Identification of Industrial Sectors Promising for Commercialisation of Solar Energy

Commercialisation of Solar Energy in Urban and Industrial Areas – ComSolar

giz

On behalf of

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Executive Summary

The growing emphasis on solar energy utilisation to achieve energy security as well as to combat the menace of climate change and global warming has resulted in the formulation of one of the world's most ambitious solar missions in India. While the larger focus of the Mission is on grid connected projects for electricity generation, there are great opportunities for deployment of solar energy technologies for various off-grid industrial applications as well. This demands the initiation of studies to identify suitable applications for solar energy technologies and estimate their replication potential across industrial sectors. One such joint initiative of GoI and GIZ aims to identify promising sectors for the commercialisation of solar energy in industrial sectors in the country. The objective of the study was to identify opportunities which are commercially viable, have the potential for replication and can also contribute to India's National Solar Mission target of 15 million m^2 of solar thermal collector area by 2017 and 20 million m^2 by 2020.

Identification of the promising industrial sector

Energy intensive industrial sectors can contribute to rapid scaling up of off-grid solar applications if they actively exhibit eagerness and willingness to substitute their energy requirement from conventional sources to solar energy. However, it is important to identify industrial sectors that possess significant potential for adopting solar applications to meet their process energy requirements in a commercially viable manner so that these industries act as successful demonstration projects with a high replication potential.

Leveraging the experience in carrying out such tasks and based on extensive secondary research from sources like the "National Energy Conservations Awards reports by BEE, Annual survey of industries database and 'Prowess database', a list of various energy intensive industrial sectors existing in India was prepared. The list was potentially exhaustive and covered all the sectors where energy intensive industrial applications constituted a significant share of the overall production costs. All identified 37 industrial sectors were mapped against various energy consuming processes/applications which formed a part of their production cycle. The mapping exercise helped in identifying the different low and high grade heating/cooling applications which could be potentially replaced with suitable solar technology applications. Out of the 37 sectors identified above, 15 sectors were shortlisted for further study based on the following parameters:

Grade of heat required (high/low): Sectors like steel, aluminium and ceramic have a number of processes which require high grade heat (temperatures ranging above 800 °C) which cannot be met by solar applications in a cost-effective manner. Even if there is a low grade heat requirement in some of the processes, waste heat streams from other high-grade heat processes can meet this requirement at no additional cost. Free low grade heat makes solar applications unviable in these sectors and these sectors were not considered for further analysis.

Growth prospects of the sector: Some sectors are small in size and have low requirements of heat as well as electricity, but they are growing at a very fast pace. Keeping in mind the growth prospects of such sectors, such as Agromalls, they were selected for further analysis.

Ongoing interventions in the sector: Sectors like Telecom have very good potential for solar applications but were not considered for further analysis as the sector is already undergoing a lot of interventions from both the government as well as sector players. Any further intervention in such sectors may just be a duplication of efforts and resources.

Based on the criteria mentioned above, 15 potential industrial sectors were selected for further analyses on a different set of criteria to find the most promising sectors for the commercialisation of solar energy technologies in these sectors. The list of these 15 sectors is given below:

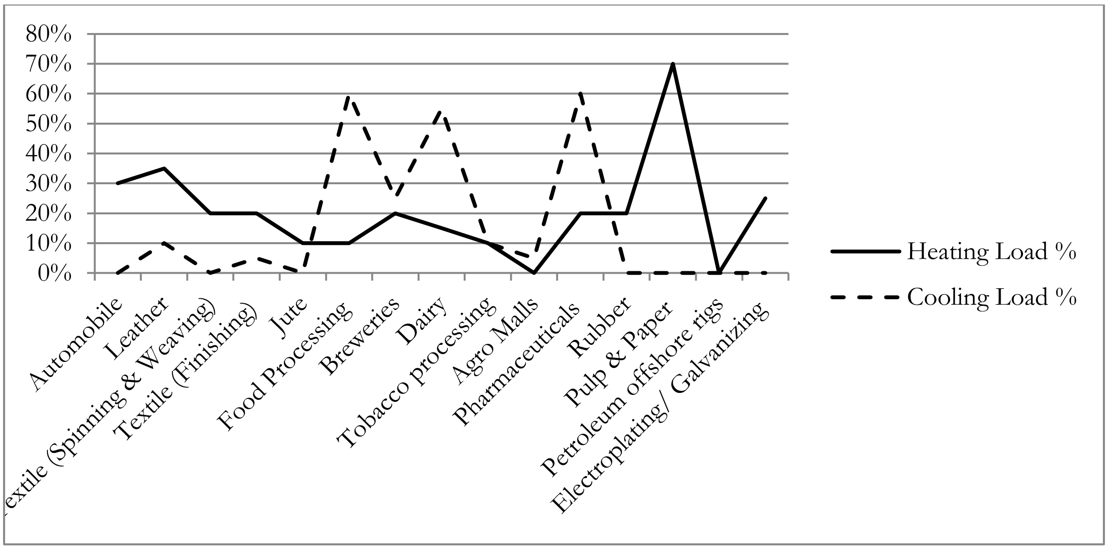
S. No.	Sector	S. No.	Sector	S. No.	Sector
1	Automobile	6	Petroleum offshore rigs	11	Textile (Finishing)
2	Breweries	7	Pharmaceuticals	12	Electroplating/Galvanizing
3	Dairy	8	Rubber	13	Tea and Tobacco processing
4	Food processing	9	Pulp and Paper	14	Agro malls
5	Leather	10	Textile (Spinning & weaving)	15	Jute

In order to rank and arrive at a list of 10 sectors out of the 15 shortlisted sectors compiled above, parameters were defined to characterize the potential utilisation of solar energy in these sectors:

- ✓ Energy consumption: Energy consumption is one of the critical parameters used to analyse the potential for solar technology applications in industrial sectors. Energy intensive industries typically have different processes consuming large quantities of fossil fuels like conventionally generated electricity, coal, gas and other petroleum products. The heavy reliance on fossil fuels indicates the possibility of replacing some of these with solar energy.

- ✓ Heating/Cooling load as percentage of total energy consumption : The heat requirement of many industrial processes ranges from 50 ˚C to 250 ˚C. These processes account for a significant share of energy consumption, indicating a potential for the application of solar thermal technologies at medium and medium-to-high temperature ranges. There are hardly any studies quantifying this parameter across the various industrial sectors. An extensive secondary research was carried out to identify and estimate the heating/cooling loads in different industrial sectors.

  Due to lack of existing secondary research on the percentage heating/cooling loads in these 15 short-listed industries, consultations with sector experts and energy auditors in relevant organizations (that have extensive experience of studying the energy profiles of various manufacturing processes), along with study of various energy audit reports helped in establishing the average percentage of heating/cooling loads in these sectors.



- ✓ Power Generation/DG sets/Captive Load : The deficit between demand of electricity and its supply in the country has compelled many large and medium scale industries to set up their own captive power plants, both grid-connected as well as off-grid. For industries requiring relatively less power and low amounts of process steam, the diesel generator set is a preferred choice. Diesel based captive power generation accounts for 40% of captive load in the country today. The cost of such power generation is very high because of the high price of diesel fuel, and is almost comparable with cost of power generated from solar sources.

- ✓ Number and dispersion of units within a sector in India: The geographic dispersion of individual units in a sector plays a key role in determining the overall potential for adopting solar technology applications and the ease of replication. Clustered units have the advantage of jointly adopting such technologies with effective risk and cost sharing.. The similarities and symmetry in clustered industrial units enhance the replication potential of solar technologies thus providing a larger market for solar applications.

- ✓ Past solar experience in identified sector: The past experiences of implementing solar applications, both as pilot and large scale projects, provides an oppurtunity to study the key barriers/risks, understand economics of scale and uncertainties in cash flows. Prior examples of successful solar applications is likely to provide increased funding options for similar future initiatives, with many institutions willing to finance such projects in the key industrial sectors. The industrial sectors with prior experience with solar technologies can also effectively evaluate government policies as compared to sectors with no prior solar experience.

Each of these parameters was provided a weightage and each sector was given scores from 1 through 15 (15 being highest) against each parameter, to rank all the 15 sectors and arrive at the top 10. Sector specific data for each parameter was collected using extensive interactions and secondary research. The ranking for all 15 sectors is as follows:

Sector	Total marks	Rank
Textile (Finishing)	900	1
Pulp and Paper	790	2
Pharmaceuticals	770	3
Leather	730	4
Food processing	730	4
Dairy	690	6
Textile (spinning and weaving)	630	7
Electroplating/Galvanizing	620	8
Automobile	600	9
Agro malls	500	10
Rubber	490	11
Breweries	480	12
Jute	370	13
Tobacco processing	300	14
Petroleum offshore rigs	290	15

Pre-feasibility analysis in promising industrial sectors

A detailed pre-feasibility study was carried out for the top 10 sectors. The study involved identifying various processes in the industry, mapping different solar technologies for the identified processes and estimating the replacement potential of conventional energy. The fundamental tenets of the pre-feasibility study were:

- identifying processes that can be complemented with solar energy in the industry
- mapping suitable solar technologies to all the identified processes
- estimating the conventional energy replacement potential for industrial process
- replication potential of utilizing solar applications in identified processes across industrial sector

The findings of the pre-feasibility study of 10 sectors are given below:

a. **Textile (Finishing):** Textile sector is one of the highest energy consuming sector in the country. Textile processing covers steps ranging from singeing (removal of protruding fiber) to finishing and printing of the fabric and manufacturing polyester, polyester filament yarn, acrylic, nylon, viscose, cotton textiles etc. As per the ASI statistics, the primary energy consumption in the sector was 4.46 Mtoe in 2007-08.

Textile processing requires a lot of hot water in the range of 40 ˚C to 110 ˚C at different stages of the process. The hot water at these temperatures can easily be generated through solar energy. The amount of conventional energy that can be replaced by solar applications in the textile industry is shown in the table below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Textile (Finishing)	383	7,692

b. **Pulp and Paper industry**: The pulp and paper sector is one of the most energy intensive sectors within the Indian economy. There are about 515 units engaged in the manufacture of paper, paperboards and newsprint in India. The sector consumes a lot of energy to generate steam that is mainly required in debarking & chipping, digesting & washing, pulping, bleaching and paper drying. ASI has estimated the primary energy consumption of this sector to be 7.56 Mtoe in 2007-08. The sector has a good potential to replace some part of this conventional energy with solar applications. Replacing existing energy use with solar applications to the extent possible is estimated as below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Pulp and Paper industry	45	1,700

c. **Food processing:** Food processing sector is a highly fragmented industry and widely comprises of the following sub-segments: fruits and vegetables, milk and milk products, beer and alcoholic beverages, meat and poultry, marine products, grain processing, packaged or convenience food and packaged drinks. ASI estimates indicate that food processing sector consumed around 4.50 Mtoe of primary energy in 2007-08. Mapping various processes in the food processing industry indicated that some can be suitably replaced by solar interventions. Replacing existing energy use with solar applications to the extent possible is estimated as below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Food processing	80	1,782

d. **Leather industry:** The leather sector in India is predominantly unorganized and decentralised. As this sector comprises of units making different leather products at different stages of the industry's value chain, the production units can be broadly classified into following categories:

- tanneries – process raw hides/skins to produce semi-finished and finished leather
- consumer goods production units – produce leather products like safety and fashion footwear and as well as its components, saddles and harnesses, garments, gloves and other goods using finished leather
- integrated units – process raw hides/skin and produce downstream consumer goods.

ASI estimates indicate that leather sector consumed around 150 ktoe of primary energy in 2007-08. An analysis of the energy requirements of different processes in the leather manufacturing process reveals that tanning has a high potential for using solar applications to meet its hot water and hot air needs. Replacing existing energy use with solar applications to the extent possible is estimated as below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Leather	17	1,026

e. **Dairy industry:** India has emerged as the largest milk producing country in the world with the present level of annual milk production estimated at 100 million tonnes. The dairy industry is dominated by the co-operative sector with 60% of the installed processing capacity. It has been estimated that the dairy industry consumed 210 ktoe of primary energy in 2007-08. The industry consumes a substantial amount of thermal (heat) energy for milk processing (pasteurization, sterilization, spray drying, evaporation, etc.) and electrical energy for refrigeration during milk pre-chilling, milk chilling after pasteurization, cold storage of packed milk, compressed air requirement for pneumatic milk packaging machines, milk homogenisation and clarification operations. The solar mapping exercise revealed that a vast potential exists in the dairy industry for installing various solar applications. Solar thermal systems can enormously contribute in reducing the conventional energy use in the various thermal processes in the dairy industry that demand water at temperatures <120 °C. Apart from this, solar PV systems can also contribute in reducing conventional electrical energy consumed for refrigeration. Replacing existing energy use with solar applications to the extent possible is estimated as below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Dairy	27	916

f. **Textile (Spinning and weaving):** The textile spinning and weaving industry is also one of the largest and oldest sectors in the country and very important to the economy of the country in terms of output, investment and employment. ASI statistics show that this sector consumed 3.34 Mtoe of primary energy in 2007-08. While analysing the energy requirements of the sector, it was found that in one of the process of weaving called sizing, hot water with temperature of 80-85 °C is required. Hence, solar thermal intervention is possible in the sizing process. Conventional energy replacement potential in sizing as well as other operations in this sector has been estimated and is shown in the table below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Textile (Spinning & weaving)	20	740

g. **Electroplating:** The Electroplating can be categorized in to two types- (i) primary user & original equipment (OE) manufacturers who carry out electroplating as one of their overall manufacturing activity and (ii) job work units, who carry out plating of a large variety of components for both domestic and export purposes. The industry has a diversified product base and a majority of the electroplating units are SMEs. It is estimated that the sector consumes approximately 118 ktoe of primary energy in 2007-08. Most of the operations in electroplating industry require hot water at a temperature of 40-85 ˚C and have the potential for using solar water heating applications to meet this requirement. Based on certain empirical analysis the total energy replacement potential in the sector is estimated to be about 21 ktoe/ annum.

h. **Agro-malls:** An agro mall is a rural business centre, which is creating a far-reaching positive impact by bringing a qualitative change and revolutionizing the farming sector in India. Agro mall chains seek to empower the farmer by setting up centers, which provide all encompassing solutions to the farmers under one roof. Study of energy audit reports of Agro malls and its further analysis has revealed that the agro mall sector consumes approximately 12 ktoe of primary energy per year. It has been found that most of the agro malls located in rural areas are provided with diesel generator (DG) sets and have a fairly un-shaded and strong roof structure able to support the weight of a roof-top solar installation. It is expected that the integration of solar PV systems would not only reduce the use of fossil fuels but would also mitigate CO_2 emissions. Replacing existing energy use with solar applications to the extent possible is estimated as below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving Rs. Million/annum)
Agro mall	4.30	160

i. **Automobile:** The automotive industry in India is one of the largest in the world and is one of the fastest growing globally. India manufactures over 11 million 2 and 4-wheeled vehicles and exports about 1.5 million every year. As per the estimates, 590 ktoe of primary energy was consumed in the automobile sector in 2007-08. It was also found that processes involved in the automobile industry uses a significant amount of thermal energy. The temperature requirement in certain processes of automobile industry is well beyond 300 ˚C whereas some processes have a temperature requirement of <150 ˚C. Therefore, solar thermal energy as well as solar photovoltaic applications has the potential to replace conventional fuel currently being used for carrying out its processes. The estimated conventional energy replacement potential and monetary savings are given in the table below:

Sector	Energy replacement potential (ktoe/annum)	Estimated monetary saving (Rs. Million/annum)
Automobile	10.5	607

j. **Pharmaceutical:** The Indian pharmaceutical industry ranks 3rd in the world in terms of production and volume. It is estimated that the sector consumed 930 ktoe of primary energy during 2007-08. The sector consumes both electrical and thermal energy at different stages of its processes. Hence, chances of replacing conventional sources of energy by solar energy are good. Most of the thermal energy applications in pharmaceutical units require low range temperatures which are easily achievable by solar systems. It has been observed that approximately 20% of the total energy consumption in the units within pharmaceutical sector is heat load. Based on certain empirical analysis it was determined that 5% of the heat load could be suitably replaced by solar energy applications. Based on the aforementioned assumptions, the total energy replacement potential in the sector is estimated to be about 9 ktoe/ annum.

It would be noteworthy to mention here that all sectors covered in the aforementioned analysis have a sizable potential for incorporating solar applications. Based on the results of the analysis presented above, five sectors were selected for further analysis by field visits to:

- identify the conventional energy applications which can be complemented with solar energy
- collect data for detailed cost-benefit analysis and;

- understand issues and gauge willingness for setting up pilot projects.

The industrial units for field visits and walk-through energy audits were selected in the identified clusters based on the following major parameters:

- the identified units are representative of the units present in the selected industrial sectors
- units located in a cluster that has many similar units for future replication

Two units in each of the selected sectors were identified for carrying out field visits. The sectors selected were:

- Electroplating
- Textile (Spinning and weaving)
- Food processing
- Pharmaceuticals
- Pulp and Paper

Findings of field studies in 5 sectors

Electroplating: The units visited in this sector are using electricity and diesel for water heating for their electroplating processes. It was observed that the units have the potential of replacing use of conventional fuel with the solar applications to meet a part of their energy requirements. The temperature required is in the range of 40 ˚C to 60 ˚C, which could be easily obtained by using Flat Plate Collector (FPC) and Evacuated Tube Collector (ETC). Cost-benefit analysis of installing these solar equipments shows that the Internal Rate of Return (IRR) has been estimated to be between 19% and 28%, depending on the fuel used without taking into account any subsidy. This subsidy refers to as the one prescribed and enshrined in the 'Off-Grid Guidelines' under the Jawaharlal Nehru National Solar Mission (JNNSM) for off-grid solar applications.

Pulp and Paper mills: During the field visits conducted in the selected pulp and paper units**,** it was found that consumption of primary energy to meet the energy requirement of different processes is a blend of pet coke and rice husk with an occasional use of coal. The units were using steam to supply heat to most of their processes like debarking, chipping, digesting, washing, pulping, bleaching and paper drying. A boiler was being used to supply makeup water at normal temperature to fulfil the requirements of steam for the processes. Analysis indicated that there is potential to reduce the existing fuel consumption by preheating the makeup water using solar energy. This can be achieved by using Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC). Cost-benefit analysis of use of solar water heaters for such applications indicated very low Internal Rate of Return (IRR) of the order of 1% and 8% depending on the fuel used without accounting for subsidy. The IRR can be further improved if expensive fuels like furnace oils are used and/or any solar related subsidy is considered in calculations. The subsidy refers to as the one prescribed and enshrined in the 'Off-Grid Guidelines' under the Jawaharlal Nehru National Solar Mission (JNNSM) for off-grid solar applications.

Pharmaceuticals: Two units in this sector, in north and west India respectively were visited as part of the field study. It was revealed that the boiler accounts for a majority of fossil fuel use in the plant. The boiler is continuously being supplied makeup water at normal temperature to fulfil the requirements of steam for the processes. The boiler is continuously being supplied makeup water at normal temperature to fulfil the requirements of steam for the processes. One of the units in the visit was using low cost fuel like rice husk and while another was using high cost fuel like furnace oil. The plant uses steam/ hot water mainly for applications like distillation, evaporation, drying and carbon treatment. Analysis indicated that there is potential to reduce the existing fuel consumption by preheating the makeup water with solar energy. This can be achieved by using a Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC). The IRRs estimated here were between 5% and 30% depending on the fuel used and without considering any subsidy component as enshrined in the 'Off-Grid Guidelines' under the Jawaharlal Nehru National Solar Mission (JNNSM) for off-grid solar applications.

Food processing: During the field visit to the identified units of the sector, it was found that furnace oil and diesel oil are the major fuels being used. The major energy consuming applications are washing, cleaning, cooking, extraction, mashing, brewing, baking, pasteurization/blanching, drying and dehydration. It was also observed that the units had high potential for replacing the use of conventional fuels with solar applications. The technologies feasible for applications in this sector are Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC). The expected IRRs by using these technologies in the identified processes are between 27% and 34% depending on the fuel used without providing subsidy as enshrined in the 'Off-Grid Guidelines' under the Jawaharlal Nehru National Solar Mission (JNNSM) for off-grid solar applications.

Textile: The field visits to selected textile (spinning and weaving units) units revealed that they are meeting their energy requirements from electricity. The potential application found was heating required for sizing and yarn conditioning. Both these processes can be easily complemented with solar energy as the temperature required is around 60 ˚C to 80 ˚C which can be obtained by using Flat Plate Collectors (FPC) and Evacuated Tube Collectors (ETC). The IRRs expected by incorporating these technologies in the identified processes was found to be between 30% and 52% depending on the fuel used.

Way Forward

Results of the field visits and analysis of the data generated indicated that some of the energy consuming applications in these sectors can be suitably complemented with various solar energy technologies. The large-scale rollout as well as widespread adoption and replication of these solar technologies could be undertaken through different business models.

The business models most suited for solar energy technology promotion for industrial applications should have direct participation of the project beneficiaries. Outright grants or capital subsidies undermine the owner-accountability for the project results and has a detrimental effect on sustainability. Accordingly, it is important to have arrangements with a blend of debt and project beneficiary contributing for the equity. This is the classic project-financing model that is followed for a large number of renewable energy initiatives. The model is suitable for project beneficiaries that have the financial ability to arrange (raise or plough back from savings) the required equity contributions or for renewable energy projects that are not capital intensive. However, developers find it difficult to invest in projects which are capital intensive.

An alternative that addresses this deficiency is offered by Renewable Energy Service Companies (RESCO) model. This model is a relatively new financial innovation that allows the project beneficiaries to make periodic payments against renewable energy services (either payment for renewable energy based power or energy savings) instead of bearing (a part of) the upfront capital cost. The RESCO will absorb this burden and also provide annual maintenance and repairs to guarantee the minimum service delivery. This model has the benefit of allowing the project-beneficiary to simply make payments against services received without worrying about maintenance and repairs or upfront capital cost. The potential drawback of this model is the need for a mutually agreeable measure for the quantum of service provided to ensure both parties are satisfied with the financial agreements.

Some of the feasible RESCO business models are as follows:

- User Financing
- Shared- Saving RESCO
- RESCO-User Bank Facilitation

The following section provides an insight on the aforementioned business models.

a. **<u>RESCO-User-Bank Facilitation model</u>:** Under this business model, the RESCO companies install the solar applications in the consumers' premises while returns for the RESCO companies are secured through the monthly bill raised against the service. In this model, the RESCO is funded through lending institutions like commercial bank and IREDA. The RESCO needs to enter into a performance contract with the project owner and the end user will pay a onetime refundable security deposit to the RESCO. The lending institutions require the submission of proof of successful installation of solar equipment, as well as energy savings achieved in order to release the capital subsidy to the RESCO. The lending institution relies on the services of an energy auditor to verify the claims of energy saved. The bank where the project owner has his/her account will facilitate in payment of the monthly bill to the RESCO for their services provided.

b. **<u>Shared-Saving RESCO model:</u>** Under this business model, the RESCO companies are also supposed to carry out the installation work of solar applications in the consumer premises while returns for the RESCO companies are secured as a negotiated percentage of savings achieved by solar interventions. In this model, the RESCO is funded through the lending institutions like commercial bank and IREDA. Also, the RESCOs are required to carry out a baseline survey of energy used at the intended consumers premises. Following the submission of the baseline data to the lending institutions and verification of the same by energy auditor, the RESCO would be permitted to install the solar interventions. The lending institutions require the submission of proof of successful installation of solar equipment, as well as energy savings achieved in order to release the capital subsidy to the RESCO. The lending institution relies on the services of an energy auditor to verify the claims of energy saved.

c. **<u>User Financing RESCO model:</u>** Under this model, the users themselves arrange for project financing. The end user has to submit the proof of installation along with necessary documents to IREDA for availing the capital subsidy. In this model, operation and maintenance of system is carried by an RESCO, in exchange for a monthly operation and maintenance payment made by the end user. The RESCO enters into a guaranteed performance contract with the end user.

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List of Abbreviations

ACC	Asbestos Corrugated Cement
ACMA	Automotive Component Manufacturers Association
ASI	Annual Survey of Industries
BEE	Bureau of Energy Efficiency
BFW	Boiler Feed Water
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
CII	Confederation of Indian Industry
CPP	Captive Power Plant
CSP	Concentrating Solar Power
DC	Direct Current
DCS	Dairy Cooperative Societies
DG	Diesel Generator
ECS	Electronic Clearing Services
EMT	Energy Manager Training
ESCO	Energy Service Company
ETC	Evacuated Tube Collector
FDI	Foreign Direct Investment
FPC	Flat Plat Collector
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GOI	Government of India
HPMV	High Pressure Mercury Vapour
HPSV	High Pressure Sodium Vapour
HTST	High Temperature & Short Time
IRR	Internal Rate of Return
IREDA	Indian Renewable Energy Development Agency
JNNSM	Jawaharlal Nehru National Solar Mission
ktoe	Kilo Tonne of Oil Equivalent
LDO	Light Diesel Oil
LPD	Litre per day
MoFPI	Ministry of Food Processing Industries
MNRE	Ministry of New and Renewable Energy
MoPNG	Ministry of Petroleum & Natural gas
Mtoe	Million Tonne of Oil Equivalent
MW	Mega Watt
NIC	National Informatics Centre
O & M	Operation and Maintenance
PTC	Parabolic Trough Collector
PV	Photo-Voltaic
PwC	PricewaterhouseCoopers
RESCO	Renewable Energy Service Company
SAH	Solar Air Heating
SIAM	Society of Indian Automobile Manufacturers
SITRA	South India Textiles Research Association
SME	Small and Medium Enterprise
SWH	Solar Water Heater
TPH	Tonne per hour

Conversion Table

Unit	Conversion factor
1 kWh	860 kcal
1 Joule	0.24 Calorie
1 m^3	1000 litre
1ktoe	Thousand tonnes (10^3 tonnes) of oil equivalent

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1 Introduction

1.1 Background

In partnership with the GoI, GIZ has launched the ComSolar project to promote the application of viable solar technologies in urban and industrial sectors. The project aims to commercialise solar applications by encouraging its use in urban and industrial areas by developing viable business models and undertaking pilot projects. ComSolar also aims at introducing new solar energy technologies through promotional programmes designed to target the most economically viable replacement alternatives.

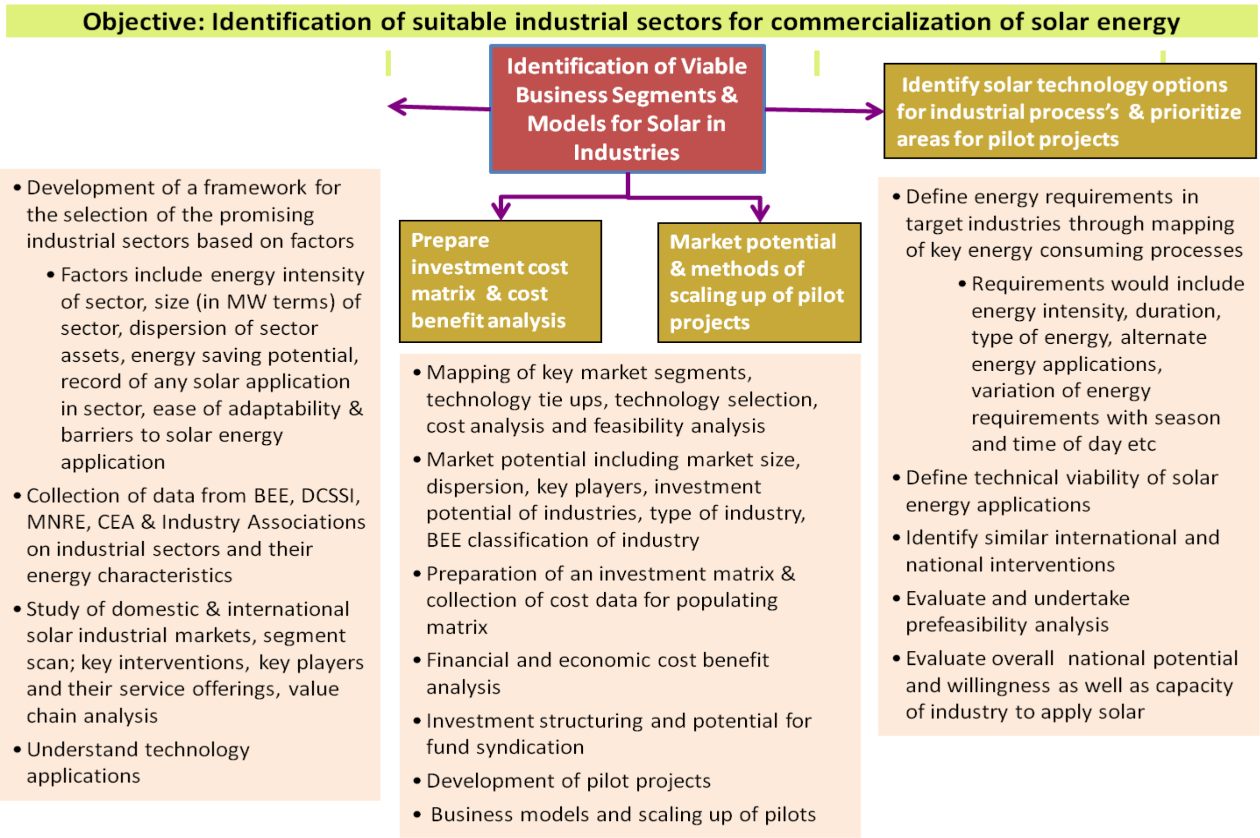
This study aims to identify commercially viable applications of solar technologies in industrial sectors.

1.2 Approach and Methodology of the study

1.2.1 Approach

The overall approach of the study was based on the requirements of promoting the sustainable development of solar energy markets in viable consumer segments, in order to achieve the goals as envisaged in the National Solar Mission. This included the development of and suggestions for new and innovative methods for promotion of solar applications, detailed economic and financial analysis to review the impact of alternative scenarios as well as the current and emerging business models that can be adopted by the sector. A consultative approach was followed at various stages of the study to ensure appreciation of each party's objectives & interest and creating a consensus on decisions and stakeholder buy-in to achieve the intended goals. The approach taken is presented in the Figure-1.

Figure-1: Approach chart



1.2.2 Methodology

The assignment was divided into five tasks as mentioned in detail below:

1.2.2.1 Identifying industrial sectors which are promising for the commercialisation of solar energy

In this task the project team identified a set of industries for detailed study. For this, a framework was developed which helped in selecting promising industrial sectors for the commercialisation of solar energy in the country. The framework was based on different parameters like energy intensity of the sector, size (MW terms) of the sector, dispersion of the sector's assets, past record of any solar application in the sector, ease of adaptability and barriers to solar energy application deployment. Data was collected from ASI database 2007-08; BEE Energy Conservation Awards reports and through consultations with sector experts, manufacturers/suppliers, etc. to shortlist the 10 potential sectors for further detailed investigation and analysis. This was done to determine the potential of reducing fossil fuel consumption in the shortlisted sectors and in the country as a whole.

1.2.2.2 Pre-feasibility analysis of the selected sectors

The processes that can be powered using solar energy technologies in the selected sectors were assessed against commercially available solar technologies. Secondary research, literature review and select consultations with stakeholders like industry representatives, technology manufacturers and MNRE was used besides using in-house experience and expertise to draw up a list of solar applications compatible with the 10 shortlisted industrial sectors for further analysis. The potential for the use of solar energy required that the conventional energy replacement potential in each of the process/sector was also estimated. The main steps in determining sector energy replacement potential are as follows:

- assessment of production
- assessment of specific energy consumption and energy requirement for hot water
- assessment of penetration of solar applications
- assessment of energy replacement potential

1.2.2.3 Prioritizing pilot project

Based on a detailed study on process mapping and estimated potential, 5 sectors were selected for field studies to conduct cost benefit analyses of different applications within these industries and identifying pilot projects. Walk though energy audits were carried out across two industrial units in each of the 5 sectors. These walk through energy audits helped in the collection of technical data and information on the capability of these industries to adopt the solar technology on a commercial scale in terms of investment potential, conventional energy replacement potential, technology know-how, land availability, willingness of the unit to participate, etc. The key players in the solar sector in the Indian market, their value chain, their offerings, and successful case studies were also identified. The results of the above analysis provided the specific areas where pilot projects of solar energy application could be implemented across industries.

1.2.2.4 Investment requirements and cost-benefit analysis

The purpose of this task was to estimate the financial feasibility of identified solar applications in selected sectors. The cost benefit analysis considered factors like the mapping of industrial processes that have a potential for replacement with solar technology applications, key market segments and available technologies & services. The cost of project implementation at site was estimated using inputs from the industries, consultations and interviews with solar energy equipment & solution providers as well as the project team's own experience in the sector. Based on this analysis as well as considering other inputs like financial incentives from MNRE etc., an excel based model for analysing the costs and benefits for these interventions across the sectors was designed.

1.2.2.5 Market and replication potential for scaling up pilot projects

The task was aimed at devising methodologies for scaling up pilot projects in the country. For this, replication potential at a national level was assessed across the 5 shortlisted industrial sectors. While estimating the potential for replication of solar technology applications, factors like expected penetration were considered. For the commercialisation of solar technology applications and its large scale rollout, self financing and RESCO based business models could be considered as suitable mechanisms. The latter assists in meeting the large capital requirement and in mitigating the risk involved in self financing. The suitability of the model to be used depends on parameters such as the size of the project, the quantum of capital employed, returns and the risk involved.

