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Abstract: Pakistan has been experiencing energy crisis owing to its sole dependence on fossil fuels. Reduction in local fossil fuel reserves has led to an increase in their prices, thereby increasing the cost of electricity. Since the tariff remains the same, Pakistan is over-burdened with circular debts and observes a daily power shortfall of about 12–14 h. Being an Agra-economic country, many major and minor crops are produced and exported in large quantities. This results in a bulk of the agricultural waste which are not utilized. The waste can be utilized to meet the country's energy demand while mitigating climate change and its impact. The study examines the electricity production potential and social benefits of rice husk in Pakistan. It is estimated in this study that if 70% of rice husk residues are utilized, there will be annual electricity production of 1,328 GWh and the cost of per unit electricity by rice husk is found at 47.36 cents/kWh as compared to 55.22 cents/kWh of electricity generated by coal. Importantly, the study will increase the awareness of the benefits of utilizing agricultural waste for useful products such as silica, with several social and environmental benefits such as a reduction of 36,042 tCO_{2e}/yr of methane, reducing

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PUBLIC INTEREST STATEMENT

Increasing population has resulted in increasing demand for energy which has a role to play in economic growth and human development. Nevertheless, there is a global crusade for universal access to clean and affordable energy and its related services while mitigating climate change and its impact. Pakistan as an agrarian country has being battling with agricultural waste disposal which has resulted in poor air quality due to burning of such residues. However, residues from agriculture have a potential of producing electricity and other social benefits. The study examines the electricity production potential and social benefits of rice husk in Pakistan. The study will increase the awareness of the benefits of utilizing agricultural waste (rice husk) for useful products with several social and environmental benefits such as reducing carbon dioxide emissions, improving air quality, and decreasing unemployment rate.

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carbon dioxide emissions, improving the air quality, and providing 4.5 k new jobs. The paper concludes with the policy recommendations based on this study.

Subjects: Bio Energy; Clean Tech; Clean Technologies; Environmental; Renewable Energy; Traditional Industries - Clean & Green Advancements

Keywords: biomass; rice husk; renewable energy; energy demand; power generation; agricultural waste; Pakistan; climate change; fossil-fuel reduction; environmental sustainability engineering

1. Introduction

There is a growing need for clean energy technologies throughout the world to meet energy demand due to a global decline in fossil fuel reserves within the last decades (S. Asumadu-Sarkodie & P. A. Owusu, 2016e). The need for energy and its related services to satisfy human need; social and economic development, welfare and health is increasing (Owusu & Asumadu-Sarkodie, 2016; Owusu, Asumadu-Sarkodie, & Ameyo, 2016). Energy development is closely linked with the economic development of a country. Supplying the energy demand for residential use, industrial use, and commercial use will directly affect the economic growth of a country (S. Asumadu-Sarkodie & P. Owusu, 2016). However, the inadequate energy supply, power outages, and load shedding have become challenging in developing and least developing countries due to increasing population and energy demand (S. Asumadu-Sarkodie & P. A. Owusu, 2016d). Pakistan's current generation capacity is not enough to keep up with its ever-increasing demand, causing an electricity shortage of up to 4,500–5,500 MW. This has caused the supply and demand gap to increase dramatically over the past 5 years (Ministry of Water & Power, 2013). Figure 1 shows the main sources of electricity production in Pakistan. The main sources of electricity production are hydro, thermal, and nuclear with 6,858, 15,440, and 750 MW installed capacity, respectively. During July–March 2013–2014, the installed capacity of electricity was 23,048 MW. Thus, the hydropower capacity accounts for 29.7%, thermal 67.0%, and nuclear 3.3%. Nonetheless, the power production is practically 50% of installed capacity (Ministry of Finance, 2013).

