FORUM ON NUCLEAR ENERGY AS AN OPTION FOR MALAYSIA

THE CASE OF RENEWABLE ENERGY- GENERAL PROSPECTS, INCLUDING BIOENERGY

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Abstract

Malaysia is an energy driven fast growing economy. Currently, Malaysia has power generation capacity of 24,000 MW with production mix of 61% from natural gas, 31% from coal and peat, 6% from hydro and 2% from oil. In 8th Malaysian Plan, the government incorporated renewable energy (RE) as the fifth energy source in national energy supply mix. Malaysia is rich in renewable resources, estimates show that the nation has electricity production potential of 11,742 MW from RE resources of which 5,000 MW from biomass alone. However, the progress in RE industry development is slow. To boost the development, government introduced Feed-in Tariff (FiT) mechanism, under which companies can sell electricity from RE resources to power utilities at a fixed premium price over a stipulated time. In the present studies, a biomass based steam-Rakine cycle power plant of capacity 10 MW has been modeled as a base case scenario. A list of assumptions is made in developing the model. The model provides information about the biomass and raw materials requirements, waste generation, the cost of planting the plant, and cost of electricity production per kWh. The model predicts the cost of producing electricity from empty fruit bunch (with 35% moisture content) is Sen29/kWh (based on our assumptions). Technological and economic specific uncertainty analysis has been performed to study impact of the uncertainty parameters on the cost of electricity production per kWh. Among the uncertainty parameters, the most significant are, installed equipment cost, energy efficiency, and feedstock costs. Economic of scale was also studied and compared with FiT tariff mechanism. The economics of scale favors plants with large capacities. However, supply chain logistics are not included in the model and analysis.

Keywords: Steam-Rankine cycle, electricity production, cost, economics of scale, FiT, biomass

Introduction

Malaysia is a fast growing developing country, has transformed its economy from raw materials producer into an emerging multi-sector economy, with a vision to achieve high-income status by 2020. The national GDP growth rate in 2010 was 7.2 (DoS, 2011) and expected to be 5.26 and 5.1% in 2011 and 2012 respectively (Damodaran, 2011). This rapid economical advancement led to an unprecedented increase in energy demand. In 2009, Malaysia produced 105,000 GWh of electricity (WB, 2012), and projected to reach 141,000 GWh in 2015 (TWN, 2011) and expected to reach or exceed OECD per capita energy demand level by 2030 (Bayar, 2011). Currently Malaysia's electricity production mix is 61% from natural gas, 31% from coal and peat, 6% from hydro and 2% from oil (IEA, 2012). In 1981, Malaysia enacted Fuel Diversification Strategy to reduce dependency of crude oil by promoting four major energy resources: hydroelectricity, natural gas, and coal and peat as an alternative to fossil oil. This policy successfully helped reducing national oil dependence from 90% in 1980 to less than 10% in 2003 (Sovacool and Drupady, 2011). Malaysia is also rich in renewable energy resources (agriculture, plantation and forestry industry residues, and municipal solid wastes) and is located in equator with unique geography and heavy rainfall provides potential for solar and hydro energy as well. Estimates show that Malaysia has the renewable energy (RE) electricity production potential of 11,500 MW, of which nearly 4,500 MW from biomass alone (some source estimates much higher than 6,500 MW). Malaysia's current total power generation capacity is nearly 24,000 MW which is

Table 1. Renewable Energy Potential for Malaysia (MPOB, 2012; Milbrandt & Overend, 2008; Sovacool & Drupady, 2011)

Resources	Sub category	Potential Electricity (MWe)
Biomass	Oil Palm[*]	3,695
	POME[*]	515
	Paddy (Rice husk)	72
	Paddy (Straw)3	80
	Sugar (Bagasse)3	31
	Wood (Sawn timber)3	50
	Wood (Plywood & Veneer)3	5
	Wood (Molding)3	2
	Municipal Solid Waste3	9
	Sub-total	**4,459**
Hydropower	Mini-hydro	**500**
Solar		**6,500**
TOTAL		**11,459**

