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Industrial Application of Rice Husk as an Alternative Fuel in Cement Production for CO_2 Reduction

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Abstract. The cement industry generally spends about 30-40% of production costs to provide energy for production. It forces the cement industry to look for cheaper and widely available alternative energy sources to increase its competitiveness. The dominance of fossil fuels poses another problem for the cement industry in the form of high CO_2 emissions. To overcome this, PT Indocement Tunggal Prakarsa (ITP) Tbk, Palimanan Unit, is committed to continuously looking for alternative energy sources by utilizing rice husks in the suspension preheater unit. This study aims to evaluate the performance, especially the reduction of CO_2 emissions and the economic benefits of energy substitution applications using rice husks. Based on the calculation in 2020, there will be an increase of 37% in 2021, and the total energy of rice husks will reach around 1,996,671 GJ. It is equivalent to using fossil fuel coal of approximately 106,450 tonnes. The contribution of rice husks to primary energy consumption seems to continue to increase yearly. A significant increase occurred between 2020 - 2021, and the contribution of rice husks reached 23%. Rice husks usage has reduced CO_2 emissions by almost 220,000 tons of CO_2e and brought production cost benefits to around 40 billion by 2021. Therefore, the substitution of coal fuel using rice husk has proven to be effective in reducing CO_2 emissions in the cement production process. By still paying attention to the reliability of the process and the quality of the cement products produced, these efforts can be continuously encouraged to realize cement products that are more environmentally friendly.

Keywords: Rice Husks, Alternative Fuel, CO_2 Reduction

INTRODUCTION

Cement is an essential adhesive agent in the construction industry, so it is produced in large quantities in Indonesia and the world. The cement production process requires very high energy and produces massive CO_2 emissions (Worrell *et al.*, 2001). The cement industry generally spends around 30-40% of production costs to provide energy for production (Chatziaras *et al.*, 2014). The primary energy source is coal, whose existence is increasingly limited, with prices that continue to rise. It forces the cement industry to look for cheaper and widely available alternative energy sources to increase its competitiveness (Panjaitan *et al.*, 2020). The dominance of fossil fuels poses

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another problem for the cement industry in the form of high CO_2 emissions. This industry is responsible for 5% of total CO_2 emissions globally (World Steel Association., 2020). Based on the existing process, CO_2 emissions in cement production come from four different sources. The most significant proportion, about 50-60%, comes from the decomposition of limestone ($CaCO_3$) into lime (CaO) as a cement base material, and 30-40% comes from burning fossil fuels for energy sources in the preheater, calciner, and rotary kiln. The rest comes from electricity usage for production facilities (Benhelal *et al*., 2021). Therefore, the cement industry faces serious problems related to energy sources and environmental pollution from high CO_2 emissions.

Various efforts have been encouraged to be carried out, including optimization of operating conditions, energy efficiency improvement programs, and the use of alternative energy sources. Using alternative energy sources, especially renewable and carbon-neutral energy, is a realistic and attractive choice because it can simultaneously solve the problem of energy costs and CO_2 emissions. It is also supported by the configuration of existing processes and equipment in the cement industry, where the energy generation process is flexible enough to use various types of fuels and operate at high temperatures (Purvis *et al*., 2004). By using proper system configuration, biomass utilization in the cement industry showed prospective results (Le *et al.,* 2007). Several types of alternative energy sources that have the potential to be used include used tires, municipal solid waste (MSW), Spent pot liners, plastic waste, Sewage sludge, Solvent and spent oil, and Agricultural biomass waste (Rahman *et al*., 2015 and Usón *et al*., 2013). The high carbon content, high heating value (35.6 MJ/kg), and low moisture content make used tires prominent in the cement industry (Corti, A., & Lombardi, L., 2004). High burner temperatures above 1000 °C make cement plant furnaces suitable for MSW combustion, producing low levels of dioxins and furans (Garg *et al*., 2009). Meanwhile, plastic waste is suitable for use because it is available in large quantities and has a high heating value of 29-40 MJ/kg (Ariyaratne WKH., 2009). Several types of energy sources, such as used tires, plastic waste, and spent oil, can only solve problems related to the availability of energy sources and their prices, while issues related to CO_2 emissions cannot be resolved because the essential ingredients of these materials are still fossil fuels. Alternative energy sources in biomass waste offer a solution to the problem of not only availability and price but also CO_2 emissions because biomass is carbon-neutral.