2 Identification of industrial sectors promising for solar applications

The initial task of this study was to identify industrial sectors that are promising for the commercialisation of solar energy in the country. The primary aim of this task was to identify industrial sectors/processes which are energy intensive and have potential for investments in solar energy applications. Based on in-house experience and exstensive research, a list of the sectors which are energy intensive and have various heating/cooling applications that can be potentially complemented with solar applications, was prepared. The list was potentially exhaustive and covered all the sectors where energy intensive industrial applications constitute a significant share of the overall production costs.

All the industrial sectors identified above were mapped against the various energy consuming processes/applications which are part of their production cycle (see Table-1). This mapping helped in identifying the different low grade and high grade heating/cooling applications which can be complemented with any suitable solar technology applications.

Table-1: Mapping of industrial sectors with their low & high grade heating/cooling applications

S. N.	Industrial sector	Process												
		Cleaning	Drying	Evaporation	Distillation	Pasteurisation	Sterilization	Cooking	Process heating	Boiler Feed Water Heating	Heating/Cooling	Lighting	DG Power	CPP (Coal or Gas)
1	Automobile	X							X		X	X	X	
2	Aluminium	X							X	X	X	X		X
3	Breweries	X	X	X	X	X	X	X	X	X	X	X	X	X
4	Cement								X	X	X	X		X
5	Ceramic	X	X					X	X		X	X	X	
6	Chemical	X	X	X	X		X		X	X	X	X	X	X
7	Dairy	X	X	X	X	X	X	X	X	X	X	X	X	X
8	Fertilizer		X	X					X	X	X	X		X
9	Food processing	X	X	X	X	X	X	X	X	X	X	X	X	
10	Telecom										X	X	X	
11	Integrated steel plant								X	X	X	X		X
12	Steel re-rolling								X	X	X	X		X
13	Foundry								X		X	X		X
14	Leather		X	X				X	X	X	X	X	X	
15	Mining											X	X	
16	Non ferrous metals	X							X	X	X	X		X
17	Petrochemicals	X		X	X		X		X	X	X	X		X
18	Petroleum offshore rigs	X									X	X	X	
19	Petroleum refineries	X	X	X	X		X	X	X	X	X	X	X	X
20	Pharmaceuticals	X	X	X	X		X	X	X	X	X	X	X	X

S. N.	Industrial sector	Process												
		Cleaning	Drying	Evaporation	Distillation	Pasteurisation	Sterilization	Cooking	Process heating	Boiler Feed Water Heating	Heating/Cooling	Lighting	DG Power	CPP (Coal or Gas)
21	Plastics and Polymer	X	X	X	X				X	X	X	X	X	X
22	Pulp and Paper		X						X	X	X	X		X
23	Rubber		X	X					X	X	X	X	X	X
24	Sugar	X	X	X					X	X	X	X		X
25	Textile (Spinning)	X	X						X	X	X	X	X	X
26	Textile (Dyeing and weaving)	X	X						X	X	X	X	X	X
27	Electroplating/ Galvanizing	X	X						X		X	X	X	
28	Tea and Tobacco processing	X	X		X				X	X	X	X		
29	Wood and Furniture	X	X									X	X	
30	Glass	X							X	X	X	X	X	
31	Bricks/ Building Materials	X							X		X	X	X	
32	Electronics and Electrical equipments										X	X		
33	Chlor-Alkali	X							X		X	X		X
34	Lime Kilns		X						X	X	X	X	X	
35	Machinery	X									X	X	X	
36	Agro Mall	X	X								X	X	X	
37	Jute Mills	X	X						X	X	X	X	X	X

Out of the 37 sectors given in the table above, 15 sectors were shortlisted for further study, based on the following parameters:

Grade of heat required (high/low): Sectors like steel, aluminium and ceramic have a number of processes which require high grade heat (temperatures ranging above 800 °C) which can not be met by solar applications in a cost-effective manner. Even if there is a low grade heat requirement in some of the processes, waste heat streams from other high-grade heat processes can meet this requirement at no additional cost. Free low grade heat makes solar applications unviable in these sectors and these sectors were not considered for further analysis.

Growth prospects of the sector: Some sectors are small in size and have low requirements of heat as well as electricity, but they are growing at a very fast pace. Keeping in mind the growth prospects of such sectors, such as Agromalls, they were selected for further analysis.

Ongoing interventions in the sector: Sectors like Telecom have very good potential for solar applications but were not considered for further analysis as the sector is already undergoing a lot of interventions from both the government as well as sector players. Any further intervention in such sectors may just be a duplication of efforts and resources.

Based on the criteria mentioned above, 15 potential industrial sectors were selected for further analysis on a different set of criteria to find the most promising sectors for the commercialisation of solar energy technologies in these sectors. The list of these 15 sectors is given below:

Table-2: List of 15 Industrial sectors selected for further analysis

S. No.	Sector	S. No.	Sector	S. No.	Sector
1	Automobile	6	Petroleum offshore rigs	11	Textile (Finishing)
2	Breweries	7	Pharmaceuticals	12	Electroplating/Galvanizing
3	Dairy	8	Rubber	13	Tea and Tobacco processing
4	Food processing	9	Pulp and Paper	14	Agro malls
5	Leather	10	Textile (Spinning & weaving)	15	Jute

To prepare a priority list of 10 sectors out of the 15 sectors selected above, a set of parameters (see Figure-2) were defined to characterize the potential utilisation of solar energy. Each parameter was provided a weightage and each sector was given scores from 1 through 15 (15 being highest) against each parameter to rank all the 15 sectors and arrive at the top 10 sectors. Any non-quantitative parameters ware given ranking as per the best judgement of the project team and views of the various stakeholders. A lot of secondary research as well as interactions were carried out to collect the data pertaining to these parameters. A matrix was formulated to analyse the 15 shortlisted sectors (see Table-2). The matrix is given in Annexure 1.

Figure-2: Set of parameters to prioritize 15 industrial sectors

- Energy consumption in the sector
- Heating/cooling load as a percentage of total energy consumption
- Power generation/DG sets/Captive load
- Number and dispersion of units within a sector
- Past solar experience in the sector

3 Framework to identify potential sectors

This section provides the details of the methodology adopted and information sources used for compiling data pertaining to the parameters listed in Figure-2. The parameters described in Figure-2 have been described in detail in the following sub-sections. Limitations and reliability of data have also been highlighted in the following sub-sections:

3.1 Energy consumption in the sectors

Energy consumption is one of the critical parameter used to estimate the potential for solar technology applications in industrial sectors. Energy intensive industries typically have different processes consuming huge amounts of different fuels like coal, electricity, petroleum products, etc. The consumption levels of these fuels act as a proxy for the potential for replacing these with solar energy. The primary source of data pertaining to this parameter has been taken from the Annual Survey of Industries (ASI) database, which is a principal source of industry statistics in India.

However, the ASI database is limited in its coverage of the entire scope of industrial sectors in the country. Sectors like telecom, petroleum offshore rigs and electroplating/galvanizing are not covered in this database. The consumption of petroleum products and other fuels in various industries are reported in terms of their purchase value for the corresponding year. This presents a significant challenge in the quantification of the petroleum products being consumed in industrial sectors in a particular year. To overcome this, the average retail price of the petroleum products for the year 2007-08 as per the Ministry of Petroleum and Natural Gas (MoPNG) has been considered.

Table-3: Energy consumption estimates in industrial sectors

Industrial sector	Industry code - 2, 3, 4 digit (as defined by NIC, 2004)	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (HSD, LDO, FO, LPG and others) (Rs. Million)	Quantity of petroleum products used (kilo tonne)	Total energy consumption (ktoe)
Automobile	341, 342, 343	7.75	3,518	11,755	310.97	590
Leather	191, 192	37	663	1,589	42.06	150
Textile (S&W)	1711, 1713	1,193	16,059	14,240	376.72	3,340
Textile (Finishing)	1712, 1714, 173, 181	2,672	3,591	7,009	185.43	4,460
Jute	1721, 1722, 1723	100	640	1,650	43.67	240
Food processing	151, 152, 153, 154, 155, 160	2,224	9,385	25,043	662.50	4,700
Breweries	1551, 1552, 1553	196	466	2,580	68.28	400
Dairy	152	47	864	2,680	70.92	210
Tobacco processing	160	78	171.89	765	20.24	150
Agro malls	1513, 1531	77	2,792	3,502	92.66	410
Pharmaceuticals	2423	364	2,762	6,806	180.05	930
Petroleum refineries	232	0	775.71	29,759	787.24	880
Rubber	251	360	1,811	2,891	76.50	750
Pulp and Paper	210	4,779	3,287	5,716	151.23	7,560

Source: ASI database: 2007-08

For sectors like telecom and petroleum off shore rigs, energy consumption has been estimated based on the type of primary energy sources utilised, specific energy consumption and annual production volumes/ capacity.

For the petroleum offshore rig industry, the average size/capacity of rig equipment (diesel engine, electric drilling equipments, mud pumps, top drive, etc) used for operations were considered. Table-4 shows the estimated values of total energy consumption in this sector.

Table-4: Energy consumption in Petroleum Offshore Rig industry

Parameter	Average size/capacity of the rig equipment (HP)	Total no. of off shore rigs currently operating in the country	Annual operating hours of the rig equipment (hrs)	Total energy consumption (ktoe)
Value	5,000	37	24*360	102
Source	Rig Zone offshore database	Rig Zone offshore database	PwC estimates	

For telecom industry, estimations were made regarding the average annual electricity consumption (grid connected) of telecom towers in the country based on the findings of various studies previously undertaken for major telecom tower operators in India. Apart from this, the annual diesel consumption for off-grid electricity supply was also estimated. Table-5 shows the estimated values of the total energy consumption in the telecom sector.

Table-5: Energy consumption in Telecom Tower Infrastructure

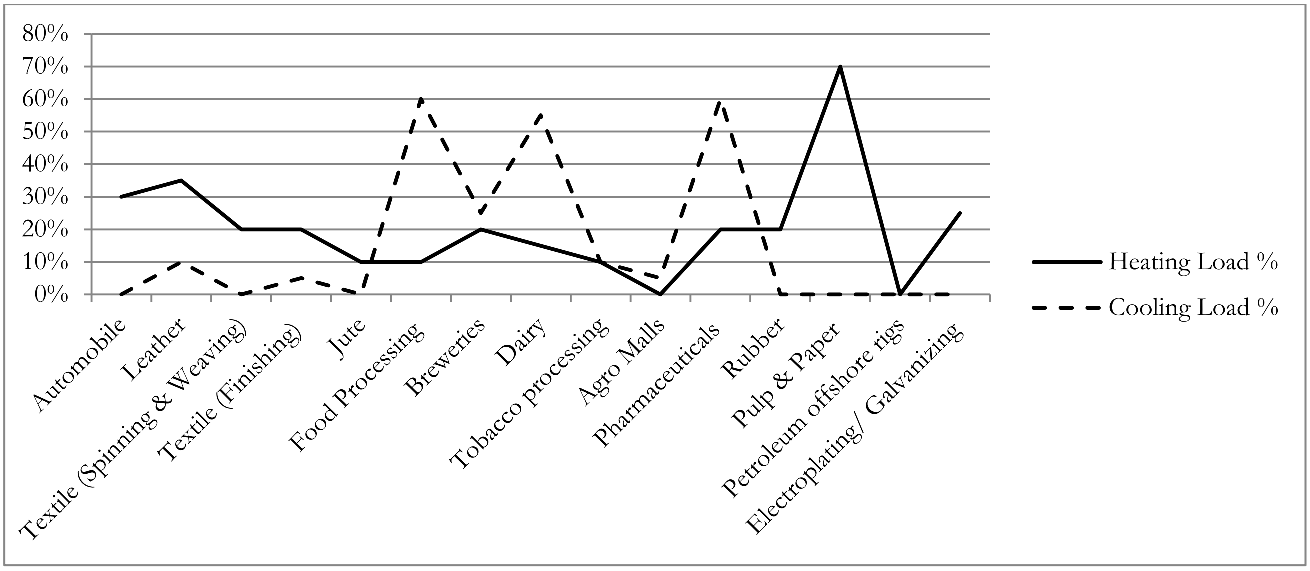
Parameter	Average annual electricity consumption (Grid connected) per telecom tower (kWh)	Total no. of telecom towers currently installed (lakhs)	Annual diesel consumption by telecom tower infrastructure in the country (for off-grid electricity supply (billion litres)	Total annual energy consumption (ktoe)
Value	32,952	3.50	2	994
Source	PwC estimates	India Infrastructure report 2009-10	India Infrastructure report 2009-10	

3.2 Heating/Cooling load as a percentage of total energy consumption

Typically the heat requirements of many industrial processes range from 50 °C to 250 °C. These processes account for a significant share of energy consumption, indicating a potential for solar thermal technologies at medium and medium-to-high temperature ranges. There are hardly any studies quantifying this parameter across various industrial sectors.

Consultations were carried out with sector experts and energy auditors in relevant organizations that have extensive experience with studying the energy profiles of various manufacturing processes in the 15 shortlisted sectors. This helped in establishing the average heating/cooling loads in these sectors. Figure-3 shows the profile of heating/cooling loads as a percentage of the total energy consumption in the 15 shortlisted sectors. The analysis indicates that in sectors like food processing, dairy, textile (finishing), pulp and paper, heating and cooling loads comprise more than 40% of their total energy consumption.

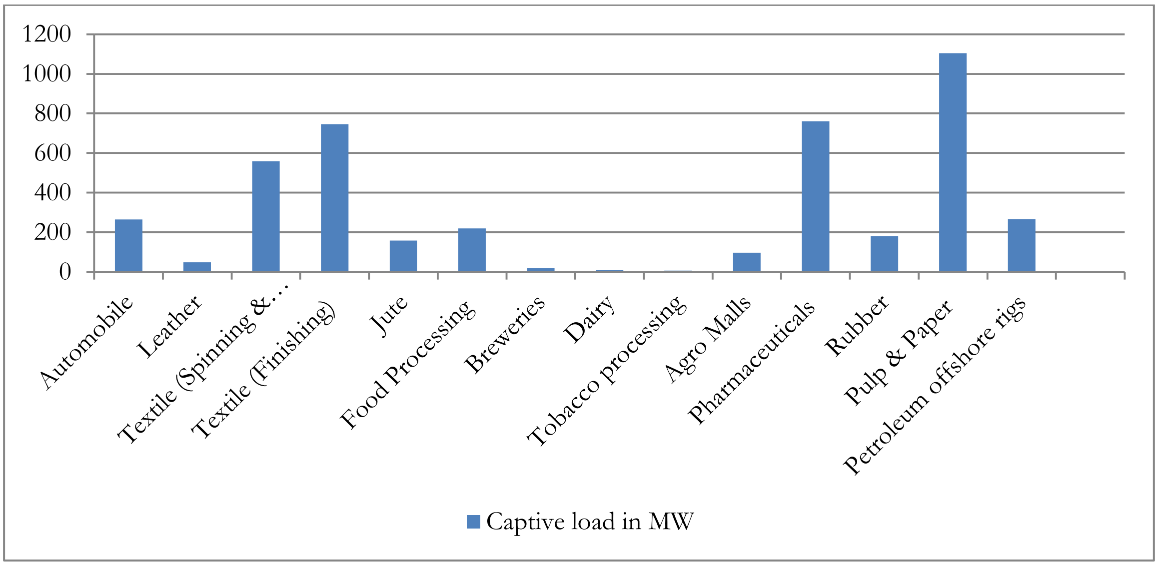
Figure-3: Heating and cooling loads in different industrial sectors



3.3 Power generation/DG sets /Captive load

The deficit between demand of electricity and its supply in the country has compelled many large and medium scale industries to set up their own captive power plants, both grid-connected as well as off-grid. For industries requiring relatively less power and low amounts of process steam, the diesel generator set is a preferred choice. Diesel based captive power generation accounts for 40% of captive load in the country today. The cost of such power generation is very high because of the high price of diesel fuel and is almost comparable with cost of power generated from solar sources. This analysis clearly indicates the edge solar power will have in the near future, as the fuel prices in case of DG sets is expected to rise and the cost of solar power is expected to reduce due to technological advancements. The captive power generations capacity of the 15 shortlisted sectors is shown in Figure-4.

Figure-4: Captive Power Generation in shortlisted Industrial Sectors



Various sources for incorporating data on captive generation were explored. Very few sources reported this data industry wise. The Infraline power database has been considered as the primary source for this data for many sectors. For other sectors like petroleum off shore rigs an estimates were made for this parameter.

3.4 Number and dispersion of units within a sector

The geographic dispersion of individual units in a sector plays a key role in determining the overall potential for adopting solar technology applications and the ease of replication. Clustered units have the advantage of jointly adopting such technologies with effective risk and cost sharing. The similarities and symmetry in clustered industrial units enhance the replication potential of solar technologies thus providing a larger market for solar applications.

Most of the data pertaining to these parameters were taken from the studies undertaken by Ministries of food processing, textiles, chemicals and other relevant sources of government sponsored studies. For industrial sectors with clustered units, the important clusters of the sector have been mentioned in the subsequent sections of the report.

3.5 Past solar experience

The past experiences of implementing solar applications, both as pilot and large scale projects, provides an oppurtunity to study the key barriers/risks, understand economics of scale and uncertainties in cash flows. Prior examples of successful solar applications is likely to provide increased funding options for similar future initiatives, with many institutions willing to finance such projects in the key industrial sectors. The industrial sectors with prior experience with solar technologies can also effectively evaluate government policies as compared to sectors with no prior solar experience.

Several studies available in the public domain indicate significant potential for solar applications (especially for industrial process heating, drying, steam, etc.) in sectors like textile (finishing/dyeing), pulp and paper, leather, food processing, breweries, pharmaceuticals, dairy and electroplating. However, very few studies have actually reported case studies on the adoption of such applications in the past.

Due to incomplete availability of relevant data, other sources like discussions with associations, sector experts along with in-house expertise were used for making qualitative judgements about this parameter.

3.5.1 Ranking based on the weightage of the different parameters

The weightage for each parameter was given in the matrix developed above and the total was used to rank all the 15 industrial sectors. The ranking of all the 15 sectors is given in Table-6 (For detailed analysis, please refer to Annexure 1).

Table-6: Final ranking of the 15 sectors

Sectors	Total marks	Rank
Textile (Finishing)	900	1
Pulp and Paper	790	2
Pharmaceuticals	770	3
Leather	730	4
Food processing	730	4
Dairy	690	6
Textile (Spinning and weaving)	630	7
Electroplating/Galvanizing	620	8
Automobile	600	9
Agro malls	500	10
Rubber	490	11
Breweries	480	12

Sectors	Total marks	Rank
Jute	370	13
Tobacco processing	300	14
Petroleum offshore rigs	290	15

A further detailed study was carried out for the top 10 sectors in the table given above. The detailed study included the identification of various processes in the industry, mapping different solar technologies for all the identified processes and estimation of conventional energy replacement potential.

4 Solar energy technologies

The integration of solar generated heat into industrial production processes is a challenge for both the process engineer and the solar expert. The unavailability of solar power around the clock and the constant demand for process heat is a challenge for the application of solar energy to industrial production processes. It is therefore very important to keep in mind these factors while mapping any solar technology to a specific industrial application.

Two major sources of solar energy utilisation have been considered in this study: solar thermal and solar PV. The utilisation of these two technologies has been explained in brief in the following paragraphs:

4.1 Solar thermal applications in industries

The heat produced from solar energy can be used for various industrial applications like process heating, drying, distillation/desalination, water heating, space heating, refrigeration etc.

4.1.1 Solar water heating

A solar water heater is a combination of an array of collectors, an energy transfer system, and a thermal storage system. In active SWH (solar water heating) systems, a pump is used to circulate the heat transferring fluid through the solar collectors, whereas in passive thermo-siphon systems; the natural circulation of working fluid is used. The amount of hot water produced from a solar water heater critically depends on design and climatic parameters such as solar radiation, ambient temperature, wind speed etc.

Solar water heaters are basically classified into two types:

- Flat Plate Collectors
- Evacuated Tube Collectors

4.1.1.1 Flat Plate Collectors

The most commonly used panels for solar water heating are flat-plate collectors. These consist of a thin metal box with insulated sides and back, a glass or plastic cover (the glazing) and a dark colour absorber. The glazing allows most of the solar energy into the box whilst preventing the escape of much of the heat gained. The absorber plate is in the box painted with a selective dark colour coating, designed to maximize the amount of solar energy absorbed as heat. Running through the absorber plate are many fine tubes (usually made of copper), through which water is pumped. As the water travels through these tubes, it absorbs the heat. This heated water is then gathered in a larger collector pipe through which it can be transported into the hot water system.

4.1.1.2 Evacuated Tube Collectors

These collectors are more modern and more efficient in design. These can heat water to much higher temperatures and require less area. However, they are also correspondingly more expensive. Instead of an absorber plate, water is pumped though absorber tubes (metal tubes with a selective solar radiation absorbing coating), gaining heat before going into the collector pipe. Each absorber tube is housed inside a glass tube from which the air has been evacuated forming a vacuum. The glass tube allows solar radiation through to the absorber tube where it can be turned into heat. The vacuum eliminates convective as well as conductive heat loss and virtually all heat absorbed is transferred to the water. Difference between FPC and ETC is as follows:

Table-7: Difference between ETC and FPC

ETC (Evacuated tube collector)	FPC (Flat plate collector)
• higher annual energy gain • lesser collector area needed for the same energy gain • higher efficiency at higher collector temperatures and low irradiation (winter) • temperature range 60-90 °C	• better cost/performance ratio • ability to substitute a conventional roof • better emptying behaviour and lower stagnation temperatures than evacuated tube collectors • temperature range 40-80 °C

4.1.2 Solar air heating

SAH (solar air heating) systems use air as the working fluid for absorbing and transferring solar energy. SAH system is used for the production of hot air for drying/space-heating applications.

4.1.3 Solar steam generation

Solar energy can be used to generate high-pressure steam. Three methods have been employed to generate steam using PTC collectors, namely, the steam-flash concept, the direct or in situ concept and the unfired-boiler concept.

4.1.4 Solar thermal refrigeration/cooling

Solar cooling can be considered for two related processes: to provide refrigeration for food as well as medicine preservation and to provide comfort cooling. It appears to be an attractive proposition due to the fact that the cooling demand is highest when the sunshine is strongest and this technology harnesses the sunshine to provide comfort cooling.

4.1.5 Solar PV

The photovoltaic effect refers to photons of light knocking electrons into a higher state of energy to create electricity. Solar cells produce direct current (DC) electricity from sun light, which can be used to power various types of equipments. Depending upon the type of absorbing material used, manufacturing technique/process adopted, and type of junction formed, the solar cell technologies can be broadly classified as the following:

- Wafer based crystalline silicon solar cells
- Thin-film solar cells, which includes, Copper Indium Gallium Diselenide (CIGS), Cadmium Telluride, Amorphous silicon (a-Si), etc.
- Concentrating Photovoltaic (CPV)

4.2 Supply and Value Chain

4.2.1 Solar PV- Crystalline Technology

The Solar PV- crystalline technology is based on the compound, silane polycrystalline trichlorosilane (SiH_4), which is processed to make ingots and wafers. Ingots and wafers form the building blocks for the solar cells. Solar cells are electrically connected and encapsulated as a module. Solar cells are also usually connected in series in modules, creating an additive voltage. Connecting cells in parallel will yield a higher current. Modules are then interconnected in series or parallel, or both, to create an array with the desired peak DC voltage and current. Photovoltaic modules often have a sheet of glass on the side facing the sun allowing light to pass while protecting the solar cells from abrasion due to wind-driven sand and debris, rain, hail etc.

In India, the ingots, wafers and fabricated solar cells are largely imported particularly from China, Taiwan and Europe due to technology constraints and low domestic manufacturing capacity. However, there is a large manufacturing base for solar modules in India as it is a labour intensive process. System integrators in India assemble modules to form solar panels which are used in a variety of applications like powering telecom towers, railway signals, irrigation, and water pumps.

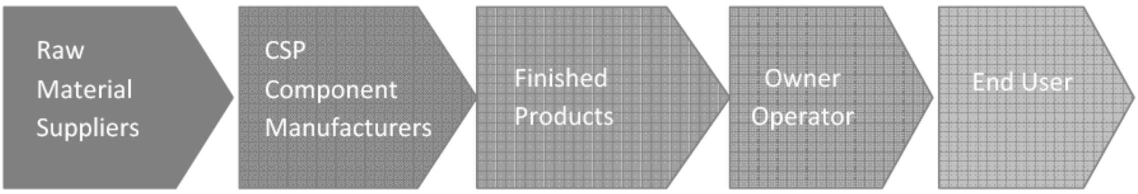
4.2.2 Solar PV- Thin Film Technology

The Solar PV- Thin Film (Amorphous silicon) technology is based on the raw material amorphous silicon, which is presently imported and then sprayed on to a substrate made of glass, steel, plastic to make thin film solar cells. These thin film cells are electrically inter-connected to form modules. These modules are further integrated to form solar panels which are used mainly for power generation.

4.2.3 Solar Thermal technology

The value chain of the solar thermal technology is depicted below:

Figure-5: Solar Thermal value chain



The value chain for solar thermal technologies starts from the raw material suppliers of steel, copper and brass. Concentrating solar power (CSP) technologies have four major components: the steam collector, steam generator, heat storage and central control. Manufacturers of these CSP components are the second part of the value chain. The collector system components vary according to the type of CSP plant. Third in the value chain are the finished products which include solar technology integrators/providers and plant developers. The developers or the project integrators integrate the manufactured components into a functioning plant. Owners are either the developer or the customers who have commissioned the plant.

5 Detailed study of potential sector

A detailed study of the shortlisted 10 sectors was carried out to identify the various processes in the industry, map the different solar technologies for all the identified processes and to estimate the potential for conventional energy replacement. The following methodology was used for the detailed study:

Identification of various processes in the industry: This task involved a comprehensive assessment of all the industrial processes currently prevailing in the industry.

Mapping of suitable solar technologies to all the identified industrial processes: The solar technology applications identified in the previous task were mapped to the individual processes based on the possibility of achieving desired operating parameters for that process. Stakeholder consultations were carried out wherever necessary to derive the essential parameters and take subjective decisions for mapping of the solar applications to industries.

Estimation of conventional energy replacement potential for identified industrial processes: An estimate of the various conventional energy sources (coal, petroleum products, electricity, etc.) being used by the different industrial processes was made. A fair estimate of the potential to replace this conventional energy with solar energy was made assuming factors like load profiles, usage hours, etc. A detailed explanation of the methodology and calculations involved in determining the conventional energy replacement potential in the 10 shortlisted sectors for the prefeasibility analysis is given in Annexure-2.

The detailed pre-feasibility study of the 10 shortlisted sectors is given in the subsequent sections.

5.1 Textiles (Finishing)

5.1.1 Overview

The textile sector is one the largest and oldest sectors in the country and amongst the most important in the economy in terms of output, investment and employment. The sector employs nearly 35 million people and after agriculture, it is the second largest employer in the country. Its importance is underlined by the fact that it accounts for around 4% of the country's Gross Domestic Product (GDP), 14% of industrial production, 9% of excise collections, 18% of employment in industrial sector and 16% of the country's total export earnings. While textile exports are increasing, with India becoming the largest exporter of cotton yarn and an important player in readymade garments, the country's international textile trade constitutes a mere 3% of the total world trade in textiles.

Textile processing is a general term that covers steps right from singeing (removal of protruding fiber) to finishing and printing of the fabric. Of the entire industry volume of about 5 million tonnes, polyester and polyester filament yarn account for about 1.7 million tonnes, and acrylic, nylon and viscose for 300,000 tonnes, the balance is represented by cotton textiles. A majority, approximately three fourths of the textile mills, are privately run. Textiles units are by and large cluster centric. Table-8 below gives details of major production centers in the country.

Table-8: Textiles cluster locations in India

State	Locations	Product
Maharashtra	Solapur	Terry Towel
Tamil Nadu	Salem	Cotton Fabrics

Tamil Nadu	Erode	Textile Fabrics
Haryana	Ludhiana	Knitwear
Haryana	Panipat	Home Furnishing
Tamil Nadu	Madurai	Cotton Yarn
Tamil Nadu	Karur	Home Furnishing
Gujarat	Ahmadabad	Textile and Clothing
West Bengal	Kolkata	Hosiery
Uttar Pradesh	Kanpur	Defence Textiles and Hosiery
Gujarat	Surat	Polyester Fabrics
Orissa	Bhubaneswar	Ikkat Fabrics
Madhya Pradesh	Chanderi	Chanderi Silk
Karnataka	Bellary	Jeans
Rajasthan	Jaipur	Sanganer Print
Jammu Kashmir	Srinagar	Khadi
Kerala	Kannur	Home Furnishing

Source: Ministry Of Textiles, Govt. of India

5.1.2 Energy consumption profile

ASI has reported 4.46 Mtoe of primary energy consumption in Textile (Finishing) in 2007-08. Table-9 and Figure-6 show the primary source wise share of energy consumption for the year 2007-08.

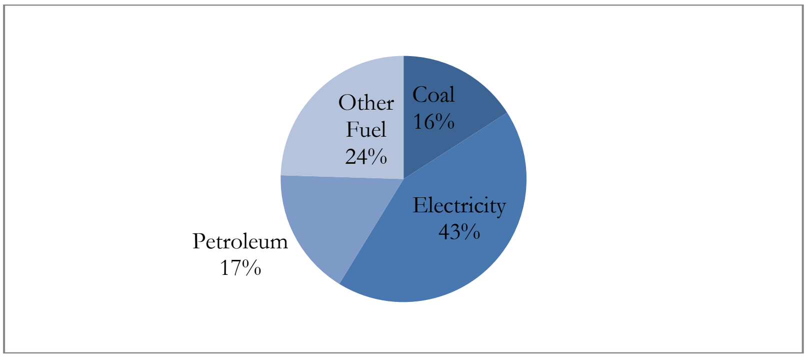
Table-9: Source-wise distribution of energy consumption in Textile Finishing Industry

Industrial sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)
Textile (finishing)	Wet process	2,672	3,590	185

Source: ASI database-2007-08

In order to derive the cost wise share of different fuels employed in the textiles finishing sector, the quantity of different fuels (source ASI database 2007-08) was monetized and its corresponding monetary share is depicted in the graph below:

Figure-6: Cost-wise share of different fuels in Textile Finishing Industry



Source: PwC analysis-based on ASI database-2007-08

5.1.3 Process flow

The textile finishing industry involves lot of operations to convert the inputs into a final product. It is not necessary that all the products follow the same process sequence but broadly these do not vary by a large extent. The major operations involved are:

5.1.3.1 Desizing

For fabrics made from cotton or blends, the warp threads are coated with an adhesive substance know as 'size' to prevent the threads from breaking during weaving. After weaving, the size must be removed again in order to prepare the fabric for dyeing and finishing. This process is called desizing and it must be carried out by treating the fabric in a detergent solution such as acids, alkali or oxidising agents at temperatures up to 90 °C and then rinsing them with fresh water.

5.1.3.2 Scouring

Scouring is an important process. In this process, non-cellulosic components from native cotton are completely or partially removed. Scouring gives fabrics a high and even wetability to be bleached and dyed successfully. Scouring processes use steam and detergents like highly alkaline chemicals and caustic soda to remove oils and minerals. High temperatures between 90 °C to 110 °C and long retention times up to 12 hours are used to ensure thorough saturation and cleaning. Finally, the fabric is rinsed.

5.1.3.3 Bleaching

Natural fabrics such as cotton are normally bleached with hydrogen peroxide before dyeing. Bleaches are highly reactive chemicals and any peroxide left on the fabric can interfere with the dyeing process. Thus, a thorough 'bleach cleanup' is necessary. The traditional method is to neutralize the bleach with a reducing agent, but that has to be controlled precisely. In this process the fabric is bleached, washed and rinsed several times to achieve uniformity and improve its ability to absorb dyestuffs later in the finishing operation.

5.1.3.4 Mercerizing

A treatment of cotton yarn or fabric to increase its luster and affinity for dyes is know as mercerizing. The material is immersed under tension in a cold sodium hydroxide (caustic soda) solution in warp or skein form or in pieces, and is later neutralized in acid. The process causes a permanent swelling of the fiber and thus increases its luster. It is an optional step and produces a warm wastewater stream. Mercerizing requires temperatures in the range of 60 °C to 70 °C.

5.1.3.5 Dyeing

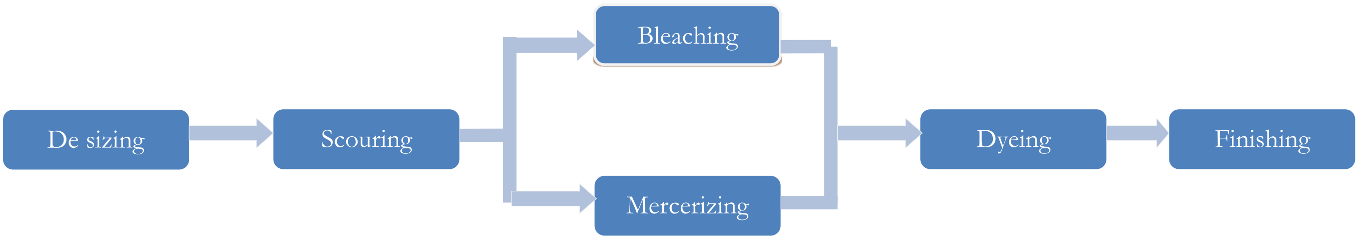
It is the process of colouring fibres, yarns or fabrics with either natural or synthetic dyes. Dyeing requires temperatures in the range of 70 °C to 90 °C.

