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Solar Energy Based Continuous Cooker

Presented by

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Batch cooking: Eco-Cooker

- Cooking device developed by ICT and LRI (NGO)
- Available in various sizes of 3.5, 6, 24, 40, 120, and 160 liter
- Thermal efficiency: 60 % - 70 %
- Working Principles

  -Reduction in heat loss to the surroundings

  -Early shut-off of the heat supply

  -Optimum heating rate (matching heat uptake rate with supply rate from the burner)

Continuous cooking system

Large Scale Cooking in India

Hostels, Jails, Industrial Canteens Religious places, Mid-day meal schemes

1000- 100,000 meals/ day

Batch operations limitations/ challenges

Usable till 300 meals/ batch

Continuous Cooking System concept

Rice and water are contacted at temperatures between 95 to 100 ^oC at predetermined residence time.

Kinetics of Cooking

- Assumptions
  - Spherical particle
  - Particle size increases as cooking takes place
  - Overall rate is controlled by
    1) External mass transfer
    2) Diffusion through cooked material
    3) Chemical reaction

Kinetics of Cooking

Degree of Starch Gelatinization

Images for Cooking of Unsoaked Rice at 90°C at different cooking time intervals

5 min. **10 min.** **20 min.** **40 min.**

Translucent Portion is Cooked

Opaque Portion is Uncooked

Rice Cooking

Kinetics of Cooking

- External mass transfer

$$\theta = \left(\left[R_e^{\,3} - \frac{\left(R_e^{\,3} - R_0^{\,3}\right)}{R_0^{\,3}} R_c^{\,3} \right]^{1/3} - R_0 \right) \Big/ \left(R_e - R_0\right)$$

- Diffusion through Swollen Cooked Mass

$$\theta = \left\{ \frac{R_c^{\,2} - R_0^{\,2}}{2} + \frac{1}{2\left(R_e^{\,3} - R_0^{\,3} \big/ R_0^{\,3} \right)} \left[\left(R_e^{\,3} - (R_e^{\,3} - R_0^{\,3}) \left(\frac{R_C}{R_0} \right)^3 \right)^{2/3} - \left(R_0^{\,3}\right)^{2/3} \right] \right\} \Big/ \left\{ -\frac{R_0^{\,2}}{2} + \frac{1}{2\left(R_e^{\,3} - R_0^{\,3} \big/ R_0^{\,3} \right)} \left[\left(R_e^{\,3}\right)^{2/3} - \left(R_0^{\,3}\right)^{2/3} \right] \right\}$$

- Chemical Reaction Controlled

$$\theta = \left(\left\{ R_e^{\,3} - (R_e^{\,3} - R_0^{\,3}) \left(\frac{R_C}{R_0} \right)^3 \right\}^{1/3} - R_C \right) \Big/ R_e$$

Where:
$\theta = t/\tau$;
τ is time required for complete cooking

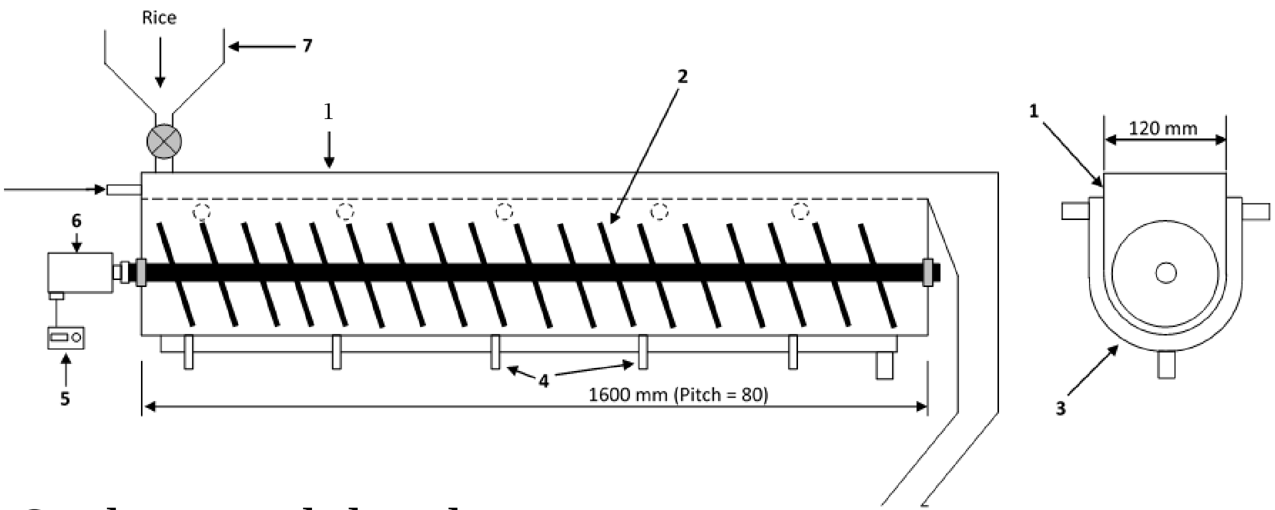
Time for complete cooking of Rice

- Effect of Temperature on Cooking Time

(Juliana et al, 1986; Singhal et al 2012)

