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International Journal of Electrical and Electronics Research (IJEER)
Case Study | Volume 12, Issue 2 | Pages 611-616 | e-ISSN: 2347-470X

The Potential of Rice Husks for Electrical Energy Generation in Cambodia

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ABSTRACT- The purpose of this study was to ascertain the electrical potential of rice husk as a viable fuel source for electricity generation in Cambodia. The rice husk potential in Cambodia for each year was determined by analyzing statistical data on rice output from 2000 to 2021. The results indicate a significant 120% improvement in the capacity of rice husk to be transformed into power during a span of 22 years. On average, about 5.4% per year. Annual husk potential was calculated using 2019 statistical data. In 2019, there is a potential of about 1,741 million tons of husks, equivalent to about 864,408 tons of coal, which provides electricity and a potential of about 6,483 GWh and 740,075 MW. This potential can be turned into fuel to use rice husk as a fuel to convert into local electricity and contribute to reducing coal consumption and negative environmental impacts in Cambodia. Despite the carbon emissions associated with rice husk, its overall positive impact surpasses that of coal-fired power plants. In this paper, however, the economic analysis of rice husk for electricity generation is not studied.

Keywords: Rice husk, fuel, energy potential, electrical energy, power generation.

ARTICLE INFORMATION

Author(s): Sophea Nam, Vanna Torn, Chivon Choeung and Horchhong Cheng;

Received: 09/05/2024; **Accepted**: 31/05/2024; **Published**: 25/06/2024;
e-ISSN: 2347-470X;
Paper Id: IJEER 0905-08;
Citation: 10.37391/IJEER.120237
Webpage-link:
https://ijeer.forexjournal.co.in/archive/volume-12/ijeer-120237.html

crossref member CROSSREF.ORG THE CITATION LINKING BACKBONE

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1. INTRODUCTION

Today, electricity is the most important energy for humanity in the world that needs to be used. In developed countries, developing countries are all needed to operate their major sectors. Thus, researchers are looking for various energy sources that can generate electricity. Rice husk refers to the outer layer of rice grains that is removed when the grains are milled. In Cambodia, where agriculture is a dominant sector, there is an abundance of rice husks which are commonly seen as a byproduct with little value. Nevertheless, because of the rising need for sustainable energy sources, there has been a surge in interest in using rice husks as a viable renewable energy source. This has the capacity to not only decrease waste but also offer a dependable and ecologically sustainable energy alternative for the nation. The production of electricity can be drawn from various energy sources, such as hydropower, solar energy, fossil fuels, biomass power. Cambodia is a developing country with a high demand for electricity, but domestic power generation does not yet supply enough, making it necessary for Cambodia to buy electricity from neighbouring countries such as Thailand, Laos, and Vietnam [1]. Biomass is a source of renewable energy that comes from agricultural waste, human waste, and manure and can be converted into electricity. Rice husk (HR) serves as a significant energy resource to produce electricity [2]. Multiple studies have been conducted on HR to transform it into sources of energy [3]. The utilization of HR in direct combustion has mostly been employed for the purpose of enhancing efficiency and addressing environmental concerns [4]. It's worth mentioning that there are two rice husk power plants in Cambodia, namely SOMA with a 1.5 MW power plant and Angkor with a 2 MW power plant. The combustion of HR results in much lower emissions of CO2, SOX, and NOX compared to the combustion of coal and oil [5]. The mining activities of coal leads to deforestation and habitat destruction. Furthermore, the disposal of coal ash waste and its impact on soil quality and water contamination is another critical issue that arises from coal mining operations. Countries in Asia, like Cambodia, account for over 92% of the total renewable heat (HR) production, with a calorific value (CV) ranging from around 12 to 18 MJ/kg. In contrast, European countries provide only around 0.5% [6]. The objective of this study was to ascertain the electrical potential of rice husk as a viable fuel source for the generation of electricity in Cambodia. The rice husk potential in Cambodia for each year was determined by analyzing statistical data on rice output from 2000 to 2021. The findings indicate a significant 120% improvement in the capacity of rice husk to be transformed into power during a span of 22 years. The number of farming families is about 2/3 of the total number of households in the country [7]. According to the 2019 census in the Kingdom of Cambodia by the National Institute of Statistics, Ministry of Planning, using the de facto method as of March 3, 2019, there were 15,288,489 people (These figures do not include overseas workers).