Owing to the major reliance on thermal fuel sources, the cost of electricity production is extremely high (i.e. PKR 12/unit). The cost of supplying electricity per unit to the customers has been set at Rs. 14.70 by the NEPRA. This shows that PKR 2.70 per unit must be added as a subsidy to meet the cost of electricity production (Ministry of Water & Power, 2013). According to Yasmeen and Sharif (2014)

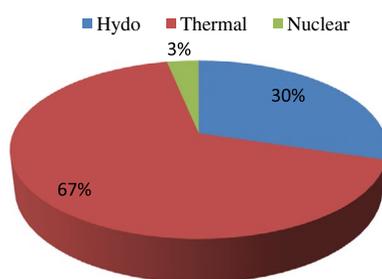**Figure 1. Electricity production in Pakistan (Ministry of Finance, 2013).**

Table 1. Circular debt due to expensive power generation	
Date	**PKR (billion)**
1 June 2009	214
30 June 2009	216
18 May 2010	120
2014–2015	250

the present power crunch has affected the entire country including the industrial sector such as: small-scale to large-scale enterprises, exports and employments causing business to lose almost 157 billion rupees while 400,000 employees losing their jobs (Yasmeen & Sharif, 2014). Due to a rise in international oil price in 2008, the condition became more problematic. As the subsidy element (difference between cost and tariff) increased, enormous quantity of circular debt was created whereby power generation companies could not disburse payment to the fuel suppliers as a result of non-payments from supplier-companies (Ministry of Finance). Table 1 shows the circular debt due to expensive power generation.

This circular debt resulted in disruption of power supply causing an increase in demand and supply gap. Utilization of Biomass such as rice husk can provide a solution to this problem. Pakistan as an agrarian country has been battling with agricultural waste disposal which has resulted in poor air quality due to burning of such residues. However, residues from agriculture have a potential of producing electricity and other social benefits. As suggested by some studies, heat and power generation from combustion of Biomass has now become mature technology offering the solution of sustainable fuel and waste disposal (Amer & Daim, 2011). This combustion of biomass is an efficient and environmental friendly approach of disposing of the public waste which is gathered in huge amounts each day in different towns and cities of the country (Ashraf Chaudhry, Raza, & Hayat, 2009). According to S. Asumadu-Sarkodie and P.A. Owusu (2016b) the development and adoption of a renewable energy technology like biomass power plant will save costs on buying the conventional type of fuel (fossil-based) and result in a large techno-economic potential for climate change mitigation which will satisfy the sustainable development goals (S. Asumadu-Sarkodie & P. Owusu, 2016; S. Asumadu-Sarkodie & P. A. Owusu, 2016c).

There are a few existing studies in literature that have investigated biomass energy potential particularly in Pakistan. Mirza, Ahmad, and Majeed (2008) investigated biomass energy utilization in Pakistan, discussed the different dimensions of producing electricity in the rural areas through biomass. They concluded that biomass is a clean and cost-effective fuel option with tremendous potential for application in Pakistan. However, there is a need to allocate necessary resources for improving these technologies through a widespread dissemination plan. Bhutto, Bazmi, and Zahedi (2011) highlighted the issues and challenges in the efficient and effective utilization of biomass as an energy source in Pakistan. They focused on electricity production, industrial, and domestic fuels. They identified areas that require attention for establishing and improving biomass energy production and delivery system. Zuberi, Hasany, Tariq, and Fahrioglu (2013) examined the potential of two major biomass energy resources available in Pakistan: Livestock and Bagasse. They determined that biomass resources in Pakistan are capable of contributing 42% of the power portfolio of the country. They also suggested that utilizing this technology can contribute immensely toward raising the economy, reducing not only the oil and natural gas imports and carbon emissions but also the fraction of unemployment by 17.1%.

This study, however, narrows down the focus to rice husk in particular and examines the electricity production potential and social benefits of rice husk in Pakistan. The study will increase the awareness on the benefits of utilizing agricultural waste (rice husk) for useful products with several social and environmental benefits such as reducing carbon dioxide emissions, improving air quality, and decreasing unemployment rate.

2. Energy generation methods from rice husk

Although carbon dioxide (CO_2) is produced by combustion of biomass such as rice husk, the carbon produced is absorbed by the plants by the process of photosynthesis. Hence, the combustion of biomass and biogas reduces the global warming effect since CO_2 net emission becomes zero. While combustion of conventional fossil fuels adds an extra amount of CO_2, causing global warming.