As one of the leading companies in cement production in Indonesia, PT Indocement Tunggal Prakarsa (ITP) Tbk, Palimanan Unit is committed to continuously seeking alternative energy sources to make its production process more sustainable and also reduce existing CO_2 emissions. This commitment is realized utilizing various alternative fuels, including waste tire, sawdust, rice husk, coffee shell, sludge oil, municipal waste, other biomass AF, and spent bleaching earth. The biomass rice husk had appropriate characteristics related to heating value and ash content as an alternative fuel in the industry (Radenahmad *et al.,* 2020). Of the various alternatives, rice husks dominate as an energy source in this industry (Kumar *et al.,* 2013). This condition is in line with the high potential and availability of rice husks in the community. As an agricultural country, Indonesia has enormous potential for biomass energy, especially agricultural waste in the form of rice husks. With the popularity of rice as a staple food, the energy potential of rice husks reaches around 39.07 GWh electricity equivalent (Alit *et al.*, 2020). This study aims to evaluate the performance, especially the reduction of CO_2 emissions from using rice husks as an alternative energy source in the cement production process at the PT ITP Palimanan Unit Plant. The economic benefits gained will also be presented further to encourage the commercialization of this application in other industries. The use of data from factories on an industrial scale will make the results of this evaluation interesting to be presented and discuss so that it can inspire similar companies to carry out similar activities.

MATERIALS AND METHODS

Materials

The data used in this research and evaluation was obtained from PT Indocement Tunggal Prakarsa (ITP) Tbk, Palimanan Unit in Cirebon, West Java, Indonesia. Rice husks were obtained from the Indramayu and surrounding areas, West Java, and have undergone a quality test to meet the specifications presented in Table 1.

Table 1. Rice husk material specifications

Parameter	Unit	Specification
Water content	%	15 max.
Gross heating value	Cal/g	3450 min.

By controlling the water content in rice husks, the stability of the heating value can be maintained so that it can be fed into the process. This stability is the primary key to ensuring the quality of the clinker and cement products.

Method and data analysis

In addition to the raw materials of rice husk with certain specifications, the equipment and operating system for cement production are the same as normal conditions when using coal as an energy source. By using the dry process, PCC (Portland Composite Cement) and OPC (Ordinary Portland Cement) cement are currently produced by PT. ITP Palimanan Unit, Cirebon, through 2 installed factories, namely plant 9 and plant 10. The limestone, clay, silica sand, and iron sand as the primary raw materials for manufacturing cement were obtained from the area around the factory's location. As shown in Fig. 1, several stages were undergone by the existing raw materials to procure cement products, including crushing, pre-homogenization, preheating, recalcining, clinker production, cooling, blending, cement grinding, and storing.

The use of alternative fuels in the cement production process is carried out at the pre-calcination stage in the suspension preheater unit. Using an automatic control system, alternative fuels are fed in a defined amount based on the adjusted energy requirements. The raw limestone ($CaCO_3$), which has been heated in the preheating stage, enters the pre-calciner, which will undergo initial calcination using a heat source derived from the combustion of the rice husks.

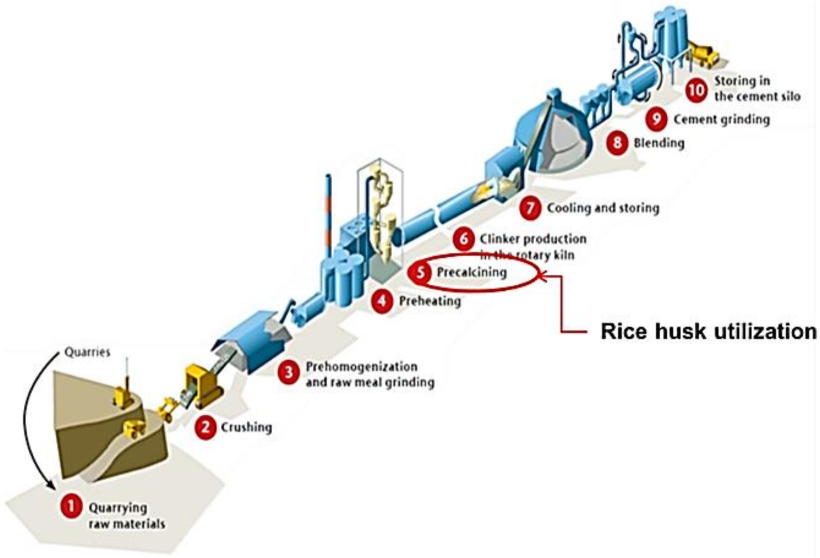

Fig. 1: Schematic Diagram of Cement Production and the Location of Rice Husk

The amount of rice husk fed in this section is recorded and used to evaluate absolute energy, CO_2 emissions, and economic savings.

