Cofiring biomass with coal: Opportunities for Malaysia

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Abstract. Malaysia generated 108,175 GWh of electricity in 2010 where 39.51% was sourced from coal. Coal power generation is also planned to overtake natural gas as the main fuel for electricity generation within the next two decades. Malaysia also has a vast biomass resource that is currently under-utilised for electricity generation. This paper studies the option of cofiring biomass in existing Malaysian coal power plants to increase the nation’s renewable energy mix as well as to reduce its power sector carbon dioxide emission. Benefits of cofiring to the nation were discussed and agricultural residues from palm oil and paddy was identified as a potential source of biomass for cofiring. It was also found that there is a willingness for cofiring by stakeholders but barriers existed in the form of technical issues and lack of clear direction and mechanism.

Keywords: cofiring; agricultural residues; Malaysia coal power stations

1. Introduction
Malaysia's currently has a total of 7680 MW$_e$ of installed generation capacity from six coal power stations. These power stations accounted for 39.51% of the energy mix and are as listed in Table 1 [1]. Additional capacity of 1000 MW$_e$ each at Manjung and Tanjung Bin has been approved for construction, and another plant up for 2000 MW$_e$ is going through the request for quotations process. It is estimated that the share of electricity sourced from coal is going to surpass natural gas to become the largest contributor to the nation’s energy mix by the year 2030. The nation’s high dependence on coal had resulted in high carbon dioxide (CO$_2$) emission of 47.63 million tonnes in 2010 [2]. This accounted to 52.29% of the total CO$_2$ emission from electricity and heat production [3].

| Power Station                   | Location                        | Coal Generation Capacity |
|---------------------------------|---------------------------------|--------------------------|
| Sultan Azlan Shah Power Station | Manjung, Perak                  | 2100 MW$_e$ (+ 1000 MW$_e$) |
| Tanjung Bin Power Station       | Tanjung Bin, Johor              | 2100 MW$_e$ (+ 1000 MW$_e$) |
| Sultan Salahuddin Abdul Aziz Power Station | Kapar, Selangor                  | 1600 MW$_e$            |
| Jimah Power Station             | Jimah, Negeri Sembilan         | 1400 MW$_e$            |
| Mukah Power Station             | Mukah, Sarawak                  | 270 MW$_e$             |
| Sejingkat Power Station         | Sejingkat, Sarawak              | 210 MW$_e$             |

Cofiring is defined as combustion of two or more different fuels in a single furnace although through previous experience, the term has been specifically used for describing partial substitution of coal as a main fuel in a utility scale boiler [4]. Cofiring is very popular in Europe and Australia where it is commercially practiced at almost all of the coal fired power plants there. Most of these plants are
cofiring less than 20 \%_{th} substitution although some plants are capable of 100 \%_{th} fuel switching from coal to biomass. Cofiring is currently going through various trials and demonstration stages in the United States of America and Japan. It is also garnering interests of legislators and operators in Korea, China and other coal power producing countries as a mean to increase utilization of biomass in their renewables portfolio.

2. Rationale for Cofiring in Malaysia

Generally, the main benefit of cofiring is the reduction of fossil fuel CO$_2$ emission from electricity generation as coal is the most carbon dense fossil fuel. CO$_2$ emission reduction can be determined from the level of biomass substitution as it directly replaces the amount of coal to be combusted for a specific energy output. Reduction in sulphur dioxide (SO$_2$) emission is also expected as sulphur content in biomass is very small when compared to coal [5].

Cofiring is a cost effective way of increasing biomass utilization. The cost for a Malaysian biomass power plant firing empty fruit bunch recently costs RM 120M for 12 MW$_e$ of installed capacity [6]. The costs for cofiring can be substantially lower for a similar sized of biomass substitution, for example 2 \%$_{th}$ substitution in a 600 MW$_e$ furnace. This is because at low substitution levels, only minor modification is required to facilitate fuel handling and storage [7]. Furthermore, there is no additional cost downstream of the power plant required, for example for grid connection and grid reinforcement, as these are already in place at the existing power stations.

Another important advantage of cofiring is that coal fired furnaces operate at higher combustion temperatures compared to a dedicated biomass power plant resulting in higher conversion efficiencies. The Energy Commission reported that in 2010 Malaysian coal power stations achieved an average thermal efficiency of 33.1 \%. In contrast, modern dedicated biomass power plant operates at thermal efficiencies of in the range of 25 \%– 28 \%. Furthermore, future planned coal fired furnaces are of the supercritical-steam type that would have thermal efficiency of over 40 \%. This would ensure better utilization of the nation’s available biomass resources.

Cofiring biomass residues diverts it from being landfilled and hence would reduce the volume of waste material to deal with. More importantly, it would directly reduce the amount of methane being released into the atmosphere from biomass decomposition. Methane is a greenhouse gas that is 23 times more potent than CO$_2$ in trapping heat in the atmosphere.

Several motivations exist at the national level for cofiring biomass in existing Malaysian coal fired power plants. Firstly, cofiring could be used to meet the current target of 330 MW$_e$ of installed biomass capacity by 2015 where currently, grid connected biomass capacity is still below 50 MW$_e$. Cofiring only 5 \%$_{th}$ substitution at the four largest existing coal power stations would have surpassed this target at 360 MW$_e$. Secondly, replacing coal with biomass when cofiring would assist in meeting Malaysia’s voluntary target of 40\% reduction of CO$_2$ emission compared to 2005 levels as announced at the 15$^{th}$ Conference of Parties (COP15) in 2009. Cofiring could also be used to cater for more aspiring targets on renewables and greenhouse gas emission that will be necessary in the future. Finally, cofiring would also improve fuel security and supply as Malaysia currently imports most of its coal. Only Mukah Power Station utilizes coal from its local Mukah-Balingan reserve, which accounted for 9.92 \% of total coal consumption in 2010.