Several methods have been formulated for energy extraction from biomass, which includes liquefaction, anaerobic digestion, alcoholic fermentation, trans-esterification, pyrolysis, direct combustion,

and gasification. Each technology has its own advantages, depending on the economics of biomass availability and the end product desired (Mirza et al., 2008). The end product could be either power/heat, transportation fuel, or chemical feedstock. The various options of biomass utilization are shown in Figure 2 (Cheng, 2009). Currently there are two methods used for producing heat and electrical power from rice husk (waste of rice mills) namely gasification and direct combustion. S. Asumadu-Sarkodie and P. A. Owusu (2016b) analyzed the feasibility of biomass heating system in Middle East Technical University, Northern Cyprus campus using rice straw as the main source of fuel. They reported the economic feasibility, GHG emission reduction, and the advantages of using the proposed technology. It is reported that direct combustion (Steam turbine) consumes 1.3 kg of rice husk per kWh electricity while 1.86 kg of rice husk consumes per kWh of electricity by gasification (Islam & Ahiduzzaman, 2013).

Several other methods have also been introduced for the conversion of agricultural byproducts such as rice husk into electrical energy. Straw-fired power station started its operation in 2000 at Sutton, Ely in Cambridge shire with an output capacity of 36 MW, and the cost was £60 M. Yearly 200 thousand tons of straw are utilized. The annual electric output by conventional steam turbine and generator was over 270 GWh/year (Boyle, 2004).

A rice husk power system was installed in India, which required sack loads of rice husk or other biomass residues poured into the gasifier hopper for every 30–45 min. The biomass then burn in a restricted supply of air to produce an energy-rich gas. The gas passes through a series of filter for cleaning, after which the gas is used as the fuel engine that drives the electricity generator. Electricity is then distributed to customers via insulated overhead cables (Pandey, 2011).

EGCO Group (2006) carried out a Green Power Project in Rio Et that used rice husk as the primary fuel for an SPP-Renewable Power plant to generate electricity. This pilot project had a 10 MW capacity, which uses 225 tons of rice husk and 1,400 tons of water in a day. The plant has a power requirement of 1 MW and its net power output is about 8.8 MW (Chungsangunsit, Gheewala, & Patumsawad, 2005).

Denmark has the largest biomass-fired combined heat and power plant with a capacity of 26,000 MWh of electrical power and 50,000 MWh of heat each year at very favorable prices. In this

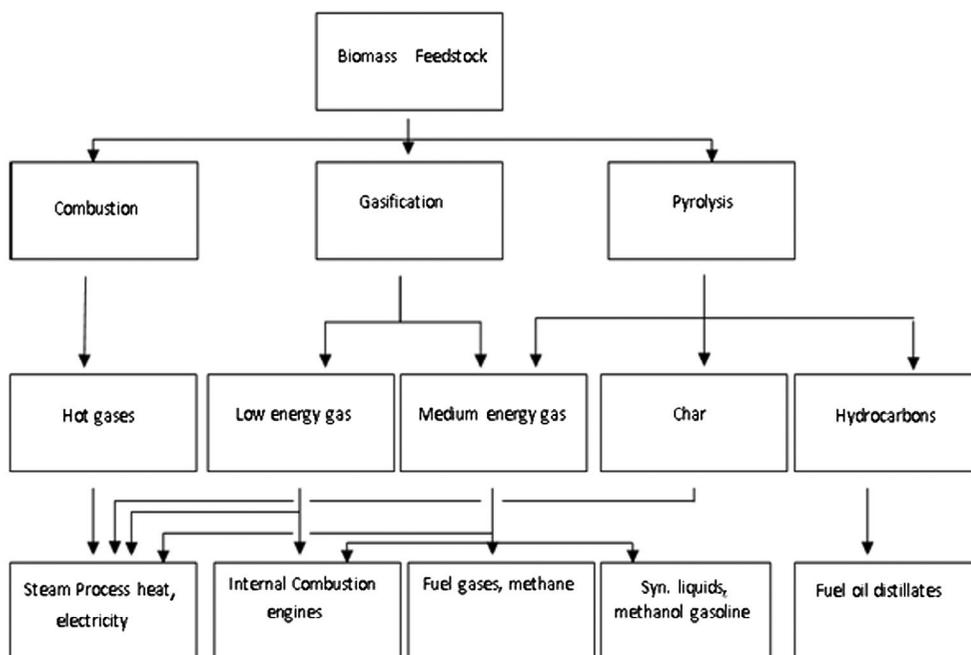**Figure 2. Biomass thermochemical conversion pathway (Cheng, 2009).**

