# FEASIBILITY STUDY OF CONCENTRATING SOLAR THERMAL (CST) TECHNOLOGY FOR PROCESS HEAT APPLICATION IN A RICE PROCESSING INDUSTRY IN INDIA

## 1. Introduction

Industrial process heat accounts for a significant share of global energy consumption, particularly in Micro, Small, and Medium Enterprises (MSMEs), where fossil fuels and biomass dominate. Decarbonizing low and medium-temperature heat (<150°C) remains a key challenge for sustainable industrial development.

Rice processing industries in India are energy-intensive and typically rely on biomass-fired boilers for steam generation. These systems contribute to greenhouse gas (GHG) emissions and operational inefficiencies. Solar thermal technologies, particularly Concentrating Solar Thermal (CST) systems, offer a viable alternative for supplying process heat in this temperature range.

This study presents the design, performance assessment, and techno-economic feasibility of implementing a CST system for a rice processing unit located in Vellore, Tamil Nadu, India. The facility currently relies on a biomass-fired boiler operating at temperatures up to 150°C, consuming approximately 840 tonnes of cashew nut shells annually.

## 2. Methodology

The feasibility study has been carried out through (1) Site survey for suitability of installation of CST system (2) Solar resource assessment (3) Analysis of process heat demand (4) Suitable technology selection according to the site and process heat demand (5) System design and integration strategy and (6) Project cost estimation and economic analysis

The selected rice mill operates a 2 TPH biomass boiler producing steam at 150°C. The facility processes paddy in batch operations requiring both steam and hot air.

Solar resource analysis indicates that the site receives annual average 5.32 kWh/m²/day Global Horizontal Irradiance (GHI) and 3.67 kWh/m²/day Direct Normal Irradiance (DNI). These values confirm solar potential for CST deployment.

The plant requires steam for boiling and hot air for drying at 80 - 150°C which is met through a 2 TPH biomass boiler operating about 280 days/year. Each year, the boiler uses around 840 tonnes of cashew nut shells.

A comparative evaluation of CST technologies (PTC, CPC/xCPC, Parabolic Dish) was conducted based on temperature requirement, space availability, integration feasibility and fixed and recurring costs.

The Crossed Compound Parabolic Concentrator (xCPC) was selected due to:

- Suitability for 70 - 150°C range
- Fixed tilt (no tracking required)
- Low maintenance
- Rooftop compatibility

The proposed system includes 40 collector assemblies (2.5 $m^2$ each), with gross aperture area of 180 $m^2$ to be mounted on 600 $m^2$ shadow-free roof area of the building. The CST system will be integrated to preheat the boiler feedwater and dryer intake air using heat exchanger.

Performance modelling was carried out using simulation tools Greenius and economic analysis has been carried out using excel based financial model.

**Table 1: Monthly thermal output from the proposed CST system at Vellore Rice Mill**

| Months | Ambient Temperature ($^oC$) | Thermal Output ($MWh_{th}$) |
|---|---|---|
| January | 23.1 | 12 |
| February | 24.9 | 14 |
| March | 27.3 | 17 |

| | | |
|---|---|---|
| April | 29.2 | 16 |
| May | 31.8 | 15 |
| June | 30.6 | 13 |
| July | 29.5 | 9 |
| August | 28.7 | 9 |
| September | 27.8 | 11 |
| October | 27 | 9 |
| November | 24.6 | 7 |
| December | 23.8 | 8 |
| | Total per year | 140 |

## 3. Results and Discussion

The CST system is estimated to generate 140 $MWh_{th}$/year of thermal energy delivering heat in the range of 70°C to 150°C which is suitable for the rice processing cycle.

The solar system partially replaces biomass fuel consumption, leading to reducing dependence on cashew nut shells, improving energy efficiency and lowering operational costs. The rice mill currently spends approximately INR 8.4 million annually on fuel, indicating strong economic potential for solar integration.

The CST project will also contribute to reduction of 1,840 tonnes of $CO_2$ emission over 20 years. This contributes to climate mitigation and aligns with India's renewable energy targets.

The key advantages of xCPC based CST system are lower O&M cost due to system simplicity with no tracking system, modular and scalable design, suitable for retrofitting in existing industries and reduced heat losses due to evacuated tubes.