5.1.3.6 Finishing

All the processes through which the fabric is passed after bleaching, dyeing or printing in preparation for the market or its use is called finishing. Finishing includes operations such as heat-setting, napping, embossing, pressing, calendaring and the application of chemicals that change the character of the fabric. The term finishing is also sometimes used to refer collectively to all processing operations above, including bleaching, dyeing, printing, etc. Finishing plants are thermal energy-intensive, requiring large quantities of hot water ranging from 40 °C to 100 °C. The hot water is almost universally heated with steam using steam-to-water heat exchangers, direct spurging or storage tank heating.

Many plants recover heat from waste streams with heat exchangers in order to preheat the process water. Large quantities of steam are also used for heating drying cans and to a lesser degree for humidifying space conditioning air. Figure 7 shows the entire finishing process flow.

Figure -7: Operations sequence in Textile Finishing (Wet Process)



5.1.4 Mapping solar technology applications

As explained above, textile finishing requires hot water at temperatures ranging from 40 °C to 110 °C at different stages of the process. The hot water of this range can easily be generated through the use of solar energy. Various solar technologies were identified which can be used to meet these hot water requirements. The recommended technologies are given below in Table-10.

Table-10: Solar mapping in Textile Finishing

Process	Energy being used	Temperature required °C	Recommended solar technology
De-sizing	Thermal	60-90	ETC
Scouring	Thermal	90-110	ETC/Concentrators
Bleaching	Electrical	----	Solar PV
	Thermal	90-93	ETC
Mercerizing	Electrical	----	Solar PV
	Thermal	60-70	FPC
Dyeing	Thermal	70-90	FPC
Finishing	Thermal	40-100	ETC

Source: IIT Delhi paper

5.1.5 Solar energy potential assessment

Conventional energy replacement potential in this sector has been estimated at a national level. With regards to the employment of solar applications as a conventional energy replacement measure, it is assumed that the usage of solar applications will be done by integrating it in to the existing energy supply system. Table-11 shows the conventional energy replacement potential available with the adoption of different solar thermal technologies for various processes of the finishing industry and it has been estimated to be about 383 ktoe. In monetary terms this potential is equivalent to Rs. 7,692 million/annum.

Table-11: Conventional energy replacement potential through solar applications in Textile Finishing

Process	Energy replacement (ktoe)	Estimated monetary savings (Rs. Million/annum)
Desizing	65	1,306
Scouring	51	1,035
Bleaching	65	1,306
Mercerizing	18	361
Dyeing	108	2,166
Finishing	75	1,516
Total	**383**	**7,692**

Source: PwC analysis

5.2 Pulp and Paper industry

5.2.1 Overview

The pulp and paper sector is one of the most energy intensive sectors within the Indian economy. The paper industry in India is the 15th largest paper industry in the world and accounts for about 1.6% of the world's production of paper and paperboard. There are about 515 units engaged in the manufacture of paper, paperboards and newsprint in India. The paper industry has been considered in the category of Designated Consumers by Bureau of Energy Efficiency (BEE). The geographical presence of the industry in India is shown in Table-12.

Table-12: Location of Pulp and Paper clusters in India

State	Locations
West Bengal	Titagarh
Maharashtra	Pune, Ballarshah
Andhra Pradesh	Kaghaznagar, kamalapuram, Sarapaka, Vikarabad, kakinada, Rajahmudry
Orissa	Jaykapuram, GaganPur
Tamil Nadu	Kagithapuram
Haryana	Yamuna nagar, Bahadurgarh
Uttar Pradesh	Saharanpur
Goa	Dandel

Source: NPC report "Development of guidelines for water conservation in pulp and paper sector"

5.2.2 Energy consumption profile

ASI reports 7.56 Mtoe of primary energy consumption in the pulp and paper sector in 2007-08. Table-13 shows the energy consumption by fuel type in the pulp and paper industry.

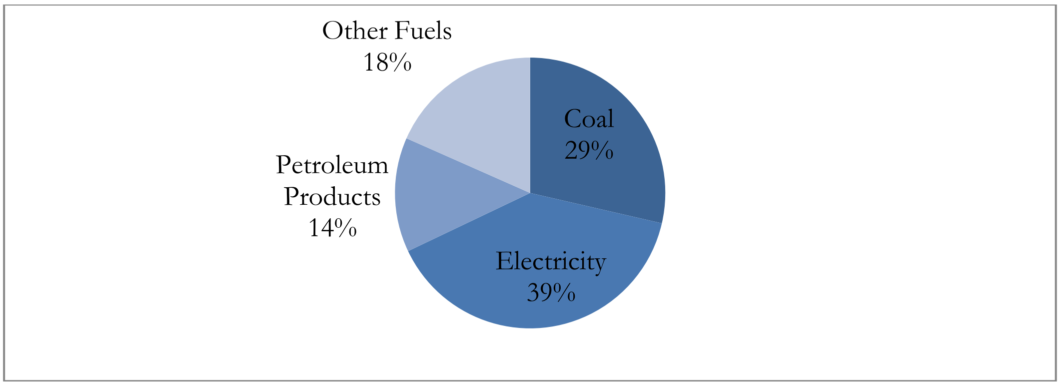
Table-13: Source-wise distribution of energy consumption in Pulp and Paper Sector

Industrial sector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)
Pulp and Paper	4,779	3,286	151.23

Source: ASI database 2007-08

In order to derive the cost -wise share of different fuels employed in the pulp and paper sector, the quantity of different fuels (Source: ASI database 2007-08) was monetized and its corresponding monetary share is depicted in graph Figure- 8.

Figure- 8: Cost-wise breakup of fuel used in the Pulp and Paper Industry



Source: PwC analysis-based on ASI database-2007-08

5.2.3 Process flow

The pulp and paper industry converts fibrous raw materials into pulp, paper and paperboard. First, raw materials are processed into pulp, then paper and paper products are produced out of this pulp. Different plant categories exist depending on whether they produce only pulp (pulp mills) for further processing or only paper out of purchased pulp and / or recycled waste paper (paper mills). The third category consisting of the integrated pulp and paper mills combines the two processes and is the most common in the paper industry.

The five principal steps in pulp and paper production are wood preparation, pulping, bleaching, chemical recovery and papermaking.

5.2.3.1 Wood preparation

Wood preparation involves breaking the wood down into small pieces suitable for subsequent pulping operations. Major wood preparation processes include debarking and chipping. This process requires little energy.

5.2.3.2 Pulping

Wood is ground and pulped to separate the fibres from each other and to suspend them in water. Pulping breaks apart the wood fibres and cleans them of unwanted residues. Pulping can be performed using chemical, mechanical or combined chemical-mechanical techniques. In chemical pulping, wood chips are cooked in an aqueous solution at high temperature and pressure. Chemical processes dissolve most of the glue that holds the fibres together (lignin) while leaving the cellulose fibres relatively undamaged. This process results in high quality paper with a yield of only 40-60% of the weight of the dry wood.

5.2.3.3 Bleaching

Bleaching whitens pulps for the manufacture of writing, printing, and decorative papers.

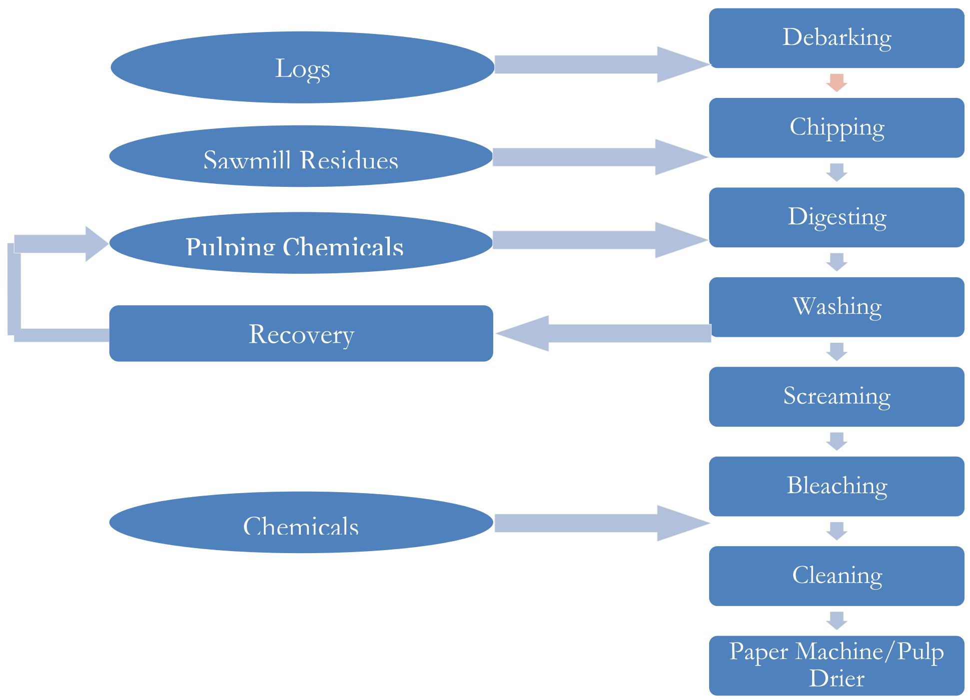
5.2.3.4 Chemical recovery

Chemical recovery regenerates the spent chemicals used in kraft chemical pulping. Chemical pulping produces a waste stream of inorganic chemicals and wood residues known as black liquor. The black liquor is concentrated in evaporators and then incinerated in recovery furnaces many of which are connected to steam turbine cogeneration systems.

5.2.3.5 Papermaking

Papermaking consists of the following steps: preparation, forming, pressing and drying. Preparation and drying are the most energy intensive processes.

Figure-9: Pulp and Paper making process



5.2.4 Mapping solar technology applications

A majority of the processes in this industry require high volumes of water at critical working temperatures thus creating a huge demand for hot water supply and storage systems. Also, there are other thermal processes which require significant process heat at temperatures well below 250 °C. There is also a huge demand for drying applications which are critical for processing the final products. A variety of solar drying systems can be very effective in reducing a significant amount of conventional energy consumption which is normally used for drying applications. Table-14 shows mapping of solar technologies to different processes in the pulp and paper industry.

Table-14: Mapping of solar technologies in Pulp and Paper Industry

Process	Energy being used	Application media	Temperature required ˚C	Recommended solar technology
Debarking and chipping	Thermal	Hot water	40-60	FPC
Digesting and washing	Thermal	Hot water	> 90	ETC, Solar Concentrators
	Electrical			Solar PV
Pulping	Thermal	Process heating	>120	Solar Concentrators
	Thermal	Boiler feed water	70	FPC
Bleaching	Thermal	Process heating – boiler feed water heating	70	FPC
	Thermal	Process heating – Steam	> 120	Solar Concentrators
Paper drying	Thermal	Hot air supply	> 120	Solar air heating systems

Source: NPC report "Development of guidelines for water conservation in pulp and paper sector"

5.2.5 Solar energy potential assessment

There is a high potential of using solar water heating (SWH) in the different processes of this sector. Solar air heating systems are also technically feasible for adoption in the paper drying applications. The potential applications of SWH in the pulp and paper industry are:

- Integration of SWH to provide process heat: In this application the SWH can be effectively integrated in the soaking of pulp to provide the process heat required during the day-time
- Pre-heating of boiler feed water: In this application, either the entire boiler feed water or a part of it is heated in solar water heaters to a temperature of 60-80 °C before being supplied to the boiler. This reduces the demand of heat or fuel being used in the boiler.

The conventional energy replacement potential has been estimated at a national level, considering the integrated solar energy systems and the existing energy supply systems. Table-15 shows the conventional energy replacement potential estimated in the pulp and paper industry. The total energy replacement potential is estimated to be about 45 ktoe.

Table-15: Conventional energy replacement potential through solar applications

Processes	Type of fuel	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
Wood preparation, pulping, bleaching and paper drying	LDO, Coal, Rice Husk, Pet Coke	45	1,700.00

Source: PwC analysis

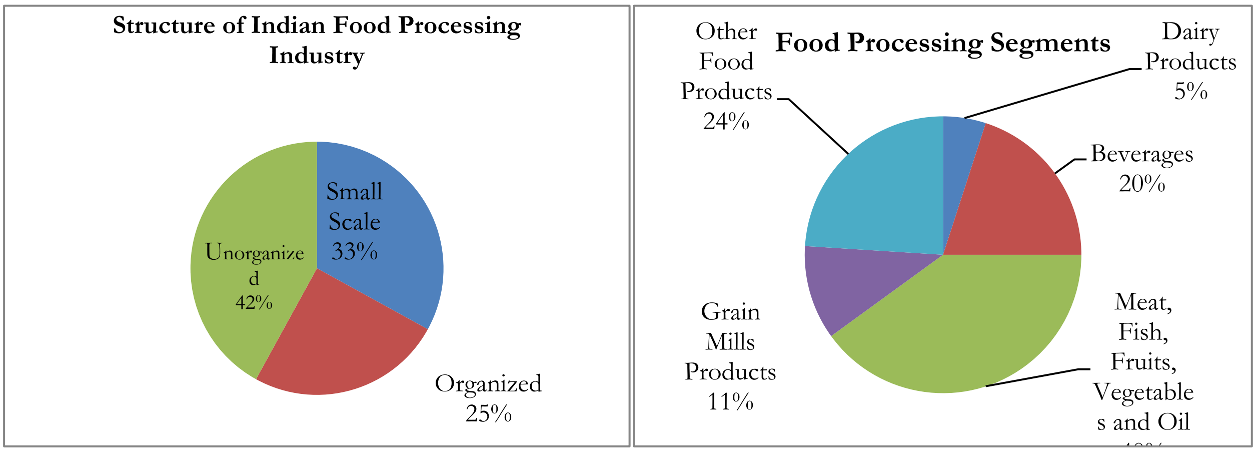
5.3 Food Processing

5.3.1 Overview

The food processing sector is a highly fragmented industry and it widely comprises of the sub-segments like: fruits & vegetables, milk & milk products, beer & alcoholic beverages, meat & poultry, marine products, grain processing, packaged or convenience food and packaged drinks. Most entrepreneurs in this industry are small in terms of their production and operations and are largely concentrated in the unorganized segment. Though the organized sector seems comparatively small, it is growing at a much faster pace.

Figure-10: Structures and share of different segments in Food Processing Industry in India

Source: Ministry of food processing, Government of India



Since the dairy industry has been considered separately for analysis in this study, this section will focus mainly on the other four major segments of food processing industry as shown in Figure-10. The following sections will discuss in brief the current status of the four major segments in the food processing industry in India.

5.3.1.1 Meat, fish, fruits, vegetables and oil

The installed capacity of the fruits and vegetables processing industry has doubled from 1.10 million tonne in January 1993 to 2.10 million tonne in 2006. The major processed items in this segment are fruit pulps and juices, fruit based ready-to-serve beverages, canned fruits and vegetables, jams, squashes, pickles, chutneys and dehydrated vegetables.

Presently the processing level of buffalo meat is estimated at 21%, poultry is estimated at 6% while marine products are estimated at 8%. However, only about 1% of the total meat is converted into value added products like sausages, ham, bacon, kababs, meatballs, etc.

The processing of marine produce into canned and frozen forms is carried out completely for the export market. With regards to infrastructure facilities for the processing of marine products, there are 372 freezing units with a daily processing capacity of 10,320 tonne and 504 frozen storage facilities for safe storage with a capacity of 138,229.10 tonnes, besides. Besides this, there are 11 surimi units, 473 pre-processing centers and 236 other storage facilities.

Oil seed processing is another major segment, an activity largely concentrated in the cottage industry. According to estimates, there are approximately 2.5 lakh 'ghanis' and 'kolus' which are animal operated oil expellers, 50,000 mechanical oil expellers, 15500 oil mills, 725 solvent extraction plants, 300 oil refineries and over 175 hydrogenated vegetable oil plants.

5.3.1.2 Grain mill products

The processing of grain includes milling of wheat, rice and pulses. In 1999-2000, there were more than 91,000 rice hullers and 260,000 small flourmills engaged in primary milling. There are 43,000 modernized rice mills and huller-cum-shellers. Around 820 large flourmills in the country convert about 10.5 million tonnes of wheat into wheat products. Also, there are 10,000 pulse mills milling about 75% of pulse production of 14 million tonnes in the country.

5.3.1.3 Beverages

India is considered to be the third largest market for alcoholic beverages in the world. The demand for beer and spirits is estimated to be around 373 million cases per year. The Indian soft drink segment is considered to be the 3rd largest in the packaged foods industry. Over 100 plants are engaged in the aerated soft drinks industry and provide significant employment. It has attracted one of the highest FDI in the country. Strong forward and backward linkages with the glass, plastic, refrigeration, sugar and transportation industry further strengthen the position of this industry.

5.3.1.4 Other food products

This mainly consists of ready-to-eat and ready-to-cook products, salted snacks, chips, pasta products, cocoa based products, bakery products, biscuits, soft drinks, etc. There are around 60,000 bakeries, several pasta food units and 20,000 traditional food units in India. The bakery industry is among the few processed food segments whose production has been increasing consistently in the country over the last few years. Products of bakery include bread, biscuits, pastries, cakes, buns, rusk, etc. This activity is mostly concentrated in the unorganized sector. Bread and biscuits constitute the largest segment of consumer foods with an annual production of around 4 million tonne. Cocoa products like chocolates, drinking chocolate, cocoa butter substitutes and cocoa based malted milk foods are highly in demand these days, 20 production units are engaged in their manufacture with an annual production of about 34,000 tonnes.

5.3.2 Energy consumption profile

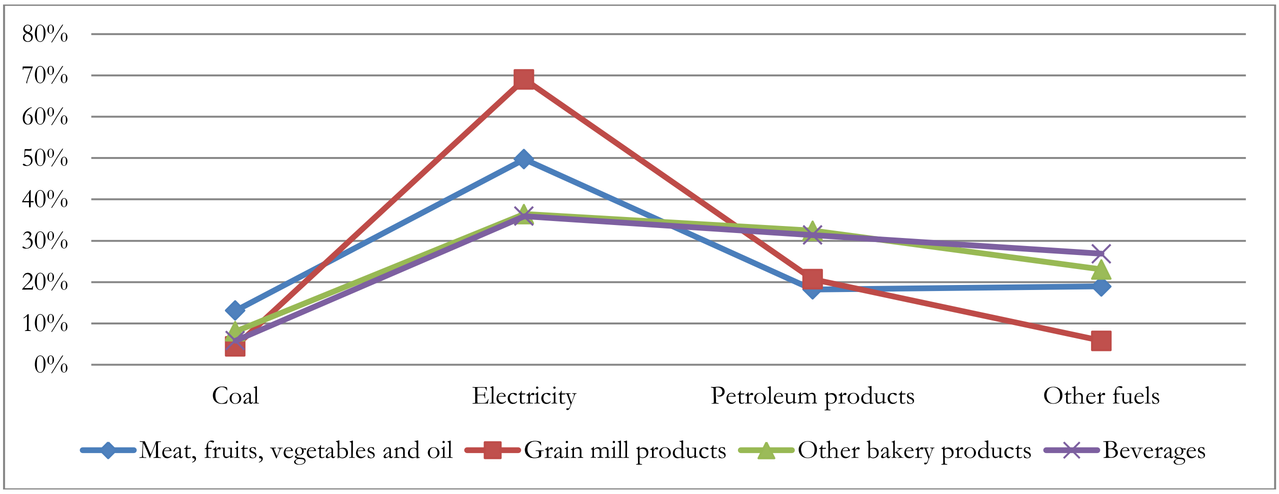
ASI has reported a primary energy consumption of 4.5 Mtoe in the food-processing sector during 2007-08. Table-16 and Figure-11 shows the primary source wise distribution of energy consumption by the various segments of food processing industry.

Table-16: Source-wise distribution of energy consumption in Food Processing Sector

Industrial sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)
Food processing	Meat, fish, fruits, vegetables and oil	961	2,278	111.68
	Grain mill products	63	2,535	72.28
	Beverages	619	2,163	250.85
	Other food products	196	873	98.89

Source: ASI database-2007-08

Figure-11: Primary Source-wise distribution of energy consumption



Source: PwC analysis-based on ASI database-2007-08

Figure-11 suggests that all four segments of this industry are energy intensive. The meat, fruits, vegetables, oil and grain mill product segments mainly use electrical energy for preservation and processing. Segments like beverage and other food products have a significant heat demand in many of the processes which account for a high share of petroleum products and other biomass fuels that produce the steam.

5.3.3 Process flow

This section will give the details of various thermal, physical, mechanical and chemical processes prevalent in the four major segments of the food processing industry.

5.3.3.1 Meat, Poultry, Fish, Fruits, Vegetables and Oil

Overview of the steps being followed in the meat & fish processing plants, poultry, fruits, vegetable & oil processing is shown below:

Figure-12: Meat and fish processing techniques

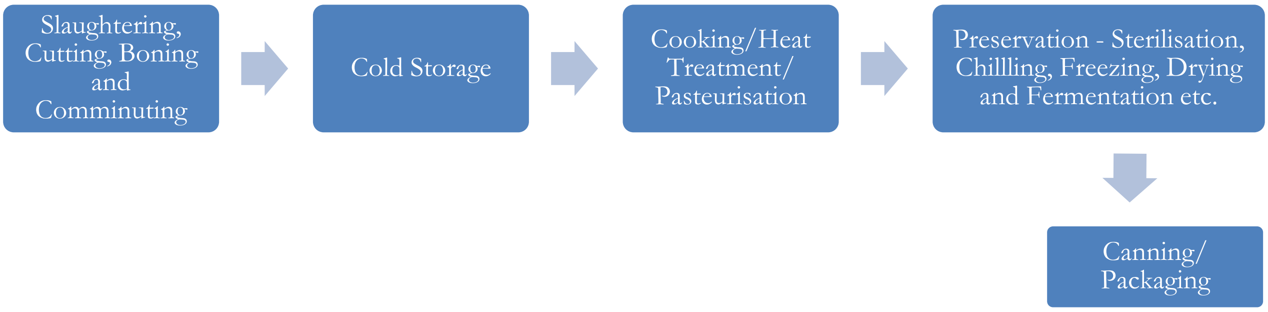


Figure-13: Poultry processing techniques

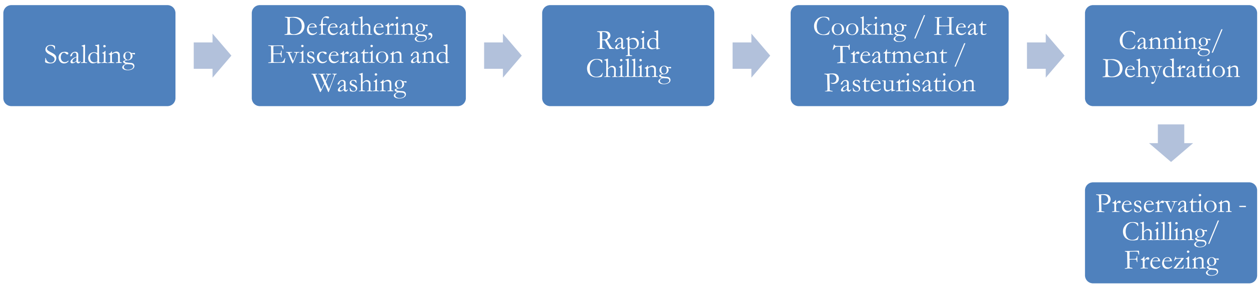


Figure-14: Fruits and vegetables processing flow

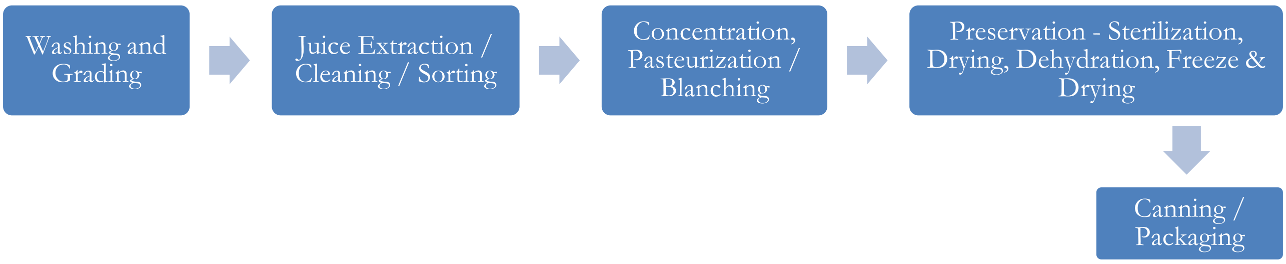
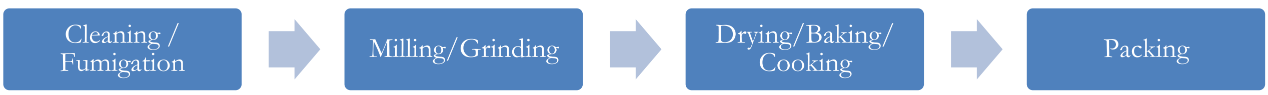


Figure-15: Vegetable oil process flow

5.3.3.2 Grain Mill products

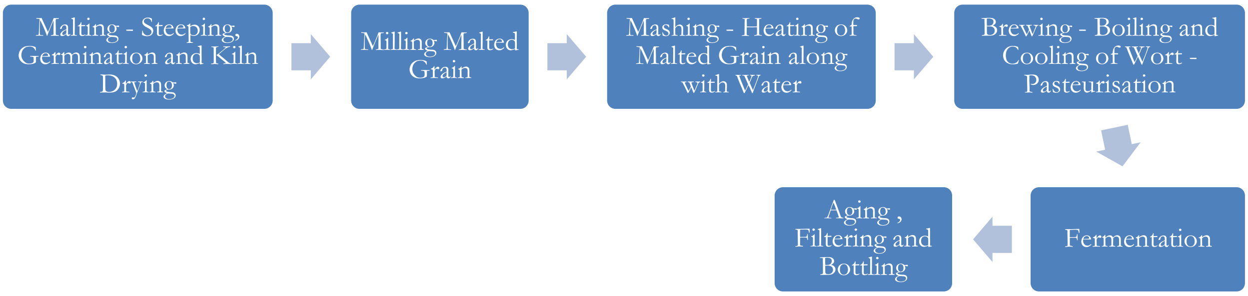
Figure-16: Grain mill process flow



5.3.3.3 Beverages

Overview of the steps being followed in the beverages making is shown below:

Figure -17: Beverage processing flow



5.3.3.4 Other food products

Overview of the steps being followed in this industry is shown below:

Figure -18: Miscellaneous food product process flow

Figure-- 12,-, 13,-, 14,-, 15,-, 16,-, 17 and -18 show that heat treatment processes like pasteurisation, sterilisation and food preservation through techniques such as drying, freezing/chilling, packaging and canning are the common processes prevalent in the major sub-segments of the food processing industry. These operations consume most of the energy required in the industry.

5.3.4 Mapping solar technology applications

This industry employs a large number of thermal processes which require high volumes of hot water and storage systems. There are also other thermal processes which require significant process heat with temperatures well below 250 °C. The preservation techniques, which adopt various cooling applications, also significantly contribute to the heat energy consumed in this industry. Apart from these, there is also a large demand for drying applications which are critical for processing the final products. A variety of solar drying sytems could be effective in significantly reducing the consumption of conventional energy, fuels which are normally required for drying applications. Table-17 shows the mapping of solar energy technologies with the potential processes of this industry.

Table- 17: Solar technology mapping in Food processing

Process	Energy/Fuel being used	Application media	Temperature required ˚C	Recommended solar technology
Washing and cleaning	Electricity and Boiler fuels like furnace oil, rice husk, etc.	Hot water	40-60	FPC
Chilling/cold storage	Electricity and diesel	-	< 5	Solar evacuated tube systems, driving absorption chillers

Cooking, extraction, mashing, brewing and baking	Boiler fuels like furnace oil, rice husk, etc.	Process heat	80 – 100	ETC
Pasteurization/ Blanching	Boiler fuels like furnace oil, rice husk, etc.	Process heat	70	FPC
Sterilization/ Bleaching/ Hydrogenation	Boiler fuels like furnace oil, rice husk, etc.	Process heat	100-120	Solar concentrators
		Boiler Feed Water	60-70	FPC
Drying/ Dehydration	Electricity and Boiler fuels like furnace oil, rice husk, etc.	Hot air	70-80	ETC (Air based)

5.3.5 Solar energy potential assessment

The food processing sector in India, especially segments like meat, poultry, fruits and vegatables are mostly unorganized. MoFPI has estimated that only 2.20% of the total production of fruits and vegetables in the country are processed before consumption. However, there are a number of solar energy installations being reported in various secondary sources for these segments, especially for drying applications.

Table-18 shows the estimated potential for replacing conventional energy in the identified processes/segments in this industry. The estimate is based on the total production estimates, specific energy consumption, fuel mix, solar system penetration capacity and other essential parameters gathered from various secondary sources. The potential assessment considers only the integrated solar energy systems with the existing energy supply systems in the industry.

Table -18: Conventional energy replacement potential through solar applications

Process	Energy/Fuel being used	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
Edible oil processing	Boiler fuels like furnace oil, rice husk, etc.	43	830
Breweries	Boiler fuels like furnace oil, rice husk, etc.	29	560
Breweries	Electricity	6	300
Drying fuits, Vegetables	Electricity and Boiler fuels	2	92
Total		**80**	**1,782**

Source: PwC analysis

5.4 Leather Industry

5.4.1 Overview

The leather sector in India occupies a very important place on account of the substantial export earnings, employment opportunities and numerous applications in the down-stream sectors of the consumer products industry. The industry has a diversified product base and a majority of them are SMEs. The industry structure is predominantly unorganized and decentralised. The products include semi-finished and finished leather, footwear, garments, gloves, saddles, harnesses and other leather goods. The production of leather and leather products is by and large cluster centric. Table-19 below provides the details of major production centers in the country.

Table- 19: Major leather clusters in India

State	Locations	Products
Andhra Pradesh	Hyderabad	Leather
Delhi	Delhi	Leather Garments and Leather Goods
Maharashtra	Mumbai	Leather and Footwear
Punjab	Jalandhar, Ludhiana	Leather
Tamil Nadu	Chennai, Ambur, Ranipet, Vaniyambadi, Trichi, Erode and Dindigul	Leather and Footwear
Karnataka	Bangalore	Leather Garments
Uttar Pradesh	Kanpur, Agra	Leather, Footwear and Saddles
West Bengal	Kolkata	Leather and Leather Goods

Source: ILFS study "Diagnostic Study of Kanpur Leather Cluster"

As the leather sector in India comprises of units making different leather products at different stages of the industry's value chain, the production units can be broadly classified into the following categories:

- tanneries –which process raw hides/skins to produce semi-finished and finished leather
- consumer goods production units – which produce leather products like safety and fashion footwear and as well as its components, saddles and harnesses, garments, gloves and other goods using finished leather
- integrated units – which process raw hides/skin and produce downstream consumer goods as mentioned above

A recent study by CII shows that the Indian leather market has been fragmented with about 2,200 tanneries of which 2,100 are small scale units, and over 8,000 leather product manufacturing units. The tanning industry is concentrated in three states viz. Tamil Nadu, West Bengal and Uttar Pradesh. Of the total number of tanneries in India, Tamil Nadu accounts for 52%, West Bengal 23% and U.P 12%.

5.4.2 Energy consumption profile

ASI has reported that 150 ktoe of primary energy was consumed in the leather sector in 2007-08. Table-20 and Figure-19 show the primary source wise distribution of energy consumption in the sector.

Table-20: Source-wise distribution of energy consumption in the Leather Sector

Industrial Sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)	Other fuels (kilo tonne)
Leather	Tanning and dressing	21	213	14.62	90.28
	Leather products	16	449	27.43	90.50

Source: ASI database-2007-08

Above table indicates that a fairly significant portion of the energy requirement is met through fossil fuels. However, electricity is the major source of fuel driving most of the processes in the industry.

5.4.3 Process flow

The leather industry comprises of two major production cycles which characterize the adoption of different chemical and physical processes. The processing of raw hide / skins into semi -finished and finished leather called 'tanning' forms the first cycle and the production of consumer leather products from the finished leather forms the second cycle.