[*] 2011 data; the rest are 2007 data

twice the renewable energy potential (The Economist, 2010). The government of Malaysia recognizes the importance of renewable energy resources and has incorporated it in the 8th Malaysian Plan (2001-2005) as the fifth energy source in the national energy supply mix, and has taken initiatives to ensure the sustainable development of energy resources, both depleting and renewable, in meeting the energy demand. On June 2010, the government of Malaysia announced the National Renewable Energy Policy and Action Plan to enhance utilization of indigenous renewable energy (RE) resources to contribute towards national electricity supply security and sustainable socioeconomic development with a conservative SMART (specific, measurable, achievable, realistic and time-specific) target of increasing renewable energy mix from 1% (217 MW) of total electricity supply in 2011 to 6% (330 MW from biomass, 100 MW from biogas, 290 MW from mini-hydro, 55 MW from solar PV, and 200 MW from solid waste) by 2015 (Figure 1). The action plan will also help avoid CO_2 emission by 850 metric ton (MT) in 2011 and 3.7 million metric ton (MMT) in 2015 (Figure 1).
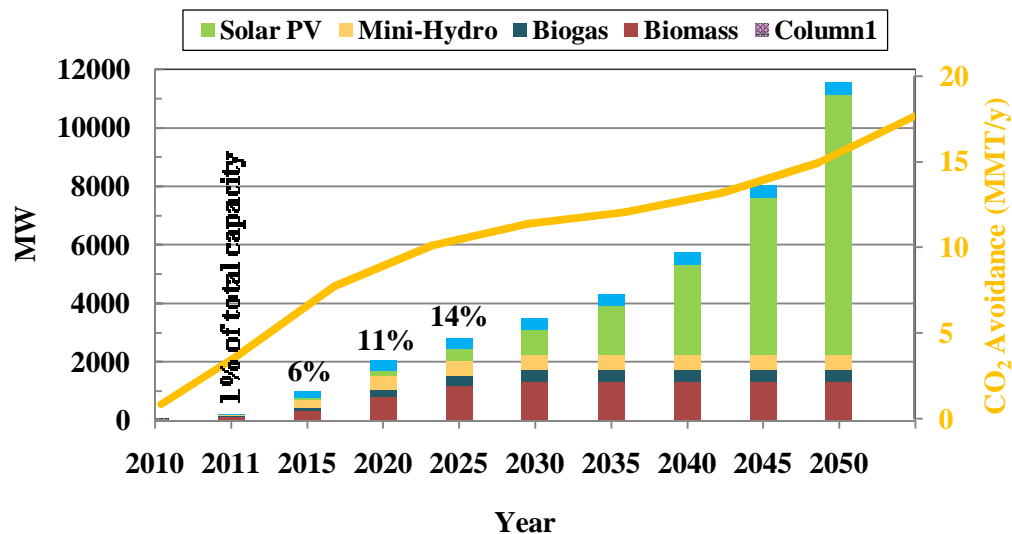

Figure 1. Renewable Energy SMART Target (Malek, 2010)

However, despite rigorous initiatives, the progress in developing renewable energy industry is slow. The renewable target set out under the Ninth Plan (from 2006 to 2010) was not achieved. Under the Tenth Plan (2011-2015), the government has introduced Feed-in Tariff (FiT) mechanism to boost the development of RE industry. The FiT mechanism allows electricity produced from RE to be sold to power utilities at a fixed premium price and for a specific duration (16 to 21 years depending on the source of the energy) (Table 2).

Table 2. Renewable Energy (RE) Feed-in Tariff (FiT) rates and duration (SEDA, 2012)

Biomass (16 years)		Biogas (16 years)		Solar PV (21 years)		Mini-hydro (21 years)	
Capacity (MW)	Rate (RM)	Capacity (MW)	Rate (RM)	Capacity (kW)	Rate (RM)	Capacity (MW)	Rate (RM)
10	0.31	4	0.32	4	1.23	10	0.24
10-20	0.29	10-20	0.30	4-24	1.20	10-30	0.23
20-30	0.27	20-30	0.28	24-72	1.18		
-	-	-	-	72-1000	1.14	-	-

This will provide a conducive and secured investment environment which will make financial institutions more comfortable in providing loans with longer period to finance the renewable energy projects. However, RE energy technologies are new or at different stages of development. The new technologies are often vulnerable to operational failure that leads to capacity loss and escalation of capital investment. These uncertainties lead to higher production cost at the initial stages of new technology adoption. It is anticipated that cost of production of electricity from RE will be higher initially as it is a new technology and has no direct subsidies compared with conventional energy sources. The FiT mechanism is expected to bridge this gap, but over the time as the RE technologies matures the cost of production will be equal or lower compared to conventional energy sources.

