Process Mapping of Food Processing Sector for CST Intervention

UNDP GEF CSH Project

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Introduction

India is the world's second largest producer of food next only to China. The food processing industry in India is ranked fifth in terms of production, consumption and growth. As per estimates of CII the industry has potential of attracting investments in the range of USD 33 billion in the next 10 years. The major segments in the food processing sector comprise of Fruits and Vegetables, Dairy, Edible Oils, Meat and Poultry, Non-alcoholic beverages, Grain-based products, Marine products, Sugar and sugar-based products, Alcoholic beverages, Pulses, Aerated beverages, Malted beverages, Spices, and Salt.

1 Processes in food processing industry in sample units

The processes identified in the food industry were done on a sample basis and their energy requirements were mapped to assess the potential of solar thermal interventions. These data were in turn utilised to arrive at techno-economic feasibility as has been highlighted in the subsequent sections.

1.1. Pasteurization

Pasteurization is the process of heating a liquid to below the boiling point to destroy microorganisms. The objective of pasteurization is twofold:

- To increase milk safety for the end consumer by destroying disease causing microorganisms (pathogens) that may be present in milk.
- Increasing the shelf life of milk by destroying microorganisms that lead to its spoilage.

The process of pasteurization involves rapid heating of milk at elevated temperatures and then rapid cooling.

1.2. Food drying

Drying is a method of food preservation that inhibits the growth of bacteria, yeasts, and mold through the removal of water. Dehydration has been used widely for this purpose since ancient times. Different industries use different techniques for drying including bed drying, oven drying, spray drying, open air drying via sunlight etc.

1.3. Process steam for formulation of premix

Many processes in the food processes require vigorous heating of pre-mix to prepare the food materials for further processing. This process is used in numerous industries including industries involving preparation of jam, jelly, chayavanprash, butter melting etc.

1.4. Boiler feed water pre-heating

Pre heating of boiler feed water is a simple process where the temperature of input water to the boiler is raised so as to reduce the fuel requirement of the boiler. Boiler feed water pre heating is effective in two ways: a) it reduces the plant operational costs and b) it also reduces the thermal shock to the boiler metal when hot water is introduced instead of water at ambient temperature. This can be done in a number of ways including pre heating it by solar concentrator based thermal systems.

2 Process Information and existing setup for sample unit

As has been highlighted earlier structured questionnaires and walk through audits were conducted to understand the current fuel dependence of the various sample units where these processes were identified. The current thermal energy requirements and generation details were captured so as to analyse the same from a solar thermal perspective. Although these processes shall be similar in different sample units but there quantum may differ according to their production requirements.

2.1. Pasteurization

The thermal energy requirement in the process is currently fulfilled by use of a diesel based boiler. The process for a typical sample unit requires 50 litres of diesel oil for one batch of 7 hours. The thermal energy calculations for the batch are as follows:

Parameter	Value	Unit
Fuel Consumption	50	litres/batch of 7 hours
Fuel calorific value	9500	Kcal/litres
Total calorific output from fuel	475000	kilo calories
Efficiency of boiler	85%	Percentage
Total calorific output for process	~558000	kilocalories

The sample unit uses diesel based generator to generate hot water for the pasteurization process. Solar thermal options are to be explored to satisfy the heat requirements for the process described above.

2.2. Food Drying

The thermal energy requirement in the process is fulfilled by use of furnace oil in the sample unit. In the process for a typical sample unit the drying process involves raising the temperature of 15000 m^3 of air from ambient to 80 C. The fuel utilisation in this case is 170 litres/batch:

Parameter	Value	Unit
Fuel Consumption	170	litres/batch of 7 hours
Fuel calorific value	8500	Kcal/litres
Total calorific output from fuel	1445000	kilo calories
Efficiency of boiler	70%	Percentage
Total calorific output for process	~1000000	kilocalories

The sample unit uses furnace oil fired boiler system to generate hot air system. Solar thermal options are to be explored to satisfy the heat requirements for the food drying process described above.

2.3. Process steam for formulation of premix

The thermal energy requirement in the process is fulfilled by use of LPG in the sample unit. In the process for a typical sample unit the drying process requires 1000 kgs steam daily at 3 bar 120 C. The fuel utilisation in this case is 60 kgs/batch:

Parameter	Value	Unit
Fuel Consumption	60	kgs/batch of 7 hours
Fuel calorific value	12000	Kcal/kgs
Total calorific output from fuel	720000	kilo calories
Efficiency of boiler	85%	Percentage
Total calorific output for process	~600000	kilocalories

The sample unit uses LPG fired boiler system to generate steam. Solar thermal options are to be explored to satisfy the heat requirements for the steam generation process described above.

