives. In addition, many state governments have also started providing benefits to those who deploy solar thermal - water heating systems. MNRE has certified 99 channel partners for off-grid and decentralized solar thermal systems. There are 160 and 63 approved manufacturers for Evacuated Tube Collector based solar systems and Flat Plate Collector based solar systems respectively (MNRE, 2013a) (MNRE, 2013b), (MNRE)<sup>3,4</sup>.

### TECHNICAL DESCRIPTION

The three different types of solar systems that may be used to heat water are:

- Flat plate type (FPC)
- Evacuated tube type (ETC)
- Concentrated type solar system

The output of a solar system is measured according to the volume of hot water per day. A 100 (lpd) litre per day system is assumed to be adequate for a family of four. The efficiency of FPC systems is in the range of ~50% and for ETC it is ~31% (Jain Irrigation)<sup>5</sup>. The efficiency of concentrated type solar systems may vary according to technology though it is typically higher than the FPC and ETC systems. A concentrated system developed by Clique Solar based on Fresnel technology may have an efficiency of 50-80 per cent, but may depend on many factors (Kedare, 2006).

Flat plate or evacuated tube type solar systems are generally used for applications with a temperature requirement in the range of 60 to 80°C and can therefore be deployed across India. A flat plate collector consists of a metallic box (absorber) with channels and tubes to carry water and is covered with a glass sheet. The heat absorbed by the metallic box is transferred to the flowing water (Delhi Transco Limited)<sup>6</sup>.

An evacuated tube solar system consists of double-layered borosilicate glass which is evacuated to provide insulation. The outer wall of the inner tube is coated with a selective absorbing material which absorbs the sun's rays and transfers the heat to the water flowing in the inner tube.

A concentrated solar thermal system produces heat from sunlight by focusing the direct insolation component using lenses or mirrors. Systems with trackers allow it to follow

1 [http://mnre.gov.in/file-manager/UserFiles/brief\\_swhs.pdf](http://mnre.gov.in/file-manager/UserFiles/brief_swhs.pdf)

2 [http://mnre.gov.in/file-manager/UserFiles/potential\\_electricitySavings\\_swhs.pdf](http://mnre.gov.in/file-manager/UserFiles/potential_electricitySavings_swhs.pdf)

3 [http://mnre.gov.in/file-manager/UserFiles/list\\_fpc\\_manufacturers.pdf](http://mnre.gov.in/file-manager/UserFiles/list_fpc_manufacturers.pdf)

4 An accredited channel partner can submit the project proposal directly to MNRE and apply for subsidy, whereas approved manufactures may have to submit a project proposal through state nodal agency (state ministry for renewable energy) to apply for subsidy.

5 <http://www.jains.com/Solar/jain%20solar%20water%20heater%20ETC%20type.htm>

6 <http://www.delhitransco.gov.in/EnergyEfficiency/SOLAR%20WATER%20HEATER-ENGLISH%20.pdf>



movement of the sun during the day. Presently MNRE is promoting two types of technology, a Scheffler dish with an automatic East-West tracker and ARUN concentrated dishes based on Fresnel technology which can completely track the sun (MNRE)<sup>7</sup>.

Solar concentrator systems should typically be employed in arid areas with clear skies. This increases the fraction of direct radiation in the solar insolation. States like Rajasthan, Gujarat and Maharashtra have favourable conditions for the implementation of concentrated solar systems (Ramachandra, 2011). There are very few examples of successful implementation of hot water systems through concentrated solar systems.

## APPLICATION MARKET

Presently over 7.27 million meter square collector area is installed in India (MNRE, 2013c). It is estimated that India has a potential of 35-40 million m<sup>2</sup> of collector area and the country aims to deploy 15 million collector area by 2017 and 20 million m<sup>2</sup> by the end of the National Solar Mission in 2022 (MNRE, 2010).

The estimated use of solar water heater region may vary according to location and need. An indicative use of solar water and their savings electricity units is given below.

**Table 1: Estimated use of solar water heaters in India**

	Northern Region	Eastern Region	Southern Region	Western Region
Expected number of days of use of hot water per year	200	200	300	250
Expected number of units of electricity saved per year	1,000	1,000	1,500	1,250

Source: (MNRE)<sup>8</sup>

## COST & SUBSIDY

The central government and a few state governments provide subsidy for solar thermal systems. The benchmark cost since May 2013 is as follows:

**Table 2: MNRE subsidy on solar thermal systems**

Type of System	Category	Benchmark Cost per sq meter (INR)	Subsidy (30% of benchmark subject to the maximum of) (INR)
ETC	Domestic	8,500	2,550
	Commercial	8,000	2,400
FPC	Domestic	11,000	3,300
	Commercial	10,000	3,000
Concentrator with manual tracking	-	7,000	2,100
Concentrator with single axis tracking	-	18,000	5,400
Concentrator with double axis tracking	-	20,000	6,000

<sup>7</sup> [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Solar\\_Steam\\_generating\\_Systems.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Solar_Steam_generating_Systems.pdf)

<sup>8</sup> [http://mnre.gov.in/file-manager/UserFiles/faq\\_swh.pdf](http://mnre.gov.in/file-manager/UserFiles/faq_swh.pdf)

Note: 1. Below 500 lpd are categorized as domestic systems and above 500 lpd are categorized as commercial systems.

2. Soft loans at 5 per cent interest rate are available for 50 per cent of the total system costs.<sup>9</sup> States categorized as special category receive 60 per cent subsidy. They are Himachal Pradesh, Jammu & Kashmir, Uttarakhand, and the North-eastern states including Sikkim.

Source (MNRE, 2013d) (MNRE, 2013e) (NABARD, 2013)

A solar water heating system may last for up to 15 years and does not require regular maintenance. Problems such as leakages can be repaired by common plumbers. In case of hard water corrosion, de-scaling of collectors once every few years may be required.

Payback of a system may vary according to location, operational hours and external support from the government. A solar system may have a payback period of 3.3 to 4.5 years without any external support and with 30 per cent central subsidy the payback period may reduce to 2.5-3.5 years (CEEW, 2012)<sup>10</sup>.

## POLICY SCENARIO

MNRE provides financial support either through capital subsidy, loan at 5 per cent interest rate for 50 per cent of the benchmark cost. Some states and municipalities provide additional incentives in the form of capital subsidy, monthly electricity rebate or tax rebate in property tax (MNRE)<sup>11</sup>. A few states which provide additional incentives are:

- **Capital subsidy:** Chandigarh, Chhattisgarh, Delhi, Haryana, Jharkhand, Jammu & Kashmir, Kerala, Madhya Pradesh and West Bengal.
- **Rebate in electricity:** Jammu & Kashmir, Rajasthan, Karnataka and Uttarakhand.
- **Rebate in property tax:** A few municipal corporations of Maharashtra provide additional rebate on property tax.

## BENEFITS

A 100 lpd (litre per day) solar system abates carbon dioxide emission by over one tonne annually. (CEEW, 2012). When operational, a 100 lpd system can potentially replace a 2 kW electric geyser for 2.5 hours, saving five units of electricity. Installation of one million such systems can potentially save 1200 units electricity each year. Assuming that 50 per cent of such systems are switched on at the same time, a peak load shaving of 1000 MW can be achieved (MNRE)<sup>2</sup>.

## CONSTRAINTS

Despite a low payback period, solar water heating systems do not seem an attractive option to customers. Lack of awareness, declining quality due to cost pressures and high transaction costs in securing subsidies decrease the rate of uptake of solar hot water systems. Other factors such as international price fluctuations in raw products (copper, aluminium, iron and steel) and rupee devaluation (since many components including tubes for ETC solar collectors are imported from China) have led to an increase in the cost of solar systems (CEEW, 2012).

9 To avail a soft loan, a customer will have to provide 20 per cent of the overall cost.

10 Additional financial support from state governments can reduce the payback periods further.

11 <http://mnre.gov.in/file-manager/solar-thermal-newsletter/volume-1-issue-8/EN/featureStory.php>



for a living planet

INSTALLATION OF  
SOLAR WATER HEATER  
TO PROMOTE USE OF  
ALTERNATIVE ENERGY  
RESOURCES

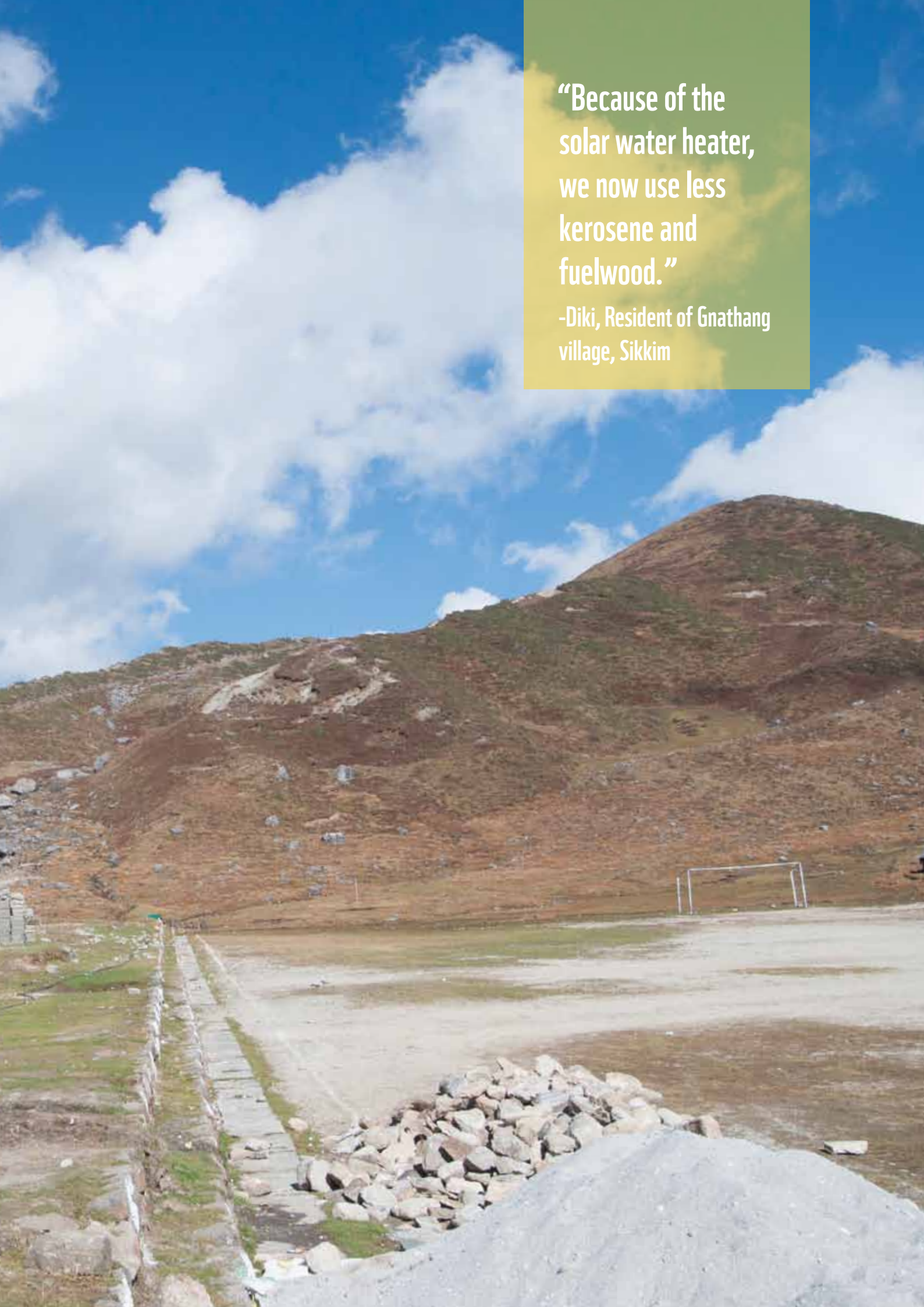
PROJECT NAME: CLIMATE CHANGE ADAPTATION  
NUMBER OF INSTALLATIONS: 100

7000

TATA BP SOLAR







“Because of the  
solar water heater,  
we now use less  
kerosene and  
fuelwood.”

-Diki, Resident of Gnathang  
village, Sikkim

## CASE STUDY:

# ROOFTOP SOLAR WATER HEATERS AT NATIONAL LAW UNIVERSITY, DELHI<sup>12</sup>

National Law University, Delhi is one of the seventeen national law colleges in India. It was established in 2008 and is located in Dwarka, New Delhi.

The university decided to install solar thermal - water heaters to meet the hot water requirements for bathing, cooking and cleaning of dishes in student hostels and guest houses. Solar hot water systems were installed at two undergraduate hostels, one postgraduate hostel and one guest house. The hot water was required for four months in the case of bathing and throughout the year for kitchen purposes.

### TECHNICAL DESCRIPTION

Solar water heaters based on FPC technology were installed on the rooftops of the hostels. Sixteen systems of capacities ranging from 200 to 2000 lpd were installed at the university. The cumulative capacity of the systems was 25,700 lpd.

### PROJECT DESCRIPTION

National Law University offers a five-year undergraduate degree and a two-year postgraduate degree in law and with an intake of 80 and 25 respectively. The total capacity of students is 450. There are 24 bathrooms in graduate student hostels in all with four bathrooms to a floor. A 2,000 lpd system meets the requirement of six bathrooms.

The breakups of installation at various hotels are:

**Table 3: Breakup of capacity**

Building	System Capacity	
	For use in bathrooms	For use in kitchen
Boys Hostel	2000 x 4	1000
Girls Hostel	2000 x 4	1000
Postgraduate student hostel	2000 x 2	500
Guest House	1500 x 2	200

Source: (GKSPL, 2011)

<sup>12</sup> The information was collected from a study 'Market Assessment of Solar Water Heating Systems In Five Potential States/NCR Region' done by Greentech Knowledge Solutions Private Limited in 2011 with some additional calculations.

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## **COST**

The total cost was INR 5 million at a cost of INR 195 per litre. The return on investment (RoI) in this particular instance is expected to be in five-six years compared to a longer RoI on electrical geysers.

## **BENEFITS**

These systems are interconnected which helps them cater to the needs of other bathrooms should there be an increase in demand. An electrical backup has also been provided to meet the higher demand for water heating during cloudy days.

While designing the system, a capacity of 40 lpd for hot water per student was assumed. Sixteen solar hot water systems with a cumulative capacity of 25,700 litres per day were installed at the hostels and guest house. A 100 lpd solar thermal water heater can save around INR 1,300,000 by avoiding usage of 257,000 units of electricity on an annual basis<sup>13</sup>.

## **CONSTRAINTS**

Few systems have recorded lower than expected temperatures of their heating units due to the close proximity of collectors and insufficient sunlight due to walls. However the system was able to meet the demand of hot water on most occasions.

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<sup>13</sup> It has been assumed that a 100 lpd system is operational for 200 days in northern region of India; the cost per unit is assumed to be INR 5. The savings may go up if the cost per unit of electricity is increased. Also, it is difficult to estimate the number of electrical geysers which may have been installed if the solar system was not deployed, because electrical geysers are of different types and can operate anytime with electricity. Hence it may not be correct to compare the number of electrical geysers that may have been replaced. A calculation on savings of electricity can give a better picture.







## SOLAR/WIND DESALINATOR

Seawater desalination has been recognized as a potential solution to India's limited freshwater reserves and an ever-increasing demand for it by the country's burgeoning population. According to TERI, it has been estimated that "of 575,000 Indian villages, about 162,000 struggle with brackish or contaminated water and scarcity of fresh water" (TERI)<sup>14</sup>. Coastal areas in particular are struggling with severe salinity ingress due to excessive pumping of groundwater. A large section of India's urban and rural population reportedly consume water with TDS (total dissolved solids) levels of about 1500 to 2000 mg/litre which is well above permissible limits (specified by BIS) (TERI)<sup>15</sup>.

Desalination is a process by which dissolved minerals (including salts) are removed from seawater or brackish water<sup>16</sup>. Conventional desalination processes (powered by fossil fuels) require large quantities of energy. Therefore, coupling renewable energy sources such as solar and wind with desalination systems is the most promising option especially in remote and arid regions which lack access to grid electricity or face severe power outages.

The first largest solar distillation plant for desalination was installed by Central Salt & Marine Chemical Research Institute (CSMCRI), Bhavnagar to supply drinking water in Awania village and Chhachi lighthouse in 1978 (Arujnan et al., 2009). At present, several R&D efforts on solar desalination technologies, with the support of Indian R&D institutions such as Bhabha Atomic Research Centre (BARC), CSMCRI, and IITs as well as international institutions/donors (outlined in Table 4) are being undertaken across the country in an effort to commercialize solar/wind desalination technologies (solar based desalination in particular). Table 4 outlines some of the key players in solar desalination in India.

**Table 4: Key players/actors in solar desalination**

Category	Key players
Private companies/ NGOs	KG Design & Imperial Inc; Taylormade Solar Solutions (TSS) Pvt. Ltd.; Gerindtech; Photon Energy Systems; Jal Bhagirathi Foundation; Claro Ventures; Kotak Urja; Saurya Eneritech; NRG
R&D institutions	Central Salt & Marine Chemical Research Institute (CSMCRI); Bhabha Atomic Research Centre (BARC); Department of Science & Technology (DST); The Energy and Resources Institute (TERI); Solar Energy Centre (SEC); IIT – Madras; IIT-Delhi; Sardar Vallabhbhai National Institute of Technology (SVNIT);
International companies, donors and research institutes	Aqua-Aero Water Systems; Fraunhofer Institute; GIZ; Heriot Watt University, U.K.; Mage Water Management; Acumen Fund; Japan-based Hitachi, ITOCHU Corporation and Singapore-based Hyflux Ltd
Government	MNRE

Source: CEEW compilation

14 [http://www.teriin.org/index.php?option=com\\_content&task=view&id=62](http://www.teriin.org/index.php?option=com_content&task=view&id=62)

15 Water is fresh when its total dissolved solids (TDS) concentration is below 500 mg/L as per Bureau of Indian Standards (BIS) specifications. Salinity, in some cases, is expressed by the water's chloride concentration, which is about half of its TDS value

16 Seawater is having a total dissolved solids (TDS) concentration of about 35,000 milligrams per litre (mg/L) and brackish water has a TDS concentration range between 1,000 mg/L and 10,000 mg/L.

## TECHNICAL DESCRIPTION

All desalination processes contains three liquid streams – the saline feedwater which is the brackish water or seawater; the low salinity product water; and brine (also called reject water)<sup>17</sup>. Currently available conventional desalination technologies can be categorized as follows (Table 5):

**Table 5: Categorization of desalination technologies**

Process	Principle	Application of the principle
Phase change/ thermal processes	Involves distillation process involving heating the feed (seawater, brackish water or other impaired waters) to boiling point at the operating pressure to produce steam, and condensing the steam in a condenser unit to produce freshwater.	Solar distillation (SD); Multi-effect distillation (MED); Multi-effect humidification (MEH); Multi-stage flash distillation (MSF); Mechanical vapour compression (MVC) and thermal vapour compression (TVC)
Non-phase change/ membrane	Involves separation of dissolved salts from the feed waters by mechanical or chemical/electrical means using a membrane barrier between the feed (seawater or brackish water) and product (potable water).	Electrodialysis (ED) and reverse osmosis (RO)
Hybrid processes	Involves combination of phase change and separation techniques (as in the case of non-phase change processes) in a single unit or in sequential steps to produce pure or potable water.	Membrane distillation (MD); Reverse osmosis combined with MSF or MED processes.

Note: The Multi Stage Flash (MSF) process is divided into sections or stages in which saline water is heated at the boiling temperature between 90 and 110 C°, with decreasing pressure through the stages. Similar to MSF, Multi Effect Distillation (MED) is a multi-stage process variant in which vapour from each vessel (stage) is condensed in the following vessel and vapourized again without the need to supply additional heat unlike MSF.

Multiple Effect Humidification involves use of heat from highly efficient solar thermal collectors to induce multiple evaporation/condensation cycles.

In Vapour Compression (VC) distillation process, the heat for water evaporation comes from compression rather than from direct heating. This process is generally used in combination with other processes (MED) to improve overall efficiency.

In the Reverse Osmosis (RO), the seawater pressure is increased above the osmotic pressure, thus allowing the desalinated water to pass through the semi-permeable membranes, leaving the solid salt particles behind.

Electrodialysis technology is usually limited to brackish feedwater.

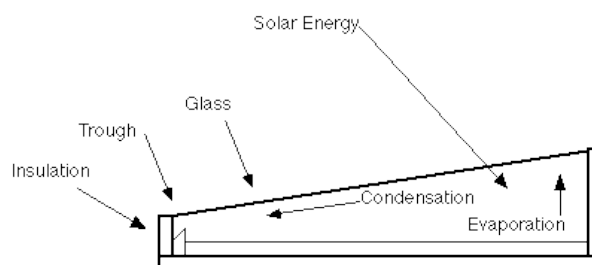
Source: (Gunde et al., 2010)

<sup>17</sup> Brine is a concentrated salt solution (with more than 35,000 mg/L dissolved solid) that must be disposed carefully

The above mentioned conventional fossil-fuel driven desalination systems can be coupled with renewable energy (RE) sources such as solar/wind. The best coupling of RE with desalination systems is determined by various criteria, such as the required quantity of potable water (plant capacity); feedwater salinity; remoteness; the system's efficiency; the investment and operational cost; type and potential of the local renewable energy resource; as well as availability of operational personnel; the possibility for future increase of the system capacity and so forth. Various combinations of renewable energy sources and desalination systems have been proposed and implemented, each one with its own characteristics and suitability under certain criteria. This study found that desalination systems driven by solar power are the most frequent RE desalination plants in India.

## Solar driven desalinators

- a) **Solar distillation:** Solar distillation deploys solar stills for desalination. A solar still consists of a shallow triangular basin and deploys evaporation/distillation in a single chamber for purifying water. The bottom of the basin is painted black for effective heat absorption and the basin's top is covered with a transparent glass tilt to ensure the passage of maximum solar radiation. The outlet is connected with a storage container as shown in Figure 1 (GEDA)<sup>18</sup>. Both small and large scale solar distillation plants deploying solar stills have been implemented in the country since 1970s and have also undergone series of technological improvements since then (Arjunan et al., 2009). The construction of a solar still is simple and involves low operation and maintenance rigours. Typical still efficiency of 35 per cent with a low productivity of 3–4 L/m<sup>2</sup> and large area requirements are two factors that prevent large-scale applications of solar stills (Gunde et al., 2010). It is noteworthy that productivity of solar stills can be improved by integrating them with a solar concentrator (for example, single basin coupled with flat plate collectors) (Arjunan et al., 2009).



Source: (SolAqua)<sup>19</sup> (GEDA)<sup>18</sup>

Figure 1: Solar Stills

<sup>18</sup> [http://geda.gujarat.gov.in/applications\\_solar\\_stills.php](http://geda.gujarat.gov.in/applications_solar_stills.php)

<sup>19</sup> <http://www.solaqua.com/solstilbas.html>

- b) **Solar thermal collectors/Concentrated Solar Power (CSP):**<sup>20</sup> Solar collectors capture solar irradiation and can be classified into two categories based on concentration ratios – (i) non-concentrating type primarily used for low temperature applications such as space/water heating (for example - flat plate collectors are often used for distillation); and (ii) concentrating type solar collectors (example parabolic troughs, dish, heliostat collectors are used in CSP for power generation). CSP plants can be integrated either with RO (utilize electricity) or thermal desalination units (for example, MSF and MED that utilize steam) (Gunde et al., 2010). Furthermore, CSP can be coupled with thermal storage, and/or hybridized with coal/natural gas which enables them to operate in limited or in the absence of solar radiation. Such features make CSP plants a viable alternative for seawater desalination (IRENA-ETSAP, 2012). Table 6 provides the possible combinations of solar collectors with various desalination technologies (Gunde et al., 2010)

**Table 6: Possible combinations of solar collectors with desalination technologies**

Type of solar collector	Source of salt water	Desalination process
Direct solar	Seawater, brackish water	Solar stills
Flat panel collectors	Seawater	MED
Evacuated tube collectors	Seawater	MSF/TVC
Parabolic trough collectors	Seawater	MED
Photovoltaic thermal collectors	Seawater, brackish water	MED

Source: (Gunde et al., 2010)



**Figure 2: A solar -seawater desalination plant in Ramanathapuram district of Tamil Nadu**

Source: (CSP Today)<sup>21</sup>

In October 2012, KG Design Services together with Empereal Inc. commissioned India's first CSP-powered desalination plant using Linear Fresnel technology in Ramanathapuram district of Tamil Nadu. Empereal KGDS considers Linear Fresnel technology suitable for solar thermal applications like desalination, especially in the Asian and Indian context due to factors such as: simple and reliable system because of the single axis tracking of reflectors and fixed receivers; cost-effectiveness and land-

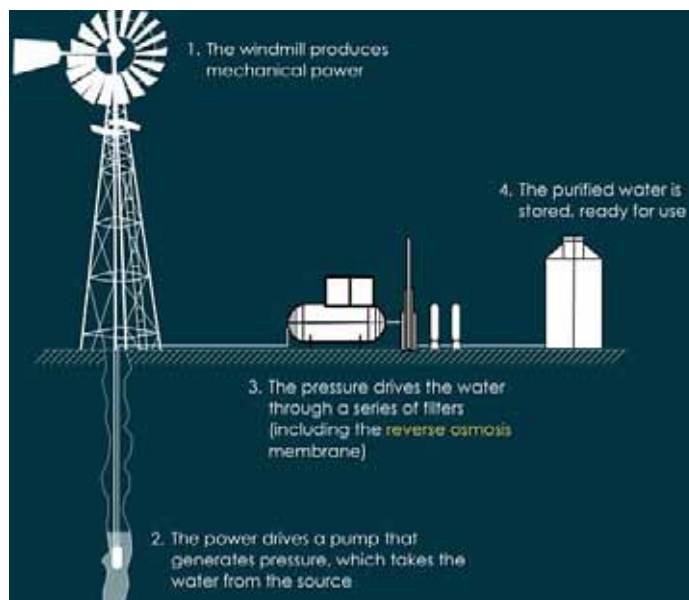
efficiency. These advantages drive the selection of Linear Fresnel technology for applications ranging in output temperature from 110°C to 450°C (CSP Today)<sup>21</sup>.

<sup>20</sup> CSP plants use collectors to concentrate (focus) irradiation/heat and convert it into steam that drives a turbine for generating electrical power.

<sup>21</sup> <http://social.csptoday.com/emerging-markets/executive-viewpoint-manoj-divakaran-president-coo-empereal-inc#sthash.nHIKT0ny.dpuf>

- c) **Solar photovoltaic (PV) modules:** Photovoltaic (PV) technology can be connected directly to reverse osmosis (RO) or electrodialysis (ED) desalination processes, which are based on electricity as the input energy (IRENA-ETSAP, 2012). The potential combination of solar PV power with RO has generated growing interest because of its inherent simplicity and low specific energy consumption. The cost of PV modules has declined in the past few years which makes solar PV powered desalination systems an attractive option (Gunde et al., 2010). Capital and operational costs (regular replacement of RO membranes) associated with solar PV-RO can be offset by: building a solar PV-RO system without a battery and integrating hybrid processes such as solar PV – RO/ultrafiltration/nanofiltration that can lead to lower specific energy consumption (Gunde et al., 2010).

## Wind-based desalination



In a wind driven desalination system, the electrical and mechanical power generated by a wind turbine can be used to power desalination plants, notably RO and ED desalination units, and vapour compression distillation process (in particular, mechanical vapour compression, MVC). In general, wind power based desalination can be a promising option for seawater desalination, especially in coastal areas with a high wind potential. However, wind powered seawater desalination units are still to be reality in India (IRENA-ETSAP, 2012).

Figure 3: Wind powered desalination  
Source: [www.ecofriend.com](http://www.ecofriend.com)

## APPLICATION MARKET

India has about 53,000 habitations with salinity greater than 1500 mg/litre, most being remote and arid areas with saline water (TERI, 2013)<sup>14</sup>. Most places in India suffering from salinity lie in high radiation zones—5.4 to 6.4 kWh/m<sup>2</sup> (annual average). The problem of water scarcity is more pronounced during the summers but at that time desalination systems also become more effective since solar insolation is higher than average.

For rural and urban municipal water applications, solar desalination technologies such as distillation, multiple-effect dehumidification, reverse osmosis requiring smaller capex investments is more appropriate. Not every part of India can benefit from a CSP solution because locations need to have adequate direct normal irradiation (DNI) levels. As far as application for solar desalination of industries is considered, the technological advances achieved for the municipal water applications can be evaluated on economic grounds (the overall economics of the water treatment process) and accordingly extended for industrial



application. Affordability of reuse/disposal is also an important factor that should be taken into account.

Wind powered desalination can be a promising alternative for India's coastal areas due to the high availability of wind resources in Tamil Nadu, Gujarat, Maharashtra, Andhra Pradesh, Karnataka. More specifically, wind energy can be used efficiently on condition that the average wind velocity is above 5 m/s). Table 7 shows that significant research is being undertaken and pilots are being implemented in an effort to improve, reduce costs and commercialize desalination through solar thermal multi-effect humidification (MEH), solar stills and solar PV reverse osmosis. There was no data suggesting the implementation of wind powered desalination pilot/demonstration projects in India.

