Renewable & Appropriate Energy Laboratory
Energy & Resources Group
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Clean Energy Options for Sabah

an analysis of resource availability and unit cost

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Collaborators & Supporters

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Glossary of Acronyms, Units, and Concepts

Baseload Demand refers to the continuous demand for electricity by power consumers. Typically baseload demand is served by low-cost sources like as nuclear, coal, and hydropower.

BIPV – Building-integrated Photovoltaic. A distributed approach to solar power development, in based on rooftop solar photovoltaic equipment, often sending surplus power to the grid.

Capacity Factor is the amount of electric energy actually produced by a power plant divided by the electricity it would produce if it operated at its full rated capacity over the whole interval. For example, a hydropower plant with a rated capacity of 10 MW and an annual production of 70,080 MWh has a capacity factor of 80%.

Conversion Efficiencies and Heat Rates are measures of how efficiently a power plant can convert heat energy to electric energy. For example, a boiler might convert 85% of the potential heat energy in biomass to hot steam, with 15% of the energy being lost. A steam turbine with an efficiency of 33% would in turn convert 33% of the heat energy in steam to electric energy. Together, the boiler and the turbine have a combined efficiency of 28%. Sometimes this overall efficiency is reported as a **Btu/kWh heat rate**—i.e. the fuel energy needed to make a kWh of electric energy. The 28% efficiency figure above corresponds to a heat rate of 12,185 Btu/kWh.

Electric Energy is a measure of the amount of work that can be done by an electricity system. Throughout this report, we measure electric energy in kilowatt-hours (**kWh**), megawatt-hours (**MWh**), or gigawatt-hours (**GWh**). These units follow the standard base-10 metric conversion system: 0.001GW=1MW=1,000kW=1,000,000W.

Energy is a measure of the amount of work that can be done by a resource or system. This report employs three different energy units: **Joules (J), British Thermal Units** (**Btu**), and **Watts** (**W**). These units can be converted using the following factors: 1 Wh =3600 J = 3.412 Btu. Like most other units used in this report, energy units follow the standard base-10 metric conversion system: 0.001GJ=1MJ=1,000kJ=1,000,000J.

Emissions factors indicate the amount of greenhouse gas or other emissions produced per unit of energy, and is quoted throughout this report in terms of metric tons of **carbon dioxide (CO_2)** equivalent emissions per MWh of electricity produced (**tCO_2e/MWh**). "**CO_2 equivalent**" refers to the fact that all greenhouse gas emissions have been converted to the amount of CO_2 gas by weight that would cause an equivalent amount of greenhouse. Thus if methane gas has a global warming potential 25 times higher than that of CO_2, and a power plant produces 0.1 tonne of methane and 0.1 tonne of CO_2 per MWh, the plant's emission factor is .26 tCO_2e/MWh.

Heat Energy is usually measured in terms of Mega-Joules (MJ) (for all other fuels) or Million British Thermal Units (Mmbtu) (for natural gas). For example, biomass might contain 10 MJ or potential heat energy per kg.

IPP – Independent Power Producer. A separately-incorporated, non-public business that owns a power plant and sells power to a regulated electric utility.

IRR – Internal Rate of Return. The discount rate at which a project would have a NPV of zero.

NPV – Net Present Value. A measure of the current value of a stream of future costs and benefits, given a discount rate that reflects the existence of positive interest rates, inflation, and consumers' preference for present over future consumption.

Peak Demand refers to the demand that typically occurs at midday and in the evenings, when consumers' demand electricity for air conditioning and appliance use is at its most extreme. Peak demand is often served by diesel or natural gas "peaker plants" that can start quickly in response to increasing demand, but run for only a few hours each day. Solar generation can also meet peak demand in many situations.

A **Power Purchase Agreement (PPA)** is a long term contract under which an independent power producer (IPP) sells electricity to a regulated utility.

Power is the rate at which energy is produced and consumed. Electric generators are typically rated by the amount of power they are able to produce. A 1 kW generator running for one hour produces one kilowatt-hour (kWh) of electricity.

PTM – Pusat Tenaga Malaysia. The research arm of ST Malaysia.

PV – Photovoltaic. One major technology for turning solar energy into electric energy.

Reserve Margin - is a measure of the amount of power generation capacity available compared to peak demand. It is calculated as (power available-peak power demand)/peak power demand. For example, 750 MW of capacity against 500 MW of peak demand is a 50% reserve margin.

RM – Malaysian Ringgit. At the time of writing, 1 RM = 0.29 US$; 1 US$ = 3.4 RM.

SESco – Sarawak Electricity Supply Corporation. Sarawak's electric utility.

SESB – Sabah Electricity Sdn. Bhd. Sabah's electric utility. Eighty percent owned by TNB; twenty percent owned by Sabah's state government.

ST Malaysia – Suruhanjaya Tenaga Malaysia. The national energy regulatory commission, which is organized under the Ministry of Energy, Green Technology, and Water.

SREP – Small Renewable Energy Production programme. A national initiative that provides a legal framework for the sale of renewable energy by IPPs to Malaysia's utilities.

TNB - Tenaga Nasional Bhd. Peninsular Malaysia's electric utility. Sixty percent owned by Malaysia's Federal Government

Tonne is used throughout this report to indicate a metric ton, or 1000 **kg**. **Ton** or **t** is used to indicate an imperial ton. 1 ton = 0.907 tonnes = 907 kg = 2000 **pounds (lbs)**.

Contents

Executive Summary

Sabah is a Malaysian state on the island of Borneo. It has a population of over 3,000,000, and a growing economy based on the export of palm oil, timber and other natural commodities, and tourism. Sabah is a significant exporter of natural gas and oil.

Sabah has a current estimated nameplate electricity generation capacity of roughly 900 MW against about 700 MW of peak demand—a 28% reserve margin. However, electricity demand is growing at over 7% per year, and much of Sabah's existing capacity is in the form of aging, expensive, and increasingly unreliable diesel plants. Unplanned outages lead to costly service interruptions throughout Sabah, and especially on the east coast, which is almost wholly dependent on diesel plants.

Sabah's electric utility—Sabah Electricity Sdn. Bhd (SESB)—plans to add significant generation capacity to its grid over the next decade, both to meet electricity demand, which is forecast to grow at 7% a year, and to allow it to decommission some of diesel plants. The new capacity is slated to come primarily from three 100-300 MW natural gas plants, three 100-200 MW hydropower plants, and one 300 MW coal plant. The coal plant has been controversial. The first two locations proposed for the plant were abandoned,[1] primarily due to community resistance to ash ponds, high-temperature water discharges, acid rain-causing sulphur dioxide, hazardous arsenic contamination, and other local environmental effects expected from the plant. Preparations for an environmental impact assessment for the third site, a rural area on the coast of the Lahad Datu administrative district in southeast Sabah, are currently underway.

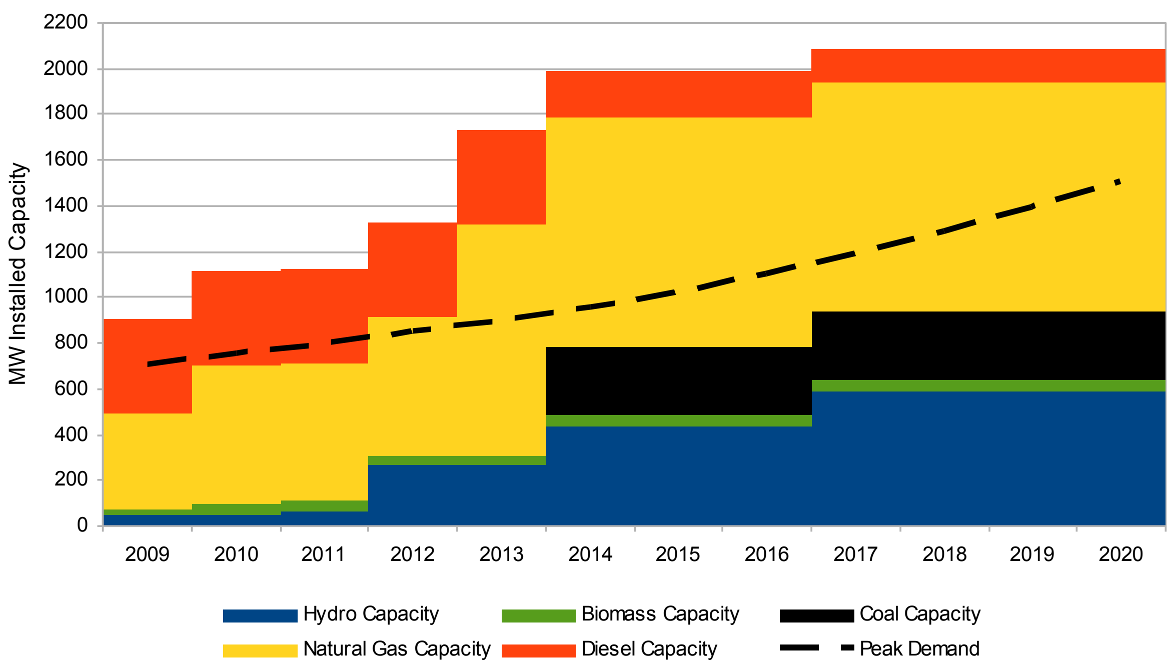

Figure ES-1: SESB's Plant-Up Plan, 2009-2020

[1] SESB, Corporate News, "TNB Responds to Cancellation of the Lahad Datu [Coal Plant]," http://www.sesb.com.my/corporate_news_view.cfm?id=7.

This report aims to present and analyze information on the potential of renewable energy in Sabah to provide an environmentally-friendly, cost-effective alternative to the proposed coal plant. Sabah's energy needs and unique environmental biodiversity, valuable tourism opportunities, and natural beauty warrant such an analysis. The energy and environmental team in Professor Kammen's Renewable and Appropriate Energy Laboratory has over 20 years experience in conducting these types of studies in North America, Europe, Asia, Africa, and Latin America.

For each renewable option we examine—biomass waste, hydropower, solar, wind, geothermal, and demand-side energy efficiency—we compiled cost information from similar existing projects, published benchmark values, scientific data on weather patterns, and agricultural statistics. We used this data to generate cash-flow projections for hypothetical independent renewable power projects, allowing us to report the price that an independent power producer would need to receive in order to attain a benchmark rate of return on its investment.

Our estimates price in two financial incentives available to renewable energy in Malaysia. The first is the "Pioneer Tax Allowance," a deduction to corporate income tax equal to 100% of a renewable energy project's profit over the first 10 years of its life. This tax incentive is applied on top of the standard accelerated depreciation schedule available to capital investments in Malaysia. The second incentive is revenue from carbon offset sales under the Kyoto Protocol. Businesses and governments in nations that accepted a binding emission cap under Kyoto can meet their obligations with offset credit through financing emissions-reducing projects in nations like Malaysia that are not bound by an emissions cap. The amount of revenue a clean energy project can expect from offset sales depends on its size, the emissions from the alternative projects that might have been implemented instead of the clean energy investment (e.g., if the project replaces a relatively dirty coal plant, it will receive more credit than if it replaces a relatively clean natural gas plant), and the balance between supply and demand in the international market for carbon credit. We apply a conservative carbon offset price of 10 euros per tonne of CO_2-equivalent greenhouse gas eliminated to each of the renewable options we evaluate, and assume that renewable energy produced by such projects displaces energy with an emissions intensity of 0.40 tCO2e/MWh, the 2010-2015 average we estimate in Part 3 of this report.

Based on these incentives and the cost figures we have collected, we find that biomass waste projects at large palm oil mills are cost-competitive with coal. These projects rely on supply-side efficiency improvements—higher-pressure boilers and more efficient steam turbines—to upgrade their electricity generation capacity to levels that allow export of power in addition to power for in-house use. Feeding currently unused palm oil waste into these efficient combustion systems solves two environmental problems at once: the problem of disposing of potentially-hazardous mill waste in open ponds and landfills and the problem of supplying Sabah's energy demand. Several such projects are already operational in Sabah, and a number of national incentives aim to stimulate further investments. Based on 2008 palm oil-industry production statistics and conservative growth estimates, we calculate that 700 MW of theoretical baseload capacity will be available from palm oil mill waste by 2020, and that over 400 MW of this capacity is economically feasible and logistically achievable via a 4 project per-year ramp-up programme. We recommend that Sabah support these projects.

We also find that hydropower, including relatively environmentally-friendly run-of-the river hydropower, is cost-competitive with coal. Existing hydropower projects in Sabah have high capacity factors and produce baseload power year-round. Because the only hydropower data to which we had access at the time of publication dated to the mid-1980s we recommend further research into potential hydropower sites.

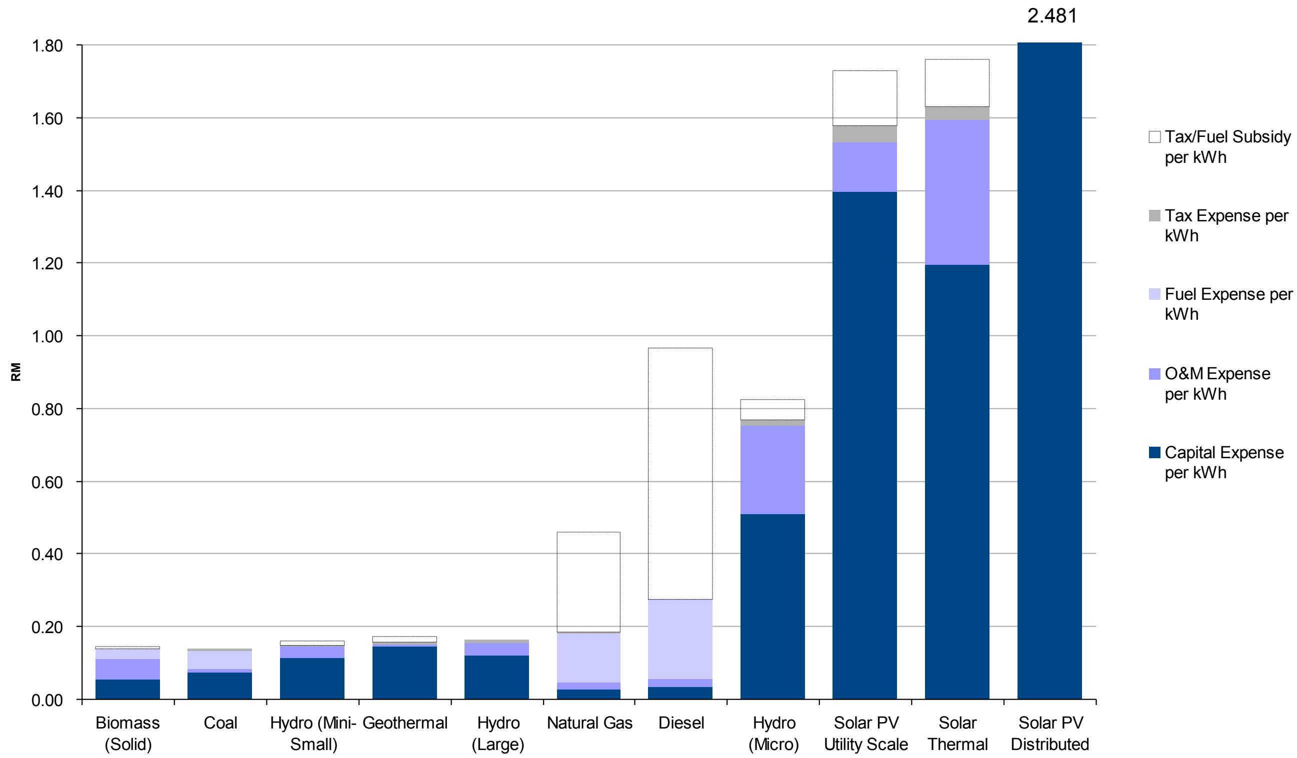

Figure ES-2: Levelized Cost Estimates for Electricity Generation in Sabah

Geothermal power is not quite cost-competitive with coal, but it is nearly so, and prospecting has already identified a site on Sabah's East Coast that is well-suited to a 67 MW baseload power plant. Study of the possibility of developing this resource should continue.