2.4. Boiler feed water pre-heating

The thermal energy requirement in the process is fulfilled by use of diesel in the sample unit. In the process for a typical sample unit the process is done by increasing the temperature of the input water from 25°C to 85°C. Currently in the sample unit there is no provisioning of pre heating of boiler feed water and water at ambient temperature is fed to the boiler and converted to steam/pressurized hot water as the case may be for use in various industrial processes. The unit has a requirement of 1700 litres / hour boiler feed water. The thermal energy calculations for the batch are as follows:

Heat input required for heating 1700 litres/hour water at 25°C to 90°C (ΔT=90-25=65°C)

= 1700*1*65 = 110500 kilo calories/hour

For a 7 hour shift the energy required will be

= 110500*7 = 773500 kilo calories

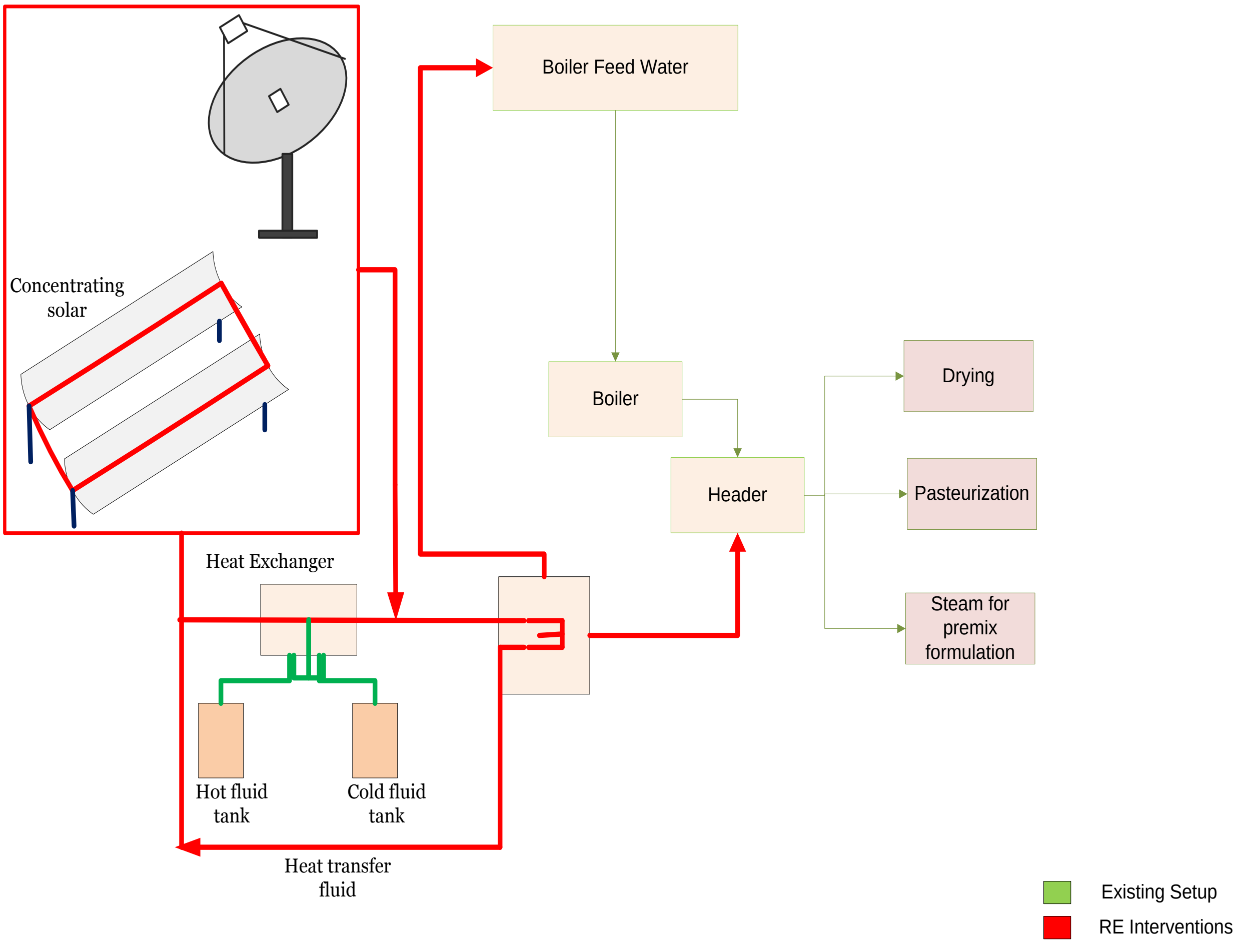
Solar thermal options are to be explored to satisfy the heat requirements for the boiler feed water pre heating process described above. Based on the process study, the new solar concentrator based system is proposed to be integrated with the existing boiler.