**Table 7: Status of solar/wind desalination technologies/projects in India**

Solar/wind desalination technologies/projects	Status
Solar stills with better efficiency and increased output (7L/day) – CMSCRI	Not commercialized yet; trials to be conducted in remote areas of Rajasthan, Madhya Pradesh, Gujarat, Rameshwaram, Sunderbans and northern regions of India. CMSCRI has filed for a provisional patent
Water Pyramid in Kutch (Gujarat) and Roopji Raja Beri in Barmer district (Rajasthan) - Aqua-Aero Water Systems BV (Netherlands); Acumen Fund (US) and Jal Bhagirathi Foundation	Under operation
Solar thermal (multi-effect humidification) demonstration plant in Bitra Island, Lakshwadeep – MNRE & GIZ	Under operation
75 MGD desalination plant at Dahej, Gujarat (touted to be Asia's largest desalination plant once it is operational)	Under development
Solar thermal (multi-effect humidification) pilot plant in Chennai (MiniSal 1000 project) – Mage Water Mangement	Under operation
Solar thermal (Linear Fresnel) plant in Ramanathapuram district, Tamil Nadu – KG Design Services and Empereal Inc.	Commissioned in 2012
Swajal Aqua pilot project using solar RO purification technology – developed by Saurya Enertech (funding from REEEP) in villages of Khoda and Behrampur, U.P.	Under operation
Flat-plate collector-based solar desalination system installed at the Solar Energy Centre, Gual Pahari, Gurgaon – TERI	Under operation
Multi-stage evacuated solar desalination system – IIT Madras and Heriot Watt University, UK	Experimental stage
Solar powered RO plant at Sardar Vallabhbhai National Institute of Technology, Surat	Under operation
Solar/Wind PV RO desalination – BARC	Not commercialized yet

Source: CEEW compilation

## COSTS

The economics of a solar/wind desalination system differ from conventional plant economics since it is almost entirely based on the fixed costs of the system. There are no fuel costs for the system. Site-specific aspects, which also have a significant impact on final costs, include feedwater transportation, freshwater delivery to end-users, brine disposal and the size of the plant. In general, desalination based on renewable energy sources is still expensive compared to conventional desalination, because both investment and generation costs of renewable energy are higher. However, with the rapid decrease of renewable energy costs, technical advances and increasing number of installations, renewable desalination is likely to reduce significantly its cost in the near future (CSP Today)<sup>21</sup>.

Solar stills for individual use are the cheapest amongst solar desalination technologies. Basin-type solar stills with an output of 2.0-2.5 litres of water at a time cost INR 5000. The desalination plant – “Water Pyramid”, in village – Roopaji Raja Beri having a capacity of 1000 L/day costs INR 1.5 lakh (The Hindu, 2009). The plant has a capacity to produce 1,000 litres of safe drinking per day. The solar thermal - MiniSal 1000 (MEH technology) with a daily capacity of 1000L costs about EUR 15,000 (approximately INR 1,257,746) (Global Solar Thermal Energy Council, 2010)<sup>22</sup>. The Dahej project in Gujarat (capacity 75 MGD), which is under development is expected to cost INR 2,000 crore. The proposed cost of the water from the Dahej solar desalination plant is likely to be INR 40 per 1,000 litres (The Indian Express, 2013).

## POLICY SCENARIO

MNRE subsidy applicable for solar PV-RO units: The “off-grid and decentralized solar applications scheme” of the Jawaharlal Nehru National Solar Mission (JNNSM) also covers solar PV powered RO plants (SPV plant of maximum capacity of 250 Wp each). The MNRE extends capital subsidy to the eligible project developer. The entire funding under this scheme is project-based and requires submission of a detailed project report (DPR) to avail capital subsidy. MNRE provides a combination of 30 per cent capital subsidy of the benchmark cost and/or 5 per cent interest bearing loans to the eligible project (MNRE)<sup>23</sup>. Capital subsidy of 90 per cent of the benchmark cost is available for special category states i.e. those in the northeast, Sikkim, J&K, Himachal Pradesh and Uttarakhand.

**Table 8: MNRE subsidy on solar thermal systems**

Type of System	Category	Benchmark cost per m <sup>2</sup> (INR)	Subsidy (30% of benchmark subject to the maximum of) (INR)
Evacuated tube collector (ETC)	Domestic	8,500	2,550
	Commercial	8,000	2,400
Flat plate collector (FPC)	Domestic	11,000	3,300
	Commercial	10,000	3,000
Concentrator with manual tracking	-	7,000	2,100
Concentrator with single axis tracking	-	18,000	5,400
Concentrator with double axis tracking	-	20,000	6,000

22 Assuming 1.00 EUR = 83.8 INR

23 [http://mnre.gov.in/file-manager/UserFiles/jnnsms\\_spv\\_mini\\_grid\\_plants.pdf](http://mnre.gov.in/file-manager/UserFiles/jnnsms_spv_mini_grid_plants.pdf)



Note: 1. Below 500 L/day are categorized as domestic systems and above 500 L/day are categorized as commercial systems.  
2. Soft loans at 5 per cent interest rate are available for 50 per cent of the total system costs. States under the special category receive 60 per cent subsidy. They are Himachal Pradesh, Jammu & Kashmir, Uttarakhand, and the north eastern states including Sikkim.

Source: (MNRE, 2013a) (MNRE, 2013b) (NABARD, 2013)

Policy support for wind powered desalination through MNRE programme on Small Wind Energy and Hybrid Systems: The objective of the programme is to develop technology and promote applications of water pumping windmills and aerogenerators/wind-solar hybrid systems. The programme extends support to the following activities:

- Central financial assistance (CFA) for setting up water pumping wind mills and aerogenerators/wind solar hybrid systems
- Field trials and performance evaluation
- Grid connected SWES on demonstration basis
- Research & Development

However, it is noteworthy that as per the 2013 amendment to the programme, central financial assistance (CFA) is confined only to community users as per specifications outlined in Table 9 (MNRE, 2013c). MNRE support for installation of aerogenerators is confined to a maximum capacity of 10 kW (project capacity) (MNRE, 2013c).

**Table 9: Central financial assistance (CFA) for wind pumps**

Type of Windmill	Maximum MNRE support	
	General Area	Island
Direct drive gear-less wind-mills such as Modified 12 PU 500 and similar other wind-mills	INR 20,000	INR 30,000
Gear type windmill	INR 30,000	INR 50,000
AV55 Auroville type windmill	INR 45,000	INR 80,000

Source: (MNRE, 2010)

Pilot projects: Government of India is promoting renewable powered desalination technologies through pilot demonstration projects. As part of Com Solar Project, MNRE in collaboration with GIZ has undertaken a demonstration pilot project to set up a 10,000 L/day solar water desalination plant at Bitra Island of Lakshadweep facing a severe shortage of drinking water for its small population. The desalination plant demonstrates a solar and waste heat-assisted water desalination system at Bitra using an efficient Multiple-effect Humidification (MEH) Desalination Technology which is low on energy demand and maintenance. Co-financing for this project is being done by GIZ and the Department of Science & Technology, Lakshadweep<sup>24</sup>.

<sup>24</sup> Com Solar project is a part of Com Solar Project to enhance Cooperation among German and Indian project developers to demonstrate business models for commercialization of solar technologies in India and technology transfers through Public Private Partnerships.

## BENEFITS

The most vital impact of desalination on the environment is that it reduces the pressure on conventional water resources and emission of greenhouse gases (GHG). Solar/wind powered desalination systems can offset costs and negative environmental repercussions of conventional desalination systems driven by fossil fuels such as diesel. For example, solar desalination plant in Bitra, Lakshadweep offsets the expenditure incurred on importing large amounts of diesel (used in conventional method of desalination) and on transportation of fresh water from neighbouring areas. Further, it curbs air or sound pollution, requires minimum maintenance and offers constant power generation efficiency throughout its lifetime.

The social benefits of solar desalination projects, especially in water scarce areas with poor income households is brought out in Roopaji ki Beri where villagers no longer face the ignominy of stealing water from neighbouring villages after the installation of ‘water pyramid’ (The Hindu, 2009).

## CONSTRAINTS

In India, desalination plants driven by solar power (both PV and CSP) have seen a wider uptake as opposed to wind-based desalination systems. Intermittent nature of solar/wind energy source a drawback for desalination systems powered by these sources. Although RO desalination is simple with use of PV modules, the rechargeable batteries used to store the produced electricity require high capital costs and periodic maintenance. Problems encountered with batteries include their premature failure, leaks in the lead-acid batteries and battery efficiency. It is important to further technology advancements in order to develop low cost storage solution for desalination considering high costs associated with battery (for electrical storage) and thermal storage.

For the operation of a wind-powered desalination plant, it is most important to have a plant that is insensitive to repeated start-up and shutdown cycles caused by sometimes rapidly changing wind conditions. Coupling of a variable energy supply system, to a desalination unit requires either power or demand management, and there is not much experience on it in India. However, the prospects of this combination are high mainly due to the low cost of wind energy.

The reverse osmosis (RO) plant at the Kotri village in Rajasthan produces 600 liters of water per hour for six hours each day and meets the drinking water needs of more than 1,000 men, women and children.

Source: Barefoot College





सौर ऊर्जा द्वारा संचालित आर.ओ.प्लांट  
ग्राम भोपा की दाणी जिला अजमेर, वर्ष-2011



## CASE STUDY:

### SOLAR POWERED RO PLANT BY BAREFOOT COLLEGE AT KOTRI VILLAGE, RAJASTHAN<sup>25</sup>

Barefoot College is a non-governmental organization that has been involved in offering basic services and sustainable solutions to alleviate problems of rural communities with the objective of making them self-sufficient. These 'Barefoot solutions' can be broadly categorized into the delivery of clean water, solar electrification, education, livelihoods and activism.

On 3 September, 2006, Barefoot College implemented India's first ever solar powered Reverse Osmosis (RO) plant for desalination at a small voluntary organization called Manthan located in Kotri, a small village in Ajmer district of Rajasthan (Figure 4). Kotri is located ten miles away from Sambhar lake, a large saltwater lake faced acute drinking water shortage. Nearly 100 villages with a population of over 250,000 surround the lake, where villagers earn their livelihoods by way of manufacturing (pumping salty water of TDS as high as 18,000 ppm



**Figure 4: Barefoot College's solar RO desalination unit, Kotri, Rajasthan<sup>26</sup>** Source: (Barefoot College)<sup>27</sup>

from open wells to salt pans for evaporation) and marketing salt. There are around 150 open wells spanning an area of 1800 km<sup>2</sup> with highly brackish water (TDS ranging from 3000-4000 ppm) unfit for drinking purposes. With the potable sources of water having dried up in the area, water pumped from open wells and supplied through pipelines had high TDS concentration and was too brackish to consume or use for cooking and cleaning. Consumption of this water led to skin ailments and stunted growth in children as well as gradually began to render the soil infertile for agricultural use.

The Barefoot College had collaborated with the scientists from the Central Salt & Marine Chemical Research Institute (CSMCRI) to design this small desalination that could be managed, repaired and operated by members of the rural community (Barefoot College)<sup>27</sup>. CSMCRI installed the plant and trained two Barefoot College solar engineers to operate and maintain it. The plant meets the drinking water needs of around 3,000 men, women and children from Kotri and its surrounding villages.

<sup>25</sup> Information collected from secondary sources.

<sup>26</sup> Information for this case study has been collated through secondary research.

<sup>27</sup> <http://www.barefootcollege.org/solutions/water-old/>

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## TECHNICAL SPECIFICATION

Brackish water from Sambhar Lake is supplied to village through the government pipelines which is pumped through the solar-RO desalination plant and stored in a 5,000 litre tank. The plant is made from components that are simple and locally available: a booster pump, a sand filter, motors, pressure gauges, valves, a cartridge and a carbon filter that prevents waste and impurities from mixing with the desalinated water. It is noteworthy that the membrane (for carrying out reverse osmosis) was sourced from CMSCRI.

The RO plant runs on a 2.5-3 kilowatt power solar PV plant that allows it to produce 600 litres of water per hour for six hours each day.

## BENEFITS

The RO plant reduces salinity levels/TDS from 4,000-6,000 ppm to only 450 ppm, making the water clean and safe for consumption. Even though Kotri already receives electricity from the traditional electric grid, the coverage is erratic and rarely powers the village for more than three hours per day. For this reason, the plant was solar electrified to ensure an uninterrupted supply of electricity for six hours, with some power to spare for a computer, a STD booth, a solar workshop, fans and light (six in number). The power produced from this plant also serves farmers engaged in used for shearing of wool. The biggest advantage from the implementation of this desalination plant has been that solar PV RO installations can be managed seamlessly by people/communities with minimal technical help.

## COST

The cost of installing this solar powered mini-RO plant was INR 1.5 million with financial aid from MNRE (Barefoot College)<sup>28</sup>. Each family receives 40 litres of potable drinking water every day for a token fee of INR 10 per month.

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28 <http://www.barefootcollege.org/solutions/water-solutions/solar-powered-reverse-osmosis-ro-water-desalination-plants/>







## SOLAR THERMAL PASTEURIZER

Contamination of raw milk can cause multiple diseases. Pasteurization is a process to destroy bacteria by heating milk to a specific temperature for a set period of time and then immediately cooling it to a lower temperature. If solar energy is used to generate heat, it is called solar pasteurization.

During large-scale milk pasteurization, the milk is heated through the thermal energy from heaters or boilers. The source of thermal energy may be electricity, fossil fuels or solar. India being the largest producer of milk, solar pasteurization can play an important role in reducing the dependence on fossil fuels for heating (GKSPL, 2012). Solar energy has been widely used by dairies in India to heat water but application of solar energy to pasteurize milk is still in its infancy as well as demonstration phase. There are multiple methods to pasteurize milk, few of them are:

**Table 10: Types of Pasteurization**

Type	Temperature (°C)	Time
Vat Pasteurisation	63	30 minutes
High temperature short time Pasteurisation (HTST)	72	15 seconds
Ultra Pasteurisation (UT)	138	2 seconds

Source: (IDFA, 2009)

Mahanand dairy, Latur, Maharashtra was the first dairy in India to replace the conventional furnace oil boiler with a solar system. It has the capacity to pasteurize 30,000 litres of milk and a day-long energy storage capacity. The system was developed by Clique Solar with support from IIT Bombay and the Ministry of New and Renewable Energy (Kedare, 2006). Later a similar system was also installed at Chitale Dairy in Sangli Maharashtra. Greentech Knowledge Solutions Private Limited has prepared a detailed project report for milk pasteurization at Dudhmansagar Dairy, Manesar, Haryana. MNRE has accredited 99 organizations for non-concentrated solar thermal applications and seven organizations for concentrated solar thermal applications (MNRE, 2013a) (MNRE, 2013b)

### TECHNICAL DESCRIPTION

The three different types of solar systems that can be used to heat water are: Flat Plate Collectors, Evacuated Tube Collectors and Concentrated Solar Thermal System. These have also been used for processes such as milk pasteurization.

Flat plate collectors are mostly used for cleaning and boiler feed water heating. A similar system is to be installed at Himachal Milkfed Dairy, Mandi, Himachal Pradesh. It will replace the diesel option for preheating the boiler feed water and will be used for cleaning purposes. The cost of the system is estimated to be INR 2 million with a three year payback. This process can help save up to 14,000 litres of diesel every year (GKSPL, 2012).

Dudhmansagar Dairy at Manesar, Haryana is in the process of deploying a hybrid system of evacuated solar collector with a waste heat recovery system to pasteurize milk. It is estimated that the system would cost INR 10.7 million with a payback of one year and can save up to 820 kg of furnace oil per day (GKSPL, 2012).

A concentrated solar thermal system will use the heat produced to boil the water and generate steam which is used for milk pasteurization. A system based on Scheffler technology comprises parabolic solar collectors which are aligned in an east-west direction. There are receivers at the focus which are connected to a pipe which carries the water. The heat is absorbed by water and is converted into steam (MNRE)<sup>29</sup>.

ARUN, a concentrated solar system based on Fresnel technology, tracks the movement of the sun on both the axes to capture the maximum possible amount of heat. The heat is concentrated on the focus with a receiver and is transferred for its use. A Scheffler concentrated solar system which may typically comprise of six dishes each of 16 m<sup>2</sup> can generate 150 to 200 kg of steam and can potentially save 4,500 litres of diesel per year (MNRE)<sup>29</sup>.

Presently there are no known examples of ETC or FPC systems being deployed by dairies for the pasteurization of milk.

## APPLICATION MARKET

The organized sector processes about 15-20 per cent of the total milk production (GKSPL, 2012). States like Gujarat and Rajasthan and parts of Maharashtra, Madhya Pradesh, Andhra Pradesh, Karnataka and Tamil Nadu have favourable conditions for large-scale implementation of concentrated solar systems (NREL, 2010). Though the system may still be installed at other locations but the size and cost of the system may increase. Gujarat and Rajasthan produced ~18 per cent of the total milk in 2011-12 (NDDB, 2013).

**Table 11: State wise Milk Production in 2011-12**

State	Milk Production
Uttar Pradesh	22,556
Rajasthan	13,512
Andhra Pradesh	12,088
Gujarat	9,817
Punjab	9,551
Maharashtra	8,469
Madhya Pradesh	8,149
<b>India (Total)</b>	<b>127,904</b>

Source: (NDDB, 2013)

Only a handful of dairies have implemented solar systems to pasteurize milk. While there are many players who provide solar thermal solutions, the only known examples are of Clique Solar which has implemented milk pasteurization systems in two dairies as of now.

A Fresnel concentrated solar system named ARUN has been built by Clique Solar with trackers has an aperture area of 169 m<sup>2</sup> may have an efficiency of 50 to 80 per cent at an operating temperature of 200 to 300°C. It has the capacity to process 20,000 to 30,000 litres of milk daily; however systems with smaller capacities have also been developed (Kedare, 2006). The cost of the system is estimated at approximately INR 5 million with an average payback period of five to six years (Energetica India, 2012).

29 [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Solar\\_Steam\\_generating\\_Systems.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Solar_Steam_generating_Systems.pdf)

## COST AND SUBSIDY

The central government and a few state governments provide subsidy for solar thermal systems based on the size of the collectors. MNRE does not provide subsidy for balance of system. The benchmark cost since May 2013 is as follows:

**Table 12: Benchmark cost and subsidy for solar thermal systems in India**

Type of System	Category	Benchmark Cost per m <sup>2</sup> (INR)	Subsidy (30% of benchmark subject to the maximum of) (INR)
ETC	Domestic	8,500	2,550
	Commercial	8,000	2,400
FPC	Domestic	11,000	3,300
	Commercial	10,000	3,000
Concentrator with manual tracking	-	7,000	2,100
Concentrator with single axis tracking	-	18,000	5,400
Concentrator with double axis tracking	-	20,000	6,000
<p>Note: 1. Below 500 lpd are categorized as domestic systems and above 500 lpd are categorized as commercial systems.</p> <p>2. Soft loans at 5 per cent interest rate are available for 50 per cent of the total system costs<sup>30</sup>. States under the special category receive 60 per cent subsidy. They are Himachal Pradesh, Jammu &amp; Kashmir, Uttarakhand, and the north eastern states including Sikkim.</p> <p>Source: (MNRE, 2013c) (MNRE, 2013d) (NABARD, 2013)</p>			

Payback of solar thermal systems may vary according to technology and location of the system. It is estimated that an ETC based solar pasteurizer system may have a payback of one year whereas a system based on Fresnel collectors may have a payback of three to four years (GKSPL, 2012) (Energetica India, 2012).

## POLICY SCENARIO

Presently there are about 7.27 million m<sup>2</sup> of solar collectors installed in India and MNRE aims to install 20 million m<sup>2</sup> of solar collectors by 2022 (MNRE, 2010) (MNRE, 2013e). The Indian government also aims to install 225 solar thermal systems of 250 m<sup>2</sup> of collected area for process heat applications by 2017 (Planning Commission, 2012).

MNRE provides financial support for solar thermal systems either through capital subsidy, loan at 5 per cent interest rate or accelerated depreciation (CEEW, 2012). The support is however calculated on the collector area and is not available on the balance of the system. MNRE had financially supported IIT Bombay and Clique Solar in 2004 to develop concentrated solar thermal solutions for milk pasteurization at Mahanand Dairy in Latur, Maharashtra.

30 To avail soft loan, a customer will have to provide 20 per cent of the overall cost.

The Project Management Unit of MNRE has recently sanctioned a demonstration project for the milk pasteurization system at Salem District Co-operative Milk Producers Union Ltd in Tamil Nadu (MNRE, 2013d).

## **BENEFITS**

Solar thermal systems reduce the amount of fossil fuels being used and hence reduce GHG emissions. However such savings would highly depend on the operating hours, system capacity and the fuel it replaces. A concentrated solar pasteurizer based on ARUN technology which pasteurizes 20,000 to 40,000 litres of milk per day may save from 15,000 to 30,000 litres of oil per year and may save up to 50 to 200 tonne of CO<sub>2</sub> emissions. It is also estimated that the system can save up to 6-10 per cent of India's oil import bill (Kedare, 2006).

A solar concentrator system with 96 m<sup>2</sup> of dish area, based on Scheffler technology can potentially generate 150 to 200 kg steam per day and save 4,500 litres of diesel in a year (MNRE)<sup>29</sup>.

## **CONSTRAINTS/BOTTLENECKS**

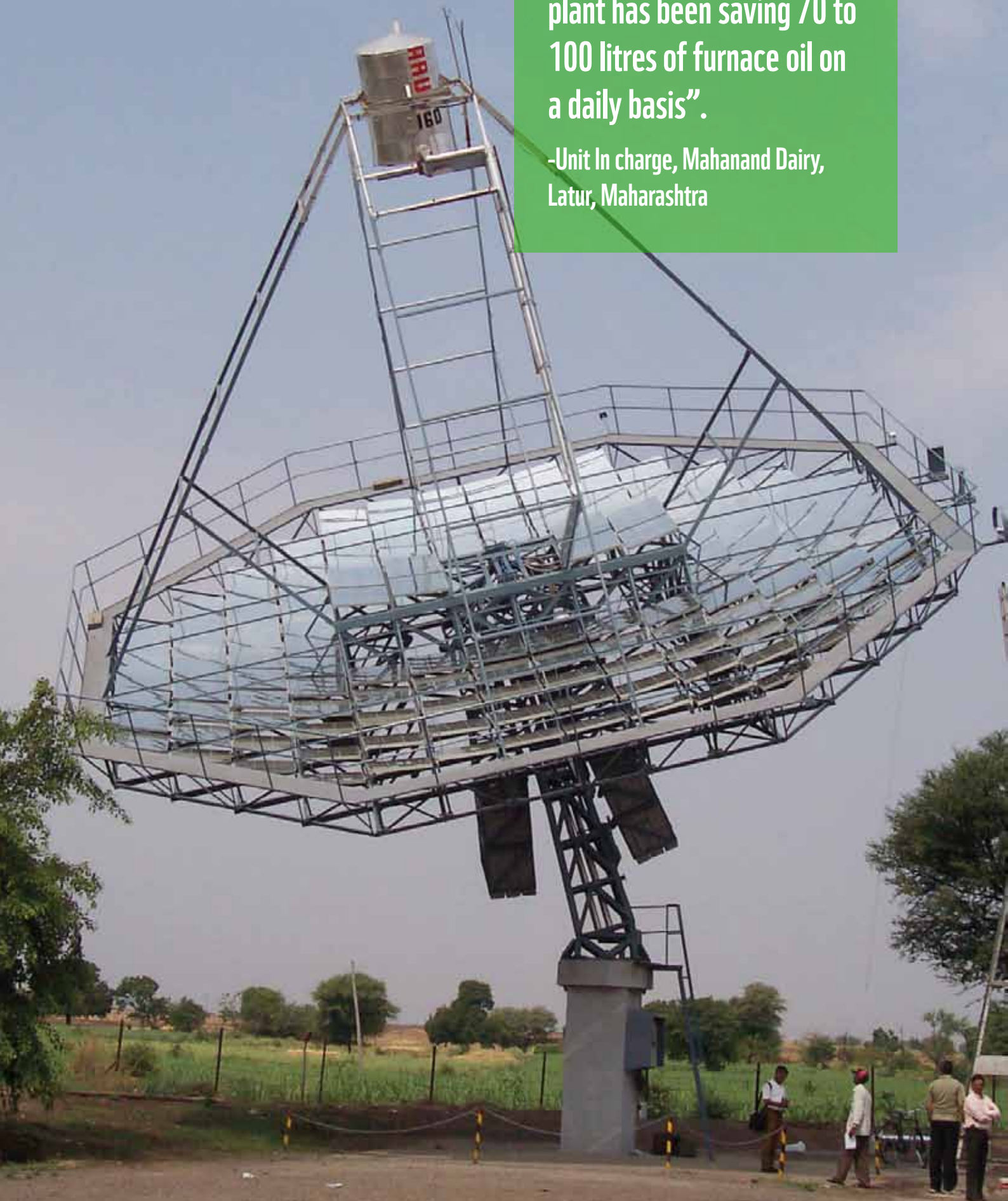
Despite attractive payback periods, very few organizations provide milk pasteurization solutions. This may be attributed to lack of expertise and experience for large scale solar thermal application and high upfront costs. Few of the reasons are (GKSPL, 2012):

- Lack of awareness about possible solar energy applications and economics
- Limited number of suppliers for solar thermal solutions to dairies
- Few existing installations for reference
- High upfront cost



“Since the installation of solar thermal system, the plant has been saving 70 to 100 litres of furnace oil on a daily basis”.

-Unit In charge, Mahanand Dairy,  
Latur, Maharashtra



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## CASE STUDY:

# CONCENTRATED SOLAR HOT WATER SYSTEM BY CLIQUE SOLAR PVT. LTD. AT MAHANAND DAIRY IN LATUR, MAHARASHTRA<sup>31</sup>

Clique Solar, a Mumbai-based organization has installed a concentrated solar hot water system at Mahanand Dairy in Latur, Maharashtra. The system has been in operation since February 2006.

Clique Solar are MNRE channel partners and provide solar thermal solutions for applications in industrial process heating, cooling, cooking, desalination and effluent treatment through their indigenously manufactured ARUN systems.

The system was sponsored by the Ministry of New and Renewable Energy and was developed by Clique Solar with testing support from IIT Bombay.

## TECHNICAL DESCRIPTION

The ARUN systems consist of Fresnel parabolic reflectors with point focus. The receiver at the focus point is designed in a manner to minimize thermal loss. An insulated pipeline is provided which delivers this heated energy for use. An inbuilt tracker helps the system to track the path of the sun and operate at its peak capacity for eight to 10 hours a day.

## PROJECT DESCRIPTION

The aim of the project was to develop, design, fabricate, install, commission and test a large solar concentrator for generating process heat at about 200°C, store it and supply it at desired process temperature (Kedare, 2006).

During the day, the system heats the inlet water to an ambient temperature and sends it to the insulated storage tank. The pressurized water tank stores the hot water for use when required for milk pasteurization. The used water is returned back at lower temperature and is re-heated by parabolic dish (Clique Solar)<sup>32</sup>.

A few challenges were faced while developing the project. Storage was a major issue since most of the milk pasteurization takes place within three hours and solar energy is available for only eight to 10 hours. Hence a storage system in the form of insulated pressurized water storage tank was designed and integrated with the system. Pressurized water was selected as the storage medium since it has high specific heat, is not a fire hazards, is compatible with food products and has low operational costs.

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31 Based on information provided by Clique Solar and other publicly available documents  
32 <http://www.cliquesolar.com/DairyIndustry.aspx>



The key features of the system are as follows:

**Table 13: Key features of 'ARUN 160'**

Parameter	Output
Delivery	Upto 18 bar and 180°C
Thermal power (annual average)	50-80 kWth
Dish numbers	1
Aperture area	160 m <sup>2</sup>
Arial space required	25 x 20 x 18 m height
Foot print	3 x 3 m
Daily energy output	6 lakh k cal
Dry saturated steam (per day)	1,200 kg
Hot water (@65°C)	25,000 litres
Milk pasteurization	30,000 litres

Source: (Clique Solar)<sup>33</sup>

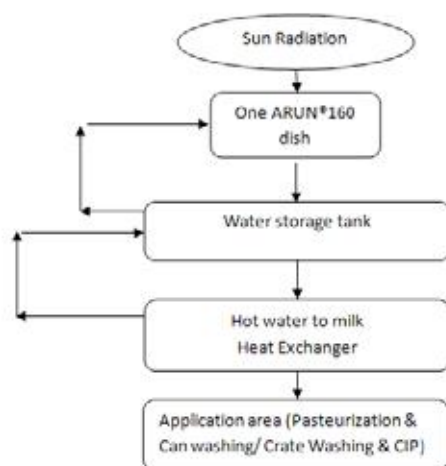
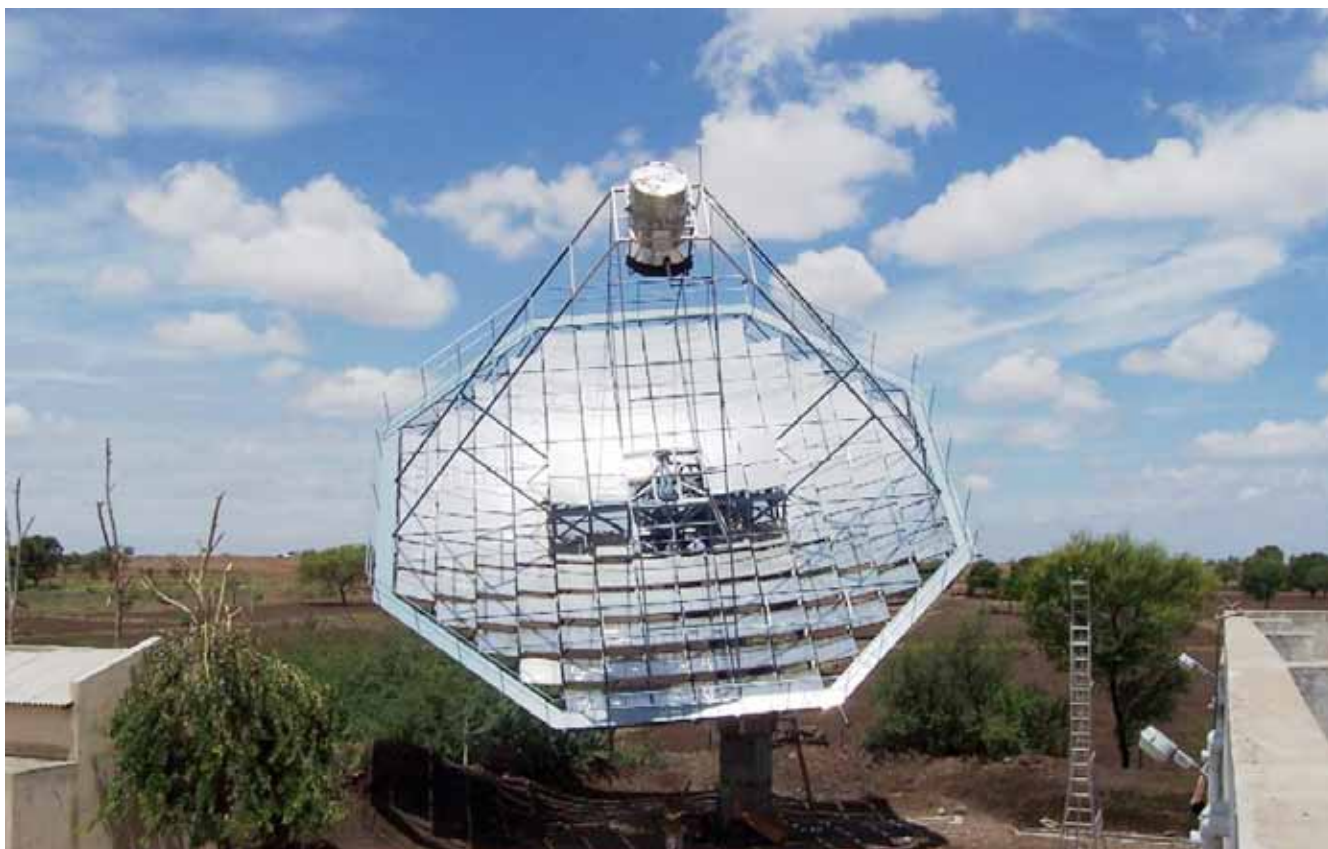


Figure 5: Flow of operation at Mahanand Dairy  
Source: (Clique Solar)<sup>32</sup>

33 <http://www.cliquesolar.com/Arun160.aspx>



**Figure 6: 'ARUN 160' at Mahanand Dairy**

Source: (Clique Solar)<sup>32</sup>

## COST

A solar driven milk pasteurizer based on 'ARUN 160' may cost approximately INR 5 million. The cost decreases with support from MNRE as capital subsidy and through accelerated depreciation. A system has an operational lifetime of 20 to 25 years with a payback period of three to four years (Energetica India, 2012).