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Figure 3. Total crop production of Pakistan in 2011 (Bhutto et al., 2011).
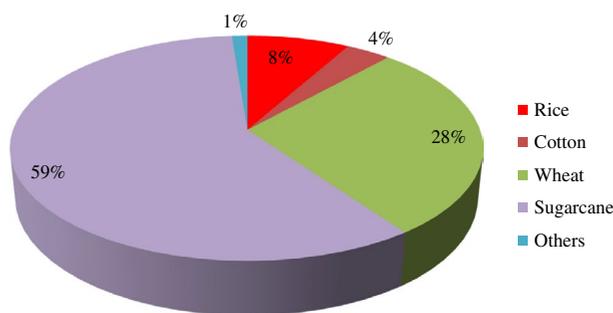
Table 2. Rice husk availability in Pakistan (Mirani, Ahmad, Kalwar, & Ahmad, 2013)		
Year	**Paddy production (1,000 tons)**	**Rice husk (1,000 tons)**
2008	6,952	1,390.4
2009	6,883	2,064.9
2010	4,823	1,446.9
2011	6,160	1,848
2012	5,536	1,660.8
2013	6,798	2,039.4
2014	7,005	2,101.5
2015	6,900	2,070
Average	6,382	1,828

process, much of the fuel fed to the boiler is combusted while flying through the chamber, and the large parts burn in the grate. The heat from the boiler is used to produce steam at a high temperature of 525°C. It has an electrical power efficiency of 27% (Morten Tony Hansen, 2014).

A biomass gasifier was installed in 2007 in Bangladesh, which consisted of a gasifier and a dual fuel internal combustion engine, with the capacity of 250 kW. Biomass are burned in a controlled way with the partial oxidation technique to form syngas, the gas filter for purification and is then burned in the engine with an initial start-up from diesel and when desired amount of syngas is produced, then the ratio of syngas to diesel becomes 70:30 (IDCOL, 2007).

3. Rice husk availability and price in Pakistan

Pakistan is an agriculture country producing all major crops like wheat, maize, rice, sugarcane, and cotton. In 2014–2015 production of rice is 6,900 thousand tons, which was 7,005 thousand tons in 2013–2014 (Ministry of Finance, 2013). Figure 3 represents the total crop production in Pakistan (Bhutto et al., 2011). There is a considerable potential of generating electricity from biomass in the form of crop residues, animal waste (manure), and municipal waste in Pakistan. Presently 50,000 tons of solid waste and approximately 1,500 m³ of forestry firewood are generated daily. 225,000 tons of crop residue calculated with 1.7% rice husk and 16% bagasse (residue from sugar mills) daily and animal manure is estimated 1 million tons every day (Uqaili, Harijan, & Memon, 2007).

Rice is cultivated mainly in interior Sindh and Punjab provinces of Pakistan. Rice husk is obtained after separating the rice grain from its husk in the rice mills as a byproduct and it consists of 20% by weight of rice. Availability of rice husk in Pakistan per annum for the past 8 years is shown in Table 2. It can be seen that in last four years, average production of rice husk was around 1,828 ton per annum.

Rice husk obtained as a byproduct is considered as a waste and usually huge quantities of the rice husk are dumped as waste causing waste disposal problems and emissions of methane. The

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Figure 4. Global radiative forcing.

