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Energy Consumption Assessment of Grain Drying Industry in India

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ABSTRACT: -
The cost and use of energy in agricultural sector have enhanced the productivity rate on large scale. On other hand making it necessary to be more energy economical. For this purpose, the existing systems should be completely analysed. The Rice processing industry is among the most energy-consuming industries as far as labour, energy, and capital is concerned. The required utilities during a rice processing industry are electricity, steam, water, air, etc. Electrical energy is the primary energy supply for the rice processing. The electrical energy is employed to run pumps, motors, fans, blowers, lights, conveyors, etc. The variations within the utilization of energy in the utilities throughout the method should be accounted for the finished product.
This study investigates various types of energy consumption patterns utilized in rice processing industry and the use of renewable energy to exchange the dearer fossil fuels which result in the Green House Gas Emissions.
Keywords: Solar thermal process heating, rice industry, Renewable energy integration, PVSYST, parboiling, soaking

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I. INTRODUCTION

The Rice is the 2nd most growing food crop in the world and also an important food in India. It is the high densely populated area of the world and a daily food for millions of people from Africa, Latin America, and Asia. In India rice processing is oldest and also largest agro-processing industrial sector. Recently, it has a turnover more than Rs. 3,405,547 Million in 2020. India processed about 117.47 million tonnes last year which provides the main food grains and other valuable goods consumed by the population. Recently, about 10 % of the total rice production in the country is processed with hand pounding, 40% by using traditional mills, and the rest and rest 50 % with modern mills.

In the current situation of the international energy shortage, possibilities of reduction in energy are explored by every developing country. Solutions to the energy crisis strongly depend on how energy is utilized by technology. The time of low-cost energy has passed, but there are some industrial sectors which are energy guzzlers. In the agricultural sector, both energy use and cost are continuously increasing. Since the revolution in the agricultural sector and the promotion of high-input, automation, irrigated cropping systems, agriculture uses more energy, directly and indirectly, due to its many production inputs, activities, and needs like tillage, land preparation, fertilizers, irrigation (pumping), and harvesting. Therefore, increased energy efficiency is an important objective for both policymakers and farmers; However, efforts to harness the optimum

utilization of potential of energy use in agriculture are declining. The consumption of fossil fuels and other non-renewable energy resources hasexaggerated quickly since the 19th century because of increased population and technologicaldevelopment in several countries. Several scientists are distressed due to their restricted reserves; fossil fuels will become insufficient of supporting international energy demand within the coming years. Due to the increasing use, high commercial demand and exhausting fuel-based technologies that have caused overall temperature changes globally over a decade the price of the fossil fuels is increasing exponentially. It's been rumoured that international greenhouse gas (CO_2) emissions exaggerated to 33,234.8 million metric tons in 2018 from 30,295 million metric tons in 2008.[1]

II. MATERIALS AND METHODS

INDIAN SCENARIO FOR RICE INDUSTRY

The rice-growing regions in the country have been divided into five regions as given below:

1. North-Eastern Region: The North-Eastern states and Assam are the main rice growing areas. Rice is grown in the Brahmaputra river basin of Assam.

2. Eastern Region: This area includes Chhattisgarh, Bihar, West Bengal, Jharkhand, Uttar Pradesh, Madhya Pradesh, Eastern, Odisha. The region comprises of Ghats of the Ganges and Mahanadi rivers and the intensity of rice cultivation is the highest in the country. The region receives heavy rainfall and rice is grown mainly in rainfed conditions.

3. Northern Region: The region includes Punjab, Haryana, Western Uttar Pradesh, Himachal Pradesh, Uttarakhand, and Jammu and Kashmir. Due to the lower winter temperatures, a single rice crop is grown from May-July to September December.

4. Western Region: This region comprises of Maharashtra, Rajasthan and Gujarat. High rainfall conditions during June-August to October–December makes suitable weather for rice growth.

5. Southern Region: The region comprises of Andhra Pradesh, Kerala, and Karnataka. High rainfall and longer coastal area make it ideal conditions for Rice cultivation.