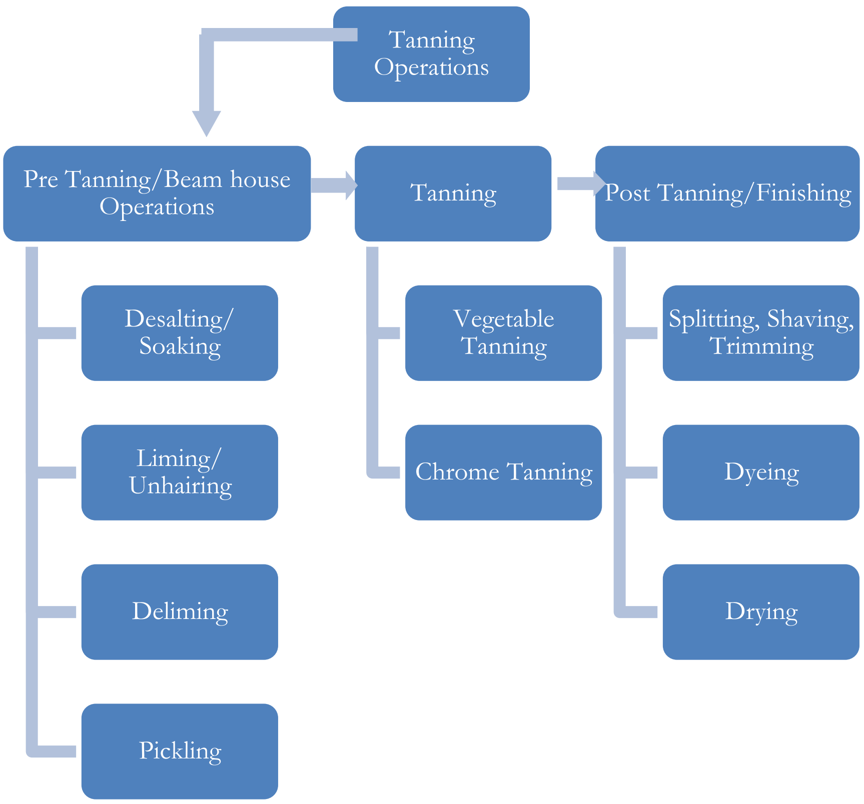
The following major operations come under the tanning process:

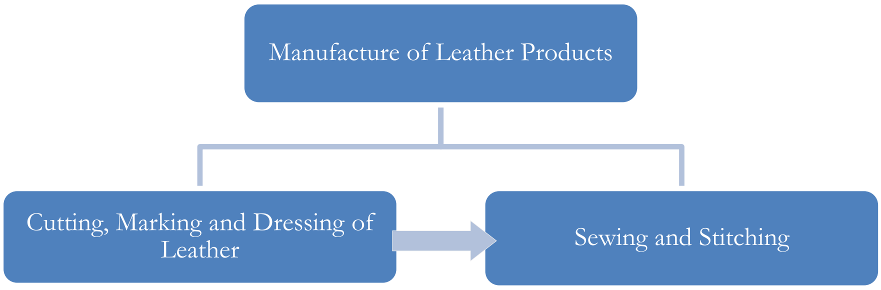
- beam house (pre-tanning) operations
- tanning operations
- post tanning and finishing operations

The manufacturing of consumer leather products include the following major operations:

- marking, cutting and dressing finished leather
- sewing and stitching

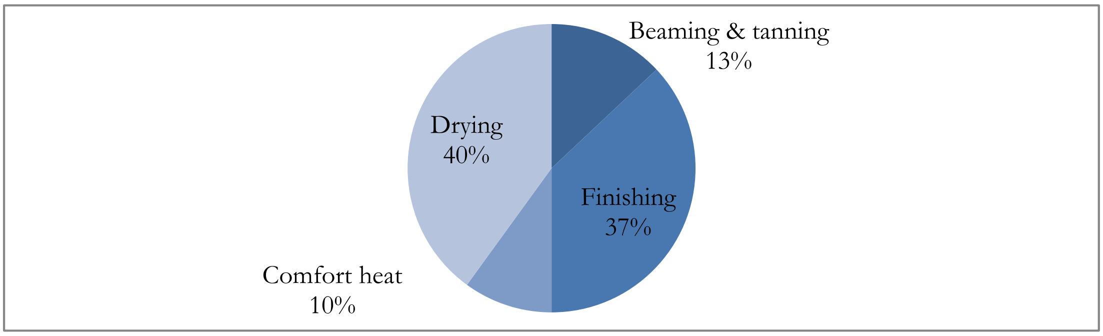
Figure -19: Process flow in Leather Industry





The tanning operations account for most of the heat energy consumed in the leather industry (see Figure-20). 'Wet-blue' is the intermediate stage of processing where the hide is converted from its raw state into a suitable material which will not putrefy or be attacked by bacteria. This process consists of a series of chemical and physical processes, and it requires high volumes of water at critical working temperatures, thus creating a huge demand for hot water supply and storage systems normally at temperatures in the range of 60–80 ˚C. This indicates a significant potential for solar thermal applications which have been proven to be very efficient in the temperature ranges mentioned above. Apart from these operations there is also a demand for drying applications which are critical for producing good quality leather. A variety of solar drying systems can be very effective in reducing significant conventional energy consumptions normally adopted for drying applications.

Figure-20: Process-wise energy consumption profile in Leather Industry



Source: Government College of Engineering & Leather Technology-Kolkata

5.4.4 Mapping solar technology applications

As mentioned earlier, tanning operations account for most of the industrial process heat consumed in the leather industry. These operations have a huge demand for hot water supply. Also, the drying applications used in the post tanning operations indicate a significant potential for adopting solar air and space heating technologies, thereby reducing conventional energy use. Apart from tanning operations, other processes are mostly mechanical operations (cutting, sewing, stitching, etc.) with electricity as the major source of energy consumption. Table-21 shows the mapping of solar energy technologies to various processes in the leather industry.

Table- 21: Solar technology mapping in Leather Industry

Process	Energy/Fuel being used	Application media	Temperature required ˚C	Recommended solar technology
Pre-tanning/beam house operations – soaking, liming, pickling, etc.	Electricity and Boiler fuels like furnace oil, rice husk, firewood, coal, etc	Hot water supply	40-60	FPC
Tanning (Chrome and	--do--	Hot water	60-80	ETC

Vegetable)		supply		
Post tanning operations – finishing, drying	--do--	Process heat	70 – 100	ETC (Air Based)

5.4.5 Solar energy potential assessment

The analysis given above makes it clear that the tanning operations of the leather industry are promising in terms of the adoption of solar thermal collectors (water-based) and solar air heating/drying systems. Table-22 shows the potential for replacing conventional energy consumption through the adoption of different solar thermal technologies for various processes in the tanning operations of the leather industry. It has been estimated that about 17 ktoe of energy can be replaced in the Indian leather tanning industry by solar thermal technologies.

Table- 22: Conventional energy replacement potential through solar applications

Process	Energy/Fuel being used	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
Pre-tanning and tanning operations (Chemical mixing)	Electricity and petroleum products	5	333
Post tanning operations (drying)	Electricity and petroleum products	12	693
Total		**17**	**1,026**

Source: PwC analysis

5.5 Dairy Industry

5.5.1 Overview

India has emerged as the largest milk producing country in the world with the present level of annual milk production estimated at 100 million tonnes. The dairy industry is dominated by the co-operative sector with 60% of the installed processing capacity in this sector. The 13.41 million farmer members of the dairy cooperative societies at the village level are a part of 128,799 village Dairy Cooperative Societies (DCS) also known as Primary Milk Producer Societies (consisting of about 130 farmers per DCS), which are connected to 180 district milk cooperatives (Milk Unions) and 17 State Federations. (Source: Study by RaboBank, 2010).

Milk processing in India is around 35% of total milk production, of which the organised dairy industry accounts for 13% of the milk produced while the rest of the milk is either consumed at farm level or sold as fresh, non-pasteurised milk through unorganised channels (Source: MoFPI). Tabe-23 shows the product mix of the Indian dairy industry.

Table- 23: India's Dairy product mix

Products	Percentage share
Fluid milk	46.0
Ghee	27.5
Butter	6.5
Curd/Yogurt	7.0
Khoa (Partially Dehydrated Condensed Milk)	6.5

Milk powder and Dairy whiteners	3.5
Paneer and Chhana (Cottage Cheese)	2.0
Others, including Cream, Ice Cream	1.0

Source: Global Agricultural Information Network-Report

5.5.2 Energy consumption profile

ASI has reported 210 ktoe consumption of primary energy in the dairy industry in 2007-08. Table-24 shows the source wise primary energy consumption in the dairy industry.

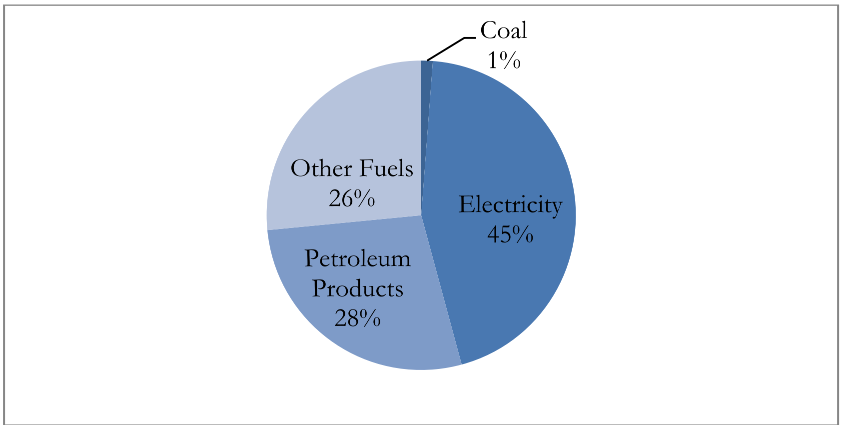
Table- 24: Source-wise distribution of energy consumption in Dairy sector

Industrial sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)	Other fuels (Rs. Million)
Dairy	Milk & derived products	47	863	70.92	2,569

Source: ASI database 2007-08

In order to derive the cost wise share of different fuels employed in the dairy sector, the quantity of different fuels was monetized and its corresponding monetary share is depicted in the graph below:

Figure-21: Cost-wise breakup of fuel being used in Dairy Industry



Source: PwC analysis-based on ASI database-2007-08

Figure-21 indicates that electricity drives most of the processes in the industry with petroleum products and other fuels such as rice husk, firewood etc. also account for a significant share of the energy consumed.

5.5.3 Process flow

Based on the major production cycles in the dairy industry, it can be broadly classified into two major segments:

- the primary production and processing of liquid milk
- the production of milk derived products

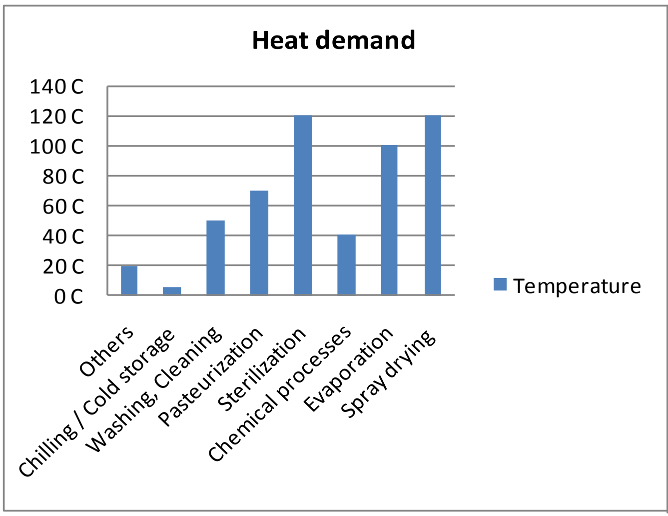
Figure-22 shows the detailed process flow for the processing of liquid milk and the major milk derived products.

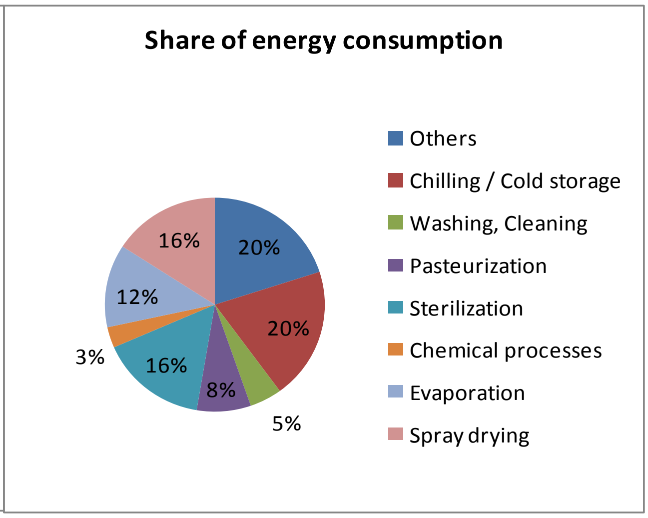
Figure -22: Dairy Industry process flow

After collecting the milk from various sources, it is stored at less than 7 °C at the plant and is usually processed within 24 hours but can be held for up to 72 hours (3 days) before processing. Before processing, the milk is cleaned either by clarification or filtration for the complete removal of unwanted organic material. Then, the milk is pasteurized using a high temperature short time (HTST) continuous process of at least 71.6 °C for 15 seconds. The processed milk is chilled in cold storage for further packaging and distribution.

The industry consumes a substantial amount of thermal (heat) energy for milk processing (pasteurization, sterilization, spray drying, evaporation, etc.) and electrical energy for refrigeration during milk pre-chilling, chilling of milk after pasteurization, cold storage of packed milk, compressed air requirement for pneumatic milk packaging machines, milk homogenization and clarification operations. Figure-23 shows the heat required for various thermal processes (both low and high temperature processes) and the share of energy consumption among the major processes in the industry.

Figure-23: Process wise heat demand and share of energy consumption in the Dairy Industry





5.5.4 Mapping solar technology applications

Solar thermal systems can enormously contribute to driving the various thermal processes in the dairy industry which demand water at temperatures <120 °C. Apart from this, solar PV systems can also constribute to saving electrical energy consumed for refrigeration purposes. Table-25 shows the mapping of various diary processes with different solar technologies.

Table- 25: Solar technology mapping in the dairy sector

Process	Energy/Fuel being used	Application media	Temperature required ˚C	Recommended solar technology
Washing and cleaning	Electricity and Boiler fuels like furnace oil, rice husk	Hot water	40-60	FPC
Chilling/Cold storage	Electricity and diesel	-	< 5	Solar thermal systems, driving absorption chillers
Pasteurisation	Boiler fuels like furnace oil, rice husk	Process heat	70	FPC
Sterilization/ Evaporation	Boiler fuels like furnace oil, rice husk	Process heat	100-120	ETC or solar concentrators
Spray drying	Boiler fuels like furnace oil, rice husk	Hot air	120	ETC (Air based) or solar concentrators

5.5.5 Solar energy potential assessment

The solar mapping given above shows the vast potential that exists in the dairy industry for installing various solar applications. A fair estimation of the total potential in the country has been made by considering the integration of solar energy systems in the existing energy supply systems in the industry. This assumption is crucial for a conservative and pragmatic estimate of the energy replacement potential given the limitations in the availability of solar energy all round the year.

Table-26 shows the estimated potential for various processes in the dairy industry that can adopt solar applications. The total potential has been estimated at about 27 ktoe.

Table -26: Conventional energy replacement potential through solar applications

Process	Energy/Fuel being used	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)

Cleaning and washing	Furnace oil, rice husk	5	93
Boiler feed (Pasteurisation, Sterilisation and Evaporation)	Furnace oil, rice husk	12	233
Pre heating for chemical processes	Electricity	.8	50
Cold storage – chilling plants	Electricity	5	291
Spray drying	Electricity	4	249
Total		**27**	**916**

Source: PwC analysis

5.6 Textiles (spinning and weaving)

5.6.1 Overview

The Indian textile industry is one the largest and oldest sectors in the country and among the most important in the economy, in terms of output, investment and employment. A strong raw material production base, a vast pool of skilled and unskilled personnel, cheap labour, good export potential and low import content are some of the salient features of the Indian textile industry. This is a traditional, robust, well-established industry, which enjoys considerable demand in the domestic as well as global markets.

5.6.2 Energy consumption profile

ASI reported 3.34 Mtoe of primary energy consumption in the textile (spinning and weaving) industry in 2007-08. Table-27 shows the primary source-wise distribution of energy consumption in the textile sector.

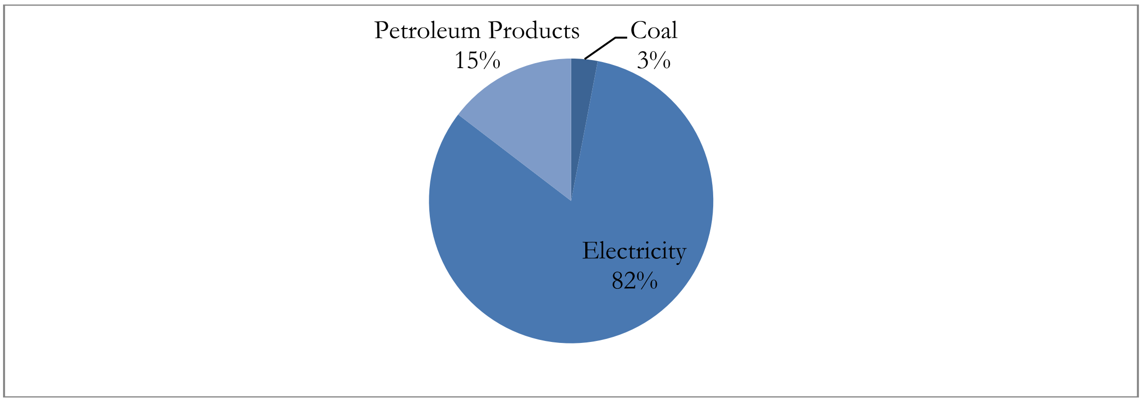
Table- 27: Source-wise distribution of energy consumption in the Textile (spinning and weaving) Sector

Industrial sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)	Other fuels (Rs. Million)
Textile	Spinning and weaving	1,193	16,059	376	8,358

Source: ASI database 2007-08

In order to derive the cost-wise share of different fuels employed in the textile (spinning and weaving) sector, the quantity of different fuels consumed was monetized and its corresponding monetary share is depicted in the figure below.

Figure-24: Cost-wise break-up of fuel in the Textile (spinning and weaving) sector



Source: PwC analysis-based on ASI database-2007-08

5.6.3 Process flow

The spinning involves following major operations:

The **blow room** process involves taking raw cotton, opening and cleaning it. The process reduces the trash particles in raw cotton to great extent. **Carding** involves opening and cleaning of the cotton coming from the Blow Room. The carding machine converts the cotton into a continuous sliver form.

Comber Preparatory processes involve the doubling and drafting of multiple card slivers and converting them into the form of a lap. This lap is fed in to the next process called comber.

The **comber** process involves the removal of short fibres and neps from the comber lap. In this, multiple comber laps are processed together, short fibres and neps are removed and finally the multiple slivers coming out from each machine head are doubled and drafted in to a single sliver called comber sliver.

The **draw frame** process involves the doubling and drafting of multiple comber slivers into a single sliver. In this process, cotton fibres are parallelized and oriented.

In the **speed frame** process, the draw frame sliver is drafted into a thin material called rove and a minor amount of twist is imparted to it to withstand the loads that would be experienced in the following processes.

Ring Frame is the process in which actual yarn formation takes place. Here the rove material is again drafted in to a very thin strand and considerable twist is imparted to it to obtain the final yarn.

Auto Winding is the process wherein the single small yarn package formed at the ring frame stage is converted into a big package called 'cone'. In this conversion process, single yarn packages are taken and continuously unwound and wound on a package called cone.

After auto winding, the yarn on a cone passes through the process of conditioning, to add moisture by using steam. Figure-25 shows the entire spinning process flow in detail.

Figure -25: Spinning process

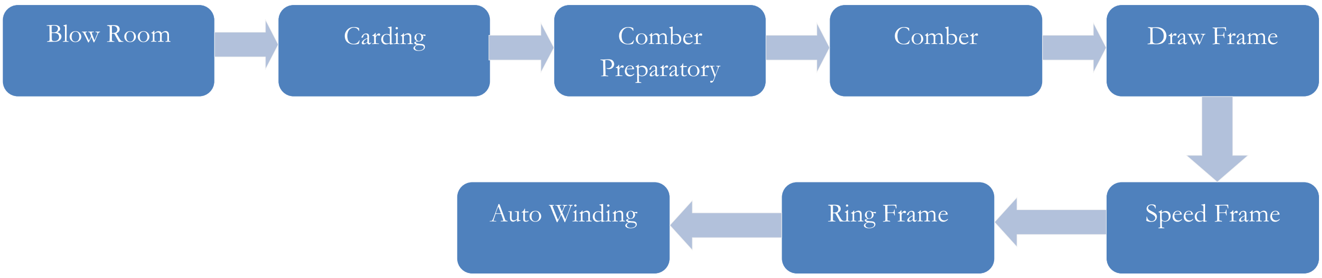
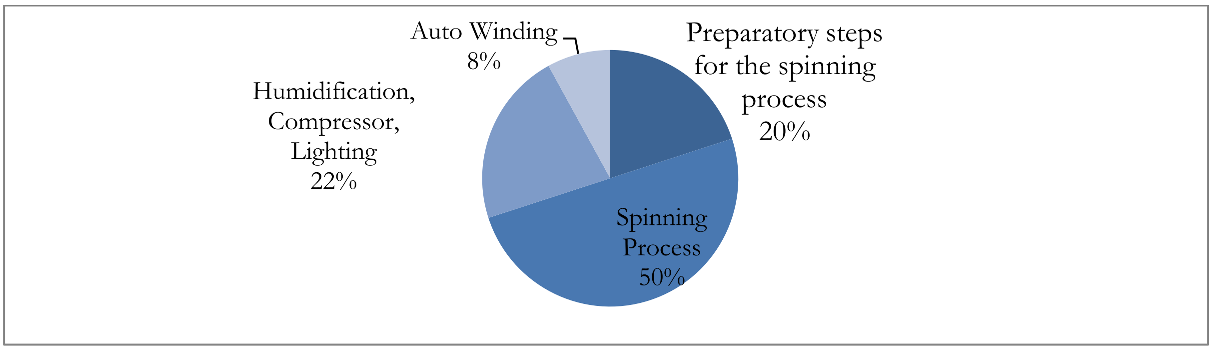


Figure-26: Share of energy consumptions in different spinning processes



Source: SITRA

Preparatory steps for the spinning include the blow room operation, carding, comber, draw frame and speed frame process.

The following major operations fall under the weaving process (see Figure-27).

Preparing warps and wefts for weaving: The warps form the basic structure of the fabric. As such, they are made to pass through many operations before the actual weaving is done. The yarn is coated with sizing with the help of a slasher machine. The yarn is passed through a sizing bath that contains the sizing medium, mixed with water and other additives depending on the formula. Sizing bath temperatures range from 80-85˚C.

Shedding: In shedding, alternate warp yarns are raised to insert the filling yarn into the warp to form a shed.

Picking: As the warp yarns are raised through shedding, the weft yarn is inserted through the shed by a carrier device. A single crossing of the filling from one side of the loom to the other is called a pick. Different methods are used for carrying the filling yarn through the shed in different kinds of looms.

Beating up: This weaving operation is also called battening. In it, all warp yarns pass through the heddle eyelets and through openings in another frame that looks like a comb and is known as a reed. With each picking operation, the reed pushes or beats each weft yarn against the portion of the fabric that has already been formed. It results in a firm and compact fabric construction.

Taking up and Letting off: As the shedding, picking and battening processes are underway, the new fabric is wound on the cloth beam. This is known as 'taking up'. At the same time, the warp yarns are released from the warp beam which is known as 'letting off'.

De-sizing: This is the last operation before dying. This consists of getting rid of the products used during the sizing process, through a chemical process. In the de-sizing operation, the temperatures range is 60-95 ˚C.

Figure -27: Weaving process flow diagram

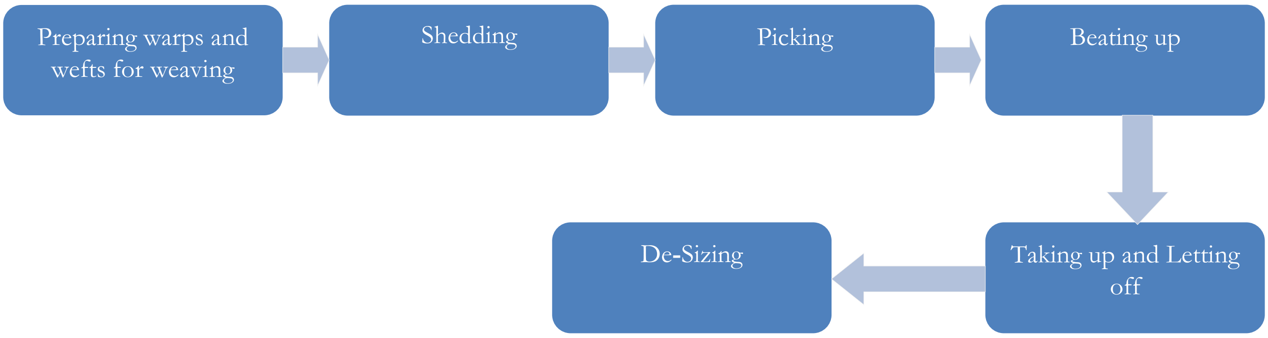
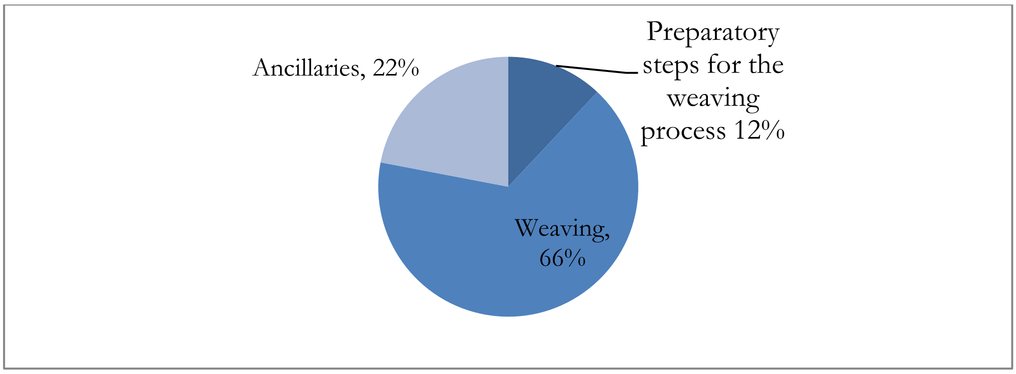


Figure -28: Share of energy consumption in weaving process



Source: SITRA

Preparatory steps for the weaving include the preparation of warps and wefts. In weaving process, energy consumption is approximately 50-60% in the weaving step and for ancillaries (humidification, compressor and lighting) it accounts for about 30-40%, depending on the type of loom.

5.6.4 Mapping solar technology applications

As discussed earlier, in the sizing step of the weaving process, hot water with temperature of 80-85 ˚C is required which can be suitably provided by a solar thermal application. Solar mapping in the weaving and spinning process is given in Table- 28 and -29.

Table-28: Solar mapping in weaving

Process	Energy being used	Temperature required ˚C	Recommended solar technology
Warping	Electrical	-	Solar PV
Sizing	Thermal	80-85	FPC
	Electrical	-	Solar PV
Winding	Electrical	-	Solar PV
Weaving	Electrical	-	Solar PV

Table-29: Solar mapping in spinning

Process	Energy being used	Temperature required ˚C	Recommended solar technology
Preparatory steps	Electrical	-	Solar PV
Spinning	Electrical	-	Solar PV

5.6.5 Solar energy potential assessment

Table-30 shows the conventional energy replacement potential estimated based on the assumption of adopting different solar thermal technologies for various processes in the sizing operation of the weaving industry. This estimate is about 20 ktoe and accounts for approximately Rs. 740 Million/annum.

Table-30: Conventional energy replacement potential through solar applications

Process	Fuel mix	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
Sizing/Slashing step of weaving process	Furnace oil	20	740

Source: PwC analysis

5.7 Electroplating Industry

5.7.1 Overview

The electroplating industry is widely spread out across the country. The industry can be categorized into two types- (i) primary user and original equipment (OE) manufacturers who carry out electroplating as one of their overall manufacturing activity and (ii) job work units who carry out plating of a large variety of components for both domestic and export purposes. The industry has a diversified product base and a majority of them are SMEs. The compounded average annual growth rate of the electroplating industry is about 16.60%. The sector employs about 130,000 people in approximately 12,000 organized units. No statistics are available for the unorganized units. Table-31 below gives the details of the major electroplating clusters in the country.

Table -31: Major electroplating clusters in India

State	Cities
Andhra Pradesh	Hyderabad
Delhi	Delhi
Maharashtra	Mumbai, Pune, Nasik
Punjab	Ludhiana
Tamil Nadu	Chennai, Madurai
Karnataka	Bangalore
Hararyana	Faridabad
Gujarat	Ahmadabad

Source: CPCB – Comprehensive industry document on electroplating industries, 2007

5.7.2 Energy consumption profile

It is estimated that the sector consumed approximately 118 ktoe of primary energy in 2007-08.

5.7.3 Process flow

All plating processes follow six basic steps:

Pre-process – This first step can include:

- optional mechanical finishing for the parts to be plated such as polishing, buffing, burnishing, etc.
- stripping off the plating or paint if the parts have been previously finished
- pre-process cleaning if the parts have heavy grease or buffing compound
- mounting of the parts on plating racks, wiring on to hooks or loading the small parts into plating barrels

Cleaning – The cleaning process varies according to the base metal of the parts being plated. Most cleaners are heated to about 50-70 °C and are alkaline based. A combination of soaking the parts in the cleaner and electro-cleaning is used. The cleaning step is always ended by a water rinse to remove the cleaning material from the parts, prior to activation.

Activation – Activation can be something as simple as submersing the parts in a 50% solution of hydrochloric acid, as is the case for steel, to more complicated processes using electric current and special acidic solutions as is the case with stainless steel. This step also ends with water rinses to remove acid activation solutions from the parts.

Plating – Electroplating uses electrolysis to deposit metal on the surface of the parts being plated. The plating process can include one or more plating deposits. For example, chrome plating over a zinc die casting typically has three deposits, copper, nickel and chrome plating. Each step is followed by water rinse to remove the plating solution from the parts.

Post-plating treatments – Depending upon the finish, the post-plating treatment can include chromate application over zinc plating, oxidation for the antique process, dyeing, dip lacquers, etc. At a minimum, parts are usually dried using a hot rinse followed by spin or oven drying.

Post-process – Post treatments can include removing parts from plating racks then carrying out inspections, testing as well as packing and then buffing, grinding, spray lacquers or painting, baking, etc.

Figure-29: Electroplating process flow

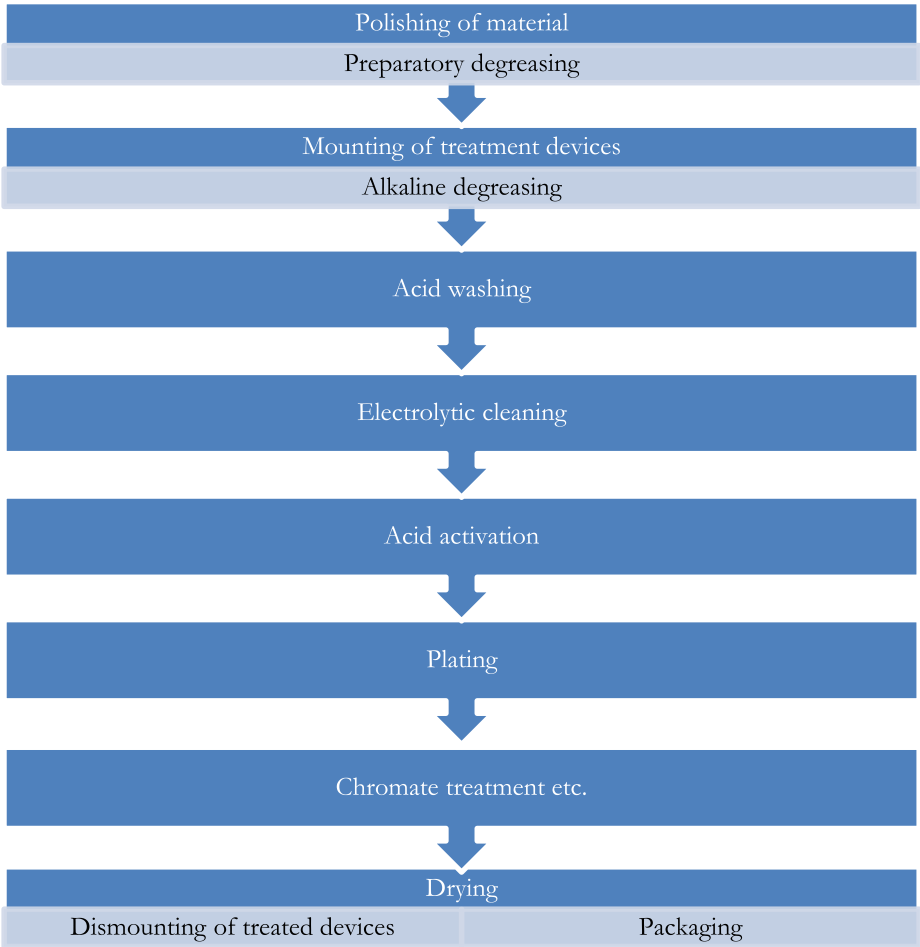
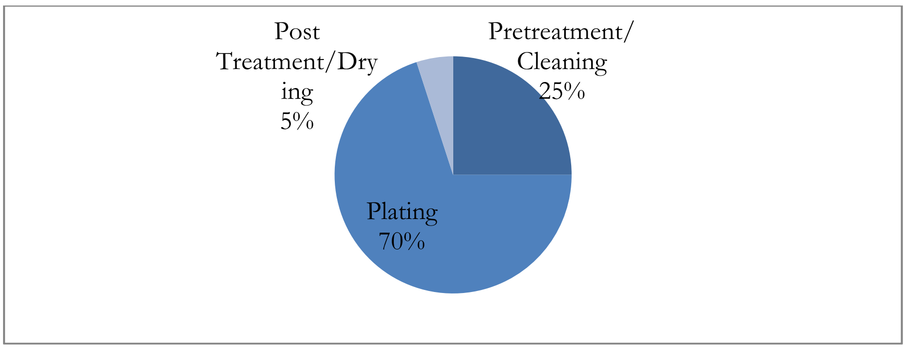


Figure-30: Share of energy consumption in Electroplating Process



5.7.4 Mapping solar technology applications

Temperature range and solar mapping of different electroplating processes is shown in Table-32 and -33 (Ni-Cr Plating).

