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TECHNO COMMERCIAL ANALYSIS OF DECENTRALISED RENEWABLE ENERGY

APPLICATIONS ACROSS AGRICULTURE, DAIRY AND FISHERY

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Programme/project description
Indo German Energy Programme – Promotion of Solar Water Pumps (IGEN-PSWP)

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Contents

Abbreviations

Acronyms	Meaning
AC	Alternating Current
Ah	Ampere Hour
AMC	Annual Maintenance Charges
BLDC	Brush Less Direct Current
CapEx	Capital Expenditure
CEEW	Council on Energy, Environment and Water
DC	Direct Current
DRE	Decentralised Renewable Energy
DX	Direct Expansion
FPC	Farmer Producer Company
GHG	Green House Gas
GST	Goods and Services Tax
GVA	Gross Value Added
H.P.	Horse Power
I.M.	Induction Motor
IGEN PSWP	Indo German Energy Program - Promotion of Solar Water Pumps
IGST	Integrated Goods and Services Tax
IIEC	International Institute for Energy Conservation
IP	Ingress Protection
IRENA	International Renewable Energy Development Agency
ISO	International Organization for Standardization
kVA	kilo Volt Ampere
kWp	kilo Watt (peak)
MNRE	Ministry of New and Renewable Energy
MPPT	Maximum Power Point Tracker
MT	Metric Tonne

Acronyms	Meaning
MUDRA	Micro Units Development & Refinance Agency Ltd.
OEM	Original Equipment Manufacturer
PAYG	Pay As You Go
PCM	Phase Change Material
PCU	Power Conditioning Unit
PMDC	Permanent Magnet Direct Current
PWM	Pulse Width Modulation
RPM	Revolutions Per Minute
SAP	Sustainable Agricultural Practices
SDG	Sustainable Development Goals
SRIJAN	Self Reliant Initiatives through Joint Action
SS	Stainless Steel
TR	Ton of Refrigeration
TSS	Thermal energy Storage System
VFD	Variable Frequency Drive

Photo credit: Vecteezy

Executive Summary

This report provides a comprehensive analysis of 20 Decentralized Renewable Energy (DRE) applications in India. The report covers, suitable business models of operation of each application, applicable subsidies and policy information, generic tech specifications, their working principle, types, and techno-economic analysis. The aim of this report is to provide insights into the feasibility and potential of Decentralized Renewable Energy applications in India across the value chains of Agriculture, Dairy and Fishery.

Business Models of Operation

The report analyses various business models of operation for Decentralized Renewable Energy applications, including pay-as-you-go, leasing, outright purchase, etc.

Applicable Subsidy and Policy Information

The report provides an overview of the applicable subsidy and policy information for decentralized renewable energy applications in India. It is to highlight that there exists no policy or financial subsidy scheme that is inclusive of small and marginal farmers. Most of the agriculture post-harvest processing infrastructure loans and subsidies are available for large sized plants and prima facie do not cater to the decentralised units as per the scope of this project.

Generic Tech Specifications of all Applications

The report provides a detailed analysis of the generic tech specifications of all 20 decentralized renewable energy applications, including their capacity, voltage, battery type, and lifespan. The report highlights that the applications vary widely in terms of their specifications, and the suitability of each application depends on the specific requirements of the customer.

Working Principle and Types

The report provides a detailed explanation of the working principle and types of decentralized renewable energy applications, including solar water pumps, among others. The report highlights that each application operates on a different principle and is suitable for different use cases.

Techno-Economic Analysis

The report provides a detailed techno-economic analysis of each decentralized renewable energy application, including its capital cost, operational cost, and payback period. The report highlights that while some applications are more cost-effective than others, the overall economic viability of decentralized renewable energy applications is dependent on factors such as government policies, customer demand, technological advancements and use pattern.

Photo credit: Freepik

01

Project Background and Entities Involved

1.1 Background of the Assignment

The 'Draft policy framework for developing and promoting Decentralised Renewable Energy (DRE) Livelihood Applications[1]' released by the Ministry of New and Renewable Energy (MNRE) explains the significance and relevance of Decentralized Renewable Energy (DRE) driven livelihood solutions. It is observed that DRE can reduce, and eventually eliminate, livelihood dependency on diesel, as well as augment grid supplies.

DRE livelihood applications are described as application areas that use renewable energy – solar, wind, micro-hydro, biomass, and their hybrid combination – that are used to earn a living directly, such as solar dryers, solar mills, solar or biomass powered cold storage/ chiller, small scale biomass briquette/pellet-making machines, and so on. The scope may also include DRE applications working in hybrid mode with grid if the system can also run independent in off-grid mode.

In India, effective pilots, and business models for DRE applications in agriculture, agro-processing, dairy, and fisheries have been evaluated at the field level by several organisations, proving their potential to be incorporated into Government programmes. However, standardisation of these validated technologies based on capacity, commodity, and application (to end users) is required for their early acceptance under government schemes/ programs.

In this regard, GIZ, wants to record the decentralised renewable energy applications (centred on solar technology) accessible for integration in the Agriculture/Dairy/Fishery sector in India, which are particularly suited and cheap for small and marginal farmers specifically. The goal is to capture the technical and financial feasibility of these technologies, which are primarily employed at various stages such as nursery, production, harvesting, post-harvesting, and processing within the above-mentioned value chain. GIZ has mandated IIEC to document DRE technologies (with a focus on solar) by delving deeply into the kind of technology/their technical specifications/ capacity-based models within the three stated value chains. This assignment's output is intended to be utilised to raise awareness among stakeholders in the three value chains and to integrate applicable technologies at the possible end user (person/group) level.

Photo credit: Vecteezy

[1] https://mnre.gov.in/img/documents/uploads/file_f-1644909209115.pdf

The IIEC is anticipated to cover at least 20 applications/technologies across the value chain as part of the proposed assignment, in addition to what is currently accessible in the public domain, such as those available on the I-REAP website, the UNDP Access to Clean initiative, and the World Bank's Energy Sector Management Assistance Program (ESMAP). Importantly, this assignment will seek to cover technologies whose technical capability has already been shown by several stakeholders and which are mature enough to be implemented on a large scale through various government programmes. This research will not address technologies in their early stages or technical aspects that have yet to be demonstrated in the field.

1.2 Objectives

The suggested task has two major aims.

- To examine and describe the potentials of decentralisednewable energy applications that may be incorporated into various phases of the Agriculture, Dairy, and Fishery value chains (Nursery/ Production/Harvesting/ Post harvesting/ Processing).
- At the individual or group level, analyse the utility/suitability and economic potential of identified decentralised renewable energy systems for small and marginal farms.

Photo credit: Freepik

02

Project Methodology and Strategy Adopted

2.1 Strategy and Methodology Adopted for this Assignment

2.1.1 Strategy

2.1.1 Interpretation of Objectives

Agriculture is the primary source of livelihood for about 58% of India's population[2]. The agriculture sector has experienced buoyant growth in the past two years. The sector, which is the largest employer of workforce, accounted for a sizeable 18.8 per cent (2021- 22) in Gross Value Added (GVA) of the country registering a growth of 3.6 per cent in 2020-21 and 3.9 per cent in 2021-22[3]. Growth in allied sectors including livestock, dairying and fisheries has been the major drivers of overall growth in the sector.

To make the growth sustainable and environment friendly, the Promotion of Solar Water Pumps (PSWP) Module aims to improve, expand, and speed-up the roll-out of sustainable and productive use of Solar Water Pumps (SWP) and other decentralized technologies in agriculture, dairy and fishery. During the last decade, a variety of DRE livelihood applications have been developed, which are not only energy efficient but also economically viable. These include a myriad of solutions such as solar dryer, solar or biomass powered cold storage/chiller, solar charkha, etc. The modular design of such DRE livelihood applications ensures scalability without large investments.

Photo credit: Freepik

[1] https://www.ibef.org/industry/agriculture-india
[2] https://pib.gov.in/PressReleasePage.aspx?PRID=1793829#:~:text=The%20Agriculture%20sector%20experienced%20buoyant,used%20to%20promote%20crop20diversification.

Besides, the energy efficiency of such solutions is also important, as it, in turn, enhances their economic viability by reducing the size of the energy generation and storage requirement. Therefore, to identify the DRE technologies and its applications at production/harvesting/post harvesting/processing stages in Agriculture, Dairy and Fishery, PSWP has proposed this study. Assessment of Economic Potential/viability/cost economics of the identified DRE applications will also be documented in the study. Following would be the broad objective for the study:

- Review & document the potentials of DRE Applications: A detailed market analysis of secondary literature, reports, publications of MNRE and State Governments, and any relevant literature from India or any other relevant country. The project team will coordinate with GIZ to hold the inception meeting and finalize the roadmap.
- Assess the utility/Suitability and economic potential of identified DRE technologies for small and Marginal Farmers at Individual or Group level.

2.1.2 Implementation Strategy

The strategic orientation is developed to fulfil the project objectives and deliverables. Following six key strategies are identified for this purpose.

i. Requirements gathering that ensure documented, clear, and coherent understanding between GIZ, and IIEC of the requirements of the DRE technologies, locale, targeted beneficiaries, data collected and content/Type of E-Learning Module.

ii. Background scoping, Reviewing and information collection aiming selected locale to identify the possible DRE technologies and their uses in Agriculture, Dairy and Fishery.

Review of Literature on DRE technology applicable for Agri/Dairy/Fishery include the following:

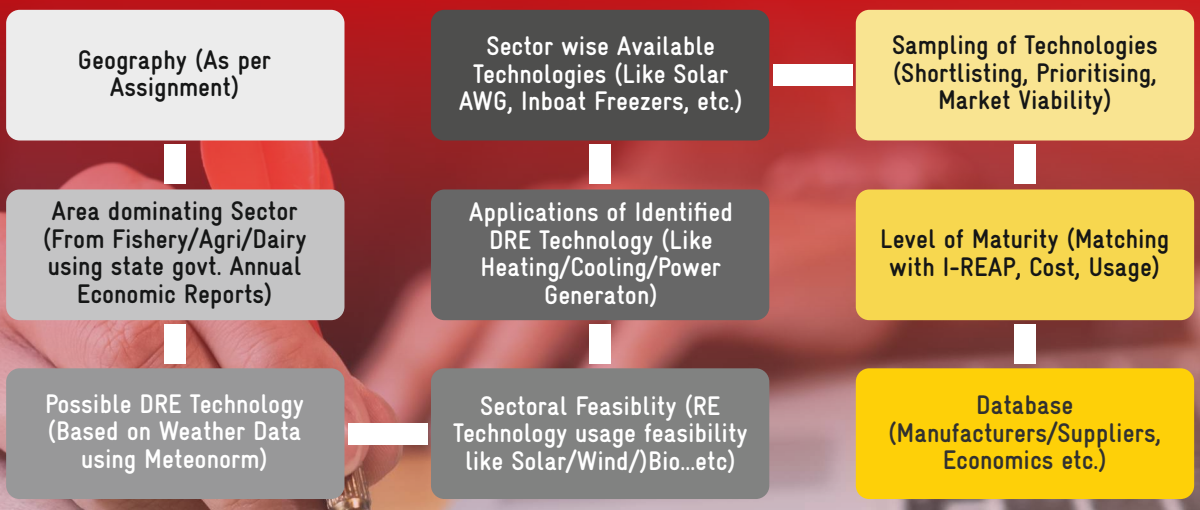

Figure 1: Literature Review Structure

Photo credit: Freepik

- Report on State of the Decentralized Renewable Energy Sector in India – Insights from CLEAN.
- MNRE Framework for promotion of Decentralized Renewable Energy Livelihood Applications.
- A Research paper on Exploring the scope of renewable energy technologies in dairy sector- International Journal OF Engineering Sciences and Research Technology.
- Annual reports of Indian Council of Agricultural Research, Department of Fisheries, Department of Animal Husbandry and Dairy.

iii. Technology specific visit and Market Assessment to document the case studies and stakeholder consultation for all the 20 DRE Technologies. The proposed visit including assessment of DRE Technologies, usage and operational mechanism, manufacturers database.

iv. Preparation of Analytical Report & Infographics would help in detailing analysis of different type of technology, technical Specifications, functioning, usage, cost economics for all the identified DRE applications across agriculture, dairy, and fishery value chain.

v. Preparation of case studies and podcast episodes would help in presenting the findings of the assignment in a manner that they might be easily fed into an e-learning mode.

vi. Stakeholder consultation through workshops: A stakeholder validation meeting would be conducted, and the identified DRE technologies would be presented and discussed with the government and private players.

2.1.3 Relevant Information Resources and Databases

The IIEC and SRIJAN project team recommends utilization of the existing information resources and databases to fulfil the data required by the project and to facilitate implementation of project activities. The IIEC project team utilized our existing relationships and contacts with the relevant stakeholders to accomplish data collection and compilation activities.

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03

Review of Potential and Documentation of DRE Applications

3.1 Review of Secondary information

3.1.1 Review of existing secondary literature, reports, publications of Ministry of New and Renewable Energy and State Governments

Integrative, Historical, Methodological and Argumentative review was conducted by the research team which included secondary literature, reports and publications available in public domain. Based on review, research team developed a takeaway on each of the document reviewed.

S.No.	Document Title	Sector (s) covered	DRE Application (s) covered	Keynote Highlights / Take Away
1.	State of the Decentralized Renewable Energy (DRE) Sector in India 2020-21 by Clean Energy Access Network (CLEAN). Source: https://bit.ly/3SO8EAn	Agriculture	Solar water pumps	The concept of 'Water as a Service or WaaS' has been highlighted where on an hourly, daily, or seasonal basis, a water entrepreneur runs the solar pump and sells water to more farms. The second model highlighted is the Water User Group Model, in which smallholder farmers create a Joint Liability Group to facilitate finance and promote efficient water use within the group.
2.	State of the Decentralized Renewable Energy (DRE) Sector in India 2019-20 by Clean Energy Access Network (CLEAN). Source: https://bit.ly/3SO8EAn	Agriculture	Cold Storage	The cold storage facility is utilised jointly by the federation's 30-40 farmers. Due to the preservation of flowers, farmers have seen a drop in post-harvest crop losses and a 200% rise in revenue over the festive season.
	State of the Decentralized Renewable Energy (DRE) Sector in India 2020-21 by Clean Energy Access Network (CLEAN). Source: https://bit.ly/3SO8EAn	Agriculture	Cold Storage	6MT cold storage was installed in one of the temple premises. Coconut and vegetable waste have decreased considerably. Due to the hot and humid weather before the installation, 800 kg of vegetables and 500 pieces of coconuts perished. Additionally, the management of the temple is currently purchasing fruits and vegetables in large quantities, saving

S.No.	Document Title	Sector (s) covered	DRE Application (s) covered	Keynote Highlights / Take Away
				money over buying them separately and in lesser quantities. Additionally, the temple can reduce its transportation expenses. By not using diesel generators, more than19 MT of CO_2 have been saved in GHG emissions.
3.	Fostering Livelihoods with Decentralized Renewable Energy – An Ecosystems Approach by IRENA – SELCO Foundation Source: https://bit.ly/3SPRhiI	Agriculture	Cold Storage	Large unmet energy needs in both the agricultural and non-agricultural sectors have led to a rising reliance on fossil fuel-based energy sources (e.g., diesel). Farm-based and non-farm-based firms are neglected as a result of electrification programmes' predominant focus on homes, a gap that can be filled by specialised decentralised renewable energy solutions. The scaled-down version of large productive applications and powering them through decentralised energy solutions which could be run with a lower threshold requirement (in terms of throughput), making it a viable alternative to large and centralised mills. In India, solar-powered processing applications are now a practical idea for farmer cooperatives or a microbusiness to own and manage for group usage or to run as a service-based model in local marketplaces. However, loan payments designed by the financial instruments must be dependent on seasonal cash flow and accordingly varied payment duration. Designing a women centric policy would be one of the major contributors to the increased uptake of DRE applications. For example, the Govt. of Nepal offers an additional 10% subsidy for productive end-uses to traditionally excluded groups such as women-headed households, single women, the poor or marginalised.

S.No.	Document Title	Sector (s) covered	DRE Application (s) covered	Keynote Highlights / Take Away
4.	Enhancing India's Milk and Meat Production: Is Hydroponics Green Fodder the Answer? by CEEW Source: https://bit.ly/3Me4kZq	Dairy	Fractional Solar Water Pump (for green fodder)	Small-scale hydroponic fodder (SSHF) units have a total available market (TAM) of USD 3.2 billion (23,905 crore). The market for green fodder is worth USD 4.2 billion annually (31,555 crore). Large scale hydroponic fodder units (or bulk deployment of SSHF units) can help create employment opportunities, along with plugging fodder deficit. Entrepreneurs can target women self-help groups (SHG) and dairy cooperatives and other local livelihood groups to deploy these units.
5.	Potential impact of cooling technologies on the fish value chain by Shell Foundation Source: shorturl.at/vFWX0	Fishery	Cold storage	Cold chain infrastructure is critical for maintaining the quality and freshness of fish during transportation and storage. However, the lack of proper infrastructure and facilities for cold storage, transportation, and processing can result in significant post-harvest losses and reduced profitability for fish farmers and fishery businesses. This issue is particularly acute in rural areas, where there is often limited access to reliable power and transportation networks.
6.	Can Small Horticulture Processors Enhance Rural Incomes? by CEEW Source: shorturl.at/tyAF3	Agriculture and horticulture	Fruit processing applications	The decentralized equipment for processing of fruits and vegetables has a total available market (TAM) worth USD 954 million (7,533 crore). This translates to more than 627,000 machines, affecting 1.3 million livelihoods. The market for processed goods such as jams, candies, and juices is well-developed for a number of fruits and vegetables. To fill a niche national and international market, entrepreneurs will need to develop and test value-added products for local crops including custard apples, jackfruit, and passion fruits. Currently, only about 10% of the total agriculture output is processed. Indian government aims to expands it to 25% by 2025. Hence this makes it a valid ground for promoting RE powered local processing units.

S.No.	Document Title	Sector (s) covered	DRE Application (s) covered	Keynote Highlights / Take Away
7.	An Analysis of Oil Seeds and Pulses in Eastern India during 2050-51. Source: shorturl.at/act0Q	Agriculture	Generic	According to data of production by National Mission on Oil seeds and Oil Palm, the production of oil seeds alone in the 8 NE states is approximately 4,15,700 MT on an average yield of 740kh/ha. However, referring to the research paper, the projected decadal growth in oil seeds productivity if we include other states such as Jharkhand, WB, Odisha, Bihar, Eastern UP and Chhattisgarh for the year of 2030-31, 2040-41 and 2050-51 are 1065.3, 1080.5 and 1412.4 kg/ha. One of the key challenges for oil production is the lack of technology dissemination, absence of proper irrigation systems and post-harvest processing facilities at the local level leading to distress sale, wastage and poor income compared to investment done by the farmers.
8.	Addressing Food Loss & Waste for a Sustainable Agriculture Value Chain in India1 by Centre for Responsible Business Source: shorturl.at/bfntM	Agriculture	Generic	In addition to being essential to sustainable agriculture, the Sustainable Development Goal (SDG) 12's definition of sustainable consumption and production aligns with the need of post-harvest food loss management and reduction as described above. Reduce food losses along the production and supply chains, including post-harvest losses, and cut down on global per capita food waste by 2030, according to SDG target 12.3. The paper also highlights various initiatives that need to be taken up to address the food wastage issues under which post harvesting activities have been stressed upon such as setting up of agro processing clusters, setting proper cold chain infrastructure, value chain development etc.

S.No.	Document Title	Sector (s) covered	DRE Application (s) covered	Keynote Highlights / Take Away
9.	Impact of Solar Powered Aerator on dissolved oxygen and fish growth by ICAR Patna Source: shorturl.at/iquMX	Fishery	Solar water aerator	A 750W induction motor based solar water aerator system was installed and energized by 900Wp solar panels and the major outcomes were: • Requirement of feed was lower to achieve higher production in aerated pond compared to non-aerated pond. • It was discovered that the fish growth performance in the pond fitted with the solar-operated sprinkler type of aerator (treatment) was significantly better than the fish growth performance in the control pond in terms of weight gain, percent weight gain, and specific growth rate, all of which can translate into higher production. • The daytime activity raises the water's oxygen content relative to breaking thermal stratification, generating a uniform dissolved oxygen profile in the pond's water. • The main drawback of this kind of technology is that the solar-powered pump can only be used during the daytime, while the demand for DO is at its peak at night. As a result, alternate arrangements like using a solar panel to charge a battery during the day and charging it again at night can be quite useful.

3.1.2 Review of GIZ-CLEAN I-REAP Portal

Research team also reviewed the GIZ supported India Renewable Energy Appliances Portal hosted on CLEAN's website (www.thecleannetwork.org) and the technology shared along with capacity relating to this assignment.

DRE Technologies available on GIZ-CLEAN I-REAP portal						
S.No.	Applications	Sector	Stage of Value Chain		Capacity/ Sizes available	Number of listed vendors
1	Milking machine	Dairy	Production		20, 25, 40 litres	2
2	Solar dryer	Agriculture	Processing		2.5-500 kg	7
3	Retrofit flour mill	Agriculture	Processing		25-60 kg/h	1
4	Juice making machine	Agriculture	Processing		40-200 litres/h	1
5	Water aerator	Fishery	Production			1
6	Rice processing machine	Agriculture	Processing	Pre-cleaning	250 kg/h	1
				Hulling	80-100 kg/h	
				Grading	180 kg/h	
				Polishing	70 kg/h	
7	Bulk milk chiller	Dairy	Storage/Processing		500-1000 litres	1
8	Cold storage	Agriculture	Storage/Post harvesting		4.5-10 MT	2
9	DC Freezers	Dairy, Fishery, Agriculture	Post harvesting/Storage		25-500 litres	6
10	Solar water pumps	Agriculture	Production		0.5-20 HP	8
11	Cattle feed grinder	Dairy	Feed		90 kg/h	1
12	Sugarcane crusher	Agriculture	Processing		120 kg/h	1

The identified vendors of the DRE Applications added in this report are in addition to who are already in the I-REAP.

3.2 Technology Identification Process

Research team has taken several approaches to identify best adoptable, scalable, and feasible DRE technologies catering Agriculture, Fishery and Dairy. Cost-competitive, quality and market readiness also been taken care-off for adopting clean, green and energy efficient technologies.
The evaluation process started with identification of available technologies, development of criterion and lastly identification of the technologies catering these 3 sectors and its value chain. These 3 sectors including its sub-sectors were analysed about their process, technique, potential for adoption of DRE technologies. To supplement the information collated through secondary sources and plug the information gaps therein, interactions were held with relevant stakeholders.

To prioritize potential technologies, a matrix including the parameters that characterise the utilisation potential of DRE was finalized. Each parameter was provided certain weightage to evaluate the same. The parameters include Applicability, Vendor availability, Technology Readiness, Technology maturity, Scalability, Policy favourability. Based on the situation / outcome, Research team has identified potential technologies for these 3 sectors.