3 Solar sizing

For satisfying the heat requirements in the different sample units, solar thermal technologies could easily be integrated in their current setups. The thermal energy requirement in the various processes is continuous and is met through a fossil fuel based system.

The size of the solar system has to be designed so as to optimize the thermal energy production and the current resources in hand. Solar thermal systems need to function so as to satisfy the process requirements of the industry in spite of variability of solar radiation over the days and seasons.

Further, the size of the system must also satisfy the cost constraints and more importantly the space requirements. Also, the system needs to be reliable within acceptable range. In order to overcome these hurdles, it is necessary to develop a design methodology and general integration approach that can be used for optimally sizing the solar concentrators. The different technologies applicable for such process requirement are parabolic trough, parabolic dish and linear paraboloid fresnel dish. The indicative layout of the processes after the integration with solar thermal systems will be as follows:



3.1. Pasteurization

The process requires ~558000 kilo calories as illustrated in **Section 2.1** for replacement of 50 litres diesel being currently utilised in the existing boilers. Assuming solar system efficiency of 95% the energy required from the system shall be

= 558000/0.95 = ~590000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day

Size of one trough module	35	m^2
Shade free area for one module	50	m^2
Calorific output required from process	~590000	Kcal/7 hours
Modules of trough required	= (590000/75000) = 8	Nos.
Energy Displaced	75000*8*0.95 = 570000	Kilo calories
Fuel displaced	570000/(9500*0.85) ~= 70	Litres of diesel
Total system size	= 35*8 = 280	m^2
Total system area required	= 50*8 = 400	m^2

Parabolic Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m^2
Shade free area for one module	100	m^2
Calorific output required from process	~590000	Kcal/7 hours
Modules of dish required	= (590000/300000) ~= 2	Nos.
Energy Displaced	300000*2*0.95 = 570000	Kilo calories
Fuel displaced	570000/(9500*0.85) ~= 70	Litres of diesel
Total system size	= 90*2 = 180	m^2
Total system area required	= 100*2 = 200	m^2

Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per day	~300000	Kcal/day
Size of one trough module	104	m^2
Shade free area for one module	110	m^2
Calorific output required from process	~590000	Kcal/7 hours
Modules of paraboloid dish required	= (590000/300000) ~= 2	Nos.
Energy Displaced	300000*2*0.95 = 570000	Kilo calories
Fuel displaced	570000/(9500*0.85) ~= 70	Litres of diesel
Total system size	= 104*2 = 208	m^2
Total system area required	= 110*2 = 220	m^2

3.2. Food Drying

The process requires almost ~1000000 kilo calories as illustrated in **Section 2.2** for replacement of 170 litres of furnace oil being currently utilised in the existing boilers. Assuming solar system efficiency of 95% the energy required from the system shall be

= 1012500 /0.95 = ~1000000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day
Size of one trough module	35	m^2
Shade free area for one module	50	m^2
Calorific output required from process	~1000000	Kcal/7 hours
Modules of trough required	= (1000000/75000) ~= 13	Nos.
Energy Displaced	75000*13*0.95 = 925000	Kilo calories
Fuel displaced	925000/(8500*0.70) ~= 155	Litres of furnace oil
Total system size	= 35*13 = 455	m^2
Total system area required	= 50*13 = 650	m^2

Parabolic Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m^2
Shade free area for one module	100	m^2
Calorific output required from process	~1000000	Kcal/7 hours
Modules of dish required	= (1000000/300000) ~= 3	Nos.
Energy Displaced	300000*3*0.95 = 855000	Kilo calories
Fuel displaced	855000/(8500*0.70) ~= 143	Litres of furnace oil
Total system size	= 90*3 = 270	m^2
Total system area required	= 100*3 = 300	m^2

Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per day	~300000	Kcal/day

Size of one trough module	104	m²
Shade free area for one module	110	m²
Calorific output required from process	~1000000	Kcal/7 hours
Modules of paraboloid dish required	= (1000000/300000) ~= 3	Nos.
Energy Displaced	300000*3*0.95 = 855000	Kilo calories
Fuel displaced	855000/(8500*0.70) ~= 143	Litres of furnace oil
Total system size	= 104*3 = 312	m²
Total system area required	= 110*3 = 330	m²

3.3. Steam for formulation of premix

The process requires almost ~600000 kilo calories as illustrated in **Section 2.3** for replacement of 60 kgs of LPG being currently utilised in the existing boilers. Assuming solar system efficiency of 95% the energy required from the system shall be

= 600000 /0.95 = ~570000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day
Size of one trough module	35	m²
Shade free area for one module	50	m²
Calorific output required from process	~570000	Kcal/7 hours
Modules of trough required	= (570000/75000) ~= 8	Nos.
Energy Displaced	75000*8*0.95 = 570000	Kilo calories
Fuel displaced	570000/(12000*0.85) ~= 55	Kgs of LPG
Total system size	= 35*8 = 280	m²
Total system area required	= 50*8 = 400	m²

Parabolic Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m²
Shade free area for one module	100	m²
Calorific output required from process	~570000	Kcal/7 hours
Modules of dish required	= (570000/300000) ~= 2	Nos.

Energy Displaced	300000*2*0.95 = 570000	Kilo calories
Fuel displaced	570000/(12000*0.85) ~= 55	Kgs of LPG
Total system size	= 90*2 = 180	m²
Total system area required	= 100*2 = 200	m²

Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per day	~300000	Kcal/day
Size of one trough module	104	m²
Shade free area for one module	110	m²
Calorific output required from process	~570000	Kcal/7 hours
Modules of paraboloid dish required	= (570000/300000) ~= 2	Nos.
Energy Displaced	300000*2*0.95 = 570000	Kilo calories
Fuel displaced	570000/(12000*0.85) ~= 55	Kgs of LPG
Total system size	= 104*2 = 208	m²
Total system area required	= 110*2 = 220	m²

3.4. Boiler feed water pre-heating

The process requires almost 773500 kilo calories as illustrated in **Section 2.4** for boiler feed water preparation process. Assuming solar system efficiency of 95% the energy required from the system shall be

= 773500/0.95 = ~800000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day
Size of one trough module	35	m²
Shade free area for one module	50	m²
Calorific output required from process	~600000	Kcal/7 hours
Modules of trough required	= (800000/75000) ~= 11	Nos.
Energy Displaced	75000*11*0.95 = 783750	Kilo calories
Fuel displaced	783750/(9500*0.70) ~= 118	litres of diesel
Total system size	= 35*11 = 385	m²
Total system area required	= 50*11 = 550	m²

Parabolic Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m²
Shade free area for one module	100	m²
Calorific output required from process	~800000	Kcal/7 hours
Modules of dish required	= (800000/300000) = 3	Nos.
Energy Displaced	300000*3*0.95 = 855000	Kilo calories
Fuel displaced	855000/(9500*0.70) ~= 128	litres of diesel
Total system size	= 90*3 = 270	m²
Total system area required	= 100*3 = 300	m²

Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per/ day	~450000 + ~300000	Kcal/day
Size of one trough module	169 + 104	m²
Shade free area for one module	273	m²
Calorific output required from process	~600000	Kcal/7 hours
Modules of paraboloid dish required	1 module of each size	Nos.
Energy Displaced	750000*0.95 = 712500	Kilo calories
Fuel displaced	712500/(9500*0.70) ~= 107	litres of diesel
Total system size	= 169 + 104 = 273	m²
Total system area required	= 180+120 = 300	m²

4 Financial Analysis

For satisfying the heat requirements in the various units, solar thermal technologies could easily be integrated in the current setup of the sample units. Following the decision on the size of the system to be installed, this exercise has been carried out to assess the indicative financial feasibility of the project, considering all the three technology options. Based on the costs of the systems and the MNRE Benchmarks for subsidy and additional UNDP support, the overall project cost is calculated.