Solar power, whether in the form of distributed, rooftop systems or in the form of utility-scale power plants, is still almost 10 times as expensive as coal in Malaysia, and if immediate cost-benefit analysis is the sole measure, it cannot be recommended as a large-scale power supply solution today. However, Sabah receives strong solar radiation, and the prices of solar equipment are falling rapidly. From a longer-term perspective, solar is in fact a viable option and one that could become a major source of the regional energy supply as well as economic growth and job creation.

From a wind power prospecting perspective, Sabah lives up to its "land below the wind" appellation. State-wide, wind speeds appear to be too low to make wind generation commercially viable. That said, at least one ridgetop site with attractive wind speeds has been identified, and we recommend that site assessment at this and similar sites should continue.

Finally, we predict that as in other parts of the world, the cheapest electricity "supply" option is reduction of electricity demand. Though a detailed inventory of the Sabah-specific electricity efficiency potential is beyond the scope of this report, it is almost certain that RM 1.00 of efficiency investments by consumers and businesses can free up more kWh of electricity than RM 1.00 of investment in generation. Our report cites several existing studies that can help guide Sabah in taking advantage of this highly cost-effective strategy.

After reporting our cost estimates, we compare several portfolios of renewable alternatives to the baseline plant-up plan summarized in Figure ES-1 above. By modelling the scenarios in the U.S. National Renewable Energy Laboratory's HOMER programme, we were able to simulate how each scenario's power plants would meet Sabah's load on an hour-by-hour and month-by-month basis.

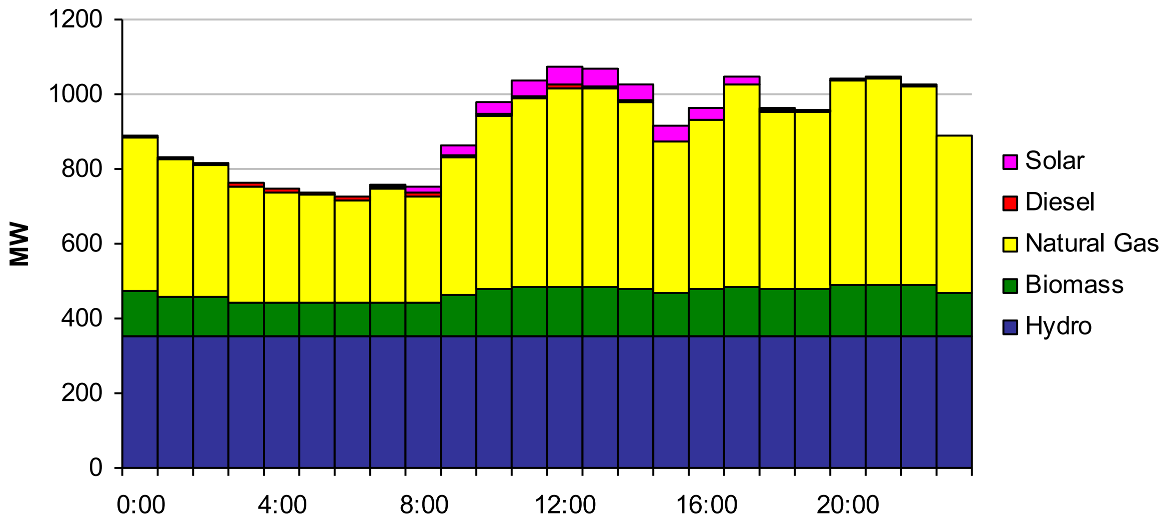

Figure ES-3: Simulation of Sabah Daily Load Serving in Biomass + Solar Scenario, 2020

We find that the coal plant scenario is likely to reduce the total per-kWh cost of electricity generation in Sabah by phasing out expensive diesel plants. However, the increasing reliance on coal after 2015 means that the per-kWh emissions of global warming-causing greenhouse gases like carbon dioxide will decrease only slightly from the diesel-heavy (and therefore relatively "dirty") grid mix of the present day, while emissions of local pollutants like sulphur dioxide gas and heavy metals will increase significantly.

We show that an alternate palm oil waste-focused scenario could meet electricity demand at a cost virtually identical to the coal scenario while dramatically reducing emissions. We also show that a portfolio of utility-scale renewable power plants—namely, a 67 MW geothermal plant at a site currently under study and 30 MW of run-of-the river hydro facilities similar to the recently-completed Esajadi projects—could meet demand at a price close to that of the baseline scenario. Finally, we find that a combination of a utility-scale solar and palm oil waste projects could meet Sabah's electricity demand while positioning the state as a renewable energy leader in East Asia; however, we predict that this portfolio would cost more than the palm oil scenario and do slightly less to reduce emissions.

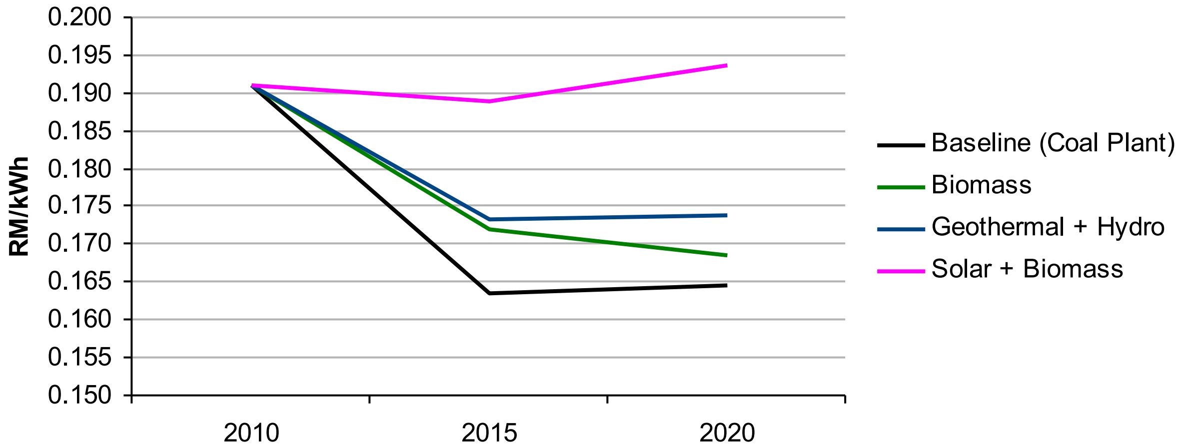

Figure ES-4: Scenario Estimates of Total Average Levelized Cost of Electricity in Sabah

Based on our analysis, we recommend that Sabah's citizens, government, and business community:

- Advocate the phase-out of the costly fossil-fuel subsidies that distort energy markets and make fossil fuels unfairly competitive with other options;
- Recognize renewable energy's status as a "premium product" with significant external environmental and job-creation benefits by paying a higher price for renewable power;
- Continue research and outreach efforts targeted at increasing the quantity of grid-connected electricity available from palm oil mills;
- Encourage efficient sizing of palm oil mill waste and run of the river hydro projects by repealing the 10 MW limit on investment under the Small Renewable Energy Power programme;
- Continue to study the feasibility of renewable investments at known geothermal, wind, and environmentally-sound micro hydro sites;
- Support the continuation and extension of Malaysia's existing solar promotion programmes, and supplement these efforts by launching a state-level solar energy commission

The sections below proceed in the order of our summary above. Section 1 contains background information on electricity supply and demand in Sabah, as well as the legal and policy environment in which power supply decisions are made. Section 2 is the levelized cost analysis, with one sub-section per fuel or renewable technology. Section 3 is the scenario analysis, with one sub-section dedicated to each scenario.

1. Sabah's Electricity Sector

In this section, we set out the background information on Sabah's electricity sector that governs the analysis that follows. We provide basic information on the time profiles and sources of electricity demand in Sabah, the location and fuel type of the power plants that currently serve this demand, SESB's plans for future supply, and the legal and policy environment in which Sabah's power supply decisions are made.

1.1 Electricity Demand in Sabah

The demand for electricity from households and businesses determines the amount of electricity that must be supplied from power plants. As in other areas of the world, peak demand for electricity in Sabah typically occurs between mid-morning and mid-afternoon. Demand falls off after about 8 pm, and is lowest during night time hours when most consumers are asleep and commercial facilities are closed. Thus, the average demand over an entire 24-hour period is much lower than peak demand—about 450 MW compared to 650 MW. Demand is significantly lower on weekends than weekdays, and lower on Sundays than Saturdays.

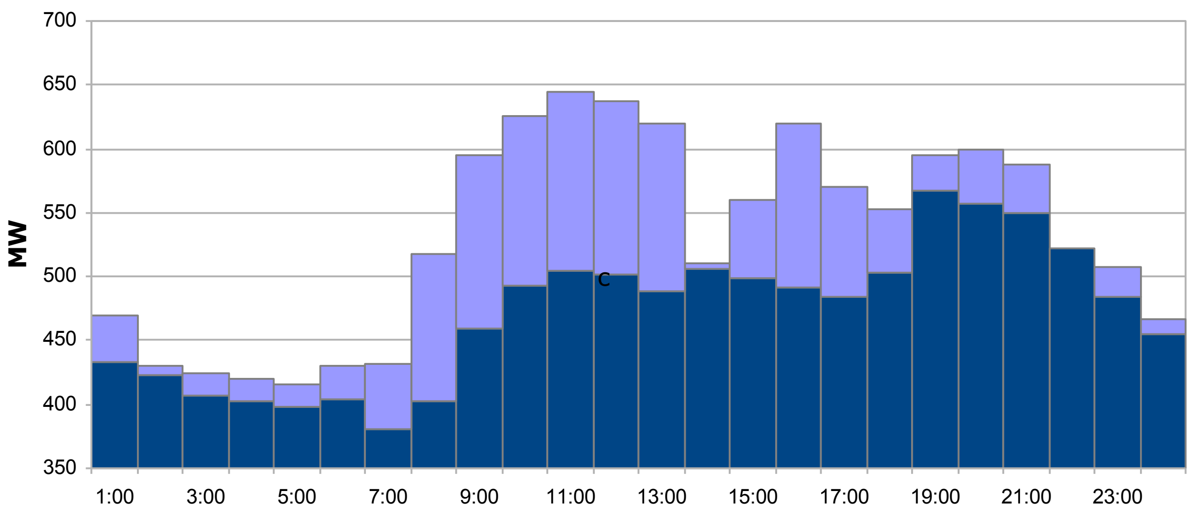

Figure 1-1: Sabah Hour-by-hour Load Profile (2008)[2]

Electricity demand in Sabah also varies somewhat on a month-to-month basis, though this variation is somewhat less important than the hour-to-hour variation. The available data

[2] Source: Khung Chiang Sing, SESB, *Energy Efficiency – Impact on SESB* (powerpoint presentation, undated). Weekend values are the average of values reported for Saturday and Sunday. The load profile represents demand in 2008. Information provided by SESB in February 2010, after this report had already been substantially completed, shows slightly higher demand for 2009 because of expected demand growth; demand growth in 2009 and 2010 is accounted for in the estimates and simulations below.

shows that the lowest peak demand occurs in March, and that it is about 15% below the highest peak demand in September.

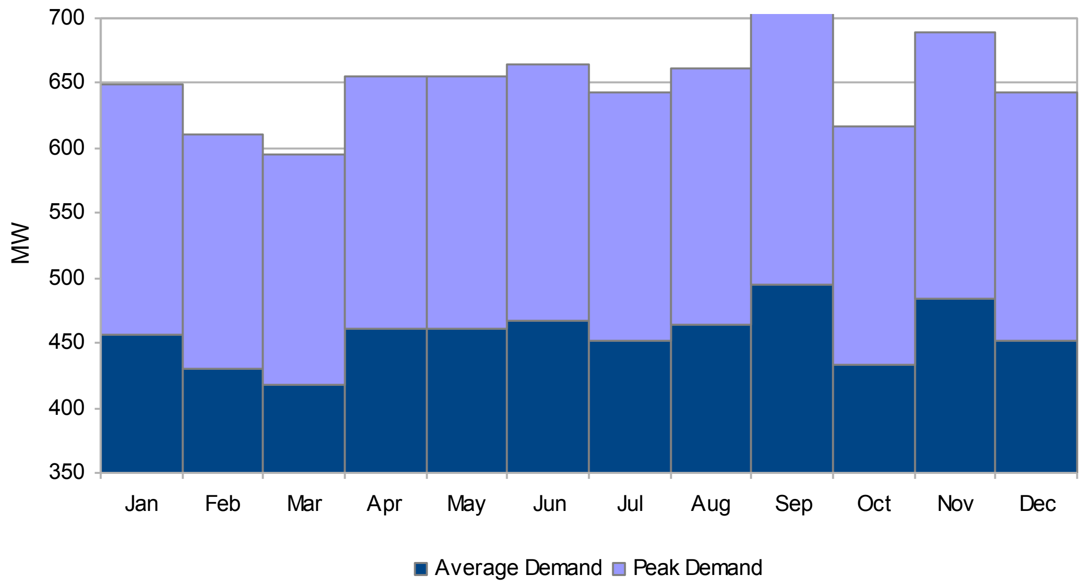

Figure 1-2: Sabah Month-by-month Load Profile[3]

Electricity demand in Sabah has grown rapidly as the state's economy has developed, exceeding even the rate of GDP growth. Between 2000 and 2006, Sabah's GDP grew by an average of about 3-4%; electricity demand increased at an average of about 8-10%.[4] Electricity demand growth is expected to continue at about 7% per year into the foreseeable future. A demand estimate published in October 2009 predicts that peak demand will reach 1000 MW by 2015 and 1500 MW by 2020.[5]

Consumers, commercial facilities, industry, and government all use electricity in Sabah. Data from the national energy commission shows that demand is evenly split between commercial, industrial, and domestic users, with each sector accounting for approximately 1/3 of consumption.[6]

The prices charged by Sabah's electric utility for the electricity vary by sector and sub-sector, ranging between RM 0.16 and RM 0.32 per kWh, depending on the type of user.[7] Prices have been stable for a number of years despite rising fuel costs, and are currently lower than those of most neighbouring countries as well as those in Sarawak.[8]

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3 Source: SESB, *Table 4: Electricity Generation and Consumption* (2008), on file with the author and available upon request. Monthly average demand is estimated for 2008 by applying 2006-2007 growth rate to source's reported 2007 average demand values. Monthly peak demand estimated for 2008 by indexing reported 2007 monthly demand and applying index to peak of 704 MW in 2008 reported by Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW coal plant* (16 October 2009), p. 9.

4 Institute for Development Studies, Sabah, *Review of Sabah's Major Economic Indicators in 2005*, p. 25.

5 Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW Coal-Fired Power Plant Project, Sabah* (16 Oct 2009).

6 SESB, *Corporate Profile*, http://www.sesb.com.my/corporate_profile.cfm.

7 *Id*.