Photo credit: Freepik

3.2.1 Review of the Existing DRE technologies

In recent years, a surge of inventors and entrepreneurs has developed several decentralised renewable energy (DRE) livelihood applications that are both energy efficient and economically feasible. Solar dryers, solar or biomass-powered cold storage / chillers, solar based aeration system, solar charkha, and other options fall under this category. The modular nature of such DRE Applications allows for expansion without requiring big expenditure. Furthermore, the energy efficiency of such systems is crucial since it defines their economic sustainability by lowering the scale of the generation and storage (if necessary) assets.

DRE-powered livelihood solutions can reduce, and eventually eliminate, dependency on diesel in livelihoods while also supplementing grid supplies. There are successful DRE livelihood projects and business models in agriculture, agro-processing, dairy, poultry, fisheries, tailoring, and other industries that have been evaluated in the field by various organisations and have the potential to be repeated in bigger amounts. However, this represents just a small portion of the broad range of livelihood activities in India.

Research team has collected information from different Govt. Department, Implementing Agencies, Practitioner to understand the Scope and Potential as per the needs of this assignment.

3.2.2 Selection of Best Adoptable DRE Technologies for these 3 Sectors

A matrix including the factors that characterise the utilisation potential of DRE was used to rank the potential Technology. Each parameter was assigned a weightage to be evaluated. Applicability, vendor availability, technology readiness, technology maturity, scalability, and policy suitability are among the characteristics. The research team has identified potential technologies for these three areas based on the circumstance/result.

Table 1: Notations: P = present/qualifies the criteria, X = doesn't qualify

Sector	Stage of Value chain	Process	Identified DRE Applications	Technology Selection Criteria					
				Project Suitability			Market Readiness		Policy
				Applicability	Vendor Availability	Technology Readiness	Technology Maturity	Scalability	Policy Favourability
Dairy									
Dairy	Feed	Feed production	Solar water pump	P	P	P	P	P	P
			Hydroponics	P	P	P	P	P	P
	Milking	Milking	Milking machine	P	P	P	P	P	x
	Collection	Testing	Milk testing machine	P	P	P	P	P	x
		Weighing	Weighing machine	P	P	P	P	P	x
	Chilling	Chilling	Bulk milk chillers	P	P	P	P	P	P
	Processing	Pasteurization	Solar flat plate collector	P	P	P	P	P	x
		Cream separation	Cream separator	P	P	P	P	P	P
		Churning	Butter churner	P	P	P	P	P	P
		Khoya preparation	Khoya making machine	P	P	P	P	P	P
	Storage	Refrigeration/ Freezing post processing	Freezers cum Refrigerators	P	P	P	P	P	P

Sector	Stage of Value chain	Process	Identified DRE Applications	Technology Selection Criteria					
				Project Suitability			Market Readiness		Policy
				Applicability	Vendor Availability	Technology Readiness	Technology Maturity	Scalability	Policy Favourability
Fishery									
Fishery	Hatching	Egg incubation	-	x	x	x	x	x	x
	Production	Aeration	Solar water aerator	P	P	P	P	P	P
	Harvesting	-	-	x	x	x	x	P	x
	Post harvesting	Refrigeration	Refrigerators cum Freezers	P	P	P	P	P	P
	Processing	Drying	Dryers	P	P	P	P	P	P
		Deboning	Fish deboning machine	P	P	P	P	P	P
		Mincing	Meat mincing machine	P	P	P	P	P	P

Sector	Stage of Value chain	Process	Identified DRE Applications	Technology Selection Criteria					
				Project Suitability			Market Readiness		Policy
				Applicability	Vendor Availability	Technology Readiness	Technology Maturity	Scalability	Policy Favourability
Agriculture									
Agriculture	Post harvesting	Storing	Cold storage	P	P	P	P	P	P
	Production	Irrigation	Water pump	P	P	P	P	P	P
	Processing	Pre-cleaning	Pre-cleaning machine	P	P	P	P	P	P
		De-hulling	Hulling machine	P	P	P	P	P	P
		Polishing	Polishing machine	P	P	P	P	P	P
		Grading	Grading machine	P	P	P	P	P	P
		Milling	Oil milling machine	P	P	P	P	P	P
		Slicing	Slicing machine	P	P	P	P	P	X
		Drying	Solar dryers	P	P	P	P	P	P
		Powdering	Pulveriser machine	P	P	P	P	P	P
		Juicing and pulping	Multipurpose fruit processing machine	P	P	P	P	P	P
		Packaging and storage	Multipurpose packaging machine	P	P	P	P	P	x
		Milling	Flour mill	P	P	P	P	P	P
		Textile processing	Charkha, Loom	P	P	P	P	P	P

3.2.3 Development of Technology Selection Criteria

Project Suitability, Market Readiness and Policy are the main identified key parameter to select or identify the Technology.

Project Suitability

- **Applicability** - Technology applicability for small and marginal farmers.
- **Vendor availability** - whether 5+ vendors are available for the technology or not.
- **Technology Readiness Level** - Basic Principle/ Formulated application/Proof of concept/ Functional verification/Prototype/Pilot/ Commercial.

Market Readiness

- **Technology maturity** - if any standards/ certification are available for the technology.
- **Scalability** - if any research is conducted on potential market scoping in India.

Policy Enabling

- **Policy favourability** - if Central Govt./ State Govt. have schemes to support implementation of the technology.

Photo credit: Freepik

3.3 Sector wise Process specific DRE Technology Identified

Under this section, the overview of the identified technologies for different process from the 3 sectors are provided.

3.3.1 Agriculture

The Indian economy is ranked sixth among the world's leading economies. Agriculture provides a living for the majority of the country's inhabitants. Agriculture accounts for around 14% of the country's overall GDP[4]. Although the agriculture sector is critical to the Indian economy, it is constantly declining, whilst the service sector is growing.

The Indian economy is an agrarian economy; the challenge with such an agrarian economy is that the agriculture sector is largely dependent on the production, distribution, and consumption cycles. Productivity is yet another issue with the agricultural industry. Currently, Indian farmers produce 2.4 tonnes of rice per hectare of land, falling well short of their true potential. China and Brazil, on the other hand, produce 4.7 and 3.6 tonnes of rice per acre, respectively[5]. Despite its many drawbacks, agriculture remains the most important industry in the Indian economy.

Photo credit: Freepik

[4] https://tradingeconomics.com/india/gdp-from agriculture#:~:text=It%20is%20estimated%20that%20India's,very%20important%20for%20economic%20activity.[5]
[5] https://www.livemint.com/Opinion/nw9JKiPrDPpqCuWfmoibPN/Indias-agricultural-yield-suffers-from-low-productivity.html

Photo credit: Freepik

3.3.2 Fisheries

India is a maritime country with abundant water resources both in the interior and marine sectors that are used for catching and culture fisheries. The Indian fisheries industry operates in a varied range of environments, from the pristine waterways of the Himalayas to the vast Indian Ocean. The country's fisheries biodiversity includes a diverse range of physical and biological components that sustain the livelihoods of millions of people.

The fisheries sector is critical to the Indian economy. It contributes to national income, exports, food and nutritional security, and job creation. This industry is also a major source of income for a substantial portion of the country's poor people, particularly in coastal districts. India has risen to become the world's third largest fish producer and fourth largest exporter of fish and fishery goods, propelling Brand India from 'Local to Global'. India is the world's second largest fish producer, accounting for 7.56 percent of worldwide output. It accounts for around 1.24 percent of the country's GVA and more than 7.28 percent of agricultural GVA.

The country's fisheries sector is one of the most important and fastest expanding sectors. The sector has grown at a rate of roughly 8% per year on average, with aquaculture rising at a rate of more than 10% per year. The fisheries industry has been designated a 'Sunrise Sector,' with an extraordinary double-digit average annual growth rate of 10.87% since 2014-15, and a record fish output of 161.87 lakh tonnes (provisional) for 2021-22[6].

[6] https://pib.gov.in/FeaturesDeatils.aspx?NoteId=151155&ModuleId%20=%202

3.3.3 Dairy

Dairy is India's single most important agricultural commodity. It provides 5% to the national economy and directly employs 80 million dairy farmers India is first in milk production, accounting for 23% of world milk output. Milk output in the country has increased at a compound annual growth rate of around 6.2 percent, from 146.31 million tonnes in 2014-15 to 209.96 million tonnes in 2020-21[7].

Over the previous five years ending in 2020, the cattle industry has expanded at a compound annual growth rate (CAGR) of 8.15%. Liquid milk growth, which accounts for more than half of the dairy business, is expected to stay constant (6-7%). The structured dairy sector, which accounts for 26-30% of the industry (by value), has grown faster than the unorganised sector.

Photo credit: Freepik

3.3.4 Finalised DRE Applications covered for the Detailed Study

The identified top 20 DRE applications, the following details of which have been compiled as the project deliverable:

Agriculture

- Millet processing machine
- Rice processing machine
- Water pump
- Pulveriser machine
- Oil mill
- Flour processing machine
- Dryer
- Dal processing machine
- Cotton weaving
- Refrigerator cum freezer
- Cold storage

Dairy

- Milking machine
- Bulk milk chiller
- Cream separator
- Khoya making machine

Fishery

- Water aerator
- Fractional water pump
- Meat mincing machine
- Fish deboning machine

Multi sectoral applications

- Dryer (agri/fishery)
- Water pump (agri/fishery)
- Fractional water pump (agri/dairy/fishery)
- Refrigerator cum freezer (agri/dairy/fishery)

[7] https://www.indiabudget.gov.in/economicsurvey/ebook_es2022/files/basic-html/page277.html#:~:text=India%20is%20ranked%201st%20in,%2D15%20(Figure%2021).

Photo credit: Freepik

04

Analysis and Documentation of Identified DRE Applications

This chapter will highlight sector wise identified DRE applications and each applications will have the following:

- Working Principle and its types
- Generic Technical Specifications (outcome of reviewed product catalogues of organizations)
- Techno-economic analysis as compared to diesel run models
- List of vendors supplying the applications (with or without the solar energy system)
- Policies and Subsidy

Assumptions and Disclaimer:

- ✓ The solar energy system size, including panels, battery, and autonomy, provided in this report is for reference purposes only. It may vary from vendor to vendor based on the exact sizing, needs, and geography of the installation.
- ✓ The cost of the solar energy system for vendors who have not provided this information has been estimated by the project team and is indicative in nature. The actual cost may vary from vendor to vendor.
- ✓ The project team has made every effort to collect accurate information from vendors, but the details provided may still vary.
- ✓ The sizes and capacities of the products mentioned in the vendor datasheets are not exhaustive and may not represent the full range of offerings. For a complete list of offerings, please contact the vendor(s) directly.
- ✓ The policies and subsidy schemes mentioned are not exhaustive in nature. The project team has tried to capture all the ongoing schemes in India. Due to the limited availability of schemes promoting the adoption of DRE applications, small and marginal farmers who are interested in utilizing these technologies must utilize programs like MUDRA Yojna.
- ✓ The techno economics and payback period of the applications are indicative in nature and is dependent on several technology specific factors and goes much beyond to what have been considered for the preparation of report under this project.
- ✓ There are a number of applications that is not direct run through solar, hence inverter can be used to convert DC power to AC power to run those applications.

Numerical Assumptions:

Table 2: All values are approximate.

Diesel consumption rate	1.2litres/h
Emission factor of diesel[8]	2.6kg/litre
Grid emission factor[9]	0.80

Photo credit: Freepik

[8] https://www.researchgate.net/publication/235458666_Estimation_of_Carbon_Footprints_from_Diesel_Generator_Emissions
[9] https://cea.nic.in/wp-content/uploads/baseline/2021/06/User_Guide_ver_16_2021-1.pdf.

Definitions:

Manufacturer: Manufacturers are companies that produce and sell products. In the context of this report, manufacturers would refer to companies that design, manufacture and supply applications and not necessarily provide solar energy components with it as well.

System Integrator: System integrators are companies that assemble and install solar systems by combining components from various manufacturers into a complete system. In addition to sourcing and installing the components, system integrators may also be responsible for designing the system, obtaining permits, and providing ongoing maintenance and support. System integrators are typically contracted by customers who want a complete solar system solution, rather than purchasing and installing the components themselves.

It's worth noting that some manufacturers may also offer system integration services, in addition to selling their individual components.

4.1 Business Models

DRE is an increasingly popular alternative to traditional sources of energy, and for good reason. Harnessing the power of the sun not only reduces reliance on fossil fuels but also lowers the carbon footprint. However, there are different ownership models related to solar power applications that can make it challenging to determine the best approach for individual needs. In this context, it is important to understand the various ownership and operational models available and their advantages and disadvantages to make an informed decision.

A. Individual

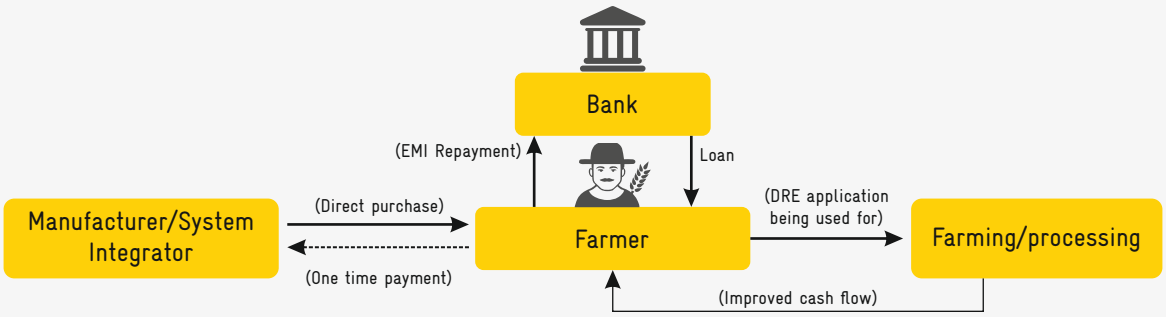


Figure 2: Schematic diagram for direct purchase model

B. Pay As You Go

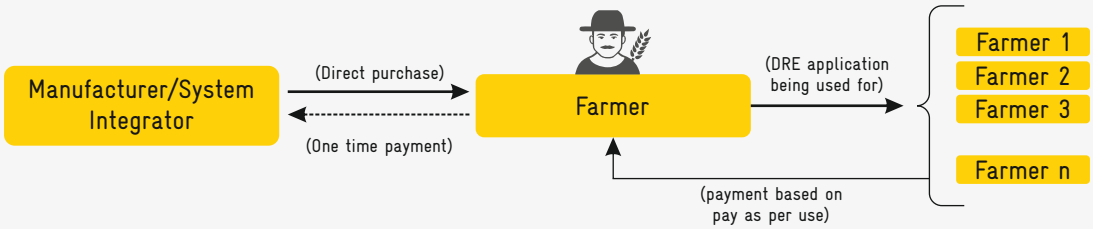


Figure 3: Schematic diagram for Pay As You Go model

C. Shared ownership

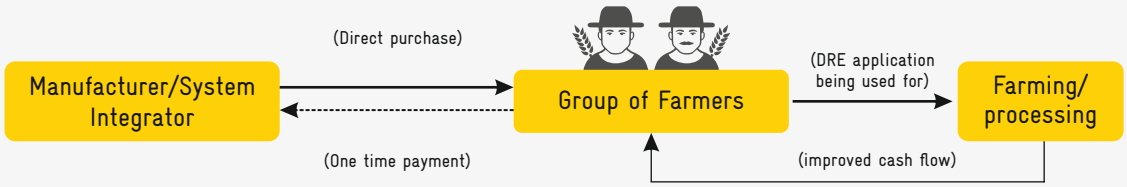


Figure 4: Schematic diagram for shared ownership model

D. Lease model

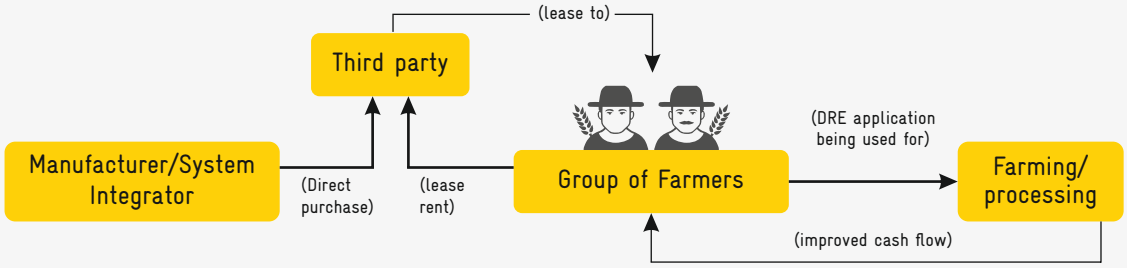


Figure 5: Schematic diagram for lease model

There are other ownership/business models as well such as community ownership, Farmer Producer Organization run, Self Help Groups etc. which have been indicated for applications wherever applicable.

4.2. From sunlight to electricity: Understanding components and functionality

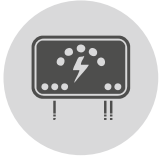
A solar energy system is a system that uses the energy from the sun to generate electricity or heat. In addition to providing electricity, solar energy systems can also be used to heat water and provide space heating.

Solar energy systems are a clean and renewable source of energy that can help to reduce dependence on fossil fuels and lower greenhouse gas emissions.

Components of Solar Energy System:

Solar Panels

Solar panels (also known as photovoltaic panels) convert sunlight into DC electricity.



Charge Controller

A charge controller regulates the amount of electricity that flows from the solar panels to the battery bank, preventing overcharging or deep discharging of the batteries.

Battery Bank

A battery bank stores the excess electricity generated by the solar panels for later use, such as during periods of low sunlight.

Inverter

An inverter converts the DC electricity stored in the battery bank into AC electricity, which can be used to power household appliances and other electrical devices.

Types of Solar Energy system

1. Off-grid energy system:

An off-grid solar energy system is a type of solar energy system that operates independently of the electrical grid. This means that the system is not connected to the utility power lines, and instead relies on batteries to store the electricity generated by the solar panels for later use. Off-grid solar energy systems are commonly used in remote areas where grid power is not available, or where it is not economically feasible to connect to the grid.

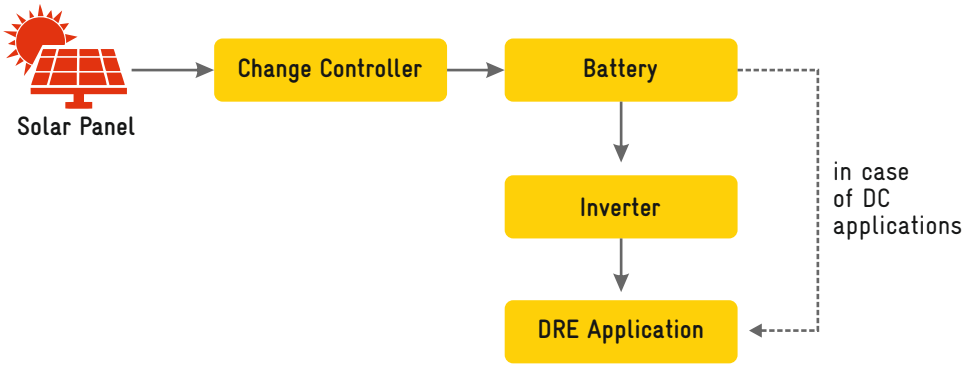


Figure 6: Schematic of off-grid solar energy system

2. On-grid energy system:

An on-grid energy system, also known as a grid-tied system, is a solar energy system that is connected to the electrical grid. This means that the solar panels generate electricity that is fed into the grid and can be used by other customers on the same grid. In return, the owner of the solar energy system typically receives credit or payment from the utility company for the electricity that they generate.

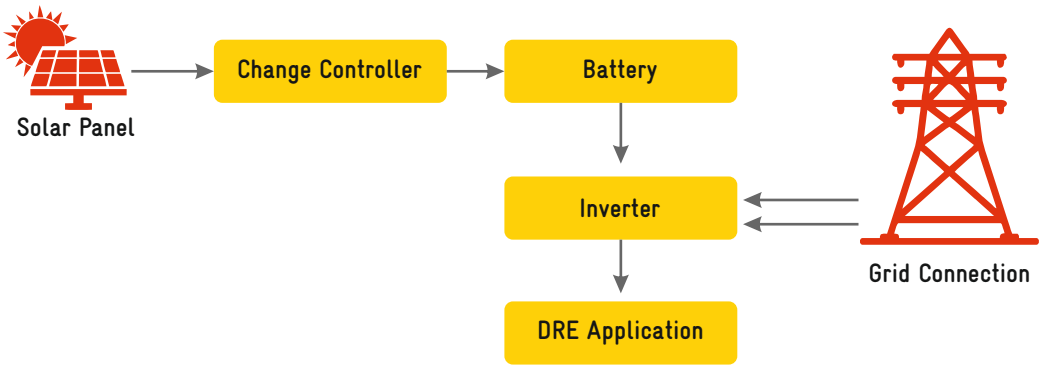


Figure 7: Schematic of on-grid solar energy system

APPLICATIONS IN Agriculture Sector

Photo credit: Freepik

1. Solar Cold Storage:

A cold storage facility, also known as a refrigerated warehouse or temperature-controlled storage, is a specialized type of warehouse designed to store perishable goods, such as fruits, vegetables, dairy products, meat, and seafood, at a specific temperature and humidity level to prevent spoilage and maintain freshness.

Components of the Solar Cold Storage:

Insulated Panels:

These panels make up the walls, ceiling, and floor of the cold storage facility, creating an insulated enclosure that prevents heat transfer.

Doors and Seals:

Specialized doors and seals are installed to prevent heat transfer between the inside and outside environment.

Refrigeration Units:

These units consist of compressors, evaporators, and condensers that remove heat from inside the enclosure and release it outside, maintaining the desired temperature.

Temperature and Humidity Monitoring Systems:

These systems include sensors placed in different locations inside the enclosure that measure the temperature and humidity level, and a central control system that adjusts the refrigeration and humidity control systems as needed.

Air Handling Units:

These units help circulate cool air evenly throughout the enclosure, removing moisture, odours, and other contaminants from the air.

Lighting:

The facility may have lighting installed to provide visibility inside the enclosure.

Backup Power System:

A backup power system, such as a generator or battery backup, ensures that the refrigeration and other systems continue to function in case of a power outage.