3. Cofiring Potential in Malaysia

3.1. Biomass Resources and Availability

Malaysia is abundance in biomass resources especially from its main agricultural industries that can be used for cofiring [8]. The current study identified residues from two of the main agricultural activities in Malaysia namely palm oil and paddy. Biomass availability was estimated using previous work done by the Malaysian Palm Oil Board (MPOB) and Malaysian Agricultural Research and Development Institute (MARDI) for oil palm and paddy residues respectively [9, 10]. Calorific values from biomass characterisation, and reported average equivalent availability factor for the coal power stations were then used to determine thermal power potential of each biomass for that particular year. This value
was then adjusted for combustion at the average thermal efficiency of coal power stations as a measure of potential power generation available when cofiring.

Palm oil mill residues consisted of empty fruit bunch (EFB), mesocarp fibre, palm kernel shell (PKS) and palm oil mill effluent (POME). The last is a liquid residue and hence is not suitable for cofiring. In 2010, fresh fruit bunch (FFB) yield in Malaysia was 18.03 tonne/hectare, planted on a total area of 4,853,766 hectares [10]. This gives a value of 87.51 million tonnes of FFB have been processed at the mills. Rice husk is the major residue from a rice mill and in 2010, paddy production was 2,464,831 tonnes giving a value of 542,263 tonnes of rice husk [12]. The potential energy available from palm oil mills and rice mills residues in 2010 is shown in Table 2. The results showed a generation potential of 7147 MW$_e$ when cofiring all the palm oil mill and rice mill residues. Notably, this value is the theoretical limit and it is impractical to utilize all of the available residues for cofiring. Even so, it can be showed that even if only 5 % of all this residues is captured would give a value of 357.35 MW$_e$ which surpassed the nation’s biomass target for 2015.

Furthermore, all six coal power stations in Malaysia are located in rural areas close to the shore as sea water is used as a cooling medium. This type of land is also flat lying and fertile making it suitable for agriculture. Conveniently, the power stations are surrounded by palm plantations and in the case of Sultan Salahuddin Abdul Aziz Power Station, rice fields, which would indicate that palm oil mills and rice mills are in relatively close proximity. This would facilitate in lowering the cost of transportation of biomass to the power stations.

### Table 2. Potential cofiring power generation from selected agricultural residues in 2010.

| Residues              | Amount /tonnes | Calorific Value /MJ/kg | Thermal Potential /MW$_{th}$ | Generation Potential /MW$_e$ |
|-----------------------|----------------|------------------------|-----------------------------|-------------------------------|
| Empty fruit bunch     | 20,128,082     | 14.6                   | 11,054                      | 3,659                         |
| Mesocarp fibre        | 11,376,742     | 14.8                   | 6,334                       | 2,096                         |
| Palm kernel shell     | 5,425,831      | 19.0                   | 3,878                       | 1,284                         |
| Rice husk             | 542,263        | 16.0                   | 326                         | 108                           |

3.2. Issues for Cofiring

Discussions with cofiring stakeholders have highlighted several concerns for cofiring to be practised commercially in Malaysia which can be classified as technical and non-technical issues. Feedback was received from major private and independent palm oil millers as well as all coal power station operators with the exception of Sejingkat Power Station.

Technical issues concerning powers station operators were mainly on logistics and boiler performance when introducing a new fuel to their existing setup and procedures. Awareness exists of the additional costs and installations to cater for transport, storage and handling of biomass. Most of these issues are actually manageable and lessons can be learned from international experiences of cofiring. Generally, some form of biomass upgrading, such as densification and torrefaction, was deemed to be necessary to facilitate in biomass logistics. Several studies in this area are currently being carried out with interests from both power station operators and biomass millers [13, 14, 15]. Boiler performance issues raised were on temperature profile, emission, ash deposition and corrosion. These issues are dependent on fuel being fired and combustion conditions. Hence, further studies are required in this respect especially when dealing with local biomass that is currently not being used for cofiring. However, it was generally accepted that cofiring low substitution levels of up to 5 %$_{th}$ would not significantly alter boiler performance.

The non-technical issues are mainly associated with the costs and effort for cofiring. All parties agreed that any additional work would not directly add value to their respective core businesses. The lack of clear direction and policy on cofiring in Malaysia also meant that current work is on voluntary basis, purely from an environmental perspective. All parties also agreed that cofiring should be possible and are expecting for some form of mechanism from the authorities to facilitate implementation.
4. Conclusion
Coal will be the major fuel source for Malaysia resulting in high fossil fuel CO\textsubscript{2} emission. Cofiring biomass at existing coal power station has been identified to be the most suited method to efficiently use available biomass, reduce greenhouse gas emission and reduce energy import. Residues from palm oil and paddy are a good source of biomass feedstock and coal power stations is in close proximity to these resources. National motivations and stakeholders’ interest do exist, but lack direction and mechanism. Cofiring is essential in not only meeting set commitments but also for future oncoming targets. There are several other technical issues that are manageable and warrant the need to further research to suit cofiring for local biomass and power stations operation.

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