8 Ministry of Energy, Green Technology and Water, *Electricity Tariff Awaits Cabinet Decision* (12 Sep 2009),

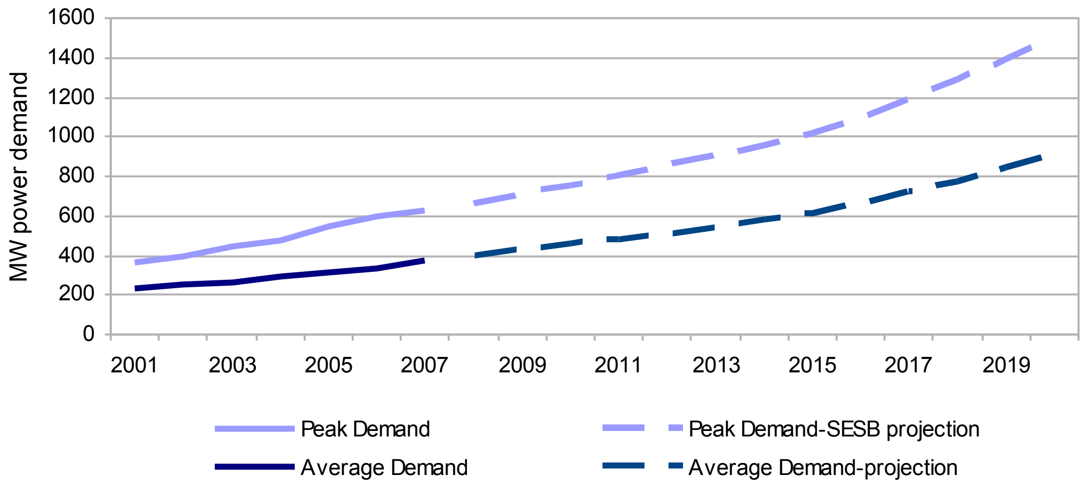

Figure 1-3: Projected Average and Peak Electricity Demand in Sabah through 2020[9]

1.2 Existing Electricity Supply in Sabah

Sabah has at least 17 major grid-connected power plants. Major plants are located near Kota Kinabalu, Labuan, Sandakan, and Tawau, with smaller plants scattered across the state. Since the completion of a transmission line connecting the East and West coasts in 2006, all of these plants have been connected to a single integrated power transmission grid that allows power produced anywhere in Sabah to be consumed at any other grid-connected location in the state. This transmission grid, however, is not connected to the Sarawak or Kalimantan grids, meaning it is currently impossible to import or export power between those states.

Eight of Sabah's 17 major plants (accounting for 46% of total installed capacity) are aging diesel plants that burn either diesel fuel or fuel oil. These plants tend to be less efficient than recently-built power plants, in the sense that they demand more fuel energy to produce a given quantity of electrical energy. Efficiency figures are not available for Sabah's power plants, but a Pusat Tenaga Malaysia (PTM) report shows that the fuel energy-to-electrical energy conversion efficiency of older diesel plants in Peninsular Malaysia is about 30%, compared with up to 45% for modern combined cycle gas plants or 34% for modern coal plants.[10] The existing diesel plants also tend to break down more than newer plants. The ARLT diesel plant in East Sabah had an unplanned outage rate of 28.9% in 2008.[11]

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http://www.kettha.gov.my/template03.asp?tt=news&newsID=478.

9 Source: 2001-2007 peak and average figures are from Suruhanjaya Tenaga, *Electricity Supply Industry in Malaysia Performance and Stat. Information 2007*, p. 87. Growth of peak demand is from peak demand figures cited for 2015 and 2020 in Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW Coal-Fired Power Plant Project, Sabah* (16 Oct 2009). Growth of average demand is estimated by applying the mean peak:average ratio from 2001-2007 to the 2008-2020 projection.

10 Suruhanjaya Tenaga, *Electricity Supply Industry in Malaysia: Performance and Stat. Information*, 2008, p. 10.

11 *Id.*, at 12.

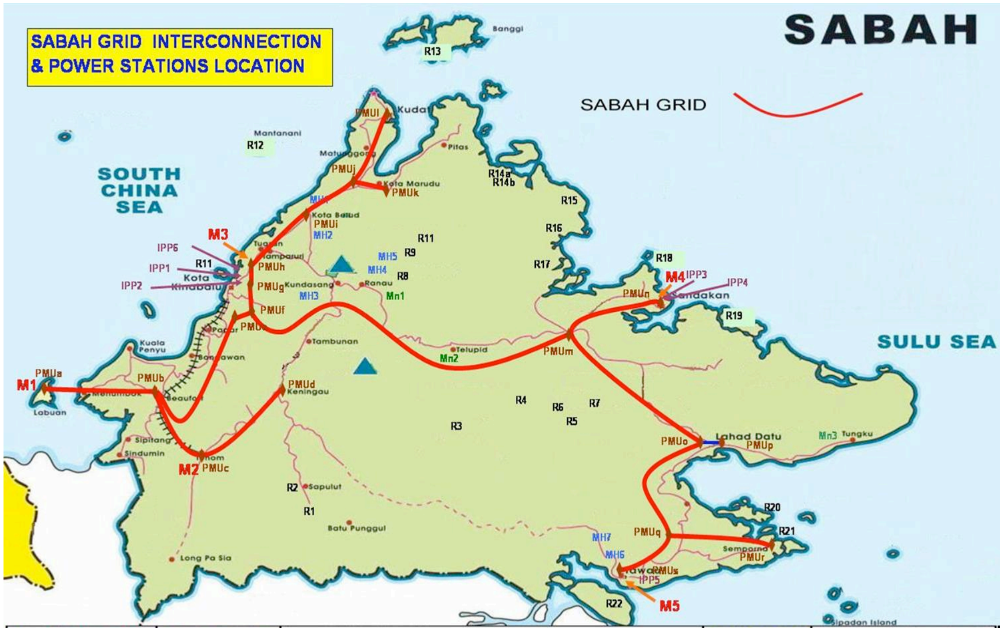

Figure 1-4: SESB Grid Schematic and Power Plant Locations[12]

Three more of Sabah's 17 major plants are combined cycle gas plants. These plants achieve high (up to 45%) efficiency by burning natural gas in a gas turbine (the "gas cycle") and then using the turbine's hot exhaust to heat steam, which is then fed through a steam turbine (the "steam cycle"). They are more reliable than the diesel plants, with unplanned outage rates of less than 10%, but not as reliable as the newest gas plants in Peninsular Malaysia, which have unplanned outage rates near zero.

Sabah's only major hydropower plant is the Tenom Pangi plant located on the Padas river near Tenom. This plant is a 66 MW run-of-the-river design, which means it relies on natural stream flow and elevation fall to generate power, rather than using a dam and reservoir to ensure consistent generation. However, relatively consistent rainfall appears to allow Tenom Pangi to maintain a high capacity factor: the plant managed to generate an average of 423 GWh per year between 1999 and 2003, implying a 73% capacity factor.[13] It is also reliable, recording an unplanned outage rate of only 3.7 % in 2008.[14] For reasons that are not clear at the time of writing, recent SESB publications downgrade Tenom Pangi to 44 MW of dependable capacity,[15] or report a lower (57%) capacity factor against its 66 MW nameplate capacity.

So far, four power plants have been built under Malaysia's "Small Renewable Energy Production" (SREP) programme. Three of these plants are located at palm oil mills. They generate electricity by burning the palm shells, fibres, and empty fruit bunches that are by-

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12 Source: SESB, *Corporate Profile*, http://www.sesb.com.my/corporate_profile.cfm.

13 Japan International Cooperation Agency, *Rehabilitation of The Tenom Pangi Hydropower Project, Field Survey*, 2003, http://www.jica.go.jp/english/operations/evaluation/oda_loan/post/2004/pdf/2-23_full.pdf, p. 5. See also Kina Biopower, *CDM Project Design Document*, http://www.jica.go.jp/english/operations/evaluation/oda_loan/post/2004/pdf/2-23_full.pdf, p. 19 (reporting an 80% capacity factor in 2005).

14 Suhuhanjaya Tenaga, *Electricity Supply Industry in Malaysia: Performance and Stat. Information*, 2008, p. 12.

15 Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW coal plant* (16 October 2009), p. 9.

products of the palm oil milling process. The fourth SREP plant is a 2 MW run-of-the-river hydro plant built in 2008 by the Esajadi corporation.

Table 1-1: Sabah's Existing Power Plants[16]

Plant Name	Ownership Category	Fuel Category	Geographical Category	MW	Capacity Factor[17]	Unplanned Outage Rate[18]	Notes
Ranhill Powertron	IPP	Gas	West	190		8.4%	Combined Cycle
Patau-Patau (Labuan)	SESB	Gas	West	112	57.1%	7.8%	Combined Cycle
SBPC	IPP	Gas	West	100		0.4%	Combined Cycle
Sandakan	SESB	Diesel	East	92	15.3%	21.7%	40 MW GT (GANT) + 52 MW DG (BSPS)
Tawau	SESB	Diesel	East	64	18.2%	20.8%	32 MW DG + 32 MW GT
Stratavest (LBRN)	IPP	Diesel	East	60		4.8%	
ARL	IPP	Diesel	West	50		28.9%	
Tenom Pangi	SESB	Hydro	West	44	57.8%	3.7%	
Melawa	SESB	Diesel	West	44	18.2%	12.1%	20 MW GT + 24 MW DG
Serudong	IPP	Diesel	East	37.5		11.6%	
Profound Heritage (Sutera Harbour)	Temporary	Diesel	West	32			Surplus from resort plant.
SPC	IPP	Diesel	East	32		8.8%	
Petronas PML (Labuan)	Temporary	Gas	West	14			
TSH	IPP	Biomass	East	10			
Kina Bioenergy	IPP	Biomass	East	10			
Seguntro BioPower	IPP	Biomass	East	10			
Esajadi Power	IPP	Hydro	West	2			
Total Capacity				**904**			

16 Source: List of power plants is from SESB, *Sabah Electricity Supply Status* (Powerpoint Presentation, 27 May 2008). SESB, *Corporate Profile*, http://www.sesb.com.my/corporate_profile.cfm, gives a lower figure of 840 MW total installed capacity, but this information may not take into account recently-added power plants and upgrades. Information provided to WWF in February 2010 shows the addition of a number of small diesel generators, and de-lists the Petronas PML plant. Because this information was received after the substantial completion of this report, and because the additions are small, they are not included in this analysis.

17 Capacity Factors are for Sep. 2008 to Sep. 2009, as provided to WWF by SESB in an unpublished document in February 2010. It is worth noting that many SESB estimates factor capacity factors and unplanned outage rates into their overall capacity figures. For example, Lahad Datu Energy Sdn Bhd*, Terms of Reference for Detailed Environmental Impact Assessment for 300 MW Coal-Fired Power Plant Project, Sabah* (16 Oct 2009) shows a "dependable" capacity of 894 MW. Similarly, unpublished information provided by SESB to WWF in Feb. 2010 shows an even lower "de-rated" capacity of 735 MW. Because the means by which this derating has been conducted are not clear, we report capacities as "nameplate" capacity rather than dependable or derated capacity throughout this report. We account for dependability issues by instead noting the effects low capacity factors and high unplanned outage rates wherever possible.

18 Suhuhanjaya Tenaga, *Electricity Supply Industry in Malaysia: Performance and Stat. Information*, 2008, p. 12.

1.3 SESB's Future Electricity Supply Plans, 2010-2020

SESB and its IPPs plan to build at least 10 major power plants over the next decade. Three new natural gas plants with an aggregate capacity of about 600 MW of capacity are slated for construction on the West Coast over the next few years. Later in the decade, SESB plans several new hydro projects with an additional 300-500 MW of capacity. These projects will also be connected to the West Coast grid. Finally, an IPP is planning to build a 300 MW coal plant on the East Coast.

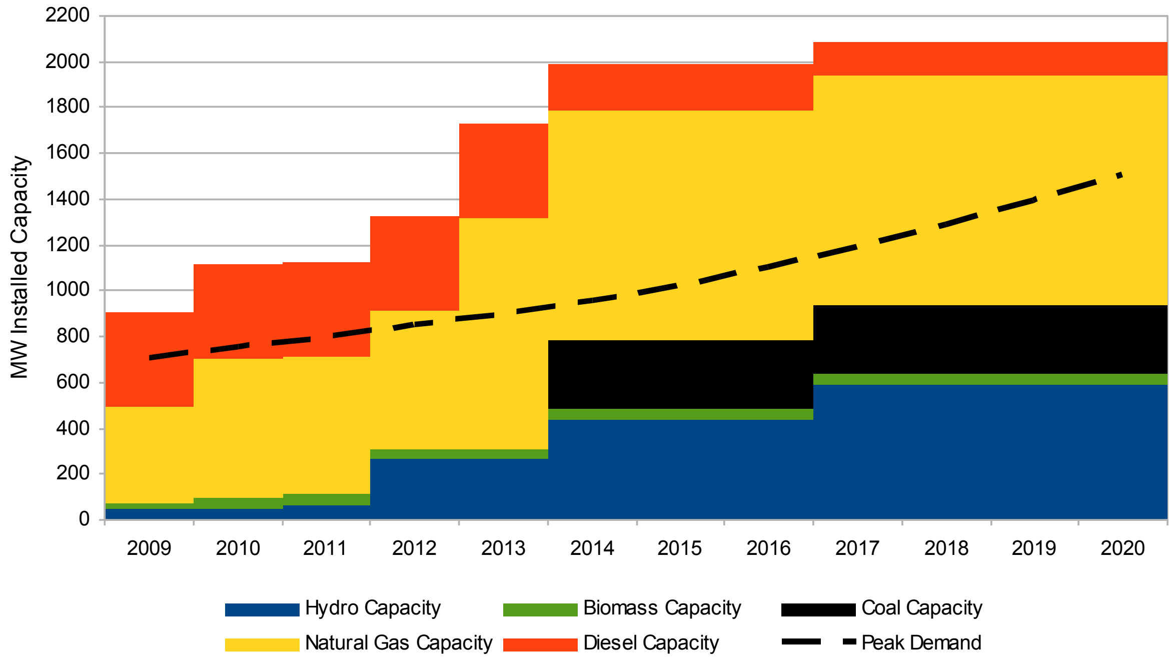

Figure 1-5: SESB Plant-up Plan, 2010-2020[19]

As these plants are commissioned, SESB plans to decommission its diesel plants. One plan calls for the decommissioning of about 160 MW of SESB-owned plants in 2013, the decommissioning of ARLT's 47 MW plant in the same year, and the decommission of more diesel plants later in the decade.[20] This would shrink diesel capacity from 47% of total capacity in 2009 to just 6% of total capacity in 2020.

The replacement of expensive diesel power with hydro, natural gas and coal power can be expected to dramatically decrease the total per-unit cost of power generation in Sabah.[21] Given the high unplanned outage rate of the existing diesel plants, it can also be expected to improve the stability of power delivery, eliminating the frequent blackouts currently experienced by electricity consumers.

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[19] Source: See Table 1-1a below.

[20] *Id*.

[21] A similar approach to decreasing the share of oil-based generation has been undertaken over the last two decades by both TNB in Peninsular Malaysia and by PLN, Indonesia's national utility. Ulysses R. Simandjuntak, *Managing Rising Fuel Prices: Removal of Fuel Subsidies vis-à-vis Economic Welfare*, (Powerpoint 2008), http://www.st.gov.my/ecom/images/publication/p1%20removal%20of%20subsidy%20on%20fuel%20prices%20vis%20a%20vis%mic%20welfare.pdf, p. 23.