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Coal-fired power plants release harmful pollutants like sulphur dioxide and nitrogen oxides, which can cause respiratory issues and other health problems in nearby communities. Mining activities leading to deforestation and habitat destruction. Disposal of coal ash waste and its impact on soil quality and water contamination is another critical issue that arises from coal mining operations.

2. MATERIALS AND METHODS

2.1. Study region and Cambodia electrification ratio

Most of the households in Cambodia grow rice, and most of these families are smallholder farmers. The average farmland per household is about 1.30 hectares, while the average farmland per household is 0.50 hectares, and the largest is 71 hectares. There exist 90% of households have less than 3 hectares of land for rice cultivation. In 2019, the total cultivated area of the country reached 3.328 million hectares, of which 2.731 million hectares were rain-fed rice, the total harvested area was 3.263 million hectares, and 2.671 million hectares were rain-fed rice. The amount of rainy-season rice harvested was 10.885 million tons. The area under dry season rice cultivation is 0.597 million hectares, and the area under dry season rice harvest is 0.592 million hectares. The total dry-season rice yield was about 2.616 million tons and dry-season rice yield was 4.41 tons/ha. The map of rice-producing region in Cambodia can be found in *figure 2*.

According to *figure 1*, rice production (PR) increased every year for 22 years (2000–2021), except in 2002 and 2004. In 2002, rice production decreased by about 6.7%, then increased by about 23% in 2003. In 2004, rice production decreased by about 11.4%, then increased by about 20% in 2005, and in 2006 it continued to increase by 24.7%. Overall, PR and HR potentials have increased by about 120.7% in 22 years, or an average of about 5.4% per year, according to data from 2000 to 2021. And these data show that rice yield (PR) has increased, so the energy potential of rice husk (HR) has also been shown to increase over the years [8].

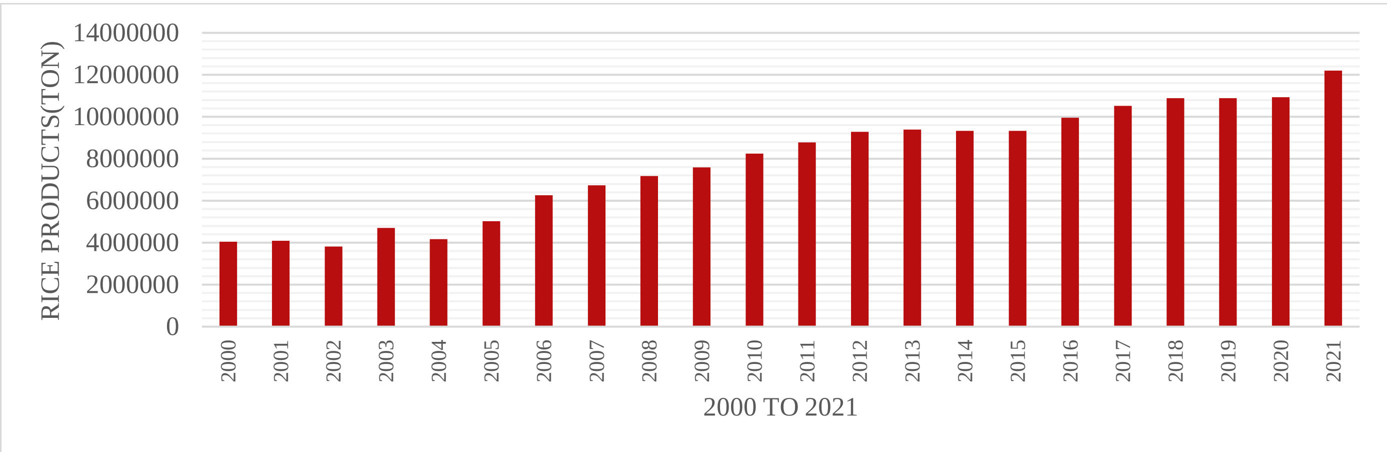

Figure1. Rice production data (PR) from 2000 to 2021

2.2. Proximate and ultimate analysis with energy and economic potential of rice husk

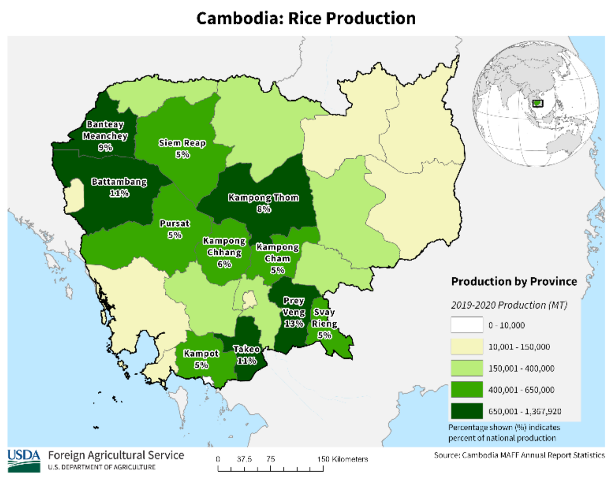

Figure 2. Map of rice production in Cambodia [12]