- Absolute energy
  Absolute energy is estimated using primary data recorded based on operating conditions. The absolute energy is estimated using the data on the number of rice husks entered and the heating value analyzed by equation [1].
  $E_{RH} = F_{RH}\ x\ HHV_{RH}$..................[1]

  where E_{RH} is the absolute energy of rice husk (GJ), F_{RH} is the amount of rice husk utilized (ton) and HHV_{RH} is the heating value of rice husk (GJ/ton).

- Reduction of CO_2 emission
  Energy sources in the form of coal, rice husks, and others are used as heat sources through the combustion process.

Assuming similar process efficiency, the amount of energy from coal replaced by alternative fuel is the same as absolute energy from rice husks included in the production system. The CO_2 reduction due to the use of rice husk energy sources can be estimated using equation [2]

$CO_2\, reduction\ = E_{RH}\ x\ CO_{2-coal}$....[2]

where CO_{2-coal} is standard CO_2 emission from coal around 0.107 tons CO_2e/GJ (Panjaitan *et al.*, 2021).

- Direct economic benefit
  As is known, the price of coal is higher than the price of rice husk, so the use of rice husk can bring economic benefits. Therefore, the direct economic benefit obtained can be estimated using the equation [3].
  $IDR_{benefit}\ = (Coal\ price - Rice\ husk\ price)\ xE_{RH}$ ..[3]

RESULTS AND DISCUSSION

The energy mix for cement production

PT. ITP Palimanan Unit has a production capacity of 3.9 Mt clinker/year and requires a thermal energy intensity of 3392 MJ/tonne clinker in 2021. With the primary energy source of coal, this plant produces CO_2 emissions in the range of 543 kg CO_2-e/ton cementitious. Various efforts have been made by management, one of which is starting to use alternative energy sources, as presented in Fig. 2

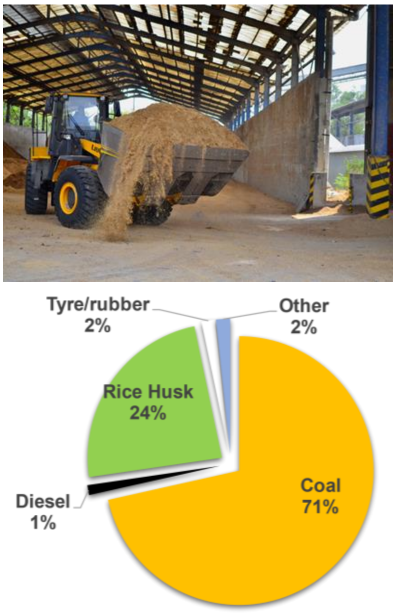

Fig. 2 Schematic diagram of cement production and the location of rice husk

The supply of rice husks was received by PT. ITP Palimanan Unit from the surrounding rice farming area and succeeded in substituting 24% of the energy used in the factory using these alternative materials by 2021. With the mechanism of supply contracts through existing business groups, the quantity and quality of rice husks sent to factories can be controlled according to applicable standards, one of which is a maximum moisture content of 15%. In addition to rice husks, this plant continues trying to find alternative fuels and use them in production facilities, such as tires/rubber, spent oil, and others. With the mixed energy distribution, PT. ITP Palimanan Unit strives to reduce CO_2 emissions and contribute to sustainable cement production.