Table 1-1a: SESB Plant-Up Plan, 2010-2020[22]

Plant Name	Ownership	Fuel	Location	MW	Availability
Powertron II	IPP	Gas	West	190	2010
Alaf Expressi	IPP	Biomass	East	10	
Kalansa	IPP	Biomass	East	5	
Esajadi Hydro[23]	IPP	Hydro	West	6.5	
Tenom Pangi Upgrade	IPP	Hydro	West	12	2011
Lawas/Other Sarawak Hydro[24]	SESB	Hydro	West	200	2012
SPR Kimanis	IPP	Gas	West	100	2013
Petronas Kimanis[25]	IPP	Gas	West	300	
Coal Pant	IPP	Coal	East	300	2014
Tenom Pangi New	SESB	Hydro	West	26	
Upper Padas HEP	SESB	Hydro	West	150	
Liwagu	SESB	Hydro	West	150	2018
Total New Capacity 2010-20				**1450**	
Decommissioned 2010-20				**253**	
Installed Capacity 2020				**2090**	

Even accounting for the decommissioning, the planned new plants will result in a larger ratio between installed capacity and projected electricity demand, which is typically referred to as the "reserve margin."[26] SESB projects that the current reserve margin of 22% will grow to

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22 Unless otherwise indicated, all information on SESB's plans are from SESB, *Sabah Electricity Supply Status* (Powerpoint Presentation, 27 May 2008). These plans match reports in a number of newspaper articles, including New Sabah Times, *Sabah's Energy Dilemma*, (25 Nov 2008), http://www.newsabahtimes.com.my/nstweb/fullstory/23785. However, information provided by Lahad Datu Energy Sdn Bhd in its Terms of Reference document for a Detailed Environmental Impact Assessment for the proposed 300 MW coal plant on the East Coast show a slower plant-up, indicating only 1571 MW of installed capacity in 2015 rather than the 1678 inferred from other published sources. We do not have access to SESB's detailed internal resource planning, and all plans are subject to change, so the projections shown in the figure and discussed in this section should be taken only as rough estimates with representative value, not relied upon for their quantitative accuracy. Furthermore, the capacity shares of different generation technologies do not correspond to the shares of electricity actually generated, which depends on the capacity factor of the plants as dispatched.

23 Alaf Expressi, Kalansa, and Esajadi Information is from PTM Malaysia, *Bio-Gen Web Portal*, http://www.ptm.org.my/biogen/.

24 SESB is negotiating for power supply from Sarawak's Lawas project. The potential supply has been variously reported as 100 or 200 MW. The higher figure is used here because Sarawak's planned dam projects give it a very large projected power surplus and SESB has indicated that it may be negotiating for power from other Sarawak projects. See SESB, *Conditions of SESB Sandakan Power plants* (30 July 2009) http://www.sesb.com.my/news_releases_view.cfm?id=145.

25 The TOR document for the proposed 300 MW coal plant lists the aggregate capacity of "two new proposed gas fired power plants…in Kimanis" as 300 MW. However, other sources indicate that the Petronas plant alone will be 300 MW, and that the SPR plant will be an additional 100 MW. See, e.g., Petronas, *300 MW Gas Fired Plant in Borneo*, 12 April 2009, http://www.energynews24.com/2009/12/petronas-300-mw-gas-fired-plant-in-borneo.

26 Here and throughout this report, we use the definition of reserve margin provided by Malaysia's association of IPPs, i.e. (total installed capacity – peak demand) / total installed capacity. Philip Tan*, Issues and Development of Malaysian Independent Power Producers,* (Powerpoint Presentation 2008), http://www.st.gov.my/ecom/images/publication/p2%20development%20%26%20issues%20of%20malaysian%20ipps.pdf, p. 21. Because some installed capacity is typically unavailable at a given moment because of maintenance, breakdowns, lower-than-average stream flow, and the like reserve margin will be larger than the

96% in 2015 and then shrink to 39% in 2020 due to increased demand.

These margins are well above the 25% that SESB considers desirable. In fact, even if SESB does not end up receiving power from the controversial 300 MW coal plant, other planned power plants would give Sabah a 66% reserve margin in 2015 and a 19% reserve margin in 2020 (see Table 1-2). The addition of 107 MW of power by 2019 would be sufficient to maintain a 25% margin. Larger-than-necessary reserve margins can raise the total cost of electricity generation, as utilities are forced to pay for power they do not need, either through under-capacity or off-take contracts with IPPs or by paying for financing and upkeep of their own under-used plants.[27] It is possible that large reserve margins in Sabah are justified by the extreme unreliability of its diesel plants, but Sabahans and SESB should consider whether reliability efforts might be a better alternative to building out more capacity.

Most of the planned capacity additions are located on Sabah's West Coast. According to SESB statistics, Sabah's East Coast currently has an installed capacity of 316 MW against a maximum peak demand of 192 MW.[28] However, because the east coast is heavily reliant on aging diesel plants, the reliable installed capacity may be significantly lower. SESB reports that power transfers of over 50 MW between West and East Sabah occur on a daily basis over the 132 kV, 255 km East-West transmission line,[29] suggesting that the East Coast plants actually generate less than 150 MW during peak periods. Transfers over the line will likely increase as demand grows and SESB decommissions aging plants, but required transfers should remain below the link's total capacity of 332 MW[30] through 2020.

SESB has indicated that "[a] power plant in the east coast is crucial to provide system reliability and generation capacity under an "islanded' operation when the east-west link is interrupted, thus providing security of supply for the whole state."[31] Presumably, this goal could be achieved in either of two ways. First, improvements to the grid network such as a second East-West link could ensure supply even if one transmission line fails. Second, SESB could add power capacity on the east coast. If SESB chooses the first option, capacity additions in the West would be able to meet demand in the East. If SESB chooses the second option, we estimate that about 98 new MW of east coast capacity would be needed by 2014 and 151 new MW would be needed by 2020 (see Table 1-2).

"extra" of power practically available at any particular moment.

27 Suruhanjaya Tenaga has indicated that large reserve margins in Peninsular Malaysia are a major cause of economic inefficiency. Suruhanjaya Tenaga, *Background: Industry Challenges* (Powerpoint Presentation 2008) http://www.st.gov.my/ecom/images/publication/%20pian%20sukro%20ec.pdf, p. 8.

28 Our estimate for the East Coast's installed capacity is based on SESB, *Sabah Electricity Supply* Status (Powerpoint Presentation, 27 May 2008).

29 Daily Express, *East-west coast grid link-up crucial for power supply in Sabah*, 3 Oct. 2009, http://www.dailyexpress.com.my/news.cfm?NewsID=67982.

30 *Id*.

31 SESB, *Why Coal for East Coast Sabah?* (6 Oct 2008) http://www.sesb.com.my/coal_fired_view.cfm?id=3. Two transmission towers collapsed in April-May 2008 after vandals stole steel support members, causing blackouts on the East Coast.

Table 1-2: Reserve Margin Projection, 2009-2020[32]

	All Sabah					East Coast Only				
	Cap-acity (No Coal Plnt)	Peak Dmd.	Reserve Margin (No Coal Plant)	MW req'd for 25% R.M.	Reserve Margin w/ 300 MW Coal Plant	Cap-acity (No Coal Plnt.)	Peak Dmd.	Reserve Margin (No Coal Plant)	MW req'd for 25% R.M.	Reserve Margin w/ 300 MW Coal Plant
2009	904	704	28%	0	28%	316	192	64%	0	64%
2010	1115	748	49%	0	49%	331	204	62%	0	62%
2011	1127	795	42%	0	42%	331	217	52%	0	52%
2012	1327	846	57%	0	57%	331	231	43%	0	43%
2013	1727	899	92%	0	92%	331	245	35%	0	35%
2014	1690	956	77%	0	108%	196	261	-25%	98	90%
2015	1690	1016	66%	0	96%	196	277	-29%	106	79%
2016	1690	1099	54%	0	81%	196	300	-35%	117	66%
2017	1790	1188	51%	0	76%	196	324	-39%	126	53%
2018	1790	1286	39%	0	63%	196	351	-44%	135	42%
2019	1790	1391	29%	0	50%	196	379	-48%	144	31%
2020	1790	1504	19%	107	39%	196	410	-52%	151	21%

However, as is evident from frequent blackouts currently experienced by East Coast consumers, our nameplate capacity-based shortfall estimates do not take into account the high unplanned outage rates of the diesel plants that supply the East Coast. Taking into account the fact that Tawau and Sandakan stations have unplanned outage rates of over 20%, it is clear that "islanded" operation of the East Coast grid would cause more immediate supply shortages. In the short term, SESB has addressed this problem by purchasing a number of small diesel generation sets which it has or will locate on the East Coast grid.[33] In the medium to long term, SESB is planning to build baseload capacity on the East Coast.

1.4 Legal & Policy Environment

Electricity in Malaysia is provided by three private utilities: Tenaga Nasional Bhd. (TNB) (Peninsular Malaysia), Sarawak Energy Supply Corporation (SESco) (Sarawak), and Sabah Electricity Sdn. Bhd. (SESB) (Sabah). SESB, the Sabah utility, was a public institution called the Sabah Electricity Board until its privatization in 1998. Since privatization, it has been owned

[32] Assumes demand projections, plant-up programme, and diesel plant decommissioning discussed above. It is significantly larger than the "dependable" estimate of 289.5 MW and the "available on a daily basis" estimate of 170 MW provided Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW coal plant* (16 October 2009). Because it is not clear from that document how existing plants' capacity is discounted for lack of dependability and lack of daily availability, we rely on the larger estimate, without forgetting that the heavy share of unreliable diesel plants on the East Coast may make a larger-than-average reserve margin desirable.

[33] Daily Express, *SESB is buying 40 more Gensets* (22 Aug 2009), http://www.dailyexpress.com.my/news.cfm?NewsID=67181

by TNB and the state government of Sabah.[34] TNB is itself part-owned by the Ministry of Finance.[35]

1.4.1 IPP System

Since 1992, non-utility Independent Power Producers (IPPs) have been able to sell power to the utilities.[36] As in other areas of the world, the liberalization of power production has aimed to lower costs to consumers by injecting competition into the electricity generation sector while maintaining regulated ownership of the transmission infrastructure, a "natural monopoly" market in which competition is generally considered not feasible. IPPs currently own 55% of Sabah's grid-connected power generation. All 4 of Sabah's SREP plants are owned by IPPs, as are 3 of its 4 natural gas plants and 4 of its 9 major diesel plants. Most of the planned capacity additions will also be owned by IPPs (hydropower investments are the exception).

1.4.2 Regulatory Framework

The electricity sector is regulated by several public organizations. The Ministry of Energy, Green Technology, and Water is the national governmental agency charged with overseeing the energy sector.[37] Suruhanjaya Tenaga (ST), a sub-agency of the ministry, is the national energy commission that regulates prices and performance in the electricity industry.[38] Pusat Tenaga Malaysia ("PTM") is ST's energy research arm, responsible for energy planning, energy efficiency promotion, and other energy research activities.[39]

Additionally, the electricity sector is subject to Acts of Malaysia's federal legislature as well as policies and guidance issued from the Prime Minister's office and other government bodies. For example, in 1981 Malaysia established the "Four Fuel Policy," which provided that investment in electricity generation should focus on Oil, Natural Gas, Coal, and Hydropower. In 2000, that policy was superseded by the "Five Fuel Policy," which added renewable energy to the other four fuels. Malaysia's economic five year plan system is another important form of guidance. For example, the 9th Malaysia plan set an electricity growth target that equalled the targeted rate of GDP growth, but the 10th Malaysia plan sets an electricity growth target that is lower than that of GDP as a whole, suggesting an increased emphasis on energy efficiency.

1.4.3 Fossil Fuel Subsidies

SESB and its IPPs, like other Malaysian utilities and IPPs, purchase fossil fuels at subsidized rates from Petronas, the national oil and gas supplier. For instance, until mid-2008, utilities bought natural gas from Petronas at RM 6.40/MMBtu. The government raised the price to RM 13.40/MMBtu as rising gas prices made its payouts under the programme unsustainable,

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[34] Ministry of Energy, Green Technology, and Water (KeTTHA), *Electricity Supply Industry*, http://www.ktak.gov.my/template01.asp?contentid=151.

[35] Loo Took Gee, ST Malaysia, *Governance and Institutional Framework,* (Ppt 2008), http://www.st.gov.my/ecom/images/publication/p1%20governance%20%26%20institutional%20framework.pdf.

[36] *Id*., at 13; Jeff Rector, *The IPP Investment Experience In Malaysia*, Working Paper # 46, Stanford University Programme on Energy and Sustainable Development (2005).

[37] Malaysia Ministry of Energy, Green Technology, and Water (KeTTHA), *Electricity Supply Industry*, http://www.ktak.gov.my/template01.asp?contentid=151.

[38] Suruhanjaya Tenaga Malaysia (ST Malaysia) Website, http://www.st.gov.my/.

[39] Pusat Tenaga Malaysia (PTM Malaysia) website, http://www.ptm.org.my/; Malaysia Energy Information Board (EIB) Website, http://eib.org.my/.

though it left the Sabah tariff unchanged at RM 6.40/MMBtu. Both prices are still far below the world market price RM 40+.

The IPP fuel subsidies have been controversial. Some Malaysians feel that the system has helped IPPs earn unfair profits, urging the government to pass a special tax on windfall profits by IPPs.[40] The IPP industry opposes the tax, arguing that the subsidies are of no benefit to IPPs because IPPs pass on the subsidy to consumers in the form of low electricity prices. In either case, it is clear that the subsidies skew the economic incentives for the IPP industry in favour of fossil fuel generation.

1.4.4 Renewable Energy Initiatives

At the same time as it continues to subsidize fossil fuels, however, Malaysia has undertaken several initiatives aimed at accelerating investment in renewable energy. In 2001, it launched the Small Renewable Energy Production (SREP) programme. The programme uses tax incentives to facilitate investment in renewable power plants under 10 MW in size, but stops short of requiring utilities to purchase green energy, preferring instead to maintain negotiation on a "willing buyer, willing seller" basis between utilities and renewable IPPs. The programme aimed to achieve 500 MW of renewable energy capacity nationwide by 2005, but later revised the target down to 350 MW by 2010. As of July 2009, there were only 43.5 MW of grid-connected renewable power in Malaysia, all of it from biomass or small hydro projects.[41]

In 2005, Malaysia and the United Nations Development Programme began the Malaysia Building Integrated Photo-Voltaic (MBIPV) project. Like the SREP program, this effort uses tax incentives to stimulate investment in distributed solar generation. It also awards a limited number of direct subsidies via lottery. The MPBIV program's goal is to achieve 1.5 MW of distributed solar capacity by 2010.[42]

The promotion of renewable energy will be supported "upstream" by Malaysia's Green Technology Financing Scheme (GTFS). The Scheme aims to position Malaysia as a leader in greentech industries, as well as to ensure a steady, low-cost supply of the components (e.g. solar panels, fuel cells, etc.) necessary to support green development. It will pursue these goals with tax breaks and other financial incentives.[43]

On the planning side, the Ministry of Energy, Green Technology and Water is also currently working on the Energy Efficiency Master Plan, Renewable Energy Policy and Action Plan and National Green Technology Action Plan. These plans aim to reduce dependency on fossil fuels, increase the renewable share of generation, and stimulate Malaysia's green technology industry.[44] Details are still under development, but the plans reportedly may include "feed-in tariffs" that require Malaysia's utilities to purchase power from renewable IPPs and building owners at pre-determined prices.[45]

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[40] The Star, *IPPs need to pay first instalment* [sic] *of windfall tax Tuesday*, (14 Aug 2008), http://biz.thestar.com.my/news/story.asp?file=/2008/8/14/business/1800217&sec=business.

[41] Steve Anthony Lojuntin, PTM Malaysia, *Renewable Energy Development in Malaysia*, (ppt, 2008) http://www.renew.com.my/downloads/SPEAKERS%20PDF%20FILE/RE%20projects%20in%20msia_srwk%20wshop-steve%202.pdf, p. 4. Other sources suggest that a number of other projects are under development.

[42] *Id*., p. 18.