Table -32: Temperature Requirement in different plating operation

Types of electroplating	Temperature requirement in plating operation ˚C
Ni- Cr plating	50-60
Cyanide silver plating	18-24
Cyanide copper plating	40-50
Acid copper plating	27-32
Nickel plating	40-60
Chrome plating	45-50
Cyanide zinc plating	30-40
Acid zinc plating	40-45

Table -33: Solar technologies mapping for Ni-Cr electroplating

Process	Energy being used	Temperature required ˚C	Recommended solar technology
Surface preparation and Pre-treatment	Electrical	----	Solar PV
Cleaning and washing	Thermal	40-50	FPC
Plating	Thermal	50-60	FPC
	Electrical		Solar PV
Post plating treatment/ drying	Thermal	70-80	Solar air heater
	Electrical		Solar PV

5.7.5 Solar energy potential assessment

Electroplating processes require hot water at a temperature of 55-85 ˚C. Conventionally, hot water or low temperature heat is produced with help of electricity, petroleum fuel based boiler/hot water generator.

A potential application of SWH in the electroplating industry is the integration of SWH to provide process heat. In this application, the SWH can be effectively integrated in the existing electroplating or degreasing baths to provide the process heat required during the day.

Table- 34: Energy saving potential using SWH system in the Electroplating Sector

Total energy consumption of the sector (ktoe)	% of heating load of total consumption	Heat load (ktoe/annum)	Energy replacement (ktoe/annum)
118	25	30	21

Source: PwC analysis

The assumption for this estimation is that around 70% of the total heat required is below 70 ˚C, which can be easily supplied by SWH systems.

5.8 Agro malls

5.8.1 Overview

An agro mall is a rural business centre, which is creating a far-reaching positive impact by bringing a qualitative change and revolutionizing the farming sector in India. Agro mall chains seek to empower the farmer by setting up centers, which provide all encompassing solutions to the farmers under one roof. Agro mall centers operate in catchments of about 20 km. A typical centre impacts the life of approximately 15,000-20,000 farmers. Agro malls are by and large cluster centric. Table-35 below gives details of major companies and centers in the country.

Table -35: Major Agro malls in India

Name of Agro mall	Company	Number of Agro malls
Champion Agro World	Champion Agro Ltd	32
ITC E-choupal	ITC Ltd	6,500
Hariyali Kisaan Bazaar	DCM Shriram Consolidated Ltd	300

5.8.2 Energy consumption profile

Study of past energy audit reports of Agro malls and its further analysis has revealed that the agro mall sector consumes approximately 12 ktoe of primary energy. Most of the agro malls are using diesel generator (DG) sets for their energy requirements. Table-36 shows the energy consumption in this sector.

Table-36: Source-wise distribution of energy consumption in Agro malls sector

Industrial sector	Sub sector	Electricity (GWh)
Agro malls	Agro malls	144

In agro malls, the major power consuming equipment are lights, fans, HPMV lamps, HPSV lamps, exhaust fans, computers, printers and submersible pumps. The total load of a typical agro mall ranges between 3- 10 kW during day time and 12 – 14 kW in the evening.

5.8.3 Activities

Agro mall is an innovative effort, aimed at empowering farmers and meeting the needs of rural households, by providing access to agricultural products, services and consultancy. The agro mall offers:

1) quality inputs (fertilizers, seeds, pesticides, farm equipment, veterinary products, animal feed, irrigation items)

2) agronomic services with teams of extension workers and agronomists like soil testing, crop inspection, weather forecasts, etc.

3) financial services including farm credit, life insurance, medical insurance and crop loan, term loan, etc.

4) access to output markets by helping farms access buy-back opportunities, commodity trading, etc.

5) information (new developments and research in agriculture, government schemes and subsidies, market prices, etc.)

5.8.4 Mapping solar technology applications

Most of the agro malls located in rural areas are provided with diesel generator (DG) sets and have a fairly un-shaded and strong roof structure capable of supporting the weight of a roof-top solar system. It is expected that the integration of solar PV systems would not only save petroleum fuels but would mitigate CO_2 emissions as well.

Figure-31: Rooftop PV installations

5.8.5 Solar energy potential assessment

The adoption of Solar PV systems is highly feasible in agro malls. Table-37 shows the conventional energy replacement potential expected from the adoption of different solar PV systems for agro malls.

Table- 37: Conventional energy replacement potential in Agro malls

Process	Energy/Fuel being used	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
All electrical requirements	Diesel based electricity	4.30	160

Source: PwC analysis

5.9 Automobile industry

5.9.1 Overview

The automotive industry in India is one of the largest in the world and it is one of the fastest growing globally. India manufactures over 11 million 2 and 4-wheeled vehicles and exports about 1.5 million every year. India is the world's second largest manufacturer of motorcycles with annual sales exceeding 8.5 million in 2009. India's passenger car and commercial vehicle manufacturing industry is the seventh largest in the world with an annual production of more than 2.6 million units in 2009. In the same year, India emerged as Asia's fourth largest exporter of passenger cars, behind Japan, South Korea and Thailand. The production of automobile and automobile accessories is by and large cluster centric. Table-38 below gives details of major production centers in the country.

Table- 38: Major automobile industry clusters in India

State	Locations	Products
Maharashtra	Pune, Nasik, Aurangabad, Nagpur	Cars and three-wheelers
Tamil Nadu	Chennai	Cars and trucks, bi-cycles

Karnataka	Bangalore, Hosur, Dharwar	Buses
Haryana	Gurgaon, Manesar	Passenger cars, motorcycles and tractors

Source: ACMA, SIAM

5.9.2 Energy consumption profile

ASI reported 590 ktoe of primary energy consumption in the automobile sector in 2007-08. Table-39 shows the primary source-wise distribution of energy consumption in this sector.

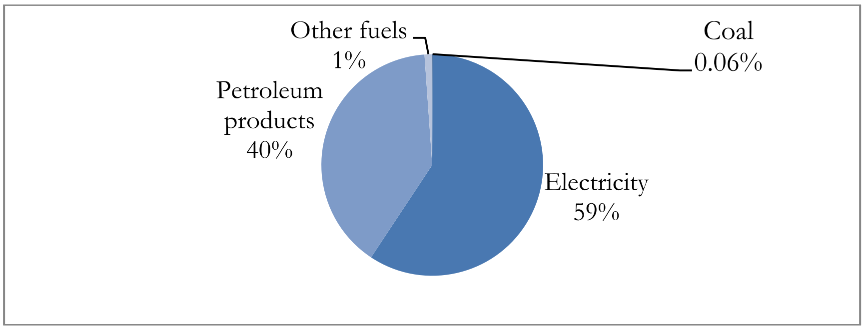
Table- 39: Source –wise distribution of energy consumption in the Automobile Sector

Industrial sector	Subsector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)	Other fuels (Rs. Million)
Automobile	Automobile	7.75	3,518	310	332

Source: ASI database-2007-08

In order to derive the cost-wise share of different fuels used in the automobile sector, the quantity of different fuels was monetized and its corresponding monetary share is depicted in the Figure-32.

Figure-32: Cost-wise break-up of fuels in the automobile sector



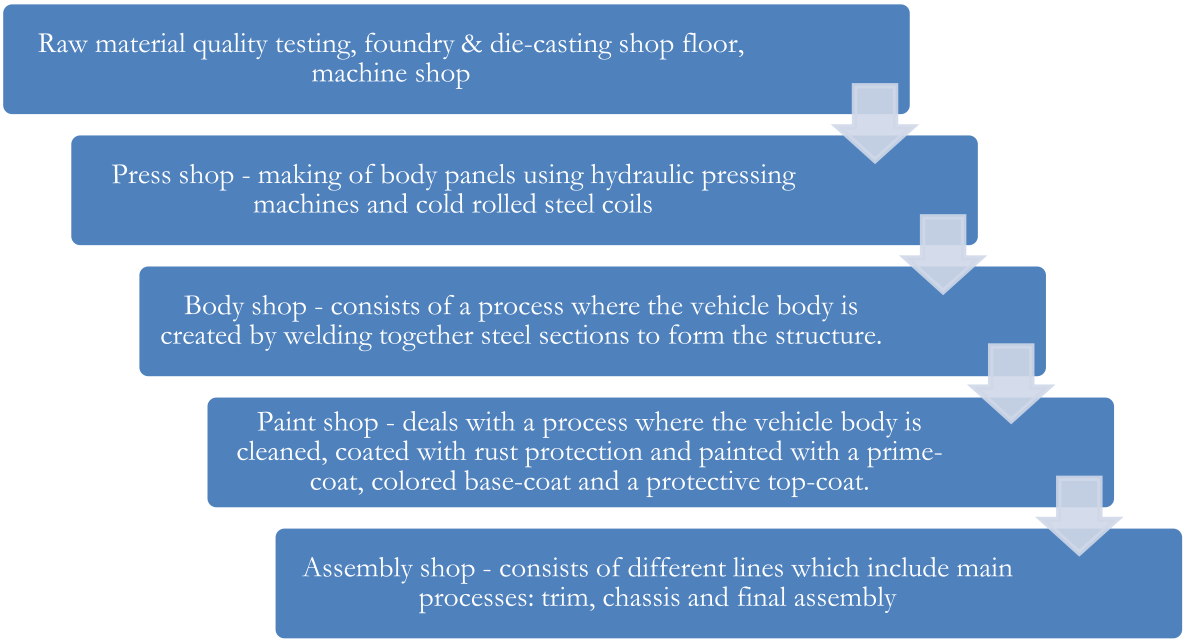
Source: PwC analysis-based on ASI database-2007-08

Figure-33 indicates that electricity drives most of the processes, followed by petroleum fuels.

5.9.3 Process flow

Most of the processes in this industry are mechanical and driven by electricity. Only a few operations, such as machine shop and paint shop, use certain conventional fuels for producing thermal energy for metal casting, steel forging, pre-treatment before painting, drying, air-conditioning, etc. Figure-33 shows the entire process flow in detail.

Figure-33: Process flow in the automobile industry



5.9.4 Mapping of solar technology applications

The process described above shows that only a few operations such as machine and paint shops use a significant amount of thermal energy. The temperature requirement in machine shops is well beyond 300 ˚C and but in paint shops it is <150 ˚C. Therefore, solar thermal energy applications are more appropriate for use in paint shops for pre-treatment, drying and air-conditioning purposes. Solar PV technologies may be applicable in the press shop, body shop and assembly shops that operate on automated machines powered by electricity. An automobile manufacturing facility consumes approximately 4 litres of water per car, mostly in the paint shop. The paint shop requires water of differing quality and temperatures. Hot water at 30-45 ˚C is generally required for rinsing the body during pre-treatment. Table-40 shows the mapping of applications relevant for processes in a paint shop.

Table-40: Solar technology mapping in the automobile sector

Process	Energy/fuel being used	Application media	Temperature required ˚C	Recommended solar technology
Press shop – electric and pneumatic machines	Electricity	-	-	Solar PV system
Body shop – electric and pneumatic machines	Electricity	-	-	Solar PV system
Paint shop – pre-treatment	Electricity and boiler fuels	Hot water	40	FPC
Paint shop –air-conditioning	Electricity and boiler fuels	Hot/cold air supply	5 – 50	ETC based chillers
Paint shop – evaporation and drying	Boiler fuels	Hot air supply	80-100	Solar air heating systems
Assembly shop – automated robots and machines	Electricity	-		Solar PV system

5.9.5 Solar energy potential assessment

Table-41 shows the conventional energy replacement potential estimated for the identified processes in the automobile industry. The energy savings assessment is based on the total production estimates, indicative hot water requirements, specific energy consumption, solar system penetration capacity and other essential parameters gathered from various secondary sources. The potential has been estimated at about 10 ktoe.

Table-41: Conventional energy replacement potential

Process	Energy/fuel being used	Energy replacement (ktoe/annum)	Estimated monetary savings (Rs. Million/annum)
Pre-treatment, hot water rinsing of vehicle body in the paint shop	Electricity	10.2	597
Drying, air conditioning of wet paints in the paint shop	Boiler fuels	0.3	10
Total		**10.5**	**607**

Source: PwC analysis

5.10 Pharmaceutical industry

5.10.1 Overview

The Indian pharmaceutical industry is ranked 3rd in the world, in terms of production volume, and 14th in terms of domestic consumption value. Currently the pharmaceutical industry is growing at a rate of 14% per year. The market capitalization of Indian pharmaceutical industry was estimated at USD 19.4 billion in FY09. In terms of the value of pharmaceutical business, formulation business accounts for about 65% and bulk drugs for the remaining 35%. The industry is expected to reach USD 43.8 billion in FY14. Bulk drug exports are expected to grow fast at about 35% followed by formulation exports at about 25%. The domestic formulation market is expected to grow at about 11% with key growth drivers being increased per capita spend on pharmaceuticals, improved medical infrastructure, greater health insurance penetration and increasing prevalence of lifestyle related diseases. Table -42 shows the locations of major clusters of pharmaceutical industry in India.

Table-42: Clusters of Pharmaceutical Industry in India

State	Locations	Product
Himachal Pradesh	Baddi	Pharmaceuticals
Delhi	Delhi	Pharmaceuticals
Gujarat	Ahmedabad	Pharmaceuticals
Maharashtra	Mumbai Thane and Belapur	Basic drugs
Andhra Pradesh	Hyderabad	Drugs

5.10.2 Energy Consumption Profile

ASI reported 930 ktoe of primary energy consumption in the Pharmaceutical industry in 2007-08. Table-43 shows the primary source wise distribution of energy consumption in pharmaceuticals industry.

Table-43: Source wise distribution of energy consumption in Pharmaceutical Sector

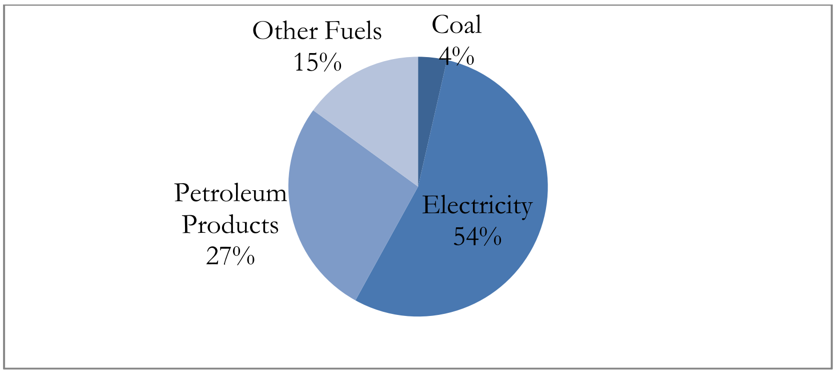
Industrial sector	Coal (kilo tonne)	Electricity (GWh)	Petroleum products (kilo tonne)

Pharmaceutical	364	2,761	180

Source: ASI database 2007-08

The cost wise share of different fuels utilised in the Pharmaceutical sector was derived by the quantity of different fuels used (source ASI database 2007-08) and its corresponding monetary share. The cost share is depicted in the graph below:

Figure-34: Cost-wise breakup of fuels in the Pharmaceuticals Sector



Source: PwC analysis-based on ASI database-2007-08

5.10.3 Process flow

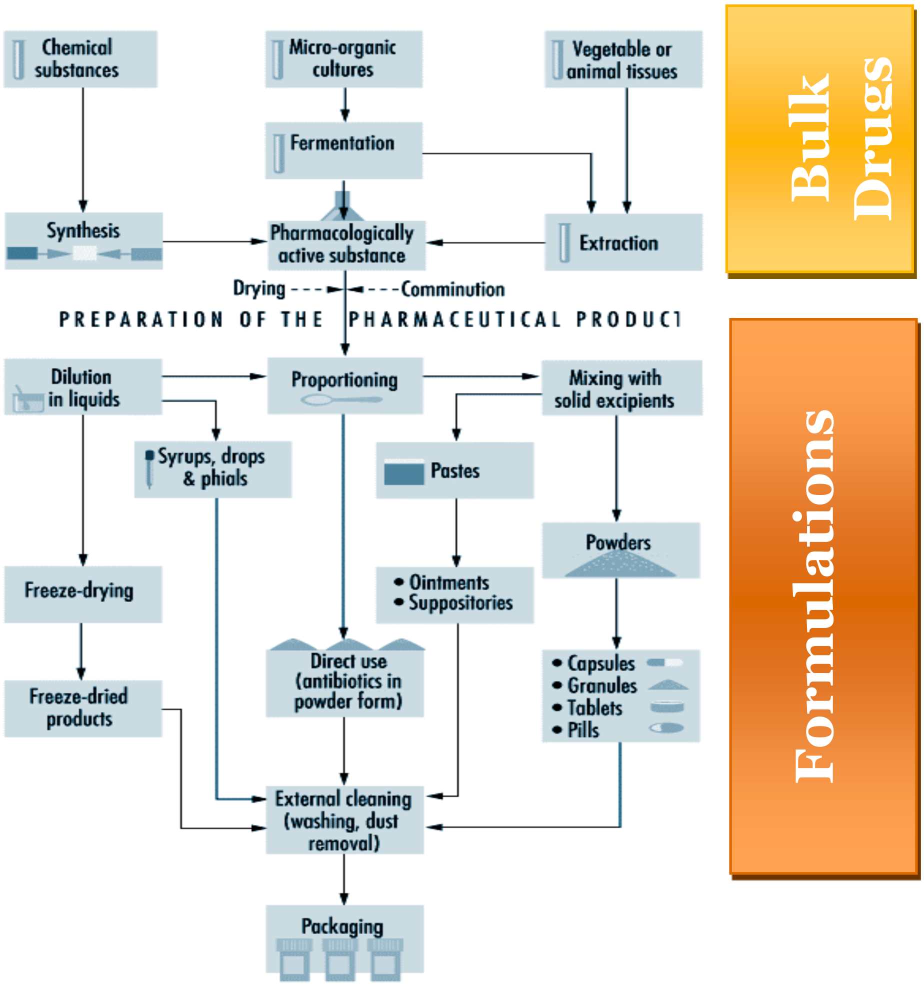


Table-44: Different stages in bulk pharmaceutical manufacturing

Research & Development	Four stages: 1. Pre-clinical R&D: determine if substance is active and safe (6 years) 2. Clinical R&D: human testing (6 years) 3. Review of new drug application (1-2 years) 4. Post marketing surveillance
Conversion of natural substances to bulk pharmaceutical substances	Types of conversion: • Chemical Synthesis • Fermentation • Extraction
Formulation of final products	Conversion of substances at a much larger scale

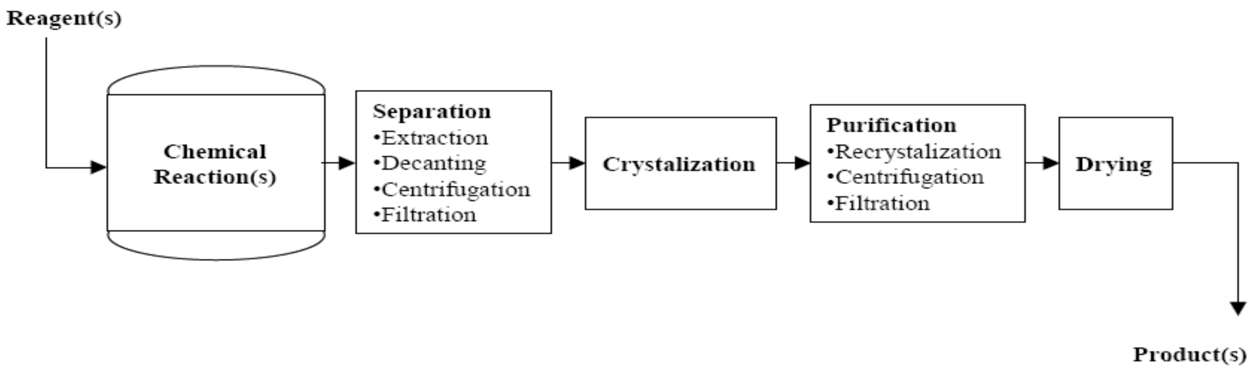
Bulk pharmaceutical substances are produced via chemical synthesis, extraction, fermentation or a combination of these processes.

5.10.3.1 Chemical synthesis

A simplified diagram of the chemical synthesis process for pharmaceuticals is shown in Figure-35. There are five primary stages in chemical synthesis, namely:

- reaction
- separation
- crystallization,
- purification, and
- drying

Figure-35: Chemical synthesis process



5.10.3.2 Product extraction

Extraction is used to separate components of liquid mixtures or solutions. This process utilizes difference in solubilities of the components rather than differences in volatilities. Precipitation, purification and solvent extraction methods are used to recover active ingredients in the extraction process.

5.10.3.3 Fermentation

In fermentation, micro-organisms are typically introduced into a liquid to produce pharmaceuticals as by-products of normal micro-organism metabolism. The fermentation process is typically controlled at a particular temperature and pH level under a set of aerobic or anaerobic conditions that are conducive for rapid micro-organism growth. The process involves three main steps:

- Seed preparation
- Fermentations
- Product recovery

5.10.4 Mapping solar technology applications

The sector consumes both electrical and thermal forms of energy at different stages of their processes. Hence, the possibility of replacing conventional energy by solar energy is high. Additionally, solar energy can replace thermal energy more economically and viably than electrical energy. Most of the thermal energy applications in pharmaceutical units require low range temperatures which are easily achievable by the use of solar systems. Solar energy may also replace electricity if sufficient free space is available within the plant. The process wise solar mapping is shown below:

Industrial Process	Application Media	Temp required °C	Recommended solar technology
Distillation	Hot water	55-80	FPC/ETC
Evaporation	Steam	>120	Solar concentrators
Drying	Steam/Hot air	>120	Solar hot air system

5.10.5 Solar energy potential assessment

It has been observed that heat load accounts for approximately 20% of the total energy consumption in the pharmaceuticals sector. Based on certain empirical analysis it was determined that 5% of the heat load could be suitably replaced by solar energy applications. Based on the aforementioned assumptions, the total replacement potential is estimated to be about 9 ktoe/annum.

6 Framework for ranking 10 sectors

The findings of the detailed pre-feasibility study of 10 sectors were used to further rank these 10 sectors. For this purpose, parameters that characterize the utilisation potential of solar energy were used. Each parameter was provided a weightage and each sector was given scores from 1 through 10 (10 being highest) against each parameter to calculate the overall ranking. The parameters along with their weightages are given in Table-45.

Table-45: Framework to rank 10 sectors

Parameter	Significance of parameter	Weightage
Energy replacement potential (ktoe)	Will reflect the total potential of the sector	35
Weighted average cost of fuel	More weighted average cost will increase the viability of solar application	35
Average solar insolation in major clusters of the sector	More insolation means more viability	30
Total		**100**

The scores of the individual parameters as well as the overall rankings are given in the Table-46 below:

Table-46: Ranking of 10 Sectors based on the Prefeasibility Analysis and other factors

Sectors	Saving ktoe	Rank	Weighted price of existing fuel (Rs. /Mcal.)*	Rank	Solar Insolation ($kWh/m^2/day$)	Rank	Total marks	Overall rank
Food processing	80	9	3.21	3	5.50	9	690	1
Electroplating	21	6	5.81	10	5.28	3	650	2
Automobile	10	3	4.58	9	5.33	7	630	3
Textiles (spinning and weaving)	20	5	4.31	8	5.30	5	605	4
Dairy	30	7	4.19	6	5.30	4	575	5
Textiles (Finishing)	370	10	2.01	2	5.30	5	570	6
Pulp and Paper	45	8	1.45	1	5.47	8	555	7
Agro malls	4	1	3.70	4	5.52	10	475	8
Leather	17	4	4.26	7	5.19	2	445	9
Pharmaceuticals	9	2	3.73	5	4.97	1	275	10

* (Weighted price of consumed fuel= Total money spent on consuming different fuels/Total million calories of different fuel used)

7 Case Examples

All the 10 sectors taken up for pre-feasibility have high potential of solar applications. However, only five sectors were selected for further field analysis to identify potential pilot projects in those sectors. The sectors selected were:

1. Electroplating
2. Pulp & Paper
3. Pharmaceuticals
4. Food Processing
5. Textile (spinning & weaving)

The industrial units for walk through energy audits were identified in the above selected clusters based on the following major parameters:

- are the identified units representatives of the units present in the selected industrial sectors
- are these units located in a cluster with many similar units for future replication

Two units in each of the selected sectors were identified for carrying out the walk through energy audits and field studies. The location of selected units is given in the Table-47 below:

Table-47: List of units selected for field visit and analysis

Sectors	Locations
Electroplating	
Unit 1	Ludhiana, Punjab
Unit 2	Ludhiana, Punjab
Pulp and Paper	
Unit 1	Derabassi, Punjab
Unit 2	Saharanpur, U.P.
Pharmaceuticals	
Unit 1	Tarapur, Maharashtra
Unit 2	Derabassi, Punjab
Food processing	
Unit 1 (3-Sub Units)	Baddi, H.P.
Unit 2	Ludhiana, Punjab
Textiles (spinning and weaving)	
Unit 1	Banswara, Rajasthan
Unit 2	Bhilwara, Rajasthan

8 Field visits

8.1 Electroplating sector

Ludhiana in Punjab is the largest cluster of electroplating units in the country. This town has more than 4,000 electroplating units. Most of the units do job work and supply their production to various automobile, cycle parts manufacturers, sewing machines manufacturers etc. The units selected for the study are medium sized which do job work for cycle manufacturers. Profile of the units and various related findings are given in Table-48:

8.1.1 Unit 1

Table-48: Profile of Unit 1, Ludhiana

<table>
<tr><th>Company Name</th><th colspan="6">Unit 1</th></tr>
<tr><td>Location</td><td colspan="6">Ludhiana, Punjab</td></tr>
<tr><td>Company profile</td><td colspan="6">The unit was established in 1960.
It is an electroplating unit which carries out Ni-Cr plating.
The unit has an annual turnover of approximately Rs. 11 crores.
The unit does plating of bicycle rims and various other bicycle parts.
The daily production of bicycle rims is around 5,000.</td></tr>
<tr><td>Available roof area for solar applications (m^2)</td><td colspan="6">280</td></tr>
<tr><td>Processes feasible for use of solar energy</td><td colspan="6">Cleaning: For cleaning process, 2 tanks each of 700 L capacity are being used. Heat required for cleaning process is at a low temperature i.e. 60-70 ˚C.
Ni-Plating: For Ni-plating 3 tanks, each of 1,800 L capacity are employed. Heat required for Ni-plating process is in the range of 50-60 ˚C. Nickel plating of 9 micron is coated on bicycle rim with retention time of 35-40 minutes.
Cr-Plating: For Cr-plating two tanks of 2,000 L capacity each are employed. Heat required for Cr.-plating process is in lower range of 35-40 ˚C. Cromium thickness of 3 micron is coated on bicycle rim with retention time of 60-90 seconds.</td></tr>
<tr><td>Existing technologies</td><td colspan="6">The plant uses electric heaters to heat and maintain the temperature for cleaning as well as plating baths.</td></tr>
<tr><td rowspan="5">Energy consumption related parameters</td><td rowspan="2">Process</td><td rowspan="2">Number of electric heaters</td><td rowspan="2">Rating of each heater</td><td colspan="2">Operation hrs per day</td><td rowspan="2">Total operation days per annum</td></tr>
<tr><td>Summer</td><td>Winter</td></tr>
<tr><td>Cleaning</td><td>4</td><td>3</td><td>5</td><td>12</td><td rowspan="3">300</td></tr>
<tr><td>Ni-Plating</td><td>12</td><td>3</td><td>5</td><td>12</td></tr>
<tr><td>Cr-Plating</td><td>4</td><td>3</td><td>5</td><td>12</td></tr>
<tr><td>Source of energy</td><td colspan="6">Electricity from grid</td></tr>
<tr><td>Total electricity consumption</td><td colspan="6">For heating of plating baths – 153 MWh/year</td></tr>
</table>

8.1.1.1 Potential solar thermal application

8.1.1.1.1 Heating of plating bath

Proposed solar technologies: In electroplating units, temperature requirement for heating of plating baths ranges from 35-60 ˚C which is subject to the kind of electroplating being undertaken. For such a range of temperature, FPC and ETC could be the possible off-grid solar thermal technologies which could replace electricity for heating of the plating baths.

Comparative Table of FPC and ETC: A comparison of 100 LPD solar water heater based on FPC and ETC technology is given in the Table-49 below:

Table-49: Comparative Table of FPC and ETC

Particulars	Details of Solar Thermal Technology		Source
	FPC	ETC	
Size of the system (LPD)	100	100	MNRE
Area required per collectors (m^2)	2	1.5	MNRE
Collector efficiency for closed loop system (%)	45	55	Discussions with manufacturers
Collector efficiency for open loop system (%)	65	75	Discussions with manufacturers
Land/Roof area required per collector (m^2)	3.5	2.6	Report from TATA BP Solar
Price of system (Rs.)	20,000	14,000	Discussions with manufacturers

The sizing of different solar water heating systems proposed in this report has been done based on the parameters given in the above table.

System integration and working principle: During electroplating, metal parts are treated in the plating bath at a temperature of 40-60 ˚C. Generally, electrical heaters are used for heating plating bath. With regard to the usage of the solar thermal system to heat the bath using closed loop system, it is worth mentioning here that the solar thermal system shall act only as a support system with its usage on partial basis. To integrate solar thermal system with the existing heating system, it is contemplated that heat exchanger coils shall be duly laid at the bottom of plating bath for transferring heat to the plating solution in order to maintain the desired temperature. It is imperative to state that during day time, the heating of the plating bath can be done by solar thermal system with forced circulation of hot water in heat exchanger coils. However, during the monsoon season and other unfavourable weather conditions, existing electrical heaters can be used to heat the plating bath.

Estimated size of the proposed system: The sizing of solar water heating system was done considering the actual requirement of the process and availability of solar irradiation in that area. The proposed solar water heating systems can supply hot water to all the processes i.e. cleaning and plating. To estimate the number of collectors, the aggregate heat load of the specified application was estimated and subsequently equated to the total heat produced by one collector. The results are shown in Table-50.

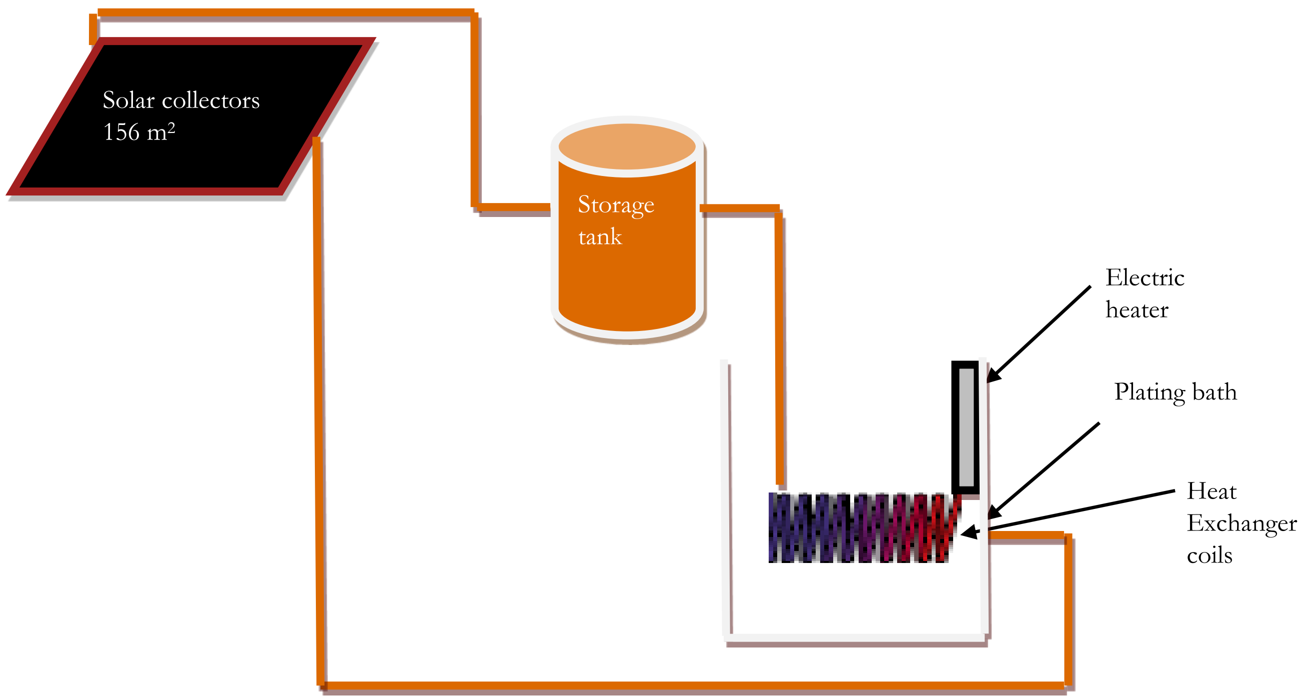
Table-50: Electroplating Sector –Unit 1: Estimated sizing of SWH system

Description	Value
Collector type	Flat Plat Collector
Number of collectors	78
Size of solar water heating system (LPD)	7,800
Replacement of electricity (kWh/annum)	79,200

Source: PwC analysis

Schematic diagram of the proposed system: Lay out of the SWH system shown in Figure-36.

Figure- 36: Electroplating Unit1: Schematic diagram of the proposed solar water heating system



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-51.

Table-51: Financial analysis of installation of SWH in Unit 1

Particulars		FPC	ETC
Collector area (m^2)		156	127
Area required for solar system (m^2)		273	221
Capacity of the system (LPD)		7,800	8,510
Life of project (Years)		15	15
Total subsidy amount (Rs.)		468,071	421,262
Capital cost (Rs. with subsidy)		1,092,166	770,185
Capital cost (Rs. without subsidy)		1,560, 237	1,191, 447
Replacement cost for tubes after 5 years		Not Applicable	25% of project cost
Energy replacement (kWh/annum)		79,200	79,200
Project IRR (%)	With subsidy	29	40
	Without Subsidy	19	25
Payback period (Years) (with subsidy)		2-3	2-3
GHG emission reduction due to electricity replacement (tonne CO_2 per year)		64.92	64.92

Source: PwC analysis

8.1.1.2 Solar PV applications

The area has good solar irradiations and hence the potential of electricity generation from solar PV but if the SWH is installed as recommended above, the plant may not be able to install solar PV due to the paucity of land.