## BENEFITS

An 'ARUN 160' system can reduce the dependence on fuel and lead to reduction in carbon dioxide emissions.

**Table 14: Savings from 'ARUN 160' on a clear sunny day**

Parameter	Saving
Effective saving of fuel per day	80 - 100 litres
Effective saving of electrical energy per day	800 kWh
Average CO <sub>2</sub> emission saving per annum	60 -70 tons

Source: (Clique Solar)<sup>33</sup>

## **CONSTRAINTS:**

Challenges such as high upfront costs and a handful of installations often discourage dairies and other users to adopt technology.



## SOLAR FOOD DRYER

Crops are dried to preserve food quality, enhance storage life, minimize losses during storage and to reduce transportation costs of agricultural products (Purohit, 2006).

Those crops with high moisture content are susceptible to fungal infections, attack by insects, pests and increased respiration (Dhiwahaar, 2010). Open drying of crops underneath the sky is an age-old practice; however recently crops have been dried in ovens using wood or fossil fuels. The former highly depends on weather fluctuations, is unhygienic and time-consuming and; the latter is expensive and pollutes the atmosphere.

Solar crop dryer offers an attractive alternative since it uniformly dries the crops, is more efficient and less expensive (VijayaVenkataRaman, 2012).

### TECHNICAL DESCRIPTION

Solar food dryers are broadly classified according to exposure of product to sunlight (direct/indirect type) or on their air flow movement (passive/active type).

In a direct type solar food dryer the product is exposed to direct solar radiation whereas in an indirect type solar dryer the product is kept in a closed chamber. A passive solar dryer induces air through a natural force whereas electrically powered fans and blowers (mostly solar powered) are used to produce air current in an active dryer.

Direct solar food dryers act as a greenhouse. The product to be dried is kept in a cabinet with a blackened interior, covered with a transparent sheet. The air enters the cabinet from the bottom and escapes from an exit at the top. Solar radiation hitting the transparent surface either gets reflected or transmitted inside the cabinet. The component which is transmitted inside is either reflected by the crop surface or absorbed by it. This leads to an increase in temperature of the crop leading to a long wavelength emission, which cannot escape due to the glass cover. Hence, the glass cover serves an important purpose for reducing the convective losses to the atmosphere which helps in increasing the crop and the cabinet temperature. However such dryers have their limitations such as their small capacity, crop discoloration because of direct exposure to sunlight and insufficient rise in crop temperature.

In indirect solar food dryers, the product to be dried is located in shelves inside an opaque cabinet. The cabinet is attached to a solar collector (a separate unit for heating the air). The heated air flows from collector to the product container and provides the required heat for moisture evaporation. This method offers better control over the process (leading to an increase in product quality); attainment of higher temperature and greater efficiency.

In passive solar food dryers, the heated air is circulated naturally with buoyant force or wind pressure or in combination of both. This type of drying is common in small agricultural communities due to its low cost, simplistic design and ease of operation. Active solar dryers incorporate external means like fans or pumps for transporting the heated air from the collector area to dry beds. These dryers are generally used for large-scale commercial drying operations and are hybridized with conventional fossil fuels (Visavale, 2012).



**Table 15: Examples of crops dried in active and passive solar dryers**

Passive solar dryer	Active solar dryer
Banana	Papaya
Pineapple	Kiwi Fruit
Mango	Brinjal
Potato	Cabbage
Carrots	Cauliflower slices

Source: (Visavale, 2012)

The capacity and output of a solar food dryer depends heavily on the design of a solar dryer which in turn depends on need, crop and its properties and the prevalent atmospheric conditions. However, the capacity may be in the range of 50-500 kg/batch of crop (Unisol)<sup>34</sup>. It is generally assumed that moisture removal of 3kg/m<sup>2</sup> may be possible in dry areas.

The efficiency of a dryer may vary according to local conditions, crop, design and moisture content. However, the average efficiency of the dryer may be taken as 25 per cent (Purohit, 2006).

## APPLICATION MARKET

India is a large producer of the dried and preserved vegetables like preserved and dehydrated onions and dehydrated garlic flakes. Dried and processed vegetables have a share of 40 to 42 per cent (in terms of volume and by value) in the processed product export. In 2012-13, India exported INR 833.55 crore (133.45 thousand MT by weight) of dried and preserved vegetables (APEDA, 2013).

The price difference between a raw product and dehydrated product is shown below:

**Table 16: Price difference in raw and dehydrated products**

Product	Raw INR cost/kg	Dehydrated INR cost/kg
Onion	50	100
Garlic	200	350
Grapes	80	150
Fish	250	500

Source: (Science for Society, 2013)

Also, it is expected that India loses approximately 33 million tonnes of vegetables and fruits every year due to lack of storage, transportation and processing facilities (IPS, 2013). A solar dryer can be easily operate for 290 days in a year in India and help farmers in India to process their produce (Sreekumar, 2013)(Chandak et al., 2013).

34 <http://www.solarheater.co.in/solar-dryer.html>

## COST & SUBSIDY

The cost of a solar food dryer may vary according to technology, capacity and required application. A solar dryer with a flat plate collector may cost approximately INR 5000 to 10,000 per m<sup>2</sup> and will be on the higher side in the case of active solar food dryers. A low cost solar dryer has recently designed by an Indian NGO Science for Society. The price is in the range of INR 3,000 to 3,500 which is one-third of the price of conventional solar food dryers.

The cost of drying may vary according to the product, for instance it is estimated that the per unit cost of solar food dryers may be INR 3.72/kg for coffee whereas it may be INR 22.53/kg for garlic flakes (Purohit, 2006).

A solar food dryer may have two to four years of payback with minimal maintenance and may last for up to 15 years (MNRE)<sup>35</sup>. The government offers 30 per cent subsidy to a maximum limit of INR 3,600 /m<sup>2</sup> for the solar collector system for direct heating applications (MNRE, 2012a).

## POLICY SCENARIO

MNRE has been supporting a programme to deploy solar air heating system with flat plate solar collectors. As of now 2000 m<sup>2</sup> of collector areas have been installed at various locations in the country. There have been installed at various industries which require air temperature in the range of 50-80°C for the drying of both edible and non-edible products. Many small and large fish drying systems have also been installed at Kerala and Manipur under this programme (MNRE, 2012b).

Presently MNRE does not have any specific standards for solar food drying technology and puts the onus of the system quality on the customer. However it does list names of eight manufacturers/institutions of flat plate collector-based solar food driers and provides financial subsidy to individuals who aim to buy these systems (MNRE)<sup>36</sup> (MNRE, 2012a).

## BENEFITS

A solar food dryer not only saves energy but also saves time, improves the quality of product, requires less area, makes the process more efficient, reduces losses (due to deterioration and transportation delays) and protects the environment by replacing fossil fuels (VijayaVenkataRaman, 2012).

Table 17 compares the component of the drying cost in the overall price, the internal rate of return and a breakeven price for different products according to the 2005-06 price level. A lower fraction of drying costs, higher internal rate of return and higher breakeven price suggests financial attractiveness to deploy a solar dryer system, which means that it may be financially viable to deploy a solar food dryer system with a cost of INR 39,000 to dry cardamom with a 205 per cent IRR.

35 [http://mnre.gov.in/file-manager/UserFiles/solar\\_energy\\_potential\\_in\\_industries.pdf](http://mnre.gov.in/file-manager/UserFiles/solar_energy_potential_in_industries.pdf)

36 [http://mnre.gov.in/file-manager/UserFiles/list\\_ahs.pdf](http://mnre.gov.in/file-manager/UserFiles/list_ahs.pdf)

**Table 17: Comparison of benefits against sun drying in 2006**

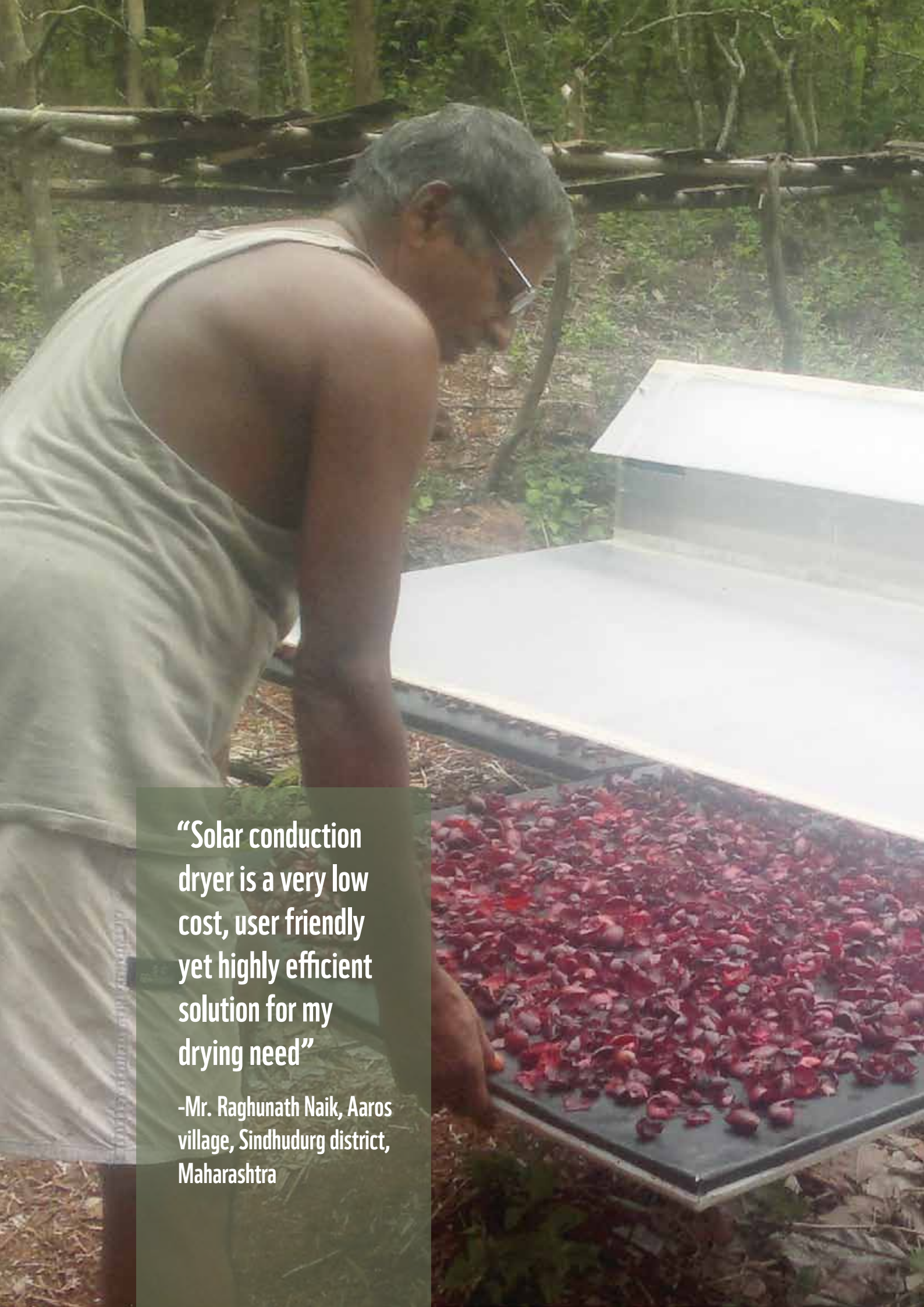
Product	Fraction of drying cost in the wholesale selling price	Internal rate of return	Breakeven price of collector (INR/m <sup>2</sup> )
Coffee	9%	38%	7,963
Onion Flakes	23%	17.9%	4,692
Garlic Flakes	32%	8.2%	3,262
Chillies	22%	7.24%	3,139
Tea	8%	44.85%	9,168
Cardamom (Small)	2%	205.8%	39,796
Pepper	7%	49.44%	10,026

Note: All the calculations above were done according to prices in 2005-06. The prices of most of the products have risen and the cost of solar dryers has come down, hence a lower fraction in the overall cost and a higher rate of return may be observed in the present date.

Source: (Purohit, 2006)

## CONSTRAINTS

Despite low cost and attractive payback in terms of improved sales and reduction in loss, solar food dryers are not popular among farmers. Lack of awareness among users, the practice of open sun drying, absence of good technical information and dearth of local practical experience proves to be a hurdle which in turn proves to be an impediment for increase in uptake of solar dryers(Purohit, 2006) (VijayaVenkataRaman, 2012).



**“Solar conduction  
dryer is a very low  
cost, user friendly  
yet highly efficient  
solution for my  
drying need”**

**-Mr. Raghunath Naik, Aaros  
village, Sindhudurg district,  
Maharashtra**



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## CASE STUDY:

# SOLAR CONDUCTION FOOD DRYERS BY 'SCIENCE FOR SOCIETY'<sup>37</sup>

Science for Society is an NGO set up in 2009 by a group of motivated individuals from Institute of Chemical Technology and other institutes, Mumbai. It aims to solve societal problems by commercializing scientific innovations.

### TECHNICAL DESCRIPTION

Science for Society has invented a low cost solar food dryer which combines conduction, convection and radiation. The system reduces the drying time by 30 to 66 per cent and increases the nutritional value of the product by 45 per cent. The system has a self-regulatory temperature of 60°C which is considered ideal for most food products.

It is designed as a rectangular box with a blackened interior and a transparent lid. The operation is very simple requiring the farmer to place sliced fruits and vegetables on the surface, which is then dried by the heat. The system can be dismantled easily by two persons and may prove helpful to farmers if the drying location changes seasonally.

### COST

The cost of the dryer is approximately INR 3,000 to 3,500/m<sup>2</sup> which is one-third of the cost of a similar conventional solar food dryer. It has an operational lifetime of 10 years and an efficiency of 20 to 25 per cent. With no operational and maintenance requirement, it promises to pay back the upfront cost in six months by reducing losses and increasing the product value.

A typical system with 10kg capacity and 4 m<sup>2</sup> surface area may cost INR 10,000- INR 20,000 depending upon various models with possible a payback period of less than 100 days.

### PROJECT DESCRIPTION

Science for Society plans to sell solar dryers to women self-help groups and empower them. Raw materials like turmeric, ginger, amla, leafy vegetables and mushrooms are sold to them on a regular basis. The product would be bought back after processing and would be sold in the urban market at higher rates.

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37 Based on information provided by Science for Society and other publicly available documents.



**Figure 7: Stages of product development**

Source: Science for Society



The system was developed in collaboration with National University of Singapore and has received recognition and accolades from UNESCO, Government of Maharashtra, IIT Bombay and IIM Ahmedabad. In 2013, the team won the Dell Social Innovations Challenge.

The team has applied for both Indian and International patent and is closely working with UNEP and Bayer, Germany to lower the cost, improve technology and aid in technology transfer to other developing countries.

## BENEFITS

It is believed that 100 such dryers can have a cumulative processing capacity 250 tonne annually and can generate 125 jobs. Thirty driers have been installed on the ground and the team aims to install 1,000 dryers by 2014 and 5,000 by 2015.

## CONSTRAINTS

Presently no subsidy has been availed from government, but presence of subsidy can make the system financially attractive to the farmers. Lack of awareness about solar dryers often creates hurdles for organizations which try to market such products in rural areas.



## SOLAR WATER PURIFIER

In India, over one lakh people die of water-borne diseases annually. It is reported that groundwater in one-third of India's 600 districts is unfit for drinking purposes owing to the excessive concentration of fluoride, iron, salinity and arsenic which exceed tolerance levels (Deccan Herald)<sup>38</sup>. Solar water purification involves purifying water for drinking and other purposes through the usage of solar energy in the following treatment methods: solar water disinfection (SODIS); solar distillation; solar water pasteurization and solar power (electricity) to drive purification technologies (reverse osmosis). Low cost solar water purification options (such as SODIS) are particularly beneficial for rural communities since they can neither afford the conventional expensive water purifiers nor have access to electricity to operate such devices. Although, very few of the solar water purification technologies such as solar stills have been around for a very long time, there are several ongoing research efforts to commercialize various solar-powered water purification methods that can cater to both rural and urban India. For example, Panasonic has developed a new water purification photocatalyst that does not need to be fixed to a panel or filter which runs on solar power (specifically the ultraviolet part of the spectrum); it plans to promote this prototype with the help of Jadavpur University, Kolkata (The Green Optimistic, 2013). Taking cognizance of increasing water woes, various NGOs, international companies and donor agencies have stepped in to implement solar-based water purification pilot projects.

Table 18 outlines some of the key players in solar water purification in India

**Table 18: Key players/actors in solar water purification**

Category	Key players
Private companies/ NGOs	Jakson Power Solutions; El-Sol Energy Systems; Panasonic; Kotak Urja; Claro Ventures; NRG; Zero B; Deccan Water; Saurya Enertech; Social Awareness Newer Alternatives (SANA); Barefoot College; Synergy International; Taylormade Solar Solutions (TSS) Pvt. Ltd.
R&D institutions	Bhabha Atomic Research Centre (BARC); Jadavpur University; AN College, Patna; Delhi University (Zakir Hussain College); Malanadu Development Society; Central Salt and Marine Chemical Research Institute (CSMCRI); Developing Indigenous Resources (DIR); IIT; The Energy and Research Institute (TERI); Sardar Vallabhai National Institute of Technology (SVNIT)
International companies, donors and research institutes	Nedap (Dutch company); Aqua Infinitum; Solvatten; Sunlabob; Germany's AquaSolis GmbH; Karlsruhe University of Applied Sciences in Germany; Indo-Canadian Village Improvement Trust (ICVIT); Pentair; International Finance Corporation (IFC); United Nations Development Programme (UNDP); Renewable Energy and Energy Efficiency Partnership (REEEP);
Government	MNRE; Department of Science & Technology (DST)
Individuals	Vemula Lakshminarayana from Tadipatri town of Anantapur district (designed Raqxa - Solar Water Purifier with Integrated Storage and Automatic Supply)

Source: CEEW compilation

## TECHNICAL DESCRIPTION

The following is a description of the most common methods for solar water purification.

- a) **Solar distillation:** Solar distillation utilizes the natural process of evaporation to capture purified water. The structure used in solar distillation is called a solar still, which utilizes the heat from the sun to drive evaporation, and ambient air to cool the condenser film<sup>39</sup>. Since evaporation is the mechanism of purification, this technology is effective for the complete removal of all chemical, organic, and biological contaminants from feedwater. However, solar distillation using basin stills require higher amounts of solar energy for longer periods of time (more than even solar pasteurization) and are only viable for small-scale applications. On the other hand, solar distillation using solar collectors (with considerably higher solar energy capture capacity) is a more viable alternative for treating large quantities of water in a cost effective manner.

- b) **Solar Water Disinfection (SODIS):** SODIS is a relatively simple and cost-effective method of providing disinfected drinking water in small quantities utilizing sun's ultraviolet radiation. The process involves contaminated water being filled in transparent PET or glass bottles which are then exposed to the sun for approximately six hours on a bright day or two days under cloudy sky. The ultra violet (UV) rays of sun eliminate the diarrhoea-causing pathogens, thereby making the water fit for consumption. For example, Raqxa, a contrivance by Vemula Lakshminarayana from India's Tadipatri town of Anantapur District uses a number of glass purification cells (fixed to a solar panel) to contain water for exposure up to 20 hours. Raqxa was one among the 52 projects shortlisted for the 'India Innovation Initiative – i3 National Fair' in 2010 (The Hindu, 2010).



Figure 8: SODIS-Raqxa developed by Vemula Lakshminarayana

Source: (The Hindu, 2010)

- c) **Solar Water Pasteurization:** Pasteurization is a thermal disinfection process which is widely used for purifying milk but is only recently become of interest for the process of water purification. It involves the use of moderate heat or radiation captured by solar cookers to kill disease – causing microbes<sup>40</sup>. Aside from cookers, heat can also be provided through solar collectors. Water from pond/river/well water can be pasteurized by solar thermal systems for large scale use in food industries, dairies, military or paramilitary in remote places, small and remote villages and so forth (TSS India)<sup>41</sup>. Solar pasteurization, like solar distillation depends on solar energy for purifying small quantities of water for individual or family use. Solar pasteurization can provide safe drinking water in most cases where water does not contain contaminants such as inorganic chemical pollutants or arsenic. While SODIS focuses on a combination of the antibacterial role of solar UV radiation and elevated temperature, solar pasteurisation utilizes only the thermal energy.

39 Solar still has a slanted glass cover over a black-painted, water filled basin

40 Pasteurization can take place at much lower temperatures than boiling, depending on the time the water is held at pasteurization temperature (usually 65°C-75°C) (SSWM)

41 <http://www.tss-india.com/pasteurization>



Solar water pasteurization for domestic use using solar cookers has not taken off in India but has been demonstrated as a viable solar water purifying method in countries like Kenya (water decontaminated through solar cookers) (Ray & Jain, 2011).

- d) **Solar powered purification processes:** This method integrates electricity generated from solar energy for water purification. Solar PV panels generate power for a battery which is used for purification systems (for example solar powered reverse osmosis, RO, for desalination). These structures are generally mobile and can be designed in various sizes to cater to varying needs. Solar PV – RO plant requires less energy compared to solar thermal (collectors) driven purification processes and are techno-economically feasible for domestic and small-scale use. Solar thermal powered desalination systems are more suited for large-scale use – villages level, industries, institutions, and so on.

## APPLICATION MARKET

**Table 19: Application status of key solar powered purification projects/systems in India**

Solar Purifier	Status
Solar Purifiers – based on ultra-filtration developed by BARC	Under the process of commercialization by Jakson Power Solutions; Jakson plans to roll out 10,000 units of solar water purifier on an annual basis
BARC Solar RO – desalination plant	Testing completed
Raqxa that deploys SODIS – developed by Vemula Lakshminarayana	Tested but not been commercialized
Sunllob (Laos based company)-SANA (Delhi NGO): solar water purification system installed in Rajkiya Pratibha Vikas Vidyalaya (RPVV) School in Surajmal Vihar	Under operation
Panasonic solar powered photocatalyst	Testing stage (tested by Jadavpur University)
Solar powered arsenic removal; developed by Karlsruhe University of Applied Sciences in Germany; AN College, Patna and Applied Solar in Ramnagar, Patna	Under operation; would end in 2013
Swajal Aqua pilot project using solar RO purification technology – developed by Saurya Enertech (funding from REEEP) in villages of Khoda and Behrampur, U.P.	Under operation; not been commercialized
TERI-Flat plate collectors desalination unit at SEC, Gual Pahari	Under operation
Solar powered ultra-filtration water purification plant developed by I.C.V.I.T and Aqua Infinitum (Switzerland)	Under operation in Hoshiarpur district, Punjab

Source: CEEW compilation

Although only a few of the community scale solar purification systems are in pilot phase and are yet to be commercialized (evident from table 19), it is essential to spread the word about those technologies that have forayed into the market or are on the verge of doing so (for example, solar stills, SODIS, BARC ultrafiltration systems tailored for small-scale domestic consumption).

## COSTS

Costs of solar purifiers are driven by the type of technology deployed and capacity. The operational and maintenance costs of solar-based purifiers, except for membrane systems (such as solar RO plant) are quite low since they operate without fossil fuel/electricity.<sup>42</sup> The cost of simple solar stills is the least delivering 2.0 L – 2.5 L is approximately INR 5000 whereas the cost of a solar energy based water distillation system (manufactured by company - Deccan Water) producing 100 L per day is around INR 90,000 per unit (The Times of India, 2010). The cost of a solar purifier (manufactured by Zero B) with a tank capacity of 4L deploying a six-stage purification/filtration is around INR 7,490 (Zero B)<sup>43</sup>. International donors such as the Renewable Energy and Energy Efficiency Partnership (solar powered RO plants in Khoda and Behrampur villages), the IFC (providing Deccan Water a soft loan of INR 40 crore at an interest rate of 4 per cent) Indo-Canadian Village Improvement Trust (ICVIT) (1000 L per day solar powered ultra-filtration water purification plant in Hoshiarpur, Punjab) have provided financial assistance in the form of subsidies or grants to drive down the cost of implementing solar powered purification projects (The Times of India, 2010) (EAI)<sup>44</sup>.

## POLICIES

The off-grid and decentralized solar applications scheme of the Jawaharlal Nehru National Solar Mission (JNNSM) also covers solar PV powered RO plants (SPV plant of maximum capacity of 250 Wp each). The MNRE extends capital subsidy to the eligible project developer. The entire funding under this scheme is project-based and requires submission of a detailed project report (DPR) to avail capital subsidy. MNRE provides a combination of 30 per cent capital subsidy of the benchmark cost and/or 5 per cent interest bearing loans to the eligible project<sup>45</sup> (MNRE)<sup>46</sup>. The capital subsidy scheme can only be availed by the project developer if the solar equipment used in the project is sourced from MNRE accredited channel partners. Capital subsidy of 90 per cent of the benchmark cost is available for special category states i.e. those in the northeast, Sikkim, J&K, Himachal Pradesh and Uttarakhand.

Table 20 outlines subsidies provided by the central and state governments for solar collectors.

42 Solar driven RO systems require regular maintenance of membranes

43 <http://www.zerobonline.com/uv-water-purifier.html>

44 <http://www.eai.in/club/users/Nithya/blogs/1154>

45 For financial year 2013-14, the benchmark price for PV systems with battery back-up support is INR 170 per Wp and INR 90 per Wp for without storage battery.

46 [http://mnre.gov.in/file-manager/UserFiles/jnnsn\\_spv\\_mini\\_grid\\_plants.pdf](http://mnre.gov.in/file-manager/UserFiles/jnnsn_spv_mini_grid_plants.pdf)

**Table 20: MNRE subsidy for solar collectors**

Type of System	Category	Benchmark Cost per m <sup>2</sup> (INR)	Subsidy (30% of benchmark subject to the maximum of) (INR)
Evacuated tube collector (ETC)	Domestic	8,500	2,550
	Commercial	8,000	2,400
Flat plate collector (FPC)	Domestic	11,000	3,300
	Commercial	10,000	3,000
Concentrator with manual tracking	-	7,000	2,100
Concentrator with single axis tracking	-	18,000	5,400
Concentrator with double axis tracking	-	20,000	6,000
<p>Note: 1. Below 500 L/day are categorised as domestic systems and above 500 L/day are categorised as commercial systems.</p> <p>2. Soft loans at 5 per cent interest rate are available for 50 per cent of the total system costs. States under the special category receive 60 per cent subsidy. They are Himachal Pradesh, Jammu &amp; Kashmir, Uttarakhand, and the north eastern states including Sikkim.</p> <p>Source: (MNRE, 2013a) (MNRE, 2013b)(NABARD, 2013)</p>			

## BENEFITS

Solar-powered water purifiers score over their conventional counterparts as they are environmentally friendly (on account of reduced GHG emissions resulting from fossil power usage); enable consumers to save on electricity and are particularly beneficial in areas/regions which do not have access to grid electricity and face water scarcity.

## CONSTRAINTS

Increased uptake of solar water purification technologies in India is hindered by several factors including lack of awareness; higher upfront capital costs and lack of cost-effective storage options (example PV-RO) for countering the intermittent nature of solar energy. Portability and ease of use are vital factors that often impact adoption of these technologies.



Ms. Tashi Angmo of Gya village of Ladakh says that now she uses the purified water for cooking and drinking and this is good for the health of her family.





2 June, 2012  
Launch Event  
SOLVATTEN® Safe Water System  
Leh, Ladak, India



## CASE STUDY:

# SOLAR PV DRIVEN BATTERY-LESS ULTRAFILTRATION (UF) UNITS BY BHABHA ATOMIC RESEARCH CENTRE (BARC)<sup>47</sup>

Bhabha Atomic Research Centre (BARC), India's premier multi-disciplinary nuclear research centre has been conducting various projects to test renewable energy based water purification technologies in India over the years.

Indian company - Jakson Power Solutions has signed a technology agreement with BARC in which it has been granted access to technology for standalone solar PV driven battery-less UF units for water purification for a period of seven years. As per the terms of the agreement, Jakson will use the technology to manufacture and sell these products in the Indian and overseas markets. Jakson started manufacturing these solar-driven UF units in its facility at Noida, Uttar Pradesh in 2013 (Jakson Power Solutions, 2013).

## TECHNICAL DESCRIPTION

These water purification units are solar PV driven, battery-less, off-grid, stand-alone Ultrafiltration (UF) systems, as shown in Figure 9. In these units, water purification takes place by a pressure driven, membrane-based process called ultrafiltration. Electricity required for pressurization is generated with the help of the solar PV system. These units can be operated for nine to ten hours a day on clear sunny days. These units are capable of removing dust, turbidity and pathogens from drinking water. The units are available in two sizes: i) 10 L per hour capacity for domestic use and ii) 100 L per hour capacity for community use.