In the present studies, we intend to model a biomass based steam-Rakine cycle power plant of capacity 10 MW as a base case scenario. The model will give us an understanding of feedstock and raw materials requirements, waste generation, capital and operating cost requirements, and the cost of electricity production from biomass. Sensitivity analysis of critical parameters on cost of electricity production will be done. The study will also cover the economics of scale on cost of electricity production from biomass. These analyses will give us an idea of how FiT mechanism would help boosting the investment in RE industry, and how the investors may benefit from Malaysian rich renewable energy resources and the government's initiatives.

Methodology

A biomass based power plant is modeled in Aspen Plus Process Simulator environment. The capacity of the simulated bio-power plant is assumed to be 10 MW. The plant will be utilizing Empty Fruit Bunch (EFB) for the production of electricity. It is assumed that the plant receives air dried EFB bails with initial moisture content of 35%. This will be stored in temporary storage facilities until being utilized. The chemical composition of the EFB is given in Table 2.

Table 2. Empty Fruit Bunch (EFB) composition (Shamsudin etal., 2011)

Composition, dry basis (%)			
Cellulose	Hemicellulose*	Lignin	Ash
38.05	31.29	21.76	8.9

* Hemicellulose (Xylan and Arabinan)

The mass and energy flows are calculated using Aspen plus process simulator. The economic analysis are done using Excel spread sheet. Technological and economic data are obtained from published literature and via personal communication with local companies. The following list of key assumptions is made for mass and energy balances and cost of electricity production are analyzed:

- The plant will operate 8,400 hours per year.
- Minimum stack temperature is 90 ^{o}C.
- The plant life is assumed 20 years with zero salvage value
- Construction Period is 1 year, and startup time is 6 months. During startup period 50% of normal revenue is earned, variable and fixed costs are assumed 75 and 100% of normal costs respectively.
- Depreciation period is assumed 20 years for Steam and Electricity production area, and 7 years for other areas
- A Double Declining Balance method is used to calculate annual depreciation
- EFB (empty fruit bunch) price is assumed RM60/dry MT
- The project is assumed 100% equity financed
- Project contingency is 30% of Total Installed Cost
- Fixed operating cost is 2% of Total Installed Cost
- Maintenance cost is 2% of Total Capital Investment
- Income Tax Rate is 30% taxable income
- Internal Rate of Return is 10%

The cost of bio-electricity production per unit (kWh) is calculated using a discounted cash flow analysis. The program iterates the electricity selling price until the net present value of the project is zero. The technological and economic parameters that have significant impact on the cost of electricity production are identified and sensitivity analysis on those parameters is done to study the robustness of the electricity production cost (per unit basis).

Simulated Power Plant

There are various pathways to converting biomass into fuel products and energy (Figure 2). For the present studies we are interested in a simplified pathway to produce bio-electricity. The pathway we select is: direct biomass combustion to generate heat to produce high pressure superheated steam to turn turbine that drive electric generator to produce electricity.
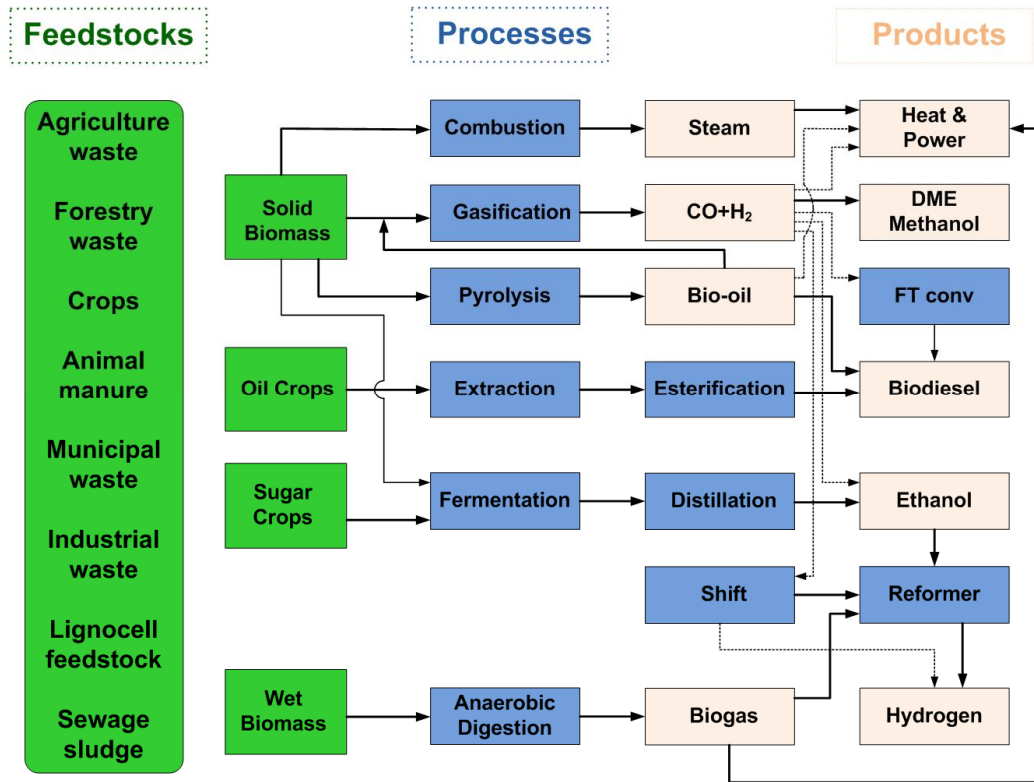

