# An Analysis of Fuel Co-Firing

**(**With special reference to ATPS, Chachai) **(M. P.)**

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*Abstract*—**The aim of this thesis is to study a co-firing between rice husk and foreign prime quality coal with in a Pulverized fuel boiler. The blending ratio (thermal basis) of rice husk to foreign prime quality coal of 10:90 was used to experiment. The potential of co-firing rice husk with coal was studied in pulverized fuel boiler. Experimental parameters as well as biomass-coal fuel mixture, air fuel ratio and relative wet content within the biomass were investigated. It had been noted that the abundant higher volatile matter content within the biomass fuels has played a key role in increasing the combustion performance within the system. However, slagging, fouling and formation of clinker can be the problems requiring attention when using biomass co-combustion in conventional boilers. We also calculated $CO_2$ emission reduction as well as fuel cost saving after co-firing.**

*Keywords— Rice husk; Co-Combustion; Residual carbon; Ash quality; Feeding method*



## 1. INTRODUCTION

An interesting and promising alternative is the thermo-chemical transformation of the biomass in conventional coal power plants in operation, usually referred to as co-firing. This recently developed technology consists of the substitution of a percentage of the fossil fuel (normally coal) by biomass [18]. Co-firing, also known as co-combustion, is the process of burning two different types of fuels in the same boiler. Although many types of materials can be burned, the term co-firing usually refers to the combustion of solid biomass with coal in coal-fired boilers.

Co-firing should not be confused with the combustion of multiple fuels in boilers designed especially for burning of multiple fuels. The basic difference between such a type of combustion and co-firing is that co-firing is achieved in a boiler originally designed to burn only a specific kind of fuel. In simple terms, biomass co-firing can be thought of as the process of partial supplementing of coal with biomass in coal-fired boilers [2].

Co-firing is a promising technology and it is gaining popularity around the world. It offers many advantages in the energy sector; some of which are discussed here:

1) Since, co-firing is carried out in existing coal-fired plants; it can be implemented in a relatively short period of time and with small investment. Therefore, it is a fast way of increasing the use of renewable energy in the energy sector.
2) As mentioned earlier, biomass absorbs the same amount of $CO_2$ as is emitted during its combustion. Therefore, biomass co-firing does not contribute to the greenhouse effect. Hence, biomass co-firing can help reduce overall $CO_2$ emissions.
3) Most biomass fuels have lower sulphur and nitrogen contents than coal; therefore, in many cases, NOx and SOx emissions can be decreased by biomass co-firing.
4) Disposal of biomass residues is a major source of methane ($CH_4$) which is considered as 21 times more potent than $CO_2$ in terms of global warming impact. Co-firing biomass residues brings additional greenhouse gas mitigation by avoiding $CH_4$ release from the otherwise land-filled biomass.
5) At present, a number of technologies are available for reducing greenhouse gas emissions. However, co-firing is the least expensive option to mitigate these harmful gases.
6) Generally, the efficiency of biomass power plants is in the range of 18 to 22% which is much lower than for large coal units. Moreover, biomass co-firing at a 3-5% ratio causes a slight decrease in boiler efficiency (less than 1%). Thus, co-firing is an efficient way of biomass utilization in power generation.
7) Co-firing offers flexibility in terms of fuel use. The plant can still operate at 100% load with coal in case of no biomass supply. This is more feasible in areas where the biomass supply can be seasonal.
8) Co-firing can also help companies get credits in countries where government offers incentives for displacing fossil fuels and using renewable energy.