8.1.2 Unit 2

Table-52: Profile of Unit 2, Ludhiana

Company Name	**Unit 2**	
Location	Ludhiana, Punjab	
Company profile	This unit was established in 1991. It is an electroplating unit carries out Ni-Cr plating. The unit has an annual turnover of approximately Rs. 6 crores. The unit does the plating of bicycle chain wheel and crank, pedals and other parts of bicycle chain wheels, crank components and spares. The average daily production of bicycle wheel chains and pedals are 2,000 and 1,300 units respectively.	
Available roof area for solar applications (m^2)	610	
Processes feasible for use of solar energy	Cleaning: For cleaning process 2 tanks of 700 L capacity each are being used. Heat required for cleaning process is at a low temperature level i.e. 60-70 ˚C. Ni- Plating: For Ni-plating 3 tanks of 1,800 L capacity each are employed. Heat required for Ni-plating process is in the range of 50-60 ˚C. Nickel plating of 9 micron is coated on the bicycle rim with a retention time of 35-40 minutes. Cr-Plating: For Cr-plating 2 tanks of 2,000 L capacity each are employed. Heat required for Cr.-plating process is at a lower range of 35-40 ˚C. Cromium thickness of 3 micron is coated on the bicycle rim with a retention time of 60-90 seconds.	
Existing mode of heating	The plant is using diesel fired boiler to heat and maintain the temperature of cleaning as well as plating baths.	
Source of energy	Diesel oil	
Energy consumption related parameters (Boiler)	Boiler capacity (kcal/hr)	200,000
	Boiler burner cut- on temperature (˚C)	70
	Boiler burner cut- off temperature (˚C)	90
	Max temperature (˚C)	140
	Operating days per annum	300
	Boiler pressure (kg/cm^2)	3.2
	Operation hr. per day	1-1.25
	Diesel oil consumption (litre/hr.)	30
Total fuel consumption	For heating of plating baths – 9,000 litre/annum	

8.1.2.1 Potential solar thermal application

8.1.2.1.1 Heating of plating bath

Proposed solar technologies: In this unit also the temperature required for heating plating baths ranges from 35-60 ˚C. For this temperature range, FPC and ETC are the possible off-grid solar thermal technologies which can replace the use of diesel in the boiler for heating the plating baths.

System integration and working principle: This will be same as mentioned for the unit 1 except that this unit already has heat exchanger coils in the cleaning and plating baths.

Estimated size of the proposed system: The sizing of solar water heating system was done considering the actual requirement of the process and available solar irradiation of that area. The proposed solar water heating systems can supply hot water to all the processes i.e. cleaning and plating. To estimate the number of collectors, the aggregate heat load for the specified application was derived and subsequently equated with the total heat produced by one collector. The results are shown in Table-53.

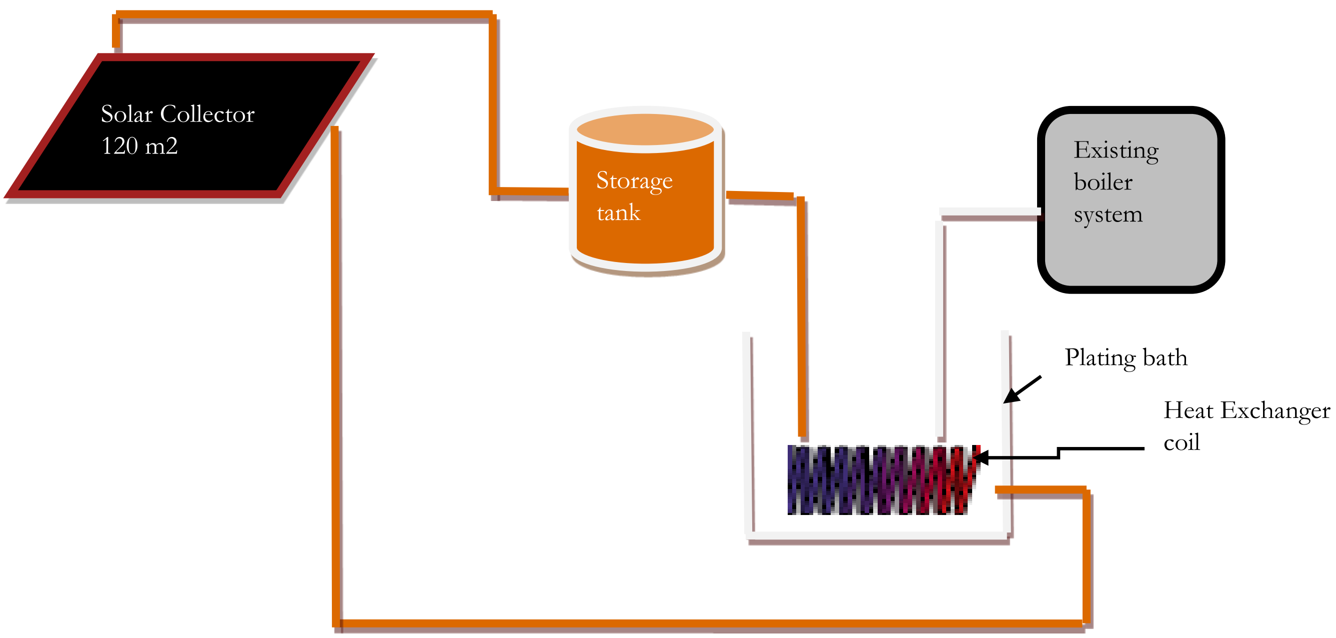
Table-53: Electroplating Sector -Unit 2: Estimated sizing of SWH system

Description	Value
Collector type	Flat Plat Collector
Number of collectors	60
Size of solar system (LPD)	6,000
Average saving of furnace oil (litre/day)	30

Source: PwC analysis

Schematic diagram of the proposed system: Layout of the SWH system is shown in Figure-37.

Figure 37: Electroplating Unit2: Schematic diagram of the proposed solar water heating system



Financial analysis

Financial analysis of the proposed solar water heating system was carried out to estimate the IRR and the payback period. The analysis is given in Table-54

Table-54: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		120	97
Area required for solar system (m^2)		210	168
Capacity of the system (LPD)		6,000	6,468
Life of project (Years)		15	15
Total subsidy amount (Rs.)		360,000	320,157
Capital cost (Rs. with subsidy)		840,000	585,336
Capital cost (Rs. without subsidy)		1,200,000	905,493
Replacement cost for tubes after 5 years		Not Applicable	25% of the project cost
Replacement of diesel (litre/annum)		9,000	9,000
Project IRR (%)	With subsidy	31	44
	Without subsidy	21	28
Payback period (Years) (with subsidy)		2-3	1-2
GHG emission reduction due to diesel replacement (tonne CO_2 per year)		34.84	34.84

Source: PwC analysis

8.1.2.2 Solar PV Applications

Due to the good solar irradiation in the area, potential for installation of small scale solar PV unit exists. The unit is currently using grid electricity. Installation of any solar PV can replace some of the grid electricity in this unit and can also feed excess power back to the grid. The power generated from this solar PV can also be used directly for the plating process rectifiers which require direct current (DC). If the unit installs the SWH recommended above, it will be left with 400 m^2 spare area for installing solar PV. As per industry standards this 400 m^2 is sufficient for the installation of approximately 30 kWp of solar PV system.

8.1.3 Conclusion – Electroplating Sector

Various field visits and analysis of the data collected during the visits has provided the following conclusion about the electroplating sector:

- the sector has very good potential for installation of solar applications. Solar technologies namely FPC as well as ETC in closed loop can be used quite effectively.
- electroplating units require water at 40-60 °C in their different processes which can be easily generated using solar heat. This can replace electric heaters or diesel / furnace oil fired boilers used predominantly across the sector.
- Field studies revealed that small sized electroplating units have a free space constraint for deployment of solar thermal application. However, medium to larger size units have sufficient free space for installation of solar systems.
- the project IRR of installation of solar applications depends on the fuel replaced and is as given in Table-55.

Table-55: Comparison of project IRRs in different scenarios in Electroplating Sector

Particulars	Fuel replaced	Any incentive	Technology used	
			FPC	ETC
Project IRR (%)	Electricity	With subsidy	29	40
		Without Subsidy	19	25

	Diesel	With subsidy	31	44
		Without Subsidy	21	28

- analysis revealed that there is a potential for replacement of 50-100% of the energy requirements in plating baths, depending on the operating hours of the unit.
- discussions with the industry association as well as unit owners revealed that there is need for increasing the awareness levels of industry owners to increase the penetration of solar systems in this sector.
- steps can be taken by MNRE to create awareness in this sector for promoting solar systems. MNRE can also provide incentives initially to the participating units.

8.2 Pulp and Paper sector

Pulp & paper industry is well spread out across the country. In this study, two paper manufacturing units were visited in Punjab and Uttar Pradesh to assess the potential for installing solar systems. The units which were selected represented the sector in terms of their sizes, processes and energy requirements. Unit-wise analysis is given below:

8.2.1 Unit 1

Table-56: Profile of Unit 1, Derabassi (Punjab)

Company Details	**Unit 1, Derabassi**	
Location	Derabassi, Punjab	
Company profile	Unit 1 is a manufacturer of absorber paper, craft board and notebook paper. The industry is using waste paper as well as agro-mass for its paper production.	
Available free area for solar applications (m^2)	5,000	
Processes feasible for use of solar energy	Pulping Cleaning and refining Disperser Dryer	
Source of energy	Pet coke and rice husk	
Boiler parameters	Rated boiler capacity (tonne/hr)	12
	Working pressure (kg/cm^2)	3.5
	Working temperature (°C)	195-200
	Pet coke consumption (tonne per day)	15-17
	Rice husk consumption (tonne per day)	40-45
	Operating days per annum	300
	Presently BFW temperature (°C)	72
	Condensate recovery system	Yes (60%)
	Operating hours/day	24
Existing process requirements	Several processes in this industry require hot water/steam which is obtained from boiler. Solar applications can help generate steam or hot water to fulfil partial requirement of the industry.	
Consumption of fuel in boiler	Pet coke: 8600 tonne/annum Rice husk: 1600 tonne/annum	

8.2.1.1 Potential solar thermal applications

8.2.1.1.1 Pre-heating of Boiler Feed Water

Proposed solar technologies: The major energy consumption in any paper manufacturing unit is in the boiler which produces steam. Boilers are fed with water with a temperature of around 50-60 ˚C due to the partial recovery of condensate from the processes. In such scenarios, solar technologies can be used to heat the fresh water which is added to the boiler at around 25-28 ˚C, to reduce fuel consumption. For such an application, FPC and ETC are the most suitable off-grid solar thermal technologies. A comparison of 100 LPD solar water heater based on FPC and ETC technology has been provided in Table-49.

System integration and working principle: In the existing setup, makeup water (at 25-28 ˚C) is mixed with the condensate (at >90 ˚C) coming back from the process which raises the temperature of mixed water to around 60 ˚C. The industry has the option of using solar technology either to produce steam or to heat the makeup water to reduce the fuel consumption in the boiler. Generating steam using solar energy is still not very viable so it is recommended to integrate solar thermal system into the process. The makeup water will be heated by this solar thermal system and mixed with the condensate water to increase the net temperature.

Estimated size and schematic diagram of the proposed system: The sizing of solar water heating system was done considering the availability of free space with the plant, the energy required to raise the temperature of makeup water in the boiler and availability of solar irradiation in that area. The results are shown in Table-57.

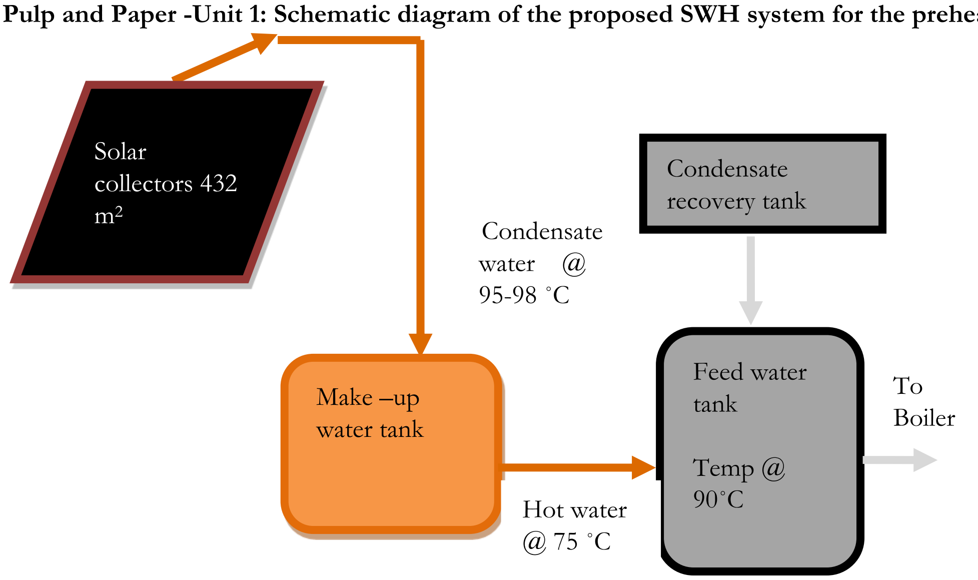
Table-57: Pulp and Paper -Unit 1: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	216
Size of solar system (LPD)	21,600
Average saving of pet coke and rice husk (tonne/annum)	40 and 43

Source: PwC analysis

For preheating the boiler makeup water, water is circulated through collectors throughout the day as long as the collector output stays at a higher temp than that of water in the storage tanks. Layout of the system is shown in Figure-38.

Figure- 38: Pulp and Paper -Unit 1: Schematic diagram of the proposed SWH system for the preheating of BFW



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-58.

Table-58: Financial analysis of solar system installation in Paper Industry (Unit 1)

Particulars		FPC	ETC
Collector area (m²)		432	369
Area required for solar system (m²)		756	640
Capacity of the system (LPD)		21,600	24,624
Life of project (Years)		15	15
Total subsidy amount (Rs.)		1,296,000	1,218,878
Capital cost (Rs. with subsidy)		3,024,000	2,228,454
Capital cost (Rs. without subsidy)		4,320,000	3,447,332
Replacement cost for tubes after 5 years		Not Applicable	25% of the project cost
Replacement of fuel (tonne/annum)		40 (pet coke), 43 (rice husk)	40 (pet coke), 43 (rice husk)
Project IRR (%)	With subsidy	13	18
	Without subsidy	6	8
Payback period (Years) (with subsidy)		8-9	4-5
GHG emission reduction due to pet coke replacement (tonne CO_2 per year)		106.23	106.23

Source: PwC analysis based

8.2.1.2 Solar PV applications

Solar PV can be an option to produce electricity in this unit. Due to good solar irradiation in the area, the unit has potential for installation of small scale solar PV based electricity generation unit. Presently, the unit uses grid supplied electricity. The unit has an area of 4200 m², which permits installation of approximately 326 kWp of solar PV system. .

8.2.2 Unit 2

Table-59: Profile of Unit 2, Uttar Pradesh

Company Name	Unit 2	
Location	Saharanpur, Uttar Pradesh	
Company profile	Unit 2 is one of the largest paper mills in India. The mills manufactures Absorbent craft, plane craft, MAP litho, poster paper, coloured paper, cultural paper and notebook paper.	
Available free area for solar applications (m²)	5,000	
Processes feasible for use of solar energy	Pulping Cleaning and refining Disperser Dryer	
Source of energy in boiler	Coal	
Boiler parameters	Boiler capacity (tonne/hr)	40
	Working pressure (kg/cm²)	9 / 3.5
	Working temperature (˚C)	180 / 148
	Operating days/annum	350
	Feed water temperature (˚C)	68

	Condensate recovery (%)	55
Existing process requirements	Several processes in this industry require hot water/ steam, which are obtained from boiler. Solar applications can help generate steam or hot water to fulfil partial requirement of the industry.	

8.2.2.1 Potential solar thermal application

8.2.2.1.1 Pre-heating of Boiler Feed Water

Proposed solar technologies: As mentioned for unit 1, this unit can also install solar systems based on FPC and ETC to pre-heat the boiler feed water. A comparison of 100 LPD solar water heater based on FPC and ETC technology has already been provided in Table-49.

System integration and working principle: Boiler makeup water can be heated using solar heating in a similar manner as explained in the analysis of Unit 1.

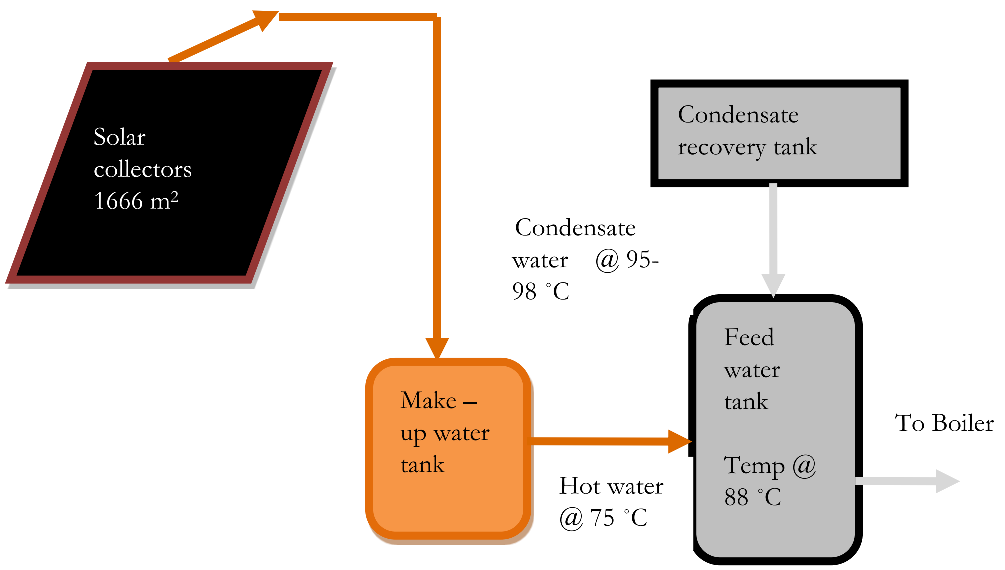
Estimated size of the proposed system: The sizing of solar water heating system was done considering the free space availability of the plant, the energy required to raise the temperature of makeup water in the boiler and the availability of solar irradiation in that area. The results are shown in Table-60.

Table-60: Pulp and Paper -Unit 2: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	833
Size of solar system (LPD)	83,300
Average saving of coal (tonne/annum)	378

Schematic diagram of the proposed system: For preheating the boiler makeup water, the water is circulated through collectors throughout the day, as long as the collector output is at a temperature higher than that of water in the storage tanks. Layout of the system is shown in Figure-39.

Figure 39: Pulp and Paper -Unit 2: Schematic diagram of the proposed SWH system for the preheating of BFW



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-61.

Table-61: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		1,666	1,424
Area required for solar system (m^2)		2,915	2,469
Capacity of the system (LPD)		83,300	94,958
Life of project (Years)		15	15
Total subsidy amount (Rs.)		4,998,000	4,700, 400
Capital cost (Rs. with subsidy)		11,662,000	8,593,660
Capital cost (Rs. without subsidy)		16,660,000	13,294,060
Replacement cost of tubes after 5 years		Not Applicable	25 % of the capital cost
Replacement of fuel (tonne/annum)		378	378
Project IRR (%)	With subsidy	7	10
	Without subsidy	1	1
Payback period (years) (with subsidy)		13-14	9-10
GHG emission reduction due to coal replacement (tonne CO_2 per year)		661.25	661.25

(Source: PwC analysis)

8.2.2.2 Solar PV applications

Electricity generation from solar PV in this unit is also possible because of the free space availability and good solar irradiation. This unit has an area of 2,000 m^2 and it can have installation of approximately 153 kWp of solar PV generating system. An inspection of the premises of the aforementioned unit revealed that 50 street lights comprising of sodium lamps of 150 W each can also be substituted by solar PV street lighting system.

8.2.3 Conclusion

Study carried out in this sector has given the following conclusion:

- many of the processes in pulp and paper industry need heat/steam,. Hence, it is technically viable to install solar water heating systems for makeup water heating for the boiler to replace the portion of the existing fuel use
- an open loop solar system is technically viable to preheat makeup water
- Boiler replacement can also be an option with the application of parabolic trough collector with proper thermal storage system. However, presently the cost of such a system is exorbitantly high; to the tune of Rs. 18-20 crores for replacing 1 TPH boiler. This makes the system commercially unviable.
- Field visits show that most of the units in this sector have sufficient shade free area for installing solar applications
- the project IRR of installation of solar applications depends on the fuel replaced and is as given in Table-62.

Table-62: Comparison of project IRRs in different scenarios in Pulp & Paper Sector

Particulars	Fuel replaced	Any incentive	Technology used

			FPC	ETC
Project IRR (%)	Pet coke and rice husk	With subsidy	13	18
		Without subsidy	6	8
	Coal	With subsidy	7	10
		Without subsidy	1	1

- without capital subsidy solar applications for boiler feed water does not seem to be viable option due to the fact that cheap fuel like rice husk, coal and pet coke are being used for steam production.
- conventional fuel replacement potential of this sector by pre-heating the boiler feed water is estimated to be 1-1.5%.
- the sector lacks awareness of solar technologies as well as the benefits associated with them. Central and State Government need to take steps to promote solar systems in paper units by creating awareness as well as by installing demonstration units

8.3 Pharmaceutical sector

Two pharmaceutical units were selected for study after discussions with the industry association. The units are located in Punjab and Maharashtra. These units were visited to assess the potential for installing of solar systems. The analysis of these units is given below:

8.3.1 Unit 1

Table-63: Profile of Unit 1, Maharashtra

Company Name	Unit 1		
Location	Tarapur, Boisar, Maharashtra		
Profile	The plant was commissioned in 1979 and it is a manufacturer of API and intermediates.		
Available free area for solar applications (m^2)	1,700 (land area + roof area)		
Processes feasible for use of solar energy	Distillation Evaporation Drying Carbon treatment		
Process parameters	Distillation	Hot water tank capacity (litre)	1,500
		Hot water temperature in hot water tank (˚C)	80
		Pump rating for circulation of hot water (m^3/hr)	22
		Δt during circulation of hot water in reactor	5
		Steam pressure (kg/cm^2)	2
		Steam temperature (˚C)	133
		Heat load per day	880,000
		Mean steam consumption rate (kg/hr)	213
	Boiler	Boiler capacity (tonne/hr)	3
		Working pressure (kg/cm^2)	3
		Working temperature (˚C)	150
		Operating days per annum	350
		Feed water temperature (˚C)	68
		Furnace oil consumption (tonne per day)	1.7

		Condensate recovery (%)	55
Existing technologies	**Distillation**: This process in the unit requires hot water at around 80 °C and it is generated from steam from boiler. **Boiler Feed Water:** In the pharmaceutical industry generally fossil fuel is used to generate steam for its process requirements. Processes like evaporation, drying and distillation consume steam. In this unit the condensate recovery is around 55% and rest of the requirement is met from makeup water. The makeup water is at a normal temperature of 25-28 °C.		
Source of energy	Furnace oil		

8.3.1.1 Potential solar thermal application

8.3.1.1.1 Distillation

Proposed solar technology: The distillation process in the unit requires hot water at 80-85 °C. To get this temperature, solar ETC technology is a viable option. Sizing details of such a system has been given in the Table-49.

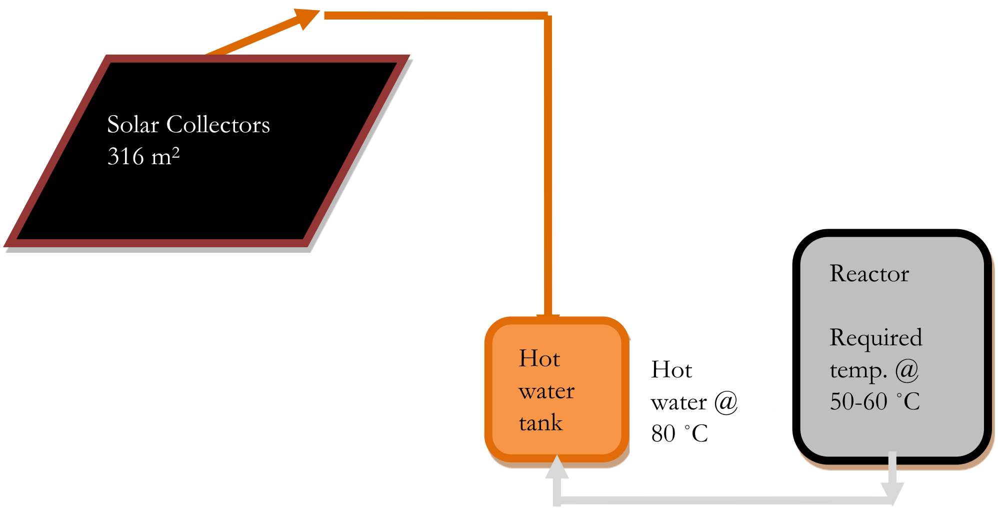
Solar equipment sizing and schematic diagram: In the present arrangement, hot water is generated from low pressure steam which is forcibly circulated in the reactor jacket in order to achieve the desired temperature of chemical reaction for distillation process. In order to estimate heat load for hot water generation, it is assumed that flow of hot water is at a rated flow of pump and Δt (temperature difference) during circulation of hot water shall be 5 °C. Based on the mentioned assumptions, the results obtained are as given in Table-64. Lay out of the SWH system shown in Figure-40.

Table-64: Pharmaceutical Unit 1: Estimated sizing of the SWH system

Description	Value
Collector type	Evacuated tube collector
Number of collectors	211
Size of solar system (LPD)	21,100
Average replacement of furnace oil (tonne/annum)	38

Source: PwC analysis

Figure -40: Pharmaceutical -Unit 1: Schematic diagram of the proposed SWH system for the distillation



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-65.

Table-65: Financial analysis

Particulars		ETC
Collector area (m^2)		316
Rooftop area require for solar system (m^2)		549
System size (LPD)		21,100
Life of project (Years)		15
Total subsidy amount (Rs.)		1,044,450
Capital cost (Rs. with subsidy)		1,909,550
Capital cost (Rs. without subsidy)		2,954,000
Replacement cost of the tubes after 5 years		25 % of project cost
Replacement of furnace oil (tonne/ annum)		38
Project IRR (%)	With subsidy	59
	Without subsidy	38
Payback period (years) (with subsidy)		1 - 2
GHG emission reduction due to furnace oil replacement (tonne CO_2 per year)		123.90

Source: PwC analysis

8.3.1.1.2 Boiler Feed Water

Proposed solar technologies: One of the major energy consumption equipment in the pharmaceutical unit is the boiler to produce steam. Boilers are fed with feed water of temperatures around 50-60 ˚C due to the partial recovery of condensate from the processes. In such cases, solar technologies can be used to heat the fresh water that is being added to the boiler at around 25-28 ˚C to reduce fuel consumption. For such an application, FPC and ETC are the most suitable solar thermal technologies. A comparison of 100 LPD solar water heater based on FPC and ETC technology has been provided in previous sections.

System integration and working principle: Boiler makeup water can be heated using solar heating in a similar way as explained in the analysis of Unit 1 of 'Pulp and Paper Sector'.

Estimated size of the proposed system: The sizing of solar water heating system was done based on the availability of free space in the plant, the energy required to raise the temperature of makeup water in the boiler and the availability of solar irradiation in that area. The results are shown in Table-66.

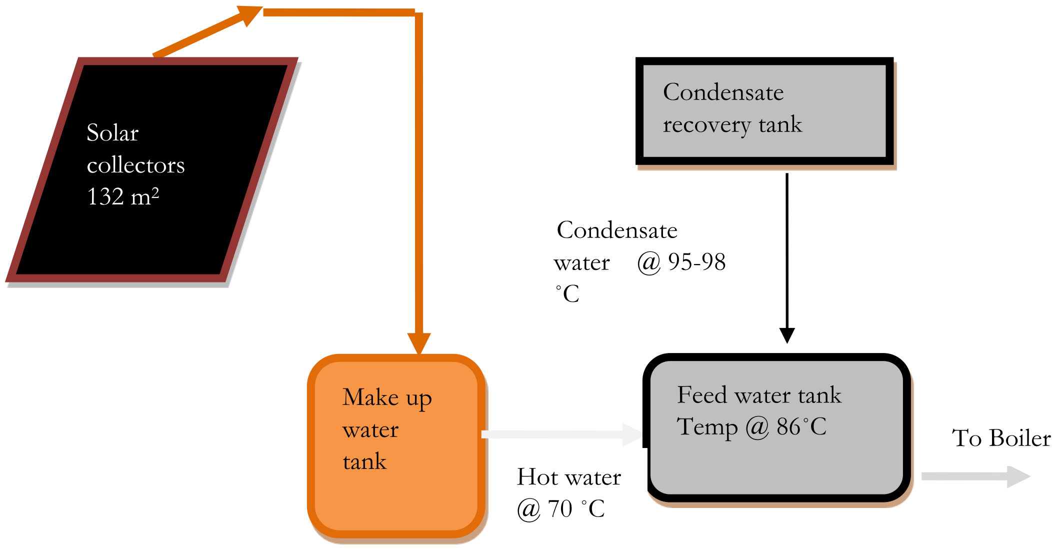
Table-66: Pharmaceutical -Unit 1: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	66
Size of solar system (LPD)	6,600
Average saving of furnace oil (kg/annum)	12,960

Source: PwC analysis

Schematic diagram of the proposed system: For preheating boiler makeup water, the water is circulated through collectors throughout the day, as long as the collector output is at a temperature higher than that of the water in the storage tanks. Layout of system is shown in Figure-41.

Figure- 41: Pharmaceutical -Unit 1: Schematic diagram of the proposed SWH system for the preheating of BFW



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-67.

Table-67: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		132	114
Area required for solar system (m^2)		231	197.60
Capacity of the system (LPD)		6,600	7,600
Life of project (Years.)		15	15
Total subsidy amount (Rs.)		396,000	376,200
Capital cost (Rs. with subsidy)		924,000	687,800
Capital cost (Rs. without subsidy)		1,320,000	1,064,000
Replacement cost of the tubes after 5 years		Not Applicable	25 % of the capital cost
Average replacement of furnace oil (kg/annum)		12, 960	12,960
Project IRR (%)	With subsidy	42	56
	Without subsidy	30	36
Payback period (years) (with subsidy)		1-2	1-2
GHG emission reduction due to furnace oil replacement (tonne CO_2 per year)		42.25	42.25

Source: PwC analysis based

8.3.1.1.3 Evaporation

Existing technology: To recover the product (Paragenamite) from the solvent, the triple effect evaporator is used. In order to extract the desired product from the solvent, low pressure steam is used. The consumption of steam in this process is approximately 500-520 kg/day. The steam characteristics enumerated for this process is 2 bars @ 133 ˚C. Steam required in this process is presently produced from the boiler.

However, replacement of the usage of the boiler with solar concentrator technology can be proposed for the production of steam. In order to achieve the required steam parameters, the best fit with respect to solar concentrator technology is the solar dish.

8.3.1.1.4 Drying

Existing technology: Drying of the bulk drugs is done through fluidised bed and tray dryer. The drying process involves inter-alia suction of the air through the blowers which is blended with steam. Consequently, the blended mixture produces hot air which is used for drying. The steam reserved for this process exhibits the characteristics of 2-3.5 kg/cm² @ 133-150 ˚C. The desired temperature range for the dried product is approximately 40-100 ˚C and the drying cycle in pursuit of this activity is 4-10 hrs.

However, it is proposed that the usage of steam in this arrangement could be replaced with solar dryer technology.

8.3.1.2 Solar PV applications

Good solar irradiation in the area and the free space available indicated that there is possibility to generate electrical energy by installing solar PV. The plant has an asbestos sheet area at the rooftop of 1375 m². Hence, the available area permits installation of approximately 105 kWp of solar PV generating system.

8.3.2 Unit 2

Table-68: Profile of Unit 2, Derabassi (Punjab)

Company Name	Unit 2	
Location	Derabassi, Punjab	
Company profile	Unit 2 is a vertically integrated, research based, pharmaceutical manufacturer and exporter, specializing in development and manufacturing of Active Pharmaceutical Ingredients (API) and API intermediates. The Company has dedicated facilities for custom research and API manufacturing at its 4 locations: 2 in Haryana (India) and 2 in Punjab (India) and exports to over 51 countries across the globe from its WHO-GMP facilities.	
Available free area for solar applications (m2)	8,000	
Processes feasible for use of solar energy	Boiler feed water heating Distillation Drying	
Operational feature	Boiler capacity (tonne/hr)	6
	Working pressure (kg/cm²)	3.5
	Working temperature (˚C)	150
	Operating days per annum	300
	Feed water temperature (˚C)	65
	Flue gas heat recovery	Yes
	Rice husk consumption (tonne per day)	20
Existing technologies	The unit uses rice husk for steam generation in the boiler and the boiler meets the thermal energy requirement of most of the processes in the plant. In majority of the industrial application, pre-heating of water is done through the condensate recovery system before feeding the water into the boiler. However, in this industrial unit, the heat content of the waste gases coming out from the boiler is extracted to pre-heat the boiler feed in water.	