Figure 9: BARC solar powered water purifier based on ultrafiltration

Source: (BARC)<sup>48</sup>

47 Based on information collected from publicly available documents.

48 [http://www.barc.gov.in/technologies/pvwp/pvwp\\_br.html](http://www.barc.gov.in/technologies/pvwp/pvwp_br.html)

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## **APPLICATION**

These units are best suited for both urban as well as remote/rural areas where electricity is not available or the voltage is not stable. The company has also lined up plans to export these products to Africa, the Middle East and Southeast Asian countries.

## **BENEFITS**

These units are compact, light-weight and portable, do not have a daily maintenance cost and require less manpower for assembly (can be assembled by a single person).







## SOLAR SPACE HEATING SYSTEM

Globally, building sector comprising both residential and commercial buildings, accounts for almost 60 per cent of the world's electricity consumption (IEA, 2009). In industrialized nations and urban areas of the developing nations, which are geographically situated in the cooler regions, space heating forms a large portion of their energy consumption. This need for heating is generally provided by a district heating system or by an on-site furnace or boiler (IPCC, 2007). In developed countries, on an average space heating, contributes to nearly 60 per cent of the energy consumption in the residential sector, and 18 per cent of the energy is utilized for water heating (UNEP, 2007).

Inadequate indoor warm comfort conditions and moisture add to the risk of respiratory and cardiovascular diseases. Thus, provision of space heating through use of cheap, clean and sustainable energy sources is a major issue (WHO, 2011). Typically, in colder regions of India, institutional, residential and commercial buildings use electricity, fuelwood or fossil fuel-based heating systems for indoor space heating requirements. Usually such systems have high installation and annual O&M (Chandel, 2009).

Renewable energy, especially solar energy can be successfully employed for meeting space heating as well as hot water needs. Solar space heating can broadly be classified into either a passive system or an active system. Solar passive heating systems use the building components and features to collect, store and distribute solar heat gains (Arvizu et al., 2011).

An active solar space heating system utilizes external features such as rooftop solar thermal collectors to collect and distribute solar radiation heat coupled with small electric fans or pumps to absorb and distribute collected heat energy in building (NCSC, 2000).

### TECHNOLOGY

Solar passive space heating is one of various building design approaches, together referred to as solar passive design. Usually a solar passive space heating system does not require any mechanical equipment since the heat gain and distribution is done by natural means such as, radiation, convection, and conductance (United Nations, 1990). Besides providing comfort heating, solar passive design intervention can also save 50-60 per cent of energy required for winter space heating (Chandel et al., 2001). Basically there are three types of solar passive building design (US DoE, 2001).

One of the simplest solar passive designs is the direct gain. In this design, the walls and floor of the building are used as solar collectors and thermal energy storages (Arizona Solar Center)<sup>49</sup>. At night, the heat stored in the walls and floor slowly convects and radiates the collected heat energy. Solar windows are a good example of direct gain passive building feature.

In the indirect gain design, thermal storage material(s) are positioned sandwiched between the inner liveable space and the sun. The storage material/wall absorbs heat during the day and radiates it back into the living space at night (Arizona Solar Center)<sup>49</sup>. Features like the solar chimney are an example of indirect heat gain passive designs.

Lastly, isolated gain gathers solar heat energy remotely from the position of the primary habitable area. For example, a sunroom attached to a house gathers naturally flowing warm air and then distributes it to the rest of the house/building.

Active solar space-heating systems involve use of the external solar energy collectors for heat gain. Heat gained is stored and distributed inside the building using external transfer and

49 <http://www.azsolarcenter.org/tech-science/solar-architecture/passive-solar-design-manual/passive-solar-design-manual-heating.html>

distribution equipments like pumps and electric fans unlike the passive design (US DoE, 2012). Presently, there are two basic types of active solar space-heating systems commercially available in the market. These systems either use liquid or air as the heat-transfer medium (US DoE)<sup>50</sup>.

Solar space heating systems using air as the working fluid for absorbing and transferring solar energy can either directly warm up the living space or can use solar heat energy to pre-heat the air passing into a heat recovery ventilator (US DoE, 2012). Air-based solar space heating systems are generally employed at commercial and industrial installations that have need of large quantities of ventilation air.

Solar space heating based on the liquid working media or solar combi- system operates in the same way as a solar water heating system. It involves a large solar thermal collector area (which can either be a flat plate collector or an evacuated tube collector) and a complex system of piping/ducts (auxiliary units and a fan coil unit) to transfer and distribute heat/hot water in the building. Lack of low-cost compact thermal storage and availability of established low-cost fossil fuel technologies in the market are two prominent reasons due to which the utilization of solar combi-systems is still not prevalent. Nevertheless, solar combi-systems account for about 50 per cent of the annually installed capacity in some developed countries like Germany, Austria (IEA, 2012).

Both of these systems collect and accumulate solar radiation, which is then transferred directly to the living area or is routed through a heat storage system. But in practice a support or backup system based on conventional fuels is also incorporated into the heat system design especially in the liquid-based heating systems, so as to make these systems robust.

## APPLICATION MARKET

In case of India, where the use of space heating is limited both geographically and seasonally, projecting market potential, penetration and public acceptance is difficult for the emerging technology like active solar space heating system. But, passive solar heating house designing has witnessed some success. The worked carried out by GERES India has witnessed implementation of 550 passive solar buildings including both houses and community buildings (GERES India)<sup>51</sup>. Similarly, Himachal Pradesh has emerged as a pioneer state in implementing more than 200 buildings with complete solar passive designs features (Chandel, 2009).

Solar combi-systems for combined hot water preparation and space heating is showing a rapidly growing market in European countries like Germany, Switzerland and Austria (Frei and Vogelsanger, 2013). By 2050 solar hot water and space heating is likely to account for 14 per cent of the total energy use for space and water heating in buildings. Also, to satisfy an annual energy demand of around 8.9 EJ (hot water and space heating) in the building sector, solar collectors are likely to achieve an total installed capacity of nearly 3500 GWth by 2050 (IEA, 2012).

According to MNRE estimates, the total technical overall potential solar water heaters in India based on techno-economic feasibility is around 35-40 million m<sup>2</sup> of collector area (MNRE)<sup>52</sup>. MNRE also lists various manufacturers and channel partners of various types of commercially available solar thermal collectors (FPC, ETC and concentrated) (MNRE, 2013a; MNRE, 2013b)<sup>53</sup>. Also MNRE gives out list of organizations practicing solar passive architecture (MNRE)<sup>54</sup>.

50 <http://www1.eere.energy.gov/solar/sunshot/index.html>

51 <http://www.geres.eu/en/energy-efficiency-and-bioclimatic-architecture-in-india#project-description>

52 [http://mnre.gov.in/file-manager/UserFiles/potential\\_electricitySavings\\_swhs.pdf](http://mnre.gov.in/file-manager/UserFiles/potential_electricitySavings_swhs.pdf)

53 [http://nicdc.nic.in/CMMS/InternetRep/InternetReportView.aspx?strstate=&strISNO=12933.001&Report=14&StrProdName=IS\\_12933 : Part 1 : 2003&strDistt=&strBrand=](http://nicdc.nic.in/CMMS/InternetRep/InternetReportView.aspx?strstate=&strISNO=12933.001&Report=14&StrProdName=IS_12933 : Part 1 : 2003&strDistt=&strBrand=)

54 [http://mnre.gov.in/file-manager/UserFiles/list\\_spa\\_a.htm](http://mnre.gov.in/file-manager/UserFiles/list_spa_a.htm)

## COST

To provide a normative cost of a passive solar design building is very difficult, since the cost of construction, operation and maintenance can vary considerably depending upon the local conditions, material availability, heating requirements and so forth. Following are few solar passive designed building with focus on heat gain in India and their cost can provide an over view of the investment required (MNRE & TERI, 2001):

**Table 21: Few solar passive designed building with focus on heat gain in India**

S No.	Building Name	Area	Cost	Features
1	Himurja office building, Shimla, Himachal Pradesh	635 m <sup>2</sup>	Initial cost of the building at INR 7 million (without incorporation of passive or active solar measures)  INR 1.3 million were incurred due to incorporation of passive and active solar measures.	<ul style="list-style-type: none"> <li>• Solar chimney</li> <li>• Specially designed solarium on south for heat gain</li> <li>• Insulated RCC diaphragm walls on the north to prevent heat loss</li> </ul>
2	Himachal Pradesh State Co-operative Bank, Shimla	1650 m <sup>2</sup>	Total building cost is INR 22 million (including solar passive and active features)	<ul style="list-style-type: none"> <li>• Sunspaces on the southern side</li> <li>• Solar wall on the southern side</li> <li>• Air-lock lobby at the main entrance</li> </ul>

Source: (MNRE & TERI, 2001)

Active solar space heating systems or the solar combi-system are expensive compared to conventional space heating options if the initial installation cost was considered. In India, the cost of a conventional 2kW electrical space heating system ranges between INR 2500 and INR 3000 per unit.

But on the longer life usability assessment, systems based on solar energy are cost-effective in cold climates with good solar radiation and at the same time they displace the non-renewable, polluting and more expensive heating fuels, such as electricity.

The cost of a solar space heating system can vary based on the supply chain, material and technology availability such as the size of the system, the particular system manufacturer and on other factors. Typically the solar space heating system can have a usable life period of 20 years. The economics of a solar space heating system improves considerably if one takes into account the generation of hot water too.

One such system has been installed at Kohima Secretariat, Nagaland where the initial cost incurred in installing the system was INR 5.9 million with per day generation of 3500 litres of hot water and 23.34 kW of solar thermal energy collected per hour. And with its annual energy savings, water, and maintenance cost the total payback period was calculated to be 4.3 years.

## POLICY SCENARIO

The normative capital cost and the subsidies available through MNRE are reviewed and amended annually. The benchmark cost (as of May 2013) for the solar thermal collector technologies are as follows:

- ETC based systems: INR 8500 per m<sup>2</sup> (domestic users) and INR 8000 per m<sup>2</sup> (commercial users).
- FPC based systems: INR 11,000 per m<sup>2</sup> (domestic users) and INR 10000 m<sup>2</sup> (commercial users).

MNRE also provides a 30 per cent capital subsidy or loan at 5 per cent interest on 50 per cent of the benchmark cost<sup>55</sup> to all the beneficiaries in the general category states. In case of the domestic and non-commercial users in special category states MNRE provides 60 per cent capital subsidy or a loan at 5 per cent interest on 50 per cent of the benchmark cost; whereas for the commercial user's category 30 per cent capital subsidy or a loan at 5 per cent interest on 50 per cent of the benchmark cost can be availed.

In India, the Solar Building Programme has been implemented by the MNRE to promote energy- efficient building designs through optimum utilization of solar energy in building energy management. Under the aegis of this programme, MNRE provides financial support for research & development activities, awareness activities and for demonstration projects.

Under the demonstration activities, for the preparation of the Detailed Project Report (DPR) for a solar passive building, MNRE provides a CFA equivalent to 50 per cent of the cost of the DPR, subject to a maximum of INR 0.2 million. For the construction of solar passive buildings, MNRE provides financial assistance for 10 per cent of the cost of the building or subject to a maximum of INR 5 million for each project, but active solar systems installed in the buildings are not covered under the scheme (MNRE)<sup>56</sup>.

At the state level, Himachal Pradesh has pioneered in promotion of passive solar designs. The state formulated a state solar house action plan in 1994. Under this plan, solar passive design features have been made mandatory throughout government/semi-government and commercial sectors, including in hotels, residential colonies, and industrial complexes which are large consumers of energy under the policy on solar passive housing, 2009 (HPSCSTE)<sup>57</sup>.

## BENEFITS

Despite the high initial installation cost of the solar space heating systems, investing in a solar space heating system provides the consumer with free fuel for space heating till the usefulness of the system runs out. Thereby guaranteeing an easy payback period and minimizing the financial risk. Also, non-mechanical intervention pertaining to passive space heating has the benefit of reducing sound pollution and a longer lifespan compared to conventional space heating systems.

In India, out of total 160 million rural and 58 million urban households, nearly 80 per cent of households use solid biofuels for a variety of day-to-day activities like cooking and heating (Venkataraman et al., 2010). In case of rural areas in the colder regions of India, space heating requirements are primarily met by using solid biomass fuels. Thus, shifting to solar space heating system is likely to negate externalities and improve indoor air quality conditions in households and institutions.

55 To avail soft loan, a customer will have to provide 20% of the overall cost.

56 <http://www.mnre.gov.in/file-manager/dec-solar-thermal-systems/swh-scheme.pdf>

57 <http://hpscste.nic.in/solar.htm>



Solar space heating system has also benefit of providing employment opportunities. For example, under the solar passive design project by GERES India, nearly 215 local masons and carpenters and over 460 artisans have been equipped with improved income-generation skills (GERES India)<sup>51</sup>.

## CONSTRAINTS

Low solar insolation in several parts of the Himalayan region of north-eastern and eastern India gets an additional number of overcast days as compared to the other states in southern and central India. Thus, at a number of areas, these solar hot water-based space heating systems work for an average of 180-200 days. Hence, the cost/L of solar hot water increases in the north-eastern region. Additionally, ample availability of cheap alternate options like electricity and firewood in the region makes solar space heating system less acceptable (UNDP, 2011).

In terms of finance, high initial capital cost of the solar space heating systems, due to high costs of material transportation and installation results in extended payback in the case of solar hot water-based space heating systems. Delays in the payout of financial support and troubles in availing subsidies for the small consumers residing in remote areas with low purchasing power is act as a barrier to technology proliferation (UNDP, 2011).

Another barrier prevalent across the region is the issue of lack of a strong local supply chain for solar thermal equipments (collectors and so on). In many regions, due to the prevailing weak supply chain, for locals procuring the systems poor after-sales services makes obtaining the equipment difficult (UNDP, 2011).

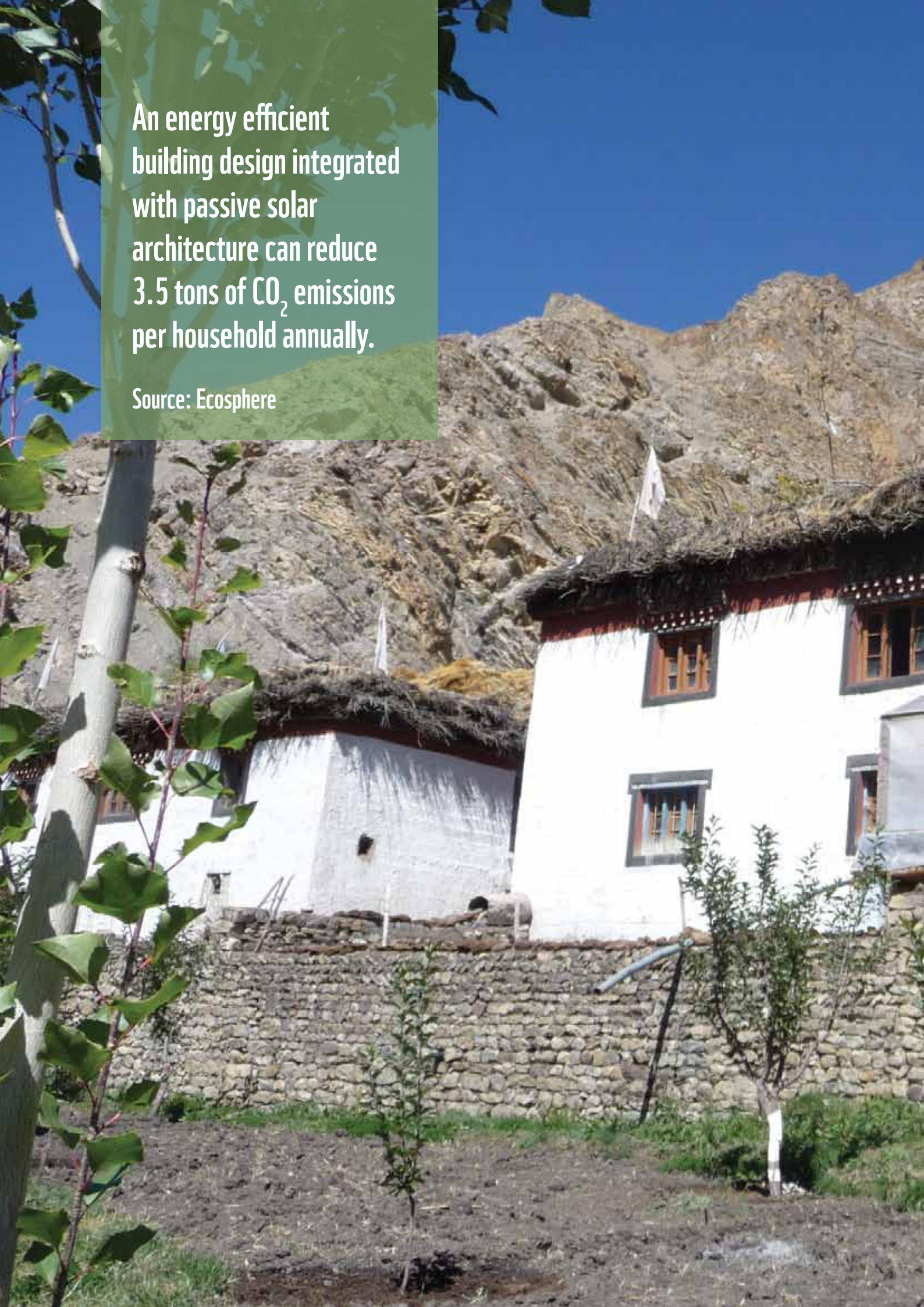
Lastly, inadequate quantification of the thermal performance of solar passive buildings is one of the main reasons why passive solar architecture is not well accepted among architects, since they need performance data to justify additional expense or design change (MNRE)<sup>58</sup>.

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58 <http://mnre.gov.in/solar-energy/ch4.pdf>

An energy efficient building design integrated with passive solar architecture can reduce 3.5 tons of CO<sub>2</sub> emissions per household annually.

Source: Ecosphere









## CASE STUDY:

# ACTIVE SOLAR SPACE HEATING SYSTEM BY ENFRAGY SOLUTIONS INDIA PVT. LTD. AT KOHIMA CIVIL SECRETARIAT, NAGALAND<sup>59</sup>

The solar combi-systems project was implemented in Kohima Civil Secretariat. It caters to the heating of 20 rooms in addition to 50 electrical room heaters with 2kW heater rating. Kohima, the capital city of Nagaland is situated at an altitude of 1444 m above sea level. Prior to the solar space heating system, the Kohima Secretariat building was using electrical room heaters with a monthly consumption of 10,000 kWh. The system is designed and installed by Enfragy Solutions India Pvt. Ltd. (formerly Eaga Energy India Pvt. Ltd.) as a pilot project.

## TECHNICAL DESCRIPTION

Solar space heating system comprises a ETHP (evacuated tube heat pipe) solar collector, water as thermal mass, a hot water storage tank and a network of heat transfer pipes around the building to carry hot water.

Evacuated ETHP solar collectors were placed facing south, at a suitable angle to receive maximum solar radiation during winters. ETHPs are glass tubes with a copper conductor inside vacuum space. The glass surface allows solar radiation to enter the tube and heat the copper conductor and vacuum prohibits heat loss. ETHP solar thermal collectors enable energy collection even in low ambient temperature. Several numbers of such tubes in a series passes on the heat to thermal mass such as water.

Water is heated and stored in an insulated tank. This hot water is circulated around the dwelling space in insulated pipes. Each room has a FCU (fan coil unit) where warm water exchanges the heat with air.

The warm air is blown into the room through a fan providing thermal comfort. The cooled water is returned back to the cold water tank to be reheated at the collector surface. Electric water heaters are connected to the water tank for heating water as a backup on cloudy days. The SSHS generates 3500 litres of hot water per day and 23.34 kW of solar thermal energy is collected per hour. The average electrical savings amounts 846 kWh per day.

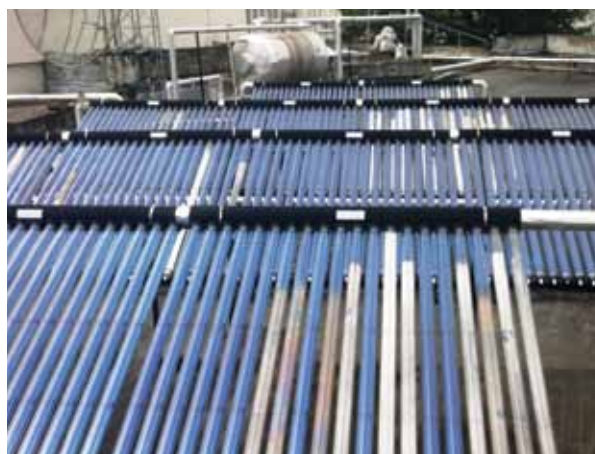


Figure 10 &11: Solar combisystems project implemented at Kohima Civil Secretariat, Nagaland

<sup>59</sup> Based on Information provided by Enfragy Solutions India Pvt. Ltd and publicly available documents.



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## APPLICATION MARKET

Enfragy Solutions India Pvt. Ltd. has designed and installed the active solar space heating system only for institutional purposes. Till now, Enfragy has supplied one unit of SSHS as a pilot and is looking to explore the market in other northern regions of India with good solar insulation/irradiance.

## COST

The total cost of the system is INR 5.9 million with zero cost for operation and maintenance for the first five years. The simple payback period for the complete system is around 4.3 years. This payback period can further be reduced by availing subsidies from MNRE, which in this case was not utilized.

## BENEFITS

- Fuel/electricity savings: 2,79,180 kWh per year.
- GHG Reduction: Approx. 218,000 kg of CO<sub>2</sub> per year.
- Improvement of environment quality: Improvement of environment quality with reduction of smoke and soot.
- Reduction in workload: Negligible maintenance.

## CONSTRAINTS /BOTTLENECKS

### Market Barriers

- High upfront cost.

### Institutional Barriers

- Supplies of highly efficient EHP manufacturers are very few in the market.

### Technological Barriers

- Large rooftop space is required to install the system compared to other conventional space heating systems.
- Technology being new, there is insufficient in-built service mechanism.
- The seasonal application, can work efficiently only 200 days in a year.

### Social Barriers

- Lack of awareness.
- Belief that renewable energy is expensive.
- Belief that solar does not work. The requirement varies with each consumer; therefore systems have to be made customized leading to high costs.



# Renewable Energy Technologies and Applications: **Cooling**

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## SOLAR AIR-CONDITIONING SYSTEM

The urban population of India is poised to grow significantly in coming decades resulting in a demand for housing and commercial spaces in the country. The realty sector is already witnessing the steep rise in the demand for new constructions. Based on the data by Energy Conservation and Commercialization (ECO-III) estimates, as of 2010, the total commercial floor space in India is around 659 million m<sup>2</sup> (Kumar et al., 2010).

Air-conditioning is one of the most important energy demanding activity in many parts of the world today. In India, residential building cooling (fans, evaporative cooling an air conditioners) accounts for 45 per cent of the energy consumption; whereas in commercial buildings HVAC consumes the 55 per cent of the total energy utilized (Planning Commission, 2011).

Predominantly, all air-conditioning systems currently being used all over the world are based on vapour compression technology running on grid-electricity. The conventional method of electricity generation has externalities like GHG emissions, deforestation among others, associated with it, therefore to reduce increasing energy demand turning to the use renewable energy solutions would be prudent.

Solar air-conditioning is a renewable energy solution that might be able to reduce the externalities and at the same time meet the rising Heating, Ventilation, and Air-Conditioning (HVAC) as well as comfort cooling demands in the country. Solar air-conditioning technologies can mainly be classified into three key groups based on the source of energy supply (1) thermal-driven system (2) electricity (photovoltaic) driven system and (3) mechanical-driven system (Mittal, 2005).

In the electricity-driven system, solar energy is absorbed and converted into direct current (DC) by an array of solar cells known as a photovoltaic (PV) panel. This DC supply is then either used directly or converted into alternating current (AC) to run the compressor of a refrigerator (Sinha & Karale, 2013).

In case of the solar mechanical method, the air-conditioning system is based on the Rankine cycle engine. In this system, solar energy is used to generate energy required to drive the compressor for the air-conditioning.

The solar thermal air-conditioning system usually involves solar thermal collectors connected to thermally-driven cooling devices. Solar thermal technologies for conversion of solar energy into hot water can be classified into:

- Flat plate collectors
- Evacuated tube collectors
- Stationary, non imaging concentrating collectors
- Dish type concentrating collectors
- Linear focusing concentrators
- Photovoltaic

The collected solar energy is converted to provide cooling services by employing different process cycles (Pridasawas & Lundqvist, 2003).

At present only a handful of successfully established installations of solar thermal air-conditioning systems are operational in India. Along with commercial establishments, MNRE has also been funding installation and R& D on these technologies, but at present the supply

chain for the production and supply of the systems is still evolving in India. Few of these installations, commercially available models and manufacturers are mentioned below:

**Table 22: Examples of solar air-conditioning systems in India**

S No	Installed At	Manufacturer	Capacity	Technology
1	Mamata Energy Plant, Gujarat	Mamta Energy, Ahmedabad	25 TR	Single-effect evaporator-based vapour absorption chiller
2	Chhatrapati Shivaji Hospital, Thane	Sharda Inventions Pvt. Ltd., Nashik	160 TR	Vapour absorption cooling
3	Solar Energy Centre (SEC), MNRE, Gurgaon (demonstration project)	Thermax, Pune	28.5 TR	Triple-effect vapour absorption chiller and solar parabolic concentrators
4	National Thermal Power Corporation, Noida	Clique Solar, Mumbai	50 TR	Vapour absorption cooling
5	Mahindra Vehicles Manufacturers Ltd., Pune	Clique Solar, Mumbai	100 TR	Vapour absorption cooling
6	Turbo Energy Ltd. (TVS group) Chennai	Clique Solar, Mumbai	92 TR	Vapour absorption cooling

## TECHNOLOGY

The solar electric air-conditioning systems consist of a collection of solar photovoltaic (PV) cells, which convert solar energy into electrical energy to power electric heat pump(s) (Rona, 2004). Photovoltaic cells are made up of semiconductor material which allows direct alteration of solar energy to direct current (DC). A DC-to-AC converter or an inverter is also required, to convert DC supply from the solar PV cells to AC for powering the heat pump or it can be directly used in case a DC-powered heat pump. To stabilize and smooth the generated current, a solar charge controller consisting of a capacitor, sensors is required (Sinha & Karale, 2013).

One of the main advantages of this type of system is that an already operating conventional system, even if decentralized, can be easily transformed into a solar-powered system by simply adding solar PV panels to the internal grid. The COP of the solar electric air-conditioning can range between 0.25 and 0.56.

In the case of the solar mechanical method, the mechanical power necessary to run the compressor is produced by a solar-driven heat power cycle (Saitoh et al., 2007). The working fluid (liquid state) is vapourized at an elevated pressure in the boiler of the Rankine cycle by the solar energy collected by the solar collectors. The generated high-pressure vapour is then transferred through a turbine or a piston expander thereby leading to expansion of the vapour and drop in vapour pressure and temperature, resulting in the production of mechanical work. The mechanical work produced from the turbine is used to run the compressor of the vapour compression cycle. The condensed working fluid is exited from the turbine and pumped back to the boiler where it is again vapourized and the whole cycle is repeated again.

The efficiency/COP of the Rankine cycle-based solar air-conditioning system increases with rising temperature of the vapourized working fluid used in the expander. While the operating fluid using the flat plate collector can generate temperatures in between 80°C and 120°C and the system cooling COP ranges between 0.2 and 1.50 (Sargent & Teagan, 1972).

A characteristic solar thermal air-conditioning system comprises a solar collector, a thermal storage tank, a thermal refrigeration unit and a heat exchange system. The selection of the solar collectors is largely dependent on the temperature requirement for the air conditioning and generally flat plate collectors are used where the temperature requirement between 60 °C and 100°C, and in case of higher temperatures evacuated tube collectors or concentrating solar thermal collectors are employed (Sinha & Karale, 2013). The vapour absorption system utilizes steam as its primary energy source for chillers. The vapour absorption system could be classified into either (1) indirect-fired, double-effect absorption chillers which require steam at around 190°C and 900 kPa and (2) single-effect chillers that require hot water or steam at 75 °C -132°C (IRG, 2009).

In a vapour absorption cycle, the low-pressure vapour is absorbed into an absorber which is heated and pressurized to generate high pressure vapour (Abu-Zour & Riffat, 2007). Presently, two absorbent-refrigerant cycles in use widely are – lithium bromide (LiBr)-water (aqueous) system and water (aqueous)- NH<sub>3</sub> system. In case of the LiBr system, lithium bromide is used as an absorbent whereas water is the refrigerant. In an NH<sub>3</sub> absorption system, water is used as an absorbent and ammonia is the refrigerant.

In the vapour absorption system, concentrated absorbent goes through the absorber, which is coupled to the evaporator (Wang & Chua, 2009). The refrigerant is then converted into high pressure vapour and absorbed by the LiBr/water absorbent. The combination is then transferred to the generator where the refrigerant is evaporated using solar energy. The produced high-pressure refrigerant vapour then moves to the condenser from where heat is dispersed to the surroundings to condense the refrigerant back to liquid, thus completing the loop (Sinha & Karale, 2013). The COP of LiBr/water absorbent cycles has been found to be around 0.5-0.6 (Chakraborty & Bajpai, 2013) (Bajpai, 2012). The cooling output for a single effect LiBr system is 4°C-38°C, COP is in the range of 0.6-0.8 (Kedare, 2011) and 4°C-27 °C for a double-effect with COP achievable up to 1.2. The cooling effect range is -51°C-4°C in the case of the aqueous ammonia refrigeration system (Kedare, 2011).

## APPLICATION MARKET

At present the HVAC market in India, in terms of volume, is estimated to get to around 5 million TR in 2015 (BuildoTech Magazine, 2011). The use of solar air-conditioning is still a virgin area with a large untapped potential. In India, the expected market potential for solar air conditioning is about 0.75 million TR, and is increasing at the rate of around 17 per cent per annum (VSM Solar)<sup>60</sup>.