### *1.2. Technology Options for Co-firing*

Biomass co-firing refers to the combustion of a mixture of fossil fuels such as coal and biomass fuels. Biomass proportions in co-firing range from a few percent up to approximately 40%, although most existing commercial projects are in the range of 3 to 5% by mass. Co-firing is a very attractive option for producing electricity from biomass because it takes advantage of the large investment, established power generation infrastructure and higher efficiencies of existing large-scale power plants while requiring comparatively low investment costs to include a fraction of biomass in the fuel. Because of the lower

nitrogen and sulphur contents in biomass compared with coal, and the virtually $CO_2$-neutral nature of biomass to power production chains, biomass co-firing can be a very effective method for reduction of NOx, SOx and greenhouse gas emissions from fossil-fuelled power plants [2].
As mentioned earlier, co-firing has been employed in all kind of boilers used for power generation in coal-fired power plants. According to the current state of the art, there are three basic technology configurations for biomass co-firing in power plants:

1) Direct Co-firing
2) Parallel Co-firing
3) Indirect Co-firing

In direct co-firing, the appropriately prepared biomass is fed directly into the coal furnace. There are a number of ways in which this may be done. The simplest approach involves blending the biomass with coal on the fuel pile and providing the mixed fuel as input to the coal mills before supply to the boiler's coal feeding system. This method is generally used at low biomass blend percentages. Alternatively, the biomass fuel preparation and feeding may be handled by a separate system which then feeds the prepared biomass to the coal burners or to separate, dedicated burners [2].
Indirect co-firing involves separate gasification of the biomass to produce a low calorific value fuel gas which is then burnt in the coal-fired boiler furnace. The gasifier is usually of the air-blown, atmospheric pressure, circulating fluidised bed type. Indirect co-firing avoids risks to burner and boiler operation associated with direct combustion, but is more expensive than direct co-firing and is currently only available for wood fuels [2].
In parallel co-firing, biomass is combusted in a separate boiler and the steam produced is fed to a coal-fired power station where it is upgraded to the higher temperature and pressure conditions of the large coal plant. The overall efficiency of conversion from energy in biomass to electrical energy is thereby increased. In an alternative form of parallel co-firing, the flue gases from combustion of biomass in a separate combustion chamber are fed into the boiler of the coal power plant. The need for a separate biomass combustion installation in parallel co-firing leads to higher costs [2].

### *1. 3. Reasons for Co-Firing*

Some of the environmental, economic and customer service reasons for co-firing are listed below [3]:

1) Environmental compliance strategies for coal-burning power plants:
   a) Mitigate fossil $CO_2$ emissions from coal-fired boilers.
   b) Reduce NOx and $SO_2$ emissions from cyclone and PC boilers.
   c) Provide a mechanism for generation and sale of cost-effective, dispatch able green or renewable power.
2) Economic benefits:
   a) Co-firing in existing boilers is potentially a least-cost way for coal-burning utilities to use renewable fuels.
   b) Co-firing opens a market for biomass and other co-firing fuels that have a "green" or renewable/sustainable energy potential.
   c) Co-firing could save money in competitive markets through fuel diversity.
   d) Co-firing could help companies get credits for early voluntary greenhouse gas abatement measures.
   e) Co-firing uses fuels such as wood wastes or used tires that may present disposal problems for customers.
   f) Co-firing is a proactive approach to meeting Renewable Energy Portfolio Standards.
   g) Attention to the problem may encourage legislation favourable to the use of refuse-derived fuels.

### *1.4. Rice Husk*

Rice husk has poor flow characteristics, rendering it difficult to be handled and fed into the fluidised bed. It has low bulk density (~100 $kg/m^3$), abrasive and has interlocking nature. Feeding of such low-density biomass materials into the fluidised bed combustor is difficult as they tend to be elutriated into the freeboard region prior to completion of combustion. Therefore, it is usually force-fed as near as possible into the hot bubbling bed region to achieve a higher burnout rate in the fluidised bed. This is done either mechanically by a screw feeder or pneumatically by air [5].

RICE HUSK AVAILABILITY: Rice husk is one of the most widely available agricultural wastes in many rice producing countries around the world. Globally, approximately 600 million tons of rice paddies are produced each year. On average 20% of the rice paddy is husk, giving an annual total production of 120 million tonnes [19]. In M.P. rice is grown in the area of about 15.59 lakh ha with production of 14.62 lakh tons and 35% of total production of rice is produce in shahdol region, means 5 lakh tons rice and 1 lakh tons rice husk are produce per year [20]. In majority of rice producing countries much of the husk produced from processing of rice is either burnt or dumped as waste. Burning of RH in ambient atmosphere leaves a residue, called rice husk ash. For every 1000 KGs of paddy milled, about 220 KGs (22 %) of husk is produced, and when this husk is burnt in the boilers, about 55 KGs (25 %) of RHA is generated [5].