Photo credit: Nirmitee Solar

Types of cold storage:

1. Direct Expansion Mechanism

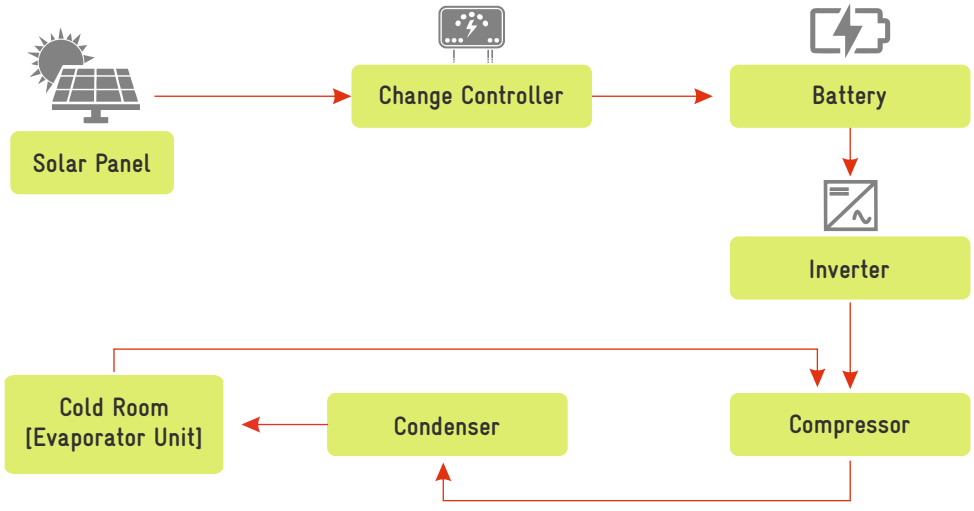


Figure 8: Schematic of direct expansion type cooling mechanism

The direct expansion (DX) mechanism is a commonly used method for cooling in cold storage applications. This mechanism uses a refrigerant, such as ammonia or Freon, to absorb heat from the air inside the storage area and transfer it to the outside environment.

In a DX system, a compressor circulates the refrigerant through a series of coils located inside the cold storage area. As the refrigerant absorbs heat from the air, it changes from a liquid to a gas. The gas is then compressed by the compressor and forced through a set of coils located outside the storage area, where it releases the absorbed heat to the surrounding environment. The refrigerant then condenses back into a liquid and is pumped back into the coils inside the storage area to repeat the cycle.

2. Thermal Energy storage mechanism

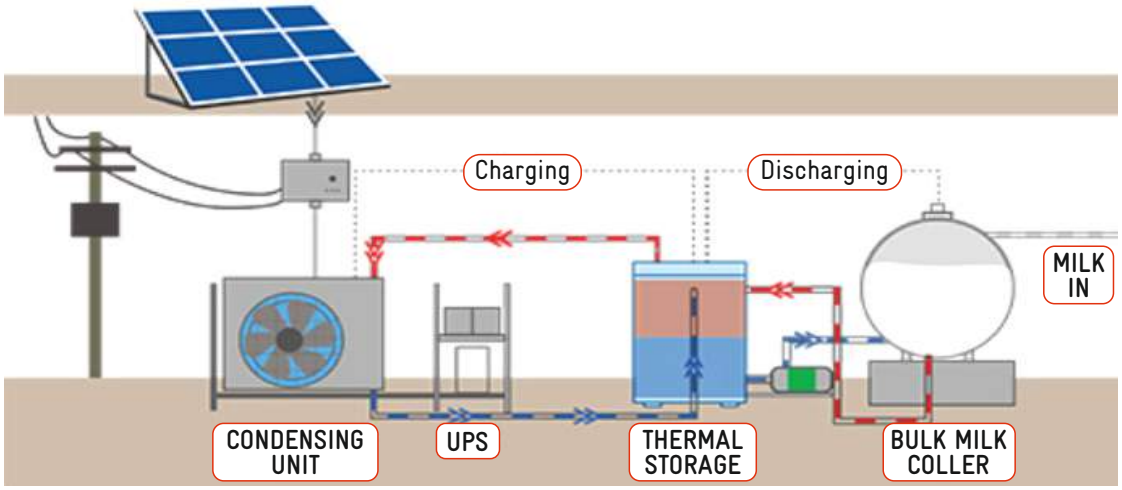


Photo credit: Krishna Defence and Allied Industries

Figure 9: Schematic of thermal energy storage type cooling mechanism

Thermal energy storage (TES) based solar cold storage works by using solar energy to generate and store thermal energy in a storage unit, which is then used to maintain a cold temperature in a storage facility.

Solar panels gather light during the day and turn it into electricity, which drives a compressor to chill a refrigerant. The heat from the storage unit is subsequently transferred to the refrigerant when it circulates via a heat exchanger after being cooled. The storage unit's temperature is lowered as a result, and the thermal energy is stored for later use.

At night or during periods of low sunlight, the refrigerant is circulated through the heat exchanger again, this time transferring the thermal energy back into the storage unit. The thermal energy released by the refrigerant warms the storage unit, which maintains the cold temperature in the storage facility.

Technical Specifications:

S.No.	Cold Storage	5MT	10MT
	Constructional		
1	Usage/Application	Agriculture/ Dairy	
2	Product dimensions (ft)	20 x 8 x 8	15 x 10 x 10
3	Cold room insulation	Polyurethane foam, 100mm thickness	
4	Cold room body	Pre-painted galvanized iron	

S.No.	Cold storage	5MT	10MT
5	Room door	Insulation: PUF or equivalent Thickness: 100mm	
6	Curtains	PVC to reduce heat infiltration on door openings	
	Operational		
7	Refrigeration TR	~1.8 - 2.6TR approx @ -5°C evaporating and 50°C condensing	~3 - 3.5TR approx @ -5°C evaporating and 50°C condensing
8	Temperature range (°C)	Minimum 2°C and maximum 20°C	
9	Humidity range	80-95% by using set point controlled humidifier	
10	Back up type	Customizable as per the requirement. Existing models available have: 1. Wall mounted plate type thermal energy storage 2. Grid hybridization (Single and three phase)	
11	Back up duration	Varies with the manufacturer and insolation value, however, generally it is: 1. 16 hours (with 10% loading and 10 times door opening condition) 2. 24-30 hours (with solar operation only at insolation of 4.19 - 5.5kW/m2/day)	
12	Pre-cooling	Pull down the temperature from 30°C to 5°C for 500-1000 kg daily.	
13	Remote monitoring	Per minute logging, GPRS based, viewable on desktop and smart phones. Few of the parameters that can be monitored are back up duration, power generated by PV system, humidity, cold Room temperature, ambient temperature, grid energy consumption, compressor speed, on-off state etc.	
	Solar energy system		
14	PV array (kWp)	4 - 710 - 14	
15	Solar module type	Monocrystalline / Polycrystalline	
16	Battery capacity (in Ah, if required)	24V/48V, 120-240Ah	
17	Alternative applicable power source	Single/Three phase grid connection	
	Additional information		
18	Portability of system	Portable	
19	Installation type (e.g. plug and play)	Plug and play	
20	Degree of protection (e.g. Ingress Protection (IP) code)	IP 65	
21	Protection against (e.g. open circuit, dry running, lightning etc.)	Protection circuitry is inbuilt for open circuit, voltage fluctuations, surge current etc.	

S.No.	Cold Storage	5MT	10MT
22	Warranty (for system as well as solar panel, battery etc.)	5 years on solar cold storage and standard warranty on the solar energy components	
23	Annual maintenance (in years)	AMC is generally included for a period of 5 years If it is not included in the package, then on an average it costs around ₹10,000 – 15,000 per year.	

Techno Economics:

Parameters	Solar	Grid
Cold storage capacity (kg)	2000	2000
Annual working days	250	250
Capex (₹)	1500000	Baseline
Power rating (kW)	3.50	3.50
Average capacity utilisation (%)	60	60
Average cost of cooling (₹/kg)	1.2	1.75
Total quantity of items cooled in a year (kg)	300000	300000
Total revenue generated per year	360000	525000
Miscellaneous cost of operation per year	8000	15000
Operational hours per day	10	10
Energy consumption per day (units)	35	35
Energy consumption per year (units)	8750	8750
Electricity tariff (₹ /unit)	-	10
Annual cost of electricity per year (₹)	-	87500

Payback period of solar cold storage of 5 MT as compared to grid electricity run model = 3 years and 4 months

GHG emissions mitigated = 7 MT/year

Ownership models:

Policies and Subsidy:

S. No.	Subsidy on	Scheme Name	Central/ State	Scheme	Scheme Details	Individual or Group	Type of eligible group(s)
1	Solarization of cold storages	Backended subsidy Scheme	Central	Agriculture Marketing Infrastructure (subscheme of Integrated Scheme for Agriculture Marketing (ISAM))[10]	• The AMI scheme envisages a back-ended capital subsidy for credit-linked investment in eligible storage and in marketing infrastructure projects. • The eligible subsidy is 25% or 33.33% of the capital cost depending upon the area and category of beneficiary • NABARD will release subsidies under the scheme to all the institutions which are eligible for NABARD refinance and to such other institutions GoI may approve for the purpose. • AMI is demand driven, credit linked, back ended subsidy scheme wherein subsidy support @ 25% and 33.33%, available to beneficiaries is routed through NABARD, NCDC and DMI / DAC&FW.	Both	SHGs, FPCs, Cooperative societies etc.

[10] http://agriinfra.dac.gov.in/Content/DocAttachment/FINALSchemeGuidelinesAIF.pdf

2. Solar Rice Milling Machines (Hulling, Grading and Polishing)

Solar rice processing machines are specialized machines used in rice processing that are powered by solar energy. These machines are designed to be environmentally friendly, cost-effective, and ideal for use in remote locations where electricity is not readily available.

The major rice processing functions are:

- **Hulling:** Hulling is the process of removing the outer husk or shell from the rice grain. This exposes the edible white rice kernel, which is the part of the rice grain that is consumed.
- **Grading:** Grading is the process of separating rice grains based on size, shape, and weight. This process is used to sort the rice into different grades, which can affect the price and quality of the rice.
- **Polishing:** Polishing is the process of smoothing and shining the surface of the rice grain. This process is used to remove any remaining bran or husk, and to improve the appearance of the rice grain.

Photo credit: Bighaat.com

Components of Solar Rice Milling Unit:

- Rice milling machine: The rice milling machine is the main component of the solar rice milling unit and is used to perform various functions such as hulling, grading, and polishing.
- Motor: The motor is used to power the rice milling machine and is powered by the electrical energy from the solar panels or battery.
- Control system: The control system is used to control the operation of the rice milling machine, and to ensure that it is operating efficiently and effectively.
- Optional accessories: Some solar rice milling units may include additional accessories such as a grain cleaner, a grader, or a polisher, depending on the specific needs of the user.

Working Principle:

- Rice Hulling: Sunlight is captured by the solar panels and converted into electrical energy and the same is stored in batteries through a charge controller. The rice hulling machine is powered by the electrical energy from the battery. The rice is fed into the rice hulling machine, where it is subjected to friction and pressure to remove the outer husk or shell. The resulting white rice kernels are collected and processed further.

Figure 10: Husked rice to hulled rice

- **Rice Grading:** A rice grading machine works by separating rice grains based on size, shape, and weight, to sort the rice into different grades. Here's how the process works:
    - Rice is fed into the machine through a hopper or feeding mechanism. The rice passes through a series of screens or sieves, each with different-sized holes, to separate the grains based on size. The rice is then subjected to air currents, which help to separate the grains based on weight, with lighter grains being blown away and heavier grains falling to the bottom. The different grades of rice are then collected and processed further, if needed.
    - The rice grading machine is designed to be efficient, accurate, and easy to use, and typically includes a control system that can be adjusted to meet the specific needs of the user. The use of a rice grading machine ensures that the rice is sorted into different grades, which can affect the price and quality of the rice. This is important for ensuring that the rice is of high quality and can be sold at a fair price.
- **Rice Polishing:** A rice polishing machine works by removing the remaining bran layer and germ from the surface of the rice kernels, resulting in a polished and smoother surface.
    - Rice is fed into the machine through a hopper or feeding mechanism. The rice kernels are subjected to friction and pressure between two rotating abrasive surfaces, such as abrasive rubber rollers or abrasive emery stones. The bran layer and germ are removed from the surface of the rice kernels, leaving a polished and smoother surface. The polished rice is then collected and processed further, if needed.

Figure 11: Unpolished and polished rice

- The use of a rice polishing machine helps to improve the appearance and quality of the rice, making it more attractive to consumers. The machine is designed to be efficient, accurate, and easy to use, and typically includes a control system that can be adjusted to meet the specific needs of the user. Additionally, the use of a rice polishing machine can improve the shelf life of the rice by removing any impurities or contaminants from the surface of the rice kernels.

Technical Specifications:

S.No.	Solar Rice processing machine (Huller and Polisher)	
	General Information	
1	Usage/Application	Agriculture
2	Processing Capacity (kg/hour)	100 - 160
3	Power rating (H.P)	3 - 5
4	Motor type	Single phase induction motor
5	Construction material	Varies with manufacturer, generally mild steel, stainless steel and cast iron is used.
6	Hopper capacity (kg)	10 - 25
7	Weight of the machine (kg)	150 - 250
8	Hulling efficiency (%)	85 - 95
	Solar energy system	
9	PV array (kWp)	6.70 - 10
10	Solar module type	Polycrystalline/Monocrystalline
11	Battery capacity (in Ah, if required)	200Ah x 8, 96V, 7.5 kVA - 220Ah x 10, 120V, 12.5kVA
12	Battery backup (hours)	6 hours
13	Electronics (if inverter etc. are required)	Inverter is required since all reviewed products are induction motor based
	Additional Information	
14	Warranty Conditions	One year manufacturing defect and on the rest of the parts such as gear box, electric motor, starters etc. as per the conditions of the OEM.

Techno Economics:

Parameters	Solar		Diesel	Grid
	Rice huller only	Rice mill combo (with huller and pulveriser)		
Power (kW)	2.3	2.3	10	2.3
No. of hours of operation per day	4	4	4	4
Processing charges (₹/kg)	3	4.5	7	5
Processing capacity (kg/hour)	120	120	160	135
Processing per day (quintal)	4.8	4.8	6.4	5.4
Monthly income (₹)	43,200	64,800	1,34,400	81,000
Operational months per year	6	6	6	6
Capex (₹)	7,50,000	8,00,000	baseline	-
Fuel charges (₹)	0	0	28,800	13,248

Simple payback period of single rice huller as compared to diesel run and grid electricity run model = 2 years 8 months and 2 years 10 months respectively.

Simple payback period of combo mill (hulling and pulveriser) as compared to grid electricity run model = 1 year 11 months and 2 years respectively.

GHG emissions mitigated as compared to diesel run = 2.3 MT/year

GHG emissions mitigated as compared to grid electricity run = 1.3 MT/year

Ownership models:

Policies and Subsidy information:

The project team did not find any schemes for financial support to set up small solar powered rice mill across the country.

The financial support is available for a minimum processing capacity of 1MT/hour through Chief Minister's Samagra Gramya Unnayan Yojana (CMSGUY) in convergence with Agriculture Infrastructure Fund (AIF) in Assam[11].

[11] https://government.economictimes.indiatimes.com/news/smart-infra/assam-government-to-set-up-1000-mini-rice-mills-under-agriculture-infrastructure fund/93794200#:~:text=Exclusive, Assam%20government%20to%20set%20up%201000%20mini%20rice%20mills%20under,the%20capacity%20of%20the%20mill.

3. Solar Water Pump:

A pump that is used to pump the water for different applications using solar energy.

Components of solar water pump

Solar Panel

A panel designed through collection of solar (or photovoltaic) cells, to use the sun's rays as a source of energy to generate electricity.

Controller

To control and enable on/off switching of the water pump.

Motor

To maintain the operation of pump's prime mover. It serves to replace diesel generators.

Pump

It uses mechanical action to move fluids (liquids or gases), or occasionally slurries. Electrical energy is often transformed into hydraulic energy.

Photo credit: Freepik

Types of Solar Pump:

1. Surface pumps:

A solar surface water pump is a type of pump that is powered by solar energy and is designed to pump water from a source such as a lake, river or shallow well. It is typically installed at ground level or above the water source and is used to lift water to a higher elevation, such as to irrigate crops or provide drinking water for livestock.

Working principle: A solar surface water pump uses solar panels to convert sunlight into electricity, which powers a DC/AC motor that drives an impeller. The impeller draws water from a source and pushes it through a discharge pipe to the desired location.

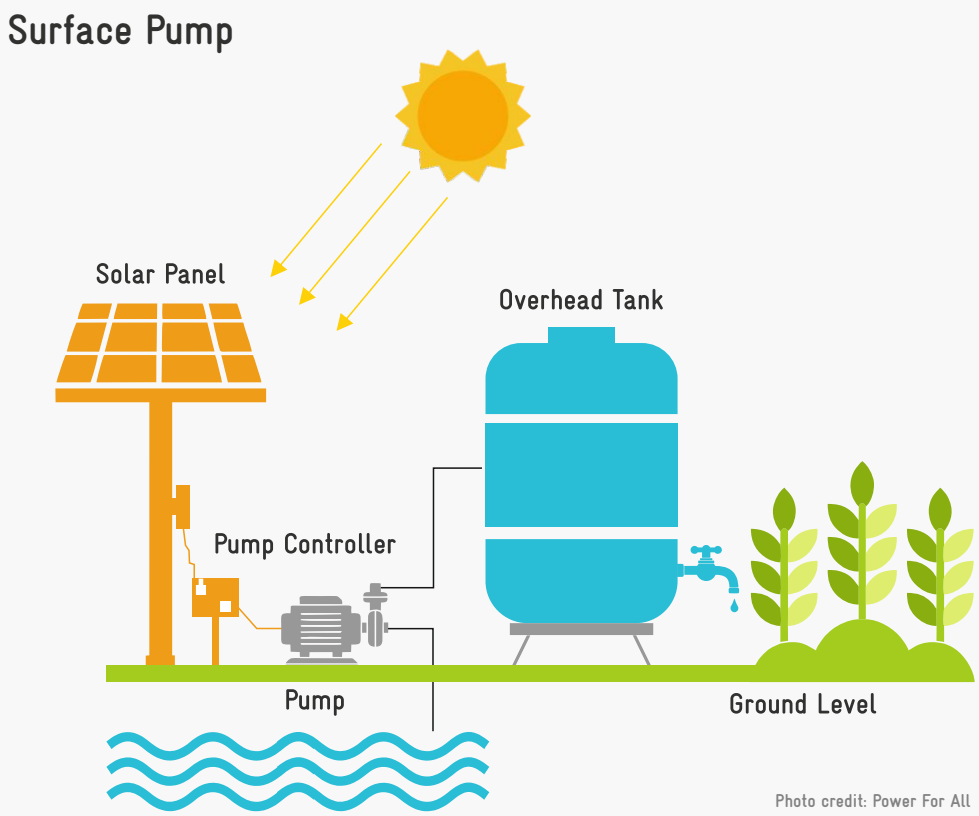


Figure 12: Schematic of solar surface water pump

2. Submersible:

Submersible pumps are pumps that are designed to be submerged in water or other fluids to pump them from one location to another.

Working Principle:

A submersible pump works by using a hermetically sealed motor that is attached directly to the pump body. When the pump is immersed in water or other fluid, the motor drives an impeller that moves the fluid through the pump and into a discharge pipe, where it is transported to the desired location. The motor and pump are designed to work together as a single unit, and the fluid acts as a coolant for the motor, allowing it to operate continuously without overheating.

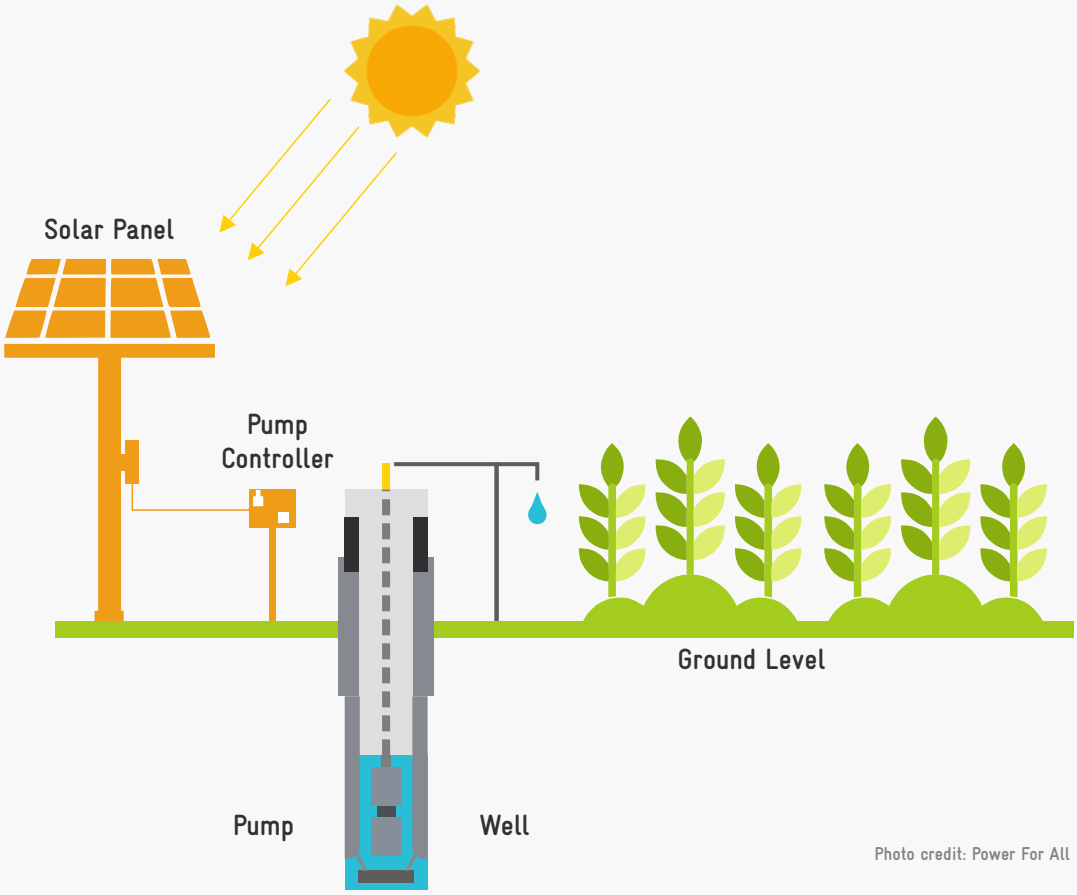


Figure 13: Schematic of solar submersible water pump

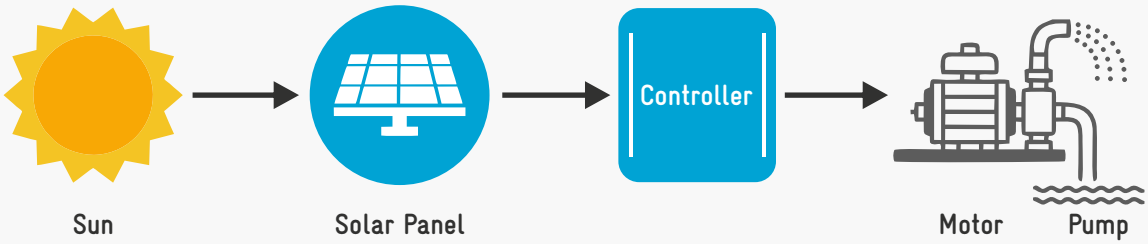


Figure 14: Flow Diagram: Solar Water Pump

Technical Specifications:

Sl.No.	Solar water pump	
	General Information	
1	Usage/Application	Agriculture/ Dairy/ Fishery
2	Water sources	Borewell, Tubewell, Water stream, Pond
3	Solar pump type	Surface / Submersible
4	Motor pump set	DC motor pump set with or without brushes and Induction motor with suitable VFD and inverter set
5	Electronics	1. 1. Inverter with MPPT based variable frequency drive (VFD) PWM power controller for AC pumps. 2. 2. IGBT/any other power electronic switch based PWM controller with MPPT technique for DC pumps. 3. 3. Some manufacturers also provide option of 'Tank full/ Source empty' sensor for auto start and stop
6	Fixed or Portable	Fixed / Portable / Semiportable
7	Installation type	Plug & play and easy to operate
8	Solar module type	Monocrytalline / Polycrystalline
9	Degree of protection	IP54 or above. IP65 models are also available and is generally preferred. Motors have Class B insulation
10	Protection against	Input reverse polarity, under and over voltage, overload, short circuit, pump dry run, pump block discharge, over temperature, phase loss
11	Remote monitoring system	With data logger and GSM based integrated remote monitoring for various operational parameters such as PV array voltage, array current, power, pump RPM, pump on/off status, discharge etc.
12	Warranty	5 years warranty from the date of installation on the system for Govt. supported projects and 25 years for solar panels
13	Annual maintenance	1 year AMC on controller and pump for non-subsidised sale and 5 years for government subsidized pump.
14	Asset insurance	On site insurance available based on request of the beneficiary in case of non-subsidized sale while insurance exists for projects government supported/subsidized. This must be claimed by the beneficiary directly.