8.3.2.1 Solar thermal application

8.3.2.1.1 Boiler Feed Water

Proposed solar technologies: This unit also has the potential of heating boiler feed water, but only to a certain extent. Boilers are fed with feed water of temperatures around 50-60 ˚C due to the partial recovery of condensate from the processes. In such a case, solar technologies can be used to heat the fresh water which is added to the boiler at around 25-28 ˚C, to reduce the fuel consumption. For such an application, FPC and ETC are the most suitable solar thermal technologies. A comparison of 100 LPD solar water heater based on FPC and ETC technology has been provided in Table-49.

System integration and working principle: Boiler makeup water can be heated using solar heating in a similar way as explained in the analysis of Unit 1 of 'Pulp and Paper Sector'.

Estimated size of the proposed system: The sizing of solar water heating system was done considering the availability of free space within the plant, the energy required to raise the temperature of makeup water in the boiler and the availability of solar irradiation in that area. The results are shown in Table-69.

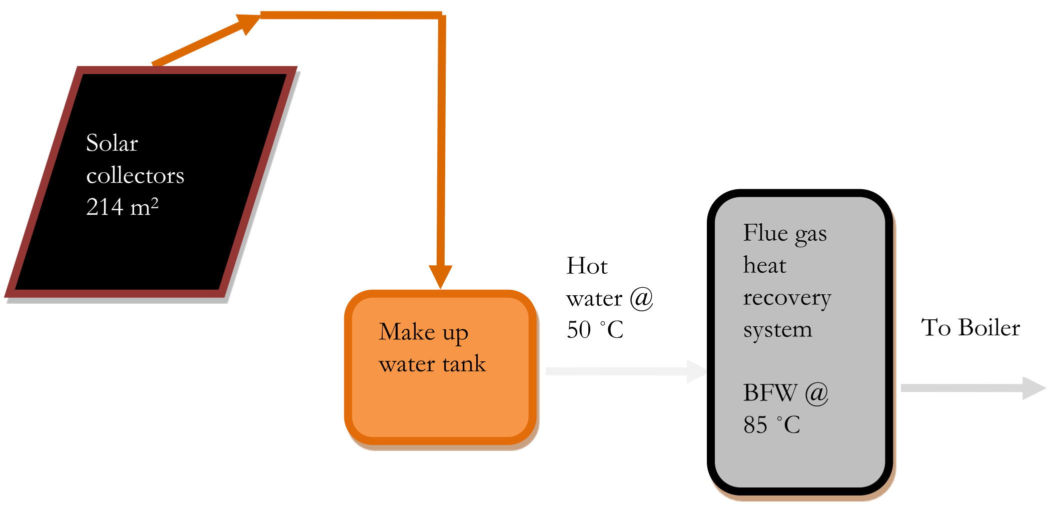
Table-69: Pharmaceutical -Unit 2: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	107
Size of solar system (LPD)	10,700
Average saving of rice husk (tonne/annum)	64

Source: PwC analysis based

Schematic diagram of the proposed system: For preheating the boiler makeup water, water is circulated through the collectors throughout the day, as long as the collector output is at a temperature higher than that of water in the storage tanks. Layout of system is shown in Figure-42.

Figure- 42 : Pharmaceutical -Unit 2: Schematic diagram of the proposed SWH system for the preheating of BFW



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-70.

Table-70: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		214	183
Area required for solar system (m^2)		374.5	317
Capacity of the system (LPD)		10,700	12,200
Life of project (Years)		15	15
Total subsidy amount (Rs.)		642,000	603,900
Capital cost (Rs. with subsidy)		1,498,000	1,104,100
Capital cost (Rs. without subsidy)		2,140,000	1,708,000
Replacement cost of the tubes after 5 years		Not Applicable	25% of the capital cost
Replacement of rice husk(tonnes/annum)		64	64
Project IRR (%)	With subsidy	11	15
	Without subsidy	5	5
Payback period (years) (with subsidy)		11-12	5-6

Source: PwC analysis

8.3.2.2 Solar PV applications

Good solar irradiation in the area and the free space available indicated that there is possibility to generate electrical energy by installing solar PV. The plant has land area of 7625 m^2. Hence, the available area permits installation of approximately 586 kWp of solar PV generating system.

Walk through audit in the premises of the aforementioned unit revealed that 60 street lights comprising of mercury vapour lamps with 250 W each could be substituted by solar PV street lighting system.

8.3.3 Conclusion

The findings of the field studies and other analysis of the pharmaceutical industry are as shown below:

- most of the processes in pharmaceutical industries use steam. Hence, it is a viable option to install solar water systems for makeup water heating for the boilers to replace a part of the existing fuel use
- to preheat makeup water an open loop solar system is technically feasible
- for hot water generator system in the process, closed loop solar system is technically feasible
- Field studies revealed that units in this sector have insufficient free space for installing solar applications because of exhaustive utility piping network over the roof, which is generally available for solar applications in other sectors
- when the fuel used is both furnace oil as well as rice husk, the cost benefit analysis for installing these solar water heating systems for preheating of makeup water/boiler feed water shows following IRR in Table-71

Table-71: Comparison of cost parameters for different technologies for BFW application

Particulars	Fuel replaced	Any Incentive	Technology used	
			FPC	ETC
Project IRR (%)	Furnace oil	With subsidy	42	56
		Without subsidy	30	36
	Rice husk	With subsidy	11	15
		Without subsidy	5	5

The cost benefit analysis of installation of solar water heating systems for carrying out distillation process shows the following IRR in Table-72.

Table-72: Comparison of the IRRs for different technologies for distillation application

Particulars	Fuel replaced	Any incentive	Technology used
			ETC
Project IRR (%)	Furnace oil	With subsidy	59
		Without subsidy	38

- the Central and State Government can promote solar systems in pharmaceutical industries by creating awareness about the usage of system and by formulating potential measures to weed out technical bottlenecks in integrating SWH systems in pharmaceutical units.

8.4 Food Processing sector

Two units were visited for field study in the food processing sector. A unit wise analysis is given below:

8.4.1 Unit 1

Table-73: Profile of Unit 1, Baddi (HP)

Company Name	Unit 1	
Location	Baddi, Himachal Pradesh	
Company profile	Unit 1 is the fourth largest FMCG Company in India with revenues of US$750 Million (Rs 3416 Crore) and a market capitalisation of US$3.5 Billion (over Rs 16,000 Crore). Based on a legacy of quality and experience of over 125 years, Unit 1 operates in key consumer products categories like Hair Care, Oral Care, Health Care, Skin Care, Home Care, and Foods.	
Unit 1 - Hajmola Plant		
Available free area for solar applications (m^2)	1,350	
Processes feasible for use of solar energy	Pre heating of Boiler Feed water	
Boiler parameters	Boiler capacity (tonne/hr)	0.75
	Working pressure (kg/cm^2)	3.5
	Working temperature (˚C)	195-200
	Operating days per annum	300
	Presently BFW temperature (˚C)	44
	Furnace oil consumption (kg/day)	200
	Condensate recovery	Yes
Existing process	At the Unit 1-Hajmola plant, furnace oil is being used to generate steam for its process requirements. The plant is recovering only 20% condensate from the process. The rest of the demand is being met by feeding makeup water to the boiler at normal temperature.	
Source of energy	Furnace oil	
Unit 1 - Honey Plant		
Available free area for solar applications (m^2)	2,450	
Processes feasible for use	Pre heating of Boiler Feed water	

of solar energy		
Boiler parameters	Boiler capacity (tonne/hr)	1.5
	Working pressure (kg/cm^2)	3.5
	Working temperature (°C)	195-200
	Operating days per year	300
	Feed water temperature (°C)	30
	Furnace oil consumption (litre/day)	700
	Condensate recovery	No
Existing process	Same as for Hajmola plant.	
Source of energy	Furnace oil	
Unit 1 - Chavanprash Plant		
Available free area for solar applications (m^2)	3,400	
Processes feasible for use of solar energy	Pre heating of Boiler Feed water	
Boiler parameters	Boiler capacity (tonne/hr)	5
	Working pressure (kg/cm^2)	3.5
	Working temperature (°C)	195-200
	Operating days per year	300
	Feed water temperature (°C)	58
	Furnace oil consumption (tonne/day)	30
	Condensate recovery	Yes
Existing process	At the Unit 1-Chavanprash plant, furnace oil is being used to generate steam for its process requirements. The plant is recovering only 40% condensate from the process. The rest of the demand is being met by feeding makeup water to the boiler at normal temperature.	
Source of energy	Furnace oil	

8.4.2 Unit 1-Hajmola Plant

8.4.2.1 Potential solar thermal application

8.4.2.1.1 Boiler Feed Water

Proposed solar technologies: One of the major energy consuming equipments in this unit is the boiler to produce steam. Boilers are fed with feed water of temperatures around 45-60 °C due to the partial recovery of condensate from the processes. In such cases, solar technologies can be used to heat the fresh water that is being added to the boiler, at around 25 °C, to reduce fuel consumption. For such an application, FPC and ETC are the most suitable solar thermal technologies. A comparison of 100 LPD solar water heater based on FPC and ETC technology has been provided in previous sections.

System integration and working principle: Boiler makeup water can be heated using solar heating in a way similar to as explained in the analysis of Unit 1 of 'Pulp and Paper sector'.

Estimated size of the proposed system: The sizing of solar water heating system was done considering the available free space with the plant, the energy required to raise the temperature of makeup water in the boiler and available solar irradiation in that area. The results are shown in Table-74.

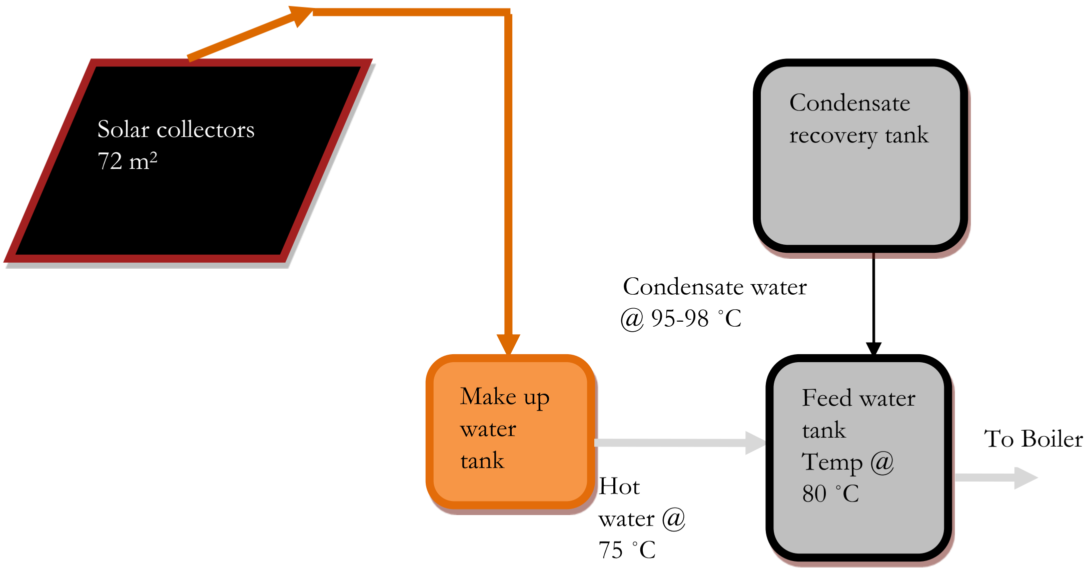
Table-74: Food Processing -Unit 1.1: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	36
Size of solar system (LPD)	3,600
Average saving of furnace oil (kg/annum)	6,480

(Source: PwC analysis)

Schematic diagram of the proposed system: For preheating boiler makeup water, water is circulated through collectors throughout the day as long as the collector output is at higher temperature than that of the water in the storage tanks. Lay out of the proposed system is shown in Figure-43.

Figure- 43 : Food Processing-Unit 1.1: Schematic diagram of the proposed SWH system



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-75.

Table-75: Financial analysis

Particulars		FPC	ETC
Collector area (m²)		72	61.50
Rooftop area required (m²)		126	106
System size (LPD)		3,600	4,100
Life of project (Years)		15	5
Total subsidy amount		216,000	86,100
Capital cost (Rs. with subsidy)		504,000	371,050
Capital cost (Rs. without subsidy)		720,000	574,000
Replacement cost of tubes after every 5 years		Not Applicable	25 % of the project cost
Average replacement of furnace oil (kg / annum)		6,480	6,480
Project IRR %	With subsidy	39	52
	Without subsidy	27	34
Payback period (Years)(with subsidy)		2-3	1-2
GHG emission reduction due to furnace oil replacement (tonne CO_2 per year)		21.13	21.13

Source: PwC analysis

8.4.2.2 Solar PV applications

The plant has around 1224 m² area available for installation of solar PV. This area is sufficient to install approximately 94 kWp of solar PV electricity system.

8.4.3 Unit 1-Honey Plant

8.4.3.1 Potential solar thermal applications

Honey making plant is using steam to generate hot water which can be produced by using solar water heating systems based on FPC and ETC technology.

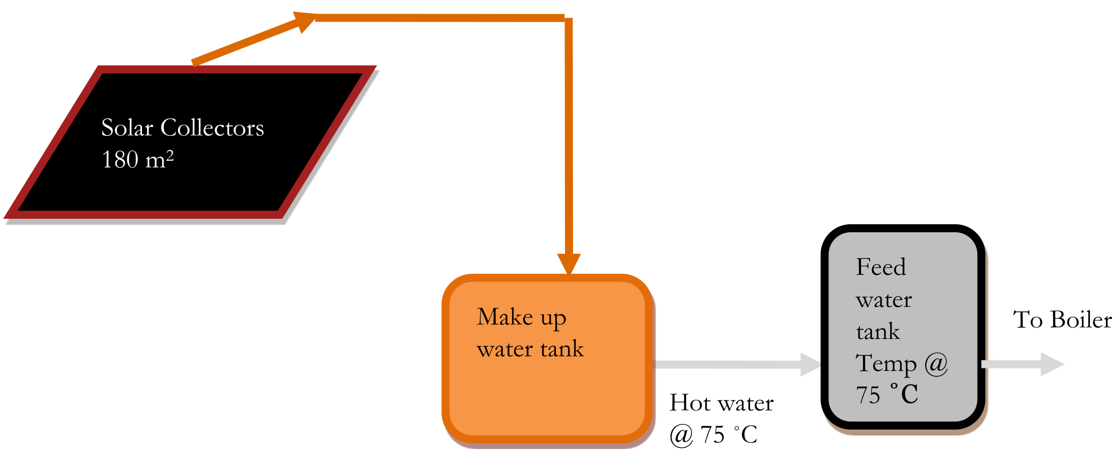
Table-76: Food Processing -Unit 1.2: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	90
Size of solar system (LPD)	9,000
Average saving of furnace oil (kg/annum)	16,200

(Source: PwC analysis)

Schematic diagram of the proposed system: For preheating boiler makeup water, water is circulated through collectors throughout the day as long as the collector output is at higher temp than that of water in the storage tanks. Lay out of the proposed system is shown in Figure-44.

Figure- 44: Food Processing-Unit 1.2: Schematic diagram of the proposed SWH system



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-77.

Table-77: Financial analysis of installation of SWH system in Unit 1.2 – Food Processing

Particulars	FPC	ETC
Collector area (m²)	180	154.50
Rooftop area required (m²)	315	268

System size (LPD)		9,000	10,300
Life of project (Years)		15	15
Total subsidy amount (Rs.)		540,000	509,850
Capital cost (Rs. with subsidy)		1,260,000	932, 150
Capital cost (Rs. without subsidy)		1,800,000	1,442,000
Replacement cost of tubes after 5 years		Not Applicable	25% of capital cost
Average replacement of furnace oil (kg / annum)		16,200	16,200
Project IRR (%)	With subsidy	39	51
	Without subsidy	27	34
Payback period (Years) (with subsidy)		2-3	1-2
GHG emission reduction due to furnace oil replacement (tonne CO_2 per year)		52.82	52.82

(Source: PwC analysis)

8.4.3.2 Solar PV applications

The plant has around 2135 m² area available for installation of solar PV. This area is sufficient to install approximately 164 kWp of solar PV generating system.

Unit 1-Chavanprash Plant

8.4.3.3 Potential solar thermal applications

8.4.3.3.1 Boiler Feed Water

Proposed solar technologies: This section of the plant is also using boiler to produce steam which is one of the major energy consuming equipments. As the condensate recovery is partial from the process so the feed water temperature to the boiler is around 50-60 ˚C because of mixing of condensate and makeup water. This also has the potential to install solar water heating system for heating of makeup water using FPC and ETC based solar technologies.

System integration and working principle: Boiler makeup water can be heated using solar heating in a way similar to as explained in the analysis of Unit 1 of 'Pulp and Paper Sector'.

Estimated size of the proposed system: The estimated size of the solar water heating system for this plant is given in Table-78.

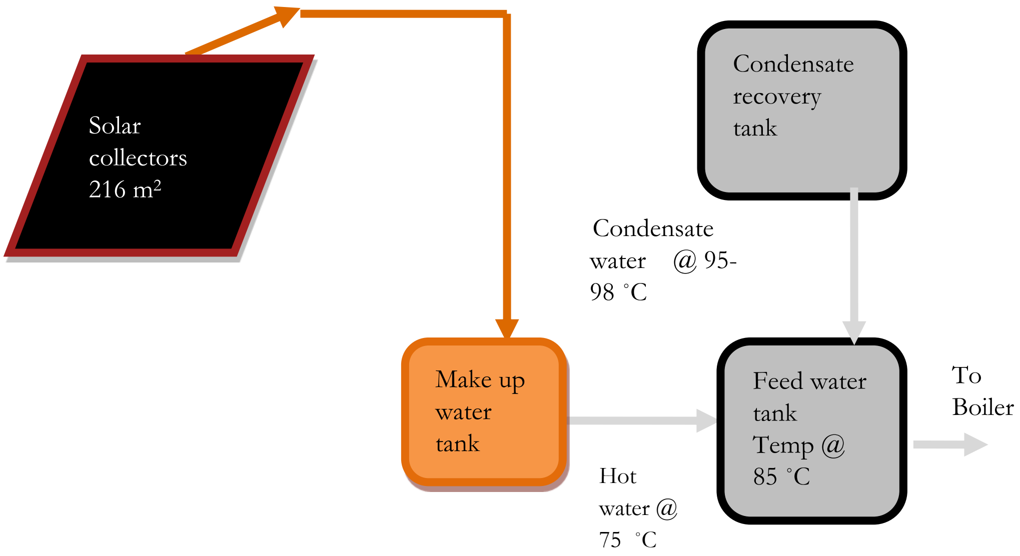
Table-78: Food Processing -Unit 1.3: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	108
Size of solar system (LPD)	10,800
Average saving of furnace oil (kg/annum)	19,440

(Source: PwC analysis)

Schematic diagram of the proposed system: For preheating boiler makeup water, water is circulated through collectors throughout the day as long as the collector output is at higher temp than that of water in the storage tanks. Layout of the proposed system is shown in Figure-45.

Figure- 45: Food Processing-Unit 1.3: Schematic diagram of the proposed SWH system



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-79.

Table-79: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		216	185
Rooftop area required (m^2)		378	320
System size (LPD)		10,800	12,300
Life of project (Years)		15	15
Total subsidy amount		648,000	608,850
Capital cost (Rs. with subsidy)		1,512,000	1, 113, 150
Capital cost (Rs. without subsidy)		2,160,000	1,722,000
Replacement cost of the tubes after 5 years		Not Applicable	25% of project cost
Average replacement of furnace oil (kg/annum)		19,440	19,440
Project IRR (%)	With subsidy	39	52
	Without subsidy	27	34
Payback period (Years) (with subsidy)		2-3	1-2
GHG emission reduction due to furnace oil replacement (tonne CO_2 per year)		63.38	63.38

Source: PwC analysis

8.4.3.4 Solar PV applications

The plant has around 3,022 m² area available for installation of solar PV. This area is sufficient to install approximately 232 kWp of solar PV electricity generation system.

8.4.4 Unit 2

Unit 2 of food processing sector is located near Ludhiana and is into the manufacturing of biscuits, sauces, snacks, buns, etc. Biscuits are made in large tunnel type kilns, which use diesel/FO as fuel to generate temperatures around 300 ˚C. Most of the processes in this plant require direct firing so it is not possible to use solar energy by replacing the diesel/furnace oil. The plant has substantial roof area which can be used for installation of Solar PV system but the existing structure is not capable of taking load of the solar PV system so solar PV can be installed only after providing proper support on the roof.

8.4.5 Conclusion

The findings of the field studies and analysis thereafter of the food processing units are given below:

- many of the processes in food processing plants need steam and it is a viable option to install solar water heating systems for makeup water heating for the boiler to replace a portion of the existing fuel use
- to preheat makeup water an open loop solar water heating system is technically viable
- units visited in this study shows that sector has sufficient shade free area for installing solar applications.
- the cost benefit analysis shows that installation of solar water heating systems for the preheating of boiler feed/makeup water has IRRs shown in Table-80.

Table-80: Cost Comparison of cost parameters for SWH systems

Particulars	Fuel replaced	Any incentive	Technology used	
			FPC	ETC
Project IRR (%)	Furnace oil	With subsidy	39	52
		Without subsidy	27	34

- analysis showed that the sector have potential to replace around 7-9% of the conventional fuel being used with solar energy
- the sector lacks awareness about solar technologies as well as the benefits associated with them

8.5 Textile (spinning and weaving)

In the textile sector, two units were visited to find the feasibility of installation of solar applications.

8.5.1 Unit 1

Table-81: Company Profile of Unit 1, Bhilwara (Rajasthan)

Company Name	Unit 1	
Location	Mandapam, Bhilwara, Rajasthan	
Company profile	This unit was commissioned in 1971 and presently the enterprise has approximately Rs. 2,450 crore of annual turnover The unit is manufacturer of yarn and fabric Annual production capacity of yarn is 4,560 tonne and 9.14 Million meters for fabric.	
Available free area for solar applications (m^2)	The plant has sufficient area to install any solar equipment although the roof is made up of Asbestos Corrugated Cement (ACC) sheets and cannot take the load of the systems.	
Processes feasible for use of solar energy	Electricity generation Yarn conditioning unit – yarn conditioning is a process of impregnating moisture content in the yarn.	
Operational features	Electrical load (kW)	60

	Batches(Number per day)	15-18
	Operation of heater (minutes/batch)	4-5
	Water consumption at the yarn (litres/ batch)	30-40
	Working temperature (˚C)	55-60
	Operating days per annum	300
	Energy consumption (kWh/day)	90
Existing process	Presently, the Yarn Conditioning Unit (YCU) operates through electrical heating. YCU is a cylindrical shaped hollow unit, which houses the processed yarn for moisture impregnation. Bottom part of the YCU contains a water tank with electrical heaters. Whole unit works under the vacuum of 650 millibar. The water evaporates at 55-60 ˚C and generates the flash steam, which is absorbed by the Yarn. Yarns generally gain around 3-4% moisture in this process.	
Source of energy	Electricity from grid	
Total annual electricity consumption for yarn conditioning	27 MWh	

8.5.1.1 Potential solar thermal application

8.5.1.1.1 Water heating in yarn conditioning unit

Proposed solar technologies: In the existing process, the water temperature is raised up to 60 ˚C in the yarn conditioning unit, which operates in a vacuum. With the whole unit maintained at -650 millibar at 60 ˚C, water is converted to flash steam that is required for the process. Electrical heaters are being used to heat the water and produce the flash steam at negative pressure. This causes steam to come in contact with the yarn which is required for its strengthening. For this requirement, FPC and ETC are most feasible solar thermal technologies which can replace the existing method of heating water for flash steam generation.

System integration and working principle: The yarn is put in the conditioning unit where it absorbs moisture. The water consumption in the process is around 30-40 litres/batch totalling to around 700-800 litres per day. This process involves water heating through electrical heating. Cold water is fed through a water pump in the water storage tank where it is heated to the desired temperature level. At around 55-60 ˚C at negative pressure, the steam generation starts. The proposed solar system will provide water at the desired temperature which will be converted into steam as soon as it enters in the yarn conditioning unit. The proposed system will replace the use of electrical heater, which will remain in the unit as standby and can be operated when solar heating is not available.

Estimated size of the proposed system: The sizing of solar water heating system proposed here is given in Table-82:

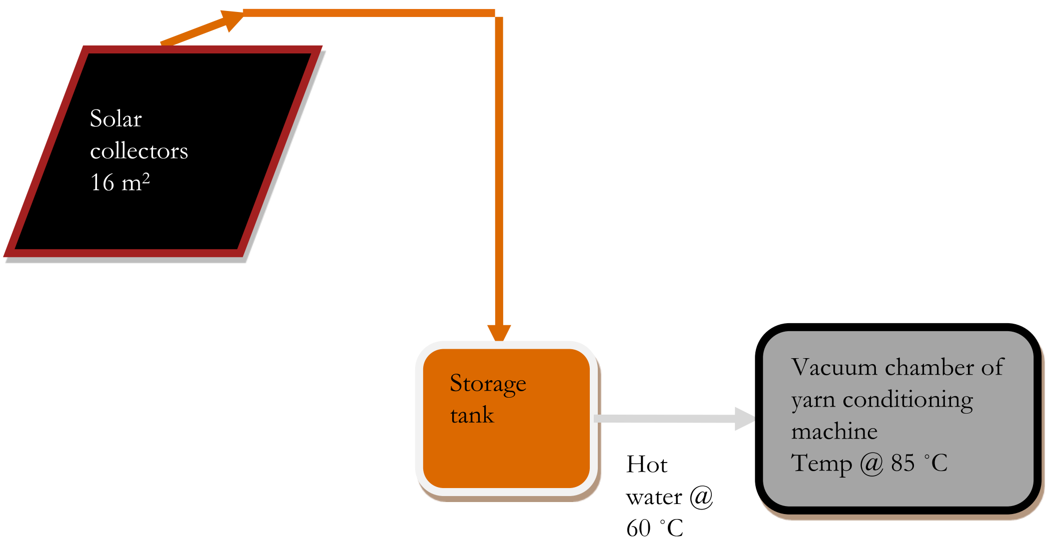
Table-82: Textiles-Unit 1: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	8
Size of solar system (LPD)	800
Average saving of electricity (kWh/day)	50

Source: PwC analysis

Schematic diagram of the proposed system: For preheating boiler makeup water, water is circulated through collectors throughout the day as long as the collector output is at higher temperature than that of water in the storage tanks. Layout of proposed system is shown in Figure-46:

Figure- 46 : Textiles Unit 1: Schematic diagram of the proposed SWH system for the yarn conditioning



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-83:

Table-83: Financial analysis

Particulars		FPC	ETC
Collector area (m^2)		16	12
Total area required (m^2)		28	21
System size (LPD)		800	800
Life of project (Years)		15	15
Total subsidy amount		48,000	39,600
Capital cost (Rs. with subsidy)		112,000	72,400
Capital cost (Rs. without subsidy)		160,000	112,000
Replacement cost of tubes after 5 years		Not Applicable	25 % of the capital cost
Average saving of electricity (kWh/annum)		15,000	15,000
Project IRR (%)	With subsidy	52	80
	Without subsidy	37	52
Payback period (Years) (with subsidy)		1-2	1-2
GHG emission reduction due to electricity replacement (tonne CO_2 per year)		12.30	12.30

(Source: PwC analysis)

8.5.1.2 Solar PV applications

Due to good solar irradiations in the area, the plant can generate electricity through solar PV. The plant has a huge area available on the roof but it is made up of asbestos sheets, which cannot take the load of the solar PV systems without proper support. So, if the plant provides proper support on the roof it can be used for solar PV installation.

8.5.2 Unit 2

Table-84: Company Profile of Unit 2, Banswara (Rajasthan)

Company Details	Unit 2	
Location	Industrial Area, Dahod Road, Banswara, Rajasthan	
Company profile	This unit was commissioned in 1976 and presently the enterprise has approximately Rs. 630 crores of annual turnover The unit is manufacturer of Yarn and fabric. Annual production capacity is 144,380 spindles	
Available free area for solar applications (m^2)	The plant has sufficient area to install any solar equipment although the roof is made up of ACC sheets and cannot take the load of the systems.	
Processes feasible for use of solar energy	Electricity generation Yarn conditioning unit – yarn conditioning is a process of impregnating moisture content in the yarn.	
Operational features	Electrical load (kW)	108
	Batches(Number per day)	15-18
	Operation of heater (minutes/batch)	4-5
	Water consumption at the yarn (litres/batch)	40-50
	Working Temperature (˚C)	55-60
	Operating days per annum	300
	Energy consumption (kWh/day)	150
Existing process	Presently, the Yarn Conditioning Unit (YCU) operates through electrical heating. YCU is a cylindrical shaped hollow unit, which houses the processed yarn for moisture impregnation. Bottom part of the YCU contains a water tank with electrical heaters. Whole unit works under the vacuum of 80 millibar. The water evaporates at 55-60 ˚C and generates the flash steam, which is absorbed by the Yarn. Yarns generally gain around 3-4% moisture in this process.	
Source of energy	Electricity from grid	
Total annual electricity consumption for yarn conditioning	45MWh	

8.5.2.1 Potential solar thermal application

8.5.2.1.1 Water heating in yarn conditioning unit

Proposed solar technologies: In the existing process, the water temperature is raised up to 60 ˚C in the yarn conditioning unit, which operates in vacuum. With the whole unit maintained at the -80 millibar at 60˚C, water starts generating flash steam that is required for the process. Electrical heaters are being used to heat the water and produce the flash steam at negative pressure. This causes steam to come in contact with the yarn which is required for its strengthening. For this requirement, FPC and ETC are most feasible solar thermal technologies which can replace the existing method of heating water for flash steam generation.

System integration and working principle: The yarn is put in the conditioning unit, where it absorbs moisture. The water consumption in the process is around 30-40 litres/batch totalling to around 900-1000 litres per day. This process involves water heating through electrical heating. Cold water is fed through a water pump in the water storage tank, where it is heated to the desired temperature level. At around 55-60 ˚C at negative pressure, the steam generation starts. The proposed Solar system will provide water at the desired temperature which will be converted into steam as soon as it enters in the yarn conditioning unit. The proposed system will replace the use of electrical heater, which will remain in the unit as standby and can be operated when solar heating is not available.

Estimated size of the proposed system: The sizing of solar water heating system proposed above is given in Table-85:

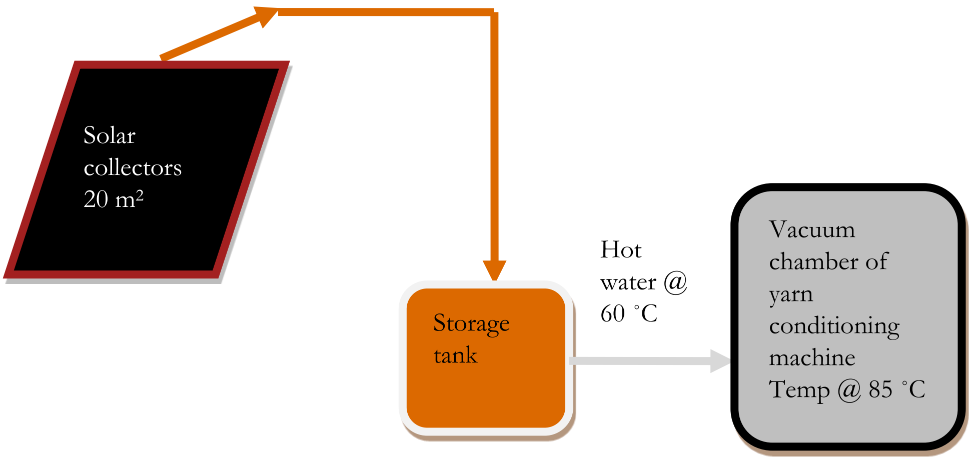
Table-85: Textiles-Unit 2: Estimated sizing of SWH system

Description	Value
Collector type	Flat plat collector
Number of collectors	10
Size of solar system (LPD)	1000
Average saving of electricity (kWh/day)	50

Source: PwC analysis

Schematic diagram of the proposed system: For preheating boiler makeup water, water is circulated through collectors throughout the day as long as the collector output is at higher temp than that of water in the storage tanks. Layout of proposed system is shown in Figure-47:

Figure- 47 : Textiles Unit 2: Schematic diagram of the proposed SWH system for the yarn conditioning



Financial analysis: Financial analysis of the proposed solar water heating systems was carried out to estimate the IRR and payback period. The analysis is given in Table-86:

Table-86: Financial analysis

Particulars	FPC	ETC
Collector area (m^2)	20	15
Total area required (m^2)	35	26
System size (LPD)	1000	1000
Life of project (Years)	15	15
Total subsidy amount	60,000	49,500
Capital cost (Rs. with subsidy)	140,000	90,500
Capital cost (Rs. without subsidy)	200,000	140,000
Replacement cost of tubes after 5 years	Not Applicable	25 % of capital cost
Average saving of electricity (kWh/annum)	15,000	15,000

Particulars		FPC	ETC
Project IRR (%)	With subsidy	42	64
	Without subsidy	30	42
Payback period (Years) (with subsidy)		1-2	1-2
GHG emission reduction due to electricity replacement (tonne CO_2 per year)		12.30	12.30

Source: PwC analysis

8.5.2.2 Solar PV applications

Owing to good solar irradiations in the area, the plant can generate electricity with installation of solar PV. The plant has a huge area available on roof but it is made up of asbestos sheets, which can not take the load of the solar PV systems without proper support. So, if the plant provides proper support on the roof it can be used for solar PV installation.