The rice production in India is about 117.47millon tonnes as per 2019-2020. It is higher than the last five-year average production which is 107.80 million tonnes. [2]

- **POST HARVESTING PROCESS**

The post harvesting processes consist of 2 stages which are as follows: -

1. Parboiling:

The processing of paddy before milling is known as parboiling which is hydrothermal treatment of paddy. The developing countries like India, Bangladesh, Sri Lanka, and other rice exporting countries uses ancient method of rice processing. Both traditional and modern ways are used to produce the parboiled rice (PBR). Various instruments and techniques for parboiling have been developed. Modern methods are capital and energy intensive and not feasible for small scale production at the rural level. Direct or indirect heating and single or double steaming is used by parboiling devices, all of which consume different energies. Agricultural waste or residue is the main sources of energy for local parboiling, especially rice husk from rice processing industries. However, drying under sun is a common practice in local dry processes. Nearby ponds, rivers, lakes, or wells are sources of water. [3]

2. Dehusking and Milling

The dehusking and milling process makes the outer portion of paddy rice edible. The three main types of stones are stone dehullers, impeller type, and rubber rolls. Stone hulls are common in tropical Asia, where BR is immediately mingled with an abrasive or an abrasive mill. It has been estimated that different types of liners affect performance significantly. The use of steel hulls is now prohibited in commercial rice processing area, as they cause high grain breakage and lower milling recovery. Frictional milling equipment's are used to remove the bran. The process of dehusking before milling improves both head rice yield and milling. During thistreatment the husk get separated and becomes loose, causing fainting to disappear. The energy demand during the de-husking process is also due to the effectiveness of the steaming treatment and decreases with the increase of the steaming time.

METHODS TO PERFORM VARIOUS POST HARVESTING OPERATIONS

Some of commonly used methods are explained below: -

1. Traditional Method:

The traditional process includes soaking of paddy in the water at ambient temperature
for about 24–48hrs, steaming in conical tanks under atmospheric pressure and drying in sunlight. [5]

2. Central of Food Technological Research Institute (CFTRI) Method: -

Central of Food Technological Research Institute Mysore has developed a parboiling system whose main aims are to improve the quality of the rice, lower equipment costs, shorten processing time, and ensure that the system is as simple as possible to operate. A boiler produces steam under pressure which is feed to the steaming and steeping containers. The performed pipes running the length of the cylindrical container are used to supply the steam. At the base, there are a greater number of perforated tubes which are arranged radial manner to provide the better steam distribution. The cylinders with conical base used for steaming and steeping and this conical based base are waterproof. The valve for carrying away condensate and for draining off the steeping water is placed at the bottom side of cylinder. The base of the steeping and the steaming cylinder is raised about 1m above ground level. Steps and a platform enable the cylinder to be filled with rice by hand from above. The cylinders are filled with water at ambient temperature, which then heated to 85°C by steam injection and paddy is poured manually into the cylinder.

The water temperature will then drop to70-75ºC from 85ºC. The water is drained off after 2-3hrs of steeping. The heating is continued until the husks just begin to crack open by feeding pressurized steam into the tank. The condensate collected at the bottom of tank is drained off by opening the valve. The high temperature wet rice unloaded by opening the bottom hatch, when heating is completed and is then transported to the dryer section where it is spread out. A pump is provided to recycle the water continuously through the filter in order to prevent the steeping water fermentation. After filtering continuous injection of steam is used to keep water at higher temperature.[6]

3. Rice Processing Engineering Centre (RPEC) Method: -

The Paddy parboiling is a process of gelatinization of rice starch in a situation that requires moisture and heat. Paddy and moisture can be supplied by soaking in water slightly above or below the starch's gelatinization temperature. Instead of supplying moisture and heat in two separate operations, such as soaking and steam taking, it is currently done by traditional and modern methods. [5]

4. Pressure Parboiling Method: -

This method of parboiling was developed at Thiruvarur in Tamil Nadu. In this process water vapour under pressure is passed over the paddy to achieve parboiling. This results in the gelatinization of kernel starch. Paddy is kept for soaking for 40 minutes at about 85-90°C. It then bangs for 18 minutes under pressure. The water vapour that enters the kernel drive enters the air. It is estimated that this entire process requires 1 to 1.5 hours to complete. The colour obtained by this method parboiling is slightly yellow for rice bran. The main advantages of this process are its short duration of paddy processing. It is also seen that pressure parboiled paddy has much better shelling, rice grain storage life is increased, and bran has more fat. [7] & [8]

ENERGY CONSUMPTION IN POST HARVESTING METHOD

The requirement of energy for processing rice is depend on the type and quality ofgrain, instruments used, processes and other parameters. This include size of grain, quality ofgrain, end-product quality, uniformity, grain hardness,type/capacity/age/combinationofinstruments used, fuel and power source,power transmission and drive efficiency.