Temperature (°C)	Time (min)
80	57.0
90	24.0
95	18.0
100	13.5

Schematic of continuous cooker



1. U trough
2. Screw conveyor
3. Steam jacket
4. Sparging nozzles
5. VFD
6. Motor
7. Hopper

Cooking trial details

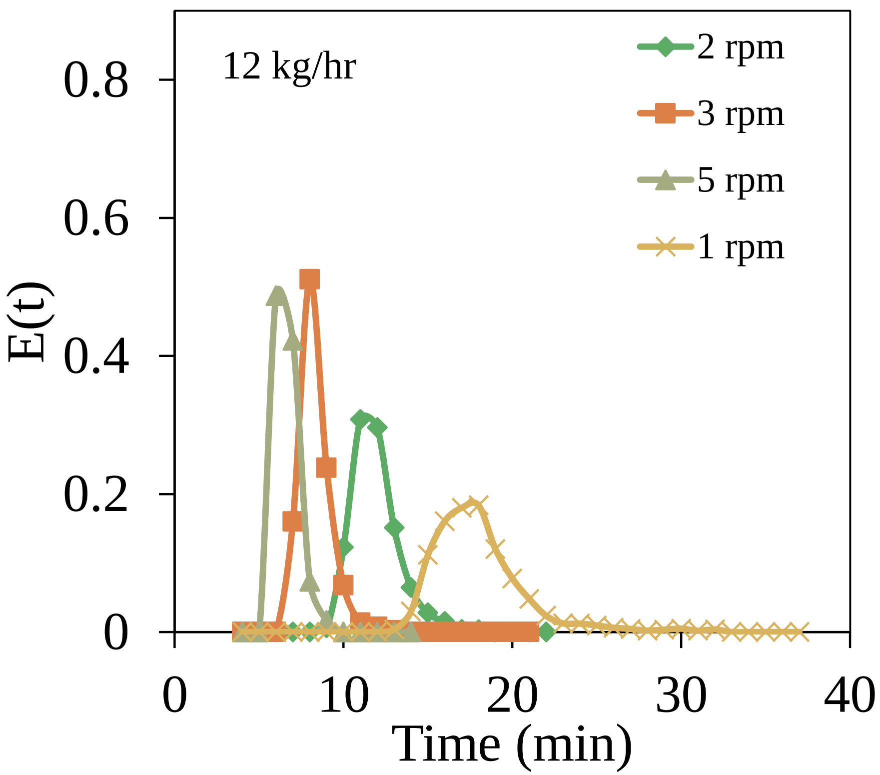
Parameter	Unit	Typical value
Rice addition	kg/hr	5
Water	kg/hr	15
Total mass feed rate	kg/hr	20
Screw rotation speed	rpm	1
Residence time	min	20
Length	m	1.6
Width	m	0.12