[43] Ministry of Energy, Green Technology and Water, *Welcome Speech by Y.B. Dato' Sri Peter Chin Fah Kui* (26 Jan 2010), http://www.ktak.gov.my/template03.asp?tt=speech&speechID=551

[44] The Star*, Council to Chart Green Technology Development*, http://thestar.com.my/metro/story.asp?file=/2010/1/12/southneast/5446070&sec=southneast

[45] The Star, *Tenaga to Buy Green Power* (19 Jan 2010),

At the December 2009 Copenhagen climate negotiations—the most recent step in the world's attempt to address the global warming phenomenon that threatens environments and economies worldwide—the Prime Minister of Malaysia announced that Malaysia was ready to commit to cutting its per-GDP carbon emissions by up to 40% below 2005 levels by 2020, a step that some other similarly-situated nations did not take.[46] If Malaysia maintains this position in subsequent negotiations, it will likely need to undertake policy initiatives that favour renewable energy even more strongly during the next few years. The Prime Minister recently suggested as much when he signalled to the World Future Energy Summit in Abu Dhabi that Malaysian utilities may be required to increase their renewable energy purchases from their current level of approximately 50 MW up to 2,000 MW by 2020.[47]

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http://thestar.com.my/news/story.asp?file=/2010/1/19/nation/5497335&sec=nation

[46] The Star, *UK lauds Malaysia's pledge to cut carbon emissions* (18 Dec 2009), http://thestaronline.com/news/story.asp?file=/2009/12/18/nation/20091218134734&sec=nation; Malaysia's Ministry of Foreign Affairs Website, http://www.kln.gov.my/?m_id=15&hid=1147 (text of speech).

[47] Official Website of the Prime Minister's Office of Malaysia, Speeches, http://www.pmo.gov.my/?menu=speech&news_id=189&page=1676&speech_cat=2.

2. Sabah's Electricity Resources: Cost, Availability, and Environmental Quality

In this section, we estimate the Sabah-specific levelized costs of electricity for several supply options. For each fuel or technology, we set out technological background information, describe its role in the electricity sector worldwide, and then describe our levelized cost estimate and any important assumptions underlying the estimate. Where applicable, we also attempt to quantify the size of the resource, in order to indicate how much electricity it might provide in Sabah.

All of our estimates rely on the common parameters set out in Table 2-1. In addition, each estimate relies on technology-specific assumptions for capital cost, operations and maintenance costs, fuel cost, capacity factor, and domestic as well as international incentives. We have assembled these estimates from publications and from our interviews in Sabah, and we cite our sources in the footnotes to the sub-sections that follow.

Table 2-1: Assumptions for levelized cost analysis

Real Discount Rate	8%
Inflation Rate (applied to all costs)	2.5%
PPA Escalation Rate	0%
Debt/Equity ratio	60/40
Interest Rate on Loan	8%
Tax Rate[48]	0.25
Depreciation Schedule[49]	34% in year 1; 14% in year 2-5, 10% in year 6
Economic Life of Project	20 years
Required Return on Equity	15%
Emissions Factor of Sabah Grid[50]	0.40 t CO2e/MWh
Carbon Offset Sale Price	RM 46.99 (€ 10.00)

We estimated levelized costs by solving for the electricity tariff that would give a project the required 15% internal rate of return on the equity share of project investment. In other words, they can be interpreted as the power purchase agreement tariff that an IPP would have to negotiate to make the investment economically attractive. For example, an estimate of RM 0.12/kWh for a palm mill waste electricity generation project means that given the applicable

48 Pusat Tenaga Malaysia, *Government Incentives*, http://www.mbipv.net.my/content.asp?higherID=5&zoneid=4&categoryid=8.

49 *Id*.

50 The emissions factor is a measure of how "dirty" an electric grid in terms of the amount of greenhouse gas it emits per unit of electricity. A Malaysian government publication suggests a figure of 0.745 for Sabah, and projects that have received CDM approval have used figures of 0.699 and 0.745. PTM, *Study on Grid-Connected Baselines* (2005), p. 4; Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ; Esajadi Bhd Sdn, *CDM Project Design Document*, http://www.jqa.jp/service_list/environment/file/esajade_070606.pdf. However, we use a much more conservative assumption of 0.40 because a switch to natural gas and hydro (see above) is quickly making Sabah's grid "cleaner." The 0.40 figure is the average of the emissions factors we estimate for 2010 and 2015 in our baseline scenario in Part III of this report.

costs and subsidies, a palm oil mill would need to negotiate a RM 0.12 electricity tariff in order to achieve an internal rate of return of 15%.[51] Higher tariffs would result in higher rates of return and make the project even more attractive. Lower tariffs would result in lower rates of return, and potentially make the attractive unattractive to investors. Of course, some power plants may be built by SESB rather than IPPs. In such cases, the levelized cost metric is less natural but no less valid: it still provides a means to fairly evaluate the comparative attractiveness of SESB's own investment against investments by others. All cost estimates are quoted in nominal terms; real (inflation-adjusted) costs are slightly lower in each case. A sample of our methodology is provided in Table 2-2.

Table 2-2: Simplified Sample Cash Flow for Levelized Cost Analysis (300 MW Coal Plant)

	Year 0	Year 1-10	Year 2-20
Capital Expense	(1,700,000,000)		
O&M Expense		(163,569,403)	(209,382,665)
Fuel Expense		(783,300,998)	(1,002,691,501)
Debt Paydown		(697,105,344)	(697,105,344)
Electricity Income		2,328,582,102	2,328,582,102
Carbon Income		0	0
Income Before Taxes		684,606,357	419,402,592
Income Net of Expenses		1,381,711,701	1,116,507,936
Interest Deduction		(490,723,372)	(251,542,145)
Depreciation Allowance		(1,372,208,640)	0
Pioneer Status Allowance		0	0
Corporate Tax Rate		0	0
(Tax Due) / Tax Savings		187,635,998	(216,241,448)
Cash Flow		804,911,435	203,161,144
IRR			15%
Implied PPA Electricity Price			.139

Our analysis accounts for the fact that renewable technologies in Malaysia benefit from tax incentives. Both the SREP and MBIPV program allow investors to choose between two different tax incentives.[52] The "Pioneer Tax Allowance" provides a deduction to taxable income equal to 100% of project revenue for the first ten years of the projects' existence. The alternate "Investment Tax Allowance" provides a deduction equal to 100% of capital investment in year one. Both tax incentives may be carried forward into future years.

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[51] In reality, IPPs often negotiate more complex payment structures with utilities. For example they may be payed a flat "capacity fee" as well as a per kWh price. Our estimates levelized all these different forms of payment into a per-kWh price.

[52] Pusat Tenaga Malaysia, *Government Incentives*, http://www.mbipv.net.my/content.asp?higherID=5&zoneid=4&categoryid=8. Some non-renewable projects may also receive these tax incentives, especially if they are categorized as "innovative." For the sake of simplicity, however, we apply the tax incentives only to renewables.

In practice, the ability of an investor to benefit fully from these tax advantages depends on the size of the investor's tax liability, whether the tax losses can be carried forward, and a number of other investment-specific considerations that are beyond the scope of this project. Thus, we have assumed for the sake of simplicity that all tax advantages are fully monetized in each year by a project's owner. In other words, if the standard depreciation allowance gives a project the right to deduct $100,000, and Malaysia's "Pioneer Status" programmes gives it the right to an additional $100,000 deduction, we assume that the project has received a tax savings of 25% * ($100,000 + $100,000), or $50,000. We maintain this assumption even if the project has a taxable income of $0. In essence, this approach amounts to an assumption that the project's owner has tax liabilities from business activities other than the project that amount to more than $50,000, or that it has secured the participation of limited partner with tax liabilities of that magnitude from all enterprises. While this assumption is not likely to be realistic for all cases, its consistent application allows a fair levelized cost analysis of the different renewable options, almost all of which benefit from the same tax advantages.

Many renewable energy projects in Malaysia are eligible for an international subsidy on top of Malaysia's tax subsidy. Under the Kyoto protocol's Clean Development Mechanism, businesses and governments in "developed" nations that accepted a binding emission cap (e.g. Europe, Japan) can meet their obligations with offset credit resulting from emissions-reducing projects financed in "developing" nations that are not bound by such a cap (e.g. Malaysia).[53] The amount of revenue a clean energy project can expect from offset sales depends on its size, the emissions from the alternative projects that might have been implemented instead of the clean energy investment (for example, if the project replaces a relatively dirty coal plant, it will receive more credit than if it replaces a relatively clean natural gas plant), and the balance between supply and demand in the international market for carbon credit.

We apply a conservative carbon offset price of 10 euros per tonne of CO_2-equivalent greenhouse gas eliminated to each of the renewable options we evaluate. We also assume that renewable energy produced by such projects displaces energy with an emissions intensity of 0.40 tCO2e/MWh, the 2010-2015 average we estimated in Part 3 of this report. We note that this emissions factor is considerably lower (i.e. less favourable to renewable projects) than the emissions factors of 0.699-0.745 reported by projects in Sabah that have already received CDM approval; however, given that hydro and natural gas power are expected to replace much of Sabah's emissions-intense diesel generation over the next few years, we believe that it is more accurate for the period we are analyzing.

One more word of caution is in order. Even where our assumptions about tax and carbon offset incentives are realistic, our estimates are likely to be imprecise for other reasons. In many cases, publicly available information on the costs of power plant development is unavailable, imprecise, or self-contradictory. In fact, because we have endeavoured to standardize assumptions wherever possible, some of the numbers we report deviate from the known costs of similar existing projects. For that reason, it bears repeating that the aim of our exercise is comparative only—we seek to provide a framework for analyzing the attractiveness of competing renewable options, not to accurately assess the expected profitability of any single investment.

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[53] For more information on the CDM, see McNish, T. et al, *Sweet Carbon: an Analysis of Sugar-Industry Carbon Market Opportunities under the Clean Development Mechanism*, 37 ENERGY POL'Y 5459 (2009).

2.1 Fossil Fuels

Fossil fuel-fired power plants currently account for 90% of Sabah's current installed capacity. All of these plants burn either natural gas or diesel/fuel oil. Several additional natural gas-fired plants are under development, as is a proposed coal-fired plant that would be the first of its kind in Sabah. Thus, it is important to compare the renewable energy options that are the subject of this report with levelized, Sabah-specific estimates of the cost of the fossil fuel power generation, as well as with a basic understanding of those fuels' effects on the local and global environment.

2.1.1 Diesel & Fuel Oil

Diesel fuel is refined from oil. Fuel oil or "bunker fuel" is a similar product. Compared with gasoline, diesel and fuel oil require less refining and contains more energy per litre. Additionally, diesel engines achieve higher fuel energy-to-electricity conversion ratios than other internal combustion engines.

In part because of these efficiencies, diesel generators are a preferred solution worldwide for small applications where connection to an electricity grid is not feasible, or where a backup generator is needed to ensure power in the event of a grid failure. However, because diesel fuel is typically expensive compared with other utility-scale power generation options, the use of oil-derived fuels in large, grid-connected power plants is less common. In fact, for the most part, such reliance on diesel is limited to islands and other isolated regions where cheaper fuels are not available.

Compared to other power plant fuels, oil-derived fuels are relatively "dirty." Diesel has a greenhouse gas emission factor of about 0.7 tCO2/kwh, which means that production of one kWh of electricity with diesel requires the release of about 700 kg of carbon dioxide, the leading cause of global warming. This emissions factor is higher than those of natural gas but lower than that of coal. Oil-derived fuels also release a number of local pollutants and require environmentally-disruptive mining.

Malaysia is a major oil producer, with proven oil reserves of 4 trillion cubic feet. In the Asia region, only China and India have larger oil reserves than Malaysia. In 2008, Malaysia's total oil production was 727,000 billion barrels per day (bbl/d) against an estimated consumption of 547,000 bbl/d, implying net exports of about 180,000 bbl/d. Malaysia has six major oil refining plants owned by Petronas, Shell, and ExxonMobil. These plants allow it to meet most of its demand for petroleum products like diesel internally.[54]

The Malaysian government subsidizes the price of diesel for both consumers and power producers. Under the subsidy system, diesel buyers pay the national fuel producer (PETRONAS) a lower-than-market price set by the Malaysian government, and the government pays Petronas the difference between the subsidy and the world price. The government was forced to increase the consumer-facing retail price of diesel to close to the free market level as rising oil prices dramatically increased government payouts under the programme in 2008. However, industry participants that we interviewed for this report indicated that SESB and its IPPs are still paying subsidized prices of about RM 0.49/L for diesel and RM 0.45/L for medium fuel oil.[55] These prices are about RM 1.5/L below the world wholesale price of approximately

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54 U.S. Energy Information Agency Website, http://www.eia.doe.gov/cabs/Malaysia/Oil.html.

55 The Star, *Petrol price up by 78 sen - and will be reviewed monthly,* 4 Jun 2008,

RM 2.00.[56] The Prime Minister recently suggested that subsidies may be "phased out," leaving power producers exposed to this total cost rather than the subsidized cost.[57] If so, diesel power producers would be subject to this world price rather than the subsidized price, and the cost of supplying electricity would be substantially higher.

Sabah currently has eight major diesel-based generating stations. Together, these stations account for 412 MW of nominal capacity. During the 5-year period between 2000 and 2004, 35% of Sabah's total grid electricity came from diesel plants.[58]

Even with the government subsidy in place, these plants are expensive to operate. Assuming fuel prices of RM 0.49/L for diesel and RM 0.45/L for medium fuel oil, an average electricity conversion efficiency of 0.3,[59] a capacity factor of 0.8,[60] capital costs of RM 1.1 million/MW, and operation & maintenance (O&M) costs of RM 114,000/MW/yr, we estimate the levelized cost of producing electricity with new diesel generation capacity at RM 0.276/kWh.[61] However, the true cost to Malaysia as a whole is much higher, because it includes the money that taxpayers pay to subsidize the diesel that power producers buy as well as the cost that electricity consumers pay for diesel-derived electricity. We estimate the cost to taxpayers of the diesel subsidy at RM 0.67/kWh, and the total cost to Malaysia of diesel generation capacity at RM 0.98/kWh.

Because of this high cost of diesel generation, as well as the unreliability of many of Sabah's aging diesel plants, no new major diesel plants are under development in Sabah, and SESB plans to gradually phase out these plants as natural gas and hydropower plants come

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http://thestar.com.my/news/story.asp?file=/2008/6/5/nation/21461533&sec=nation.

56 Based on data from the Australian department of commerce and a wholesaler's margin of 10%, we estimate that the price of a wholesale litre of diesel in Malaysia would be about RM 2.04 with no subsidy and no excise tax. See http://www.fuelwatch.wa.gov.au/news/dsp_fuelfacts.cfm.

57 Zulkifli Abd Rahman, *Malaysia Must Man Up, Subsidies on the Way Out*, The Star (Feb. 8, 2010), http://thestar.com.my/news/story.asp?file=/2010/2/8/nation/20100208194310&sec=nation.

58 Esajadi Bhd Sdn, *CDM Project Design Document*, http://www.jqa.jp/service_list/environment/file/esajade_070606.pdf, p. 21.

59 This is the efficiency figure given for TNB's "conv. oil & gas" plants in Suruhanjaya Tenaga, *Electricity Supply Industry in Malaysia: Performance and Stat. Information 2008*, p. 10.

60 The actual capacity factor is much lower (see Table 1-1). However, diesel plants are capable of operating at this capacity factor, and for the purposes of levelized comparison of hypothetical new investments we therefore consider it fair to use an 80% figure.

61 SESB reports a slightly higher per-kWh production cost of RM 0.3078 for its diesel plants, and suggests that the high cost partly reflects the high cost of maintaining and repairing aging plants. See Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW Coal-Fired Power Plant* (16 Oct 2009), p. 10.

online over the next decade.