Energy substitution program by rice husk Material

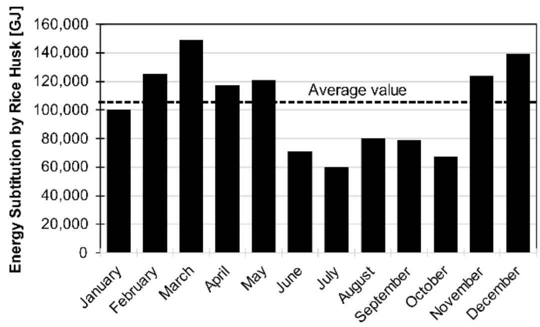

Fig. 3 Energy substitution by rice husk each month

The use of rice husks is highly dependent on the availability of materials and quality. Fig. 3 presents the use of rice husks throughout the year and the amount of energy successfully substituted. The fluctuation in the amount of rice husk energy depends on the harvest season and the existing climatic conditions. As a source of rice husks, the Indramayu area has a harvest season around February, July, and November every year. Harvesting in July will produce lower rice husks due to the dry season, reducing the amount of rice produced by farmers. Knowledge of the rice harvest season is beneficial for predicting and optimizing alternative energy sources for rice husks that can be used in factories. As shown in Fig. 3, rice husks' highest substitution occurred in March at 148.812 GJ and the lowest in July at around 60,132 GJ. With an average substitution energy value of 102.762 GJ, there is still a wide gap between time, providing opportunities for future improvements. Efforts to find sources of rice husks in other areas and pre-treatment are feasible options to consider to increase the portion of rice husk substitution.

Table 2. Absolute energy calculation per year utilization

Year	Feeding amount [ton]		Heating value [MCal/ton]		Total Absolute energy (Plant 9 and Plant 10)	
	Plant 9	Plant 10	Plant 9	Plant 10	[MCal]	[GJ]
2017	30,457	16,507	3,225	3,178	150,983,493	631,714
2018	42,520	33,911	3,192	3,183	224,982,166	1,025,005
2019	54,371	39,374	3,000	3,016	280,426,561	1,173,304
2020	73,050	40,007	2,552	2,556	296,233,477	1,239,440
2021	92,767	49,177	3,362	3,362	477,215,728	1,996,671

Table 2 shows detailed data on the rice husk amount and the heating value. Based on equation [1], the absolute energy supplied to the system and replaces coal fuel can be estimated. It can be seen that the rice husk used has an average heating value of 3063 MCal/ton, which is similar to brown coal and is very suitable to be used as an alternative fuel. The difference in heating value, which is not too big with coal, is advantageous because the modifications needed to plant equipment are insignificant.

The contribution of rice husk energy continues to increase in the performance of PT. ITP Palimanan Unit every year. Based on the calculation in 2020, there will be an increase of 37% in 2021, and the absolute energy of rice secant will reach around 1,996.671 GJ. With coal heating value data ranging from 4483 MCal/ton, this factory can reduce fossil fuel use by about 106,450 tons in 2021. Only fuel with a heating value in a particular range can be used in the fuel substitution program with the function for energy sources. The significant difference in heating value will cause problems in equipment modification, especially the furnace and feeder system.

The ratio of the absolute energy of rice husk to the total thermal energy requirement of the factory operation is used to evaluate the contribution of rice husk as an alternative fuel, as shown in Fig. 4. Presented the primary energy needs of PT. The ITP of the Palimanan unit fluctuates according to the clinker production capacity, around 3392 MJ/ton clinker.

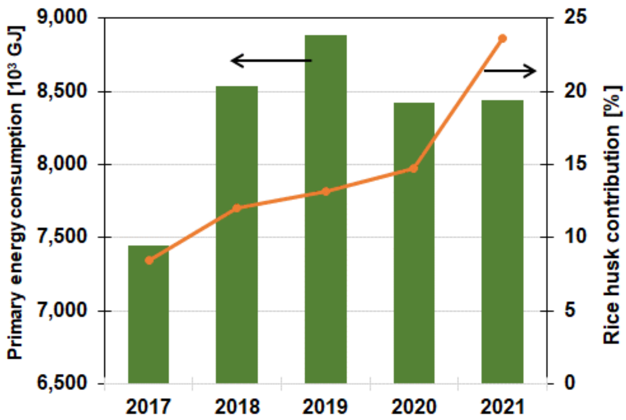

Fig. 4. Rice husk contribution to primary energy consumption in last 5 years

The contribution of rice husks substitution to primary energy consumption seems to continue to increase yearly. A significant increase occurred between 2020-2021, and the contribution of rice husks reached 23% of the total primary energy needs. This is a significant achievement in recent years and the genuine commitment of PT. ITP Palimanan Unit on the environment and sustainability.