Figure 2. Biomass conversion pathways to fuel and energy

For the present studies a circulating fluidized bed combustion (CFBC) system is selected. This system replaces traditional grate by a bed of inert granular material, usually sand or crushed limestone. Preheated air is blown upwards through the granular bed with such force that the granules in the bed circulate and bubble randomly, like a boiling liquid. The ground biomass is blown into the combustion chamber to burn in suspension with nearly complete combustion. Based on this technology, a simplified steam-Rankine cycle power plant block diagram is developed as shown in Figure 3 below. The plant is divided into 4 sections: biomass feed handling, combustion and turbo-generator, water treatment, and cooling tower.
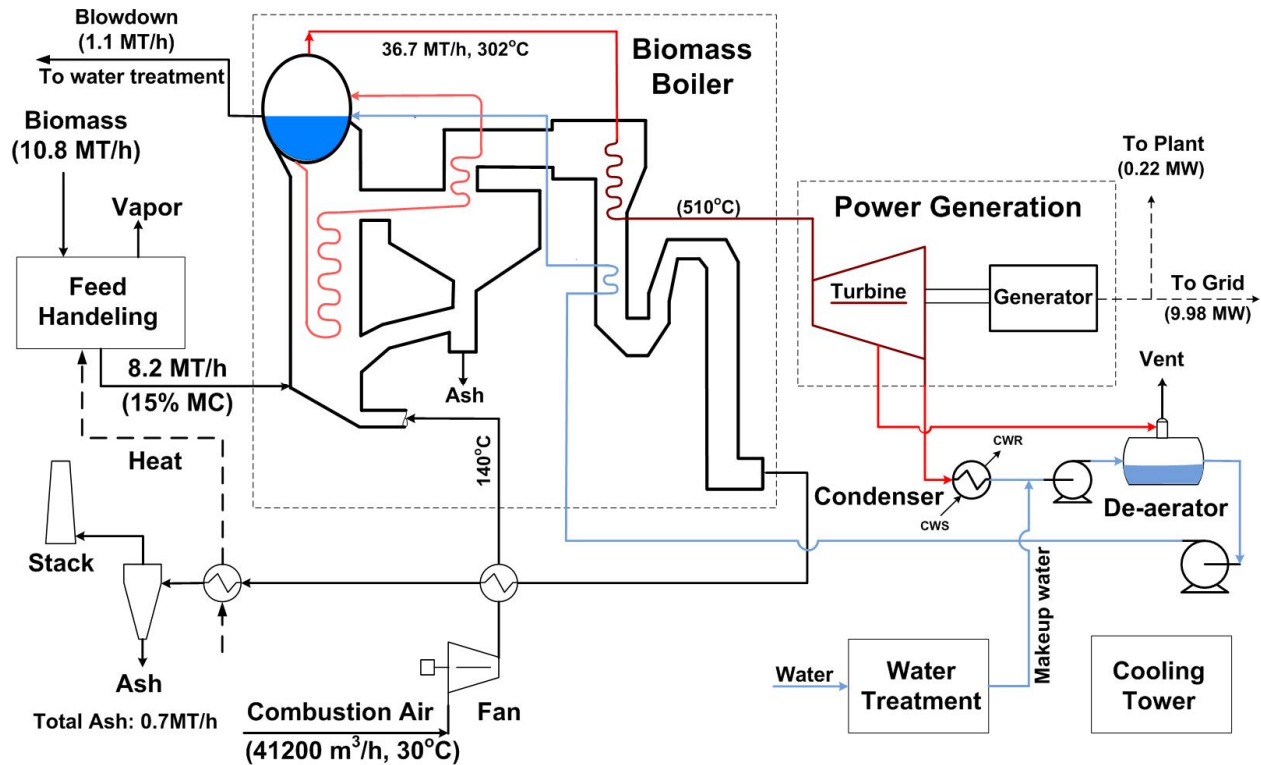
Figure 3. Schematic diagram of a steam-Rankin bio-power plant