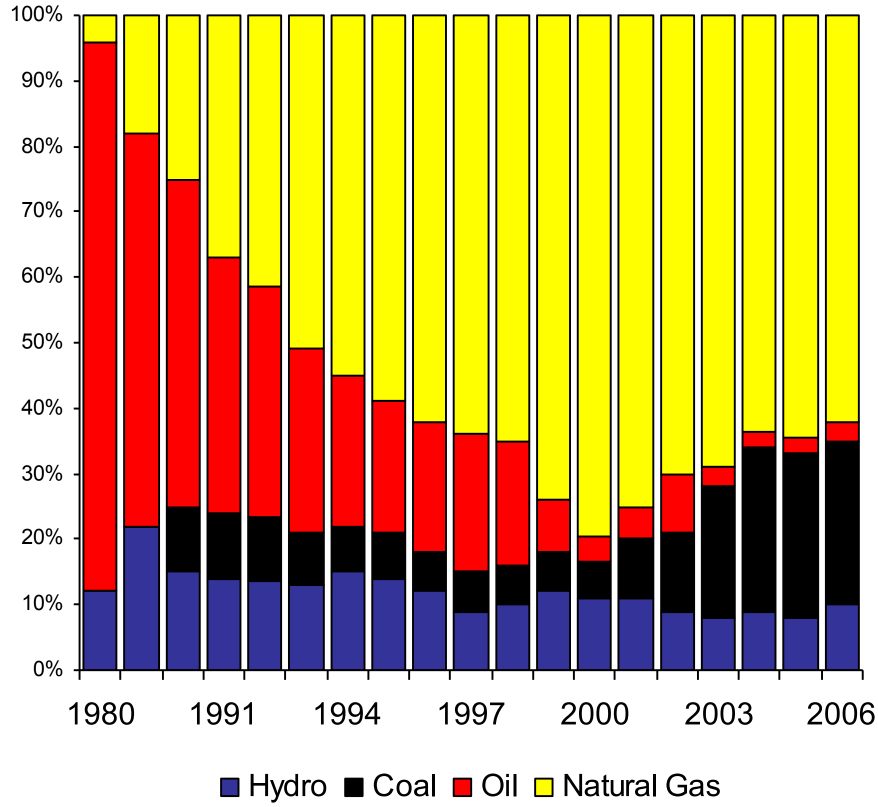

Figure 2-1: Malaysia-wide electricity generation mix, 1980-2006. The figure reflects a move in Peninsular Malaysia away from oil-based generation and toward natural gas and, later, coal. SESB's current plant-up programme would duplicate this shift in Sabah.[62]

2.1.2 Natural Gas

"Natural gas" refers to naturally-occurring hydrocarbon gases in several different molecular configurations. It is obtained from mining operations and is often found alongside oil. Because of the difficulty of transporting natural gas, it was once flared off when encountered at oil wells rather than captured. It was not until the 1920s that the construction of natural gas pipelines brought the fuel into wider use, especially for the heating of buildings in cold climates. Later, the proliferation of combined cycle gas turbine (CCGT) generation—a system by which combustion of gas turns a gas turbine and the exhaust from the gas turbine then heats steam for a steam turbine—made natural gas generation one of the most efficient technologies in terms of conversion of fuel energy to electrical energy. Compared to coal and hydropower plants, natural gas plants are relatively cheap and quick to build. They can also be shut down and turned on quickly, making them suitable for use as "peaker" plants that come online at midday to serve peak electricity loads. Moreover, compared to other fossil fuels like coal and oil, natural gas releases less greenhouse gases per unit of energy. Natural gas has an emissions factor of about 0.4 tCO2/kwh, meaning that it releases about 400 kg of CO2 for each kWh of electricity

[62] Source: Suruhanjaya Tenaga, *Background: Issues and Challenges* (Powerpoint presentation, 19 June 2008), p. 3.

produced, compared to about 700 kg/kWh for diesel and up to 1000 kg/kWh for coal. Together, these environmental, practical, and economic advantages make natural gas one of the most popular power plant fuels in the world.

Malaysia has natural gas reserves of 83 trillion cubic feet (Tcf), the world's eighth-largest endowment. Several large gas fields are active offshore of Sabah. Production of gas has risen steadily over the last several years, reaching about 2.4 Tcf/yr in 2009. Much of this gas is exported from Peninsular Malaysia to other Asian countries via pipelines or in tanker ships designed to carry liquefied natural gas. Malaysia also has three terminals capable of liquefying natural gas, all of which are located at Bintulu, Sarawak;[63] the output of these terminals makes Malaysia the world's second-largest exporter of liquefied natural gas.[64] The Sabah Oil and Gas Terminal project will link the natural gas fields at Kimanis and other offshore locations with the Bintulu terminal via pipeline, allowing Sabah to export gas to worldwide markets.[65]

At the same time as Malaysia's production of gas is increasing, however, domestic consumption also continues to rise. Currently, Malaysia consumes about 1.2 Tcf/yr, more than 50% of its total production. Much of this consumption is in the electricity industry. Natural gas grew from 1.2% of the energy input to electricity production in 1980 to over 70% in 1999 before declining to about 56% in 2007 as several new coal-fired plants came online.[66] Even at that level, however, natural gas's share of electricity production in Malaysia is significantly higher than in most other countries, where natural gas is sometimes considered a "luxury" fuel that is too expensive to use for the majority of baseload power generation.[67] The United States and Japan both obtain less than 25% of their electricity from natural gas.

As described in Section 1 above, natural gas already accounts for the largest share of electricity generation capacity in Sabah (60%). SESB plans to expand this capacity by about 590 MW during the next few years. As a result, natural gas will be Sabah's main baseload electricity generation resource by 2015, as it already is in Peninsular Malaysia.

As with diesel, the Malaysian government subsidizes the price of natural gas for domestic power producers by setting a price and then compensating Petronas for the difference between that price and the world price. Through mid-2008, electricity producers paid RM 6.40 per Mmbtu of gas. That price was adjusted to RM 14.31 per Mmbtu in 2008, but the Sabah tariff was left untouched at RM 6.40. Both prices are far below the world price of roughly RM 40/MMBtu. If subsidies are eventually phased out, gas-fired power producers would be exposed to this world price.

Both SESB and the Malaysian government have expressed concern about excessive reliance on natural gas, and have made diversification away from gas an explicit policy goal. The world supply of gas is increasingly tight, especially as concern over global warming increases demand for the comparatively-clean fuel. If prices continue to rise in the future, the Malaysian government's payouts under its subsidy system will also increase, meaning that whether or not the subsidy system is maintained, the total cost to Malaysia of reliance on gas will rise. Moreover, at the current rate of production, the nation's gas reserves may be exhausted

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63 Mohd. Zamzam Jaafar, Wong Hwee Kheng, and Norhayati Kamaruddin, *Greener energy solutions for a sustainable future: issues and challenges for Malaysia*, Energy Policy 31 (2003) 1061–1072.

64 U.S. Energy Information Agency, http://www.eia.doe.gov/cabs/Malaysia/NaturalGas.html.

65 Daily Express, Oil, gas terminal set to transform Sabah, 18 Jan 2008, http://www.dailyexpress.com.my/news.cfm?NewsID=55355.

66 Pusat Tenaga Malaysia, *Energy Information Highlights*, http://medis.ptm.org.my/highlights.html.

67 U.S. Energy Information Agency, http://www.eia.doe.gov/cabs/Japan/Electricity.html.

within several decades, at which point Malaysian power producers will presumably be exposed to the world price of gas. These concerns are one reason that SESB supports investment in coal-fired capacity.[68]

Assuming a rate of 14.31/MMBtu for a new power plant,[69] a capital cost of RM 3 Million per MW, O&M costs of RM 114,000/MW/yr, and a capacity factor of 90%, we estimate the levelized cost to an IPP producer of using natural gas for electricity supply at RM 0.19/kwh. The total cost to Malaysia as a whole, however must take into account government expenditures under the fuel subsidy programme, which are paid for by Malaysian taxpayers. At a world price of about RM 40/MMBtu, this subsidy amounts to RM 0.27/kwh, making the total price of natural gas to Malaysia RM 0.46/kwh.

2.1.3 Coal

Coal was one of the first sources of non-human mechanical energy, having been used to power steam engines since the early industrial revolution in Britain. Coal's wide availability keeps its prices lower than natural gas and oil, making it one of the most widely-used electricity-generation resources worldwide. Coal accounts for 42% of worldwide electricity generation, and is particularly important in the United States and China, where upwards of 50% of all electricity comes from coal.[70] China adds more than 40,000 MW of coal-fired capacity annually.[71]

Malaysia's domestic coal industry is much smaller than its domestic oil & gas industry. The nation has estimated coal reserves of about 4.5 million tonnes (mostly located in Sabah and Sarawak, including in Sabah's Maliau Forest Reserve), and produces just 1 million tonnes annually against a domestic consumption of 19 million tonnes, meaning that it imports about 90% of its coal needs.[72] Most of this coal is burned in Peninsular Malaysia's existing coal-fired power plants, which have an aggregate total capacity of over 7,000 MW.[73] Coal is the second-most important power-plant fuel in Malaysia, accounting for about 35% of national electricity production.[74]

Even compared to other fossil fuels, however, there are significant environmental problems with the use of coal to generate electricity. Coal-fired power plants emit about 1 tCO_2 of greenhouse gas per MWh, twice as much as natural gas and significantly more than diesel. Indeed, coal accounts for 41% of greenhouse gas emissions from energy use worldwide,[75] meaning that coal fired power plants are one of the single-largest contributors to the global

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[68] The Star, *Petrol price up by 78 sen - and will be reviewed monthly,* 4 Jun 2008, http://thestar.com.my/news/story.asp?file=/2008/6/5/nation/21461533&sec=nation.

[69] Local energy sector experts indicate that natural gas is still being sold to utility/IPP purchasers in Sabah at the pre-2008 subsidized rate of RM 6.40/MmBTU. However, there are indications that gas-fired power producers will be exposed to rate increases in the future; thus, we consider it more accurate to use the newer RM 14.31/MmBTU price.

[70] U.S. Energy Information Agency, http://www.eia.doe.gov/oiaf/ieo/coal.html.

[71] New York Times, *China Outpaces U.S. in Cleaner Coal Fired Power Plants*, 11 May 2009, http://www.nytimes.com/2009/05/11/world/asia/11coal.html.

[72] U.S. Energy Information Agency, http://www.eia.doe.gov/cabs/Malaysia/Full.html.

[73] Rusli Bin Urdus, Hurdles in Securing Energy Supply – Coal, http://www.st.gov.my/ecom/images/publication/p1%20hurdles%20to%20securing%20energy%20supply%20-%20coal.pdf, p. 7.

[74] Overview of Policy Instruments for the Promotion of Renewable Energy & Energy Efficiency in Malaysia, p. 6.

[75] Massachusetts Institute of Technology, *The Future of Coal Summary Report* (2008), http://web.mit.edu/coal/The_Future_of_Coal_Summary_Report.pdf.

warming phenomenon that threatens the environments and economies of every nation in the world. At the same time, coal is a major source of various types of local pollution. Coal mining is a major source of ecosystem destruction and pollution of soils and water. Sulphur dioxide released by burning coal causes acid rain. Heat exchange requires the discharge of large quantities of heated water outside the plant. And disposal of coal ash presents a major hazardous waste problem, one that was brought home when the recent collapse of a coal pond dam in the United States flooded downstream communities with toxic sludge.

As a result of these concerns, some nations have begun taking steps to limit the growth of coal-fired power. The Sierra Club reports that of 150 power plants planned for construction in the United States during the past decade, 100 have been cancelled, mostly as a result of environmental concerns.[76] In 2009, not a single new coal-fired plant was built in the United States.[77] In addition, some utilities are decommissioning existing coal plants as they turn toward renewable strategies.[78]

The possibility of building commercial-scale "clean coal" plants that can produce cheap electricity while addressing these environmental concerns has been much discussed, but has yet to become reality.[79] Scrubbers such as flue gas desulphurizors take much of the acid-rain causing sulphur out of coal plant emissions, but do nothing to limit the carbon dioxide that causes global warming or to eliminate the local dangers of ash disposal. The most advanced presently available coal technologies are the "supercritical" and "ultra super critical" coal plants use efficient combustion techniques such as coal gasification to squeeze more electricity out of each tonne of coal, thereby decreasing the quantity of pollutant released per unit of electricity. However, the effect of these efficiency improvements is not nearly enough to lower coal plant pollution to the level of cleaner fossil fuels, let alone to the level of renewable technologies. Finally, while the possibility of capturing coal plant carbon dioxide emissions and storing them underground has attracted a lot of attention, the technology is not yet operational at the necessary scale and faces a number of unresolved engineering, logistical, and economic challenges.[80]

Sabah's first coal-fired power plant is proposed for development by Lahad Datu Energy, an IPP. If constructed, the plant will have a capacity of 300 MW. The plant is estimated to cost about RM 1.7 billion, and intends to purchase coal from Kalimantan. The first two sites proposed for the plant were rejected after strong opposition from nearby communities.[81] A

[76] Ruedigar Mathes, *100 Down: Sierra Club Celebrates the Abandonment of Another Coal-Fired Power Plant*, (9 July 2009), http://planetsave.com/blog/2009/07/09/100-down-sierra-club-celebrates-the-abandonment-of-another-coal-fired-power-plant/; Sierra Club, *Stopping the Coal Rush*, http://www.sierraclub.org/environmentallaw/coal/plantlist.asp.

[77] Sierra Club, *Stopping the Coal Rush*, http://action.sierraclub.org/site/MessageViewer?em_id=150401.0

[78] The New York Times, *Big Utility to Close 11 Plants Using Coal*, (1 December 2009), http://topics.nytimes.com/topics/news/business/energy-environment/coal/index.html.

[79] Time, *Exposing the Myth of Clean Coal Power*, (10 Jan 2009), http://www.time.com/time/health/article/0,8599,1870599,00.html; New York Times, *Collapse of the Clean Coal Myth*, (23 Jan 2009), http://www.nytimes.com/2009/01/23/opinion/23fri3.html; The Guardian, *Time to Bury the "Clean Coal" Myth*, (30 Oct 2008), http://www.guardian.co.uk/environment/2008/oct/30/fossilfuels-carbonemissions.

[80] Mathew Wald, The New York Times, *Re-fitted to Bury Emissions, A Plant Draws Attention*, (21 Sep 2009) http://www.nytimes.com/2009/09/22/science/earth/22coal.html.

[81] SESB, C*orporate News, TNB Responds to Cancellation of the Lahad Datu [Coal Plant],* http://www.sesb.com.my/corporate_news_view.cfm?id=7.

"terms of reference" document for an environmental impact assessment of the new site is under development, and SESB projects that the plant will be online by 2014.[82]

Assuming the reported capital cost of RM 5.6 million per MW, O&M costs of RM 73,666 per MW/yr, fuel cost of RM 257 per tonne,[83] and a capacity factor of 95%, the levelized cost of meeting electricity demand in Sabah with coal-fired capacity is estimated at RM 0.139/kwh. This makes coal one of the cheapest electricity supply options in Sabah, rivalled only by palm mill waste and hydropower.