Financial modelling has been done so as to estimate the payback period of the three technologies for the various processes. The results of the model will be instrumental in the capital investment decision. The overall cost (Cost of system-MNRE subsidy-UNDP support) of the system is the upfront investment which brings about significant savings in terms of the fuel saved. Current dependence on fossil fuel for thermal energy production in the four processes, MNRE subsidy of 30%, additional support from UNDP and year around operation of the unit leading to increased utilization will ensure that the payback periods are less. List of assumptions made for preparing the financial models is tabulated below.

Assumptions	
Annual escalation in fuel price	10 %
Debt : Equity for beneficiary's contribution	70:30
Cost of Equity	16 %
O & M as a % of project cost	2 %
Inflation in O&M	1 %
Deration	1 %
Life of Project	20 years
Days of operation per annum	270

Based on this financial modelling exercise, the financial performance indicators of all the three technology options for the four processes are obtained.

4.1. Pasteurization

In this process the unit is using diesel (@Rs 65/litres) and the solar thermal intervention is able to bring about savings in the current dependence as described in **Section 3.1**. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Parabolic Dish	Linear Fresnel Paraboloid dish
System size proposed	8	2	2
Surface Area (A)	280 m²	180 m²	208 m²
Footprint	400 m²	200 m²	220 m²
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 60,00,000	₹ 60,00,000	₹ 48,00,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m²	₹ 6,000/ m²	₹ 6,000/ m²
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 15,12,000	₹ 10,80,000	₹ 12,48,000
UNDP Grant For Demonstration*	₹ 7,56,000	₹ 5,40,000	₹ 6,24,000
Overall cost (E= B-D)	**₹37,32,000**	**₹43,80,000**	**₹29,28,000**
Fuel Savings per day (7hrs)	70 litres	70 litres	70 litres
Project IRR	34.97%	31.47%	41.14%
Equity IRR	80.99%	68.81%	102.34%
Payback (Years)	3.08	3.46	2.55

4.2. Food Drying

In this process the unit is using furnace oil (@Rs 45/litre) and the solar thermal intervention is able to bring about savings in the current dependence as described in **Section 3.2**. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Parabolic Dish	Linear Fresnel Paraboloid dish
System size proposed	13	3	3
Surface Area (A)	455 m²	270 m²	312 m²
Footprint	650 m²	300 m²	330 m²
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 97,50,000	₹ 90,00,000	₹ 72,00,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m²	₹ 6,000/ m²	₹ 6,000/ m²
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 24,57,000	₹ 16,20,000	₹ 18,72,000
UNDP Grant For Demonstration*	₹ 12,28,500	₹ 8,10,000	₹ 9,36,000
Overall cost (E= B-D)	**₹60,64,500**	**₹65,70,000**	**₹43,92,000**
Fuel Savings per day (7hrs)	155 litres	143 litres	143 litres
Project IRR	2.92 years	3.34 years	2.45 years
Equity IRR	86.61%	72.15%	42.10%
Payback (Years)	36.06%	32.02%	107.37%

4.3. Steam for formulation of premix

In this process the unit is using LPG (@Rs 85/kg) and the solar thermal intervention is able to bring about savings in the current dependence as described in **Section 3.3**. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Parabolic Dish	Linear Fresnel Paraboloid dish
System size proposed	8	2	2
Surface Area (A)	280 m²	180 m²	208 m²
Footprint	400 m²	200 m²	220 m²
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 60,00,000	₹ 60,00,000	₹ 48,00,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m²	₹ 6,000/ m²	₹ 6,000/ m²
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 15,12,000	₹ 10,80,000	₹ 12,48,000

UNDP Grant For Demonstration*	₹ 7,56,000	₹ 5,40,000	₹ 6,24,000
Overall cost (E= B-D)	**₹37,32,000**	**₹43,80,000**	**₹29,28,000**
Fuel Savings per day (7hrs)	55 kgs	55 kgs	55 kgs
Project IRR	84.04%	71.51%	106.00%
Equity IRR	35.80%	32.20%	42.15%
Payback (Years)	2.99 years	3.37 years	2.48 years