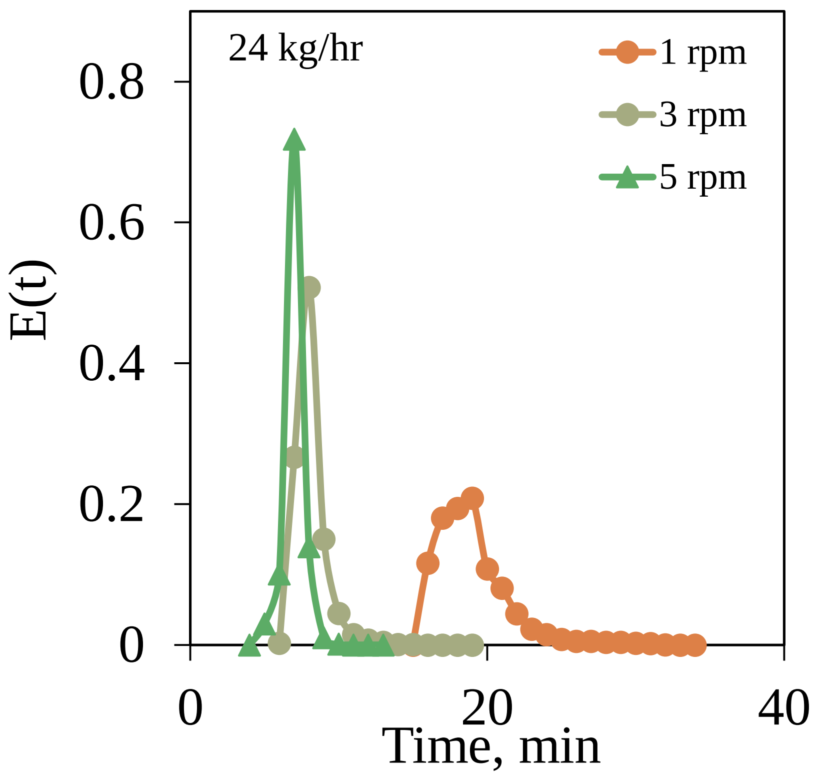
Hydrodynamic performance

- Liquid phase Axial Mixing
  - Water flow rate: 15, 25, 35 lph
  - Mean residence time: 8-24 min
  - Screw speed: 1,2,3,5 rpm

- Solid phase Axial mixing
  - Screw speed: 1, 3, 5 rpm
  - Rice feed rate: 12, 24 kg/hr

Hydrodynamic performance





Solid RTD

Solid phase RTD

Flow rate (kg/hr)	Screw rpm	MRT (min)	σ_d^2	Pe
12	1	18.20	0.0245	81.50
	3	9.18	0.0102	195.85
	5	6.37	0.0110	181.52
24	1	18.54	0.0161	124.11
	3	8.40	0.0157	127.74
	5	7.30	0.0084	239.39

Cooking Experiments

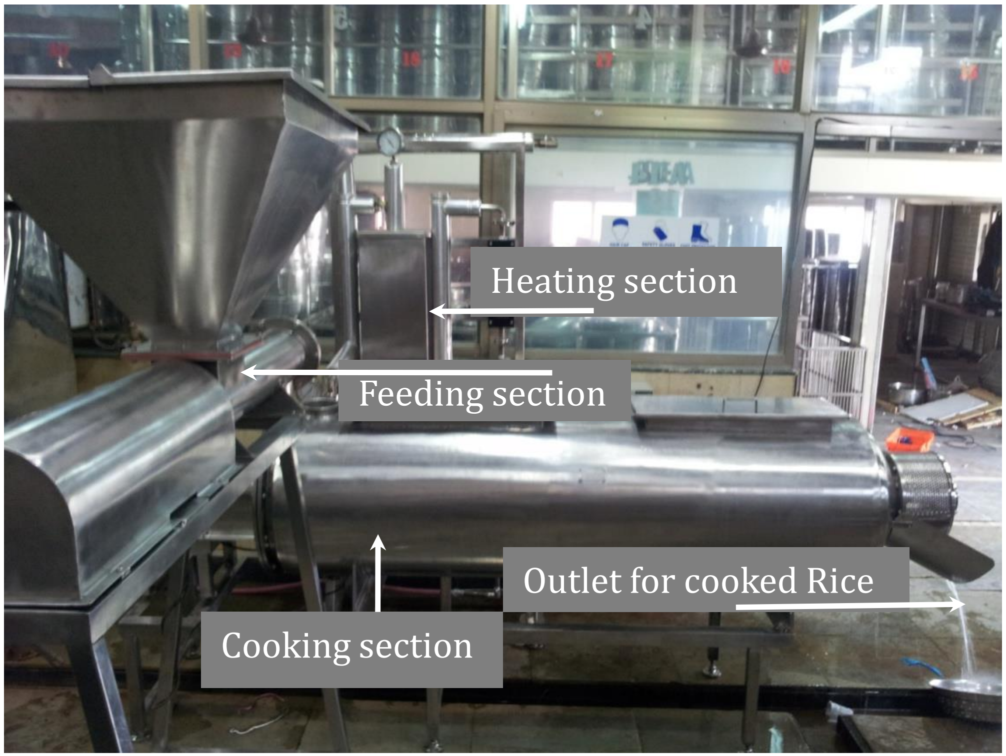
Rice Cooking: 20 min residence time (1 rpm)

Sr No.	Rice (kg/hr)	Water (lph)	Quality of cooked material	Efficiency
1	5	25	Cooked, free flowing	60%
2	5	17.5	Cooked, free flowing	61%
3	5	12.5	Cooked, sticky	59%

Dal Cooking : 95 min residence time (0.2 rpm)