A.C.		Motor Pump Set Capacity (H.P.)	1	2	3	3	5	5	5	7.5
A.C.	Surface	PV Array (Wp)	1200	1800	2700	2700	4800	4800	4800	6750
A.C.		Total Dynamic Head (m)	10	10	10	20	10	20	30	10
A.C.		Shut off dynamic head (m)	12	12	12	25	12	25	35	12

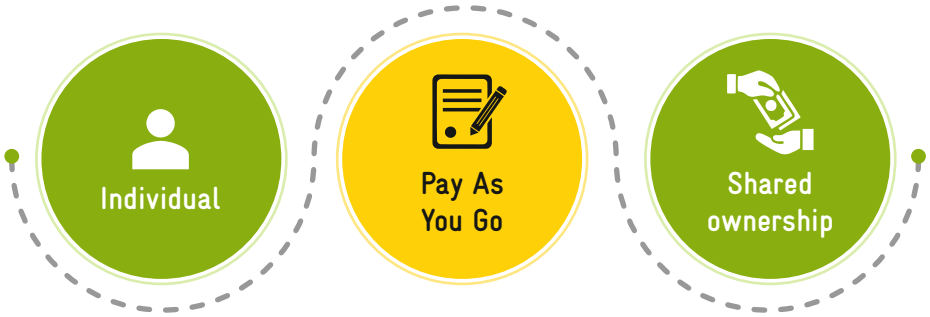
A.C.		**Motor Pump Set Capacity (H.P.)**	**1**	**2**	**3**	**3**	**5**	**5**	**5**	**7.5**
A.C.		Average Water output (litres per day)	89,100	1,78,200	2,67,300	1,21,500	4,75,200	2,16,000	-	6,41,025
A.C.	Submersible	PV Array (Wp)	1,200	1,800	3,000	3,000	3,000	4,800	4,800	4,800
A.C.		Motor Pump Set Capacity (H.P.)	1	2	3	3	3	5	5	5
A.C.		Total Dynamic Head (m)	30	30	30	50	70	50	70	100
A.C.		Shut off dynamic head (m)	45	45	45	75	100	70	100	150
A.C.		Average Water output (litres per day)	40,000	60,000	1,00,000	60,000	42,000	95,000	65,000	42,000
D.C.	Surface	**Motor Pump Set Capacity (H.P.)**	**1**	**2**	**3**	**3**	**5**	**5**	**5**	**7.5**
D.C.		PV Array (Wp)	900	1,800	2,700	2,700	4,800	4,800	4,800	6,750
D.C.		Total Dynamic Head (m)	10	10	10	20	10	20	30	10
D.C.		Shut off dynamic head (m)	12	12	12	25	12	25	45	12
D.C.		Water output (litres per day)	99,000	1,98,000	2,97,000	1,48,500	5,28,000	2,64,000	-	7,42,000
D.C.	Submersible	Motor Pump Set Capacity (H.P.)	1	2	3	3	3	5	5	5
D.C.		PV Array (Wp)	1200 (900 for drinking water appli cation)	1,800	3,000	3,000	3,000	4,800	4,800	4,800
D.C.		Total Dynamic Head (m)	30	30	30	50	70	50	70	100
D.C.		Shut off dynamic head (m)	45	45	45	70-75	100	70	100	150
D.C.		Average Water output (litres per day)	44,400	66,600	1,09,500	66,000	43,500	1,05,600	69,600	48,000

Technical Specifications:

Parameters	Diesel	Solar	Grid
Power rating (HP)	5	5	5
Power rating (kW)	3.73	3.73	3.73
Operating hours per day	6	6	6
Specific fuel consumption (litres/kWh)	0.301	-	-
Density of diesel (kg/l)	0.832	-	-
Number of days of operation	280	280	280
Fuel price (₹ /litre or kWh)	90	-	3
Annual fuel cost (₹)	1,69,750	-	5,040
Maintenance cost (₹)	3,000		2,500
Capital cost (₹)	30,000	5,00,000	30,000

The simple payback period of solar water pump of 5HP = 2 years 11 months
GHG emissions mitigated as compared to diesel run = 4.9 MT/year
GHG emissions mitigated as compared to grid electricity run = 1.3 MT/year

Ownership models:



Policies and Subsidy:

#	Name of policy/ scheme	Nodal agency	Year of Inception	State/ Central	Objective	Target	Subsidy	Other Nuances	Achievements
1	Kisan Urja Suraksha Evam Utthaan Mahaabhiyan (KUSUM)	MNRE	2018	Center	Incentivize farmers to run solar farms and water pumps for generating solar power for extra income	28.25MW solar power over 10yrs: a) 10GW solar generation on barren farmlands b) 1.75 mn pumps c) solarization of grid-connected farm pumps 7.25GW (sell surplus solar power to DISCOM) d) solarization of tube-wells 8.25GW	a) 60% for solar pumps (30% MNRE and 30% states) b) In 30%, 10% upfront by farmer and 90% debt to farmer	No subsidy for solar farms but 50 paise/unit for buying power from farmers for 5 years;	-
2	Scheme for Solar Pumping Program for Irrigation and Drinking Water (under Off-grid and Decentralized Solar Application Scheme)	MNRE; Carried out via State Nodal Agencies	2012	Center	Subsidize 1 million solar pumps by 2021	a) Develop models to foster scalable deployment of solar power for pumping in rural areas. b) Address and support rural development, over and above basic service of water c) Energy access	Below 3HP 25%. 3-5HP 20%	-	-

#	Name of policy/ scheme	Nodal agency	Year of Inception	State/ Central	Objective	Target	Subsidy	Other Nuances	Achievements
3	CFA for Solar Pumping (part of Scheme for Solar Pumping Program for Irrigation and Drinking Water)	MNRE; carried via NABARD	2012	Center	Promote solar pumps in agriculture via credit inked-subsidy scheme	Initial target 10,000 solar pumps; later revised to 30,000 and further revised to 1,00,000 in 2015	40%	20% upfront by the farmer; 40% subsidized loan from RRBs and other rural FIs	1,744 pumps till Dec 2016
4	Rashtriya Krishi Vikas Yojana	Ministry of Agriculture	2007	Centre	Incentivize states to draw a comprehensive plan for the agriculture sector;	pumps component aims to promote reliable power for irrigation by subsidizing solar pumps	State + center 75% 2HP and 50%	The state is eligible only if it maintains or increases % expenditure on agriculture and allied sectors w.r.t state plan expenditure	
5	Andhra Pradesh Solar PV Water Pumping Program	New & Renewable Energy Development Corporation of Andhra Pradesh	2014	State	Subsidize solar pumps to improve irrigation via reliable power	10,000 in 2016-17	3HP: 86%. 5 HP:85%	-	2014-2015 and 2015-16: 6725
6	Solar pump scheme Andhra Pradesh		2018	State		NA	3 HP 82%	Only areas where groundwater is within 75mts	
7	Bihar RE policy	Bihar Renewable Energy Development Agency	2017	State	Improve irrigation access	10,000 pumps by 2022	-	-	-
8	Bihar Saur Kranti Sichai Yojna		2012	State	Subsidize solar pumps to improve irrigation via reliable power	2,85,000 pumps over 2012-2017 (phase 1 pilot 2012-13: 560 pumps)	90% (40% MNRE + 50% state)	-	527
9	Mukhyamantri Navin & Navnirman Urja Yojna		2016	State		3,300 pumps till 2021-22 (2016-17 target 1,000)	-	-	993 (2016-17)

#	Name of policy/ scheme	Nodal agency	Year of Inception	State/ Central	Objective	Target	Subsidy	Other Nuances	Achievements
10	Saur Sujala Yojana Scheme	Chhattisgarh Renewable Energy Development Agency	2016	State	Empower farmers by providing them with solar irrigation patps on subsidized rates	51,000 farmers till 31 March 2019 (including 11,000 in 2016-17)	3HP and 5HP: 95-98%	-	Cumulative 7,448 till FY2016, rising to 18,586 till Jan 2018
11	Solar Water Pumping Scheme	Haryana Department of Renewable Energy	2016	State	Subsidize solar pumps to improve irrigation via reliable power	2016-17 – 885 2017-18 – 2,195 2018-19 – 25,000	90%	-	-
12	Surya Raitha Scheme	Karnataka Renewable Energy Developmen t Agency	2014 pilot; 2018 extended to all	State	a) Reduce use of conventional source in power generation – pumps to supply 1/3rd of total energy generated to the nearby grid b) promote solar energy for uninterrupted power to farmers during the day and increase farmers' earnings by enabling the sale of excess electricity to DISCOMs	310 pumps in phase 1 pilot	90% (this includes part interest-free debt from DISCOM to the farmer; part of payments from DISCOM to a farmer for electricity used to pay off that loan)	Pump installed 1.5 times the capacity; Government purchases power at Rs 7.8/unit, if subsidy not availed and ₹ 6.3 if availed	250 5-7HP pumps in pilot phase 1
13	Mukhyamantri Solar Pump Yojana Madhya Pradesh	Madhya Pradesh New & Renewable Energy Department	2015	State	Subsidize solar pumps	a) arrange irrigation in off-grid areas. b) reduce pollution by diesel. c) reduce financial burden on farmers by using diesel	90% below 3HP, 85% 3- 5HP	-	-

#	Name of policy/ scheme	Nodal agency	Year of Inception	State/ Central	Objective	Target	Subsidy	Other Nuances	Achievements
14	Solar Pump Scheme Maharashtra	Maharashtra Energy Development Agency	2015	State	Subsidize solar pumps to improve irrigation via reliable power	2,600 solar pumps	80% (22% MNRE + 58% state)	Eligible for only 1- 5HP pumps	-
15	Hi-tech Technology/ For Agriculture Solar Powered Pump Scheme	Rajasthan Horticulture Development Society	2018	State	Supply, Commissioning and maintenance of solar pumping infrastructure and after-sales services for 10 years (Includes 5 years guarantee period).	7500 nos. solar pump	70%	The implementing firm is also required to establish a customer care center, farmer training service center, and toll-free number	-
16	Rajasthan solar pumps program	Rajasthan Renewable Energy Corporation Limited	2014	State	Subsidize solar pumps to improve irrigation via reliable power	2014-15: 2,900 2015-16: 4,702 2016-17: 7,500 2017-18: 5,000 2018-19: NA	2014-15: 70% 2015-16: 60- 75% 2016-17: 60- 75% 2017-18: 50- 70% 2018-19: 55% 3HP and 60% 5HP (draft) (includes MNRE component)	a) Subsidy varies by access to electric pumps: b) no additional state subsidy for farmers already using electric pumps c) Highest subsidy for farmers who have applied for electric pumps and willing to surrender connection	
17	Solar Pump Scheme Tamil Nadu	Tamil Nadu Energy Development Agency	2017	State	Improve irrigation scenario in the agriculture sector (about 4.3 lakh farmers waiting for free power connections,	1,000 5-10HP pumps in phase 1	90% (MNRE 20%, State 40%, TANGEDCO 30%)	Farmers to pay 10% upfront and forfeit free power connection (or application for it)	-

#	Name of policy/ scheme	Nodal agency	Year of Inception	State/ Central	Objective	Target	Subsidy	Other Nuances	Achievements
18	UP Solar Pump Yojna	UPNEDA	2016	State	Subsidize solar pumps to a) reduce cost of irrigation b) 24x7 power to all and c) environment conservation	10,000 pumps in 2016-17; total target 50,000 pumps till 2022	70% on 2 HP; 65% on 3HP and 40% on 5HP	-	2016-17: 5,458 pumps

Table 3 IIEC's research

4. Solar Dryer:

A solar dryer is a device or structure that uses the sun's energy to dry food, crops, or other materials placed inside it, by circulating hot, dry air.

Basically there are three types of solar dryers–direct, indirect and combined.

- ✓ **Direct dryers:** The product is heated by direct solar radiation. The moisture in the grain is evaporated and removed by moving air. Since temperature control in drying using this type of dryer is difficult, a product can be dried too quickly giving "case-hardening" or at too high a temperature resulting in a poor-quality product.
- ✓ **Indirect dryers:** The product is dried by moving air heated outside the drying chamber.
- ✓ **Combined dryers:** The product is dried both by direct radiation and by heated moving air.

Photo credit: Shutterstock

Components of solar dryer:

Collector:

This is the part of the dryer that captures the sun's energy and converts it into heat. It can be a flat plate, a parabolic reflector, or other shapes and sizes.

Absorber:

This component absorbs the heat generated by the collector and transfers it to the air or the material being dried.

Air Circulation System:

This system circulates air through the dryer to remove moisture from the material being dried.

Drying Chamber:

This is the area where the material being dried is placed. It is usually enclosed to protect the material from insects, dust, and other contaminants.

Exhaust:

This component allows the moist air to exit the drying chamber and maintain proper air circulation.

Monitoring System:

Some solar dryers may have a monitoring system that measures temperature, humidity, and other parameters to ensure optimal drying conditions.

Controls:

These components regulate the air circulation, temperature, and other parameters to achieve the desired drying results.

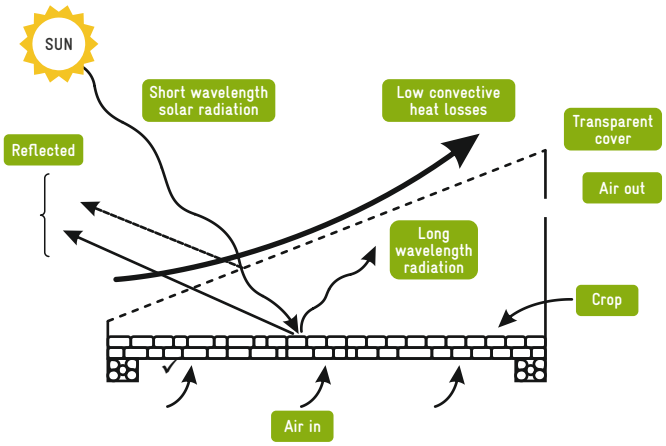
In terms of construction and design, solar dryers are of 4 types:

A. Tray Dryer: A tray dryer is a simple and low-cost solar dryer that uses trays to hold the materials to be dried. The trays are placed in a chamber, which is covered with a transparent cover to allow sunlight in. The heat from the sun dries the materials on the trays.

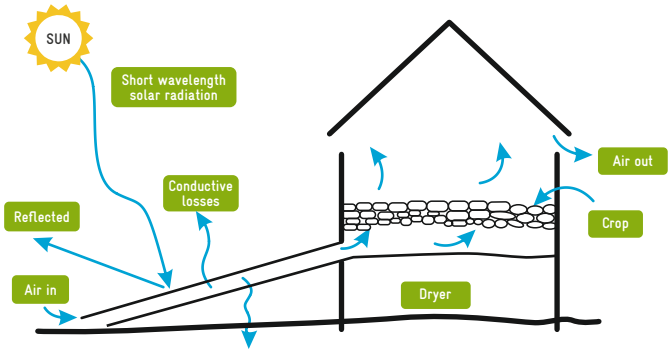
B. Cabinet Dryer: A cabinet dryer is a more advanced type of solar dryer that is enclosed in a cabinet. The cabinet has a transparent cover that allows sunlight in, as well as an exhaust system to remove moisture from the drying chamber.

- **Types of Cabinet dryer:**

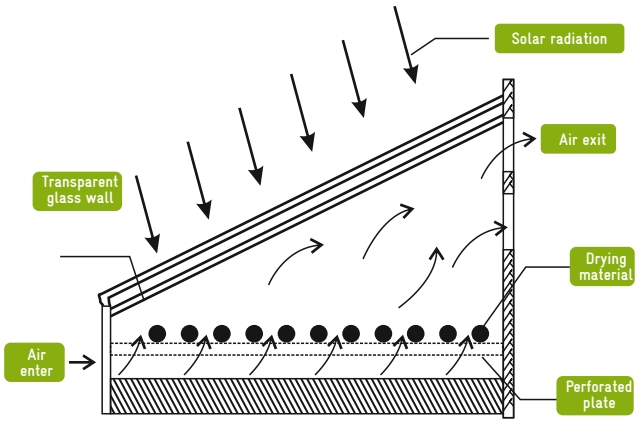
✓ **Direct Solar Cabinet Dryer:** This type of dryer uses the sun's direct radiation to heat the air inside the cabinet, which then dries the materials.



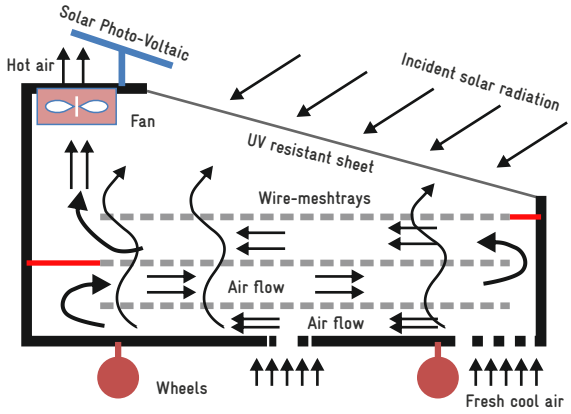
✓ **Indirect Solar Cabinet Dryer:** This type of dryer uses a heat exchanger to transfer heat from the sun to the drying chamber, which then dries the materials. This type of dryer is often used to dry delicate materials that may be damaged by direct sunlight.



✓ **Forced Convection Solar Cabinet Dryer:** This type of dryer uses a fan to circulate the air inside the cabinet, which increases the convective heat transfer and helps to dry the materials more quickly.



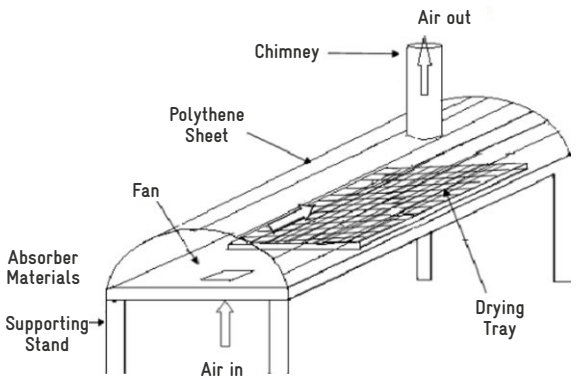
✓ **Passive Solar Cabinet Dryer:** This type of dryer does not have any mechanical components and relies on natural convection to circulate the air inside the cabinet. This type of dryer is often used for low heat drying applications.



✓ **Solar Convective Dryer:** This type of dryer is also known as a Solar Conductive Dryer and uses both conduction and convection to dry materials. It consists of a drying chamber with an insulated wall, a heating source, and a fan to circulate the air inside the chamber.

Overall, the type of Solar Cabinet Dryer used will depend on the specific drying application and the type of materials being dried. Each type of Solar Cabinet Dryer has its own unique advantages and disadvantages, and it is important to choose the right type of dryer for the specific drying application.

C. **Solar Tunnel Dryer:** A solar tunnel dryer is a type of solar dryer that uses a long, tunnel-like structure to dry materials. The tunnel is covered with a transparent cover, and the materials to be dried are placed on a conveyor that moves through the tunnel. The heat from the sun dries the materials as they pass through the tunnel.



D. **Hybrid Solar Dryer:** A hybrid solar dryer is a type of solar dryer that uses a combination of solar energy and other energy sources, such as electricity or biomass, to dry materials. This type of dryer is often used when sunlight is not available, or when the drying process requires additional heat.

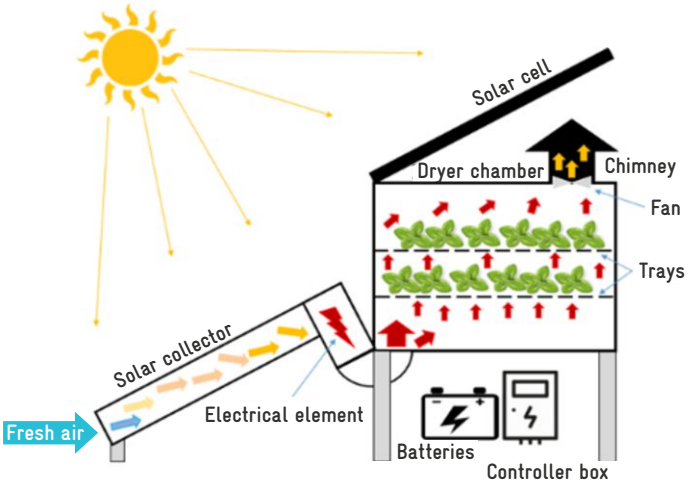
These are some of the most common types of solar dryers, but there are many other variations and designs available as well. The choice of a solar dryer depends on the type of materials to be dried, the desired capacity, and the specific needs and requirements of the user.

Working Principle:

The basic principles employed in a solar dryer are:

Converting light to heat:

Any black on the inside of a solar dryer will improve the effectiveness of turning light into heat.



Trapping heat:

Isolating the air inside the dryer from the air outside the dryer makes an important difference. Using a clear solid, like a plastic bag or a glass cover, will allow light to enter, but once the light is absorbed and converted to heat, a plastic bag or glass cover will trap the heat inside. This makes it possible to reach similar temperatures on cold and windy days as on hot days.

Moving the heat to the food:

Both the natural convection dryer and the forced convection dryer use the convection of the heated air to move the heat to the food.