**Table 2: Inputs and assumptions for financial analysis**

| Sl. No. | Financial inputs | Unit | Value |
|---|---|---|---|
| 1 | Upfront capital cost | Million INR | 5.12 |
| 2 | Annual thermal energy generation | $MWh_{th}$/ year | 140 |
| 3 | Fuel price | INR/ton | 10,000 |
| 4 | Escalation of fuel price | Percent/ year | 3% |
| 5 | Operation and maintenance cost | INR /year | 51,000 |
| 6 | Escalation in O&M | Percent | 3% |
| 7 | Interest rate for term loan | Percent | 10% |
| 8 | Financial assistance @15% | Million INR | 0.675 |
| 9 | Plant life assumed for working of depreciation | Year | 25 |
| 10 | Residual Value | Percent | 10% |
| 11 | Depreciation of plant | Percent/year | 3.60% |
| 12 | Equity @ 30 % | Million INR | 1.536 |
| 13 | Term loan @ 55% | Million INR | 2.91 |
| 14 | Term loan period | Years | 10.00 |
| 15 | Discounting Factor | Percent | 7% |
| 16 | Accelerated depreciation for income tax benefit | Percent/year | 40% |

**Table 3: Financial results for the proposed CST system at Vellore Rice Mill**

| Sl. No. | Financial Parameters | Unit | 0% Financial assistance | 15% Financial assistance | 30% Financial assistance |
|---|---|---|---|---|---|
| 1 | Internal Rate of Return (IRR) | Percent | 10% | 13% | 17% |
| 2 | Project payback period | Years | 9.02 | 7.05 | 4.03 |
| 3 | Average cost of energy generation | INR per $kWh_{th}$ | 2.24 | 2.14 | 2.05 |
| 4 | Net Present Value (NPV) | INR million | 1.16 | 1.79 | 2.43 |
| 5 | Average DSCR | Ratio | 1.55 | 1.83 | 2.28 |

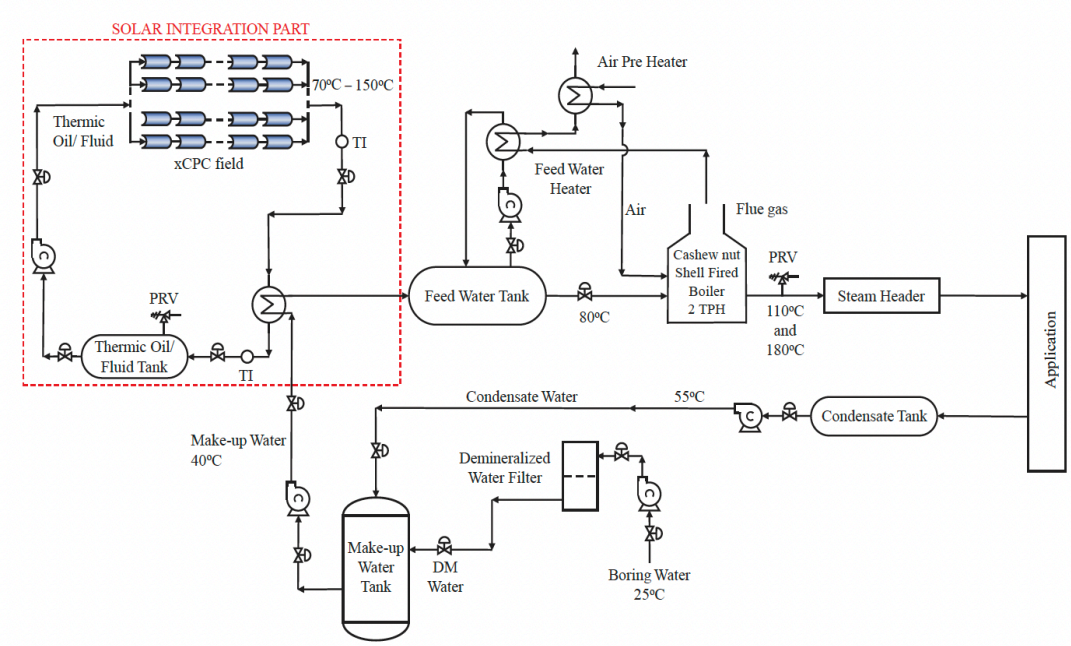


**Figure 1: Block diagram of CST integration with the existing system**

## 4. Conclusion

This study demonstrates that CST technology, particularly xCPC collectors, is a technically and economically viable solution for industrial process heat in rice milling applications. With a thermal output of 140 MWh/year and significant GHG emission reductions, the system offers a sustainable pathway for decarbonizing MSME industries. The results highlight the scalability and replicability of CST systems across similar agro-processing clusters in India and other developing regions.

**Keywords:** Concentrating Solar Thermal (CST); Industrial Process Heat; Rice Mill; xCPC; Solar Heat for Industrial Processes (SHIP); Decarbonization

## 5. References

1. IEA SHC Programme Reports on Solar Heat for Industrial Processes
2. NASA POWER Database (Solar Resource Data) https://power.larc.nasa.gov/docs/methodology/
3. Renewables 2022 - Global Status Report by REN21
4. MNRE-GEF-UNIDO report India's CST Sector: Vision 2022. Available at https://downloads.unido.org/ot/12/71/12714793/India%20CST%20Roadmap%202022Prot.pdf
5. Srinivasan, Gokul & Mahajan, Aditya & Seth, Rajiv & Mahajan, Rakesh. (2022). Comprehensive review on bio-briquettes developed from processed cashew nut shell wastes. DOI:10.20944/preprints202212.0071.v1