CO_2 reduction and economic benefit

As is known, biomass produces carbon-neutral, where CO_2 emissions are not counted as direct emissions to the environment because it is a closed cycle where CO_2 will be absorbed again by plants/biomass and used for their metabolism. Therefore, using rice husk biomass will reduce emissions from conventional cement production operations that use coal. By using equation [2], the CO_2 reduction obtained by PT. ITP Palimanan Unit by using alternative fuel for rice husk is presented in Fig. 5.

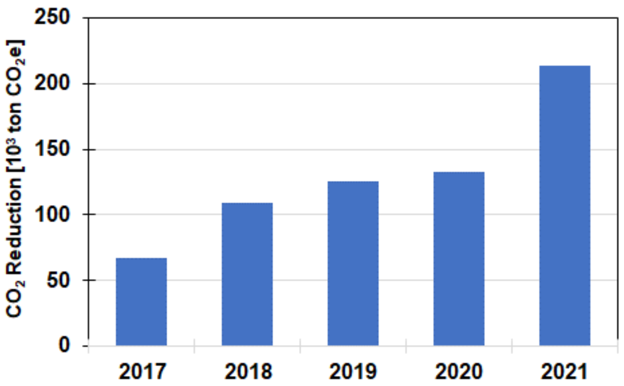

Fig. 5. Effect of rice husk utilization on CO_2 reduction in the last 5 years

The trend of reducing CO_2 emissions is continually enhanced every year, in line with the increase in biomass and the absolute energy substituted by rice husks. With a total reduction of CO_2 emissions of almost 220,000 tons of CO_2e in 2021, the substitution of coal fuel using rice husk has proven to be effective in reducing CO_2 emissions in the cement production process. By still paying attention to the reliability of the process and the quality of the cement products produced, these efforts can be continuously boosted to attain cement products that are more environmentally friendly.

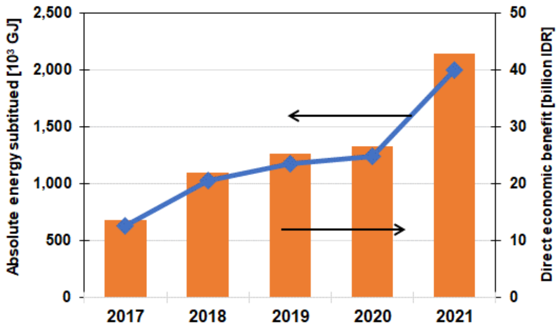

Fig. 6. Direct economic benefit due to rice husk utilization

In addition to improving environmental quality, using rice husks also brings direct benefits in saving energy operating costs. It happens because rice husk prices are lower than coal for the same purpose and function as an energy source. Based on local conditions, PT. ITP Palimanan Unit obtained coal with prices ranging from IDR 53.776/GJ and rice husks around IDR 32.265/GJ. Based on the absolute energy produced, the energy cost savings from using alternative fuel materials are presented in Fig. 6.

Fig. 6 shows that the absolute energy produced is proportional to the direct economic benefit generated, and this is because the price of fuel is not based on its mass but on its energy content. The use of rice husks in 2020 can bring profit in production costs in the range of 25 billion and experience a significant increase in 2021 of around 40 billion rupiahs.

CONCLUSIONS

The substitution of rice husk fuel is carried out on an industrial scale in the suspension preheater unit for the pre-calcination process of PT. ITP Palimanan Unit to realize environmentally friendly cement production. Based on the calculation in 2020, there will be an increase of 37% in 2021, and the absolute energy of rice husks will reach around

1,996,671 GJ. It is equivalent to using fossil fuel coal of approximately 106,450 tonnes. The contribution of rice husks to primary energy consumption seems to continue to increase yearly. A significant increase occurred between 2020-2021, and the contribution of rice husks reached 23%. The rice husks usage has reduced CO_2 emissions by almost 220,000 tonnes of CO_2e and brought production cost benefits to around 40 billion in 2021. Therefore, the substitution of coal fuel using rice husk has proven to be effective in reducing CO_2 emissions in the cement production process. By still paying attention to the reliability of the process and the quality of the cement products produced, these efforts can be continuously encouraged to realize cement products that are more environmentally friendly.

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