An evaluation was conducted to assess the suitability of HR as a fuel source for power plants, using proximate, ultimate, and calorific value assessments. A proximate analysis was performed to determine the levels of moisture, ash, volatile matter, and fixed carbon. A comprehensive study was conducted to ascertain the levels of carbon, hydrogen, oxygen, nitrogen, and sulphur. An investigation of the calorific value (CV) was conducted to quantify the energy content of HR. The energy content of a fuel is a crucial factor in evaluating its suitability for usage in power plants [9]. The proximate analysis was conducted according to the ASTM D 3172–3175 and ISO 565 standard procedures, whereas the ultimate analysis was conducted according to the ASTM D 3176, ASTM D 4239, and ASTM D 5373 standard processes. The CV of HR was tested using the ASTM D.5865 standard protocol, which involved the use of a bomb calorimeter. This strategy is consistent with prior research [10] [11].

Rice and husk production was assessed based on the area of the field, which was collected by farmer households. Average rice production per household is calculated based on the area of rice fields occupied or leased by farming families in both the dry and wet seasons. Cambodia's average total rice yield in 2019 and 2020 was about 3.3 tons per ha [13]. Husk-to-grain (*HGR*) ratio value and *HR* production are the foundations of rice husk potential (*HR*). This is approximately 0.2 [14] [15] [16] [17], but it can increase to 0.23–0.33 [18], meaning that *PR* will generate 20%–33% *HR*. It is expected that 100% of the *HR* that is converted from rice products (*PR*) is used as fuel based on the data above. Therefore, the formula *HR* = *HGR* × *PR* can be used to find the potential of *HR*. Nevertheless, during the grinding process, some *HR* is lost. It is estimated that roughly 20% of *HR* is lost. This indicates that only roughly 80% of PR's potential is available for use as fuel from *HR*. Consequently, the following formula determines the potential of *HR* that can be used as fuel:

$$HR = EC \times HGR \times PR \tag{1}$$

Where *EC* represents the efficiency of rice husk collection = 80%, *HGR* denotes the husk-to-grain ratio = 20%, *PR* represents rice production.

The electric potential energy (EPE_{HR}) and PE_{HR} can be determined using the techniques of [6] [19]. The following equation can be used to find the PE_{HR}:

$$PR_{HR} = N_{HR} \times VC_{HR} \tag{2}$$

where N_{HR} denotes the quantity of *HR* and VC_{HR} represents the calorific value of *HR*, which is 13.44 MJ/kg.

The EPE_{HR} generated can be calculated using the equation:

$$EPE_{HR} = \frac{PE_{HR}}{CF} \tag{3}$$

where *CF* is the factor of conversion for J to Wh. The equation bellow can be used to determine the electrical power potential of rice husk:

$$PP_{HR} = \frac{EPE_{HR}}{CF_P} \tag{4}$$

where CF_P represents the factor of conversion to obtain electrical power potential.

The economic potential of using *HR* as a fuel source for power plants can be assessed by comparing the energy content of *HR* to that of coal. The equation can be used to get the corresponding value of HR when coal (Eq_{Coal}) is considered as:

$$Eq_{Coal} = \frac{PE_{HR}}{CV_{Coal}} \tag{5}$$

where Eq_{Coal} denotes the calorific value of coal, which is 27.0 MJ/kg.

2.3 The rice husks' calorific value

The EPE_{HR} was calculated using the low calorific value (*LCV*) of *HR*, which was 13.4 MJ/kg based on the experiment results. The lower calorific value (*LCV*) of a substance is a measure of the amount of heat released when the substance is burned completely, with the resulting products being cooled back down to the temperature of the initial reactants. This value accounts for the heat that is lost as a result of the water vapor produced during the combustion process condensing into liquid water. In other words, *LCV* represents the maximum amount of energy that can be extracted from a fuel source. The *LCV* fell between the range of values found in earlier research, which were 12.34 MJ/kg [20] and 13.30 MJ/kg [21]. 13.42 MJ/kg [22], 13.48 MJ/kg [23]. It is evident that the *LCV* of *HR* found in earlier research ranges from roughly 12.34 to 14 MJ/kg. There is considerable variation in the higher calorific values (*HCV*) of *HR*, ranging from approximately 14.61 MJ/kg [24] to 14.98 MJ/kg [25] to 15.84 MJ/kg [18]. 16 MJ/kg [26], 16.05 MJ/kg [27], and 16.59 MJ/kg [28]. *Figure 2* shows the *CV* of *HR* together with a few different fuel sources.