Sr No.	Dal(kg/hr)	Water (lph)	Quality of cooked material	Efficiency
1	1	5	Cooked, free flowing	58%
2	1	3.5	Cooked, free flowing	60%
3	1	2	Cooked, sticky	59%

Continuous Cooking System



Photograph of Scaled up model
(capacity100 kg/hr)

Parameters	Unit	
Rice addition	kg/hr	100
Water	kg/hr	350
Total mass feed rate	kg/hr	450
Screw rotation speed	rpm	0.5
Residence time	min	20
Length	m	2
Diameter	m	0.48

Techno-Economical Feasibility

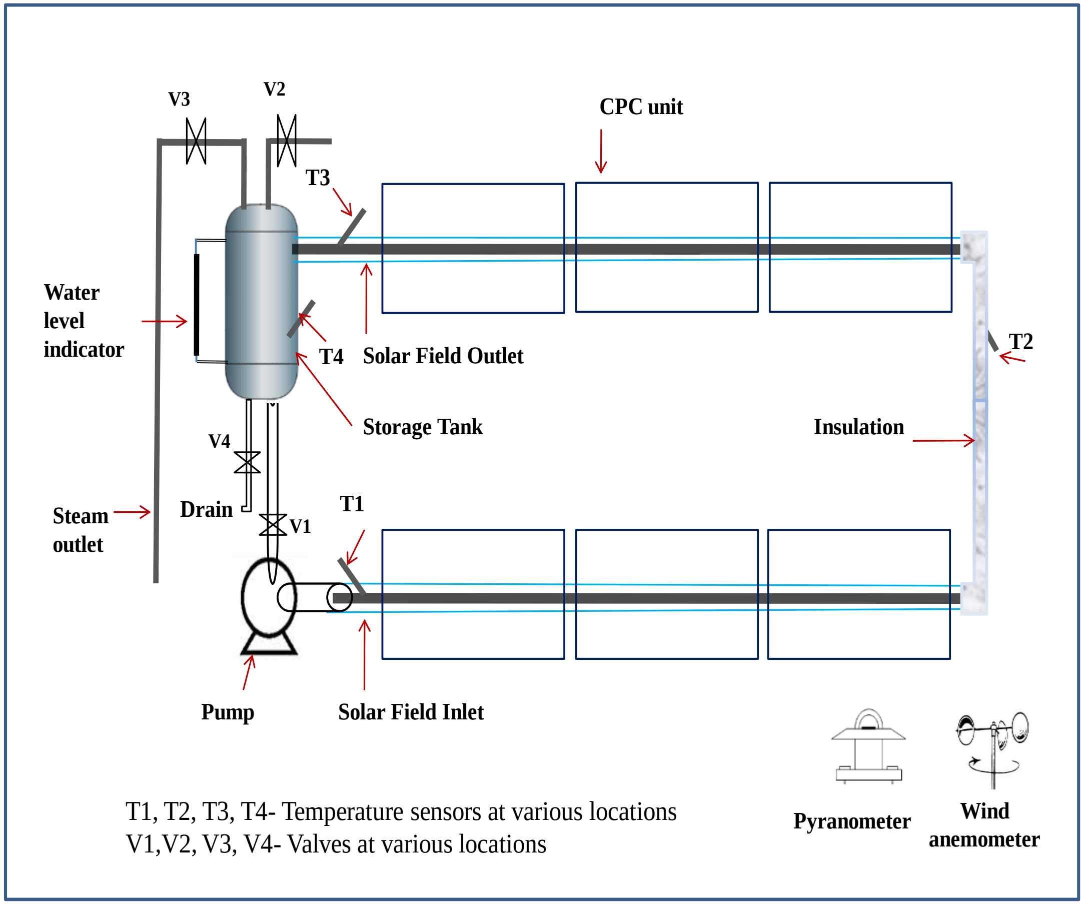
- Basis: 50000 meals
  - Once a day
  - LPG cost Rs. 65/-per kg.
  - Number of Meals per day : 50000
  - Rice and Dal Needed : 5000 kg (4 parts rice, 1 part dal)
  - Labor Cost : Rs. 300/- per person per day

Techno-Economical Feasibility

	Parameters	Unit	Open-Pan Cooker	Continuous Cooker
1.	Total Cooking Time	hr	7.5	5.0
2.	Labour requirement	Persons	20	2
3.	Capital Investment	Rs.	1,00,000/-	32,00,000/-
4.	Labour and Overhead Costs	Rs./day	7,000	1,600
5.	Fuel Required	kg LPG/day	560	235
6.	Fuel Cost	Rs./day	36,400/-	15275/-
7.	Total Operating Cost	Rs./day	43,400/-	16,875/-
8.	Operating Cost per Annum	Rs./year	86,80,000/-	33,75,000/-
9.	Annual Savings	Rs./year	-	53,05,000/-
10.	Depreciation	Rs./year		1,60,000/-