There arenumber of factors that affect energy requirements in rice processing industries. Parboiling is ahydrothermal which performed before milling treatment and carried in three steps. Theimportant controlling factor involved in the rice quality is time and temperature of soaking;time, pressure, and stage of steam, drying time and temperature, these vary from mill to mill.[9]

Parboiling and Drying:

Some researchers estimated the energy requirements for various parboiling processes and methods. The energy requirement for RPEC Method, CFTRI Method, Pressure Parboiling Method are 9.54×10^5 J/kg, 16.4×10^5 J/kg, 3.75×10^5 J/kg respectively. The hot water requirement was estimated about 1,200 kg (1.2 times the weight of paddy) to soak one ton of paddy. About72,000 kcal (83.72 kWh) heat is required to raise the temperature of water from25°C – 85°C. As soon as soaking of paddy is done the steaming operation is carriedimmediately, requires the heat about 21000 kCal/kg (24.42 kWh) per ton of paddy. The drying ofone ton of paddy consumes about 137000 kCal energy and requires minimum hot airtemperature about 80°C to the extent of air flow velocity about 50 m3/ min for 40h.Therefore, the total energy required for complete parboiling operation for ton of paddy isabout 2,30,000 Kcal. [9]

Table 1. Process wise energy consumption

Sr. No	Operations	Temperature Range (°C)	Energy Consumption MJ per tonne of paddy	Reference
1.	Soaking	25-85	301	[9]
2.	Steaming	100-120	88	[9]
3.	Drying	80	573	[9]
Total Energy Requirement = 962 MJ per tonne				

ENERGY PRODUCTION IN RICE MILLS

Basically, there are two techniques of energy production systems in rice processing industry which are commercially available are as follows: -

1. Gasification: -

The gasification is a thermos-chemical conversion of biomass. The gasification of biomass involves the combustion of biomass in presence of limited air supply (approximately 1/3rd of air supply). This produces a mixture of combustible gases known as

producer gas. The gasification includes irritation of biomass such as rice husk, peanut shell, pigeon stalks, etc.
It consists of:
(a)The conversion of carbon into carbon monoxide, and carbon dioxide,oxidation of carbon dioxide in carbon monoxide,
(b) release of H2 from chemical bonding,
(c) formation of methane gas (CH_4) in small quantity.
Researchers have estimated theconversion efficiency of the gasification process which is generally around 70–80%. Thethermodynamic efficiency of the thermal engine working on producer gas was about 37%.The alternator is coupled to the shaft of thermal engine working on the producer gas allowsthe power output with efficiency about 93%. [10]

2. Direct Burning: -
The direct combustion of solid fuel is the most adopted method of energy production.

Prolonged burning of solid fuels produces flue gaseous substances and a solid residue consist of carbon and ash. Direct combustion of solid carbon contained in the fuel bed and burning of combustible gases in the furnace space or in the combustion chambers occurs simultaneously.

In the furnace space and in gaseous combustible cases, the air is supplied through the bed for the burning of fuel and partly in the furnace space on the fire bed. To ensure complete combustion of solid fuel, the furnace is always supplied with excess air. It estimated that about 200 kg of husk is obtained when one ton of paddy is processed. This can produce 660 kg of steam which can used to generate 100 kWh of electricity through a steam turbine. But for processing of one tonne of paddy consumes about 65 kWh of electricity, thus remaining 35 kWh as excess energy.[10]

III. RESULT AND DISCUSSION

CASE STUDY
Name of Industry:A leading rice industry in Andhra Pradesh
Capacity: 18 tons per hour
No. of Working Hrs: 16
Longitude & Latitude: 82.19°E & 16.90°N.