However, the levelized cost of coal-fired generation is sensitive to the price of coal, such that increases in the coal price make coal-fired capacity less competitive with other resources. . In 2007, the coal price was over $120/tonne (RM 400/tonne), with some analysts expecting it to rise to $175/tonne (RM 580/tonne), though TNB managed to contract for all of its 2008 coal needs at $75/tonne. The economic crisis of 2008 and 2009 brought world prices down, but recent reports from late 2009 and early 2010 show prices rising again, in part because of strong demand from China. At prices over about $100/tonne, coal loses its cost advantage over many of the renewable options discussed in this report.[84]

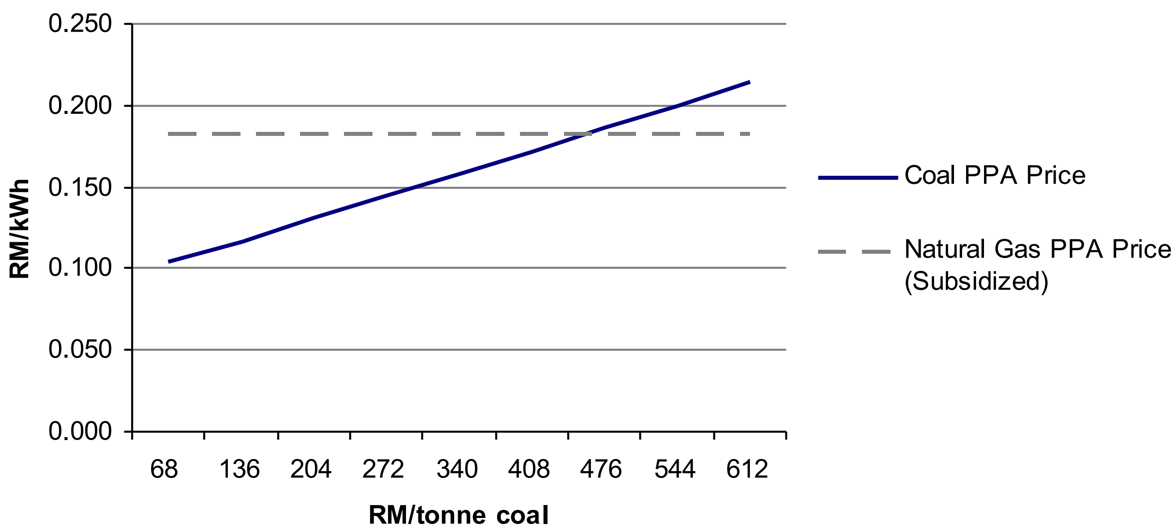

Figure 2-2a. Sensitivity of Levelized Cost of Coal-Fired Power to Coal Price. Baseline scenario price is RM 255/tonne.

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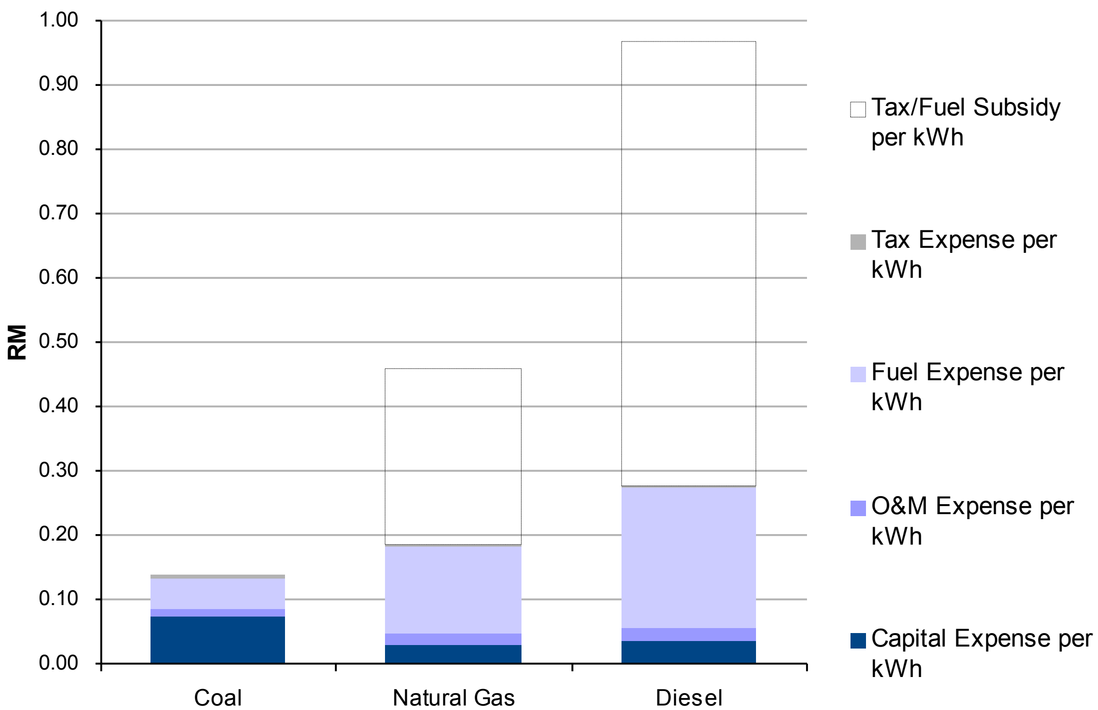
82 Lahad Datu Energy Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment for 300 MW Coal-Fired Power Plant Project, Sabah* (16 Oct 2009).

83 This estimate is from TNB's 2008 contract for coal supplies, reported in Dato' Izzadin Idris, *Coal Pricing Strategies*, (Power Point Presentation 2008), http://www.st.gov.my/ecom/images/publication/p2%20elecricity%20pricing%20strategies.pdf, p. 17. See also Rusli Bin Urdus, *Hurdles in Securing Energy Supply – Coal*, http://www.st.gov.my/ecom/images/publication/p1%20hurdles%20to%20securing%20energy%20supply%20-%20coal.pdf, p. 16.

84 Dato' Izzadin Idris, Coal Pricing Strategies, (Power Point Presentation 2008), http://www.st.gov.my/ecom/images/publication/p2%20elecricity%20pricing%20strategies.pdf, (price of $175/tonne expected in 2008); Archana Chaudhary, NTPC Coal Imports to Jump 67%, May Burn Lower Grades (30 Jan 2008), http://www.bloomberg.com/apps/news?pid=20601091&sid=aW.UnbYcUbxg&refer=india (predicting coal prices of $125 to $150 per ton); Commodity Online, *Coal Prices to Surge in 2010 Despite Ample Supply*, (20 Oct 2010), http://www.commodityonline.com/news/Coal-prices-to-surge-in-2010-despite-ample-supply-22154-3-1.html.

2.1.4 Conclusions and Policy Recommendations

Figure 2-2 summarizes our levelized cost results for Coal, Natural Gas, and Diesel. As a general matter, these natural gas and diesel estimates can be distinguished from the renewable estimates presented below by the large size of the government subsidy. If it were not for Malaysia's fossil fuel subsidy program, natural gas-derived electric power would be twice as expensive as it is today, and diesel-derived power would be three times as expensive. It goes without saying that such large government market interventions affect investors decisions and skew power development toward natural gas and diesel. While the government and utilities have been pursuing a diversification strategy by setting legal or policy limits on the development of natural gas power, policymakers may wish to consider achieving this objective more directly by eliminating the distortionary subsidies altogether. Indeed, fossil fuels have significant external environmental costs that are not accounted for in their market price, and the public sector should therefore arguably aim to *increase* the price of fossil fuels, not decrease it. Re-structuring incentives in this fashion would tend to make renewable options more cost-competitive and stimulate increased clean energy development.



	Coal	Natural Gas	Diesel
Capital Cost/MW	RM 5,666,667	RM 3,000,000	RM 3,000,000
O&M Cost/MW	RM 73,667	RM 114,000	RM 114,000
Fuel Cost per MWh electric	RM 42	RM 108	RM 173
Typical Plant Size (MW)	300.00	300.00	300.00
Capacity Factor	0.95	0.95	0.80
Levelized Cost per kWh	RM 0.14	RM 0.19	RM 0.28
Fuel incentive per kWh	RM 0.00	RM 0.25	RM 0.69
Total cost to Malaysia per kWh	RM 0.14	RM 0.44	RM 0.97

Figure 2-2: Key Assumptions & Results – Fossil Fuels Levelized Cost Analysis

2.2 Hydroelectricity

Hydroelectric plants use the energy of moving water to turn a hydroelectric turbine. Such systems are very efficient in comparison to thermal combustion plants, and can convert up to 85% of the water's kinetic energy into electrical energy.

There are several kinds of hydroelectric setups. In large, traditional hydropower projects, a dam is constructed to provide a suitable vertical fall before the turbine setup, and to create a reservoir that evens out water flow (and therefore electricity generation) between rainy and dry seasons. Smaller "run-of-the-river" installations do not rely on a dam, but harvest the river's natural kinetic energy by diverting water into a pipe running alongside the river, passing it through a turbine, and then returning it back to the river channel. "Micro-hydro" installations are similar to run-of-the-river plants, but smaller in size. Micro-hydro is most often used for electrification of remote villages. Because these three types of hydro projects differ in cost, environmental impact, and availability, each one is discussed separately below.

2.2.1 Large, dam-based hydropower

No large dam projects have been built in Sabah, but plans for several plants are under development. The 150 MW Upper Padas dam, upriver of the Tenom Pangi run-of-the-river project (discussed below) is planned for 2014, and the 150 MW Liwagu project for 2018. If development of these plants is successful, they will make hydro the second-largest electricity resource in Sabah by 2020.

These projects do not appear to exhaust Sabah's hydropower resource. A comprehensive 1984 study identified hydropower as one of Sabah's most attractive electricity generation resources. The study identified 68 sites that were feasible for hydroelectric projects. Based on stream flow statistics and geographical information, the study's authors estimated that these sites have a potential for 1,900 MW of capacity. Subsequent studies by SESB and other power developers have likely refined and revised these estimates, though we have been able to obtain neither updated estimates nor any estimates of the potentially serious environmental consequences (see below) of development at these sites.

Table 2-3: Results of 1984 Study of Potential Dam Sites in Sabah[85]

River Catchment	No. of Sites Identified	Potential Capacity
Kinabatangan	8	180
Liwagu	9	245
Padas	15	570
Pensiangan	4	375
Segama	6	145
Sugut	4	145
Tawau	7	110
West Coast	15	130
Total	68	1,900

85 Tenaga Ewbank Perunding (M) Sdn Bhd, *Sabah Power Development Master Plan Study, Draft Final Report Volume One*, p. 3-7.

Additionally, twelve dam projects are under development in Sarawak, including the 2,400 MW Bakun project. These projects will give Sarawak a very large surfeit of electricity generation capacity. However, most of this power is expected to be exported to Peninsular Malaysia via a planned undersea transmission linkage, rather than to Sabah. SESB's negotiations for Sarawak hydropower have apparently been limited to a proposed deal for 100-200 MW of power from the Lawas dam project near the Sabah-Sarawak border.[86]

Figure 2-3: Upper Padas 150 MW Proposed Dam Site[87]

Figure 2-3a: The Bakun Dam Construction Site[88]

86 SESB Explains on Bakun Supply, Daily Express, 29 May 2009, http://www.dailyexpress.com.my/print.cfm?NewsID=65319. Another source indicates the possibility of more extensive import to Sabah, http://www.st.gov.my/ecom/images/publication/p5%20powering%20the%20south%20east%20asia%20grid%20through%20sarawak%20energy.pdf, p. 16.

87 Chemsain Konsultant Sdn Bhd, *Terms of Reference for Detailed Environmental Impact Assessment, Proposed Upper Padas Hydroelectric Project, Sabah* (12 Dec 2008).

Hydropower is a low carbon technology that does not directly release any greenhouse gases. However, forest clearing, cement use, and the anaerobic decomposition of submerged vegetation can create significant indirect emissions.[89] Moreover, the effect of dams on river ecosystems is objectionable on other environmental and economic grounds: they decrease fish populations, lead to destructive erosion, displace human populations, and can deprive downstream users of access to river water. For those reasons, large dam projects are typically opposed by environmentalists, social groups, and indigenous peoples.

All hydroelectric projects, and especially large hydroelectric projects, are characterized by large up-front capital costs for construction of infrastructure and very low ongoing costs of operation. Water flow, unlike diesel, coal, and natural gas, is free. Based on an estimate of RM 5 billion for construction of a 2,400 MW facility at Bakun, O&M costs of about RM 175,000/MW/yr, and Tenom Pangi's capacity factor of 73%, the levelized cost of a large dam project is estimated at RM 0.163 per kWh. This is slightly higher than the cost of coal-fired generation at the current coal price, but would match coal's levelized cost if the price of coal rises by about 20% to (i.e. from RM 255 to RM 300).

2.2.2 Small and Mini Run-of-the-River Hydro

As of 2009, two run-of-the-river hydroelectric plants were operational in Sabah. The older of these two plants is located on the Padas River near Tenom, and has an installed capacity of 66 MW. It produces approximately 14% of Sabah's electricity. Additionally, one small (2 MW) hydroelectric project was completed by Esajadi Sdn Bhd under the SREP programme in 2009. This project's two sister projects (2.5 and 4 MW, respectively) are scheduled for completion by the same company in 2010.

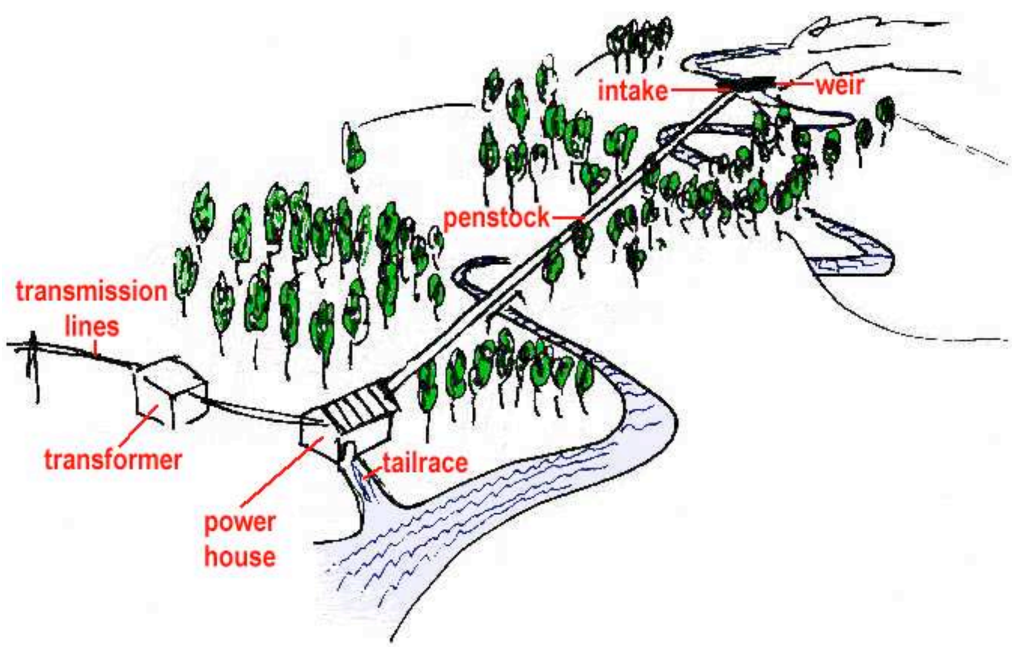


Figure 2-4: A Run-of-the-River Hydropower Scheme.[90]

[88] Source: http ://media1.malaysiakini.com/129/3aaba7e123d10cd6d9c8d689e5fa76f6.jpg.
[89] See International Rivers, http://www.internationalrivers.org/node/1398.
[90] Source: http://www.microhydropower.net/.

Run-of-the-river projects can achieve the greenhouse gas benefits of larger dam projects while limiting the local and downstream environmental disruptions caused by a dam. The primary downside of such projects is that they have no reservoir to even out river flows over time. In many regions, low precipitation or precipitation in the form of snow during certain seasons means that hydro power is only available during certain months of the year. In Sabah, however, rainfall appears sufficient to make hydropower available year round in non-drought years. The Tenom Pangi hydropower facility achieved a 73% capacity factor against its installed capacity of 66 MW for the five years between 2000 and 2004, and the Esajadi plants predict a 77% capacity factor.[91]

An estimate of potential locations for additional Esajadi-like projects was not available at the time of writing, but many of the sites listed in the 1984 Master Plan study are likely appropriate for run-of-the-river hydro. For example, three of the nine schemes identified in the Tawau basin on Sabah's East Coast proposed the use of a relatively small "barrage" to divert water into a tunnel. The total capacity from the implementation of these schemes was estimated at 22-44 MW. Similar estimates appear for other river systems. Therefore, more research is recommended to determine the feasibility, cost-effectiveness, and environmental attractiveness of further development of run-of-the-river hydro.