The use of this technology is steadily picking up due to the introduction of favorable policies and incentives like the introduction of the national solar mission and provision of incentives and subsidies for procurement of solar equipments and so on. The market analysis study by KPMG estimates the market potential for the solar cooling segment to be about 0.13 million m<sup>2</sup> of collector area (~INR 2 billion) (KPMG, 2012).

60 [http://www.vsmsolar.com/market\\_potential.html](http://www.vsmsolar.com/market_potential.html)

## COST

MNRE has fixed up a benchmark cost for concentrated thermal solar contractor systems, with manual tracking cost INR 7000 per m<sup>2</sup>, a system with single axis tracked systems has benchmark cost of INR 18000 per m<sup>2</sup> of dish area and INR 20,000 for two axis tracked systems. In the case of the flat plate collector, MNRE has defined a benchmark cost of INR 8500 per m<sup>2</sup> for the domestic user and INR 8000 per m<sup>2</sup> for the commercial user. Evacuated tube collectors have a benchmark cost of INR 11000 per m<sup>2</sup> for non-commercial users and INR 10000 per m<sup>2</sup> for commercial consumers.

MNRE provides 30 per cent capital subsidy on the benchmark cost or loan at 5 per cent interest on 50 per cent<sup>61</sup> of the benchmark cost to all the beneficiaries in the general category states. This subsidy goes up to 60 per cent in the special categories states like Himachal Pradesh, Jammu & Kashmir, Uttarakhand and the northeastern states including Sikkim.

The cost of a conventional air-conditioning HVAC system ranges between INR 0.05 million and 0.1 million per TR. The cost of installation in the case of a solar air-conditioning system is about Rs 0.15 million per TR (Business Standard, 2006). The operation & maintenance activities require negligible running cost, but the solar heat collectors need to be changed every four to five years and cost about 10 per cent of the system cost.

Thus, the total payback period without depreciation and subsidies benefit offered by government is estimated at four to five years. The average life span of an average size (25 TR) solar air conditioning system is about 25 years (Mamta Energy)<sup>62</sup>.

## POLICY SCENARIO

Ministry of New and Renewable Energy (MNRE) under its Jawaharlal Nehru National Solar Mission (JNNSM) have been giving out incentives and capital subsidies for solar thermal and solar photovoltaic equipments and machinery. At present, there is subsidy of INR 5400 per m<sup>2</sup> for concentrating systems if it has single axis tracking and INR 6000 per m<sup>2</sup> if it has double axis tracking. The solar air conditioning system based on the solar thermal collectors like FPC or EPC subsidies provided by MNRE has been elaborated upon in the cost section.

Under the Phase II of the JNNSM, the government has a target for at least 200 systems, 30 TR each on an average (60,000 m<sup>2</sup>) for air conditioning/refrigeration systems by 2017 (MNRE, 2012).

Apart from subsidies and incentives, there are a few policy mechanisms like standards and codes that directly influence the building energy conservation and its efficiency. Standards and codes like the National Building Code (NBC) and Energy Conservation Building Codes (ECBC) provides broad-spectrum guidance on possible energy efficiency aspects of components like daylight integration; artificial lighting requirements and heating, ventilating, and air conditioning (HVAC) design standards for commercial buildings (Tathagat, 2011). Various market-driven voluntary Green Building Rating Programs such as Indian Green Building Council (IGBC) programmes – LEED, TERI-GRIHA and Eco-housing are also promoting the use of renewable energy-based technologies to be integrated in the building operations.

61 To avail soft loan, a customer will have to provide 20% of the overall cost.

62 [http://www.mamataenergy.com/temp\\_control/thermal\\_ac\\_tcs.php](http://www.mamataenergy.com/temp_control/thermal_ac_tcs.php)



## BENEFITS

Solar air-conditioning system has multiple direct and indirect benefits which range from GHG emission reduction to employment generation and green image. Traditionally, HVAC uses conventional fossil energy sources to generate steam in the boilers which in turn is passed through the process “path” to achieve air conditioning. Using the solar air-conditioning system considerably reduces the use of conventional fuel such as wood, natural gas, heavy oil and so on. Some other indirect benefits include employment generation and the green image creation for the technology consumer.


## CONSTRAINTS

One of the primary reasons for solar air-conditioning systems still being in the nascent stage is because of the market ecosystem such as economics of cost. The solar air-conditioning system has a high upfront investment thereby making it economically unattractive in spite of its multiple benefits. Other market barrier involve, lack of a strong base of established manufacturers and suppliers in the sector. Presently, there are very few manufacturers in the Indian market providing such services.

Being a new technology in India, there are not many dedicated manufacturers of solar air-conditioning systems in India due to which the supply chain for the system equipments becomes constrained. There are only a few types of solar collectors that can deliver the temperatures required by the vapour absorption machines. Also, being a new technology, solar air-conditioning systems have to fair against conventional HVAC systems which in India is at a mature stage, technologically. The lack of availability of small capacity chilling units commercially is also a barrier. For the installation of solar thermal air-conditioning systems installation, provisions need to be in place in the early stages of building construction.

Lastly, social barriers such as lack of awareness leading to unfounded beliefs that renewable energy is expensive and does not work compared to conventional systems are a few key bottlenecks that are hindering the successful uptake of solar air-conditioning systems in India.



A photograph of a hospital ward with several beds, white curtains, and medical equipment. A person in pink scrubs is standing in the foreground, and another person is visible in the background. The floor is highly reflective.

The market potential for solar cooling segment in India is around 1.3 lakh square meters of collector area (INR 200 crore).

Source: KPMG, 2012

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## CASE STUDY:

# SOLAR AIR-CONDITIONING SYSTEM AT KAILASH CANCER HOSPITAL AND RESEARCH CENTRE (KCHRC), VADODARA, GUJARAT<sup>63</sup>

KCHRC is a 160-bed hospital established and run by Muni Seva Ashram (MSA), an NGO set up in 1980 by the Late Anuben Thakkar. Prior to the installation of the solar air conditioning system at Muni Seva Ashram, steam for the HVAC system was produced by a wood-fired boiler used to run the Li-Br based double effect vapour absorption chiller for air-conditioning. The solar air-conditioning plant was manufactured, supplied and installed by Gadhia Solar Energy Systems Pvt. Ltd.

## TECHNICAL DESCRIPTION

A hundred Scheffler dishes of 12.5 m<sup>2</sup> have been installed at the site, each generating 400 kg/hr steam at 8.5 kg/cm<sup>2</sup> at 167° C. The steam is sent to a 100 TR Li-Br-based vapour absorption chiller. The chilled water generated at 6°C is piped and sent to air handling units (AHUs) in the hospital which cools the incoming ambient air. The cooled air is ducted in the building through central air-conditioning. The chilled water in the process gets heated to 12°C and is re-circulated to VAC where it gets chilled again at 6°C. It is a closed loop system where the chilled water again goes to AHUs to cool the air.

Through this system, the Ashram is saving about 1000 kg of bio-mass/wood, which was earlier being used to generate the 400 kg/hr steam every day. The use of solar generated steam for air conditioning instead of bio-mass generated steam helped to save costs and in turn protect the environment. The bio-mass boiler serves as a back-up to give additional steam required to run the other 500 TR vapour absorption chillers.

## APPLICATION MARKET

The system installed is for the Ashram and its hospital's captive use, but the larger aim of the MSA is to adopt and use the technology for cold storages in the adjoining villages.

## COST

The total cost of the system is INR 12 million for only the solar system because the existing vapour absorption chiller and back-up boilers shared part of the 100 TR load. The system has negligible running costs but the mirrors of the parabolic dishes need to be changed every four or five years and comprise 10 per cent of the system cost. The simple payback period for the complete system is around four to five years without any depreciation benefit offered by the government.

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<sup>63</sup> Based on information provided by Muni Seva Ashram and publicly available documents



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## BENEFITS

- Fuel/electricity savings: 1000 kg/day of wood.
- GHG reduction: Approx 330,000 kg of CO<sub>2</sub> per year.
- Improvement of environment quality: Improvement of environment quality with reduction of smoke and soot.
- Reduction in workload: Saving in cutting, storage, transportation and handling of wood.

## OTHER BENEFITS INCLUDE

- Employment generation
- Energy self-sufficiency
- Green image for the technology user

## CONSTRAINTS /BOTTLENECKS

### **Market Barriers**

- Lack of integrated approach

### **Institutional Barriers**

- Delay in subsidy disbursement

### **Technological Barriers**

- Technology being new there is insufficient in-built service mechanism
- The seasonal application can work efficiently for only 300 days in a year

### **Social Barriers**

- Lack of awareness.
- Belief that renewable energy is expensive.
- Belief that solar does not work.
- Difficulties in getting government subsidy and support.



## GEOHERMAL COOLING SYSTEM

In India, residential and commercial sectors account for 29 per cent (out of which the residential sector contributes 21 per cent and commercial sector the remaining 8 per cent) of the total electricity consumption. This demand for energy is growing annually at a rate of 8 per cent (Planning Commission, 2011). Cooling activities (fans, evaporative cooling and air conditioners) in residential buildings, account for 45 per cent of the energy consumption, whereas in commercial buildings HVAC consumes 55 per cent of the total energy utilized. CO<sub>2</sub> emissions from conventional buildings in India are estimated to be 40,000 tonnes of CO<sub>2</sub> per million square feet in 2005. At this pace, emissions from the commercial building sector are projected to be 610 Mt of CO<sub>2</sub> in 2020 and 1,370 Mt of CO<sub>2</sub> in 2030 (Planning Commission, 2011).

Conventional centrally air-conditioning expels building heat into the atmosphere using either an air-cooled or water-cooled heat exchanger pump. The outside temperature heavily influences the efficiencies of the air-conditioning systems, because under high external temperatures, air conditioning efficiency decreases and vice versa (Vibhute et al., 2012).

Alternatively, a geothermal heat sink system uses the earth as heat sink instead of outside atmosphere. The earth temperatures are lower than atmospheric temperatures thereby increasing the efficiency of the geothermal heat sink system. Thus, the geothermal heat exchange system is proving to be an economically efficient and environmentally sustainable air-conditioning option.

### TECHNOLOGY

In a conventional set-up, the building heat is ejected into atmosphere through either air-cooled condenser coil or via a cooling tower. The geothermal cooling system modifies the process of heat rejection. The system's crux lies in rejecting the heat into the earth through piping loops.

Nearly 46 per cent of sun's energy is absorbed by the Earth. Also, the ground has a high heat storage capacity because of its low thermal conductivity, hence, its temperature changes slowly. This thermal energy potential can be exploited for space cooling and heating in buildings (RET Screen International)<sup>64</sup>.

A geothermal heat pump system is typically made up of three components: one is the ground heat exchanger, a heat pump unit, and an air delivery system. The heat exchanger is basically a system of pipes and tubes called a loop, which is buried in the shallow ground near the building. A circulating heat absorbing fluid (e.g. water) circulates through these pipes to absorb or expel the available heat (Wong et al., 2012).

The building heat is channelized through a geo field (water looping system in the earth), where the loop gives away heat to the Earth. There are two types of looping systems: (1) open loop in which water is drawn from a water body/aquifer and used in the system and later discharged into another water body/aquifer and; (2) closed loop, as name suggests, it uses working fluid which is continuously circulated in the closed loop. A geo field utilizing the close loop piping system ensures that there is no loss of water. This makes the use of water-cooled chiller systems viable even in areas where there is a dearth of water.

A geothermal system when coupled with traditional air-conditioning systems can enhance the system's efficiency by 50-70 per cent. For example, traditional air-conditioning equipment could consume 0.9-1.0 Input kW/TR (IKW/TR) and this consumption can be reduced to 0.4-

64 <http://www.retscreen.net/>

0.5 IKW/TR when coupled with the geothermal system (GIBBS)<sup>65</sup>.

Furthermore, 100 per cent water efficiency with closed loop geothermal system saves a substantial amount of water. Secondly, the geothermal cooling system if coupled with a rainwater harvesting system increases the moisture content of the Earth thereby enhancing the heat transfer efficiency of the geo field. This increase in efficiency is due to the lowering of the heat transfer area of the piping system and secondly, facilitating quick distribution of heat away from the geo field.

**Table 23: Energy Efficiency Ratio (EER)<sup>66</sup> values of different air conditioning systems**

System	EER
Air source conditioning system	9.5
Cooling tower conditioning system	10.5
Geothermal system	18

Source: (Geothermal India, 2013)<sup>67</sup>

## APPLICATION MARKET

Globally, the demand for geothermal heat exchanger systems is growing to meet the air conditioning needs for building sector. The geothermal heat exchanger (based on geothermal heat pumps) accounts for 69.7 per cent and 49.0 per cent of the worldwide capacity and use of geothermal energy. The installed capacity of geothermal heat pumps is 35,236 MWt and the annual energy use of 214,782 TJ/yr. Geothermal heat exchanger systems are used in the commercial sector in 43 countries with majority of the total installations located in North America, Europe and China (Lund et al. 2010). The market for geothermal cooling systems in Asia is currently much less established compared to Europe and North America, but China and Japan are emerging as leaders in this sector. So far around 630 MWt geothermal heat pumps capacities have been installed in China (Navigant Consulting, 2009).

In India, the combined current market for the geothermal, hot water and lighting systems is estimated to be around INR 600 billion and it is expected to grow at a CAGR 20-25 per cent (GIBBS)<sup>65</sup> which aligns with the growth of air-conditioning market in the country.

## COST

Cost of conventional air-conditioning system range between INR 50,000-1,00,000 per TR. A geothermal system coupled with conventional system, would have an additional cost in the range of INR 35,000-60,000 per TR. Typically, savings per annum range from INR 40,000-70,000 per TR making the payback fall in the range of six to eighteen months (GIBBS)<sup>65</sup>.

65 <http://www.gibss.in/geothermal.html>

66 The efficiency of the air conditioning systems are reported in terms of Energy Efficiency Ratio (EER). The EER of any cooling equipment refers to as the ratio of cooling output (in BTU/h) to input electrical power (in watts) at a given operating conditions of 50% relative humidity, 95 °F outside temp and an inside temp of 80 °F (US DoE, 2012).

67 [http://www.geothermalindia.in/product\\_efficeincy.html](http://www.geothermalindia.in/product_efficeincy.html)



## POLICY SCENARIO

The Ministry of New and Renewable Energy (MNRE) in past has executed demonstration application projects for small-scale power generation in poultry farming and greenhouse cultivation using geothermal fluids. National Geophysical Research Institute (NGRI), on behalf of MNRE, has been doing studies to delineate potential geothermal potential areas in India (MNRE)<sup>68</sup>.

But, the use geothermal energy and policy environment for cooling applications is still in nascent stages in India. For the building sector, there are very few policies and standards in India that govern (directly and indirectly) the use of such clean technologies.

In the last few years, India has witnessed increasing interest in the concept of green buildings/energy-efficient buildings and policymakers in India have developed few standards and codes to govern and promote them. The National Building Code (NBC) developed by Bureau of Indian Standards (BIS) provides broad-spectrum guidance on possible energy efficiency aspects of components like daylight integration, artificial lighting requirements and heating, ventilating, and air conditioning (HVAC) (Tathagat, 2011).

Energy Conservation Building Code (ECBC) launched in 2005 has been developed by the Bureau of Energy Efficiency (BEE) and has been mandated by the Energy Conservation Act, 2001. ECBC covers commercial buildings or building complexes with a connected electrical load of 500 kW or more. The purpose of this code is to offer minimum requirements for the energy efficient design and construction of buildings (Tathagat, 2011). Also, various market-driven voluntary green building rating programs have considerably increased the scope for the incorporation of geothermal- based new technologies in new buildings. Major green building rating systems currently operating in India is: Indian Green Building Council (IGBC) programmes – Leadership in Energy and Environmental Design (LEED), TERI – Green Rating for Integrated Habitat Assessment (GRIHA) and Eco-housing.

## BENEFITS

Geothermal cooling systems have multiple benefits across many aspects. Business operations and activities of the building owners are positively impacted by the use of geothermal cooling systems; since its use significantly reduces the operating costs across seasons<sup>69</sup>. Geothermal design improves the efficiency of the air conditioning system by 50-70 per cent thereby reducing operating costs. Also, geothermal cooling systems do not require additional space for installation, thus reducing the need for space/land. In economic terms, the life of a geothermal cooling system is over 50 years (GIBBS)<sup>65</sup>.

Geothermal systems are an environmentally sustainable and benign technology. Since the closed loop geo-field system also offers 100 per cent water efficiency, thereby saving large quantities of water which in normal conditions would have been used as makeup water. Hence, this technology can be employed in water-stressed or water-deficient areas.

The geothermal cooling system also results in significant reduction in GHG emissions; a typical 1 TR geothermal cooling system can mitigate 1.6 t CO<sub>2</sub> eq. per year. The installation of the system can avoid almost 374 kg of H<sub>2</sub>SO<sub>4</sub> based hazardous waste chemical per 1 TR per year (GIBBS)<sup>65</sup>.

68 <http://www.mnre.gov.in/schemes/new-technologies/geothermal/>

69 As energy efficiency ratio (EER) of a conventional system decreases with the rise in ambient temperature, which in case of India is very prominent (higher temperatures during summers). While the EER of geothermal heat pumps remains largely unaffected owing to low thermal conductivity property of ground.

## CONSTRAINTS

While geothermal cooling systems continue to be common and exist in the many industrialized countries where heating and cooling energy requirements are high. The main limitation hampering increased market diffusion of geothermal cooling systems in India is their high upfront cost (Moore and Alex, 1999).

Another, constraint for large-scale acceptance of the geothermal cooling system in India are knowledge and technology barriers, because not many project developers are willing to risk using new technologies.

The geothermal cooling system is most economically viable in new construction, since this involves drilling and laying of loop tubes underground. Thus, the installation of a geothermal cooling system becomes a problem, both in terms of economics and environmental<sup>70</sup>, if the building already has a heating and cooling system installed.

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<sup>70</sup> In case of open loop technology constraints include, environmental risks of direct exchange, legal compliance risks and maintenance issues.

A photograph of a building facade, likely in an urban setting, showing multiple air conditioning units (ACs) mounted on the wall. The units are arranged in rows, with some labeled 'TOSHIBA' and others 'BLAU 13000'. Numerous pipes and electrical wires are visible, running vertically and horizontally across the wall, creating a cluttered appearance. A window is visible in the upper right, and some foliage is on the left. A teal text box is overlaid on the right side of the image.

The expected  
emissions from the  
commercial building  
sector will be 1,370  
Mt of CO<sub>2</sub> in 2030.

-Planning Commission,  
Government of India, 2011

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## CASE STUDY:

# GEOHERMAL COOLING SYSTEM BY GREEN INDIA BUILDING SYSTEMS & SERVICES PVT LTD (GIBBS) AT INDIAN SCHOOL OF BUSINESS (ISB), MOHALI, PUNJAB<sup>71</sup>

Green India Building Systems & Services Pvt Ltd (GIBBS) is a net zero energy building systems company that develops geothermal cooling systems, hot water co-generation systems and lighting systems to reduce operating costs and the carbon footprint in the buildings.

## TECHNOLOGY

At ISB Mohali, the traditional water-cooled screw chiller with a cooling tower as a heat exchanger was replaced by a water-cooled system coupled with a geothermal heat exchanger. The 235 TR geothermal system provides constant cooling water temperature of 24 °C which is substantially lower than the expected 32°C -33°C cooling water temperature from a cooling tower system. This significant difference of 6-8°C in the cooling water temperature translates to the chiller plant saving about 33 per cent of electricity consumption. Moreover, geothermal systems with 100 per cent water efficiency would save substantial amounts (in millions of liters) of treated makeup water. The sum of the savings at ISB would be over 60 per cent.

## TECHNOLOGY

The total cost of the geothermal cooling system is INR 9.04 million. The simple payback for this system is 2.3 years with no financial support from the MNRE.

## BENEFITS

- GHG Reduction: Approx. 376,000 kg of CO<sub>2</sub> per year.
- Improvement of environment quality: 87,871 kg of H<sub>2</sub>SO<sub>4</sub> based hazardous waste chemical avoided per year

## OTHER BENEFITS INCLUDE

- Green image
- Carbon credit

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<sup>71</sup> Based on the information provided by Green India Building Systems & Services Pvt Ltd (GIBBS) and publicly available documents.



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## CONSTRAINTS /BOTTLENECKS

### **Market Barriers**

- High upfront cost.

### **Institutional Barriers**

- No direct policy favoring and promoting geothermal cooling systems in India, both at central and state-level.

### **Technological Barriers**

- Technology being new, there is a gap in the service chain.

### **Social Barriers**

- Lack of awareness and general understanding of the technology.
- Belief that renewable energy is expensive.



# Renewable Energy Technologies and Applications: **Cooking**

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## SOLAR COOKER

Cooking activity accounts for about 36 per cent of India's primary energy consumption (Pillai and Banerjee, 2009). More than 85 per cent of rural households are dependent on traditional biomass fuels like animal dung and so forth for day-to-day cooking activities (MoSPI, 2013). A majority of such rural household's burn biomass fuels in traditional cook stoves or chulhas. Apart from being less efficient, these traditional chulhas emit smoke and other pollutants leading to both indoor and outdoor pollution. These externalities can be reduced with the help of renewable energy for cooking solutions.

Solar cookers use solar energy to generate heat for cooking food. The solar cooker application is rapidly rising as a safe, clean and economically viable cooking technology, which can be a promising alternative for conventional LPG cook stoves, and fire wood (ICLEI, 2013). Varieties of solar cooker designs are presently commercially available in India, and there are four major types of solar cookers (Pillai and Banerjee, 2009):

- Box cooker
- Dish cooker
- Scheffler indoor solar cooker
- Concentrated Paraboloid Solar Cooking (CPSC)

In 1954, National Physical Laboratory developed India's first solar cookers. Afterwards first box type solar cookers were developed in 1961 (Banerjee)<sup>72</sup>. In India, large-scale solar dish cookers for community application (Scheffler cooker) were developed and manufactured in early 1990s (Banerjee)<sup>72</sup>. Over the years, the performance of these large-scale solar cookers have been found to be satisfactory, evident from the fact that one of the world's largest solar cooking systems is installed and operating in India at Sri Sai Baba Sansthan, Shirdi, Maharashtra with a collector area of 1168 m<sup>2</sup> (73 reflective dishes of 16 m<sup>2</sup> each).

## TECHNOLOGY

Principally, the solar box cooker works like a type of heat-trapping enclosure. The box cooker is made up of insulating material with one side fixed with a transparent material, like glass or plastic, enabling the formation of the greenhouse effect inside the box, which in turn raises the temperature for cooking the food inside the box (Garg and Thanvi, 1976). A typical box solar cooker can meet the cooking needs of four to five persons and takes 2.5 hours to cook food<sup>73</sup>. It has an average useful life between 10 and 12 years, and a user can achieve a simple payback in two to three years (MNRE)<sup>74</sup>.

The dish or parabolic dish cooker is made of single/multiple reflectors/concentrators set tightly onto a rigid frame. The dish area for the system is usually kept 1 m<sup>2</sup> minimum and the reflectors/concentrators are typically made up of heavy-duty material with a reflectivity of over 75 per cent like bright anodized aluminum sheets. The system works on a manual tracking mechanism and thus requires adjustment within 15 to 20 minutes during cooking time. The system can generate power of about 0.6 KW, which is sufficient to boil 2 to 3 litres of water in half an hour. The system can achieve temperatures around 350 °C to 400°C. The thermal efficiency of the system is around 40 per cent which is enough to meet the needs of 10 to 15

72 [http://www.krrao.org/images/KRs\\_Comments\\_Chapter\\_4\\_by\\_Banerjee\\_SolarindiaRB\\_July9\\_2010\\_1\\_\\_8-16-10.doc](http://www.krrao.org/images/KRs_Comments_Chapter_4_by_Banerjee_SolarindiaRB_July9_2010_1__8-16-10.doc).

73 Depending on the type of food as well as the availability of solar radiations.

74 <http://mnre.gov.in/file-manager/UserFiles/pdf/Trainers%20Textbook%20-%20Solar%20Thermal.pdf>

people (MNRE)<sup>75</sup>. It has an average useful life of 20 years, and a user can achieve a simple payback in less than 2 years (MNRE)<sup>74</sup>.

The Scheffler-based community indoor solar cooker consists of an elliptical shaped solar primary reflector/concentrator with minimum 7.0 and 9.5 m<sup>2</sup> aperture areas. The reflector is made up of multiple pieces of reflecting mirrors supported by a rigid frame/structure. The dish system also has a mechanical sun tracking system, and can attain a temperature as high as 400°C generating enough heat to cook food for 50 to 75 persons in the community (MNRE)<sup>76</sup>.

In the Concentrated Paraboloid Solar Cooking (CPSC) system, to generate high pressure steam, a number of parabolic solar concentrators are employed. Solar radiation is directed onto an insulated receiver placed at the focal point, which then transfers the heat from receiver to transport medium thereby generating steam (GEDA)<sup>77</sup>.

Typically, the most preferred heat transport medium is water (steam). This steam generated from a solar system is used for steam cooking applications in community kitchens. The CPSC system also comprises a central sun-tracking system, steam header pipe, system piping, and supporting civil structures including valves and so on. A typical (96 m<sup>2</sup>) Scheffler dish-based solar steam system can generate about 150 to 200 kg of steam in a day and in turn save approximately 4,500 litres of diesel per annum (MNRE)<sup>78</sup>.

Apart from the Scheffler reflector/concentrator, in India, another reflector/concentrator technology, ARUN concentrators, is also commercially available. The concentrator works on the Fresnel reflector technology, which employs an array of flat solar mirrors to focus solar energy onto a point area. At present, these systems come in sizes of 34, 100 and 169 m<sup>2</sup> which are much bigger in size than the conventional Scheffler concentrator and are therefore able to produce dry saturated steam 220, 700 and 1200 kg each (Kedare et al., 2006).

## APPLICATION MARKET

According to MNRE, a total of approximately 639,000 box type solar cookers and dish cooker units of about 10,200 have been installed in India till the end of 11th year plan. Total of about 80 solar energy based steam generating systems (collective dish area 25,000 m<sup>2</sup>) have been installed in India till 2013 (MNRE, 2012). MNRE also has list of various manufacturers and channel partners for various types of commercially available solar cookers (MNRE, 2013a; MNRE, 2013b; MNRE, 2013c).

The KPMG report illustrates that the market potential for solar cooking segment is around 0.26 million m<sup>2</sup> of collector area which is roughly equivalent to INR 4 billion (KPMG, 2012).

The Ministry of New and Renewable Energy has kept an overall deployment target of 50,000 solar cookers with at least 100 institutions and around 25,000 installations for solar cooking applications in schools for mid-day meals under the Phase II of JNNSM.

Furthermore, under the Twelfth Plan, the planned physical targets for the solar cooking system programme are 3.5 million solar cookers (box and dish type) and 0.5 million solar cooking systems in schools for the mid-day scheme (Planning Commission, 2011).

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75 [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Dish\\_Solar\\_Cooker.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Dish_Solar_Cooker.pdf)

76 [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Indoor\\_Community\\_Solar\\_Cookers.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Indoor_Community_Solar_Cookers.pdf)

77 [http://geda.gujarat.gov.in/specification\\_solar\\_cooker.php](http://geda.gujarat.gov.in/specification_solar_cooker.php)

78 [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Solar\\_Steam\\_generating\\_Systems.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Solar_Steam_generating_Systems.pdf)

## COST

The cost of a solar box cooker in Indian market varies between INR 3,500 and INR 4,200 depending on its volume and features (MNRE)<sup>79</sup>. A dish solar cooker of smaller size (1400 mm diameter, SK -14) costs around INR 6,000 to INR 8000<sup>80</sup> (MNRE, 2013d) and is roughly able to save around 8-10 LPG cylinders per annum when used to its full capacity. Dish cookers of a bigger size cost INR 30,000 and full capacity use of this system can save around 30 LPG cylinders in a year (MNRE)<sup>81</sup>.

The major cost component in both the indoor solar cooking and solar steam generation system is the Scheffler reflector/concentrator. MNRE has fixed a benchmark cost of INR 7000 per m<sup>2</sup> for CPSC systems with manual tracking. Systems with single axis tracking have a benchmark cost of INR 18,000 per m<sup>2</sup> of the dish area and INR 20,000 for two axis tracked systems. The cost of the whole system depends on the site and size of the systems (excluding the cost of boilers, utensils for cooking and civil work, which amount to an extra 20 to 30 per cent) (MNRE)<sup>81</sup>.

An indoor Scheffler cooking system may use a reflector/concentrator area of 1 m<sup>2</sup> costing between INR 15,000 and INR 20,000 depending on the size and tracking system (MNRE, 2013d) which will save 30 to 65 LPG cylinders in a year. The operation and maintenance cost for these systems for five years roughly costs 3 to 5 per cent of the total system cost. The reflector/concentrator in the ARUN technology with an aperture area of 169 m<sup>2</sup> can generate 500 to 600 kg of steam per day and costs around INR 5.6 million. The payback period for a typical Scheffler solar steam system is around four years with inclusion of subsidies from MNRE; ARUN technology systems have a payback period of five to six years (MNRE)<sup>82</sup>.

## POLICY SCENARIO

The Indian government launched the Jawaharlal Nehru National Solar Mission (JNNSM). One of the main objectives of the JNNSM is to promote off-grid applications of solar energy (both SPV and solar thermal) to meet the target of 20 million m<sup>2</sup> of solar collectors set in 3 phases of the mission till 2022.

Under the JNNSM, MNRE either provides a capital subsidy of 30 per cent of the normative capital cost for solar thermal systems/devices or a capital subsidy based on m<sup>2</sup> of the collector area of solar thermal collectors (INR/m<sup>2</sup> of the collector area) (MNRE)<sup>83</sup>, whichever is less. In case of the special category states, the capital cost subsidy is doubled to 60 per cent of the project cost.