4.4. Boiler Feed Water pre heating

In this process the unit is assumed to be using diesel (@Rs 65/litre) and the solar thermal intervention is able to bring about savings in the current dependence as described in **Section 3.4**. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Parabolic Dish	Linear Fresnel Paraboloid dish
System size proposed	11	3	1 each of 169 & 104 m^2
Surface Area (A)	385 m^2	270 m^2	273 m^2
Footprint	550 m^2	300 m^2	300 m^2
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 82,50,000	₹ 90,00,000	₹ 61,50,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m^2	₹ 6,000/ m^2	₹ 6,000/ m^2
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 20,79,000	₹ 16,20,000	₹ 16,38,000
UNDP Grant For Demonstration*	₹ 10,39,500	₹ 8,10,000	₹ 7,60,500
Overall cost (E= B-D)	**₹51,31,500**	**₹65,70,000**	**₹37,55,500**
Fuel Savings per day (7hrs)	~118 litres	~128 litres	~107 litres
Project IRR	49.12%	43.56%	57.99%
Equity IRR	134.50%	115.39%	164.55%
Payback (Years)	2.01	2.29	1.69

5 Case Studies

In this section we are analysing sample case studies which are a combination of two or more processes defined in the previous sections. This task is done to give the readers a better understanding of the technology and the financial feasibility.

5.1. Case Study A

In this sample case study we have assumed that the unit has twice the requirement of the pasteurization process as mentioned in Section 2.1 and the same drying requirement as described in Section 2.2. Thus the overall energy requirement of the industry shall be:

2*558000 + 1000000 kilocalories = 1558000 kilocalories

5.1.1. Solar sizing

The process requires ~1558000 kilo calories as illustrated above for replacement of current diesel dependence. Assuming solar system efficiency of 95% the energy required from the system shall be

= 1558000/0.95 = ~~1600000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

5.1.1.1. Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day
Size of one trough module	35	m^2
Shade free area for one module	50	m^2
Calorific output required from process	~1600000	Kcal/7 hours
Modules of trough required	= (1600000/75000) = 21	Nos.
Energy Displaced	75000*21*0.95 ~= 1496250	Kilo calories
Fuel displaced	1496250/(9500*0.85) ~= 185	Litres of diesel
Total system size	= 35*21 = 735	m^2
Total system area required	= 50*21 = 1050	m^2

5.1.1.2. Paraboloid Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m^2
Shade free area for one module	100	m^2
Calorific output required from process	~1600000	Kcal/7 hours
Modules of dish required	= (1600000/300000) ~= 5	Nos.
Energy Displaced	300000*5*0.95 = 1425000	Kilo calories
Fuel displaced	1425000/(9500*0.85) ~= 176	Litres of diesel
Total system size	= 90*5 = 450	m^2
Total system area required	= 100*5 = 500	m^2

5.1.1.3. Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per day	~300000	Kcal/day
Size of one trough module	104	m^2
Shade free area for one module	110	m^2
Calorific output required from process	~1600000	Kcal/7 hours
Modules of paraboloid dish required	= (1600000/300000) ~= 5	Nos.
Energy Displaced	300000*5*0.95 = 1425000	Kilo calories
Fuel displaced	1425000/(9500*0.85) ~= 176	Litres of diesel
Total system size	= 104*5 = 520	m^2
Total system area required	= 110*5 = 550	m^2

5.1.2. Financial Analysis

Financial modelling has been done so as to estimate the payback period of the three technologies for the combination of the two processes. In this process the unit is assumed to be using diesel (@Rs 65/litres) and the solar thermal intervention is able to bring about savings in the current dependence as described above. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Paraboloid Dish	Linear Fresnel Paraboloid dish
System size proposed	21	5	5
Surface Area (A)	735 m^2	450 m^2	520 m^2
Footprint	1050 m^2	500 m^2	550 m^2
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 1,57,50,000	₹ 1,50,00,000	₹ 1,20,00,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m^2	₹ 6,000/ m^2	₹ 6,000/ m^2
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 39,69,000	₹ 27,00,000	₹ 31,20,000
UNDP Grant For Demonstration*	₹ 19,84,500	₹ 13,50,000	₹ 15,60,000
Overall cost (E= B-D)	**₹97,96,500**	**₹1,09,50,000**	**₹73,20,000**
Fuel Savings per day (7hrs)	185 litres	176 litres	176 litres
Project IRR	32.47%	28.40%	39.40%
Equity IRR	88.22%	73.06%	113.04%
Payback (Years)	2.82	3.24	2.31

5.2. Case Study B

In this sample case study we have assumed that the unit has a requirement of all the four processes as mentioned in Section 2.1; Section 2.2; Section 2.3 and Section 2.4. Thus the energy requirement of the industry shall be:

558000 + 1000000 + 600000 + 773500 kilocalories = 2931500 kilocalories

5.2.1. Solar sizing

The process requires ~2931500 kilo calories as illustrated above for replacement of current diesel dependence. Assuming solar system efficiency of 95% the energy required from the system shall be