➢ **Thermal Energy Requirements for Various Processes:**

1. Soaking:
The energy required to process one ton of paddy for soaking is 72000 kCal.
= 72000 × 00.00116222……………...[1kCal=00.00116222kWh]
= 83.68 kWh/t
Here we process 18 tons in 1hr;
So,
= 83.68 × 18
= 1506.24 kWh/hr.
The existing industry is working for 16hrs a day;
Hence for one day,
= 1506.24 × 16
= 24099.84 kWh/day

2. Steaming:
The energy requirement to process one ton of paddy for steaming is 21000 kCal.
= 21000 × 0.00116222
= 24.40 kWh/t
For 18 tons;
= 24.40 × 18
= 439.2 kWh/hr
For one day;
= 439.2 × 16
= 7027.2 kWh/day

3. Drying:
The energy requirement to process one ton of paddy for drying is 1,37,000kCal[10].
=137000 × 0.00116222
= 159.22 kWh/t
Now for 18 ton;
=159.22 × 18
= 2866.034 kWh/hr
Now for one day;
= 2866.034 × 16
= 45855.36 kWh/day.

4. Total thermal energy requirement;
Total thermal energy requirement = 24099.84 + 7027.2 + 45855.36
= 76982.4
=77000 kWh/day

Specifications of Proposed System:
➢ **Evacuated Type Solar Collector:**
We have selected Evacuated tube type solar collector to satisfy the thermal requirements of industry.

Advantages of ETC:
1. No solar tracking is needed due circular shape of collector always ensure the normal surface to the solar radiations.
2. Temperature between 50 to 200°C can be achieved.
3. More thermal efficiency as compared to flat plat collector.

1. Heat collecting surface area:
We know that;
The efficiency of collector is given by;

$$Ac = \frac{qu}{\eta \times Ic}$$

Where,
Ac= Heat collecting area (m^2).
Ic= Average horizontal solar irradiation (kWh/m^2/day).
qu=Useful energy converted by the collector (kWh/day).

$$Ac = \frac{qu}{\eta \times Ic}$$

$$Ac = \frac{77000}{0.4 \times 4.8}$$

$$Ac = 40104.167$$

$$\boldsymbol{Ac \approx 40105\ \mathrm{m}^2}$$

2. Hot Water Requirements:

The water requirement for soaking process is about 1.3 times of the weight of paddyand for steaming 200 kg/ton
Here we process about 18 tons/hr so the water requirements will be;
= (1300 + 200) × 18
=27000 kg/hr
Now water requirements for 16hrs;
= 27000 × 16
=432000 kg
i.e.$\boldsymbol{432000 litres}$.

3. Number of units required

Here we have assumed that average sunshine hours are 8hrs/day. So that we can
satisfy the hot water requirements for only 8hrs in a day. Now hot water requirements for
8hrs are;
=$Hotwaterrequirementsinone\ hr \times noof\ hrs$
=27000 × 8
=216000 kg/day
We have selected the unit having hot water storage capacity of 500 litters i.e. 500LPD
Hence the number of unites required became;
=$\frac{216000}{500}$
= 432 $units$

4. Cost of Proposed System

Cost per unit: 70000 $Rs/Unit$
Total cost:
= 70000 × 432
= $\boldsymbol{30240000 Rs}$.

➢ **Biomass as a Source of Renewable Energy:**

The ETC System will satisfy the hot water requirements for daytime i.e. for 8hrs. So, for remaining 8hrs, biomass is used as a fuel.

1. Heat requirements for one day:

Here we have taken 8hrs in a day.
So total Heat Requirements for 1 ton; = (Heat requiredfor Soaking) +(Heat requiredfor Steaming) + (Heat requiredfor Drying)
=301 + 88 + 573
=967 MJ/t
Then heat required for 18ton and for 8hrs/day;
=962 × 18 × 8
=138528 MJ/day
=138528 × $10^3 kJ/day$

2. Biomass Requirements:

Here the heat supplied by burning the biomass is equals to the heat requirements of
one day.
We have,
($HeatSupp$lied) = ($MassofBiomass$) × ($CalorificValueofBiomass$) × ($CombustionEfficeincy$)
138528 × 103= ($MassofBiomass$) × (12261 × 0.8)
($MassofBiomass$) = 13785.52
$\boldsymbol{\approx 13800 kg}$

3. Cost of Project:

Cost per kg of biomass:1.20 Rs/kg
Total cost of project = 1.20 × 13800
= $\boldsymbol{16560 Rs}$.