Technical Specifications:

Sl.No.	Solar Cabinet dryer	
1	Usage	Agriculture / Fishery
2	Heating mode	All 3 modes of heating: Direct radiation, Conduction and Forced convection
3	Main body material	Food grade aluminium sheet metal. The drying chamber is made of double walled fabricating casing having PUF insulation.
4	Coating on main body	Food grade special purpose powder coating
5	Temperature range	Generally, 50 - 80 deg. C
6	Average loading capacity of tray	Average 2.5kg per tray but varies from 1 - 5kg depending on the product weight/volume
7	Tray material	Food grade aluminium/SS 304 (generally kept optional at extra cost)
8	Hardware	SS 304
9	Heating	Hot air generated from solar collectors for pre-heating of inlet air to be circulated into the casing. Back up electrical heaters are provided
10	Air circulation	12/24V DC fans ranging from 3W to 2H.P blowers based on the size / 230V for electrical heater back up only (varies with the size of the cabinet dryer)
11	Control system	Humidity controls for exhaust fans
12	Environmental protection	Dust proof, insect proof, waterproof, rodent proof and coating on surface for longer life

Sl. No.	Solar Conduction dryer	
1	Usage	Agriculture / Fishery
2	Capacity	20 kg to 200kg depending on the design, application and product to be dried.
3	Heat source	Solar energy is used as the primary heat source for the dryer, with the help of solar collectors or panels.
4	Temperature range	35-70 degrees Celsius
5	Drying time	The drying time for various crops can vary from a few hours to several days, depending on the moisture content, type of crop, and design of the dryer
6	Material	The construction material used for a solar conduction dryer can vary, but commonly used materials include galvanized iron sheets, aluminium sheets, and stainless steel.
7	Control system	Some solar conduction dryers may come equipped with a control system that allows the operator to adjust the temperature and drying time.
8	Power source	Solar conduction dryers are designed to operate on solar power, so they do not require an external power source. However, some models may come equipped with a backup generator or battery system for cloudy or rainy days.

Sl. No.	Solar Conduction dryer	
9	Efficiency	Solar conduction dryers are generally considered to be more energy-efficient and environmentally friendly compared to traditional dryers that use fossil fuels
10	Maintenance	The maintenance requirements of a solar conduction dryer can vary depending on the design and manufacturer, but regular cleaning and inspection of the system are recommended to ensure optimal performance and longevity.
11	Environmental protection	Dust proof, insect proof, waterproof, rodent proof and coating on surface for longer life

Sl. No.	Solar Tunnel dryer	
1	Usage	Agriculture / Fishery
2	Capacity (kg)	5 - 300
3	Heat source	Smaller ones use highly absorptive paint and the larger size ones air heating collector. The design is customised based on the need and applications.
4	Temperature range	35-70 degrees Celsius
5	Drying time	The drying time for various crops can vary from a few hours to several days, depending on the moisture content, type of crop, and design of the dryer
6	Material	Twin wall, double sided UV coating of 6mm polycarbonate sheet with powder coated aluminium and MS structural frame.
7	Control system	Comes equipped with a control system that allows the operator to adjust the temperature and drying time. For large sizes, microprocessor suported with humidity and temperature controller to control the exhaust fans and electric heaters.
8	Power source	Solar conduction dryers are designed to operate on solar power, so they do not require an external power source. However, some models may come equipped with a backup generator or battery system for cloudy or rainy days. This is available for sizes greater than 30kg.
9	Efficiency	Generally, in the range of 70 - 85%
10	Maintenance	Regular cleaning and inspection of the system are recommended to ensure optimal performance and longevity.
11	Environmental protection	Dust proof, insect proof, water proof, rodent proof and coating on surface for longer life

Techno Economic:

Parameter	Solar dryer
Drying capacity	100
Capex (₹)	1,20,000
Number of operational days per year	250
Cost of raw tomato (₹/kg)	4
Average drying time of tomato (days)	2
Tomato dried per year (kg)	12,500
Average selling price of dried tomato (₹/kg)	350
Dried tomato output (kg)	625
O&M cost per year (₹)	5,000
Annual revenue (₹)	1,63,750

The simple payback period of solar dryer of 100kg considering tomato drying = 9 months

Ownership models:

Note that solar dryer is an extremely customizable product, and its ownership models should be based on the type of end users involved, average quantity of material to be dried and price.

Policies and Subsidy:

S.No.	Government	Ministry/ Department	Program/ Scheme/ Project	Year	Status	Description	DRE Application(s)
1	Central	Ministry of Agriculture and Farmers' Welfare	Mission for Integrated Development of Horticulture	2014	Ongoing	For the holistic growth of the horticulture sector covering fruits, vegetables, root & tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo.	Solar Dryers Solar Water Pumps
2	State	Government of Tamil Nadu and Department of Horticulture and Plantation Crops	National Agriculture Development Programme – Tamil Nadu	2014	Ongoing	This scheme is implemented in all districts of the Tamil Nadu state based on the component with 60:40 sharing pattern between central and state governments	Solar Dryer Solar Cold Storage Solar Water Pumps

5. Solar Oil Expeller:

An oil expelling machine is a mechanical device that is used to extract oil from various types of seeds or nuts, such as sunflower seeds, soybeans, or peanuts.

Components of Solar Oil Expeller:

Photo Credit: Gorek Technologies

Figure 15: Solar oil expeller

Hopper:

The hopper is the inlet through which the seeds or nuts are fed into the expeller.

Screw Press:

The screw press is the main component of the expeller, consisting of a rotating screw shaft with helical blades that crush and grind the seeds or nuts, separating the oil from the solids.

Chamber:

The chamber holds the screw press and provides the necessary space for the seeds or nuts to be processed.

Kettle:

The kettle is the receptacle that collects the oil as it is expelled from the press.

Heater:

Some oil expellers include a heater to help soften the seeds or nuts, making it easier for them to be processed and increasing the yield of oil.

Motor:

An electric motor or other power source is used to rotate the screw press.

Gearbox:

A gearbox may be used to regulate the speed and torque of the screw press.

Types of Oil Expeller:

Screw Press Expeller: The screw press expeller is the most used type of oil expelling machine in India, due to its simplicity, reliability, and ease of use. It is suitable for processing a wide range of oilseeds, including sunflower seeds, soybeans, groundnuts, and cottonseeds, among others.

Hydraulic Press Expeller:

This is particularly used for processing oilseeds with a higher oil content. It is typically more expensive than the screw press expeller, but it can extract a higher yield of oil and produce higher-quality oil with lower levels of impurities.

Working Principle:

The oilseeds are first cleaned and then crushed using an oil expeller or screw press machine. During the crushing process, the oilseeds are heated to a specific temperature to make the oil extraction easier. The pressure applied helps to rupture the cell walls of the oilseeds, releasing the oil. The extracted oil is collected in a container while the remaining solids are expelled as a by-product.

Technical Specifications:

Sl.No.	Solar Oil Expeller	
	General Information	
1	Usage	Agriculture
2	Handling capacity (kg)	20 - 40
3	Diameter of squeezing bolt (mm)	50-100 (A larger diameter squeezing bolt can provide more surface area for the oilseed to be pressed against, which can increase the extraction rate)
4	Main motor power (H.P.)	2-3
5	Heater power (kW)	1-3 (availability of this in the machine varies from vendor to vendor)
6	Operating voltage (V)	220-240 (Single phase)
7	Hopper capacity (kg)	15-30
8	Weight of the machine (kg)	200-400
9	Pump suction capacity (litres/min)	200-300 (availability depends on the manufacturer and some prefer gravity based mechanism)
10	Pump motor power (in H.P.)	1
11	RPM	60 - 80
12	Body construction material	Mild steel, stainless steel, aluminium and cast iron (varies from vendor to vendor)
	Solar energy system	
13	PV array (kWp)	2 - 6.7
14	Solar module type	Mono/Poly
15	Battery capacity (in Ah, if required)	150Ah x 4 - 200Ah x 8
16	Battery backup (hours)	6
17	Electronics (if inverter etc. are required)	PCU required: 2.5 - 7.5kVA
	Additional Information	
18	Portability of system (Fixed or movable)	Portable
19	Installation type (e.g. plug and play)	Plug and play
20	Degree of protection (e.g. Ingress Protection (IP) code)	Not available
21	Protection against (e.g. open circuit, dry running, lightning etc.)	Some oil mill manufacturers may include basic safety features, such as overload protection and emergency stop switches, as standard features on their machines. However, other safety systems such as lightning arrestors or dry running protection may not be included as standard features or may only be available as optional add-ons.
22	Remote monitoring system (any provision for web-based monitoring)	Not available

Sl.No.	Solar Oil Expeller	
23	Warranty (for system as well as solar panel, battery etc.)	Maximum 1 year warranty on the product (motor and gear), standard warranty on the solar system components.
24	Annual maintenance (in years)	Extra as per the requirement
25	Asset insurance (number of years and reason such as theft or burglary)	No
26	Certification (if any)	Not available

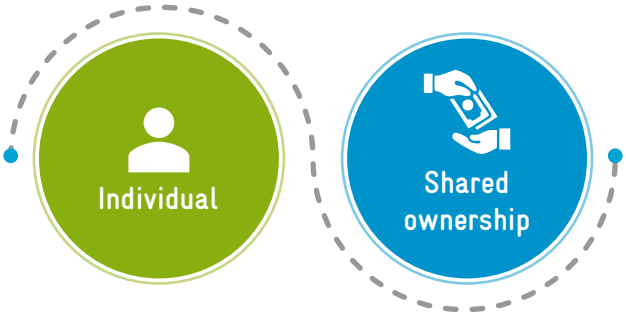
Techno Economics:

Parameters	Solar	Diesel	Grid
Power (kW)	2.3	10	2.3
Operational hours per day	5	5	5
Milling charges (₹/kg)	5	8	6
Processing capacity (kg/hour)	25	35	30
Oil milled per day (quintal)	1.25	1.75	1.5
Monthly Income (₹)	18,750	42,000	27,000
Operational months	6	6	6
Capex (₹)	7,00,000	baseline	-
Fuel charges (₹)	0	36,000	13,248

Payback Period as compared diesel run = 4 years 9 months
Payback period as compared to grid electricity = 5 years 7 months

GHG emissions mitigated as compared to diesel = 2.8 MT/year
GHG emissions mitigated as compared to grid = 1.6 MT/year

Ownership models:



Policy and Subsidies

No subsidy schemes were found for implementation of small scale solar powered oil processing unit.

6. Solar Spice Pulveriser Machine:

A spice pulverizer machine is a device used to grind and pulverize spices into fine powder or paste.

Components for Solar Powered Pulveriser Machine:

Hopper
Feeding Mechanism
Grinding Chamber
Sieving Mechanism
Collection Chamber
Motor

Figure 16: Solar spice pulveriser

Working Principle:

The functioning of a spice pulverizer machine involves loading the spices into the hopper, which feeds the spices into the grinding chamber. The grinding blades or hammers pulverize the spices into a fine powder, which is then sieved to remove any impurities. The fine powder is collected in a collection chamber, and the machine's motor powers the entire process. The efficiency and quality of the machine depend on the design and quality of these components.

Technical Specifications:

Sl.No.	Solar Spice Pulveriser	
	General Information	
1	Usage	Agriculture
2	Mill type	Generally, for flour making of wheat, rice, dal etc, stone based flour mills are mostly used. However, blade and hammer-based mills are also available.
3	Grinding wheel diameter	Ranges from 8 to 36 inch (It's important to note that smaller diameter grinding wheels will result in a coarser grind and a lower milling capacity, while larger diameter grinding wheels will provide a finer grind and a higher milling capacity)
4	Electric motor capacity (H.P.)	2 - 5
5	Energy consumption (units/ hour)	2 - 3.5
6	V-belt size	Typically, the V-belt size used in a flour mill ranges from A section (13mm wide) to C section (25mm wide). The most common V-belt sizes used in flour mills are A and B section belts.
7	Grinding capacity (kg/hour)	30 - 90
8	Grind settings	All settings are available almost in all models - coarse, medium and fine
9	Body material type	Mild steel for outer body and heavy body double aluminium chamber
10	Full set weight (kg)	120 - 250
	Solar energy system	
11	PV array (kWp)	5 - 10
12	Solar module type	Mono/Poly
13	Battery capacity (in Ah, if required)	150Ah x 8, 48V - 220Ah x 10, 120V
14	Battery backup (hours)	6
15	Electronics (if inverter etc. are required)	PCU: 5 - 12.5kVA
	Additional Information	
16	Warranty Conditions	A typical warranty for a flour mill ranges from 6 months to 2 year This does not include any shipping damage, unauthorised modifications and improper usage.
17	Safety Features	Starter panel, auto tripping switch, protective cover on V-belt.
18	Other features	Standard copper winding motor and silicon grade stamping. Some suppliers also provide trolley systems as well.

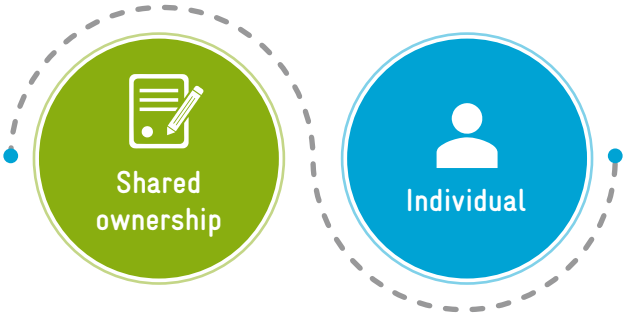
Techno Economics:

Parameters	Solar	Diesel	Grid
Power (kW)	2.3	10	2.3
Operational hours per day	5	5	5
Milling charges (₹/kg)	10	14	12
Processing capacity (kg/hour)	25	30	30
Spice milled per day (quintal)	1.25	1.5	1.5
Monthly Income (₹)	37,500	63,000	54,000
Operational months/year	6	6	6
Capex (₹)	8,00,000	baseline	-
Fuel charges (₹)	0	36,000	13,248

Simple payback period as compared to diesel run model = 3 years
Simple payback period as compared to grid electricity run model = 3 years 4 months

GHG emissions mitigated as compared to diesel run model = 2.25 MT/year
GHG savings mitigated as compared to grid run model = 0.58 MT/year

Ownership models:



Policies and Subsidy:

No financial support directly exists to set up solar powered spice pulveriser by central and state governments. The MUDRA scheme can be explored.

7. Solar Flour Mill:

A flour mill is a device that is used to grind grains into flour. It is a machine that grinds grain into a fine powder, which is then used to make various types of products.

Components for Solar Powered Flour Mill:

Hopper

Feeding Mechanism

Grinding Mechanism

Adjustment Mechanism.

Motor

Flour Collection.

Photo credit: Indiamart

Figure 17: Solar flour mill

Photo credit: Indiamart

Working Principle:

The functioning of a flour mill's grinding mechanism involves loading the grains into the hopper, which feeds the grains into the grinding mechanism. The grinding plates or stones grind the grains into fine flour, which is collected in a container or bag. The adjustment mechanism allows the user to adjust the coarseness of the flour produced, and the motor powers the entire process. The efficiency and quality of the flour mill depend on the design and quality of these components.

Difference between a spice pulveriser and flour making machine:

A spice pulverizing machine and a wheat flour making machine are both types of grinding machines, but they are designed for different purposes. Some of the main differences between these two types of machines are:

Material: The spice pulverizing machine is designed for grinding spices, such as pepper, cinnamon, cardamom, etc., into a fine powder. On the other hand, a wheat flour making machine is designed for grinding wheat kernels into flour.

Grinding mechanism: The grinding mechanism used in a spice pulverizing machine is typically a high-speed blade that cuts and crushes the spices into a fine powder. The grinding mechanism used in a wheat flour making machine is typically a set of rollers or stones that crush the wheat kernels into flour.

✓ **Blades:** Blades are commonly used in spice pulverizers as they can grind spices into a fine powder quickly and efficiently. They are typically made of metal and rotate at high speeds, cutting and crushing the spices into smaller particles. Blades are durable and require relatively low maintenance, but they are more expensive than stones.

✓ **Stones:** Stones are commonly used in flour making machines as they can grind grains into flour more effectively and efficiently than blades. They are typically made of natural stone or composite materials and rotate at slower speeds, crushing the grains into finer particles. Stones are generally less expensive than blades, but they are also less durable and require more maintenance.

Blades are typically better suited for grinding spices into a fine powder, while stones are better suited for grinding grains into flour. The choice between blades and stones will depend on the specific requirements of the user, including the desired output particle size, durability, maintenance, and cost.

Output particle size: The particle size of the final product produced by a spice pulverizing machine is typically smaller and finer than that produced by a wheat flour making machine.

In summary, a spice pulverizing machine and a wheat flour making machine are two different types of grinding machines designed for different materials and purposes. The choice between the two will depend on the specific requirements of the user.

Technical Specifications:

Sl.No.	Solar Flour Mill	
	General Information	
1	Usage	Agriculture
2	Mill type	Generally, for flour making of wheat, rice, dal etc, stone based flour mills are mostly used. However, blade and hammer-based mills are also available.
3	Grinding wheel diameter	Ranges from 8 to 36 inch (It's important to note that smaller diameter grinding wheels will result in a coarser grind and a lower milling capacity, while larger diameter grinding wheels will provide a finer grind and a higher milling capacity)
4	Electric motor capacity (H.P.)	2 - 5
5	Energy consumption (units/ hour)	2 - 3.5
6	V-belt size	Typically, the V-belt size used in a flour mill ranges from A section (13mm wide) to C section (25mm wide). The most common V-belt sizes used in flour mills are A and B section belts.
7	Grinding capacity (kg/hour)	30 - 90
8	Grind settings	All settings are available almost in all models - coarse, medium and fine
9	Body material type	Mild steel for outer body and heavy body double aluminium chamber
10	Full set weight (kg)	120 - 250
	Solar energy system	
11	PV array (kWp)	5 - 10
12	Solar module type	Mono/Poly
13	Battery capacity (Ah)	150Ah x 8, 48V - 220Ah x 10, 120V
14	Battery backup (hours)	6

Sl.No.	Solar Flour Mill	
15	Electronics (if inverter etc. are required)	PCU: 5 - 12.5kVA
	Additional Information	
16	Warranty Conditions	A typical warranty for a flour mill ranges from 6 months to 2 years This does not include any shipping damage, unauthorised modifications, and improper usage.
17	Safety Features	Starter panel, auto tripping switch, protective cover on V-belt.
18	Other features	Standard copper winding motor and silicon grade stamping. Some suppliers also provide trolley systems as well.

Techno Economics:

Parameters	Solar	Diesel	Grid
Power (kW)	3.8	3.8	3.8
Operational hours/day	4	4	4
Milling charges (₹/kg)	2.5	4	3
Processing capacity (kg/hour)	85	120	100
Flour milled per day (quintal)	3.4	4.8	4
Monthly Income (₹)	25,500	57,600	36,000
Operational months/year	6	6	6
Capex (₹)	10,000,00	baseline	-
Fuel charges (₹)	0	28,800	13,248

The simple payback period as compared to diesel and grid run model = 5 years 6 months and 6 years respectively.

GHG emissions mitigated as compared to diesel and grid run model = 2.3 and 2.2 MT/year

Ownership models:

Policies and Subsidy:

No policy or subsidy is available for installation of solar powered flour mill.

8. Solar Refrigerators cum Freezers

Refrigerators cum freezers are appliances that combine the features of a refrigerator and a freezer in a single unit. These appliances typically have a compartment for refrigerated items and a separate compartment for frozen items, each with its own temperature control settings. Refrigerators cum freezers are commonly used in households and commercial settings, providing the convenience of both refrigeration and freezing in a single appliance.

Components of Solar Refrigerators cum Freezers:

The major components of a solar freezer or refrigerator are:

•Cooling system:

Maintains the temperature inside the freezer at a set point. It typically consists of a compressor, evaporator, and condenser.

•Control unit:

Manages the operations of the cooling system, including the compressor, fan, and temperature control.

•Thermal energy storage system:

Stores thermal energy in the form of heat, which can be used to maintain the temperature inside the freezer during periods of low solar energy availability.

•Insulation:

Helps to maintain the temperature inside the freezer by reducing heat transfer to the surrounding environment.

•Cabinet:

Houses the components of the solar freezer and provides a temperature-controlled storage space for perishable goods.

Working Principle:

The compressor circulates a refrigerant, such as Freon, through a condenser and an evaporator.

As the refrigerant evaporates, it absorbs heat from the refrigerator compartment, cooling the interior. The compressor then compresses the refrigerant, which increases its temperature and causes it to release the absorbed heat to the outside environment. This process continues in a cycle, maintaining the desired temperature in the refrigerator and freezer compartments.

Photo credit: Freepik

Technical Specifications:

Sl.No.	Solar refrigerator/freezer			
	General Information			
1	Usage/Application	Agriculture / Dairy / Fishery		
2	Capacity (litres)	100-200	201-350	350-550
3	Power consumption (W)	50-140	120-180	150-180
4	Temperature Range	Freezer: Minimum -20 deg. C (settable) Refrigerator: 2-8 deg. C		
5	Door Type	Majority have single door with top open or sliding versions.		
6	Body Material	Corrosion resistant galvanized steel		
7	Product Dimensions	Minimum: (535 x 575 x 835) mm Maximum: (1640 x 620 x 835) mm		
8	Weight (kg)	40-45	50-60	65-75
9	Input voltage	12-24 V DC and 220-240V AC. AC-DC adapters are provided for DC models to be used using conventional grid power supply		
10	Insulation	High density Polyurethane foam (PUF)		
	Solar energy system			
11	PV array (Wp)	300	500	
12	Solar module type	Monocrystalline/Polycrystalline		
13	Battery capacity (in Ah, if required)	100Ah/100Ah x 2/150Ah	150Ah x 2	
14	Battery backup (hours)	6-12	12-18	
15	Electronics (if inverter/ converter, VFD, etc are required)	AC-DC cable is required to run DC models using grid.		
	Refrigeration unit			
16	Refrigerant type	R-134a		
17	Type of compressor	Rotary type brushless DC compressor are mostly used. This varies with manufacturers		
18	Input power type (A.C/D.C.)	A.C./D.C.		
19	Ambient temperature considered for design (°C)	20 - 40		
	Additional information			
20	Portability of system	Portable		
21	Installation type	Plug and play		
22	Degree of protection (e.g.Ingress Protection (IP) code)	DC freezers do come with IP 54 rating which means it is protected against dust and water splashes from any direction. It also comes with IP rating of 65, which means it is protected against dust and low-pressure water jets from any direction. This varies with the manufacturers.		

Sl.No.	Solar refrigerator/freezer	
23	Protection against (e.g. open circuit, dry running, lightning etc.)	Wrong polarity protection, LV disconnection (LVD), Power breakdown display, automatic reconnection after LVD.
24	Remote monitoring system (any provision for web-based monitoring)	Some solar freezers do have remote monitoring systems for performance analysis. These monitoring systems can provide real-time data on the performance of the freezer, including information on its temperature, energy consumption, and battery status.
25	Warranty (for system as well as solar panel, battery etc.)	1 year warranty on product and as per the OEM on the solar energy system components
26	Annual maintenance (in years)	Optional as per the requirement
27	Asset insurance (number of years and reason such as theft or burglary)	Not applicable

Techno Economics:

Parameters	Grid (180 litre model)	Solar (150 litre model)
Power rating (kW)	0.2	0.095
Operational hours per day	12	12
Increased earning per month (₹)	Assuming the fridge is not available currently	6,700[12]
Capex (₹)	35,000	1,20,000
Fuel cost	7,008	-

Payback period of solar powered refrigerator cum freezer = 1 year and 6 months
GHG emissions mitigated = 0.015 MT/year

Ownership models:

Policies and Subsidy:

No specific policy and subsidy support are available for installation of solar refrigerators cum freezers in India. However, livelihood collateral free loans for refrigeration under MUDRA can be obtained under Cold Storages (Food Products sector) loan section. This will not cover the financing for solar energy system components.