Source: Adapted from Earth System Research Laboratory (2015).
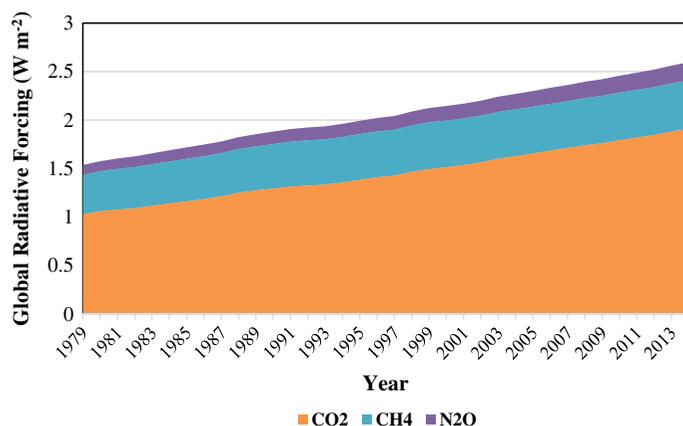
Table 3. Ultimate and proximate analysis of rice husk (Yin et al., 2002)			
Ultimate analysis (%)		**Proximate analysis (%)**	
Carbon	36.74	Volatile matters	53.1
Hydrogen	5.51	Fixed carbons	20.4
Oxygen	42.55	Moisture	11.7
Nitrogen	0.28	Ash	14.8
Sulfur	0.55		

Table 4. Comparison of coal and rice husk (Mirani et al., 2013)			
Fuel	**Heating value (MJ/kg)**	**Cost (Rs./Ton)**	**Energy cost (Rs./MJ)**
Rice husk	15	3,750	56.25
Coal	36	10,260	369.36

particulate nature of certain portions of the rice husk when inhaled affect air quality which may lead to lung cancer and heart conditions. If instead of disposing rice husk, it is used to generate electricity, the problem of the incorrect disposal method could be solved. Rice husk is a valuable source of renewable energy which should be utilized and converted to a beneficial form of energy to fulfill the thermal and mechanical energy requirement for the mills (Chungsangunsit, Gheewala, & Patumsawad, 2009).

Energy produced from rice husk mainly depends on its composition; ultimate and proximate analysis of the rice husk as shown in Table 3. Rice husk contains 16–23% ash contents which are mainly silica as its composition is approximately 95% in ash (Yin, Wu, Zheng, & Chen, 2002). Carbon and Hydrogen make around 42% of the total composition which actually take part in combustion.

Rice husk has the calorific value of approximately15 MJ/kg that means its heating value is 41% lesser than coal, however its cost is 36% cheaper than coal. Table 4 shows the amount of energy produced per kg by coal and rice husk and the cost per MJ of energy. It can be seen that energy obtained from rice husk is cheaper than coal and is carbon neutral. Although coal still is the most efficient solid fuel in the world, but its operational cost is higher because of hazardous materials present in it. In addition, it produces the highest amount of additional emissions causing global warming.

4. Methane emission from conventional rice husk disposal methods
Methane (CH_4) is one of the environmental pollutants that is considered as a greenhouse gas. Nevertheless its concentration is lower compared to carbon dioxide emissions, which increased from

275 to 345 ppm, but one molecule of CH_4 traps 30 times more heat than carbon dioxide. In Figure 4, the global radiative forcing is given. As expected, data from Earth System Research Laboratory (2015) shows that carbon dioxide emissions still dominant global greenhouse gasses, however, methane and nitrous oxide are gradually decreasing in pace yet, still experiencing exponential increase (S. Asumadu-Sarkodie & P. A. Owusu, 2016a, 2016f). Methane not only adds to the greenhouse effect, but also affects the oxidation capacity and the chemistry of the atmosphere, for instance by manipulating the concentration of tropospheric ozone, hydroxyl radicals, and carbon monoxide (Neue, 1993).