## 2. PROBLEM IDENTIFICATION

On the basis of plant visit and literature survey we find out some problem in combustion. When we use foreign higher quality coal in 120 MW units of ATPS; comparatively less coal is used for electricity generation. Then following issues are present there:

1) Furnace volume is not used properly. Because less coal is used then remaining volume of furnace is unused, which is cause of heat losses.

2) Generation cost is increases, because foreign coal is very costly as compare to Indian coal or rice husk.
3) Emission of green house gases is also increased because of high percentage of carbon.

Benefits due to co-firing in 120 MW, ATPS power plant:

a) Plant will reduce their green house gases emission.
b) Plant will get carbon emission reduction benefits in terms of money.
c) Generation cost will be reducing.
d) Less ash handling cost will be pay.

Additional advantages: - Less $SO_2$ and $NO_x$ emission, reduces $CH_4$ emission because less coal is extract from mining. Tipping or Land-filling cost of biomass is also reduces indirectly.

## 3. PARAMETRIC ANALYSIS OF FUEL

There are two methods to analyze fuel: ultimate analysis and proximate analysis.

The ultimate analysis determines all fuel component elements, solid or gaseous and the proximate analysis determines only the fixed carbon, volatile matter, and moisture and ash percentages. The ultimate analysis is determined in a properly equipped laboratory by a skilled chemist, while proximate analysis can be determined with a simple apparatus. (It may be noted that proximate has no connection with the word “approximate”) [5].

### 3.1. *Proximate analysis*

Proximate analysis indicates the proportion by weight of carbon, volatiles, ash, and wetness content in fuel. The amounts of carbon and volatile flammable matter directly contribute to the heating worth of fuel. Fastened carbon acts as main heat generator throughout burning. High volatile matter content indicates straight forward ignition of fuel. Proximate analysis is that the most frequently used analysis for characterizing coals in reference to their utilization. The hydrogen determination includes that in the organic materials in coal and in all water associated with the coal. All nitrogen determined is assumed to be part of the organic materials in coal.

### 3.2. *Ultimate analysis*

The ultimate analysis indicates the various elemental chemical constituents such as carbon, hydrogen, oxygen, sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases. This information is required for the calculation of flame temperature and the flue duct design etc. The "ultimate analysis" gives the composition of the biomass in wt% of carbon, hydrogen and oxygen (the major components) as well as sulphur and nitrogen (if any). The carbon determination includes that present in the organic coal substance and any originally present as mineral carbonate. The ultimate analysis of coal involves determination of the weight percent carbon as well as sulphur, nitrogen, and oxygen (usually estimated by difference).

Table -1 Comparison between rice husks and imported (Indonesian) coal:

| Parameter | Rice Husk | Imported Coal |
|---|---|---|
| **C. V. (Kcal/Kg)** | **3150 – 3250** | **5800 – 6000** |
| **Price (Rs/MT)** | **3000 – 3100** | **6800 - 7200** |
| **Ash** | **17.7%** | **10%** |
| **Carbon** | **36.7%** | **49%** |
| **Hydrogen** | **3%** | **4.25%** |
| **Nitrogen** | **1%** | **1.12%** |
| **Sulphur** | **0.01%- 0.03%** | **0.9%** |
| **Oxygen** | **31.20%** | **12%** |
| **Volatile matter** | **61.7%** | **25% - 45%** |
| **Fixed carbon** | **14.1%** | **16%** |