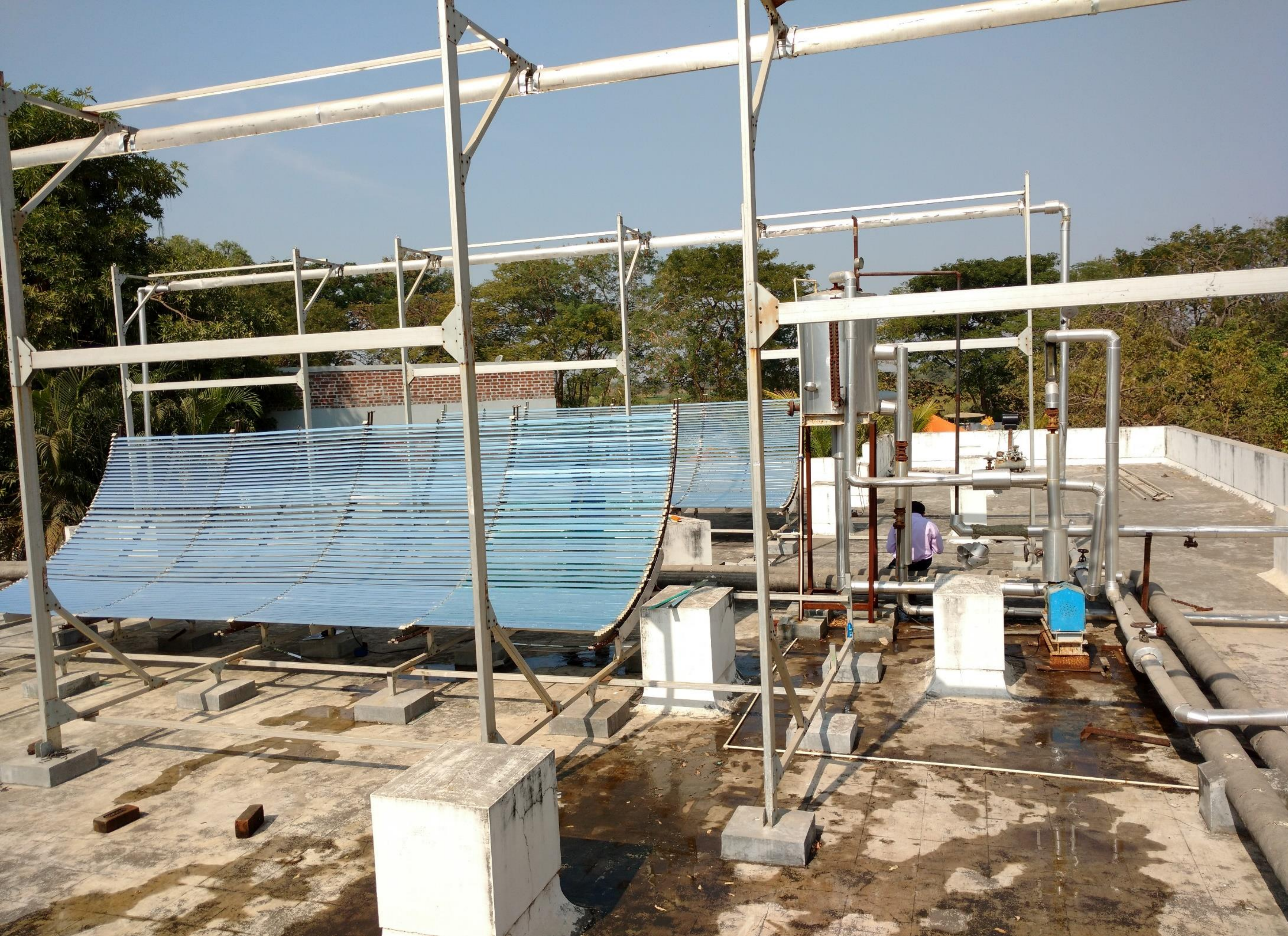
Payback Period: 7 months.

Integration with Solar Thermal System



Parameters	Value	Unit
Mounting	East-West	-
Collector aperture	2.0	m
Collector length	3.0	m
Aperture area	6.0	m^2
Total units	16	-
Total collector area	94.6	m^2
Mirror Area	107.5	m^2
Receiver diameter	0.048	m
Concentration ratio	12.9	-
Steam Generation Rate	50	kg/hr
Efficiency	40	%

Solar based Cooking System



Thank you

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