In the feed handling section, the EFB (with initial moisture content (MC) of 35%) is received and stored in a temporary storage facility. Nearly 10.8 metric ton (MT) per hour of EFB is shredded in an industrial shredder followed by drying in a drier with waste heat from the power plant to 15% MC (moisture content) and grounded to fine particles. The ground feedstock is then fed into a circulating fluidized bed combustor where it is burned at 870 ^{o}C in presence of 10% excess air (stoichiometic excess). Nearly 41,200 m^3/h of air at 30°C intake temperature is moved by a fan through a heat exchanger to the combustor. Treated water is feed into the heat exchanger circuit in the combustor to boil and superheat to produce high-pressure steam (510°C). A multistage turbine and generator are used to generate electricity. A fraction of the steam is extracted from the turbine for the de-aeration of boiler feed water in the deaerator. In the final stage of the turbine, the steam is taken down to a vacuum and condensed with cooling water for maximum energy conversion. The condensate is returned to the boiler feed water system. The steam turbine turns a generator that produces AC electricity. A part of the electricity is used in running pumps, fans, shredder and other electric equipment. The net generated electricity is sent to grid.

In the water treatment section, reverse osmosis, ion-exchange and softener system are used to remove fine particles, ions, dissolved air and other non-condensables. Makeup water and

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condensate are treated and deaerated in these units then preheated with steam to 177°C prior to entering the boiler. Boiler blowdown is 3% of steam produced in the boiler. The blowdown stream is flashed to atmospheric pressure; the vapor is vented to the air and the liquid is routed to wastewater treatment section. The turbo-generator uses a multistage turbine with one extraction port and a final condenser. Of the superheated steam leaving the boiler, 13.6% is extracted from the turbine at 4.4 bar pressure for using in the deaerator. The rest of the steam is condensed, and the condensate is pumped back to the boiler. The turbine shaft turns a generator to produce electricity. The generator efficiency is assumed to be 85%. For this base case study, a total of 10.2 MW of power is generated from the system. The plant uses 218 kW of electricity and a net 9.98 MW of electricity is sold to the grid.

Result and discussion

The simulation result shows that 1.53Gcal/h of waste heat, from flue gas to stack, is needed to dry 10.8 MT of wet EFB (35% MC) to 8.2 MT/h (15% MC). The dry biomass (7 MT/h dry basis) is ground and feed to the combustor to produce 37.6 metric ton per hour of high pressure super heated steam (510 °C). The steam turns the turbo-generator and generates 10.2 MW of electricity, of which nearly 218 kW is consumed by the plant for running different equipment and pumps, and a net 9.98 MW per hour (equivalent to annual generation of 83.9 MWh) of electricity is sent to the grit. The ash produced was 0.68 MT/h. For the present studies, ash is assumed solid waste which is to be disposed off at a cost of RM 60 per MT. However, depending on the characteristics of feedstock, ash maybe used as biochar for soil amendment, in this case ash will be considered as byproduct. The boiler blow down is 1.1 MT/h (3% of the total steam generation), and makeup water is 0.57 MT/h. Mass and energy flow rates of stream was evaluated to estimate the unit and equipment sizes. The purchased equipment costs were estimated from published literature. All cost data was scaled to plant capacity and indexed to

Table 3. Capital and operating cost in million Ringgits (MRM) in 2011 year value

Cost Item	Million Ringgit (MRM)
Total Installed Cost (TIC)	51.6
Indirect Costs (IC)	38.7
Total Capital Investment (TCI)	90.3
Other Costs (Startup, Permits, etc.)	4.5
Total Project Investment (TIC, Other costs)	**MRM 94.8**
Fixed Operating Cost (FOC)	5.5
Variable Operating Cost (VOC)	4.2
Operating Cost (FOC, VOC)	*9.7*
Annual Capital Charge (ACC)	16.7
Total Operating Cost (FOC, VOC, ACC)	**MRM 26.4**