Disposing rice husk has become problematic, dumping into the disposal site and burning in open air releases methane into the atmosphere, thereby contributing to the greenhouse effect and poor air quality. The amount of CO_2 released into the open air by burning the rice husk mainly depends on the amount of rice husk and the carbon fraction of rice husk. The total carbon and methane released from burning of rice husks can be calculated using Equations (1–3), respectively.

$$TCR = Amount\ of\ Rice\ Husk \times CF\ of\ Rice\ husk \tag{1}$$

where, TCR is a total carbon released with tons of C/yr and CF is carbon fraction of rice husk, which is taken as 0.3674.

$$AMR = TCR \times CR \times MCF \times GWP \tag{2}$$

where AMR is the annual methane released with tons of CO_{2e}/yr, CR is carbon released as CH_4 in open air taken as 0.005%, MCF is mass conversion factor and its value is taken as $\frac{12}{16}$ GWP is a global warming potential which is 21 for methane. The parameters employed in Equations (1 and 2) are adopted from the clean energy finance committee of bio-power rice husk power project (Mitsubishi Securities, 2003). Assuming 70% of rice husk is considered, following results were obtained.

Total carbon released = 457,672.38 tC/yr

Annual methane release = 36,042 tCO_{2e}/yr

It is evident from the above results that the current practice of disposing rice husk produces large amount of CH4, which leads to serious health conditions in human population and contribute to the global increase of greenhouse gasses thereby leading to climate change. Therefore, this study proposes that even if 70% of total rice husk produced in Pakistan is used to produce electricity, a reduction of 36,042 tCO_{2e}/yr of methane is possible.

5. Total potential of rice husk as electricity source in Pakistan

The study followed the experimental parameters of a pilot project in Rio Et (EGCO Group, 2006) for analyzing the total potential of electricity from rice husk. For 10 MW of SPP-Renewable Power plant, the net output is 9 MW (Chungsangunsit et al., 2005) therefore the amount of electricity generation by rice husk can be calculated using Equation (3). Rice husk availability in Pakistan is $1,779.58 \times 10^3$ tons per year. 225 tons of rice husk produce 10 MW of electricity per day. Assuming 70% of the total rice husk (1,245,706 tons per year) is utilized for electricity production then:

$$1,779,580\ tons\ \times 0.7 = \frac{10}{225}\left(\frac{MW}{tons}\right) \times 0.7 \times 1,779,580\left(\frac{tons}{Year}\right) = 55,364\left(\frac{MW}{Year}\right) \tag{3}$$

Thus:

1,245,706 tons of rice husk will produce = 55,364 × 24 MWh of electricity per year.

Annual electricity production potential = 13.28×10^2 GWh.

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Table 5. Carbon dioxide emission from different fuels (APEIS, 2003)		
Fuel	CO$_2$ emission (kg/MW)	CO$_2$ emission (kg/55,364 MWh electricity)
Coal	1,269.524	7.03×10^7
Oil	812.608	4.50×10^7
Gas	568.878	3.15×10^7
Rice husk	Neutral	Neutral

Figure 5. Pathway for electricity production from the rice husk power plant.
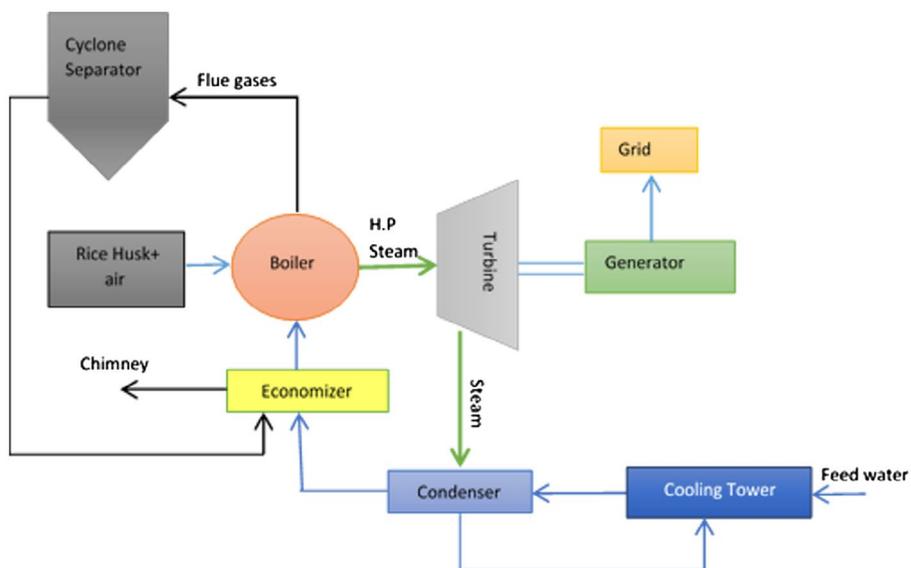
6. Total reduction potential for greenhouse gasses