8.5.3 Conclusion

The major findings of the field studies and analysis thereafter of the textiles (spinning and weaving) units are given below:

- in textile units, the process require hot water at around 55-60 °C for use in yarn conditioning process and this can easily be obtained from solar water heating systems with good system efficiency
- open loop system based solar technologies namely Flat Plate Collectors as well as Evacuated Tube Concentrators can be used in this sector
- field surveys revealed that units have sufficient free space for installing solar applications but roofs are generally made of asbestos corrugated sheets, which can not be loaded with solar panels
- the cost benefit analysis of installation of solar water heating systems after replacing the electrical heaters shows IRRs as shown in Table-87

Table-87: IRR's Comparison for yarn conditioning application

Particulars	Fuel replaced	Any incentive	Technology used	
			FPC	ETC
Project IRR (%)	Electricity	With subsidy	52	80
		Without Subsidy	37	52
	Electricity	With subsidy	42	64
		Without Subsidy	30	42

- discussions with the unit owners revealed that they lack awareness about the viability of solar applications
- unit owners showed keen interest in implementing a possible solar system retrofit
- MNRE can take steps to promote solar systems in the textile industry by installing successful demonstration systems for a large scale replication in the sector

9 Way Forward for pilot projects

Results of the field visits and analysis of the data generated indicated that some of the energy consuming applications in these sectors can be suitably complemented with various solar energy technologies. The large-scale rollout as well as widespread adoption and replication of these solar technologies could be undertaken through different business models.

The business models most suited for solar energy technology promotion for industrial applications should have direct participation of the project beneficiaries. Outright grants or capital subsidies undermine the owner-accountability for the project results and has a detrimental effect on sustainability. Accordingly, it is important to have arrangements with a blend of debt and project beneficiary contributing for the equity. This is the classic project-financing model that is followed for a large number of renewable energy initiatives. The model is suitable for project beneficiaries that have the financial ability to arrange (raise or plough back from savings) the required equity contributions or for renewable energy projects that are not capital intensive. However, developers find it difficult to invest in projects which are capital intensive.

An alternative that addresses this deficiency is offered by Renewable Energy Service Companies (RESCO) model. This model is a relatively new financial innovation that allows the project beneficiaries to make periodic payments against renewable energy services (either payment for renewable energy based power or energy savings) instead of bearing (a part of) the upfront capital cost. The RESCO will absorb this burden and also provide annual maintenance and repairs to guarantee the minimum service delivery. This model has the benefit of allowing the project-beneficiary to simply make payments against services received without worrying about maintenance and repairs or upfront capital cost. The potential drawback of this model is the need for a mutually agreeable measure for the quantum of service provided to ensure both parties are satisfied with the financial agreements.

Some of the feasible RESCO business models are as follows:

- User Financing
- Shared- Saving
- RESCO-User Bank Facilitation

Detailed analysis of the aforementioned models is provided in one of the MNRE reports titled "Development of an Area Based Energy Service Company (ESCO) Model for Solar Water Heating in India".

9.1 Recommendation for adoption of business model

The suitability of business model for different solar projects depends on the type of returns expected from that project. In solar projects, the return mainly depends on the fuel replaced with the use of solar energy. In case of costly fuels like diesel, furnace oil, electricity, etc the returns are very good and hence payback periods are short. However, in case of cheap fuels like rice husk, pet coke, coal, etc the returns are not as good and hence paybacks are long. Payback periods inversely affect the expected return from capital invested. Thus, the longer the payback period, lesser would be the incentive for end users to invest.

Table-88: Suggested business models

Payback period	Model recommended	Rationale
Long (more than 5	Self Financing, User Financing RESCO	RESCO companies would be providing operation and maintenance (O&M) services to the projects at end user sites. So

years)	model	returns are only envisaged on the O&M service, hence such arrangement would qualify for longer payback.
Moderate (3 – 5 years)	Shared- Saving RESCO model	Since the percentage negotiated on the savings incurred due to solar interventions would act as returns to the RESCO companies, the project can be expected to have a moderate payback period.
Short (up to 3 years)	RESCO-User- Bank Facilitation model	The RESCO companies would be provided with capital subsidies on solar applications as well as monthly bills for services provided at project site. Therefore returns would be high. This business model would have a shorter payback period.

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Annexure-1 Framework Matrix for Identification of Industrial Sectors

Parameter / Industrial Sector→	Weights*	Automobile	Ranking	Total marks	Leather	Ranking	Total marks	Textile (Spinning & Weaving)	Ranking	Total marks
Energy consumption in the sector (in Mtoe)	10	0.59	9	90	0.15	4	40	3.34	12	120
Heating load as a percentage of total energy consumption	30	30%	6	180	35%	7	210	20%	4	120
Cooling load as a percentage of total energy consumption	10	0%	1	10	10%	3	30	0%	1	10
Power generation/DG sets/Captive load in MW	10	264	10	100	47.80	5	50	558	12	120
Number of units in sector	20	553	6	120	10200	10	200	3267	8	160
Dispersion of sector assets	10	Clustered	10	100	Clustered	10	100	Clustered	10	100
Past solar experience in sector	10	NO	0	0	YES	10	100	NO	0	0
Total [∑(weight age*rank)]	100			600			730			630

Textile (Finishing)	Ranking	Total marks	Jute	Ranking	Total marks	Food Processing	Ranking	Total marks	Breweries	Ranking	Total marks
4.46	13	130	0.24	7	70	4.70	14	140	0.40	8	80
20%	4	120	10%	2	60	10%	2	60	20%	4	120
5%	2	20	0%	1	10	60%	6	60	25%	4	40
745	13	130	158	7	70	220	9	90	19	4	40
499177	15	300	77	3	60	183402	14	280	139	5	100
Clustered	10	100	Clustered	10	100	Not clustered	0	0	Non Clustered	0	0
YES	10	100	NO	0	0	Yes	10	100	YES	10	100
		900			370			730			480

Dairy	Ranking	Total marks	Tobacco processing	Ranking	Total marks	Agro Malls	Ranking	Total marks	Pharmaceuticals	Ranking	Total marks
0.21	6	60	0.15	5	50	0.01	1	10	0.93	11	110
15%	3	90	10%	2	60	0%	1	30	20%	4	120
55%	5	50	10%	3	30	5%	2	20	60%	6	60
10	3	30	7	2	20	96	6	60	760	14	140
70000	13	260	64	2	40	8000	9	180	20250	12	240
Clustered	10	100	Clustered	10	100	Clustered	10	100	Not clustered	0	0
Yes	10	100	NO	0	0	Yes	10	100	YES	10	100
		690			300			500			770

Rubber	Ranking	Total marks	Pulp & Paper	Ranking	Total marks	Petroleum offshore rigs	Ranking	Total marks	Electroplating/ Galvanizing	Ranking	Total marks
0.75	10	100	7.56	15	150	0.10	2	20	0.118	3	30
20%	4	120	70%	8	240	0	1	30	25	5.00	150
0%	1	10	0%	1	10	0	1	10	0	1	10
181	8	80	1104	15	150	266.62	11	110	0	1	10
121	4	80	618	7	140	37	1	20	15000	11	220
Clustered	10	100	Clustered	10	100	Clustered	10	100	Clustered	10	100
NO	0	0	NO	0	0	NO	0	0	Yes	10	100
		490			790			290			620

Annexure-2 Methodology and calculation

Methodology for energy replacement potential of identified 10 industrial sectors for pre-feasibility analysis

Assessment of production: This task assessed the volume of production at the national level. Secondary research was used to assess the production volume of end products in the various sectors. In many cases the the total hot water requirement and temperatures of hot water for carrying out various process was also evaluated.

Assessment of specific energy consumption and Energy requirement for hot water : In this task , both thermal and electrical specific energy consumption was assessed based on the energy audit reports available in the public domain. Also based on the specific energy estimates the total primary energy consumption for thermal and mechanical processes was segregated . Energy required for generating hot water in identified potential process of selected setor was also undertaken.

Assessment of penetration of solar applications: In this task, various various stakeholders were consulted to identify and analyse the penetration level of solar applications in the thermal and mechanical energy processes of different applications involved in identified sectors.

Assessment of energy saving potential: In this task, the specific energy consumption estimates was further multiplied with the production volumes and solar energy penetration to identify the energy saving potential .

Excel calculations for assessment of replacement potential of selected sector

Textile (Finishing) sector (Data and Assumptions)

Parameter	Value	Source
Water requirement of de-sizing (litres/tonne of product)	7,000-55,000	Paper on Scope for Solar Energy Utilisation in the Indian Textile Industry, IIT Delhi
Water requirement of scouring (litres/tonne of product)	8,000-35,000	Paper on Scope for Solar Energy Utilisation in the Indian Textile Industry, IIT Delhi

Parameter	Value	Source
Water requirement of dying (litres/tonne of product)	100,000-800,000	Paper on Scope for Solar Energy Utilisation in the Indian Textile Industry, IIT Delhi
Water requirement of finishing (litres/tonne of product)	8,000-16,000	Paper on Scope for Solar Energy Utilisation in the Indian Textile Industry, IIT Delhi
Solar water heating system penetration	25%	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 60˚C (joules/litre)	167,440	
Energy required to heat one litre of water up to 90˚C (joules/litre)	293,020	
Energy required to heat one litre of water up to 120˚C (joules/litre)	334,880	

Calculations

Solar water heating systems		
Parameter	**Value**	**Unit**
Total hot water requirement for Desizing/Bleaching for tonne of product	31,000	Litres/tonne
Total hot water requirement for Scouring for tonne of product	21,500	Litres/tonne
Total hot water requirement for Dyeing for tonne of product	90,000	Litres/tonne
Total hot water requirement for Finishing for tonne of product	12,000	Litres/tonne
Total hot water requirement for Mercerizing for tonne of product	15,000	Litres/tonne
Total energy savings from SWH systems for de-sizing	2.270905	Million kJ
Total energy savings	5.42746E-08	Mtoe
Total energy savings from SWH systems for bleaching	2.270905	Million kJ
Total energy savings	5.42746E-08	Mtoe
Total energy savings from SWH systems for scouring	1.79998	Million kJ
Total energy savings	4.30195E-08	Mtoe
Total energy savings from SWH systems for mercerizing	0.6279	Million kJ
Total energy savings	1.50068E-08	Mtoe
Total energy savings from SWH systems for dyeing	3.7674	Million kJ
Total energy savings	9.00409E-08	Mtoe
Total energy savings from SWH systems for finishing	0.87906	Million kJ
Total energy savings	2.10095E-08	Mtoe
Total fabric production (finishing)	6,000,000	Tonnes/Year

Results

Process	% of fabric production under to this process	Ktoe	Savings Rs. Million
Desizing	20	65	1,306

Process	% of fabric production under to this process	Ktoe	Savings Rs. Million
Scouring	20	51	1,035
Bleaching	20	65	1,306
Mercerizing	20	18	361
Dying	20	108	2,166
Finishing	60	75	1,516
Total wet process		383	7,692

Pulp and Paper sector (Data and Assumptions)

Parameter	Value	Source
Total production of Paper (Million tonne per annum)	8.6	CRISIL Research 2008-09
Amount of steam required (tonne/tonne of product)	6.5	Study by Planters energy network
Solar water heating system penetration	25%	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 60 ˚C (joules)	167,440	

Calculations and Results

Solar water heating systems		
Parameter	**Value**	**Unit**
Specific steam consumption	6.5	tonne/tonne product
Total production in India	8,600,000	Million tonne
Total steam required	55,900,000	Tonne
Total energy savings from SWH systems	233,9974	Million kJ
Total energy savings	45	Ktoe

Food processing sector (Data and Assumptions)

Parameter	Value	Source
Total production of processed edible oil in the country (million tonne per annum)	7	PwC study by consultations
Installed capacity of processed fruits and vegetables (million tonne per annum)	0.0462	MoFPI
Total production of alcoholic beverages in the country (hector litres per annum)	35,400,000	All India Distillers Association
Norms of specific energy consumption for edible oil processing		
Thermal energy (Million kcal/tonne)	0.18	Study by BEE, EMT-India, Ruchi Soya industries
Electrical energy (MWh/tonne)	0.258	

Norms of specific energy consumption for breweries		
Thermal energy (Million kcal/hector litre)	0.04	Study by BEE, EMT-India, fosters India
Electrical energy (MWh/hector litre)	15.47	
Energy parameters		
Heat consumption during drying of fruits and vegetables (kcal/kg)	1,000	PwC study based on consultation
Typical share of electrical energy consumption for cold storage and freezing purposes in beverage industry	32%	Energy Efficiency improvements and cost saving opportunities for Breweries", -LBNL study
Typical share of thermal energy consumption for brewing	64%	Energy Efficiency improvements and cost saving opportunities for Breweries", -LBNL study
Typical rate of water use in breweries (litre/litre)	8	SAB millers study, 2010
Annual operational hours of solar systems (hrs)	3,000	Study by clique and IIT Bombay
Solar water heating system penetration	34%	
Energy required to heat one litre of water up to 40 degrees C (joules/litre)	83,720	
Energy required to heat one litre of water up to 60 degrees C (joules/litre)	167,440	
Energy required to heat one litre of water up to 120 degrees C (joules/litre)	418,600	

Calculation and Results

Solar thermal heating systems	**Sub segment/ Parameter**	Total energy savings ktoe	Monetary savings based on fuel mix (Million Rs.)
	Edible oil processing	43	830.3
	Breweries	29	560.1
Solar thermal cooling systems /Solar PV systems	**Sub segment/ Parameter**	Total energy savings ktoe	Monetary savings based on fuel mix (Million Rs)
	Breweries	6	300.1
Solar air heating systems	**Sub segment/ Parameter**	Total energy savings ktoe	Monetary savings based on fuel mix (Million Rs.)
	Drying fruits, vegetables	2	92.0
Total		**80**	**1,782**

Leather sector (Data and Assumptions)

Parameter	Value	Source
No. of tanneries in the country	3,000	India environment portal, 2002
Total production of hides/skins in the country (tonnes per annum)	700,000	India environment portal, 2002
Water requirement of leather tanneries (litres/kg of hide)	60	PwC study based on stakeholder consultation, This estimate can vary up to three times for some tanneries depending on the quality of leather produced
Specific heat consumption during drying of leather (kcal/kg)	1,000	Study by Planters energy network
Solar water heating system penetration	25%	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 60 ˚C (joules/litre)	167,440	
Energy required to heat one litre of water up to 100 ˚C (joules/litre)	334,880	

Calculations and Result

Solar water heating systems		
Parameter	**Value**	**Unit**
Total hot water requirement for leather Tanneries	8.4	billion litres/annum
Total hot water that can be produced by SWH systems	1.43	billion litres/annum
Total energy savings from SWH systems	239,587	million kJ
Total energy savings	5	ktoe
Energy savings in terms of electricity	66.58	GWh
Monetary savings based on fuel mix	332.91	Rs. Million
Solar air dryers		
Parameter	**Value**	**Unit**
Total energy saved in the leather tannery industry from SAH systems	119,240.20	Million kJ
Total energy savings	12	ktoe
Energy savings in terms of electricity	138.65	GWh
Monetary savings based on fuel mix	693.26	Rs. Million

Dairy sector (Data and Assumptions)

Parameter	Value	Source
Total production of processed milk in the country (million tonnes per annum)	10	"The India opportunity in Food and Agribusiness"-Study by Rabo India Finance Ltd. (2010)
Density of milk (kg/litre)	1.03	

National norms of specific energy consumption		
Thermal energy (ml of FO/Kg)	4.85	Study by BEE, EMT-India, Mahanand dairy
Electrical energy (kWh/Kg)	0.034	
Water (litre/Kg)	1.94	

Areas of water consumption at dairy processing plants		
Area of use	**%**	**Source**
Cold storage - Chilling plants	2	UNEP study
Cleaning - washing bottles, equipment and processing areas	18	
Boiler feed (pasteurisation, sterilisation and evaporation)	18	
Chemical processes	12	
Incorporated into products	40	
Other purposes	10	

Energy parameters		
Heat consumption during drying of milk powder (kcal/kg powder)	1250	Dairy processing Handbook
Typical share of electrical energy consumption for cold storage and chilling purposes	50 %	PwC study based on stakeholder consultation
Annual operational hours of solar systems (hrs)	3,000	Study by clique and IIT Bombay
Solar water heating system penetration	34 %	
Energy required to heat one litre of water up to 40 °C (joules/litre)	83,720	
Energy required to heat one litre of water up to 60 °C (joules/litre)	167,440	
Energy required to heat one litre of water up to 90 °C (joules/litre)	293,020	
Energy required to heat one litre of water up to 120 °C (joules/litre)	418,600	

Calculation and Results

Solar thermal heating systems	**Process / Parameter**	Total hot water requirement (billion litres/annum)	Total hot water that can be produced by SWH systems (billion litres/annum)	Total Energy savings from SWH systems (million kJ)	Total energy savings in Mtoe	Energy savings in terms of electricity (GWh)	Energy savings in terms of rice husk (million kg)	Monetary savings based on fuel mix (Rs Millions)
	Cleaning - washing bottles, equipment and processing areas	3.50	1.197	200420.27	0.00479	55.70	13.36	93.2
	Boiler feed (pasteurisation, sterilisation and evaporation)	3.50	1.197	501050.67	0.01198	139.25	33.40	233.0
	Pre heating for Chemical processes	1.26	0.431	36075.65	0.00086	10.03	2.41	50.1
Solar thermal cooling systems / Solar PV systems	**Process / Parameter**	Total hot water requirement (billion litres/annum)	Total hot water that can be produced by Solar cooling systems (billion litres/annum)	Total Energy savings from Solar cooling systems (million kJ)	Total energy savings in Mtoe	Energy savings in terms of electricity (GWh)		Monetary savings (Rs Million)
	Cold storage - Chilling plants	NA	NA	NA	0.00500	58.19	NA	290.9
Solar air heating systems	**Process / Parameter**	Total hot water requirement (billion litres/annum)	Total hot water that can be produced by SAH systems (billion litres/annum)	Total Energy savings from SAH systems (million kJ)	Total energy savings in Mtoe	Energy savings in terms of electricity (GWh)		Monetary savings (Rs Million)
	Spray drying	NA	NA	NA	0.00428	49.78	NA	248.9
	Total	**8.25**	**2.82**	**737,546.59**	**0.03**	**312.93**		**916.16**

Textile (spinning and weaving) sector (Data and Assumptions)

Parameter	Value	Source
Weight in kg per m^2	0.2	PwC study based on stakeholder consultation, This estimate can vary depend on quality
Total production of cotton fabric (Million m^2)	28,000	CRISIL Research 2008-09
Total production of cotton fabric (tonnes per annum)	5,600,000	PwC analysis
Hot water requirement per kg of Fabric (litre/kg)	2	IIT Delhi Research paper
Solar water heating system penetration	25 %	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 90 °C (joules)	293,020	
Energy required to heat one litre of water up to 100 °C (joules)	334,880	

Calculation and Result

Parameter	Value	Unit
Total hot water requirement for fabric production in sizing step	11.2	billion litres / annum
Total hot water that can be produced by SWH systems	2.8	billion litres / annum
Total energy savings from SWH systems	820,456	Million kJ
Total energy savings	19.61	ktoe

Agro malls (Data and Assumptions)

Parameter	Value	Source
No. of agro malls in the country	8,000	PwC study
Total kWh consumptions in agro malls	144,000,000	PwC study
Average energy consumptions of each Agro mall (kWh)	18,000	PwC study based on stakeholder consultation
PV installation system penetration	35 %	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 80 °C (joules)	251,160	
Energy required to heat one litre of water up to 100 °C (joules)	334,880	

Calculation and results

Parameter	Value	Source
Total energy savings from PV installation system	518,400	Million kJ
Total energy savings in ktoe	4.34	ktoe

Automobile sector (Data and Assumptions)

Vehicle production estimates		
Type	Production in Thousands units	Passenger car equivalent
Passenger cars	2,200	1
SCV	150	2
LCV	120	2
HCV	200	3.7
Two and three wheelers	10,230	0.5
Tractors	420	4
Total in PCUs	10,275,000	

Parameter	Value	Source
Thermal energy required for Air heating/ drying systems (Mkcal/car)	0.001	National energy conservation awards
Typical hot water requirement (litres/car)	1000	PwC study based on stakeholder consultation
Solar water heating system penetration	25 %	PwC study based on stakeholder consultation
Energy required to heat one litre of water up to 60 °C (joules)	167,440	
Energy required to heat one litre of water up to 100 °C (joules)	334,880	

Calculations

Solar water heating systems		
Parameter	**Value**	**Unit**
Total energy savings from SWH systems	430111.5	Million kJ
Total energy savings in ktoe	10.2	ktoe
Energy savings in terms of electricity	119.53	GWh
Monetary savings based on the fuel mix	597	Rs. Million
Solar Air heating systems		
Parameter	**Value**	**Unit**
Total energy savings from SAH systems	NA	Million kJ
Total energy savings in	0.3	ktoe
Energy savings in terms of electricity	3.58	GWh
Monetary savings based on the fuel mix	10	Rs. Million

Annexure-3 Fuel price

Type of fuel	Unit	Calorific value	Unit	Price
Furnace oil	kcal/kg	10000	Rs./kg	38
Pet coke	kcal/kg	6500	Rs./kg	10
Rice husk	kcal/kg	3000	Rs./kg	4
Coal	kcal/kg	4500	Rs/kg	5

Electricity	kcal/kWh	860	per kWh	5
Diesel	kcal/kg	10500	Rs./litre	40

Annexure-4 Financial parameter for Cost Benefit Analysis

Particulars		**FPC**	**ETC**
Equity-Debt ratio		30:70	30:70
Fuel escalation rate (%)/annum		5	5
Interest rate (%)/annum		10	10
Annual O & M Cost (% of Capital Cost)		2	2
Escalation in O & M cost per year (%)		10	10
Book depreciation (Straight line method) (%)	System	6.67	6.67
	Tubes	0	20
IT depreciation (Accelerated depreciation) (%) (for the first year as per IT act)		80	80
Corporate tax		33 %	33 %

Annexure-5 GHG emission factor for different fuel (calorific value based)

Fuel type	**GHG emission factor (kg CO_2/MJ)**	**Source**
Diesel	0.074	The GHG Protocol initiative: Calculation tool for GHG emission from stationary combustion (version:4)
Pet coke	0.098	The GHG Protocol initiative: Calculation tool for GHG emission from stationary combustion (version:4)
Furnace oil	0.078	http://oee.nrcan.gc.ca/industrial/technical-info/benchmarking/csi/appendix-b.cfm?attr=24
Coal	0.093	http://oee.nrcan.gc.ca/industrial/technical-info/benchmarking/csi/appendix-b.cfm?attr=24
Electricity (kg CO_2/kWh)	0.820	CEA- User Guide for CO_2 Baseline Database version 5.0 (2008-09)

Annexure-6 Key players

PV-Thin Film players and service offerings

Channel members	**Existing domestic players**	**Upcoming domestic players**	**Key roles and responsibilities**
Amorphous silicon	-	Moser Baer, Titan Energy, Signet Solar	Currently there is no supplier of amorphous silicon in the domestic market. Mainly imported from US and Europe. It is expected that India will start domestic production of mono-silane and amorphous silicon by 2015
Cell	Titan Energy	Moser Baer, Signet Solar	Titan Energy is the only producer of thin film cell in India. Captive consumption of the cells for making modules
Module	Titan Energy	Moser Baer, Signet Solar	Exports most of the thin film modules and minimal consumption in the domestic market.

			Has little influence in the value chain as the demand of thin film modules is at a nascent stage in India
Application System	Titan Energy, Flexitron, El-SOL, Saur Oorja	Moser Baer, Signet Solar	Insignificant influence in the value chain. Mainly focused on exports
End users	-	-	Mainly use thin film technology systems for off-grid applications. MNRE, a government agency, is the major user of thin film modules

PV- Crystalline players and service offerings

Channel members	**Existing domestic players**	**Upcoming domestic players**	**Key roles and responsibilities**
Solar grade silicon manufacturer	Metkem Silicon	Lanco, Maharishi, Poseidon, Titan, Centrotherm, BHEL+BEL, Velankani Renewable Group	Engaged in the purification of silicon to solar grade. Currently Metkem is the only company who has polysilicon facility. Imports silicon material from USA and Europe for manufacturing ingots
Silicon Ingot Manufacturer	Metkem Silicon	Lanco, Maharishi, Poseidon, Titan, Centrotherm, BHEL+BEL, Velankani Renewable Group	Engaged in the manufacture of solar grade polysilicon ingots. Has negligible influence on the value chain as their volume production is much too small compared to the volume of imported wafers
Wafer manufacturer	Metkem Silicon, Maharishi Solar	Maharishi, Titan, Centrotherm, BHEL+BEL, Velankani Renewable Group	Wafer manufactures import silicon ingots and manufacture silicon solar wafers
Solar PV Cell manufacturers	Maharishi Solar, Tata Bp Solar, Usl Photovoltiacs, Central Electronics, Microsol Power, Webel Solar, BHEL, Moser Baer Photo Voltaic	Centrotherm Photovoltaics, Velankani Renewable Group, Titan Energy System, Bharat Electronics, Xl Telecom And Energy, Lanco Solar, Phoenix,	Purchase domestically or import wafers and manufacture solar cells. Dependent on international companies for technology know-how. High degree of influence in the value chain and mainly target domestic solar module manufacturers
Solar module manufacturers	Maharishi Solar, Tata BP Solar, Photon Energy System Limited, USL Photovoltaic's, Central Electronics, Access Solar, BHEL, Moser Baer Photo Voltaic, Webel Solar, Rajasthan	Centrotherm Photovoltaics, Velankani Renewable Group, Titan Energy System, Bharat Electronics, Xl Telecom And Energy, Lanco Solar, Phoenix,	Integrates the solar cells for end use application in the form of modules. High degree of influence in the value chain and targets mainly the export market. This is mainly due to high capital cost associated in

Channel members	Existing domestic players	Upcoming domestic players	Key roles and responsibilities
	Electronics and Instrumentation, Titan Energy Systems		installation of solar farms or end use application
Application system integrators	BHEL, CEL, Maharishi Solar, TATA BP Solar, Moser Baer, BEL, XL Telecom, VK Solar, Titan Energy System, Rajasthan Electronics, Webel, Access Solar, USL Photovoltaic	Centrotherm Photovoltaics, Velankani Renewable Group, Titan Energy System, Bharat Electronics, Xl Telecom And Energy, Lanco Solar, Phoenix, Surana	System integrators in designing of the end use application from the solar modules. High degree of influence in the value chain as they manufacture products for end use
Solar farm	MNRE, Andhra Pradesh, Madhya Pradesh State Electricity Boards, BHEL, PEDA, TNEB, NEPC And So On	-	In the nascent stage in India. Majority of the solar PV cells/modules are used by individual households. Government is taking aggressive steps to encourage grid interactive solar farms
End users	Individuals predominantly in rural area	-	Mainly individual households with usage in applications like lighting system, heaters, cookers, and battery charging etc

Solar Thermal players and service offerings

Type of solar thermal technology	Sub-Type	Role of the channel members	Names
Distributed solar thermal	Flat Plate Collector	Manufacturer of FPC	Photon Energy Systems, Inter Solar Systems, Sundrop Solar system, Velnet Non-conventional Energy System, TATA BP Solar, Kotak Urja, Sudarshan Saur Urja,
Distributed solar thermal	Evacuated Tube Collector	Manufacturer of ETC	Radiant Energies, Photon Energy, Shriram Greentech, Modern Solar, Redren Energy, Yogi Solar, Sun Energy, Suntron Energy, TATA BP Solar, Orb Energy, Sunrise Solar, Solsen Solar, Maharishi Solar, Solace
Centralized solar thermal	CSP-Parabolic Trough	Manufacturer of Parabolic Trough	Maharishi Solar, Gadhia Solar
Centralized solar thermal	CSP-Parabolic Dish	Developer of demonstration project based on parabolic dish	BHEL

Annexure-7 1 MW Solar PV

S. No.	Assumption Head	Sub-Head	Sub-Head (2)	Unit	Asumptions
1	Power Generation				
		Capacity			
			Installed Power Generation Capacity	MW	1
			Capacity Utilization Factor	%	20.00%
			Deration Factor	%	0.75%
			Auxiliary Consumption	%	3.00%
			Useful Life	Years	25
2	Project Cost				
		Capital Cost/MW	Power Plant Cost	Rs Lacs/MW	1300
3	Financial Assumptions				
			Tariff Period	Years	25
		Debt: Equity			
			Debt	%	70.00%
			Equity	%	30.00%
			Total Debt Amount	Rs Lacs	910
			Total Equity Amout	Rs Lacs	390
		Debt Component			
			Loan Amount	Rs Lacs	910
			Moratorium Period	years	0
			Repayment Period(incld Moratorium)	years	10
			Interest Rate	%	12.00%
		Equity Component			
			Equity amount	Rs Lacs	390
			Return on Equity for first 10 years	% p.a	19.00%
			RoE Period	Year	10
			Return on Equity 11th year onwards	% p.a	23.00%
			Weighted average of ROE		21.40%
			Discount Rate		0.1482
					0
4	Financial Assumptions				
		Economic Assumptions			
			Coal Price Escalation	% p.a	0
			HSD Price Escalation	% p.a	0
			Discount Rate	% p.a	0
		Fiscal Assumptions			
			Income Tax	%	33.20%
			MAT Rate (for first 10 years)	%	19.90%
			80 IA benefits	Yes/No	Yes
		Depreciation			
			Depreciation Amount	%	90.00%
			Depreciation Rate - First 10 years	%	7.00%
			Depreciation Rate - Remaining Years	%	1.33%
5	Working Capital				
		For Fixed Charges			
		O&M Charges		Months	1
		Maintenance Spare	(% of O&M exepenses)	%	15.00%
		Receivables for Debtors		Months	2
		For Variable Charges			
		Interest On Working Capital		%	0.12
7	Operation & Maintenance				
		First Yr	0.2% of the project cost	Rs Lakh	2.6
		Insurance Charges	0.35% of the project cost	Rs Lakh	4.55
		Total O & M Expenses Escalation		%	5.00%

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Discount Factor			1	0.871	0.759	0.661	0.575	0.501	0.436	0.380	0.331	0.288	0.251	0.219	0.190	0.166	0.144	0.126	0.110	0.095	0.083	0.072	0.063	0.055	0.048	0.042	0.036

Units Generation	Unit	Year--->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Installed Capacity	MW		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Generation	MU		1.70	1.69	1.67	1.66	1.65	1.64	1.62	1.61	1.60	1.59	1.58	1.56	1.55	1.54	1.53	1.52	1.51	1.50	1.48	1.47	1.46	1.45	1.44	1.43	1.42

Fixed Cost	Unit	Year--->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
O&M Expenses	Rs Lakh		7.15	7.51	7.88	8.28	8.69	9.13	9.58	10.06	10.56	11.09	11.65	12.23	12.84	13.48	14.16	14.86	15.61	16.39	17.21	18.07	18.97	19.92	20.92	21.96	23.06
Depreciation	Rs Lakh		91.00	91.00	91.00	91.00	91.00	91.00	91.00	91.00	91.00	91.00	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33	17.33
Interest on term loan	Rs Lakh		103.74	92.82	81.90	70.98	60.06	49.14	38.22	27.30	16.38	5.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on working Capital	Rs Lakh		5.84	5.63	5.43	5.22	5.02	4.82	4.62	4.42	4.22	4.02	2.75	2.78	2.81	2.84	2.88	2.91	2.95	2.99	3.03	3.07	3.11	3.16	3.21	3.26	3.31
Return on Equity	Rs Lakh		74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	74.10	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70	89.70
Total Fixed Cost	Rs Lakh		281.83	271.06	260.31	249.58	238.87	228.18	217.52	206.88	196.26	185.68	121.43	122.05	122.69	123.36	124.07	124.81	125.59	126.41	127.27	128.17	129.12	130.11	131.16	132.25	133.41

Levellised COG

Per Unit Cost of Generation	Unit	Levellised	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
O&M expn	Rs/kWh	0.62	0.42	0.45	0.47	0.50	0.53	0.56	0.59	0.62	0.66	0.70	0.74	0.78	0.83	0.87	0.93	0.98	1.04	1.10	1.16	1.23	1.30	1.37	1.45	1.54	1.63
Depreciation	Rs/kWh	4.51	5.35	5.40	5.44	5.48	5.52	5.56	5.60	5.64	5.69	5.73	1.10	1.11	1.12	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.19	1.19	1.20	1.21	1.22
Int. on term loan	Rs/kWh	3.08	6.10	5.50	4.89	4.27	3.64	3.00	2.35	1.69	1.02	0.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Int. on working capital	Rs/kWh	0.28	0.34	0.33	0.32	0.31	0.30	0.29	0.28	0.27	0.26	0.25	0.17	0.18	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.22	0.22	0.23	0.23
RoE	Rs/kWh	4.80	4.36	4.39	4.43	4.46	4.49	4.53	4.56	4.60	4.63	4.67	5.69	5.73	5.78	5.82	5.86	5.91	5.95	6.00	6.04	6.09	6.14	6.18	6.23	6.28	6.32
Total COG	Rs/kWh	13.29	16.58	16.07	15.55	15.02	14.49	13.94	13.39	12.83	12.27	11.69	7.70	7.80	7.90	8.01	8.11	8.22	8.34	8.45	8.58	8.70	8.83	8.97	9.11	9.25	9.40

Discount Factor			1	0.871	0.759	0.661	0.575	0.501	0.436	0.380	0.331	0.288	0.251	0.219	0.190	0.166	0.144	0.126	0.110	0.095	0.083	0.072	0.063	0.055	0.048	0.042	0.036

Levellised Tariff	13.29	Rs/Unit

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