[12] https://selcofoundation.org/wp-content/uploads/2021/11/SF_Energizing-Livelihoods-through-Decentralized-Solar-Refrigerators.pdf

9. Solar Fruit Juicing and Pulping machine

A fruit juicing and pulping machine is a piece of equipment used to extract juice and pulp from fruits such as oranges, apples, and pineapples. The machine typically consists of a feed hopper, a rotating blade or grater, a juice extractor, and a pulp separator. The extracted juice and pulp can be used for a variety of applications, including making fresh juices, smoothies, and jams.

Components of Solar Fruit and Pulping machine:

- **Hopper:** To hold the fruit to be processed.
- **Pulping Mechanism:** To separate the pulp from the skin and seeds of the fruit, typically consisting of rollers, blades, or other elements.
- **Collection Container:** To hold the extracted pulp.
- **Control Unit:** To manage and regulate the power supply, as well as control the operation of the machine.
- **Chute:** To direct the waste (skin and seeds) away from the machine.

Working Principle:

The process begins with feeding the fruits into the machine's feed hopper, where they are cut or grated by a rotating blade or grater. The small fruit pieces are then pulped by a rotating sieve, which separates the juice and pulp from the skin, seeds, and other solid materials. The juice and pulp are then separated by a pulp separator, which removes any remaining solids and fiber. The juice and pulp are collected in separate containers for further processing or consumption.

Technical Specifications:

Sl.No.	Solar Fruit Processing Machine	
	General Information	
1	Usage	Agriculture
2	Number of stages of processing	1 - 2 based on the manufacturer and design (This includes pulper, juicer and other types)
3	Weight (kg)	50 - 350
4	Frame material	Mild steel
5	Automation grade	Automatic/ Semi-automatic
6	Crusher brush material	Wooden nylon or teflon food grade
7	Electricity phase	Single
8	Availability of heat energy sources for heating	Some of the manufacturers provide heating element.
9	Motor capacity (H.P.)	0.12 - 3
10	Processing capacity (kg/hour)	50 - 600
	Solar energy system	
11	PV array (kWp)	0.2 - 6.70
12	Solar module type	Mono/Polycrytalline
13	Battery capacity (Ah)	4 x 100Ah, 24V - 200Ah x 8, 96V PCU: 1 - 7.5kVA
14	Autonomy (hours)	6

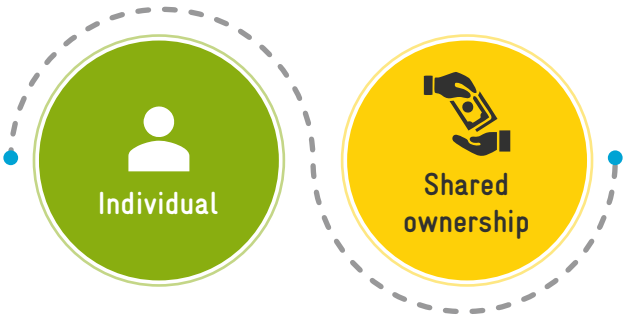
Sl.No.	Solar Fruit Processing Machine	
15	Electronics (if inverter, VFD, etc are required)	Direct solar run models are not available; hence inverter is required. Run with variable speed control AC drive.
16	Alternative applicable power source	Grid models only available, inverter – battery set will be used for operation on solar energy
	Additional Details	
17	Warranty	1 year warranty is provided on the product and standard warranty on solar energy components
18	Maintenance	Annual AMC provision available as per the location and frequency
19	Other provisions	Heavy duty solid taper and grooved screwed with juice collection arrangement, spring loaded waste discharge system. Comes with complete feed hopper, waste chute, juice discharge tray etc.

Techno Economics:

Parameters	Solar	Grid
Power rating (kW)	0.75	0.75
Operational hours per day	4	4
Price of pulp/juice (₹ /litre)	80	80
Processing capacity (kg/hour)	80	100
Operational number of days per year (considering the aggregated demand over the year and other factors)	150	150
Yearly income (₹)	19,20,000	24,00,000
Average cost of raw materials (₹/kg)	40	40
Capex (₹)	3,00,000	-
Fuel charges (₹)	-	4,800

Payback period of solar powered fruit processing machine as compared to grid electricity run = 2.5 months

Ownership Models:



10. Solar Millet processing unit

Millet hulling and pulverizing machines are specialized equipment used in the processing of millet grains. These machines are designed to remove the outer layer of the millet grain, known as the hull, and then pulverize the millet kernel into flour or other products.

Types of Millet hulling mechanisms:

Abrasive hullers: These machines use abrasive surfaces to rub against the millet grains and remove the hulls. They typically consist of a rotating drum or cylinder with rough surfaces, such as sandpaper or emery paper.

Rubber roll hullers: These machines use rubber rollers to remove the hulls from the millet grains. The rubber rollers rotate at different speeds and squeeze the millet grains between them, causing the hulls to crack and separate from the kernels.

Disc hullers: These machines use a series of rotating discs to remove the hulls from the millet grains. The discs have ridges or bumps that rub against the millet grains and remove the hulls.

Impact hullers: These machines use impact force to remove the hulls from the millet grains. They typically consist of a series of rotating hammers or blades that strike the millet grains and break off the hulls.

Types of Millet pulverising mechanisms:

Hammer mills: These machines use a series of rotating hammers or blades to pulverize the millet grains into flour or other products. They are often used in large-scale millet processing operations and are available in motorized models.

Stone mills: These machines use rotating stones to crush the millet grains into flour or other products. They are often used in small to medium-scale millet processing operations and are available in both manual and motorized models.

Components of Millet processing unit:

Hopper: This is a funnel-shaped container that holds the millet grains and feeds them into the machine.

Huller: This is the component that removes the outer layer (hull) of the millet grain. It can be an abrasive surface, rubber rollers, rotating discs or impact hammers depending on the type of hulling machine.

Photo credit: Indiamart

Figure 18: Millet hulling machine

Screen or classifier: This component separates the hulls from the millet kernels after they have been removed by the huller.

Pulverizer: This is the component that grinds or pulverizes the millet kernels into flour or other products. It can be a hammer mill or stone mill depending on the type of pulverizing machine.

Photo Credit: Industry Buying

Figure 19: Solar millet grinding machine

Motor: This component provides power to the machine, allowing it to operate.

Frame: This is the structure that holds all the components of the machine together.

Control panel: This component controls the operation of the machine, including speed and feeding rate.

Collection container: This is a container that collects the final product (such as millet flour) as it exits the machine.

Working Principle:

The millet grains are fed into the machine through a hopper, and the processed material (such as hulls or flour) is collected in a container as it exits the machine.

The working principle of a millet huller is to remove the outer layer (hull) of the millet grain, leaving behind the inner kernel. This is typically accomplished by using an abrasive surface, rubber rollers, rotating discs, or impact hammers to rub, squeeze, or strike the millet grains, causing the hulls to separate.

The working principle of a millet pulveriser is to grind or pulverize the millet kernels into flour or other products. This is typically accomplished by using a hammer mill or stone mill to crush the kernels into smaller pieces, which are then further ground into the desired consistency.

Technical Specifications:

Sl. No.	Solar Millet processing machine (Huller, Grader and Pulveriser)	
	General Information	
1	Usage/Application	Agriculture
2	Processing Capacity (kg/ hour)	Varies with the type of machine Huller: 100 - 300 Grading: 100 - 250 Pulverising: 25 - 80
3	Power rating (H.P)	1 - 3
4	Motor type	Single phase induction motor
5	Construction material	Mild steel
6	Hopper capacity (kg)	15 - 20
7	Weight of the machine (kg)	100 - 200
	Solar energy system	
8	PV array (kWp)	2 - 6.70
9	Solar module type	Mono/Poly
10	Battery capacity (Ah)	150Ah x 4, 48V - 200Ah x 8, 96V

Sl. No.	Solar Millet processing machine (Huller, Grader and Pulveriser)	
11	Battery backup (hours)	6
12	Electronics (if inverter etc. are required)	PCU: 2.5 - 7.5kVA
	Additional Information	
13	Warranty Conditions	Generally, 1 year from date of installation. On site AMC charges after 1 year @₹ 8,000 - 12,000 + GST For battery, manufacturer's off-site warranty of 5 years For inverter, manufacturer's off-site warranty of 2 years
14	Safety Features	Starter panel, auto tripping switch, protective cover on V-belt.

Techno Economics:

Parameters	Solar	Diesel	Grid
Power (kW)	2.3	10	2.3
Operational hours per day	4	4	4
De-husking charges (₹/Kg)	4	7	5
Processing capacity (kg/hour)	100	130	120
Millet hulling per day (quintal)	4	5.2	4.8
Monthly Income (₹)	48,000	1,09,200	72,000
Operational months/year	6	6	6
Capex (₹)	8,00,000	baseline	-
Fuel charges (₹)	0	28,800	13,248

Simple payback period as compared to diesel run model = 2 years 6 months
Simple payback period as compared to grid electricity run model = 2 years 8 months

GHG emissions mitigated as compared to diesel run model = 2.3 MT/year
GHG emissions mitigated as compared to grid electricity run model = 0.58 MT/year

Ownership models:

Policies and Subsidy:

Odisha Millet Mission (OMM) is a flagship programme of the Government of Odisha launched in 2017 to improve nutrition at the household level through the revival of millets in farms and on plates of tribal communities in Odisha. Budgetary allocations have been adequately made for setting up decentralised solar processing units in the identified clusters. However, it is not clear as to whether individual farmers can submit applications to avail the financial assistance or not.

[13] https://milletsodisha.com/

11. Solar Dal processing unit

A dal hulling and polishing machine is a type of agricultural machinery that is used to remove the outer skin (husk) of dal, which is a type of legume, and polish the surface of the dal to improve its appearance and texture.

Types of Dal processing mechanisms:

Vertical dal mill: This type of machine has a vertical design and is used to process different types of dal such as moong dal, chana dal, and urad dal. It has multiple chambers that perform different functions, such as cleaning, grading, and hulling.

Horizontal dal mill: This type of machine has a horizontal design and is used to process different types of dal. It can perform various functions such as cleaning, grading, hulling, and splitting.

Photo Credit: Trade India

Figure 20: Solar dal processing machine

Components of Dal processing unit:

Hopper: A container that holds the raw dal and feeds it into the machine for processing.

Cleaning sieve: A component that separates the unwanted impurities from the raw dal, such as stones, debris, and broken grains.

Huller chamber: A chamber that contains rollers, blades, or abrasive surfaces that remove the outer skin of the dal.

Polishing chamber: A chamber that contains rotating abrasive pads or brushes that polish the surface of the dal.

Blower or fan: A component that removes the hulls, chaff, and other impurities from the dal.

Grading sieve: A component that separates the processed dal into different sizes based on its shape and texture.

Control panel: A panel that includes switches, buttons, and other controls that allow the operator to adjust and monitor the machine's performance.

Collection container: A container that collects the processed dal after it has been hulled and polished.

Working Principle:

The raw dal is first loaded into the machine through a hopper, where it passes through a cleaning sieve to remove any unwanted impurities. The dal is then lifted by an elevator to the hulling chamber, which contains rollers, blades, or abrasive surfaces that remove the outer skin of the dal. The hulls and other impurities are separated from the dal by a blower or fan and are collected separately.

After hulling, the dal enters the polishing chamber, which contains rotating abrasive pads or brushes that polish the surface of the dal to improve its appearance and texture. The polished dal then passes through a grading sieve, which separates it into different sizes based on its shape and texture.

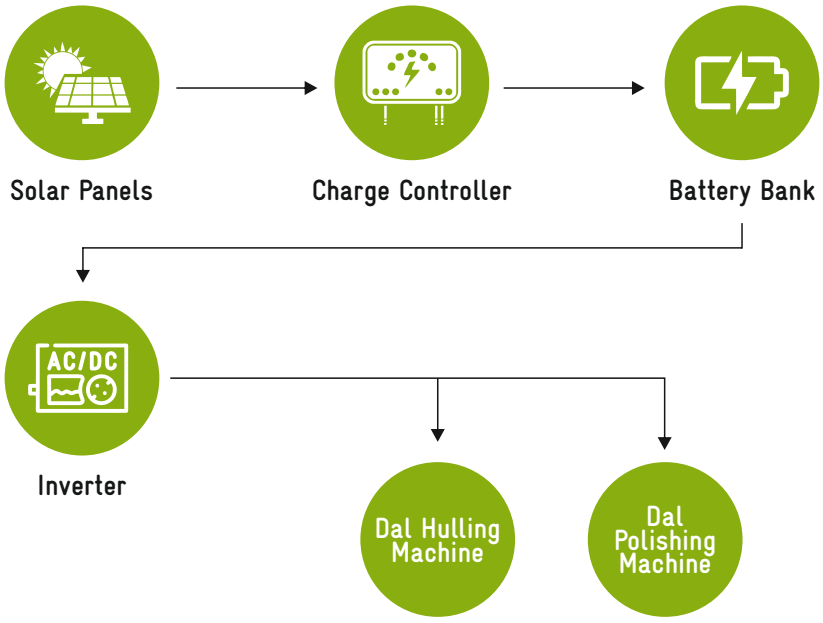


Figure 21: Schematic of solar dal processing unit

Technical Specifications:

Sl. No.	Solar Dal Processing Machine (Huller and Polisher)	
	General Information	
1	Usage/Application	Agriculture
2	Processing Capacity (kg/hour)	80 - 180
3	Power rating (H.P)	1 - 5
4	Motor type	Single phase induction motor
5	Construction material	Varies with manufacturer, generally mild steel, stainless steel and cast iron is used.
6	Hopper capacity (kg)	15 - 25
7	Recovery rate	70 - 85%
8	Driven type	Pully and V-Belt
9	Body construction material	Mild and stainless steel
10	Weight of the machine (kg)	150 - 240
	Solar energy system	
11	PV array (kWp)	2 - 10
12	Solar module type	Polycrystalline/Monocrystalline
13	Battery capacity (in Ah, if required)	150Ah x 4, 48V. 2.5kVA - 220Ah x 10, 120V, 12.5kVA
14	Battery backup (hours)	6
15	Electronics (if inverter etc. are required)	Inverter is required since all reviewed products are induction motor based
	Additional details	
16	Warranty Conditions	One year manufacturing defect and on the rest of the parts such as gear box, electric motor, starters etc. as per the conditions of the OEM.
17	Safety Features	Overvoltage protection available

Techno Economics:

Parameters	Solar		Diesel	Grid
Power (kW)	2.3		2.3	2.3
Operational hours per day	4	4	4	4
Milling charges (₹/Kg)	2	2	3.5	3
Processing capacity (kg/hour)	150	200	200	200
Dal milled per day (quintal)	6	8	8	8
Monthly Income (₹)	36,000	48,000	84,000	72,000
Operational months/year	6	6	6	6
Capex (₹)	9,28,000	11,00,000	baseline	-
Fuel charges (₹)	0	0	28,800	13,248

Simple payback period as compared to diesel run model = 3 years 10 months and 3 years 6 months respectively

Simple payback period as compared to grid electricity run model = 4 years and 3 years 8 months

GHG emissions mitigated as compared to diesel run model = 2.25 MT/year

GHG emissions mitigated as compared to grid run model = 0.58 MT/year

Ownership models:

Policies and Subsidy:

No policy and scheme exist in India to support adoption of solar dal mills at small and marginal farmers' level.

12. Solar Cotton Weaving Machine

A cotton weaving machine is a device used in textile manufacturing to weave cotton fibres into fabric. These machines use a complex process to interlace the cotton threads together to create a strong and durable fabric.

Components of Solar Cotton Weaving Machine:

✓ **Weaving loom:** This is the main component of the machine that performs the actual weaving process.

✓ **Control panel:** This allows the user to control the various functions of the machine, such as speed, tension, and pattern selection.

✓ **Drive mechanism:** This converts the electrical energy into mechanical energy that drives the weaving loom.

✓ **Electromagnetic clutch:** This controls the tension of the thread during the weaving process.

✓ **Sensors and actuators:** These monitor and control the various parameters of the machine, such as temperature, humidity, and thread tension. This is an additional feature and might not be available with all the vendors.

Working Principle:

A cotton weaving machine works by interlacing two sets of threads (the warp and weft threads) to create a fabric. The process of weaving involves the following steps:

Preparation:

- The warp threads are prepared by winding them onto a beam and tensioning them on the loom. The weft threads are wound onto a shuttle, which holds the thread for insertion into the fabric.

Weaving:

- The loom moves the shuttle back and forth across the warp threads, inserting the weft thread into the fabric. The loom raises and lowers different sets of warp threads to create an opening for the shuttle to pass through, and then closes the opening to lock the weft thread in place. This process is repeated to create the fabric.

Photo Credit: 123RF

Tension control:

- The tension of the warp and weft threads is controlled by various mechanisms, such as the take-up roller, the cloth roller, and the heddles. These mechanisms adjust the tension of the threads to ensure the fabric is tight and even.

Pattern creation:

- Different patterns can be created by changing the arrangement of the warp threads, or by using different techniques for inserting the weft thread into the fabric.

Finishing:

- The finished fabric is removed from the loom and subjected to various finishing processes, such as washing, drying, and pressing, to remove any dirt or debris and to set the fabric in its final form.

Technical Specifications:

Sl.No.	Solar Power Cotton Weaving loom	
	General Information	
1	Usage/Application	Agriculture (Cotton weaving)
2	Loom dimensions (feet)	Length = 4 - 5 Breadth = 3 – 5 Height = 4 - 6
3	Loom speed (picks/minute)	40 – 150
4	Drive mechanism	Motor drive
5	Gear wheels and picking mechanism	
6	Fixed or Portable	Fixed / Portable / Semiportable
7	Installation type	Plug & play and easy to operate
8	Solar module type	Monocrystalline / Polycrystalline
9	Remote monitoring system	Not available
	Additional Details	
10	Warranty	1 year on manufacturing defect

Techno Economics:

Parameters	Conventional/Manual	Solar
Loom rating (kW)	-	1
Operational hours per day	6	6
Daily Production (m)	8	30
Earning per metre of yarn	120	100
Daily Earning per Weaver per day	960	3,000
Capex (₹)	75,000	2,40,000
Number of working days per year	150	200
Total yarn production per year (m)	1,200	6,000
Total yearly earning (₹)	1,44,000	6,00,000
Raw material cost (₹)	72,000	3,60,000
Annual revenue (₹)	72,000	2,40,000

Payback period of solar powered weaving loom as compared to manual model = 1 year

Ownership models:

Policies and Subsidy:

There is no existing subsidy or any sort of financial assistance available for adoption and deployment of solar cotton weaving machines in India. However, there were few earlier such as Pradhan Mantri Credit Scheme for Power loom Weavers (2017) and National Handloom Development Programme (2017).

Photo Credit: Istock

APPLICATIONS IN Dairy Sector

13. Solar Milking machine:

A machine used to make milking of cows and buffaloes a quicker, hassle-free, and cost-effective process using solar energy.

The milking procedure has been made easier and takes less time thanks to a solar-powered milking equipment. A system like this, with its two milk-drawing points, pulls milk in 8–12 minutes and can be operated by one person, as opposed to the customary 30-minute time it takes to milk one cow, aside from the additional labour needed. As many as 20 to 30 cows' milk can be collected in an hour with this system.

Photo Credit: Trade India

Figure 22: Solar Milking Machine

Component of the Solar Milking machine:

- ✓ **Milking unit:** Attached to the cow's teats and designed to mimic the process of manual milking. It typically consists of a vacuum pump and pulsation system.
- ✓ **Milk collection tubes:** Carries the milk from the milking unit to a storage tank.
- ✓ **Vacuum pump:** Creates the vacuum pressure required to stimulate the release of milk from the cow's udders.
- ✓ **Control unit:** Manages the operations of the milking machine, including the vacuum pressure, pulsation, and timing of the milking process.
- ✓ **Power inverter:** Converts the direct current (DC) energy generated by the solar panels into alternating current (AC) energy, which is required to power the milking machine. This is only applicable when the motor used in the milking machine is induction motor.

Working Principle:

A solar-powered milking machine operates using energy generated by solar panels. The solar panels convert sunlight into electricity, which is then used to power the milking machine. The machine functions similarly to a traditional milking machine. It typically consists of a vacuum-powered unit that is attached to the teats of the cow, with tubes that carry the milk to a storage tank. The machine is designed to mimic the process of manual milking and can be used to milk one or several cows at a time. The vacuum pressure applied by the milking machine stimulates the release of milk from the cow's udders, and the machine's pulsation system helps to maintain the flow of milk into the tubes.