The categories of subsidies for dish solar cookers and steam generating systems are based on following type of collectors:

- Concentrators with manual tracking INR 2100/m<sup>2</sup> ; Non- imaging concentrators INR 3600/m<sup>2</sup>
- Concentrators with single axis tracking INR 5400/m<sup>2</sup> ; Concentrators with double axis tracking INR 6000/m<sup>2</sup>

79 <http://www.mnre.gov.in/related-links/decentralized-systems/solar-systems/solar-cooking-steam-generating-systems/>

80 This price can vary based on the geographical location and manufactures.

81 [http://mnre.gov.in/file-manager/UserFiles/Scope\\_CSTs\\_Cost\\_Fuel\\_savings.pdf](http://mnre.gov.in/file-manager/UserFiles/Scope_CSTs_Cost_Fuel_savings.pdf)

82 [http://mnre.gov.in/file-manager/UserFiles/Brief\\_Arun\\_Technology.pdf](http://mnre.gov.in/file-manager/UserFiles/Brief_Arun_Technology.pdf)

83 [http://mnre.gov.in/file-manager/UserFiles/subsidies\\_solar\\_thermal\\_systems\\_devices.pdf](http://mnre.gov.in/file-manager/UserFiles/subsidies_solar_thermal_systems_devices.pdf)

MNRE also extends soft loans at a 5 per cent interest rate, which can be used as an investment towards the other components of the system like installation, civil work and so forth.

Apart from the central subsidy, individual state and municipalities also give out subsidies and incentives, which is an add-on subsidy to central finance assistance.

**Table 24: List of subsidies and incentives available**

Capital subsidy	Chandigarh, Chhattisgarh, Delhi, Haryana, Jharkhand, Jammu & Kashmir, Kerala, Madhya Pradesh and West Bengal
Rebate in electricity	Jammu & Kashmir, Rajasthan, Karnataka and Uttarakhand
Rebate in property tax	Few municipal corporations of Maharashtra provide additional rebate on property tax

## BENEFITS

A solar cooking system leads to significant savings in terms of energy, for example, a typical CPSC system comprising a Scheffler dish with a collector area of 96 m<sup>2</sup> (six dishes each of 16 m<sup>2</sup>) can save around 4,500 liters' of diesel in a year (MNRE)<sup>81</sup>. Similarly, a community cooker and a dish solar cooker, when used regularly can save 35 and 10 LPG cylinders per year in community kitchens and small establishments (Balakrishnan)<sup>84</sup>.

Since a solar cooking system uses solar energy, it makes the system completely emission free, therefore it makes the cooking area pollution-free.

From the food nutritional point of view, food cooked in a typical solar system is more nutritious (Dow and Dow, 1999). Solar cooked food has better retention of Thiamine, Riboflavin, Vitamin C, etc; because of its low temperature and slow cooking process.

The other direct benefits include reduction in deforestation as well as indoor air pollution. The indirect benefits of employing solar cooking system involve employment generation in the local area.

## CONSTRAINTS

Barriers and constraints to the diffusion of the solar cooking system technology can be classified under three main categories – technical barriers, economic barriers, and other barriers which include legal, cultural or behavioral barriers.

### Technical Barriers:

- Often the institutions do not have enough space to accommodate the number of solar dishes required.
- Often the existing roof is not strong enough to bear the additional load of the system especially if it is asbestos roof, slanting roof and is not a RCC terrace.
- Lack of availability of skilled manpower to run the system.
- The glass mirrors have to be changed at regular intervals of four to five years which leads to system downtime of two to three months and entails an additional cost component.



- Availability of good quality of water needed for steam also hampers the uptake of solar cooking systems in water-stressed areas. In areas with water impurities, additional investment required for treating the water.
- The system does not work efficiently during monsoon months, thus, needing backup arrangement for cooking using some other fuel.

### **Economic and Institutional Barrier:**

- High cost of initial investment and expensive repairing as compared to available conventional cooking systems are perceived as the most severe economic constraints.
- Often the delays in getting the subsidy and the paperwork involved many small users and manufacturers are not able sustain themselves due to their financial constraints.
- The government policy on standardization and registration of the solar cooker appliance providers is perceived as a hurdle by some manufacturers and users with only a handful of players in the market. For poor households to procure low cost or cheap solar cookers becomes difficult unless provided by the government, NGOs, or voluntary agencies (Climate Parliament)<sup>85</sup>.

### **Social Barriers:**


- The government offers a considerable amount as capital incentives and subsidies for promoting investment and this leaves consumers and entrepreneurs wanting for more. Since, the policy on solar technologies fluctuates, most users prefer to wait and see until a more consumer-friendly policy is offered. The lack of awareness also makes users risk-averse. (Climate Parliament)<sup>85</sup>.
- Time constraints and adaptability to new cooking techniques also acts as hindrances to the traditional way of cooking certain dishes, best suited when prepared using biomass fuels or LPG.

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85 <http://www.climateparl.net/cpcontent/Publications/RE%20Occasional%20Paper%202%20Barriers%20in%20India.pdf>







Around 166 million households in India are still using solid biomass fuels.

Source: GACC, 2013

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## CASE STUDY:

# CONCENTRATED PARABOLOID SOLAR COOKING (CPSC) SYSTEM AT TIRUPATI TEMPLE IN ANDHRA PRADESH<sup>86</sup>

Located in the southern state of Andhra Pradesh in India, Tirumala Tirupati Devasthanam (TTD) is one of the richest temples in the world. The CPSC system at the Tirupati temple in Andhra Pradesh was installed in September 2002 by Gadhia Solar Pvt. Ltd. Earlier the kitchen in the temple was using firewood, diesel and LPG cylinders as a source of heat and energy to cook food.

## TECHNICAL DESCRIPTION

The system consists of 106 automatically tracked parabolic concentrators each of 9.2 m<sup>2</sup> reflector area arranged in series and parallel combinations. Each unit of the concentrator is connected to a central steam pipeline going to the kitchen. The CPSC system at Tirupati is designed to generate over 4000 kg of steam per day at 1800°C and 10 kg/cm<sup>2</sup> which is sufficient to cook two meals for around 15,000 persons. The system is backed up by an existing diesel-operated boiler so that the kitchen can function under all climatic conditions. The CPSC system involves a one-time installation and requires no plant modification over its lifespan of 25 years.

## APPLICATION MARKET

The system installed is operational. There are various market players manufacturing solar energy based steam cooking systems along with other solar cooking technologies (Refer: application market section)

## COST

The total cost of the system is INR 11 million (inclusive of installation cost). The simple payback period for the complete system is less than three years with financial subsidies from MNRE, which is INR 4.65 million.

## BENEFITS

- Reduction of more than 1,350 kg of GHG emissions per day.
- Saves around 450 litre/day (furnace oil).
- Improvement of the environment quality with reduction of smoke and soot.
- Reduction in workload as complete food cooking takes just 20 minutes only.

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<sup>86</sup> Information collected from secondary sources/literature. Currently decommissioned due to ongoing construction activities.





Figure 12: Aerial view of the Tirupati Temple in Andhra Pradesh.  
Source: Vimalkalyan





## BIOGAS DIGESTER

In light of the growing energy demand and fluctuating fossil fuel reserves, the importance of sustainable and clean energy has become pertinent. Decentralized biomass based energy sources such as biogas is proving to be a clean and sustainable alternative to conventional fuels.

Biogas is a clean and efficient fuel, containing about 65 per cent methane, about 34 per cent carbon dioxide and traces of other gases, such as hydrogen sulphide and ammonia. Biogas digester takes organic material such as animal dung and kitchen waste into an air-tight tank, where bacteria break down the material and produce biogas. The biogas can be burned as a fuel, for cooking or other purposes like transportation, and the solid residue can be used as organic compost.

Based on user need and finance availability, biogas plants in India can be installed at both the household as well as the community level. Biogas plant designs are now available from as small as 1 m<sup>3</sup> per day to 10 m<sup>3</sup> unit size. Many of the MNRE accepted designs/technologies are also commercially available. But, as a result of increasing demand and ongoing R&D, compact biogas plants based on kitchen waste for urban and semi-urban households are also commercially available.

Recently during the year 2008-09, the MNRE with an aim to promote biogas for power, cooling, refrigeration and heating needs, started a new demonstration initiative comprising generation, purification/enrichment, bottling and piped distribution of biogas in biogas fertilizer plants (BGFP) (MNRE)<sup>87</sup>.

## TECHNOLOGY

The family-type digesters are generally uncomplicated, inexpensive, strong, trouble-free to operate and maintain. Normally, there are no control and process heating mechanisms because these digesters operate efficiently in a hot tropical climate and have long hydraulic retention time.

The reactor functions in a semi-continuous manner, where new waste batch is added one time during a day and a similar quantity of slurry is removed per day. The reactor is kept stable without any stirring, thus the sediments are removed only two to three times per year. The effluent slurry is collected at the base of the reactor and a floating or fixed gas dome functions as a biogas reservoir.

A variety of digester models are commercially available, of which the following three models popular in India are: (1) KVIC, (2) Janata and (3) Deenbandhu model. Principally these models are similar, different only in their shape, dimensions and space and investment requirements (Singh and Sooch, 2004).

Initiated for the first time on an experimental basis in 1930 in India, later the Khadi and Village Industry Commission (KVIC) in 1961 started promoting floating dome digesters, known as KVIC model (Lawbuary, 2013). The KVIC model consists of a deep well and a floating drum to collect the generated gas. Gradually, over the years the KVIC model was experimented upon and a new model of digester was developed -- Janata system-. This system is different from KVIC model in that there is a fixed gas dome. Thus, the Janata system is about 30 per cent cheaper to build than a KVIC model of the same capacity.



In 1984, Action for Food Production (AFPRO), New Delhi, India, came out with another fixed dome biogas digester design named Deenbandhu. The model is made up of two spheres of varying diameters, combined at their bases acting as the digestion and gas storage chamber.

**Table 25: MNRE approved biogas digester models**

	Model	Size
a.	KVIC Floating Drum Type Biogas Plants having digester made of bricks or stones.	1 to 10m <sup>3</sup>
b.	KVIC Type Biogas Plants with Ferro cement digester	1 to 10 m <sup>3</sup>
c.	KVIC Type Biogas Plants with Fiber Glass Reinforced Plastic (FRP) Gas holder	1 to 10 m <sup>3</sup>
d.	Deenbandhu Model (i) Brick masonry (ii) In ferro-cement with in-situ technique (iii) Prefabricated HDPE material based prefabricated dome for Deenbandhu Model family size Biogas Plants. (iv) Solid – State Deenbandhu design fixed dome biogas plant, developed by ICAR	1 to 6 m <sup>3</sup>
e.	Pre-fabricated RCC fixed dome model (i) Shakti-Surbhi FRP based floating dome KVIC portable model biogas plant developed by Vivekananda Kendra, Kanyakumari (ii) Sintex make plastic based floating dome KVIC type biogas plant, developed by Sintex Industries Ltd., Kalol (Gujarat)	2 & 3 m <sup>3</sup> (0.5 to 2 m <sup>3</sup> biogas plants and higher for higher capacity plants)
f.	'Flxi' model Bag digester type plant made of rubberized nylon fabric manufactured by Swastik Rubber Products Ltd., Pune.	1 to 6 m <sup>3</sup>

Source: (MNRE)<sup>87</sup>

A stable biogas digester requires 25 kg of dung to produce 1 m<sup>3</sup> of biogas per day (Chawla, 1986) and in Indian conditions. Normally, the cow dung collected from a ordinary cattle ranges from 10-20 kgs, thus to run and maintain 1 m<sup>3</sup> of biogas plant usually two to three cattle heads are required. A fully operational 1 m<sup>3</sup> of biogas plant can produce biogas equivalent to 126 kg of LPG and around 2400 kg of dried slurry per year (Singh and Sooch, 2004).

In case of the biogas fertilizer plants, the main components of BGFP are: (1) Pre-treatment system; (2) Biogas generation system; (3) Biogas storage system; (4) Biogas purification (enrichment) system; (5) Biogas bottling system and (6) Slurry handling system (Vijay, 2010).

Biogas contains a large proportion of carbon dioxide and some fraction of hydrogen sulphide. Hence, biogas enrichment/purification is carried out before compression and bottling. The enrichment process is carried out using the scrubbing technique. One of the low cost and efficient techniques used for scrubbing involves use of pressurized water as an absorbent. The purified biogas is then compressed using the compressors and is filled in cylinders. Typically, a BGFP plant can produce around 15-20 kg of enriched/purified biogas and waste slurry in the range of 1000-2000 litres per day.



## APPLICATION MARKET

In India, the annual estimated potential of biogas is around 18,240 million m<sup>3</sup> which is equivalent to 220 million LPG cylinders (Kumar and Sarma, 2013). As per the estimates of the National Biogas and Manure Management Programme (NBMMP), India has a potential of installation capacity of around 12.3 million family type biogas plants in the country. This potential can increase manifold if the use of kitchen, garden wastes and other green biomass wastes available in rural, semi-urban and urban areas are also incorporated in the estimations.

A total of 4.54 million family type biogas plants have been installed in India till 31 March 2013 (MNRE, 2013a) and under Twelfth Plan nearly 0.7 million biogas plants are to be installed (Planning Commission, 2013).

Under the pilot phase, the MNRE is providing financial assistance for the implementation of a certain number of BGFP projects and by far 21 BGFP projects (total capacity 37, 016 m<sup>3</sup>/day) have been approved in 10 states across India (Chhattisgarh, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Rajasthan).

## COST

In India, 1m<sup>3</sup> family-sized biogas plant costs INR 12,080 (MNRE)<sup>87</sup>. In return, the user gets 24 metric tons per year of organic fertilizer and biogas generated is equal to 126 kg of LPG. The original investment is recoverable in less than 12 months (Singh and Sooch, 2004). A 2 m<sup>3</sup> biogas plant is enough to meet the daily cooking requirements of four persons considering per person. A 2 m<sup>3</sup> biogas plant costs around INR 20,000-25,000 and MNRE provide subsidy in the range of INR 8000-14,700 depending on the location (MNRE, 2013b). Based on conservative estimates, a typical 1000 m<sup>3</sup> BGFP requires a total investment of INR 15 million, and with an annual income generation from biogas and organic slurry, the project can fully recover the cost of the project within three years (Vijay, 2010).

## POLICY SCENARIO

In a move to facilitate clean and sustainable energy in rural India, National Program on Biogas Development (NPBD) was introduced during the Fifth Year Plan (1974-79) and implemented in the sixth year by MNRE. Prior to the NPBD, biogas was solely promoted in India by KVIC (Balachandra, 2012).

In 2006, the programme was renamed into National Biogas and Manure Management Programme (NBMMP). Under the NBMMP, central subsidy for new installation, financial support for repairing of old-non functional plants; and capacity building is provided.

To facilitate capacity-building, MNRE has been setting up BTDC (biogas technology development centre), and as on 2012-13 around 13 BTDCs are functional (MNRE, 2013a). State Nodal Departments/Agencies and Khadi and Village Industries Commission (KVIC) are the two institutions through which the programme is being implemented. The table below indicates the outline of Central Financial Assistance (CFA) available under the NBMMP (MNRE)<sup>87</sup>.

**Table 26: Central Financial Assistance (CFA) available under the NBMMP**

No.	Items for Central Financial Assistance(CFA)	Family-type biogas plants under CDM		Family-type biogas plants under NBMMP**	
		1 m <sup>3</sup>	2-4 m <sup>3</sup>	1 m <sup>3</sup>	2-4 m <sup>3</sup>
A.	Central Financial Assistance to beneficiaries of biogas plant (in Rs per plant)				
1.	NER states, Sikkim (except plain areas of Assam)	11,700	11,700	14,700	14,700
2.	Plain areas of Assam	9,000	9,000	9,000	10,000
3.	Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Nilgiri of Tamil Nadu, Sadar Kursoong & Kalimkpong Sub-Divisions of Darjeeling, Sunderbans (W.B.) and Andaman & Nicobar Islands	3,500	4,500	4,000	10,000
4.	All Others	2,100	2,700	4,000	8,000
B.	Turn-Key Job Fee including warranty for five years (in Rs per plant)	700		1,500	
C.	Additional CFA for toilet linked biogas plants (in Rs per plant)	500		1,000	
D.	Incentive for saving diesel and other conventional fuels by using biogas in engines/ gensets and/ or biogas based refrigerators (in Rs. per plant)	2,500		5,000	
E.	Administrative charges- for target range of plants (in Rs)				
1.	100-3,000	50,000@		1,00,000^	
2.	3,001-7,000	8,90,000#		10,50,000^^	
3.	Above 7001	USD 14,90,000		24,50,000 *	
F.	Training Courses (in Rs.)				
1.	Users course	1,000		2,000	
2.	Staff course	5,000		8,000	
3.	Refresher/ construction-cum maintenance course	19,000		35,000	
4.	Turkey-key operator & management course for workers of companies/ entrepreneurs	38,500		67,500	
G.	Biogas Development & Training Centres	As per existing pattern		As per existing pattern	
H.	Communication & Publicity –for target range of plants (in Rs)				
1.	Up to 1,000	1,00,000		1,00,000	
2.	1,001- 10,000	2,50,000		2,50,000	
3.	More than 10,000	5,00,000		5,00,000	
I.	Support for repair of non- functional plants with the restriction of utilization of up to 5 % of the outlay of the programme in that year of the concerned State/ UT	Nil		50% of applicable CFA category subject to sharing of 50% of the cost of repair by the beneficiary	

Family type Biogas Plants under CDM	Family type Biogas plants under NBMMP
@ Extra Rs.300 per plant in excess of 200 biogas plants.	** Maximum of 50% of the cost of the biogas plant for low cost models.
# Extra Rs.150 per plant in excess of 3000 biogas plants.	^ Extra Rs. 350 per plant in excess of 100 biogas plants.
\$ Extra Rs.100 per plant in excess of 7000 biogas plants & maximum of Rs.30 lakh.	^^ Extra Rs.300 per plant in excess of 3000 biogas plants.
	* Extra Rs. 250 per plant in excess of 7,000 biogas plants subject to maximum of Rs. 50.0 lakh.

Source: (MNRE)<sup>87</sup>

Under the demonstration phase of the BGFP initiative, MNRE provides a Central Financial Assistance (CFA) up to 50 per cent of the cost (excluding cost of land) and a project developer invests the remaining 50 per cent. However, in case of loan procurement from banks/ financial institutions including NABARD, IREDA and KVIC, the project developer needs to invest at least 20 per cent of the cost of the project.

## BENEFITS

Dumping of the animal dung and kitchen waste in heaps to allow open air degradation emits methane into the atmosphere. 1 m<sup>3</sup> of biogas plant abates almost 2 tonnes of CO<sub>2</sub> per year<sup>88</sup>. The slurry produced as a byproduct of the biogas plant is also very valuable as organic manure/ fertilizer. Since the slurry is rich in plant nutrients such as nitrogen, phosphorus, potassium (NPK) and micronutrients including other plant growth promoting and protecting substances. The bio-digester slurry is also traded which provides additional income to the farmers. One of the research study done by National Council of Applied Economic Research (NCAER), found that a 1 m<sup>3</sup> biogas plant can save roughly 1.25 tons of fuelwood every year (Joydeep, 2011). The installation of biogas plants not only reduces the burning of fuelwood but also contributes to reducing indoor air pollution and health impacts associated with it.

In the installation of a typical family-type biogas plant, nearly 30 per cent of the total installation cost is spent on the providing wages to the local laborers (skilled, semi-skilled and unskilled). Also, post installation O& M of the plant also provides employment to the local technicians. Installation of one 2 m<sup>3</sup> biogas plant generates about 30 man days of employment for skilled, semi-skilled and unskilled workers (Harsdorff, 2012).

## CONSTRAINTS

Studies have identified the lack of proper planning of the biogas requirement and feedstock availability as a hindrance to biogas plants. Another key barrier is the under feeding of the digesters. To run a 1 m<sup>3</sup> biogas digester, usually 25 kg of fresh animal dung (two to three cattle/family). Thus, the biogas plants owned by poor farmers with no cattle are operated on purchased cow dung. Thus, these systems are generally found to be underfed consequently leading to a dysfunctional biogas plant.

Another important criterion is the availability of water. Since, to make the input for digester, animal dung is mixed with water in almost in ratio of 1:1. Hence, in some water stress areas of India, the proliferation of biogas plants is limited.

At the institutional level, despite government subsidies and incentives to the users, the procedural delays in implementation and release of funds and incentives generally discourages the user/beneficiaries (Ravindranath and Rao)<sup>89</sup>.

The end users in rural India are still fascinated by the LPG and perceive it as more efficient than biomass energy, thereby leading to the under usage of biogas plants (Kaniyamparambil, 2011).

Apart from the urban settings, the high initial investment cost of installing a biogas plant is a financial barrier, coupled with the, subsidy-driven attitude of the beneficiaries which invariably leads to the neglect of the plants.

88 Theoretically, In Indian cattle scenario, 1 kg of fresh (semisolid) animal dung would emit 0.0103 kg methane into the atmosphere which is equal to 0.20 kg of CO<sub>2</sub> equivalent (Myles, 2013).

89 <http://www.tech-action.org/Perspectives/BioenergyIndia.pdf>

As for BGFP installations, one of the main constraints faced by the system is the consistent availability of raw materials (both in terms of quantity and quality) locally. The anaerobic process depends heavily on the site conditions. Thus, site selection (nature of subsoil, water table, availability of solar radiation, prevailing climatic conditions and strength of village population to supply raw materials) sometimes become a bottleneck.

The available indigenous technology developers/providers for biogas generation, purification, compression, bottling and digestate processing are very few. The technologies are not sufficiently economically viable at present.



A woman wearing a vibrant red and blue floral sari with a pink shawl draped over her head and shoulders stands in a kitchen. She is looking towards the camera. In the background, a gas stove sits on a concrete countertop with a black pot and a silver kettle. Above the stove, shelves hold various jars and containers. A semi-transparent pink box containing text is overlaid on the upper right portion of the image.

“It gives me more time to  
sell my field products, to get  
extra income for the family”.

-Sima Devi Chaudhary, Badreni Village,  
Chitwan National Park/Terai Arc  
Landscape

## CASE STUDY:

### BIOGAS FERTILIZER PLANT (BGFP) AT ASHOKA BIOGREEN PVT. LTD., NASHIK, MAHARASHTRA<sup>90</sup>

During the year 2008-09, the Ministry of New and Renewable Energy (MNRE) with an aim to promote biogas for power, cooling, refrigeration and heating needs, started a new demonstration initiative. This initiative comprises generation, purification/enrichment, bottling and piped distribution of biogas in medium sized biogas fertilizer plants (BGFP) (200-1000 m<sup>3</sup>/day).

One of such project based on dual digestion, Nisargruna technology for biomethanation, developed by Bhabha Atomic Research Centre (BARC), Mumbai has been installed at Ashoka Biogreen Pvt. Ltd., Nashik, and Maharashtra with a 500 m<sup>3</sup> biogas generation per day capacity project for the generation, purification/enrichment and bottling of biogas. The technical specifications of the BGFP plant are:

Particulars	Description	Remarks
Quantity of raw material	10 MT /day	Cow dung, agricultural waste etc.
Biogas produced	400 NM <sup>3</sup> /day	
Enriched/ purified biogas	150 NM <sup>3</sup> /day	
Purified biogas used for captive power generation 100 NM <sup>3</sup> /day	30%	
Purified biogas filled in cylinders at 150 bars	12 cylinders/day <sup>91</sup>	9 kg per cylinder
Slurry/ manure	18000 ltrs/day <sup>92</sup>	Used as liquid fertilizer

## COST

The total cost of the BGFP system installed is INR 11 million with a simple payback period of four to five years. The subsidy and incentive provided by MNRE is around INR 5.5 million.

## BENEFITS

- Produces 1.5 to 2.0 tons/day of dry organic manure.
- Helps maintain clean and healthy surrounding by taking care of environment polluting biodegradable wastes.
- The project is also eligible under the carbon offsetting projects like Clean Development Mechanism (CDM).

<sup>90</sup> Based on information provided by Ashoka Biogreen Pvt. Ltd. and publicly available documents.

<sup>91</sup> 9 kg per cylinder; Equivalent to INR 3900 of CNG or INR 8100 of commercial LPG.

<sup>92</sup> Produces 1.5 to 2.0 tons/day of dry organic manure. Up to 12000 litres is used as liquid fertilizer worth INR 13,500, and up to 6000 to 8000 litres is recycled for mixing of the feed material.





Figures 13 & 14: Biogas fertilizer plant (BGFP) at Ashoka Biogreen Pvt Ltd, Nashik, Maharashtra

## CONSTRAINTS

- Lack of availability of segregated waste.
- Availability of indigenous technology developers/providers for biogas generation, purification, compression, bottling and digestate processing are very few.
- Disposal of digestate has its own restrictions.
- Institutional delays in issuing necessary clearances/permissions/licenses to the projects.







## IMPROVED BIOMASS COOK STOVE

Biomass-based energy plays a very important role in meeting the local energy demand in many regions of the world, especially in developing countries. This situation can be gauged by the fact that nearly one-fourth of the India's energy use is constituted by combustible renewables and waste (MoSPI, 2013) and almost 85 per cent of rural households are dependent on traditional biomass fuels for their cooking energy requirements. The traditional biomass includes sources such as firewood and dung.

Despite extensive efforts by Government of India, a majority of the population is still dependent on biomass fuels. As per the latest findings of 66th National Sample Survey Organization (NSSO) report there has been a rise in fuelwood consumption by about 7.5 per cent over the past decade among rural households (Ramji et al., 2012).

In India, food is traditionally cooked on chulhas or conventional cook stoves, with efficiencies less than 10 per cent (Mohan and Kumar, 2011). These chulhas are also a significant source of pollutants, especially indoor air pollution resulting in increasing cases of morbidity and mortality especially among women and children (Bruce et al., 2000 & Smith et al., 2000). Recent studies have found a strong correlation between climate change and black carbon released due to unclean combustion of traditional cook stoves (The World Bank, 2011b). Therefore, development and diffusion of improved biomass cook stoves can significantly contribute to improving cooking efficiency, decreasing fuel consumption, reducing indoor air pollution in rural households and also help in climate change mitigation.

### TECHNOLOGY

Improved biomass based cook stoves are a fundamentally combustive apparatus designed to burn biomass-based fuel more efficiently with reduced consumption of fuel and indoor emissions. Improved biomass cook stoves are classified into two types, based on their portability, one is the fixed type and other is the portable type (MNRE)<sup>93</sup>.

Further, portable biomass cook stoves are also of two types; natural draft and forced draft ones. Improved biomass cook stoves are more efficient compared to natural draft cook stoves. These improved biomass cook stoves are appropriate for both domestic as well as community cooking needs. The portable type improved cook stoves can be prepared using materials like metal, ceramic and terracotta/pottery (durable type) and combination thereof (MNRE)<sup>93</sup>. In case of the fixed type cook stoves, a brick and cement based platform is prepared to increase durability and ease the operation. In fixed stoves with provision for two to three pots, a chimney made of cement and terracotta are provided, the chimney-size and material depend on the suitability and affordability of the user.

In India, typically the thermal efficiency of the natural draft type Portable (Metallic) Solid Biomass Chulha is more than 25 per cent, where the CO/CO<sub>2</sub> ratio is 0.04 or less, Total Suspended Particulate matter (TSP) emission is not more than 2 mg/m<sup>3</sup> and body temperature is less than 600°C (BIS, 2013). These are the minimum standards laid down by the Bureau of Indian Standards (BIS) Standard 13152 (Part I):1991, which are necessary for commercial sale of all portable cook stoves in India.

**Table 27: Classification of improved biomass cook stoves**

Natural draft side continuous fed	Forced draft side continuous fed
Natural draft top continuous fed	Forced draft top continuous fed
Natural draft top batch fed	Forced draft top batch fed
	Forced draft self power generating

Source: (BIS, 2013)

The useful energy produced by the cook stove is measured in terms of the energy produced by burning fuelwood in the stove for one hour and it is called power output rating.

**Table 28: Classification of improved biomass cook stoves the equivalent heat and power output rating**

Domestic cookstove	
Power output rating	0.5 to 3.0 kW
<b>Size</b>	<b>Power Output Rating kW</b>
Small	Above 0.5 and up to 1.0
Medium	Above 1.0 and up to 2.0
Large	Above 2.0 and up to 3.0
Community/commercial cookstoves	
Power Output rating	Above 3 to 10 kW

Source: (BIS, 2013)

In India, a number of the natural draft and forced draft cook stove models have been developed and are under commercial production. Few of these models based on their performance approved by the Ministry of New and Renewable Energy are as follows (MNRE)<sup>93</sup>:

**Table 29: List of MNRE approved improved cookstoves**

No.	Models	Power Output	Manufacturer
Natural Draft Cookstoves – Domestic Size			
1	Harsha (fuelwood)(CSIR,IMMT Design)	1.83kW	M/S Unicus Engineering Private Limited
2	Bio-classic (fuelwood)	1.49 kW	Vikram Stoves & Fabricators
3	Greenway Smart Cook Stove (fuelwood)	0.8 kW	Greenway Grameen Infra Pvt Ltd
4	Firenzal (fuelwood)	0.74kW	M/s Ravi Engineering & Chemical Works
5	Adarsh (Nirmal) (fuelwood)	0.89 kW	Adarsh Plant Protect Ltd,
6.	Chulika (fuelwood)	0.74	iSquare D Charitable Trust

Forced Draft Cookstoves – Domestic Size			
1	Oorja (fuel-pellets)-IISc -Design	0.7 kW	First Energy Pvt. Ltd.
2	TERI SPT-0610 (fuelwood)	1.08kW	The Energy and Resources Institute (TERI)
3	Eco chulha - XXL (fuelwood)	1.10kW	Alpha Renewable Energy Pvt. Ltd.
4	Agni Star(fuel- rice husk)	2.16 kW	M/S Navdurga Metal Industries (Bharat)
5.	Ojas (fuel-pellets)	1.99 kW	Sacks Right Energy Innovations
6.	RAMTARA (fuel-pellets)	1.0 kW	Ram Tara Engineering Company
Forced Draft Cookstoves - Community Size			
1.	Eco chulha-XXXL (fuelwood)	3.32 kW	Alpha Renewable Energy Pvt. Ltd.
2.	Ojas - M06(fuel-pellets)	5.43kW	Sacks Right Energy Innovations
3.	Ojas – M09 (fuel-pellets)	6.39 kW	Sacks Right Energy Innovations

Source: (MNRE)<sup>93</sup>

## APPLICATION MARKET

A majority of the population in the country is rural and approximately 67 per cent of households are still dependent on solid fuels for their cooking energy needs (The World Bank, 2011a). Based on the study done by Global Alliance for Clean Cookstoves, the overall market size in India is ~235 million households (GACC, 2013). Under the National Programme on Improved Chulhas (NPIC) 1985-86, the estimated potential for improved biomass cook stoves was around ~166 million households.

