Cost and GHG Emissions from Biomass Coal Co-firing in Malaysia: Optimizing Decisions Under Uncertainty

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Introduction

Malaysia is a rapidly developing nation and needs to develop and expand its energy infrastructure to fuel its economic activities. The electricity sector accounted for more than 40% of the country's primary energy consumption in 2009 where 92% comes from fossil fuel. Greenhouse gas (GHG) emissions from this sector are expected to increase to 130 million tonnes (Mt) in 2030, a more than 200% increase from the year 2004 (Gan, 2008). This increased emissions is partly due to increased coal generated electricity - little less than 20% in 2000 predicted to be about to about 40% by 2030 (55% natural gas, 1% oil, 4% other renewables). Currently 98% of coal fired electricity generation occurs in Peninsular Malaysia. In an effort to reduce the dependence on fossil fuels as well lowering GHG emissions, the government has outlined in its newest five-year plan, to increase the production of electricity from biomass to 350 MW (Economic Planning Unit, 2010). A study by Morrow *et al*. (2008) have shown that co-firing of biomass and coal is technically feasible. This study, on the other hand, will look at the possibility of using multiple biomass feedstock at a macro level.

Objective

This study determines the costs and GHG emissions reduction possible using various sources of biomass feedstock co-firing at existing coal power plants in Malaysia.

Data and methods

Data for the locations and availability is obtained from the respective government and government-related agencies in Malaysia on the following biomass type:

a) Processed-based residues:
- Palm oil – empty fruit bunch, shell and fiber
- Sawmills
- Plywood mills
- Rice mills – rice husk
- Wood-based municipal solid waste

b) Field-based residues:
- Palm oil – fronds and trunk
- Rubber – branches and trunks
- Cocoa – branches and trunks
- Coconut – fronds and trunks
- Logging residues
- Rice field – rice straw

Palm fresh fruit bunches near a mill

A palm oil plantation

A rice field in Penang, Malaysia

The locations of the mills were used to estimate the coordinates for projection in a Geographic Information System software, ArcGIS (**Figure 1**). Maps of locations of agricultural areas and forest were purchased in polygons image format and had to be digitized (**Figure 2**). These polygons are then converted into points, taking the center of the polygons. A road network was constructed in ArcGIS to estimate the distance from biomass resources to four coal plants in Peninsular Malaysia.

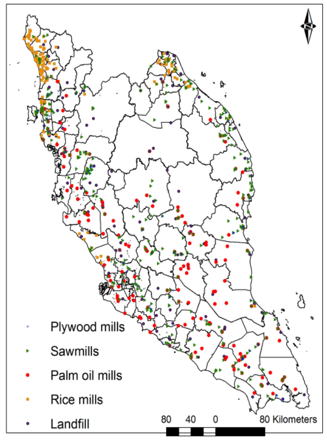

Figure 1: Processed-based residues

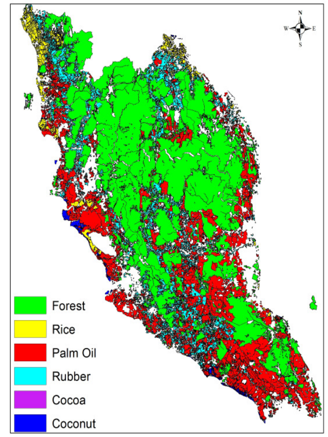

Figure 2: Field-based residues

Stochastic linear optimization is then conducted using Analytica Optimizer software. The objective is to minimize total cost or GHG emissions. There were about 13,000 locations of biomass resources to be transported to 4 different coal-fired electricity generation plants resulting in about 52,000 decision variables. These parameters and constraints have uncertainties.

The constraints are:
- Biomass supply limit
- Coal plants demand limit
- Biomass lifecycle GHG emissions - must not exceed the emissions of the displaced coal

The parameters are:
- Biomass purchase price
- Fixed transportation cost
- Variable transportation cost
- Transportation distance – with lifecycle GHG emissions

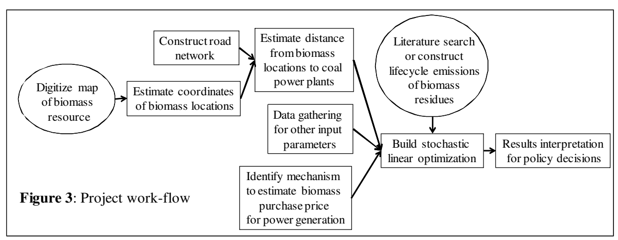

Figure 3: Project work-flow

Results

For illustrative purpose, the results of the optimization for processed-based residues using rough estimates for the values of the input parameters and constraints are as follows:

Result	Minimizing Total Cost	Minimizing GHG Emissions
Total cost (deterministically)	$59 million	$88 million
Mean total cost with uncertain values in inputs and constraints (Figure 3)	$51 million	$78 million
Range of cost	$49.3 - $52.6 million	$73 - $82 million
Mean of GHG emissions	1.1 Mt	830,000 tonnes
Range of GHG emissions	1.0 - 1.2 Mt	670,000 - 770,000 tonnes

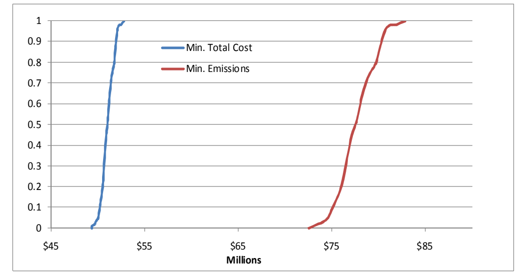

Figure 4: Cumulative probability distributions comparison through illustrative results for total cost when minimizing for total cost and minimizing for GHG emissions.

Future Work

This illustrative result shows that 75% of the biomass would come from palm oil residues and 19% from sawmills. Rice husks and plywood mills would only contribute about 1%. These are just from processed-based residues. Field residues are much more abundant and it would be interesting to assess their contribution.

We will construct the lifecycle GHG emissions of various feedstock (if they are not available in the literature) and identify the most appropriate mechanism to estimate the range of the biomass purchase price and various other costs. Work on assessing the social costs (road damage, GHG emissions price, *etc.*) on the public decision making could be explored.

Literature cited

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For further information

Please contact *mohdnorh@andrew.cmu.edu*. More information on this and related projects can be obtained at http://www.ce.cmu.edu/GreenDesign/about/index.html.