## 4. ENVIRONMENTAL IMPACT ANALYSIS



Stationary combustion sources are equipment located in fixed positions that burn fuel. Equipment associated with stationary combustion include: boilers, burners, turbines, heaters, furnaces, internal combustion engines, kilns, ovens, thermal oxidizers, dryers, flares, municipal solid waste combustors and any other equipment or machinery that combusts carbon bearing fuels or waste streams. The combustion process consists of rapid oxidation of fuel with the release of thermal energy. Following Greenhouse gases (GHG) are formed; which unless captured or controlled, enter the atmosphere through exhaust stacks [7]:

a) Carbon dioxide ($CO_2$)
b) Methane ($CH_4$), and
c) Nitrous oxide ($N_2O$)

### 4.1. *Pollution aspects*

Pollute, generally means a state where there occurs a certain disturbance in purity or contamination towards a matter. In the aspects of electricity generation, pollution or contamination occurs to several aspects which are air, water and land [9]. Generally, the ideal combustion of fossil fuel produces carbon dioxide and water.

Table-2 Carbon emission reduction calculation:

| Parameter | Indian coal | Imported | Mixed fuel |
|---|---|---|---|
| **Fuel amount responsible for $CO_2$ emission** | **85,000(Kg/Y.)** | **55,000(Kg/Y.)** | **49,500(Kg/Y.)** |
| **Heating value** | **3500 – 4000** | **5800 – 6000** | **5500– 5550** |
| **Carbon content** | **$1.044 \times 10^{-4}$** | **$1.052\times 10^{-4}$** | **$1.052 \times 10^{-4}$** |

Use Fuel Analysis Approach:-

$$\text{Emissions CO2} = \text{Fuel amount} \times \text{H.C.} \times \text{C.C.} \times \text{O.F.} \times (\text{M.wt.CO2})/(\text{M wt.(C)}) \times \text{C}$$

Where,
Emissions $CO_2$ = Total $CO_2$ emitted from all fuel (ton/year)
Fuel = Amount of fuel combusted (Kg/Year)
Heat Content = Heat content of fuel (Kcal/Kg)
Carbon Content = Carbon content coefficient of fuel (kg C/Kcal)
Oxidation Factor = Fraction of fuel oxidized,
M. wt. $CO_2$ = Molecular weight of carbon dioxide (44)
M. wt. C = Molecular weight of carbon (12)
C = Conversion factor from kg to ton (1/1000).

Table- 3 Air emission comparison between no co-firing and 10% co-firing:

| Air Emissions | No Co-firing | 10% Co-firing |
|---|---|---|
| $CO_2$ (g/kWh) | 1,018 | 970 |
| CO (g/kWh) | 0.3 | 0.23 |
| $CH_4$ (g/kWh) | 0.9 | -3.0 |
| N (g/kWh) | 3.3 | 2.71 |
| $SO_2$ (g/kWh) | 6.7 | 6.0 |
| Particulates | 9.2 | 9.0 |

Daily imported coal feed rate (based on operating history) = **55 × 24 tons/day**
Annual imported coal use (based on operating history) = **55 × 8000 tons/year**
Average heating value of imported coal = **5,800 Kcal/Kg**
Average heating value of Rice husk = **3,200 Kcal/Kg**
Annual imported coal use (based on operating history) = **55 ×8000 Tons/Yr.**
Unit cost of imported coal delivered to the boiler = **6800 Rs/Ton**
Annual biomass use proposed/estimated for boiler facility = **80000 Tons/Yr**
Unit cost of biomass delivered to the boiler = **3000 Rs/Ton**
**Total Saving = Cost Saving + CER Saving + Ash Handling Cost Saving**
= 6 CR Rs + 2.6 CR Rs – 3.4 Lakh Rs
= 5.2 CR Rs/year
= 1.734 CR. Rs/ (4 Months)
Total saving after 10% (heat basis) Rice husk mixed with imported coal is 1.734 CR. Rs/- approximate in 4 Months.