= 2931500 /0.95 = ~3000000 kilo calories

Based on this energy assessment the system sizing for different technologies is illustrated as follows:

5.2.1.1. Parabolic Trough

Parameter	Value	Unit
Calorific output per trough module per day	~75000	Kcal/day
Size of one trough module	35	m^2
Shade free area for one module	50	m^2
Calorific output required from process	~3000000	Kcal/7 hours
Modules of trough required	= (3000000 /75000) ~= 40	Nos.
Energy Displaced	75000*40*0.95 = 2850000	Kilo calories
Fuel displaced	2850000/(9500*0.85) ~= 353	Litres of diesel
Total system size	= 35*40 = 1400	m^2
Total system area required	= 50*40 = 2000	m^2

5.2.1.2. Paraboloid Dish

Parameter	Value	Unit
Calorific output per dish module per day	~300000	Kcal/day
Size of one trough module	90	m^2
Shade free area for one module	100	m^2
Calorific output required from process	~3000000	Kcal/7 hours
Modules of dish required	= (3000000/300000) =10	Nos.
Energy Displaced	75000*40*0.95 = 2850000	Kilo calories
Fuel displaced	2850000/(9500*0.85) ~= 353	Litres of diesel
Total system size	= 90*10 = 900	m^2
Total system area required	= 100*10 = 1000	m^2

5.2.1.3. Linear fresnel paraboloid dish

Parameter	Value	Unit
Calorific output per paraboloid dish module per day	~300000	Kcal/day
Size of one trough module	104	m²
Shade free area for one module	110	m²
Calorific output required from process	~3000000	Kcal/7 hours
Modules of paraboloid dish required	= (3000000/300000) =10	Nos.
Energy Displaced	75000*40*0.95 = 2850000	Kilo calories
Fuel displaced	2850000/(9500*0.85) ~= 353	Litres of diesel
Total system size	= 104*10 = 1040	m²
Total system area required	= 110*10 = 1100	m²

5.2.2. Financial Analysis

Financial modelling has been done so as to estimate the payback period of the three technologies for the combination of the two processes. In this process the unit is assumed to be using diesel (@Rs 65/litres) and the solar thermal intervention is able to bring about savings in the current dependence as described above. Based on the financial modelling a summary of the results for the three technologies is tabulated below:

Technology/ Parameters	Parabolic Trough	Paraboloid Dish	Linear Fresnel Paraboloid dish
System size proposed	40	10	10
Surface Area (A)	1400 m²	900 m²	1040 m²
Footprint	2000 m²	1000 m²	1100 m²
Tracking	Single Axis	Double axis	Double Axis
Total indicative cost of system (B)#	₹ 3,00,00,000	₹ 3,00,00,000	₹ 2,40,00,000
MNRE benchmark for subsidy (C)	₹ 5,400/ m²	₹ 6,000/ m²	₹ 6,000/ m²
Total MNRE Subsidy (D=A x C) or (30% of B)	₹ 75,60,000	₹ 54,00,000	₹ 62,40,000
UNDP Grant For Demonstration*	₹ 37,80,000	₹ 27,00,000	₹ 31,20,000
Overall cost (E= B-D)	**₹186,60,000**	**₹219,00,000**	**₹146,40,000**
Fuel Savings per day (7hrs)	353 litres	353 litres	353 litres
Project IRR	33.39%	29.31%	40.69%
Equity IRR	91.70%	76.63%	117.70%
Payback (Years)	2.74	3.13	2.23

The above results for different processes/cases are only an indicative assessment based on public information and shall be different for different sites and subject to variation by different

manufacturers. Also the UNDP support is subject to certain terms and conditions which may result in lowering of the overall support for hard capital investment.

Disclaimer

The referred data in the report have been made available by industry respondents and technology suppliers for use in the report for the task allotted by UNDP-MNRE-GEF PMU on CSH to PricewaterhouseCoopers India Pvt. Ltd. [hereinafter referred as PwC]. PwC does not take responsibility of the authenticity and accuracy of the data and in no case will be held accountable for the incorrect data. Also, the analysis in the report is based on the data provided, hence the accuracy and its utility is dependent upon the quality of data provided.

This report is in accordance with the scope of work assigned to PwC by UNDP-MNRE-GEF PMU on CSH. It will be sole discretion of UNDP to share the report with any other agency and to answer any query raised thereof.