For any amount of electricity production by coal there is some emission of CO$_2$. If the same amount of electricity is produced with the rice husk, the amount of carbon dioxide emitted will be recycled with the cultivation of new crops, and the emission of methane as a result of air pollution from open burning rice husk will be controlled leading to better air quality and healthy environment. Table 5 shows the comparison of carbon dioxide released from coal, oil, and gas with rice husk. From Equations (1 and 2), the annual CH$_4$ released by openly burning rice husk was estimated as 36,042 tCO$_{2e}$/yr and if the same amount of electricity is produced by coal than the total emissions would be 70,285.9 tCO$_2$/yr as shown in Table 5. The total savings of emission would be 106,327.93 tCO$_{2e}$/yr.

7. Estimation of cost of unit electricity

It is suggested to install rice husk electrical power plant in the district of Badin for various reasons. Badin district has an area of 6,726 km^2 and more than 60 rice mills are in operation and labor availability is guaranteed (Government of Sindh, 2013; Shalim Kamran Dost, 2007). Trucks are always available for transportation of rice husk. A large area is required for the storage of rice husk and its handling, which should be in-door. The storage and transportation costs are included in the cost of rice husk as fuel price as shown in Table 2.

In order to estimate, per unit cost, a simple steam cycle plant is assumed. Figure 5 shows the pathway and schematic of the assumed rice husk power plant. By using a conveyor belt the rice husk is transferred to the boiler for combustion, the husk will be burned in the boiler and produce a high pressurized steam, which will rotate the steam turbine connected to a shaft that turns the generator. The burned gas (flue gas) will first go through the multi-cyclone separator and later pass through the economizer to heat the water and finally emitted into the atmosphere. Carbon dioxide produced from the rice husk power plant could be viewed as carbon neutral since emissions would eventually

Table 6. Job opportunities from rice husk power plant	
Task	**Man–day/ton**
Raw material collection	0.75
Transportation process	0.25
Trading	0.33
Total	1.33

be sequestered in future biological growth. In a steady-state biological system, gross emissions would be equal to gross sequestration, thus net emissions would be zero (Della, Kühn, & Hotza, 2002). The burning of rice husk in the air always leads to the formation of ash, which is rich in silica, reported as 96.34% (Della et al., 2002; Srivastava, Mall, & Mishra, 2006). Silica is considered as a by-product which is an essential requirement of Portland cement (EPA, 2012b). It can be sold out to the cement industries or be used as a fertilizer to boost agricultural production. By using combine heat and power system (CHP) the energy can be recovered from the steam after the steam turbine makes the system more feasible and economical (EPA, 2012a).

Following the analysis of cost estimation of electricity per kWh energy conversion takes place in two stages. The first stage deals with the conversion efficiency of the boiler and combustion process. Compared to a boiler efficiency of 55–60% achievable with stepped grate furnace, the fluidized bed combustion technology gives a high efficiency of the order of 75–80%. In this case, we take 75% efficiency (IEA, 2010). Second stage deals with the steam cycle efficiency. Modern Rankine cycle adopted in coal-fired power plants has efficiencies that vary from 32 to 42% (IEA, 2010). This depends mainly on the steam parameters. Higher steam pressure and temperatures in the range of 600°C–230 bars have efficiencies around 42%. A value of 38% is assumed in this case. This results in an overall conversion efficiency of 0.28%.

$$\text{Amount of fuel (Ton/kWh)} = \frac{3600\frac{kJ}{hr}}{0.28 \times CV_{fuel}} \times PC \times 1000 \tag{4}$$

where CV_{fuel} is the calorific value of coal and PC is the proposed plant capacity. The cost of electricity can thus be found by the following equation.

$$\text{Cost of electricity}_{PC} = \text{Fuel price}\left(\frac{cents}{Ton}\right) \times \text{Amount of fuel}(\frac{Ton}{kWh}) \tag{5}$$

Assuming a calorific value of coal as 20,000 J/kg and coal price as 10.26 cents the cost of electricity production for a plant capacity of plant capacity of 100 MW is found as 55.22 cents/kWh, while the cost of electricity production by rice husk is found as 47.36 cents/kWh.