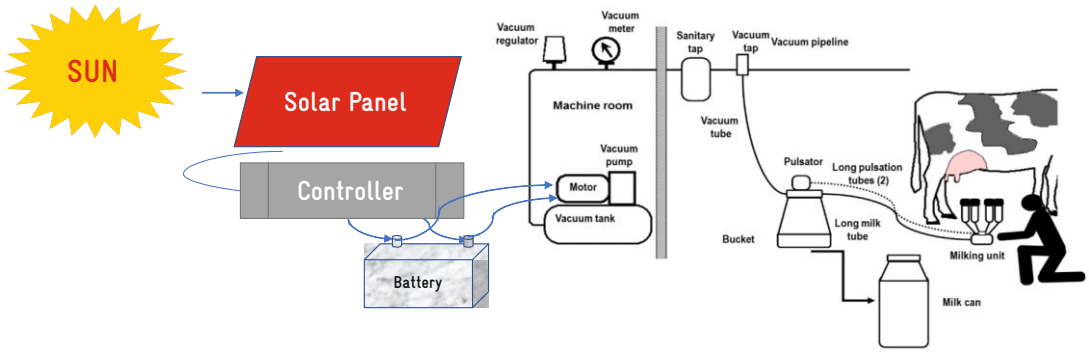


Figure 23: Components for Solar Milking Machine and process flow

Technical Specifications:

Sl.No	Solar milking machine				
	General Information				
1	Usage/Application	Dairy			
2	Milk extraction capable to (cow/ buffalo/goat etc.)	Cow and buffalo			
3	Number of buckets	One	Two	One	Two
4	Automation grade (fully automatic/ semi-automatic)	Semi-Automatic	Semi-Automatic	Semi-Automatic	Semi-Automatic
5	Tank construction material	SS-304			
6	Processing capacity (Time taken /animal	5 to 8min per cow/ 12 to 20 min per buffalo			
7	Pulsation pattern (ratio value)	50-50	50-50	50-50	50-50
8	Tank capacity (litres)	20L x 1 tank	20L x 2 tanks	20L x 1 tank	20L x 2 tanks
9	Number of milking cluster *(a milking cluster unit possesses a functional claw and four fully assembled quality teat cups and liners)*	One	Two	One	Two
10	Vacuum pump capacity (litres/ min)	65	130	65	130
11	Motor type	PMDC	PMDC	1-phase	1-phase
12	Motor size (H.P.)	0.17	0.25	0.17	0.25
13	Operating voltage (V)	12	24	220	220
14	Power rating (kW)	0.15	0.18	0.12	0.18
	Solar energy system				
15	PV array (Wp)	100	320	150	320
16	Solar module type	Polycrystalline			
17	Battery capacity (in Ah)	80	80x2	100	80x2

Sl.No	Solar milking machine				
18	Battery backup (hours)	2	3	2	3
19	Electronics (if inverter etc. are required)	30A charge controller	30A charge controller	1kVA solar PCU	2kVA solar PCU
	Additional information				
20	Portability of system (Fixed or movable)	Fixed			
21	Installation type (e.g., plug and play)	Minimum wiring & installation required, plug and play			
22	Degree of protection (e.g., Ingress Protection (IP) code)	Weatherproof solar modules. Battery, CR should not be exposed to sunlight and rain			
23	Protection against (e.g., open circuit, dry running, lightning etc.)	MCB to protect against short circuit. Dry running protection not required			
24	Remote monitoring system (any provision for web-based monitoring)	Not Available			
25	Warranty (for system as well as solar panel, battery etc.)	Milking machine - 1 year Solar module - 5years Battery - 5years Charge controller -1 year	Milking machine - 1 year Solar module - 5 years Battery - 5 years Solar PCU - 2 years		
26	Annual maintenance (in years)	2 free services in the initial year. After that AMC available as required.			
27	Asset insurance (number of years and reason such as theft or burglary)	Not applicable			
28	Certification (if any)	Solar module-ISO 14001:2015, BIS Battery-ISO 9001:2008			

Techno Economics:

Parameters	Solar	Traditional/Manual
Power rating (kW)	0.19	-
Model being used	2 animals at a time	-
Capex (₹)	125000	-
Number of animals milked at a time	6	1
Average time required for 1 animal	8	15
Total time required for 1 time milking of 6 animals (mins)	48	90
Approximate milk production (litres)	90	80
Approximate increase in milk production @10%	9	-
Time saved (hours)	0.7	-
Number of operational days per year	220	220
Rate of milk (₹)	40	40
Increased savings due to labour time and increased milk sale (₹)	1,10,000	-
Maintenance cost (₹ /year)	5000	-
Increased annual revenue (₹)	1,05,000	-

Payback period solar milking machine for 2 animal system at a time = 1 year 2 months

Ownership models:

Policies and Subsidy:

No policy and scheme exist in India to support adoption of solar milking machine at small and marginal farmers' level.

14. Solar Bulk Milk Chiller:

Solar Bulk milk chillers operated on a solar PV system that stores energy in thermal or electrical energy storage devices for use when there is no sunlight.

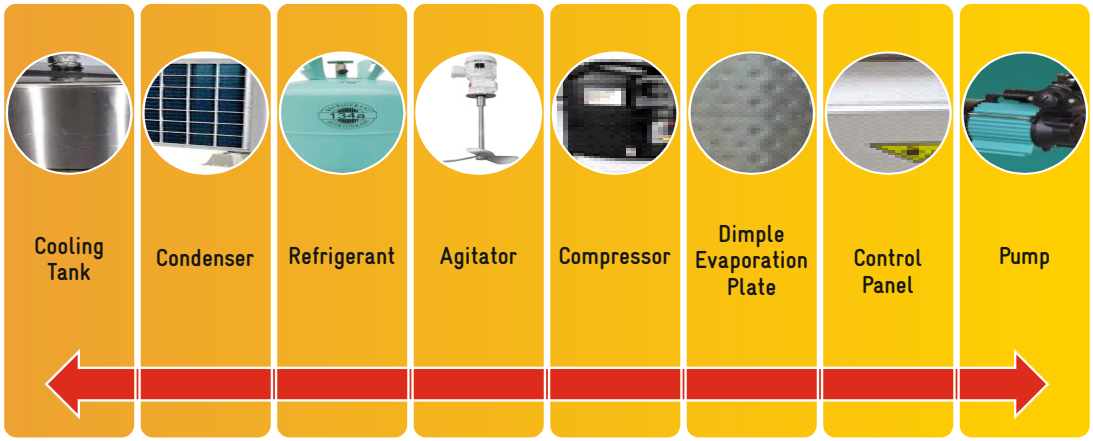
A solar bulk milk chiller is a device used to cool milk to a low temperature and maintain it until it can be transported for processing.

Photo Credit: Tooltech

Figure 23: Solar Bulk Milk Chiller

Components of Solar Bulk Milk Chiller:

Major Components of Solar Bulk Milk Chillers include the following:



- **Cooling tank:** This is a container where the milk is stored and cooled to a low temperature.
- **Condenser:** This removes heat from the refrigerant, causing it to condense into a liquid.
- **Refrigerant:** A refrigerant is a substance that is used in a refrigeration system to transfer heat from one location to another. It flows through the system and undergoes a phase change from liquid to gas and back again, absorbing and releasing heat as it does so. The refrigerant absorbs heat from the environment being cooled and releases it at a different location where it can be dissipated
- **Agitator:** An agitator is a component in a bulk milk chiller that helps to mix and circulate the milk in the tank. This is important for several reasons:
- **Cooling efficiency:** An agitator helps to ensure that the milk is evenly distributed throughout the tank, allowing for more efficient cooling.
- **Preventing cream separation:** An agitator helps to prevent the cream from separating from the rest of the milk, which can affect the quality of the final product.
- **Maintaining milk quality:** By circulating the milk, an agitator helps to prevent bacterial growth and ensure that the milk remains at a consistent temperature throughout the tank.
- **Compressor:** This compresses the refrigerant, increasing its pressure and temperature.
- **Dimple evaporation plate:** The dimple evaporation plate is a type of heat exchanger that is used to cool the milk by transferring heat from the milk to a refrigerant fluid.
- **Control panel:** It allows the operator to set and monitor the temperature of the milk. The control panel typically includes a digital display screen and a series of buttons or knobs that allow the operator to adjust the temperature settings and control the operation of the chiller.
- **Water pump:** Water Pump circulates the ice-cold water to BMC and heated water back into PCM.

Types of Bulk milk chiller:

1. Direct expansion mechanism:

Working Principle:

Direct expansion (DX) method is a process by which the refrigerant fluid is circulated directly through a set of evaporator coils that are submerged in the milk. As the refrigerant flows through the coils, it absorbs heat from the milk, causing it to cool down to the desired temperature.

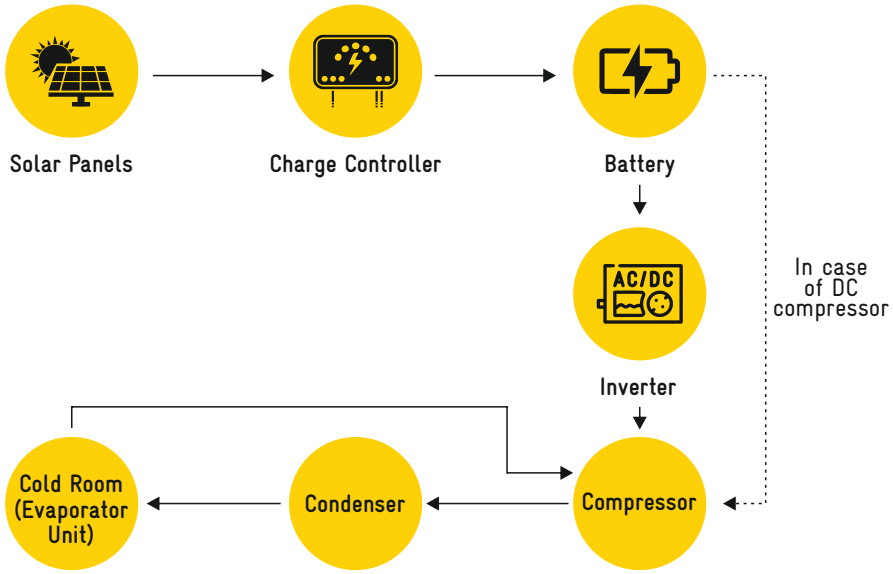


Figure 24: Working schematic of direct expansion cooling mechanism

The direct expansion method is a commonly used method in BMCs because it is efficient and effective in rapidly cooling large volumes of milk.

2. Thermal Energy storage mechanism:

The thermal energy storage (TES) method in a bulk milk chiller (BMC) involves storing thermal energy in water or ice to be used for cooling milk during peak demand periods. During off-peak periods, the BMC system chills the water or freezes the ice in the TES tank, storing the thermal energy until it is needed to cool the milk. The TES system releases the stored thermal energy into the milk through a heat exchanger, cooling the milk to the desired temperature. This method reduces the energy consumption of the BMC system during peak demand periods and ensures milk is always available at the desired temperature.

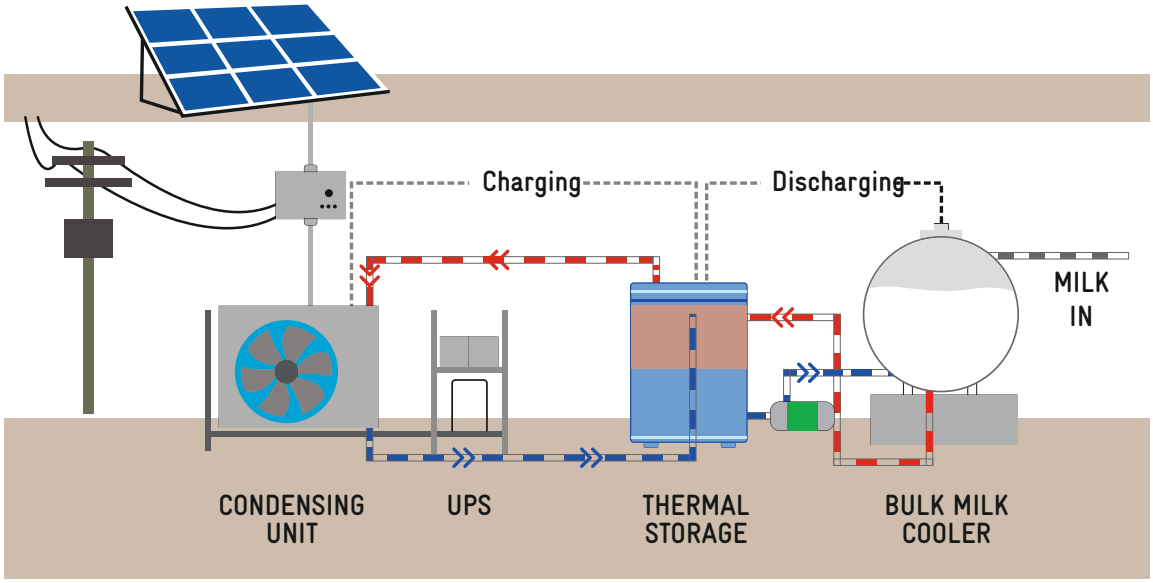


Photo Credit: Krishna Defence and Allied Industries

Figure 25: Process Flow: Solar Bulk Milk Chiller

Technical Specifications:

Sl.No.	Solar bulk milk chiller (Direct expansion based)				
	General Information				
1	Usage/ Application	Dairy			
2	Capacity (litres)	100-300	500	1000	2000
3	Input power type	Single phase		Single / Three phase	
4	Maximum cooling	First milking: From 35 deg.C to 4 deg.C in 3-5 hours Second milking: From 10 deg. C to 4 deg. C in 1.5-3 hours			
5	Shape and Orientation	Open type horizontal/vertical/round/semi-cylindrical and cylindrical upto 2000 litres. Closed type cylindrical tank for 2000, 3000, 5000 litres. (Customizable based on the order)			
6	Body Material	Corrosion resistant stainless steel			
7	Product Dimensions	Minimum: 750 x 750 x 1250mm Maximum: 2013 x 1123 x 1202mm	Minimum: 1358 x 822 x 1718mm Maximum: 1416 x 1050 x 1450mm	Minimum: 1712 x 1465 x 1350mm Maximum: 2017 x 1256 x 1430mm	Minimum: 2560 x 1506 x 1590mm Maximum: 3000 x 1300 x 1400mm
8	Number of agitator and RPM	1 / 25-30 RPM	1 / 25-30 RPM	1 / 25-30 RPM	2 / 25-30 RPM
9	Input voltage	220V/50Hz for single phase 440/50Hz for three phase			
10	Insulation	High density Polyurethane foam (PUF) - 50mm thickness in walls and 90mm above evaporator			
11	Water pump (if required)	Depends on the requirement. Generally offered for larger capacities.			
12	Milk volume measurement	SS calibrated dipstick with value chart			
	Solar energy system				
13	PV array (kWp)	3-6		10	15
14	Solar module type	Monocrystalline/Polycrystalline			
15	Battery capacity (in Ah, if required)	200Ah x 4, 12V		200Ah x 6, 12V	200Ah x 12, 12V
16	Battery back-up (hours)	2- 4		3 - 5	
17	Electronics (if inverter/ converter, VFD, etc are required)	Inverter is required to run on solar power.			
	Refrigeration unit				
18	Refrigerant type	Freon - R22 / R- 404a			
19	Type of compressor	Hermetically sealed Scroll / Reciprocating type			

Sl.No.	Solar bulk milk chiller (Direct expansion based)	
20	Ambient temperature considered for design (°C)	38-45°C
	Additional information	
21	Portability of system	Portable/Semi-portable
22	Installation type (e.g. plug and play)	Plug and Play
23	Degree of protection (e.g. Ingress Protection (IP) code)	IP65
24	Protection against (e.g. open circuit, dry running, lightning etc.)	Low/High pressure of the refrigerant gas, dust and vermin, agitator auto cut during opening of the lid, short circuits, over-voltages, lightning, earthing, etc.
25	Remote monitoring system (any provision for web-based monitoring)	Built in RS232 communication for system data transfer. Remote control (via mobile and IR remote) available. Service available with vendor(s) and optional for beneficiary to choose.
26	Warranty (for system as well as solar panel, battery etc.)	Warranty on panel and battery same as provided by manufacturing company and 1 year on BMC
27	Annual maintenance (in years)	As per the requirement
28	Asset insurance (number of years and reason such as theft or burglary)	Not available
29	Certification (if any)	Cooling tanks are manufactured according to ISO 5708 - 2A II

Technical Specifications:

Sl.No.	Solar bulk milk chiller (Thermal Storage System, TSS)				
	General Information				
1	Usage/Application	Dairy			
2	Capacity (litres)	300	500	1000	2000
3	Input power type	Single phase		Single / Three phase	
4	Maximum cooling	First milking: From 35 deg.C to 4 deg.C in 3-5 hours Second milking: From 10 deg. C to 4 deg. C in 1.5-3 hours			
5	Shape and Orientation	Open type horizontal/vertical/round/semi-cylindrical and cylindrical upto 2000 litres. Closed type cylindrical tank for 2000, 3000, 5000 litres. (Capacity, shape and orientation are customizable based on the order/ requirement)			
6	Body Material	Corrosion resistant stainless steel			
7	Product Dimensions	Minimum: 750 x 750 x 1250mm Maximum: 2013 x 1123 x 1202mm	Minimum: 1358 x 822 x 1718mm Maximum: 1416 x 1050 x 1450mm	1960 x 1080 x 1350mm (varies from vendor to vendor and customizable)	2380 x 1480 x 1400mm (varies from vendor to vendor and customizable)
8	Number of agitator and RPM	1 / 25-30 RPM	1 / 25-30 RPM	1 / 25-30 RPM	2 / 25-30 RPM
9	Input voltage	220V/50Hz for single phase 440/50Hz for three phase			
10	Insulation	High density Polyurethane foam (PUF) - 50mm thickness in walls and 90mm above evaporator			
11	Water pump (if required)	Depends on the requirement. Generally offered for larger capacities.			
12	Milk volume measurement	SS calibrated dipstick with value chart			
	Solar energy system				
13	PV array (kWp)	6	8	10	10-15
14	Solar module type	Monocrystalline/Polycrystalline			
15	Battery capacity (in Ah, if required)	150Ah x 4, 12V		150Ah x 4, 12V	150Ah x 8, 12V
16	Battery back-up (hours)	4		6	
17	Electronics Electronics (if inverter/converter, VFD, etc are required)	Inverter is required to run on solar power.			
	Refrigeration unit				
18	Refrigerant type	Freon - R22 / R-404a			
19	Type of compressor	Hermetically sealed Scroll / Reciprocating type			
20	Ambient temperature considered for design (°C)	43-45°C			

Sl.No.	Solar bulk milk chiller (Thermal Storage System, TSS)			
21	Thermal storage system capacity	400 litres	500 litres	500-1500 litres
22		700 x 700 x 850mm	1000 x 800 x 1000mm	1400 x 1200 x 900mm
23	Back up time duration	6-8 hours		
24	TSS recharge time	4-7 hours		
	Additional information			
25	Portability of system	Portable/Semi-portable		
26	Installation type (e.g.plug and play)	Plug and play		
27	Degree of protection (e.g. Ingress Protection (IP) code)	IP 65		
28	Protection against (e.g. open circuit, dry running, lightning etc.)	Low/High pressure of the refrigerant gas, dust and vermin, agitator auto cut during opening of the lid, short circuits, over-voltages, lightning, earthing, etc.		
29	Remote monitoring system (any provision for web-based monitoring)	Built in RS232 communication for system data transfer. Remote control (via mobile and IR remote) available Service available with vendor(s) and optional for beneficiary to choose.		
30	Warranty (for system as well as solar panel, battery etc.)	Warranty on panel and battery same as provided by manufacturing company and 1 year on BMC		
31	Annual maintenance (in years)	As per the requirement		
32	Asset insurance (number of years and reason such as theft or burglary)	Not available		
33	Certification (if any)	Cooling tanks are manufactured according to ISO 5708 - 2A II		

Techno Economics:

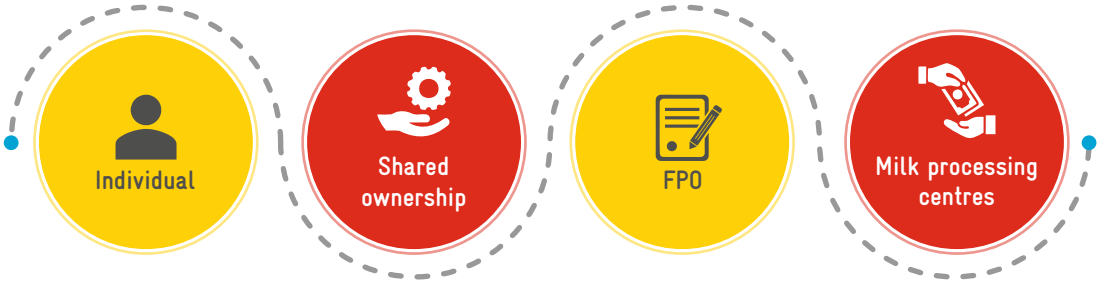
Parameters	Solar		Grid	
Bulk milk chiller capacity (litres)	500	2,000	500	2,000
Batch refrigerated in a day	2	1	2	1
Annual working days	280			
Non-lactation days	60			
Total utilisation days per year	220	220	220	220
Capex (₹)	9,61,000	16,60,000	Existing system	
Power rating (kW)	1.68	4.48	1.68	4.48
Average capacity utilisation	0.8	0.7	0.8	0.7
Average cost of milk chilling/litre	1.5	1.25	1.75	1.5

Parameters	Solar		Grid	
Total milk chilled in a year (litres)	88,000	3,08,000	88,000	3,08,000
Total revenue generated per year (₹)	1,32,000	3,85000	1,54,000	4,62,000
Miscellaneous cost of operation per year	8,000	12,000	12,000	14,000
Operational hours per day	12	8	12	8
Energy consumption per day (units)	-	-	16.12	25
Grid electricity consumption per year (units)	-	-	3,548.16	5,519.36
Electricity tariff (₹/unit)	-	-	8	10
Annual cost of electricity per year (₹)	-	-	28,385.28	55,193.6

Payback period solar bulk milk chiller of 500 and 2000 litres capacity as compared to existing grid powered systems = 5 years 10 months and 3 years 9 months respectively

GHG emissions mitigated = 2.8 and 4.4MT/year respectively

Ownership models:



Policies and Subsidy:

No specific schemes are available for solar bulk milk chiller machine but the possibilities can be explored under Dairy processing and Infrastructure Development Fund.

Policies and Subsidy:

S. No.	Government	Ministry/ Department	Program/ Scheme/ Project	Year	Status	Description	DRE Application(s)
1	Central	Department of Animal Husbandry and Dairy	Dairy processing & Infrastructure Development Fund (DIDF)	2018	Ongoing	To modernize the milk processing plants and machinery and to create additional infrastructure for processing more milk.	Milk processing, Chilling and Value added Products plants, Milk Chilling infrastructure, Renewable energy infrastructure/plants, trigen/ energy efficiency infrastructure
2	Central	Department of Animal Husbandry and Dairy	National Programme for Dairy Development (NPDD)	2021	Ongoing	Focuses towards creating/ strengthening of infrastructure for quality milk testing equipment as well as primary chilling facilities for State Cooperative Dairy Federations/ District Cooperative Milk Producers' Union/SHG run private dairy/Milk Producer Companies/ Farmer Producer Organisations.	Machineries only are covered (no mention of renewable energy infrastructure)

15. Solar Milk Cream Separator:

A milk cream separator is a machine used to separate cream from raw milk. The cream is collected and can be used for making butter, cheese, or other dairy products.

Photo Credit: Toolsvilla

Components of Solar Milk Cream Separator:

- **Centrifuge:** This is the main component of the cream separator, and it consists of a drum that spins at high speed to separate the cream from the milk.
- **Control unit:** The control unit manages the operation of the machine, and it typically includes a timer, a switch, and a regulator.
- **Milk inlet and outlet:** These are the ports where raw milk is poured into the machine, and where the separated cream and skim milk are dispensed.
- **Spout:** The spout is used to dispense the separated cream into a container.

Working Principle:

The centrifuge is the main component of the cream separator, and it consists of a drum that spins at high speed. Raw milk is poured into the centrifuge, and as it spins, the cream rises to the top and the skim milk settles at the bottom.

The control unit manages the operation of the machine, and it typically includes a timer, a switch, and a regulator. The timer allows the user to set the desired separation time, and the switch turns the machine on and off. The regulator controls the speed of the motor and ensures that the centrifuge spins at the correct speed. The milk inlet is where the raw milk is poured into the machine, and the milk outlet is where the separated cream and skim milk are dispensed. The spout is used to dispense the separated cream into a container.