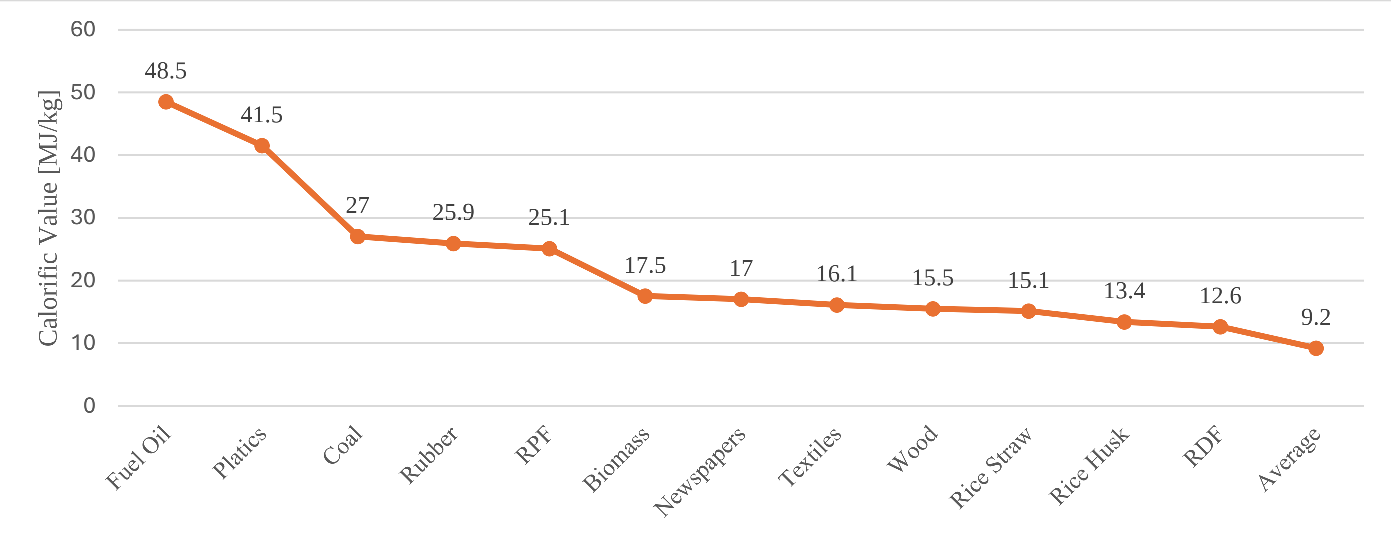

Figure 2. Calorific values of some types of fuel

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3. RESULT AND DISCUSSIONS

An estimation of HR potential for 22 years (2000–2021) was performed using *equation (1)*. *Equation (2)* is used to create power potential with an LCV of 13.4 MJ/kg. *Equations (3)* and *(4)* were used to calculate EPEHR and PPHR, respectively, and *equation (5)* showed that the husk potential was equal to the amount of coal. Is shown in Table 1 [13] [8]. PR increased every year for 22 years (2000–2021), except in 2002 and 2004. In 2002, rice production decreased by about 6.7% due to the drought, which completely damaged some seedlings and rice, then increased by about 23% in 2003 with sufficient water. In 2004, rice production decreased by about 11.4% due to the same drought crisis as in 2002, but it suffered more damage, then increased by about 20% in 2005 and continued to increase by 24.7% in 2006. Overall, PR and HR potentials have increased by about 120.7% in 22 years, or an average of about 5.4% per year, according to data from 2000 to 2021. And these data show that rice yield (PR) has increased, so the energy potential of rice husk (HR) has also been shown to increase over the years. Additionally, the use of rice husk has the capacity to not only decrease waste but also offer a dependable and ecologically sustainable energy alternative for the nation. On top of that, the utilization of rice husk aids in the conservation of natural resources and enriches the income of rice farmers by enabling them to sell rice husk for power generation purposes.