Energy Requirement of Electrical Energy:

The total electrical energy required for cleaning, drying, milling, grading and packaging, office and boiler in rice mill was approximately 238 MJ/t paddy in a parboiled rice mill. The following system is designed by PVSYST Software. The system designed below is to satisfy the electrical energy required for daytime i.e. 8hrs; Now electrical energy consumed to process one ton of paddy;
=238 × 0.2778…………………[1MJ=0.2778kWh]
=66.11 kWh/t
We process 18 tons per so that energy requirement for the process;
=66.11 × 18
=1190.095 kWh/hr
Here we have assumed that the working hours of the plant is 16 hrs so energy requirements for 16hrs;
= 1190.095 × 16
= 19041.52
≈ 19042 $\boldsymbol{kWh/day}$

Specification of Proposed PV System:
The following system is designed by considering the average sunshine hours are 8hrs/day so that energy required for the 8 hrs is as follow;
= $(EnergyRequiredfor\ 1h\ r) \times No.\ of Hours$
= 1190.095 × 8
=9521 $kWh\ /day$
Proposed PV Array Characteristics;
PV Module: Si-Mono
Model: LR5-66 HPH 480 M
Unit Nominal Power: 480 kWp (50ºC)
Manufacturer: Longi Solar
No. of Modules:19788
In Series: 17 Modules
In Parallel: 1164 Strings
Module Area: 46476 m

Inverter Specification:
Model: Free Sun FS0630 HES 330V
No of Inverters: 12Units

System Results:
Produced Energy: 14526 MWh/Year
Performance Ratio: 83.40%

Cost of the Project:
Average cost per Watt: 41.15 Rs/Watt
Total Cost of project:
= (9520.76 × 103) × 41.15
=391788794.76
$\approx \mathbf{391800000} \boldsymbol{Rs.}$

Biomass for Electricity Generation:

The system designed above can satisfy the electrical energy requirement for only daytime about 8 hrs. Therefore, for remaining 8hrs, biomass is used to produce the electrical energy. It is estimated that by processing on 1 ton of paddy we get about 200 kg of rice husk which can produce up to 660 kg of steam. This steam is capable to produce 100kWh electricity. Then quantity of rice husk requires to produce 1kWh energy;

Rice Husk required =$\frac{200}{100}$

= $2\ kg/kWh$
Now electrical energy requirements for 18tons for 8hrs/day;
=66.11 × 8 × 18
=9519.84 ~$\mathbf{9520} \boldsymbol{kWh/day}$
Hence quantity of biomass required is,
= 2 × 9520
= 19040 kg
Cost of Project:
Cost per kg: 1.2 $Rs.\ /kg$
Total Cost: 19040 × 1.20
= $\mathbf{22848} \boldsymbol{Rs}$.

IV. CONCLUSION

The case study deals with a leading rice processing plant in Andhra Pradesh and has processing capacity of 18 tons/hr. The approximate requirement of thermal and electrical energies is 77000 kWh/day, 19042 kWh/day respectively along with the hot water requirement of 432000 litres per day. Currently, these energy requirements are fulfilled by direct burning of solid fuel that can be rice husk or any other fossil fuel. The burning of these solid fuels can leads to the high carbon emission which contributes in global warming and these are exhausting rapidly. So, to reduce the dependency on these fossil fuel the solar and biomass based renewable energy conversion technologies are proposed.

To satisfy the thermal energy requirements Evacuated tube solar water heater is designed. The proposed system to satisfy the daily water requirements consumes the heat collecting surface area about 40105 m2 and 432 unit of evacuated tube solar water heater having capacity of 500 litres per day. The cost of 432 units is about Rs. 30240000 and installation cost along with labour charges are added. The ETC system is used to satisfy the energy requirement at daytime when there is good solar irradiation and for remaining 8hrs biomass is used to fulfil the energy requirements. The rice husk is taken as biomass, which consumes about 13800 kg per day and costs about Rs. 16560.

Similarly, to satisfy the electrical energy requirement Solar PV system is designed by using PVSYST software. The electrical energy requirements of rice mill are about 19042 kWh/day. The proposed PV system can satisfy the energy demand of 8hrswhich is about 9521kWh. The designed system uses 19788 number of Si-Mono type modules. To install this system requires area of about 46476 m2 and this system has capacity to produce about 14526 MWh/year of electrical energy with the performance ratio of about 83.40 %.

There are many challenges associated in adopting renewable technologies which includes mainly Initial investment, Lack of Infrastructure, Reliability of resources, etc. the utilization of renewable energy conversion technologies can also help in sustainable development and reduces the dependency on use of fossil fuels.

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