Technical Specifications:

Sl.No.	Solar Cream Separator	
	General Information	
1	Bowl material	Aluminium and Stainless steel
2	Number of discs	9 - 25
3	Separation temperature (deg. C)	35 - 40
4	Availability of heat energy sources for heating	Different models are available to run on LPG, CNG, solar concentrators and other fossil fuels as well
5	Motor capacity (H.P.)	0.25 - 0.5
6	Solid Removal time (hours)	1.5
7	Processing capacity (litres/hour)	60 - 300
	Solar energy system	
8	PV array (kWp)	1
9	Solar module type	Any type will do however monocrystalline and polycrystalline type is being majorly used by the vendors
10	Battery capacity (in Ah, if required)	4 x 100Ah, 24V PCU: 1.5kVA
11	Autonomy (hours)	6
12	Electronics (if inverter, VFD, etc are required)	Direct solar run models are not available; hence inverter is required. Run with variable speed control AC drive.
13	Alternative applicable power source	Grid models only available, inverter - battery set will be used for operation on solar energy
	Additional Details	
14	Warranty	1 year warranty is provided on the product and standard warranty on solar energy components
15	Maintenance	Annual AMC provision available as per the location and frequency
16	Other provisions	Extra safe box provided for keeping spoons and brush, Gear box, tilting mechanism for removal of content and cleaning, double blades are available

Techno Economics:

Parameters	Solar	
Power (kW)	0.19	
Capacity (litre)	65	165
Cream output/batch (litre)	6.5	16.5
Price of cream per litre (₹)	240	240
Average monthly income (₹)	7800	19800
Capex (₹)	326,000	344,000
Cost of milk/litre (₹)	20	20

The simple payback period of solar cream separator = 3 months

The economic viability of solar cream separator is highly dependent on the scale of manufacturing and number of batches processed.

Ownership models:

Policies and Subsidy:

No specific schemes are available for solar milk cream separator machine but the possibilities can be explored under Dairy processing and Infrastructure Development Fund.

Policies and Subsidy:

S. No.	Government	Ministry/ Department	Program/ Scheme/ Project	Year	Status	Description	DRE Application(s)
1	Central	Department of Animal Husbandry and Dairy	Dairy processing & Infrastructure Development Fund (DIDF)	2018	Ongoing	To modernize the milk processing plants and machinery and to create additional infrastructure for processing more milk.	Milk processing, Chilling and Value added Products plants, Milk Chilling infrastructure, Renewable energy infrastructure/plants, trigen/ energy efficiency infrastructure
2	Central	Department of Animal Husbandry and Dairy	National Programme for Dairy Development (NPDD)	2021	Ongoing	Focuses towards creating/ strengthening of infrastructure for quality milk testing equipment as well as primary chilling facilities for State Cooperative Dairy Federations/ District Cooperative Milk Producers' Union/SHG run private dairy/Milk Producer Companies/ Farmer Producer Organisations.	Machineries only are covered (no mention of renewable energy infrastructure)

16. Solar Khoya making machine:

A khoya making machine is a type of food processing equipment used to prepare khoya, a dairy-based ingredient commonly used in Indian sweets and desserts.

Components of Solar Khoya Machine:

• Vessel:

A large, cylindrical vessel made of stainless steel, copper, or aluminium. This is where the milk is heated and khoya is prepared.

• Heating element:

A heating element is used to heat the vessel and the milk inside it. The heating element can be powered by electricity, gas, or wood.

• Motor:

The motor drives a stirrer that continuously stirs and scrapes the milk solids, preventing them from sticking to the walls or bottom of the vessel.

• Temperature control:

A temperature control mechanism is used to regulate the temperature of the milk and prevent it from overheating or burning.

Working Principle:

The machine consists of a large, cylindrical vessel made of stainless steel, copper, or aluminium, which is heated using electricity, gas, or wood. The vessel is typically fitted with a mechanism that continuously stirs and scrapes the milk solids, preventing them from sticking to the walls or bottom of the vessel.

• Control panel:

A control panel allows the operator to control the temperature and speed of the stirrer.

• Discharge outlet:

Once the khoya is prepared, it can be discharged through a discharge outlet located at the bottom of the vessel.

Photo Credit: Indiamart

Figure 26: Khoya making machine

To make khoya, milk is poured into the vessel and heated over a period of several hours, until most of the moisture has evaporated, and only the milk solids remain. The resulting khoya is a dense, crumbly, and slightly sweet ingredient that is used to make a variety of traditional Indian sweets and desserts, such as barfi, peda, and gulab jamun..

Technical Specifications:

S.No.	Solar Khoya making machine	
	General Information	
1	Usage	Dairy
2	Vessel volume range (litres)	55 – 300
3	Weight (kg)	150 – 350
4	Vessel material	Full stainless steel
5	Availability of heat energy sources for heating	Different models are available to run on LPG, CNG, solar concentrators
6	Main motor capacity (H.P.)	0.5 – 2
7	Blower motor	This is not required in small capacity machines however its size is kept between 0.25 – 0.5H.P.
8	Processing capacity	1. Milk boiling capacity varies from 32 – 200 litres per batch and average time required is 40 minutes 2. Maximum milk conversion into basundi is 15 – 80litres in around 40 minutes 3. Maximum milk conversion into khoya per batch is 5 – 35 litres in 40 minutes
	Solar energy system	
9	PV array (kWp)	1 – 5.36
10	Solar module type	Any type will do however monocrystalline and polycrystalline type is being majorly used by the vendors
11	Battery capacity (in Ah, if required)	4 x 100Ah, 24V – 150Ah x 8, 48V PCU: 1 – 5kVA
12	Autonomy (hours)	6
13	Electronics (if inverter, VFD, etc are required)	Direct solar run models are not available; hence inverter is required. Run with variable speed control AC drive.
14	Alternative applicable power source	Grid models only available, inverter – battery set will be used for operation on solar energy
	Additional Details	
15	Warranty	1 year warranty is provided on the product and standard warranty on solar energy components
16	Maintenance	Annual AMC provision available as per the location and frequency
17	Other provisions	Extra safe box provided for keeping spoons and brush, Gear box, tilting mechanism for removal of content and cleaning, double blades are available

Techno Economics:

Parameters	Solar	
Power (kW)	1	
Capacity (litre)	120	180
Milk required for 1 kg of khoya preparation	5	5
Daily Khoya output (kg)	24	36
Average monthly income (₹)	64,200	96,300
Capex (₹)	3,26,000	3,44,000
Selling price of khoya/kg	240	240
Cost of milk/litre (₹)	30	30
Cost of heating fuel/batch (₹)	20	30

Simple payback period of solar powered khoya making machine = 6 months

Ownership Models:

Policies and Subsidy:

No specific schemes are available for solar khoya making machine but the possibilities can be explored under Dairy processing and Infrastructure Development Fund.

Photo Credit: Freepik

APPLICATIONS IN Fishery Sector

17. Solar water aerator:

A Solar Powered Machine which circulating the water and supplying dissolved oxygen in the waterbodies.

Components of Solar Water Aerator:

- **Water Inlet**

This is where the water enters the aerator. It is usually connected to a water supply line and regulates the flow of water into the aerator.

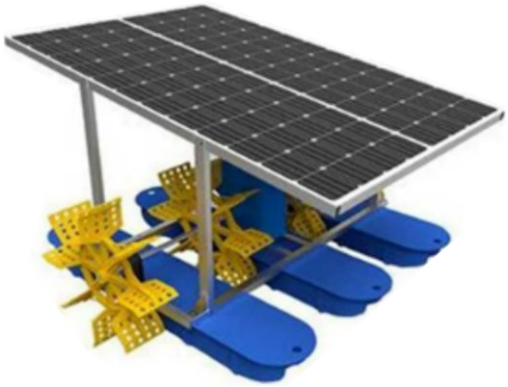


Figure 27: A paddle wheel water aerator

Photo Credit: Indiamart

- **Flow Regulator**

This component helps to control the flow rate of the water through the aerator. It can be adjusted to increase or decrease the water pressure and flow rate.

- **Spout**

This is the part of the aerator where the water exits and is dispensed. The spout can be adjusted to control the direction and flow of the water.

Types:

✓ **Paddle wheel aerator**

Paddlewheel aerators are the most common types used in large ponds. Paddlewheels consist of a hub with paddles attached in a staggered arrangement.

✓ **Pump-sprayer aerators**

Pump-sprayer aerators have pumps that discharge water at high velocity through pipes or manifolds.

✓ **Vertical pump aerators**

A vertical pump aerator consists of a submersible motor with an impeller attached to the output shaft.

Figure 28: A vertical water pump aerator

Diffusers or bubblers:

These systems use blowers or compressors to supply air to diffuse. The diffusers have many small pores that release bubbles on the pond bottom. Oxygen is transferred as the bubbles rise through the water column.

Technical Specifications:

S.No	Solar Water Aerator	
	General Information	
1	Usage	Fishery
2	Types	Diffused type, impeller, paddle, jet type etc.
3	Power rating (H.P)	Varies from 1-5
4	Input voltage (V)	220V (Three phase models are also available for larger pond sizes and paddles)
5	Oxygenation rate (kg/hour)	0.5 - 2.5
6	Cooling method	Self-cooling
7	Power rating (kW)	0.5 - 2.2
8	Aerator RPM	100 - 130
9	Area of pond can be catered	0.25 - 1 acre (multiple aerators will be required for lager size and depends upon the density)
	Mechanical Parts	
10	Gear Box	Worm and wheel bevel type
11	HDPE float	Virgin HDPE with UV
12	Impeller	Virgin plastic with UV
13	Shafting	Stainless steel - 304
14	Tripode	Virgin plastic with UV

Diffusers or bubblers:

These systems use blowers or compressors to supply air to diffuse. The diffusers have many small pores that release bubbles on the pond bottom. Oxygen is transferred as the bubbles rise through the water column.

Technical Specifications:

S.No	Solar Water Aerator	
	General Information	
1	Usage	Fishery
2	Types	Diffused type, impeller, paddle, jet type etc.
3	Power rating (H.P)	Varies from 1-5
4	Input voltage (V)	220V (Three phase models are also available for larger pond sizes and paddles)
5	Oxygenation rate (kg/hour)	0.5 - 2.5
6	Cooling method	Self-cooling
7	Power rating (kW)	0.5 - 2.2
8	Aerator RPM	100 - 130
9	Area of pond can be catered	0.25 - 1 acre (multiple aerators will be required for lager size and depends upon the density)
	Mechanical Parts	
10	Gear Box	Worm and wheel bevel type
11	HDPE float	Virgin HDPE with UV
12	Impeller	Virgin plastic with UV
13	Shafting	Stainless steel - 304
14	Tripode	Virgin plastic with UV

S.No	Solar Water Aerator	
	Additional details	
15	Warranty	Generally, 1 year warranty of gear box and spares. No warranty on motors.
16	Maintenance	Precaution must be taken to ensure motor covering is not opened during operation. Starter must be used in case of voltage issues.

Working Principle:

The working principle of a water aerator is to mix air with the water flow, creating a stream of water that is lighter and bubblier. The water flows through small holes or perforations in the mixing chamber of the aerator, where air is introduced and mixed with the water. The aerator screen further breaks down the water stream into smaller droplets, increasing the surface area for air to mix in. The result is a stream of water that is aerated and has a softer, more bubbly texture.

Techno Economics:

Particulars	Diesel	Solar
Power rating of the water aerator	2 H.P. (1.5kW)	
Size of energy source (kW)	5	5.36
Duration of usage/day	6 hours	
Capital cost	Low	High
Running cost	Very high	Zero
Running cost/day	High	Zero
Maintenance cost	High	Negligible
Routine maintenance	Diesel lubrication, minor and major servicing required	Only panel cleaning once a week or as required
Part replacement	Worn out parts are needed to be replaced more often	Batteries have to be replaced every 5-6 years and motor needs to be protected responsibly

Techno Economics:

Parameters	
Aerator (₹)	30,000
Solar system (5.36kW)	5,20,000
Capex	5,50,000
Operation & Maintenance cost of Diesel aerator	
Operating time of diesel aerator (hours/day)	6
Per hour fuel consumption (litres/hour)	1.22
Diesel cost (₹)	80
Total fuel required (litre)	7.32
Total cost of operation (₹/day)	585.6
Savings	
Annual Savings (₹)	2,13,744

The simple payback of solar water aerator as compared to diesel run = 2 years 7 months
GHG emissions mitigated = 6.9 MT/year

Ownership models:

Policies and Subsidy:

Government	Ministry/ Department	Program/ Scheme/ Project	Year	Status	Description	States	DRE Application(s)
Central	Department of Fisheries	Pradhan Mantri Matsya Sampada Yojna	2020	Ongoing	Post-harvest infrastructure including cold chain for reduction of post-harvest losses will be developed and strengthened. Requisite infrastructure for processing, storage, value addition, packaging, transportation and marketing of fish and fisheries products will be supported.	Pan India	Water aeration system (no mention of renewable energy)

18. Sub-HP/Fractional Solar Water Pump

The term "sub-HP or fractional" refers to the small size of the pump and its motor, which are designed to handle small-scale water pumping applications such as irrigation, livestock watering, and domestic water supply. These pumps are called so because they typically have a power rating of less than 1 horsepower (HP).

Components of Fractional Solar water pump:

- **Pump Controller:**

The pump controller regulates the flow of electricity from the solar panels to the pump motor. It also protects the pump motor from voltage fluctuations and short circuits.

- **DC Pump Motor:**

The DC pump motor is specifically designed to run on DC power supplied by the solar panels. It is efficient and low maintenance compared to AC pumps.

- **Impeller:**

The impeller is a rotating component that moves water through the pump and creates pressure to push it up and out through the outlet.

- **Outlet:**

The outlet is the part of the pump that delivers water to the intended destination, such as a storage tank or irrigation system.

Photo credit: Freepik

Working Principle:

The working principle of fractional solar water pumps is that they use solar energy to power a DC pump motor, which pumps water from a source such as a well or a stream and delivers it to a storage tank or irrigation system.

As the motor rotates the impeller, it moves water through the pump and creates pressure to push it up and out through the outlet. This process is continuous as long as there is sufficient sunlight to power the solar panels, and it provides a reliable and sustainable source of water in remote areas where access to electricity is limited.

Technical Specifications:

S.No.	Fractional Solar water pump	
	General Information	
1	Usage/Application	Agriculture / Dairy / Fishery
2	Water sources	Openwell, Water stream, Pond
4	Solar pump type	Surface and Submersible
5	Motor pump set	Brushless DC motor and Induction motor with suitable VFD and inverter set
6	Electronics	IGBT/any other power electronic switch based PWM controller with MPPT technique for DC pumps.
7	Fixed or Portable	Fixed / Portable / Semiportable
8	Installation type	Plug & play and easy to operate
9	Solar module type	Monocrytalline / Polycrystalline
10	Degree of protection	IP54 or above. IP65 models are also available and is generally preferred. Motors have Class B insulation
11	Protection against	Input reverse polarity, under and over voltage, overload, short circuit, pump dry run, pump block discharge, over temperature, phase loss
	Additional Information	
12	Remote monitoring system	With data logger and GSM based integrated remote monitoring for various operational parameters such as PV array voltage, array current, power, pump RPM, pump on/off status, discharge etc.
13	Warranty	5 years warranty from the date of installation on the system for Govt. supported projects and 25 years for solar panels
14	Annual maintenance	1year AMC on controller and pump for non-subsidised sale and 5 years for government subsidized pump.
15	Asset insurance	On site insurance available based on request of the beneficiary in case of non-subsidized sale while insurance exists for projects government supported/subsidized. This has to be claimed by the beneficiary directly.

Techno Economics:

Parameters	Diesel	Solar	Grid
Capacity (HP)	0.5	0.5	5
Capacity (W)	0.373		
Capex (₹)	15,000	45,000	30,000
Operational hours per day	6	6	6
Specific fuel consumption (litres/kWh)	0.301	-	-
Density of diesel (kg/l)	0.832	-	-
Number of days of operation	300	300	300
Fuel cost (₹ /litre or kWh)	90	0	3
Annual fuel cost (₹)	18,188.226	Nil	5,400
Maintenance Cost (₹)	500	Nil	2,500

Payback period of fractional solar water pump as compared to diesel run model = 2 years 5 months
GHG emissions mitigated = 0.6 MT/year

Ownership Models:

19. Solar Fish Meat mincing machine

A fish meat mincing machine is a piece of equipment used to grind fish meat into small pieces or a paste-like consistency.

Components of Solar fish meat mincing machine:

Photo credit: India Mart

- ✓ Fish meat processing
- ✓ Minced meat collection
- ✓ Control unit

Working Principle:

The fish meat to be minced is placed into the machine, usually in a hopper. The mincing mechanism, consisting of blades or other elements, works to chop the fish meat into smaller pieces. The minced fish meat is collected in a container for further processing or packaging. The machine is equipped with a control unit that manages and regulates the power supply and operation of the machine.

Technical Specifications:

Sl.No.	Solar Meat Mincing machine	
	General Information	
1	Usage	Fishery
2	Construction material	Stainless steel
3	Machine dimensions (cm)	Length = 100-150, Breadth = 50-100, Height = 50-100
4	Motor rating (H.P.)	1.5 - 5
5	Machine weight (kg)	80-200
6	Processing capacity (fish/hour)	100 - 500 (varies with the type of fish)
7	Number of blades	1 - 2
8	Blade material	Stainless steel
9	Mincing mechanism	Mechanical (some vendors with advanced version also have pneumatic mechanism)
10	Fish size range	Suitable for small to medium-sized fish, such as sardines, mackerel, and catfish.
11	Cleaning mechanism	Manual
	Solar energy system	
12	PV array (kWp)	2 - 10
13	Solar module type	Any type will do however monocrystalline and polycrystalline type is being majorly used by the vendors
14	Battery capacity (in Ah, if required)	150Ah x 4, 48V - 200Ah x 10, 120V PCU: 2.5 - 12.5kVA
15	Autonomy (hours)	6
16	Electronics (if inverter, VFD, etc are required)	Direct solar run models are not available; hence inverter is required. Run with variable speed control AC drive.

Sl.No.	Solar Meat Mincing machine	
17	Alternative applicable power source	Grid models only available, inverter – battery set will be used for operation on solar energy
	Additional Details	
18	Warranty	1 year warranty is provided on the product and standard warranty on solar energy components
19	Maintenance	Annual AMC provision available as per the location and frequency

Techno Economics:

Parameters	Solar	Grid
Operational hours per day	2	2
Price of minced meat (₹/Kg)	250	250
Processing capacity (kg/hour)	100	120
Operational number of days per year (considering the aggregated demand over the year and other factors)	150	150
Yearly Income	9,00,000	10,80,000
Average cost price of live fish (₹)	220	220
Capex (₹)	8,00,000	-
Fuel charges (₹)	-	2,880

Payback period of solar meat mincing machine as compared to grid electricity run model = 11 months
GHG emissions mitigated = 0.3 MT/year

Ownership Models:

20. Solar Fish De-boning machine

A fish deboning machine is a specialized piece of equipment used to remove bones from fish fillets or other fish products.

Components of Solar Fish De-boning machine:

- Hopper: To hold the fish to be processed
- Deboning mechanism
- Collection container
- Control unit
- Chute

Photo credit: India Mart

Figure 29: A solar fish de-boning machine

Working Principle:

The equipment receives the fish to be deboned, typically in a hopper. The deboning mechanism works to separate the fish's bones from its flesh using rollers, blades, or other components. Through a chute or other device, the bones are normally separated from the fish's flesh before being thrown away. The fish that has been deboned is gathered in a container or additional handling or packaging. A control unit that maintains and controls the machine's power supply and operation is built within the device.

Technical Specifications:

S.No.	Solar Fish Deboning machine	
	General Information	
1	Usage	Fishery
2	Construction material	Stainless steel
3	Machine dimensions (cm)	Length = 80-180, Breadth = 60-110, Height = 120-180
4	Machine weight (kg)	150 - 500
5	Processing capacity (kg/hour)	100 - 500 (varies with the type of fish)
6	Number of blades	1 - 2
7	Blade size (mm)	0.5 - 3
8	Blade material	Stainless steel
9	Fish size range	Suitable for small to medium-sized fish, such as sardines, mackerel, and catfish.
10	Cleaning mechanism	Manual
	Solar energy system	
11	PV array (kWp)	2 - 6.70
12	Solar module type	Any type will do however monocrystalline and polycrystalline type is being majorly used by the vendors
13	Battery capacity (in Ah, if required)	150Ah x 4, 48V - 200Ah x 8, 96V PCU: 2.5 - 7.5kVA
14	Autonomy (hours)	6
15	Electronics (if inverter, VFD, etc are required)	Direct solar run models are not available; hence inverter is required. Run with variable speed control AC drive.
16	Alternative applicable power source	Grid models only available, inverter - battery set will be used for operation on solar energy
	Additional Details	
17	Warranty	1 year warranty is provided on the product and standard warranty on solar energy components
18	Maintenance	Annual AMC provision available as per the location and frequency
19	Safety features	Some fish deboning machines may have safety features such as a locking mechanism or emergency stop button to prevent accidents.

Techno Economics:

Parameters	Solar	Grid
Operational hours per day	2	2
Price of deboned meat (₹/Kg)	280	280
Processing capacity (kg/hour)	150	160
Operational number of days per year (considering the aggregated demand over the year and other factors)	100	100
Yearly income (₹)	18,00,000	19,20,000
Average cost price of live fish (₹)	220	220
Capex (₹)	10,00,000	Baseline
Fuel charges (₹)	-	1,600

Payback period of solar meat mincing machine as compared to grid electricity run model = 7 months
GHG emissions mitigated = 0.08 MT/year

Ownership Models:

Photo credit: Freepik

05

Way Forward

Policy advocacy

The report can be used to advocate for development of favorable policies that would promote the adoption of DRE applications in Agriculture, Dairy, and Fishery sectors. The knowledge compiled can be shared with policymakers to create awareness about the benefits of DRE, including its environmental and economic advantages over traditional diesel and grid-based systems.

Financing opportunities

The report can be used to attract financing companies and investors who are interested in funding pilot projects in DRE applications across the 3 sectors. It can be shared with financing institutions to demonstrate the potential of DRE in these sectors and highlight the economic benefits of investing in this technology. The business models added against each of the applications will help the financing organizations to develop robust infrastructure, value chain and financial model for inclusive income generation.

Pilot projects

The report to be used to develop pilot projects that showcase the feasibility and benefits of DRE applications in Agriculture, Dairy, and Fishery sectors. The report can be shared with project implementers, including NGOs, private companies, and research institutions, to identify potential pilot sites and develop project proposals that integrate DRE applications.

Capacity building

The report will be used to develop training programs and capacity building initiatives that promote the use of DRE applications in the 3 sectors. The report can be shared with training institutions, including vocational schools and universities, to design courses and programs that incorporate DRE applications based on their technical parameters and for the development of much more energy efficient rural applications/versions and promote their use in these sectors.

Awareness building

The report can be used to create awareness among farmers, entrepreneurs, and other stakeholders about the benefits of DRE applications in the identified sectors. The report can be shared through workshops, seminars, and other awareness-building events to educate stakeholders about the potential of DRE technologies and how they can be used to improve livelihoods and promote sustainable development.

Disclaimer

The report is being developed based on research and interactions with the manufacturers, and suppliers. The present document is an attempt to put together relevant information to raise awareness on DRE applications suitable for agriculture, dairy and fishery sectors. It is strongly recommended to consult manufacturers/ suppliers/ dealers before investing in DRE applications. Please note that this document is neither exhaustive nor comprehensive. GIZ will not be responsible for any financial decision based on the information provided in the document.

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