8. Total potential of employment generation

The employment generation opportunities from rice husk are from the raw material collection, transportation, trading, and power plant working personnel. Table 6 which is obtained by a survey performed by Ahiduzzaman (2007) shows the requirements of man-day/ton for the raw material collection, transportation, and trading of rice husk. An 8-h work day was assumed in this survey.

Equation (6) is used to calculate the total number of possible employment slots.

$$\text{Vacancies} = \frac{\frac{Man-day}{ton} \times 0.7 \times \text{Total rice husk}}{365} \tag{6}$$

Since the unemployment rate is on the rise, taking advantage of this renewable energy alternative has a potential of solving this social issue to some extent. In this regard, it is important to know that

almost 4,530 job opportunities will be created from raw material collection, transportation, and rice husk trading in Pakistan.

9. Total potential of silica production

As it is discussed in Section 7 of this article, some amount of silica will be produced during the utilization of rice husk for power generation. The total potential of silica production can be found using Equation (7),

$$\text{Silica production}\left(\frac{\text{tons}}{\text{year}}\right) = \text{Total amount of rice husk}\left(\frac{\text{tons}}{\text{year}}\right) \times \text{Fraction of ash} \times 0.95 \quad (7)$$

Using Equation (7) and the fraction of ash from Table 3, the total possible silica extraction from rice husk ash is found to be 175,146.3 tons/yr.

10. Conclusion and policy recommendations

For several years, Pakistan has been experiencing energy crisis owing to its sole dependence on fossil fuels. The decline of fossil fuel reserves has led to an increase in their prices, thereby increasing the cost of electricity. Since the tariff remains the same, Pakistan is over-burdened with circular debts and observes a daily power shortfall of about 12–14 h. Being an Agra-economic country, many major and minor crops are produced and exported in large quantities. However, a large amount of it forms a bulk of the agricultural waste which are not utilized. This waste can be utilized to meet the country's energy demand while mitigating climate change and its impact. Technological advancement makes it easy to convert the agricultural waste into thermal energy which is considered as carbon neutral. Adopting these technologies would help bridge the demand and supply gap, decreasing the reliance on fossil fuel, thereby increasing the energy security and economic growth. The study examines the electricity production potential and social benefits of rice husk in Pakistan. It is estimated that if 70% of rice husk residues are utilized, there will be annual electricity production of 1,328 GWh. The following policy recommendations emanate from the study:

- Efforts by the government to implement policies that prevent waste generation through preventive measures, reduction management, recycling and encouraging reuse will be essential in combating climate change and its impact.

- The government should institute policies that encourage public and private sector to adopt sustainable practices and incorporate information on sustainability into their production, labeling, and reporting cycles.

- Efforts by a government that provide relevant and create awareness on reducing the carbon footprint and sustainable lifestyles in Pakistan is worthwhile.

- Government's effort toward the creation of an enabling environment and support for renewable energy technologies like subsidies, removal of market distortions, tax reductions, and incentives will boost the country's effort toward patronizing clean energy whiles mitigating climate change.

- Efforts by the government to sponsor scientific research on renewable energy technologies in Institutions through the provision of grants, loans, and merit-based awards will boost the scientific and technological advancement of the country.

It is believed that exploiting the renewable energy potential and utilizing agricultural waste will be beneficial to the country's energy portfolio while adding several social and environmental benefits such as reducing carbon dioxide emissions, improving air quality, and decreasing the unemployment rate. Future studies should examine how different agricultural residues in Pakistan can serve as an alternative source of electricity generation and/or social benefit based on a sensitivity and risk analysis.

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