year 2011 cost value using Chemical Engineering Plant Cost Index. The purchased equipment costs were factored to obtain installed equipment cost for individual equipment and summed up to find total installed cost (TIC). Indirect cost includes field expenses (20% of TIC), office and construction fees (25% TIC), project contingency (30% of TIC). The Total Capital Investment (TCI) is the sum of TIC and IC. Other costs such as startup, permit, etc. is assumed 5% of TIC. For the present studies, the Total Project Investment is estimated as 94.8 MRM which is the sum of TIC and other costs. Plant area wise breakdown of the installed cast is shown in Figure 4. Boiler and turbo-generator area requires nearly 87% of the total Installed costs. The cooling tower and feed handling areas costs about 6% each. The water treatment section has the smallest impact on the total installed cost.
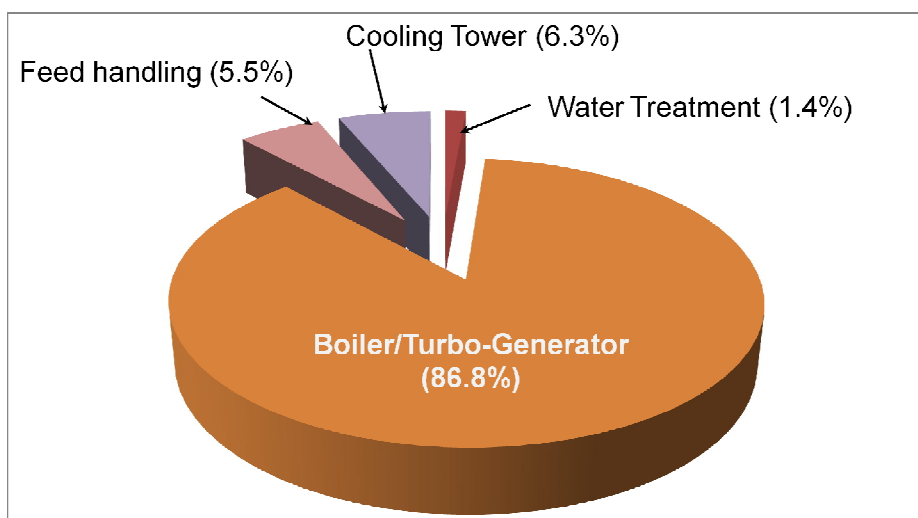

Figure 4. Plant area wise breakdown of total installed costs

The total operating cost (TOC) for the project includes staff salaries, staff benefits, feedstock and other raw materials costs, maintenance, depreciation, average income tax and average return on investment. For the base case scenario, the TOC is estimated as MRM 9.7. Detail breakdown of the TOC is shown in Figure 5. Feedstock cost is 36% of TOC, staff salary and benefit is 30%, and plant maintenance is 20% of TOC. Waste disposal and makeup water costs combined is 7% of TOC.
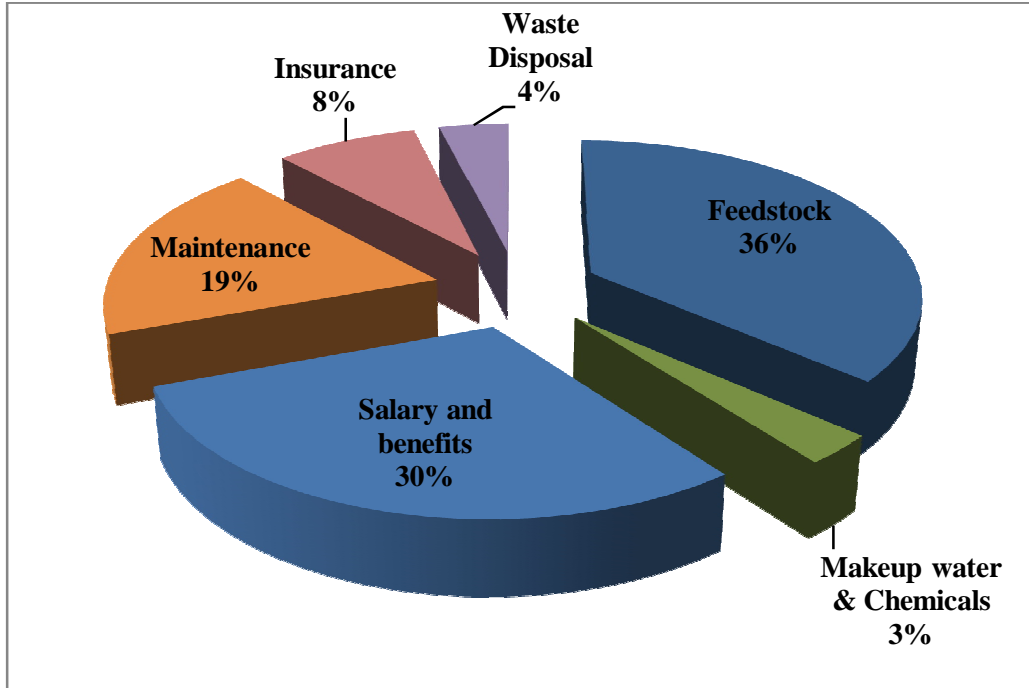
Figure 5. Breakdown of operating costs