4.2. *Stoichiometric Calculations*

In practice it is impossible to obtain complete combustion under stoichiometric conditions. Incomplete combustion is a waste of energy and it leads to the formation of carbon monoxide, an extremely toxic gas, in the products. Many solid fuels contain small amounts of oxygen and nitrogen. The oxygen present in the fuel is considered to be available for burning the carbon, hydrogen and sulfur present. The nitrogen in the fuel is taken to appear as gaseous nitrogen in the combustion products.

| Air Required | |
|---|---|
| For Imported Coal | 8.1792 Kg |
| For Indian Coal | 4.67 Kg |
| For Rice Husk | 7.367 Kg |

## 5. RESULTS AND DISCUSSION

5.1. *Combustion Parameters*

In this work we mixed 10% Rice husk with 90% foreign coal, means we mix 9.97 tons of rice husks with 49.50 tons of coal per hour. Before mixing of rice husk, 55 tons of coals are used for electricity generation per hour. So, after co-firing we minimize 5.5 tons of coal per hour and approximate 4000 tons of coal per month is used for electricity generation. In co-firing process approximates 10 tons of rice husk will use per hour and 7200 tons of rice husk per month.

5.2. *Air Fuel Ratio/Excess Air*

Rice husk is Oxygen rice fuel, so in combustion of it less oxygen as well as less air required. After co-firing of rice husk with imported coal, Air fuel ratio should be decreased from104.133 $m^3/s$ to101.480 $m^3/s$ for combustion.

5.3. *Economic Aspect of Co-firing*

After adopting co-firing we will reduce Fuel cost and get CER benefits. When we use 7200 tons rice husk per month, as a substitution for coal, we will save Rs 2 Cr. per 4 months from co-firing. By this the use of coal will get minimised by 4000 tons and as a result the emission of $CO_2$ will also reduce to 8500 tons per month. By reducing $CO_2$ emission we will get approximately Rs 2.60 Cr. per 4 months with CER benefits.
After rice husk mixing, ash production should be increased. Then after co-firing we will pay extra ash handling costs. So, we will pay the extra cost of Rs 10 lakh per 4 months in an ash handing cost of the plant. Total saving after 10% (heat basis) rice husk mixed with imported high quality semi anthracite coal is approximate Rs 1.734 Cr. in 4 Months.

5.4. *Environmental Gain*

After rice husk co-firing we will reduce the use of coal, which is the main reason for $CO_2$ emission and rice husk is renewable energy fuel so no any $CO_2$ emission after combustion of it. We will get more environmental gain in terms of (CER) $CO_2$ emission reduction. By co-firing we will minimise approximate 34,000 tones of $CO_2$ per 4 months as well as reduce $NO_X$ and $CH_4$ emission into the environment.

## 6. CONCLUSION

This work has carried out to examine the physical and combustion properties of Rice husks. Co-firing can lead to significant reductions in the environmental impacts of coal-based electricity production. The amounts of nearly all air emissions are reduced by feeding even small amounts of biomass into the boiler. Additionally, because of avoided decomposition emissions, net greenhouse gas emissions are reduced at rates greater than the rate at which Rice husk is added.

Coal and biomass fuels are quite different in composition. Co-firing biomass fuels with coal has the capability to reduce both $NO_x$ and $SO_x$ levels from existing pulverized coal fired power plants.

Co-firing technology, however, faces some technological problems. The issue of combustor fouling and corrosion due to the alkaline nature of the biomass ash needs attention. Biomass fuels have lower heating value compared to coal, blend flow rate has to be increased in order to have a heat throughput same as in coal-only case. The results of this basic research will aid in optimization of practical coal and biomass blend facilities. Despite all the issues and concerns, coal biomass blend combustion appears to be a promising combustion technology for electric utilities.

This is a positive and cheaper method of reducing the NOx emissions rather than installing other costly burners. The amount of rice husks being fed with coal to generate electricity will in turn reduce the amount of the cost needed to produce electricity. As discussed previously, the supplementation of rice husks has reduced the amount of coal to be used and therefore results in a reduction of capital costs for coal.