The process of converting rice husks into energy involves several methods such as direct combustion, biomass gasification, anaerobic digestion, pyrolysis, palletization, and co-firing. In general, direct combustion is widely regarded as the most convenient process for generating electrical energy [29].

Although the use of rice husk has significant positive impacts on society and the environment, it is crucial to consider logistical challenges, transportation costs, emissions during the conversion process, and the limited supply of rice husk during certain seasons. The collection, storage, and transportation of rice husk pose logistical challenges, particularly in regions with inadequate infrastructure. Furthermore, the expense associated with transporting rice husk to the power plant might be substantial, especially if the plant is situated a considerable distance away from the husk's origin. Although burning rice husk for electricity generation is typically seen as environmentally favorable in comparison to fossil fuels, it nevertheless emits substances like carbon dioxide and particulate matter. These emissions must be carefully controlled to limit their influence on the environment. Rice husk availability is subject to seasonality, contingent upon the date of the rice harvest. This can have an impact on the uninterrupted functioning of power plants that depend on rice husk as a fuel source.

Table 1. Electricity and potential of rice husks from 2000 to 2021

No	Years	*PR* (ton)	*HR* (ton)	Eq_{Coal} (ton)	PE_{HR} (TJ)	EPE_{HR} (GWh)	PP_{HR} (MW)
1	2000	4 040 900	646 544.00	320.877	8.664	2.407	274.724
2	2001	4 099 016	655 842.56	325.492	8.788	2.441	278.675
3	2002	3 822 509	611 601.44	303.536	8.195	2.277	259.876
4	2003	4 710 957	753 753.12	374.085	10.100	2.806	320.278
5	2004	4 170 284	667 245.44	331.151	8.941	2.484	283.520
6	2005	5 021 146	803 383.36	398.716	10.765	2.990	341.367
7	2006	6 264 123	1 002 259.68	497.418	13.430	3.731	425.871
8	2007	6 727 127	1 076 340.32	534.184	14.423	4.006	457.349
9	2008	7 175 473	1 148 075.68	569.786	15.384	4.273	487.830
10	2009	7 585 870	1 213 739.20	602.374	16.264	4.518	515.731
11	2010	8 249 452	1 319 912.32	655.068	17.687	4.913	560.846
12	2011	8 779 365	1 404 698.40	697.147	18.823	5.229	596.872
13	2012	9 290 940	1 486 550.40	737.769	19.920	5.533	631.652
14	2013	9 389 961	1 502 393.76	745.632	20.132	5.592	638.384
15	2014	9 324 416	1 491 906.56	740.428	19.992	5.553	633.928
16	2015	9 335 284	1 493 645.44	741.291	20.015	5.560	634.667
17	2016	9 952 270	1 592 363.20	790.284	21.338	5.927	676.613
18	2017	10 518 339	1 682 934.24	835.234	22.551	6.264	715.098
19	2018	10 891 735	1 742 677.60	864.884	23.352	6.487	740.483
20	2019	10 885 733	1 741717.28	864.408	23.339	6.483	740.075
21	2020	10 935 619	1 749 699.04	868.369	23.446	6.513	743.467
22	2021	12 206 988	1 953 118.08	969.325	26.172	7.270	829.902

4. CONCLUSION

With *HR* increasing at an average rate of 5.4% year during the past 22 years, or by nearly 120%, Cambodia offers enormous energy potential. *HR* potential is expected to be at 12.206 million tons in 2021, or roughly 969,325 tons of coal. This corresponds to an approximate 7,270 GWh electric potential and an approximate 829,902 MW electric potential. The possible use of *HR* as fuel for power plants can lessen Cambodia's reliance on coal and its detrimental effects on the environment. Furthermore, using rice husk helps preserve natural resources and increase revenue for rice farmers through the sale of rice husk for power generation. Further investigation into the utilization of rice husks for electricity production should involve doing a comprehensive life-cycle assessment of energy production using rice husks, as well as performing an economic analysis and evaluating the environmental impact.

Author Contributions: Conceptualization, S.N.; methodology, S.N.; software, S.N., C.C; validation, S.N., V.T.; formal analysis, S.N.; investigation, S.N.; resources, C.C., V.T.; data curation, S.N., C.C.; writing—original draft preparation, S.N.; writing—review and editing, C.C.; visualization, V.T.; supervision, H.C.; project administration, H.C.; All authors have read and agreed to the published version of the manuscript.

Acknowledgments: This work is supported by National Polytechnic Institute of Cambodia.

Conflicts of Interest: The authors declare no conflict of interest.

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