The total project investment, variable and operating costs for the project are used to estimate electricity production cost using a discounted cash flow analysis program. The program iterates on the production cost until the net present value of the project is zero. Analysis shows that the cost of electricity production from EFB is nearly sen29 per kWh when the steam Rankine plant capacity is 10MW and the efficiency is 29.6% (Table 4).

Table 4. Overall analysis results

Electricity Production Cost (Sen/kWh)	0.29
Electricity Production (GWh / Year)	83.9
Steam Rankine Plant Efficiency (%)	29.6

Technology specific uncertainty analysis involving energy efficiency, installed equipment cost and waste disposal cost has been performed to study their impact on the electricity production cost per kWh (Figure 6). The electricity production cost is most sensitive to installed equipment cost and energy efficiency. When the installed equipment cost is increased from 16.3 to 24.5 MMR, an increase in production cost of 39% is observed because larger project investment required than that of the anticipated base case scenario. The bio-power technologies are new to power industries, and have little or no experience in the area which may lead to escalation of the total project investment.

When the energy efficiency of the Steam-Rankine cycle, a basic technology, is increased from 29.6 to 40%, a decrease in 48% of electricity production cost per kWh is observed which explains that better technology with higher energy efficiency can compete the conventional non-renewable power technologies in the long run.

An overall economic uncertainty on the steam-Rankin cycle technology has also been performed. The selected uncertainty parameters are EFB price and waste disposal cost. EFB price has significant impact on the electricity production cost per kWh, however, the waste disposal cost doesn't have much impact (Figure 6). When the EFB price is doubled from RM60 to RM120 per dry MT, an increase in electricity production cost of 15% is observed. If the EFB is assumed available at free of cost then the electricity production cost per kWh will decrease by 15%. This scenario may be true at certain geographical locations in Malaysia, however, in the long term biomass will be traded as a commodity, and the price will increase depending on the geographic locations and competition for feedstock with other bio-based industries. The impact of waste disposal is observed insignificant. In the base case scenario, ash is assumed waste, however it may not be true. Ash contains minerals and chars which are essential for soil amendment. Lab and field trials are needed to validate its application in plantation and agricultural fields. In that case, ash will be traded as by product and overall economics will look better. In the present analysis CO_2 credit is not included.
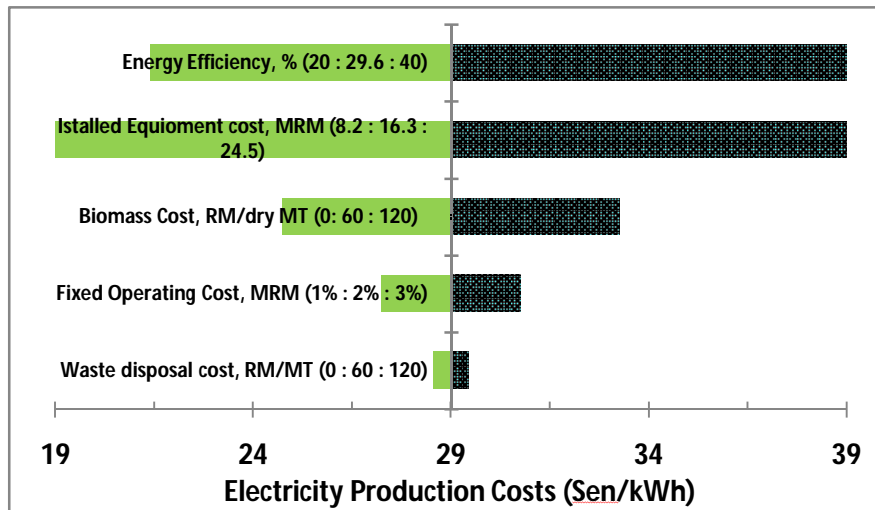