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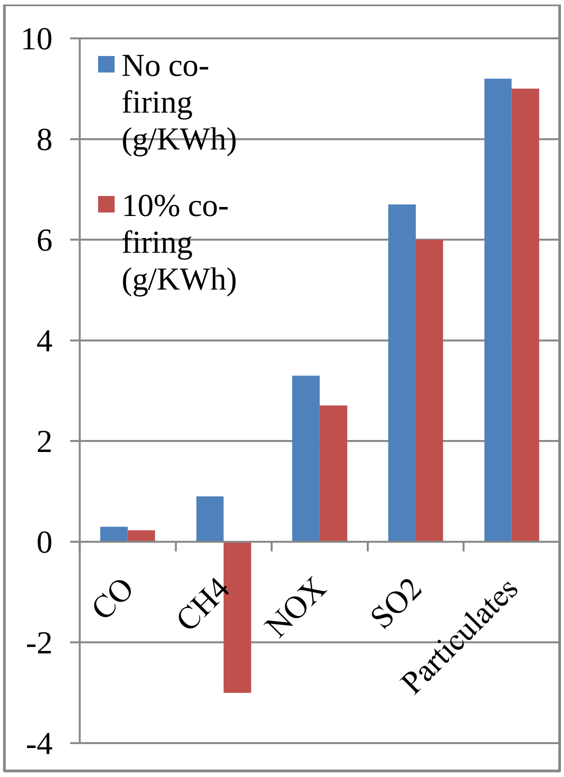
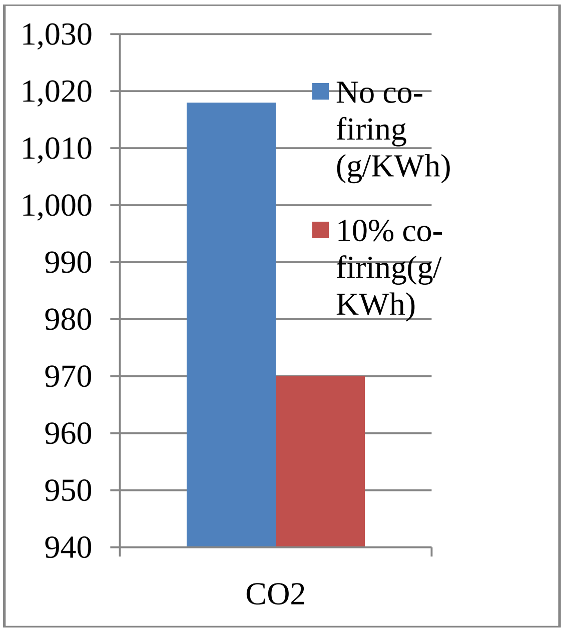
## ANNEXURE