## COST

The cost of an improved cook stove varies depending on the power output and manufacturers. Usually a domestic size portable cook stove can range between INR 1000 and INR 4000 (Thurbera et al.)<sup>94</sup>. A medium-sized community cook stove, can cost between INR 15,000 and 20,000. Based on conservative estimates for a medium-sized cook stove, an institution, catering for 300 people is expected to use 50 kg/day of biomass pellet, at a cost of INR 900<sup>95</sup>. From the monthly savings on LPG, institutions can reach a complete payback in less than six months.

## POLICY SCENARIO

National Programme on Improved Chulhas (NPIC) in 1985-86 was the first programme to be launched by the Department of Non-conventional Energy Sources (DNES) to introduce improved cook stoves in India (Balachandra, 2012). Dissemination of around ~120 million improved cook stoves to households relying on traditional and biomass stoves was one of the main aims of NPIC. The programme was implemented through the involvement of various State Nodal Departments/ Agencies in 23 states and five Union Territories. The cost of the chulhas varied in the range of INR 100-300, 50-75 per cent of which was met by a direct cash subsidy given under the NPIC (Kishore and Ramana, 2002). The programme was decommissioned in 2004. During the programmes course nearly 27 per cent (33.8 million) of the total dissemination target was achieved by 2004.

In 2009, the National Biomass Cookstove Initiative was launched by MNRE across nine states in India. A number of pilot projects focusing on community cook stoves (through mid-day

<sup>94</sup> [http://www.econ.brown.edu/fac/Sriniketh\\_Nagavarapu/Oorja05Aug2013.pdf](http://www.econ.brown.edu/fac/Sriniketh_Nagavarapu/Oorja05Aug2013.pdf)

<sup>95</sup> considering the cost of biomass pellet to be 18 INR/kg

meal schemes in government schools) and family-sized portable cook stoves (currently in the pilot phase) have been planned using several existing commercially-available and better cook stoves as well as different grades of process biomass fuel. These steps make NBCI structurally different from earlier programme like NPIC. MNRE's role involves conducting certification and field testing programmes, along with funding research and innovative projects in clean energy technology.

Recently, under the Twelfth Plan, a National Biomass Cookstove Programme (NBCP) has been proposed which at the moment is under review. As a work plan and strategy the NBCP incorporates (MNRE)<sup>93</sup>:

1. Financial support for development of new and efficient models of biomass cook stoves and process technologies for biomass fuels through R&D in institutions and industries.
2. Developing standards and test protocols and performance testing of biomass cook stoves.
3. To evaluate field performance for scaling up biomass cook stoves. Under this scheme, financial assistance includes 50 per cent of the cost of cook stoves up to a maximum of INR 400 cook stoves for natural draft type and INR 800 for forced draft type portable domestic cook stoves.

Similarly, in the case of the larger sized cook stoves, the support will be limited to 50 per cent of the cost of cook stoves up to a maximum of INR 2500 per cook stove for natural draft type and INR 5000 for the forced draft type portable community cook stoves. But, under this scheme demonstration projects in restaurants, dhabhas or any other commercial establishments have not been covered.

## BENEFITS

Considering around 166 million households in India are still using solid biomass fuels (GACC, 2013), the briquette-based cooking stoves that provide both local as well regional environmental benefits. According to estimates about 196 MT solid fuels per year, including 95 MT of wood and 6 MT of coal can be saved if the National Biomass Cook stoves Initiative is fully implemented (Venkataraman et al., 2010).

In India, crop burning in many states generates huge amounts of GHG emissions. As per government estimates, this emission mounts to 6.61 million tonnes of CO<sub>2</sub> eq in 2007 (INCCA, 2010). Briquetting of the crop residues stalls GHG emissions and local pollution. Being a carbon neutral fuel, briquette-based stoves is more environment-friendly.

Incomplete combustion in traditional cook stoves discharges products of incomplete combustion (PIC) including nitrous oxide (N<sub>2</sub>O), carbon monoxide (CO) and black carbon with a high global warming potential (GWP) (WHO, 2006). Using improved cook stoves with greater fuel combustion efficiency can reduce the issue of PICs. Wider use of improved cook stoves can decrease annual black carbon emissions by about 0.15 million tonnes, which is almost one-third of the total anthropogenic black carbon emissions in India (Venkataraman et al., 2010).



## Social benefits

The important component of the biomass-based efficient cook stove project is the supply of renewable biomass pellet on a regular basis. Thus this supply chain also provides farmers with additional income and locals with job opportunities for e.g. in pellet manufacturing, biomass transportation and so on. Based on estimates, the cook stoves installed by Nishant Bioenergy by 2014 are likely to create 600-700 jobs in rural areas. Use of solid fuel annually results in an approximate 400,000 deaths in children of less than five years of age due to acute lower respiratory infection (ALRI) and 34,000 deaths in women due chronic obstructive pulmonary disease (COPD) (Smith, 2000). This health burden on the country can be reduced by moving towards cleaner fuels and non-polluting cook stoves (US DoE, 2011).

In India, the time spent in biomass fuel collection is estimated at an hour per day (World Bank, 2011) which often requires walking long distances and at the cost of one's own safety. Thus, using biomass pellets and efficient cook stoves is both safe and a means of generating income.

## Economic benefits

India has nearly 141 million hectares of arable land producing nearly 700 MT of agricultural waste per year (Pappu et al., 2007). Even if a major portion of this amount is removed as cattle feed, a considerable amount of waste can be converted into bio-pellets, which offers a secure fuel supply option.

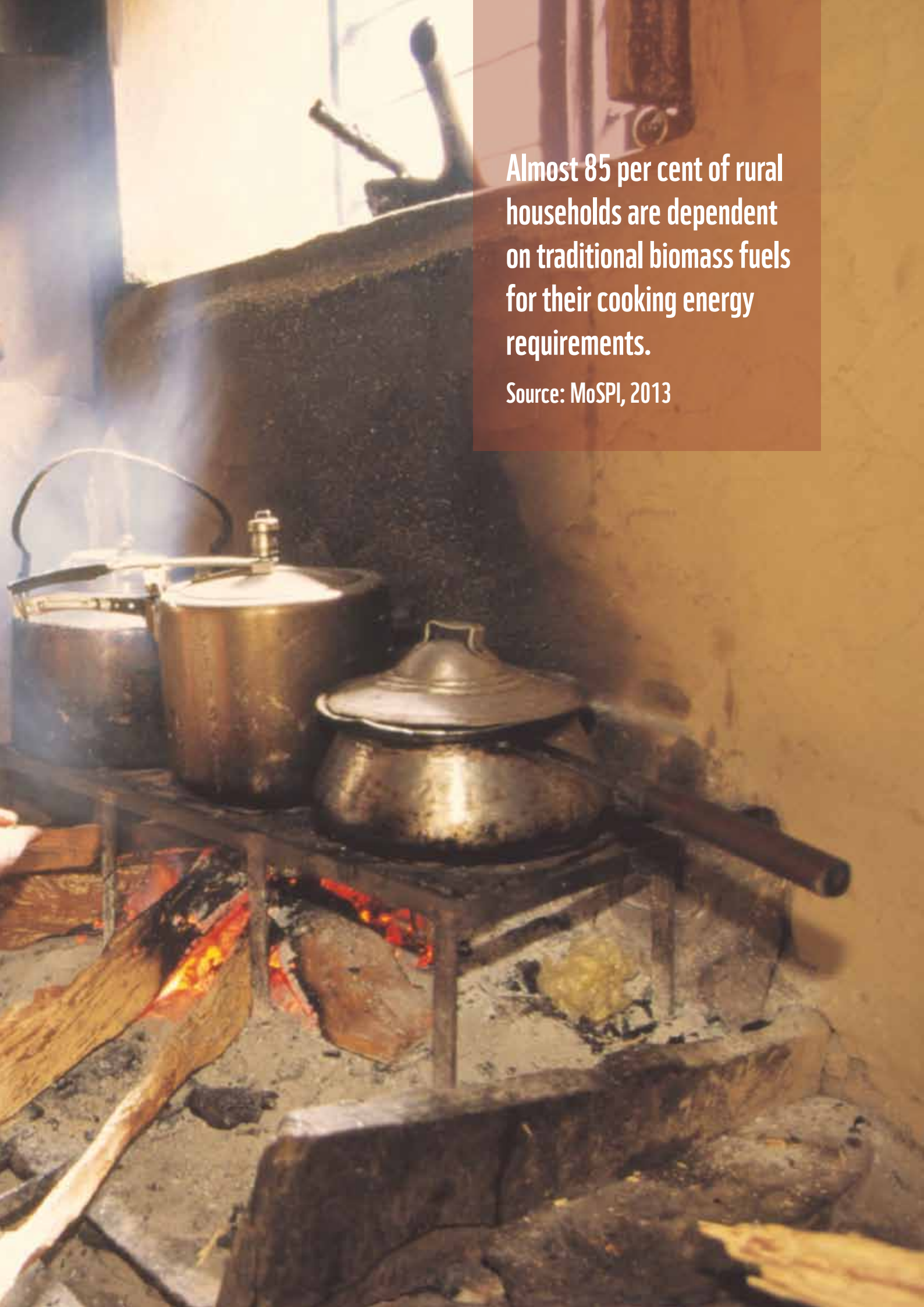
## CONSTRAINTS

The supply and distribution chain is one of the biggest barriers to penetration, widespread acceptability and scaling up of improved biomass-based cook stoves in India. The supply of biomass fuel during the monsoon season is still a big issue in India, since briquettes require moisture-free storage facilities.

Consumers in India often require high-touch service to understand the product benefits and features. Difficulty in reaching rural residents who do not have access to retail stores to purchase, repair or clean cook stoves compounds the problem. Since users in rural India seldom pay for the fuel used, they are reluctant to purchase and utilize biomass pellets. Further, the high initial cost of clean cook stoves and the lack of adequate credit and financing for improved cook stoves create hurdles for both poor households as well as for clients with large cooking needs like roadside eateries, school, hostels and so on. In India, the public distribution system (PDS) provides subsidies to make cooking fuels like kerosene available for the general public at below the market price. But, due to black marketing of these subsidized fuels to commercial sectors leads to the selling of the diverted fuel at a slightly lower price than the market prices. Small eateries use these subsidized fuels diverted from domestic use day-to-day for running their establishments (Nishant Bioenergy)<sup>96</sup>.





A photograph of a traditional biomass cooking stove. Three metal pots are placed on a metal frame over a fire. The fire is made of wood and is burning brightly. The stove is built into a wall. The background is a plain wall. The text is overlaid on the right side of the image.

Almost 85 per cent of rural households are dependent on traditional biomass fuels for their cooking energy requirements.

Source: MoSPI, 2013

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## CASE STUDY:

# BIOMASS RESIDUE BASED COMMUNITY SIZED COOK STOVES “EARTH STOVE” BY NISHANT BIOENERGY PVT. LTD.<sup>97</sup>

Nishant Bioenergy Pvt Ltd (for profit company) has been developing and manufacturing processed biomass fuelled institutional cook stoves. Since its inception in 1999 it has been selling improved biomass pellet cook stoves.

## TECHNICAL DESCRIPTION

The Earth Stove or community-sized biomass-based cook stove developed by Nishant Bioenergy Pvt Ltd. is a movable one designed to be used throughout the day. It has the capacity to make available a full meal for up to 650 people. The stove's combustion chamber is prepared using insulated fire cement, so as to minimize heat loss during operations. The outside frames and structure of the stove are made from mild steel.

Biomass fuel pellet is supplied into the combustion chamber, usually at an average rate of about 5 kg per hour. The combusting fuels produce hot combustion gases which are uniformly distributed under the hotplates and cooking utensils using one small (12 V DC, 48 watt) electric fan.

The combustion chamber supplies hot air through many holes above the pellet at top of the combustion chamber. The user can start cooking on this stove for up to one hour. If needed, more pellets can be added to finish the cooking. The remaining ash falls into an ash tray which can be cleaned as and when required. The Earth Stove is tested by approved laboratories of the MNRE and has SPM and CO emissions below the prescribed limits. Thermal efficiency is more than 25 per cent. The stove user saves around 50 per cent in fuel cost while replacing commercial LPG.

## APPLICATION MARKET

Nishant Bioenergy Pvt Ltd is presently working all across India through various partners and is being first tested in the market in Africa and Nepal. Till now Nishant Bioenergy Pvt. Ltd. has sold more than 1500 cook stoves (ranging from 10 Kwh to 100 Kwh sizes) at various kitchens such as company canteen, road side restaurants, colleges, schools, hostels and so on.

## COST

The installation of an Earth Stove (ES4DD model) costs INR 18,750 and the annual cost of operation & maintenance is around INR 500 per year. The simple payback period of the stove is less than 45 days.

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Based on Information provided by Nishant Bioenergy Pvt Ltd and publicly available documents.





Figure 15: Earth Stove (ES4DD model) by Nishant Bioenergy Pvt. Ltd.

## BENEFITS

- GHG Reduction: Approx 10,000 kg of CO<sub>2</sub> per year.
- Improvement of environment quality: Improvement of environment quality with reduction of smoke and soot.
- Reduction in workload: Negligible maintenance and faster cooking.

## CONSTRAINTS /BOTTLENECKS

### Market Barriers

- High upfront cost (mostly for poor and small establishments).
- Lack of established/mature supply chain for the cook stoves and biomass pellets.

### Institutional Barriers

- Easy availability of subsidized fossil fuel like kerosene through the public distribution system, as well as in grey market.

### Social Barriers

- Lack of awareness.
- Requirement and cooking habits varies with each consumer.



# Renewable Energy Technologies and Applications: **Mechanical**

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## WIND WATER PUMP

In order to meet various needs such as drinking water, irrigation, salt farming and aquaculture, water is pumped from the ground, rivers, canals, and wells using hand pumps, centrifugal pumps, diesel pumps, solar-powered water pumps, wind pumps to name a few. Wind pumps are particularly useful in remote coastal areas where there is good wind but no electricity for the conventional water-lifting devices, for example in Tamil Nadu, Gujarat, and Maharashtra. Most of the windmills require high cut-in speed (10-15 km/hr) which is a significantly limiting factor except for the coastal regions where wind energy is in abundance (NIF)<sup>98</sup>. Mohammad Mehtar Hussain and Mushtaq Ahmad in the district of Dibrugarh in Assam have designed a low-cost windmill (low height, drag type, made of bamboo and priced at INR 4,500) that requires low cut-in speeds of 8-10 km/hr (Table 30). This design was modified further by Gujarat Grassroots Innovations Augmentation Network-West (GIAN W) with the support of Alstom Foundation and Alstom Wind for implementation in the Rann of Kachchh, Gujarat (NIF)<sup>99</sup>.

Wind pumping received a huge boost in India when the government introduced a National Water Pumping Windmill Demonstration in the Sixth (1980-1985) and Seventh Five-Year Plans (1986-1991). This led to the installation of a number of 12-PU-500 wind pumps for shallow well water pumping. Additionally, “more than 200 indigenous gear type pumping units were also installed in nine states under the Operational Research Programme (ORP)”. However, owing to improper siting and installation, lack of awareness among users, usage of substandard material in fabrication, design complications, and an inept implementation strategy, the 12-PU-500 windmills failed to garner much success except in a few regions (CICERO, 1999).

A wind pump offers several advantages over conventional pumps – it needs no fuel, little maintenance and usually lasts 20 years or more. There are around 12 Ministry of New and Renewable Energy (MNRE) empanelled manufacturers of wind pumps in the country (as shown in Table 30). There are three categories of wind pumps manufactured in India – AV55 Auroville (one manufacturer – Aureka, Tamil Nadu); Geared type (7 manufacturers) and Modified 12 PU 500 (4 manufacturers) (MNRE, 2010).

98 Cut-in speed refers to minimum wind speed required for starting; <http://www.nif.org.in/bd/product-detail/low-cost-wind-mill>

99 The modified design costs INR 70,000; <http://www.nif.org.in/bd/product-detail/low-cost-wind-mill>

**Table 30: Key players/actors in wind water pumping**

Category	Key players
Private companies/NGOs	Aureka; Auto Spares Industries; Kamal Engineering Works; Marut Energy Equipment Pvt. Ltd; Nalanda Engineering Works; Om Engineering Works; Prototype Development Training Centre; Rural Engineering School; Sarvodaya Engineering Works; Scientific Instrument Co. Ltd; Vikas Engineering Works; Wind Fab; Gujarat Grassroots Innovations Augmentation Network-West (GIAN W); VIKAS and SAVE (Ahmedabad-based NGOs)
International companies, donors and research institutes	Alstom Foundation
Government	MNRE; Department of Science and Technology (DST); National Innovation Foundation-India (autonomous institution of DST, GoI)
Individuals	Mohammad Mehtar Hussain and Mushtaq Ahmad of Dibrugarh district in Assam designed low cost wind pump for irrigating winter crops in Assam and have been recognized for their efforts by the National Innovation Foundation-India (NIF) in its Fourth National Biennial Award, 2007; Looking at its potential in Gujarat, GIAN W modified the design with the help of other experts and installed 50 units in the salt farming area of Gujarat) <sup>100</sup>

Source: CEEW compilation

## TECHNICAL DESCRIPTION

Windmills work on the principle of converting kinetic energy of the wind to mechanical energy. The power developed by windmill is directly proportional to the area swept by the blades and the cube of the wind velocity [Power (watts) =  $1/2 \times$  the density of air  $\times$  the sweep area  $\times$  (wind speed)<sup>3</sup>] (GEDA)<sup>101</sup>.

A mechanical wind pump design consists of the following key components: a windmill (rotor and tower) integrated with a pumping system (piston with matching valve) for drawing water from a borehole. Windmill rotors are designed to harness the wind's kinetic energy and then convert it to mechanical energy. Windmills having a "horizontal axis rotor of 3-5.5 m diameter (coupled with a reciprocating pump of 50-150 mm diameter through a connecting rod) and 12-24 blades mounted on the top of a 10-20 m high mild steel tower is the most commonly used windmill" (TIME IS)<sup>102</sup>. Such windmills draw water when wind speed approaches 8-10 km/hour. Usually, a windmill is capable of pumping water in the range of 1000 to 8000 L/hour, depending on the depth of water table, wind speed, and the type of windmill (India Development Gateway)<sup>103</sup>.

Available windmills are of two types, namely direct drive and gear type (as shown in Table 31). Windmills often use a direct drive system rather than a gearbox with the intention of reducing

100 Mohammad Mehtar Hussain and Mushtaq Ahmad low cost windmill was made of bamboo and cost INR 4,500. However, following major modifications by GIAN W in consultation with experts, the system costs INR 70,000.

101 [http://www.gtu.ac.in/Board\\_Mobile\\_wireless\\_Tech/Amita.pdf](http://www.gtu.ac.in/Board_Mobile_wireless_Tech/Amita.pdf)

102 <http://www.techno-preneur.net/technology/new-technologies/energy/pumping.html>

103 <http://www.indg.in/rural-energy/technologies-under-rural-energy/energy-production/wind-energy-for-water-pumping-and-off-grid-power-generation>

the required starting torque and maintenance requirements<sup>104</sup> (Ziter, 2009).

**Table 31: Technical specifications of water pumping windmills in India**

Designs/ models	Broad technical Specifications	Estimated Water output versus head	Suitability
Direct drive windmill such as 12-PU-500 and similar other windmills	Rotor diameter – 5 m Nos. of blades – 12 Tower height – 7 m Pump diameter – 150 mm Cut in wind speed –10 km/hr Rated wind speed – 18 km/hr	8000 L/ hour at 7 m head	For shallow waterpumping up to 15 m head
Gear type windmills	Rotor diameter – 3.3 m Nos. of blades – 18 Tower height – 10 m Pump diameter – 50-100 mm Cut in wind speed –9 km/hr Rated wind speed – 18 km/hr	1000 L/per hour at 20 m head	For deep well pumping from 16m to 60 m head
AV55 Auroville direct drive windmills	Rotor diameter – 5.7 m Nos. of blades – 24 Tower height – 9-23 m Pump diameter – 64-160 mm Cut in wind speed –10 km/hr Rated wind speed – 18 km/hr	4000 L/hour at 15 m head	For shallow and deep well pumping up to 60 m head

Source: (MNRE, 2010)

## APPLICATION MARKET

India has highest wind energy potential after the China, USA, Germany and Spain (Economic Times, 2013). As per the Centre for Wind Energy Technology (C-WET) assessment, India has a wind power potential of 102 GW (GWEC, 2012). Wind installed capacity is concentrated in the five southern and western states of Tamil Nadu, Karnataka, Maharashtra, Gujarat and Andhra Pradesh, accounting for over 85 per cent of the total installed capacity, broadly reflecting wind resource potential (GWEC, 2012). In India, nearly 3,000 wind pumps are in operation (MEDA)<sup>105</sup>.

## COSTS

Cost of the water pumping windmills (Gear type) and Auroville type windmills is approximately INR 1 lakh and INR 1.50 lakhs respectively (GEDA)<sup>101</sup> (MNRE)<sup>106</sup>. The maintenance cost entail charges for painting the windmill once every six years and the cost of the replacement of pump valves and pumps washers once every four years. Furthermore, costs for foundation, storage tank and windmill installation can amount to INR 10,000-20,000. The system involves moving parts and thus requires regular maintenance. The repair and

104 Direct drive windmills do not involve gearboxes.

105 [http://www.mahaurja.com/RE\\_Wind\\_Pumping.html](http://www.mahaurja.com/RE_Wind_Pumping.html)

106 <http://www.mnre.gov.in/schemes/offgrid/small-wind/>

maintenance cost of a water-pumping windmill is about INR 2000 per year (India Development Gateway)<sup>103</sup>. Low cost windmill designed by Mohammad Mehtar Hussain and Mushtaq Ahmad of Dibrugarh district in Assam which was subsequently modified by GIAN W costs around INR 70,000 (NIF)<sup>107</sup>.

The total installation cost can be expressed as a function of the rated electrical capacity of the wind system. In general, the cost of the wind turbine decreases with an increase in the machine capacity (Gopal et al., 2013). The cost of conventional water pumps in use by farmers in India can range from INR 10,000 (Chinese brands) to INR 30,000 (Indian manufactured older 5 HP pumps) (as shown in Table 32). Although, the initial capital investment on conventional diesel pumps can be significantly lower compared to wind pumps, they entail huge operating costs arising from large amounts of fuel usage to a great extent and due to diesel engine maintenance (filters, and repairs). It is noteworthy that older 5 HP pumps consume 1-2 L/hour of diesel and newer, more efficient 2-3 HP pumps consumer around 0.5-1 litre on an hourly basis (Greenpeace, 2013). Although Chinese pumps consumer less fuel compared with their Indian counterparts, they are less reliable, prone to breakdowns, have shorter life spans and are difficult to repair locally due to the lack of a quality service network for these products (Greenpeace, 2013). Table 33 provides a breakup of expenditure incurred on operation and maintenance of AV55 wind pump.

**Table 32: Cost of conventional pumps in India (most commonly used)**

Model	Cost (INR)
5 horsepower (HP) pumps (older models – Indian manufactured)	30,000
2-3 HP pumps (Japanese designed but Indian manufactured)	20,000
Chinese brands	10,000

Source: (Greenpeace, 2013)

**Table 33: Breakup of O&M costs**

Windmill component	O&M requirements	Cost/year (INR)
Windmill and tower	<ul style="list-style-type: none"> <li>Minimal maintenance required</li> <li>Greasing of all bearings (two times a year)</li> <li>Checking for any loose bolts and nuts (two times a year)</li> </ul>	500
Wind pump maintenance	Depends on a number of factors - quality of water is crucial (presence of sand in saline water)	3000-5000

## POLICY SCENARIO

MNRE promotes applications of water pumping windmills through its programme on Small Wind Energy and Hybrid Systems. The objective of the programme is to develop technology and promote applications of water pumping windmills and aerogenerators/wind-solar hybrid systems. The programme extends support to the following activities:

107 <http://www.nif.org.in/bd/product-detail/low-cost-wind-mill>



- Central financial assistance (CFA) for setting up water pumping wind mills and aerogenerators/wind solar hybrid systems
- Field trials and performance evaluation
- Grid connected SWES on demonstration basis
- Research & Development

However, it is noteworthy that as per the 2013 amendment to the programme, central financial assistance (CFA) is confined only to community users (MNRE, 2013). This programme extends subsidies and incentives to water pumping windmills as illustrated Table 34.

**Table 34: Central financial assistance (CFA) for wind pumps**

Type of Windmill	Maximum MNRE support	
	General Area	Island
Direct drive gear-less windmills such as Modified 12-PU-500 and similar other windmills	INR 20,000	INR 30,000
Gear type windmill	INR 30,000	INR 50,000
AV55 Auroville type windmill	INR 45,000	INR 80,000

Source: (MNRE, 2010)

The MNRE provides up to 50 per cent of the ex-works cost of water pumping windmills, except for un-electrified islands and the north-eastern states including Sikkim for which up to 90 per cent of the ex-works cost, subject to the following upper ceilings for each approved design of the windmill (wind pump) as shown in Table 33. MNRE also provides administrative charges of INR 2,500 per windmill (wind pump) to the state agency.

## BENEFITS

One of the most important advantages of wind water pumps is the reduced usage of fossil fuels like diesel which in turn translates to reduced O&M costs. Less costly wind pumps can be opted for drawing water for irrigation which is seasonal (so the windmill may only be useful for a part of the year) (UNIDO)<sup>108</sup>. For example, GIAN W installed modified designs of low-cost drag-type windmills in Rann of Kachchh, Gujarat for pumping water for salt farming which led to savings of about INR 50,000 worth of diesel in a single season. Farmers were able to recover their investment in less than eight months (a single season of salt farming extends from September to May). In addition, it is estimated that this would abate 5 tons of carbon emissions for every 100 tons of salt produced (NIF)<sup>109</sup>. Wind energy water pumps are more reliable than diesel systems due to their lower maintenance, auto stop features in the case of failures and emission-friendly operation.

108 [http://www.unido.org/fileadmin/media/documents/pdf/EEU\\_Training\\_Package/Module7.pdf](http://www.unido.org/fileadmin/media/documents/pdf/EEU_Training_Package/Module7.pdf)

109 [http://www.nif.org.in/awards/awardprofile-details.php?profile\\_id=475&page=9&award\\_function\\_id=-1&st\\_id=3](http://www.nif.org.in/awards/awardprofile-details.php?profile_id=475&page=9&award_function_id=-1&st_id=3)

## CONSTRAINTS

Water-pumping windmills have a few technological limitations. They can be operated satisfactorily only in medium wind regimes (12-18 km per hour). Further, special care is needed at the time of site selection because the sites should not have buildings and trees in the surrounding areas. Wind water pumps also face stiff competition from solar powered pumps. Some of the factors make it less attractive than solar water pumps including higher costs which reduced affordability for individual consumers; performance issues due to inconsistent wind velocity; higher maintenance requirements (for water supply wind pumps) and higher losses (Gopal et al., 2013).

Most water supply wind pumps must be ultra-reliable in order to run unattended for most of the time (so they need automatic devices to prevent over-speeding in storms) only requiring annual maintenance without any major part replacements (UNIDO)<sup>108</sup>. This requires more robust construction that increases the capital cost of water supply wind pumps.



A manual water pump with a green fuel tank and a brown pump body is mounted on a wooden frame. A large, rusty metal wheel is visible in the foreground. The pump is spraying a powerful jet of water into the air. The background shows a lush green field with trees and a clear sky.

Agriculture demand  
contributes more  
than 20 percent of  
total power sales in  
India.

Source: KPMG, 2012



## CASE STUDY:

### LOW COST WINDMILL DEVELOPED BY MOHAMMAD MEHTAR AND HUSSAIN, MUSHTAQ AHMAD<sup>110</sup>

*“Necessity is the mother of all inventions, or rather innovations”* - this slightly modified phrase could well serve as a perfect ode to the low cost windmill developed by two brothers, Mohammad Mehtar Hussain and Mushtaq Ahmad from Dibrugarh district in Assam (Figure 16). Mehtar and Mushtaq, engaged in cultivating the water intensive paddy crop in their village, were on the lookout for a low cost alternative to electric and diesel pump sets for irrigation that also took care of the physical strain associated with manually-operated hand-pumps. Their quest drove them to develop a low cost windmill made of locally available materials such as bamboo and tin sheets that was connected to a hand pump. Their effort was recognized by National Innovation Foundation-India (NIF) in its Fourth National Biennial Award, 2007. Subsequently, GIAN W with support from National Innovation Foundation –North East (Figure 17) (NIF), the Alstom Foundation, experts from Alstom wind, Gujarat-based NGOs like SAVE and VIKAS, IIT Guwahati, made further improvements to Hussain and Ahmad’s design to make it conducive for salt farming in the Rann of Kachchh (by lifting groundwater for salt production) with abundant wind resource. The IPR of the innovators has been protected (1367/KOL/2008) and the benefits go back to them in a fair manner (NIF)<sup>109</sup>.



Figure 16: Mohammad Mehtar Hussain and Mushtaq Ahmad – innovators of low cost windmill  
Source: (NIF)<sup>107</sup>



Figure 17: Bamboo prototype of the low-cost windmill (left) and modified model installed for salt farming.  
Source: (NIF)<sup>109</sup>

110 Information has been collected through secondary research



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## TECHNICAL DESCRIPTION

It is a drag type low height windmill requiring low cut-in wind speed to operate (8-10 km/hr). The first prototype/basic model was made using locally available materials such as bamboo, wood, strips of old tyres, pieces of iron and so forth. Their windmill is a tall tower structure comprising two parallel bamboo posts supported by two inclined bamboo posts each. An iron shaft is mounted on bearings near the top of the tower, ends of which rest on the parallel bamboo posts on either side. A wind turbine with four blades is mounted at the centre of the shaft which is connected to the tube well handle through mechanical linkages (crank lever mechanism) Rotation of the wind turbine, sets the shaft in motion which then drives the hand-pump to draw water.

The turbine blades in modified designs (introduced by GIAN W) are made of lightweight material. The furling tail mechanism and manual brake system have been incorporated in the windmill to safeguard it against the high wind velocity. This is very useful for pumping water up to the depth of 50 feet. The water discharge capacity is about 1200-500 L/ hr at wind speed of 10-12 km/hr (NIF)<sup>107</sup>.