Figure 6. Impact of critical parameters on cost of electricity production

In the present studies, the economics of scale is evaluated as shown in Figure 7. For the base case scenario, the plant capacity is assumed 10 MW which is at the upper limit of small biomass power plant under FiT mechanism (Table 2). The cost of electricity production per kWh for the base case plant is evaluated as Sen29.2/kWh (based on our assumptions). When the plant capacity is increased from 10 to 20 MW (upper limit of mid-size biomass power plant under FiT mechanism), the cost of electricity production per kWh is reduced to Sen27.4/kWh, and when capacity is increased to 30 MW (upper limit of large-size biomass power plant under FiT

mechanism) the cost reduced to Sen24.3/kWh. We also have extended the analysis for a large plant of capacity 100 MW, the production cost for such large scale biomass based power plant is significantly reduced toSen13.3/kWh following an exponential correlation.
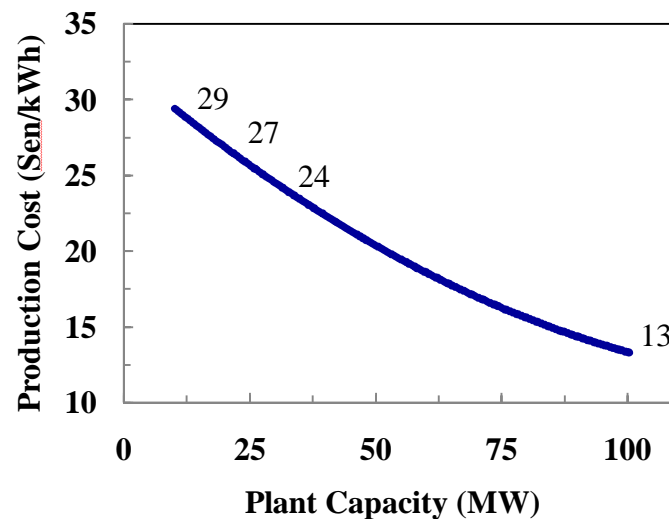

Figure 7. Effect of plant capacity on cost of electricity production

Apparently the FiT is Sen2/kWh higher than the cost of electricity production from biomass (based on our assumptions) for all capacity-tariff brackets (Figure 7, Table 2). However, unlike model predictions (which gives a continuous exponential correlation between cost of electricity production and plant capacity) FiT follows tariff-capacity brackets. A comparison of production cost prediction with FiT as a function of plant capacity is shown in Figure 8.
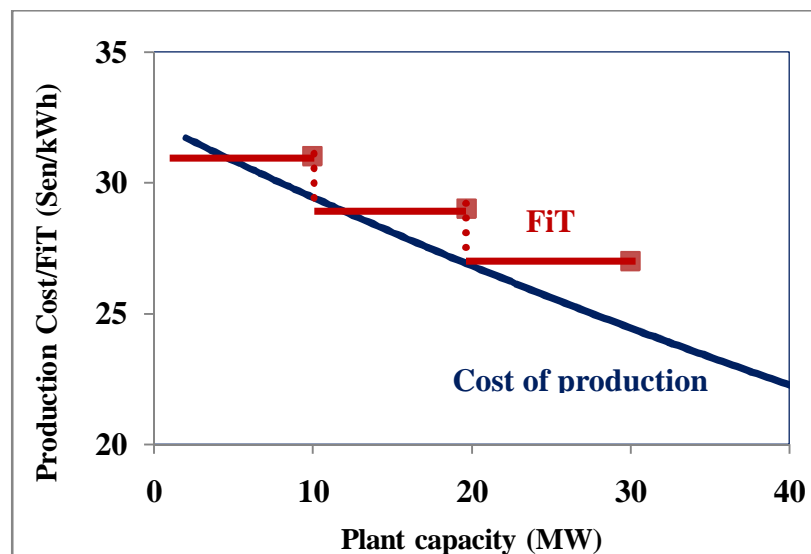

Figure 8. Effect of plant capacity on production cost and FiT brackets

According to FiT mechanism, if the biomass RE plant capacity is up to 10 MW, the operator will receive electricity tariff of Sen31/kWh, similarly for a plant with capacity between 10 to 20 MW the operator will receive sen29/kWh. However, the cost of electricity production per kWh maybe higher than the FiT tariff if the plant capacity is at the lower end of the FiT tariff bracket.

Conclusions

Renewable energy has bright prospect for Malaysia. The government of Malaysia recognizes the importance of RE for national energy security, sustainability and economic growth. The government is taking initiatives to support the development of the RE industry over the next decade by introducing FiT mechanism, and policies. RE technology is new, so there are uncertainties in terms of technological maturity, energy efficiency, feedstock variations and supply. For bio-power plants, economics of scale plays a vital role and favors large scale plants, however for a very large plant, the supply chain logistics and management maybe difficult and challenging.

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