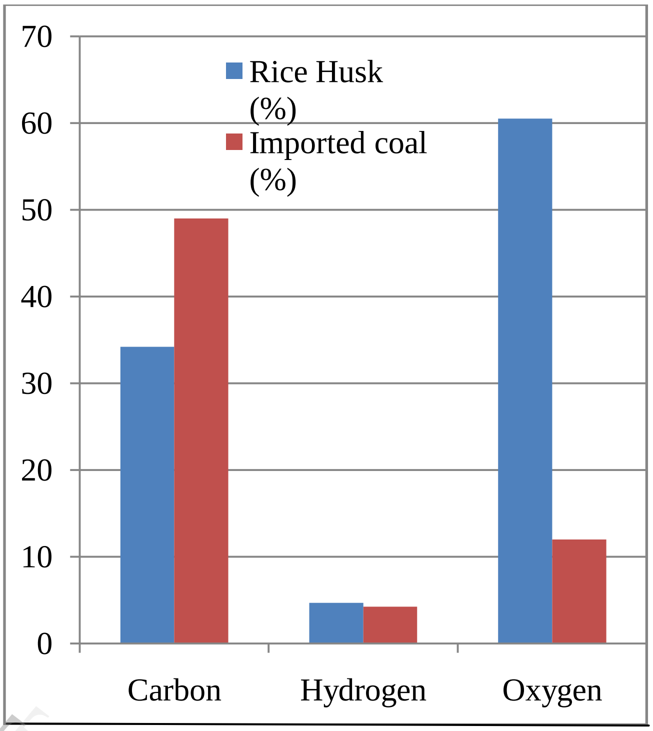
1. *AIR EMISSION COMPARISON BETWEEN NO CO-FIRING AND 10% CO-FIRING:*



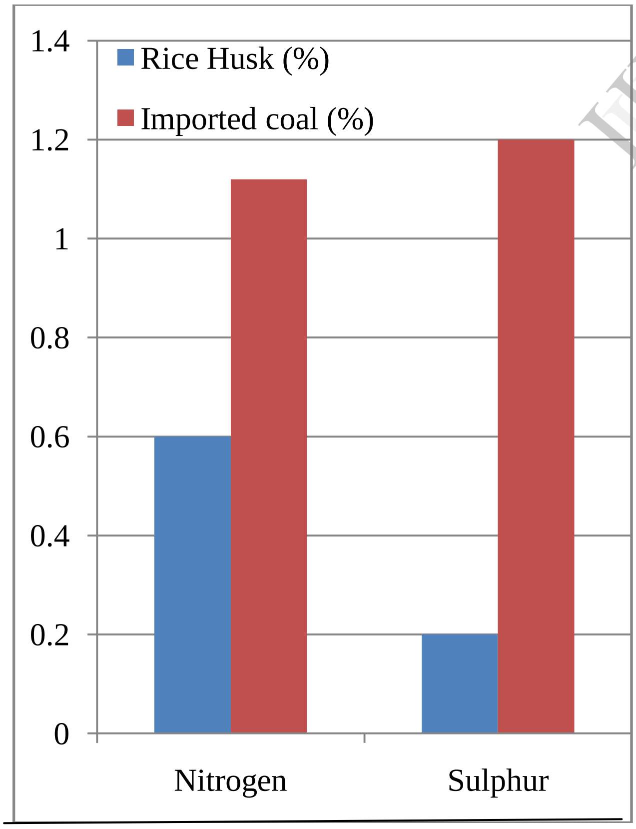
2. $CO_2$ EMISSION COMPARISON BETWEEN NO CO-FIRING AND 10% CO-FIRING:




*4. COMPARISON BETWEEN RICE HUSK AND IMPORTED (INDONESIAN) COAL:*

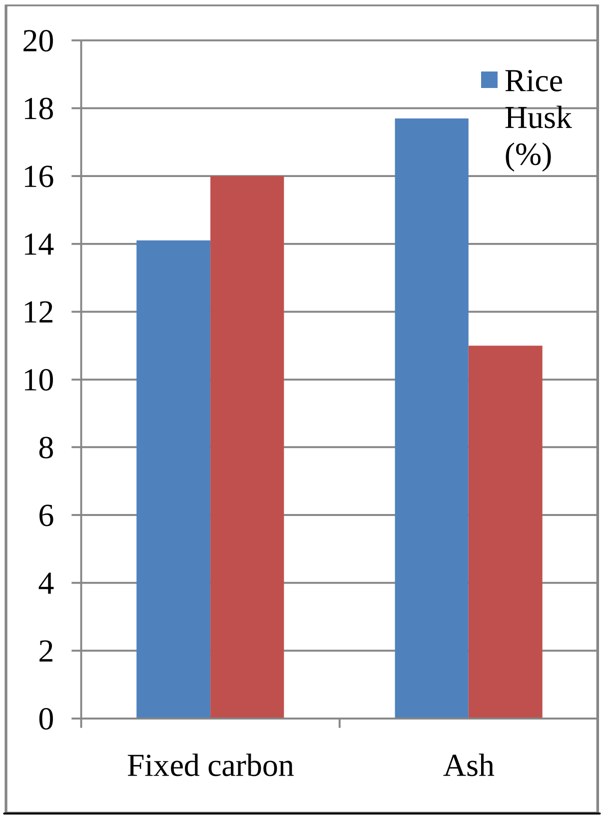



*3. COMPARISON BETWEEN RICE HUSK AND IMPORTED (INDONESIAN) COAL:*






*5. COMPARISON BETWEEN RICE HUSK AND IMPORTED (INDONESIAN) COAL:*



## 6. *COMPARISON BETWEEN RICE HUSK AND IMPORTED (INDONESIAN) COAL:*