## APPLICATION

Fitted to a tube-well or an open well it can pump water not only for irrigation but also for domestic use. Its popularity among salt farmers in the Rann of Kachchh opens up wider avenues for its application in other salt producing regions of Gujarat and India. It is noteworthy that the state of Gujarat contributes around 70 per cent of India's salt production (NIF)<sup>107</sup>. Salt workers represent one of the poorest sections in the state who have been using some of the oldest labour intensive technologies for lifting saline water for salt production. Those using diesel-powered pumps bear high annual operating costs (related to the cost of fuel). The diesel pumps used by the farmers are priced between INR 15,000 for locally manufactured and INR 25,000 for the branded ones. They consume crude oil costing between INR 6000 and INR 7000 for a barrel of 200 L (NIF)<sup>111</sup>. Thus, in the light of various economic and social challenges, it can be said that this low cost windmill has been a blessing to these salt farmers.

## COST

While the basic model costs around INR 4500, the improvised model (by GIAN W) for commercial use costs around INR 70,000 (NIF)<sup>112</sup>.

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111 [http://www.nif.org.in/bd/upload/innovator\\_profile\\_pdf/Mehtar-Hussain.pdf](http://www.nif.org.in/bd/upload/innovator_profile_pdf/Mehtar-Hussain.pdf)

112 The price does not include transportation costs, taxes, etc.

## BENEFITS

This windmill has several advantages over conventional windmills in that it requires very low wind speeds of 8-10 km/hr to start. It is a portable unit that could be dismantled when not in use and has almost zero operating costs and is cheap. The use of an alternate method of pumping water, i.e. windmill, frees at least one person in the family.

Its implementation in Gujarat has also resulted in a host of socio-economic benefits for the salt farmers. The use of eliminates drudgery in cases where water was pumped manually. It allows the women to attend to the other household and livelihood-related matters. It saves about INR 50,000 worth of diesel in a season of six months. Usage of a windmill reduces the salt workers' reliance on labour that can lead to savings of approximately INR 28,000 per season per person. The payback period is less than eight months (salt farming season lasts six months) which is important because this prevents the spilling over of high interest debt during non-productive seasons. It is also estimated to generate 5 carbon emission reductions (CERs) per 100 tons of salt produced (NIF)<sup>113</sup>.

## CONSTRAINTS

The performance of this windmill may decrease when lifting water from depths exceeding 50 ft (NIF)<sup>107</sup>.

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113      One carbon credit/CER is equal to one metric tonne of CO<sub>2</sub> (abated)









## SOLAR PHOTOVOLTAIC WATER PUMP

It is estimated that 80 per cent of the freshwater in India is used for agriculture and a major portion (70 per cent) of this is based on groundwater irrigation. Nearly 88 per cent of the total minor irrigation schemes in India are pump-based (MoWR, 2013). Though pumpsets are important for livelihoods, they also contribute to the GHG emissions since a significant percentage of them rely on diesel. It has been estimated that India may have 10 million irrigation pumpsets which rely on diesel (Business Line, 2013a).

Solar pumpsets can play an important role in reducing the carbon emissions and also increase the access of groundwater to farmers. It is a commercialized technology and many organizations offer such solutions. The Ministry of New and Renewable Energy (MNRE) does not have a specific list of organizations providing solar Photovoltaic (PV) irrigation solutions, but many MNRE channel partners (over 150) for off-grid and decentralized solar applications provide solar water pumping solutions (MNRE, 2013a).

### TECHNICAL DESCRIPTION

A solar PV water pumping system consists of a PV array (with the provision of tracking, a DC/AC motor pumpset (surface/ submersible or floating type), electronics (Maximum Power Point Tracker<sup>114</sup>, inverter and controls/protections), cables, and an 'On-Off' switch (MNRE, 2013b).

MNRE broadly lays down specifications for a solar PV system; a few of them are (MNRE, 2013b):

- PV panels should have capacity in the range of 200 Watt to 5 kW
- The motor pumpset should have capacity in the range of 0.2 to 5 HP
- The efficiency of the PV modules should be minimum 14 per cent and the fill factor should be more than 70 per cent

The output of a system may vary according to size and type. MNRE lays down system design specifications with the output of the solar insolation at the installation site at 5.5 kW/m<sup>2</sup>/day. They have been listed in Table 35 and Table 36.

114

Maximum Power Point Tracker is a technique used to get maximum power from the solar panels

**Table 35: Indicative system design for solar-powered surface water pumps**

Parameter	Model I	Model II	Model III
PV module size	900 W	1800 W	2700 W
Motor capacity	1 HP	2 HP	3 HP
Shut off dynamic head (metres)	12	15	25
Water output in litres in per day (lpd)	AC Pump: 81,000 DC Pump: 90,000 from a head of 10 metres	AC Pump: 162,000 DC Pump: 180,000 from a head of 10 metres	AC Pump:135,000 DC Pump:148,000 from a head of 20 metres
MNRE Benchmark Cost (INR )	AC Pump : 145,350 DC Pump : 171,000	AC Pump: 290,700 DC Pump: 342,000	AC Pump: 436,050 DC Pump: 513,000

Note: The cost has been calculated according to the latest benchmark cost specified by MNRE. The actual on the ground cost and output may vary according to the system design. However the subsidy will only be given on the benchmark cost. The additional costs (if any) will be borne by the user.

Source: (MNRE, 2013b)

**Table 36: Indicative system design for a solar powered submersible water pump**

Parameter	Model I	Model II	Model III	Model IV
PV module size	1200 W	1800 W	3000 W	4800 W
Maximum total dynamic head (metres)	45	45	70	70
Water output in litres in per day (lpd)	AC Pump: 38,000 DC Pump: 42,000 from a head of 30 metres	AC Pump: 57,000 DC Pump: 63,000 from a head of 30 metres	AC Pump:57,000 DC Pump:63,000 from a head of 50 metres	AC Pump:135,000 DC Pump:91,000 from a head of 50 metres
MNRE Benchmark cost (INR)	AC Pump: 193,800 DC Pump: 228,000	AC Pump: 290,700 DC Pump: 342,000	AC Pump: 484,500 DC Pump: 570,000	AC Pump: 775,200 DC Pump: 910,000

Note: 1. The cost has been calculated according to the latest benchmark cost specified by MNRE. The actual on the ground cost and output may vary according to the system design. However the subsidy will only be given on the benchmark cost. The additional costs (if any) will be borne by the user.

2. The motor is a submersible pump with an electronic controller.

Source: (MNRE, 2013b)

## APPLICATION MARKET

Approximately 10 million pumpsets in India rely on diesel and it is estimated that 75 per cent of them are present in regions with high solar radiation (Business Line, 2013a) (Arora, 2013). Presently more than 8,626 solar water pumps have been installed in India (MNRE, 2013c)<sup>115</sup>. The difference between the potential and the current status is huge and presents an opportunity for organizations to provide solar water pumping solutions to farmers.

## COST AND INSTALLATION

An indicative upfront costs of solar water pumping solution is presented below<sup>116</sup>:

**Table 37: Indicative costs of solar pumps**

Capacity in HP	Price in INR lakhs
1	2 - 2.5
2	3 - 3.5
3	4.25 - 4.75
5	7.25 - 7.75

Note: The above figures may differ than those calculated according to the benchmark costs because the system configuration and the panel size may change according to local conditions.

Source: CEEW compilation

MNRE provides 30 per cent subsidy on the benchmark cost of solar pumping solutions for systems with solar panels of capacity up to 5kW. The benchmark costs according to panel size are indicated in the table below:

**Table 38: Benchmark costs of solar water pumps**

System Type	Benchmark cost (INR/Watt)
DC system	190
AC system	161.5

Source: (MNRE, 2013d)

A solar water pumping system requires minimal maintenance though regular cleaning of solar panels may be required. AC pumps may be repaired by local technicians but it is often difficult to get DC pumpsets repaired due their motor complexity.

With certain assumptions it can be concluded that the cost per unit from a solar water pumping solution may be in the range of INR 10 to 13 per unit of electricity when compared to diesel which costs INR 17 to 20 per unit of electricity<sup>117</sup>.

<sup>115</sup> MNRE has sanctioned subsidy for 8626 water pumps as of March 2013. However this number does not include solar pumps installed without MNRE support. Hence it is expected that total number would be on the higher side.

<sup>116</sup> This cost may vary according to developer, location and size of PV array. It does not include the MNRE subsidy.

<sup>117</sup> For the above calculations it was assumed that a solar water pump would be utilized for 1,250 hours in a year with an operational life of 15 years (assumed conservatively, a solar panel generally has an operational life time of 25 years). Also, it can be assumed that a liter of diesel may generate 3 to 3.5 units of electricity and the cost of diesel was assumed to be INR 60 for the above calculation.

Also, rental cost of water from diesel gensets vary from INR 100 to 160/hour and may reduce to INR 60 to 80/hour in case of solar pumpsets. If used for 1,250 hours annually, a solar pumpset without an MNRE subsidy may have a payback period of six to eight years (when compared to a diesel pumpset) which could reduce to four to six years with an MNRE subsidy.

## POLICY SCENARIO

MNRE provides 30 per cent capital subsidy on solar water pumps. However it has been observed that due to procedural delays in disbursement of subsidy, rich farmers often do not opt for it<sup>118</sup>. In addition to the central subsidy, few state governments also provide additional incentive to the farmers<sup>119</sup>:

- Rajasthan government provides 56 per cent subsidy in addition to central subsidy to farmers. The state government plans to install 10,000 solar water pumps in the FY 2013-2014. It is expected to receive INR 148 crore from the National Clean Energy Fund (NCEF) for the programme (The Hindu, 2013a).
- Andhra Pradesh government plans to provide 20 per cent subsidy in addition to central subsidy to farmers (The Hindu, 2013b).
- Gujarat government plans to provide 80 per cent subsidy (to a maximum of INR 3.2 lakh) to 500 systems for farmers in Saurashtra region (ToI, 2013).
- Punjab government plans to provide 40 per cent subsidy (to a maximum of INR 1 lakh) in addition to MNRE subsidy for 500 solar irrigation systems in FY 2013-2014 (The Hindu, 2013c).
- Tamil Nadu government plans to provide 80 per cent subsidy (to a maximum of INR 4 lakh) for 2000 systems during FY 2013-2014 (Business Line, 2013b).

## BENEFITS

An average 5 HP (3.73 kW) capacity (Arora, 2013) diesel pump when replaced with a solar one can potentially save 2,000 litres diesel and 5,200 kg of carbon dioxide emissions, per year<sup>120</sup>. If 50 per cent of the 10 million diesel pumps are replaced with solar, they can lead to savings of the following

**Table 39: Saving if 5 million solar pumps are installed**

Saving of	Units saved if 5 million diesel pumps are replaced with solar
Installed capacity	18,650 MW
Electricity consumption	23.3 billion units
Litres of diesel	10 billion litres
CO <sub>2</sub> saved	26 million tonne

Note: It is assumed that an average pump has is of a 5HP (3.73 kW) capacity and operate for 1,250 hours a year.

Source: CEEW calculation

118 CEEW stakeholder consultation

119 This list is for indicative purpose and is not exhaustive. There may be other states which provide additional incentives for solar water pumps

120 It is assumed that a 5HP pump operates for 1,250 hours. Also, 1 litre of diesel produces 2.6 kg of carbon dioxide.



Deployment of solar water pumps can also lead to saving in T&D losses and reduction expenditure for utilities in maintaining the distribution network for agricultural loads (KPMG, 2011).

## CONSTRAINTS

High upfront costs pose a major challenge for the acceptance of solar water pumping systems. Banks are also not comfortable about providing loans for such systems. Other problems such as procedural delays in disbursement of subsidies and theft of solar panels at night have also led to discouragement among consumers<sup>121</sup>.

Often, poor experience with solar street lights and home lighting systems, discourages farmers from taking a risk. Hence, they are hesitant towards the deployment of new technology and prefer to wait for successful examples (Ennovent, 2013). Lack of portability and weather dependency also pose a significant challenge for increasing the uptake of solar water pumping systems.

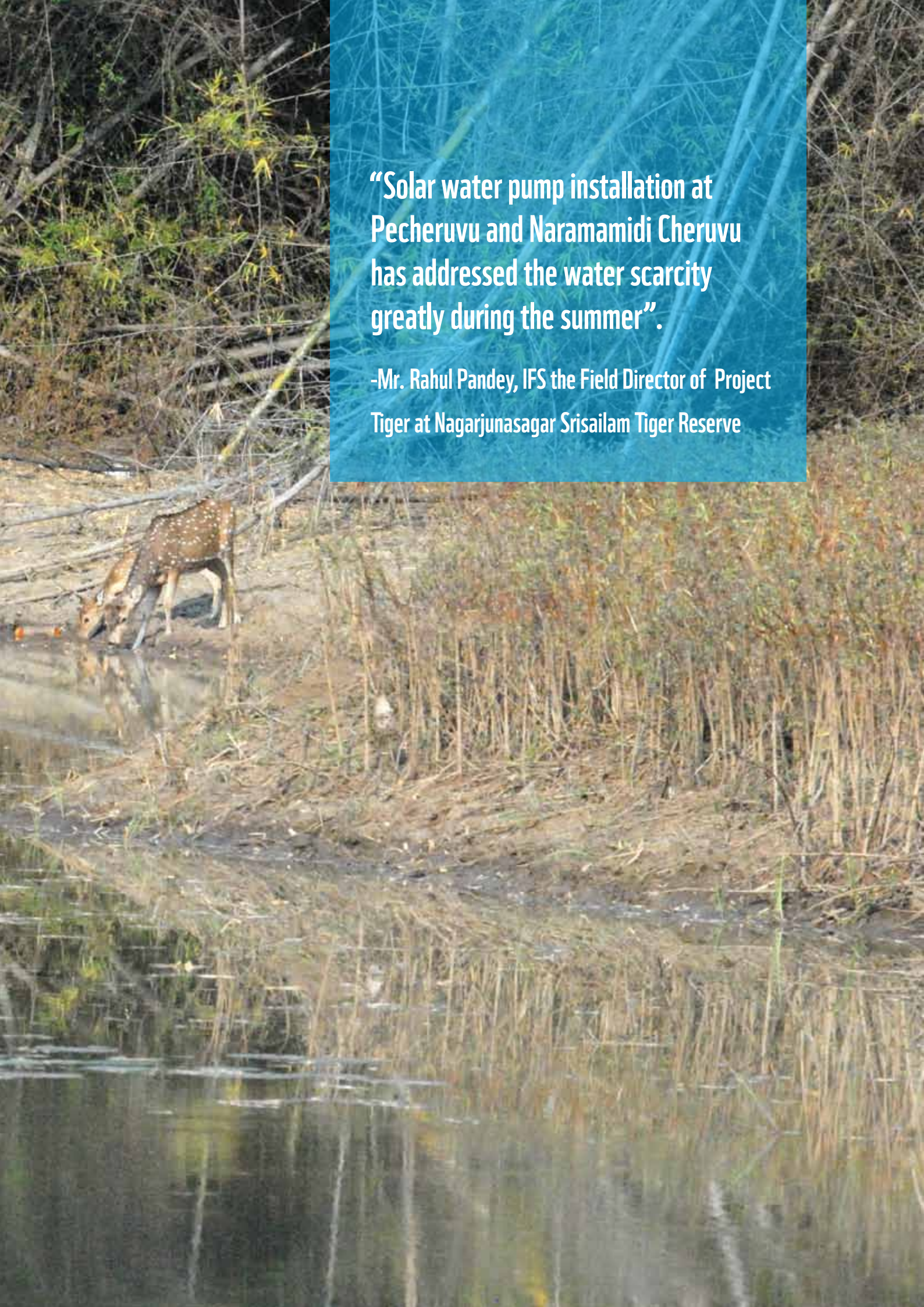
Hence it is observed that limited financial resource which is pressurized due to multiple needs are coupled with risk perception which leads to low deployment of solar water pumping systems.

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<sup>121</sup> Recently portable solar panels have been commercialized but are still costly when compared to conventional solar panels. It is expected that decrease in price can lead to increase in sale of solar systems since they would reduce the risk of panel theft.





A photograph of a spotted deer standing at the edge of a pond, drinking water. The deer has a brown coat with white spots. The pond is surrounded by dry grass and reeds. In the background, there are trees and a blue sky. A semi-transparent blue box is overlaid on the right side of the image, containing white text.

**“Solar water pump installation at Pecheruvu and Naramamidi Cheruvu has addressed the water scarcity greatly during the summer”.**

**-Mr. Rahul Pandey, IFS the Field Director of Project Tiger at Nagarjunasagar Srisailem Tiger Reserve**



## CASE STUDY:

# SOLAR IRRIGATION SYSTEM BY CLARO VENTURES<sup>122</sup>

Claro Ventures founded in 2011 offers irrigation solutions through solar energy to power deficit regions in India. It primarily operates in Bihar and has some presence in Uttar Pradesh, Jharkhand and Madhya Pradesh.

High upfront costs, risk perception among bankers to sanction loans and delay in government subsidies have eluded individual customers from buying such systems. Hence most of the systems installed by Claro are for government programmes.

## TECHNICAL DESCRIPTION

A typical solar irrigation system by Claro has a capacity of 1 to 7.5 HP and consists of a solar panel, motor pump (AC/DC), data collection mechanism for remote monitoring, connecting cables and the required electronics like Variable Frequency Drive (to convert DC power generated by solar panels into a three-phase power for AC pumps).

Previously Claro used to sell both DC and AC solar pumps but shifted to AC pumps due to problems with the former pumps. DC pumps are higher in cost and mechanics but required skillset to service them is not available<sup>123</sup>.

## PROJECT DESCRIPTION

The Department of Minor Water Resources, Bihar had launched a programme in 2012 to power 34 existing tube wells with solar energy in 20 villages of five blocks in Nalanda district of Bihar. The systems were installed by Claro with a five-year annual maintenance contract. The systems had 7.5 HP pumps with a discharge capacity of 70,000 litres per hour and a solar panel capacity of 8.5 kW (six arrays with six panels of 235 watt capacity).

## COST

An indicative cost of solar water pumps have been listed in the table below

**Table 40: Indicative costs of solar water pumps by Claro**

System Size	Cost	Payback Period (with MNRE subsidy)	Payback Period (without MNRE subsidy)
2 HP	300,000	3.9 years	5.8 years
3 HP	450,000	3.9 years	5.8 years
5 HP	750,000	4.1 years	6 years

Note: The above numbers are only indicative and may change on project basis. The payback period has been calculated assuming a use of 1,250 hours years and may increase or decrease depending on the usage.

Source: Claro Ventures

<sup>122</sup> Based on information provided by Claro Ventures and other publicly available documents.

<sup>123</sup> A 1 HP DC pump may cost INR 60,000 whereas a 1 HP AC pump may cost INR 15,000.





Figure 18: A solar water pump installation by Claro Ventures  
Source: (Wahi, 2013)

## BENEFITS

It is estimated that the installation will help in reducing 511 tonnes of carbon dioxide emissions every year. These systems provide water supply to 1,600 acres of land and have created over 45 direct and 80 indirect jobs and have affected over 3,400 families in the villages (Ashoka Changemaker, 2012).

The above solar irrigation pump could operate from six to eight hours a day and deliver approximately 60,000-80,000 litres/hour of water depending on the time of the day. This may be sufficient to irrigate one acre of land in 10 hours<sup>124</sup>. The output may vary on the depth of water and the sunshine condition (Shah & Kishore, 2012).

## CONSTRAINTS

Claro is responsible for operational and maintenance of all their systems for five years. A few problems such as leakage in pipes, wire connections breakage and theft of panels have been found. Most of these problems have been addressed by the local Claro office. All the systems are equipped with communication systems (through a SIM card), which helps the organization to address the issues instantly in case of anomalies.

Claro is now trying to venture into other states and tap their solar irrigation policies. One of the major hurdles faced by them is the high upfront cost and reluctance of banks to sanction loans to farmers.

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124 This is an average figure and may change from location to location due to local factors such as insolation and water level.



## SOLAR AERATOR

Aeration is a process of restoring the content of air in a water body. Aeration is performed by bringing water and air in contact with each other. This may be done through exposing drops or thin sheets of water to air or by generating small bubbles in water and allowing them to rise (Prasetyaningsari et al., 2013). An aerator can have multiple applications such as increasing the oxygen content, removing harmful chemicals which may be responsible for bad taste and odour, reducing the carbon dioxide content and producing good quality drinking water (Ives)<sup>125</sup>. Hence it may find its use in many industries such as waste water treatment industries, municipal corporations, aquaculture ponds and drinking water source treatments (Medoraco, 2009).

A water aerator may stimulate natural microbes, eliminate harmful gases, reduce algae growth, increase dissolved oxygen level and de-stratifies the water column. The system is still not successfully commercialized due to high costs and is still deployed only as pilot projects.

### TECHNICAL DESCRIPTION

A solar aerator may consist of solar panels, inverter, battery, pump and a diffuser. However, the system needs to be tailor made according to customer requirements and the configuration may depend on factors such as Dissolved Oxygen level (DO) and Chemical Oxygen Demand (COD).

Solar aerators have not been commercialized in India and are still in their nascent stage. They have been deployed as a pilot project in few places by few organizations. As a pilot project a small capacity solar aerator was installed at a lake in Gujarat by an educational institute with a manufacturing company. The specifications of the system have been listed in Table 41.

**Table 41: Specifications of a solar aerator developed for a pilot**

Parameter	Specification
Cost	INR 80,000
Indicative pond size	2 acre
Solar panels	300 Watt
Battery	12V, 150 Ah
Inverter	12V, 800VA
Pump capacity	1/3 HP
Daily hours of use	3 hours

Source: Supernova Technologies

A solar-powered aerator has also been designed and commercialized in USA. The aerator called 'SolarBee' is being manufactured by Medora Corporation. The system consists of 240 watts of solar panels, 0.5 HP pump with a brushless motor of 90 per cent efficiency. The system also includes an electronic control box, distribution dish, battery and an impeller. The system is designed to operate at 80 RPM which may be changed according to requirements (Medoraco, 2009).

125

[http://www.supernovawindsolar.com/product\\_series.php?productid=3&productid1=3](http://www.supernovawindsolar.com/product_series.php?productid=3&productid1=3)

## APPLICATION MARKET

A solar aerator system may find its application in removing algae, aquatic animal farming, improving the wildlife health by increasing the quality of water and in waste water treatment. They may also be used for improving the health of isolated ponds, swimming pools, golf course ponds and farms ponds with stagnation problems (Supernova Technologies)<sup>126</sup>. As of now, no study has been done to estimate the potential of solar aerators for different applications and industries.

In India, solar aerators have been tested in aquaculture industry. The demand for Dissolved Oxygen (DO) in a fish pond is high between 3 a.m. and 4 a.m. because that is when fish start to come up to the water surface.. Presently at many places, water is manually changed to increase the oxygen content. To automate the process, a few solar aerators have been successfully tested in artificial ponds and have performed satisfactorily. Supernova Technologies designed and tested solar aerators to operate for two to three hours till 6 a.m. when the demand of DO is likely to decrease<sup>127</sup>.

Solar aerators have not been deployed by waste water treatment plants in India. However, in USA, the solar aerators have been found to perform better than grid powered aerators. During a study it was observed that grid powered aerators operate for more than the required time, increasing the usage of electricity, greenhouse gas emissions and also escalating the operational costs. When replaced by solar aerators, the electricity costs were found to have reduced by 38 per cent and 87 per cent in two sites and greenhouse gas emissions also concurrently decreased. The payback of the system was found to be between 1.9 to 3.7 years (Hudnell et al., 2011) .

Indian industries have not explored the option of solar aeration primarily due to its high cost and lack of awareness. Also, there are very few institutions which are working on demonstration projects. For example, Sardar Patel University in Gujarat has developed mobile solar aerators and hybrid solar/wind aerators<sup>128</sup>. These systems are being manufactured by Supernova Technologies in Gujarat.

Another Delhi-based company, Akar Impex, is in process of developing solar aerators but those have only been installed as demonstration projects. Two systems of 3 HP and 5 HP with 2.2 kW and 3.7kW of solar panels have been designed by them. They are facing some issues in terms of battery size, variation of solar insolation, limited hours of operation and high cost of DC motors<sup>129</sup>.

## COST & SUBSIDY

A major proportion of the aerator system is the cost of the pump. The cost increases significantly in solar aerators with the addition of solar panels. Two types of pumps may be deployed in each system, AC or DC. An AC pump is used in the case of systems which run on grid electricity, whereas a DC pump is preferred for solar aerators since the output of the battery is in DC it makes it more efficient<sup>130</sup>. However, DC pumps are costly and therefore increase the overall cost of the system. Substituting a DC pump and with an AC pump requires an inverter in addition, thereby raising the overall costs and decreasing the system's efficiency<sup>131</sup>. DC pumps are generally deployed for small systems while AC pumps can be deployed for

126 [http://www.supernovawindsolar.com/product\\_series.php?productid=3&productid1=3](http://www.supernovawindsolar.com/product_series.php?productid=3&productid1=3)

127 CEEW stakeholder consultation.

128 Mobile solar aerators are moveable and can be easily deployed in different locations.

129 CEEW Stakeholder interaction.

130 It is difficult to repair DC pumps when compared to AC pumps because it requires specific skill sets.

131 There may be a loss of 5-10 per cent when inverter converts power from DC to AC.



all sizes. Hence, a system needs to be carefully designed after taking stock of certain criteria such as Chemical Oxygen Demand (COD) and Dissolved Oxygen (DO) of the water, time of operations, total hours of operation and overall costs.

**Table 42: Indicative costs of DC and AC pumps**

Capacity	DC system (INR)	AC system
1 HP	50,000	15,000
2 HP	65,000	30,000
3 HP	80,000	50,000

Note: These are only indicative costs and the actual costs may vary according to the manufacturers.

Source: CEEW compilation

Additional upfront cost of solar panels, batteries and inverters make the solar aerator system costly. However, the payback period is approximately three years compared to diesel and five years when compared to electricity<sup>132</sup>. There are no available subsidies for solar aerators and the payback period reduces when subsidies are implemented. There is a minimal maintenance requirement for the system. The battery however needs regular water topping up and replacement after every three to five years.

## POLICY SCENARIO

Presently MNRE does not provide any subsidy on solar aerators. It has been suggested by some organizations that subsidy can increase the financial attractiveness of the system since it lowers the upfront cost.

## BENEFITS

A solar aerator catering to a two-acre pond can increase the production of an aquaculture pond by up to 20 per cent. A system consisting of a 1/3 HP, 300 Watt solar panels and a 12 V battery, 150Ah can potentially save 125-150 litres of diesel leading to a 350 to 400 kg decrease in CO<sub>2</sub> emissions annually<sup>133</sup>. However as a thumb rule, each HP of solar aerator is estimated to impart 1.1 kg of oxygen per hour to the water body<sup>134</sup>.

## CONSTRAINTS

Solar aerators have not been commercialized and are in nascent stage. High costs often discourage customers to opt for solar systems. Enterprises are trying to reduce the cost of the system by designing the balance of system such as solar panels and batteries in a more optimal matter. The fear of theft of panels at night is also a concern for farmers since in most of the cases the ponds are rented as well as owned by them.

<sup>132</sup> CEEW stakeholder consultation.

<sup>133</sup> The system can generate one unit of electricity on a daily basis. It has been that on an average one litre of diesel produces three units of electricity and 2.6 kg of CO<sub>2</sub>.

<sup>134</sup> CEEW stakeholder consultation.







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## CASE STUDY:

# SOLAR AERATORS DEVELOPED BY SUPERNOVA TECHNOLOGIES<sup>135</sup>

Supernova Technologies, a Mumbai-based organization has tied up with Sardar Patel University, Gujarat to develop water aerators based on renewable energy technologies in 2011. Solar and wind/solar hybrid aerators were developed to cater to the needs of farmers who do not have access to electricity and require water aerating. The system is still in the pilot phase and has not been commercialized. The systems are indigenously designed for increasing the production of shrimps, fishes and other aquatic animal farming.

## TECHNICAL DESCRIPTION

The solar aerator is placed on a moveable trolley which provides the necessary mobility to the system. The system comprises 300 Watt solar panels, HP pump and a battery with capacity 12V/150 Ah. The system can run for approximately three hours every day. It is also incorporated with an auto controller which can be programmed for fixed hours of operation, eliminating the requirement of manual operation.

## PROJECT EXAMPLE

The systems tested by Supernova Technologies at various places included one at Gotri Lake, Vadodara, Gujarat and another at an aquaculture unit in Mumbai, Maharashtra in 2011. The system installed at Gotri Lake showed instant results with the water becoming translucent and the number of dead fishes reducing. The system restored the health of the water body and was successful in removing the smell caused by the dead fish (ToI, 2011)

## COSTS

The cost of the above system is INR 80,000. There is no support available from the government with minimal maintenance requirements. The payback period for this system is three years.

## BENEFITS

A system consisting of a 1/3 HP, 300 Watt solar panels and a battery of 12V, 150 Ah can potentially save 125-150 litres of diesel and result in a reduction of 350 to 400 kg of CO<sub>2</sub> annually<sup>136</sup>. The system is designed to operate automatically at designated hours thus eliminating the need for a manual switch-on at night.

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<sup>135</sup> Based on information provided by Supernova Technologies and other publicly available documents

<sup>136</sup> The system can generate 1 unit of electricity on a daily basis. It has been that on an average one litre of diesel produces three units of electricity and 2.6 kg of CO<sub>2</sub>.



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## CONSTRAINTS

During pilot testing, a few systems were successfully tried in ponds and fishery industries in Gujarat and Mumbai but the high upfront costs, coupled with recurring costs of replacing batteries and absence of subsidies made the system unpopular.

Supernova Technologies developed solar aerators, but have been unsuccessful in marketing their product due to the aforementioned reasons. They believe that increase in awareness about systems and financial support from government could increase the sales for solar aerators.



# Appendix-I

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WWF-India has been working on issues related to biodiversity conservation, sustainable livelihoods and governance, and climate change.

The Climate Change and Energy programme of WWF-India is working towards a climate resilient future for people, places and species that support pathways for sustainable and equitable economic growth. Low carbon development and renewable energy at scale are the thrust areas of climate change and energy programme.

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