Detailed capital and O&M information has been made public by Esajadi as part of their application for CDM credit. Based on the total capital cost in RM for the combined 9 MW capacity of the three Esajadi projects and Esajadi's forecasted 77% capacity factor, the levelized cost of electricity is estimated at RM 0.144, which makes it nearly cost competitive with coal and significantly cheaper than natural gas.

The cost-competitiveness of the Esajadi projects is due in part to national and international subsidies for the promotion of clean energy. At the national level, hydro projects under 10 MW are eligible for either a Pioneer Status Tax Allowance of 100% of statutory income or an Investment Tax Allowance equal to 100% of investment.[92] These tax advantages have a significant impact on the project's attractiveness, especially if they can be coupled to the tax liability of the investor's other income or the income of a tax equity investor. Moreover, as a result of their potential to displace comparatively "dirty" fossil fuel-based power in Sabah's grid, environmentally-friendly hydro projects can receive revenue from the international sale of carbon offset credits. The Esajadi project was approved as an emissions-reducing project by Kyoto's Clean Development Mechanism, and is projected to receive RM 0.026 in subsidies per kWh of electricity produced on top of the RM 0.17 it receives in electricity revenue under its power purchase agreement with SESB.[93]

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[91] Esajadi Sdn Bhd, *CDM Project Proposal, Annex 1*, http://cdm.unfccc.int/UserManagement/FileStorage/96X6KTNX0UP5H6PSZXI5O6WYYM5UL0.

[92] Pusat Tenaga Malaysia, *Government Incentives*, http://www.mbipv.net.my/content.asp?higherID=5&zoneid=4&categoryid=8.

[93] Esajadi Sdn Bhd, *CDM Project Proposal, Annex 1*, http://cdm.unfccc.int/UserManagement/FileStorage/96X6KTNX0UP5H6PSZXI5O6WYYM5UL0. The three projects together report emissions reductions of 45,063 tonnes CO_2, annual production of 60,487 MWh, and income from carbon credit sales of $450,643.

2.2.3 Micro-Hydro Projects

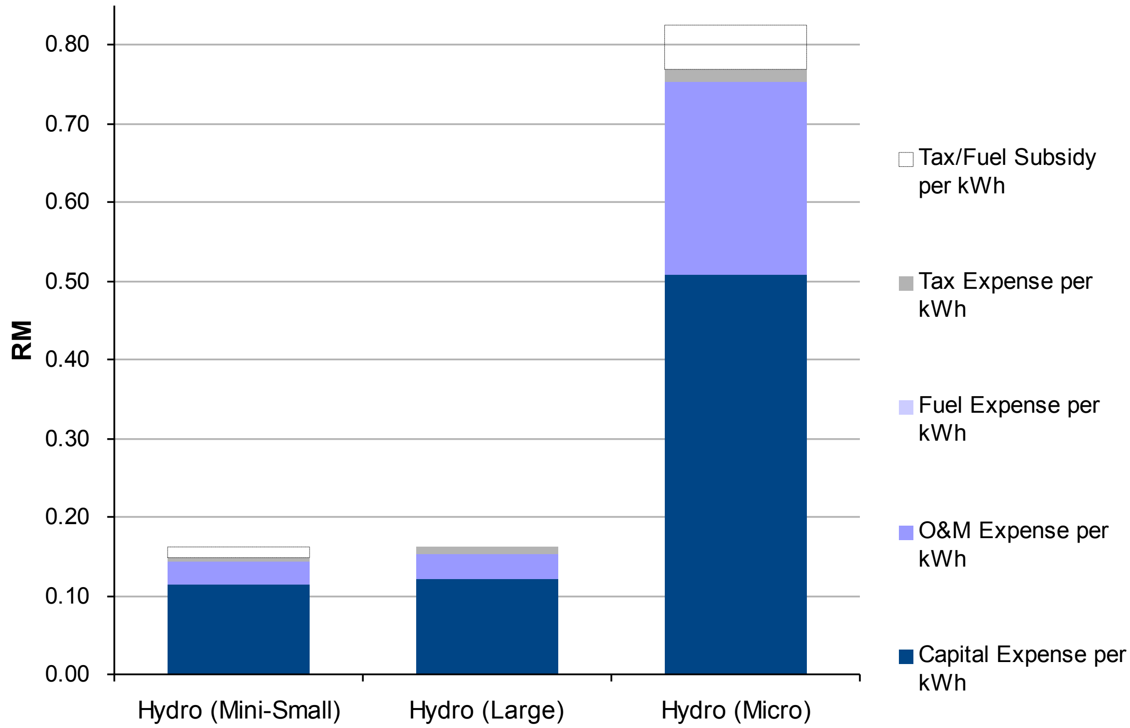
Micro-hydro projects are similar to the run-of-the-river projects discussed above, but are smaller—typically in the 1-100 kW range. Such projects are often used to electrify villages or provide power to remote, off-grid facilities. Thus, as with distributed solar capacity, micro-hydro projects can be thought of as slowing the growth of load on the grid, rather than increasing the supply of power to the grid. They also reduce the need for transmission capacity.

Information on three micro-hydro systems built in Sabah and Sarawak by PACOS trust,[94] a Sabahan NGO, shows an average capital cost for micro-hydro of about RM 32,000 per kW. Factoring in O&M and financing costs, we estimate the levelized cost of micro-hydro power supply of about RM 0.752/kwh. It should be noted, however, that all three projects were in remote locations, and that one project required delivery of materials by helicopter. Lower capital costs can be expected at less remote sites.[95] Moreover, our estimate does not account for the fact that a distributed approach would reduce the need for the construction of transmission infrastructure. Therefore, our figures are likely an overestimate.

Like the Esajadi projects discussed above, micro-hydro projects may be eligible for international subsidies for the reduction of greenhouse gas emissions, though their small size the may make it impractical to undertake the onerous process of certifying the project. In addition, rural electrification is often supported by grants or in-kind support from governments and international development organizations such as the PACOS trust.

94 Adrian Lasimbang, A Simple Technology for Complicated Woe: Micro Hydro in Sabah and Sarawak, http://indigenouspeoplesissues.com/index.php?option=com_content&view=article&id=1497:a-simple-technology-for-complicated-woe-micro-hydro-in-sabah-and-sarawak&catid=62:southeast-asia-indigenous-peoples&Itemid=84=en.

95 See, e.g., Smail Khennas and Andrew Barnett, *Best Practices for Sustainable Development of Micro-Hydro in Developing Countries*, http://microhydropower.net/download/bestpractsynthe.pdf.



	Hydro (Mini-Small)	Hydro (Large)	Hydro (Micro)
Capital Cost/MW	RM 8,234,157	RM 7,145,833	RM 32,800,000
O&M Cost/MW	RM 206,112	RM 178,870	RM 1,500,000
Fuel Cost per MWh electric	RM 0	RM 0	RM 0
Typical Plant Size (MW)	9.00	1.00	0.02
Capacity Factor	0.73	0.73	0.73
Levelized Cost per kWh	RM 0.15	RM 0.16	RM 0.77
Tax incentive per kWh	RM 0.01	RM 0.00	RM 0.06
Total cost to Malaysia per kWh	RM 0.16	RM 0.16	RM 0.83

Figure 2-5: Key Assumptions & Results – Hydro Levelized Cost Analysis

2.3 Palm Oil Waste & Other Biomass

The potential to generate electricity in Sabah with the use of byproducts from palm oil processing has been widely studied, encouraged by international and national efforts, and discussed in the press.[96] Three 10 MW+ grid-connected power plants are already operational on Sabah's East Coast, with several more under development. Below, we quantify the total available palm oil waste, estimate the amount of baseload power that palm oil waste could feasibly provide in Sabah, and report a levelized cost estimate for IPP development of the palm oil waste resource.

2.3.1 Palm Oil Industry Overview & Growth Forecast

Sabah's palm oil industry is the single largest industry in the state, accounting for 23% of the state's gross domestic product.[97] Sabah's palm plantations boast the highest yields of any Malaysian state and account for 30% of national production.

As shown in Figure 2-6, production of palm oil in Sabah is centred on the East Coast. Areas served by the East Coast electric grid account for 95% of plantation area, with significant mill infrastructure located near the Sandakan, Lahad Datu, and Tawau population centres.[98]

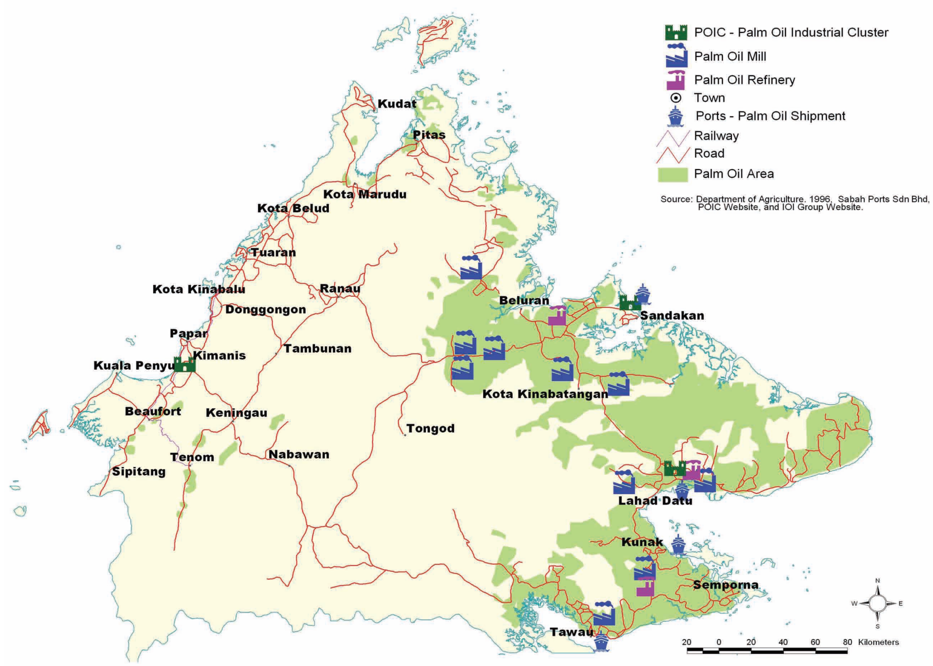


Figure 2-6: Palm Oil Regions in Sabah[99]

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96 Pusat Tenaga Malaysia, *Bio-gen Web Portal*; UNDP, http://www.undp.org.my/uploads/Renewable_Energy_Palm_Oil_Wastes.pdf; *Malaysia Generating Renewable Energy From Palm Oil Wastes*, August 2007, http://www.ptm.org.my/biogen/about.aspx; The Borneo Post, *Natural Waste can solve East Coast Power Woes*, 14 December 2009, http://www.theborneopost.com/?p=64306; Ooi Tee Ching, New Straights Times, Dec 21, 2009.

97 Department of Statistics Malaysia, Sabah, *Yearbook of Statistics Sabah 2008*, p. 44. Estimate includes Sandakan and Tawau Divisions as well as Kota Marudu and Matunggong administrative districts.

98 Department of Statistics Malaysia, Sabah, *Yearbook of Statistics Sabah 2008*, p. 44. Estimate includes Sandakan and Tawau Divisions as well as Kota Marudu and Matunggong administrative districts.

Sabah's palm oil industry experienced very rapid and sustained growth through the 1980s and 1990s, with the area planted growing at an average of well over 10% per year. In addition, palm oil farmers increased the per-hectare crop yields by a long-term compound average about 2% per year. These rates slowed as the industry matured during the 2000s; during the 2000-2008 period the growth rates of planted area and fresh fruit bunch yield were 3% and 2%, respectively, implying a 5% growth rate in total fresh fruit bunch production (see Figure 2-6).

Demand for Malaysian palm oil will likely remain strong into the foreseeable future. Increasing demand for vegetable oil is expected as strong growth continues to raise the standard of living of the citizens of India and China, and Europe continues to supplement this demand with demand for palm-oil derived biodiesel.[100] The industry is well-organized by the Malaysia Palm Oil Council,[101] benefits from continuing research on production and marketing,[102] and enjoys the support of the national and state governments.[103]

However, land constraints and environmental concerns may check the continued expansion of the supply side of the market, a trend that is already visible in the declining growth rates depicted in Figure 2-6. Moreover, growth rates continued to slow within that 10-year period. Therefore, rather than project the average 1999-2009 growth rate in FFB production into the foreseeable future, the estimates in this study rely on the assumption that the growth rate will decrease linearly from its current 10-year average of 4.63% to 0% in 2020.

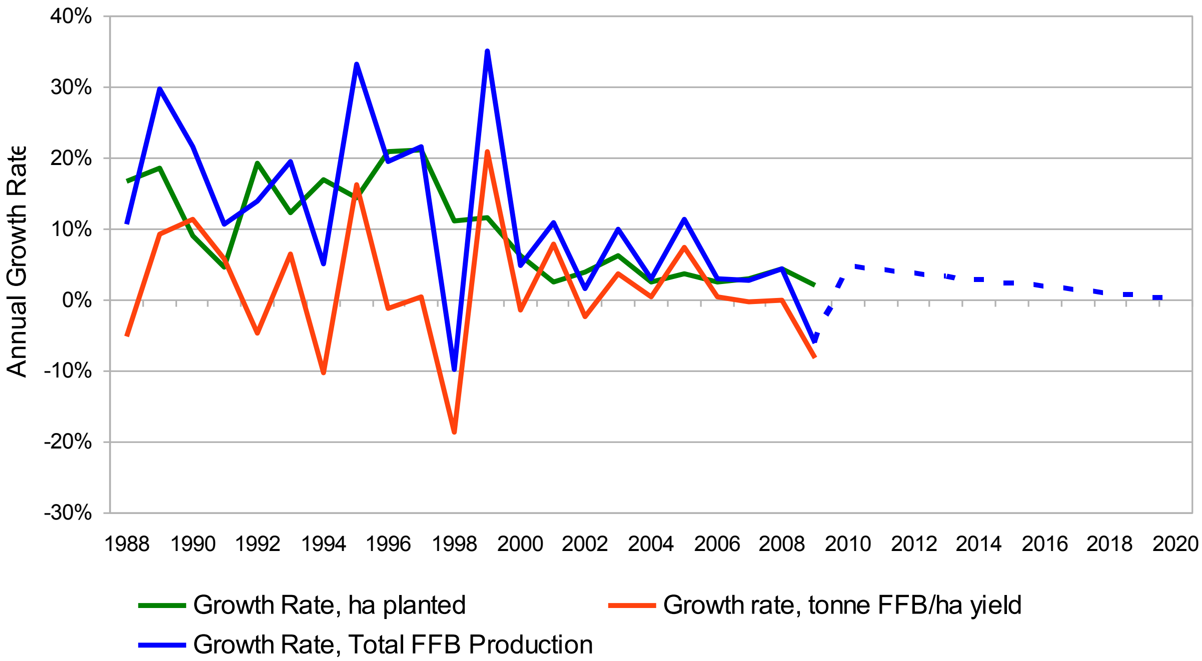

***Figure 2-7: Growth Rate of FFB Production, FFB Yield, and Palm Oil Plantation Area, and Total FFB Production in Sabah**.*[104]

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99 UNDP, http://www.undp.org.my/uploads/Renewable_Energy_Palm_Oil_Wastes.pdf, p. 17.

100 Yusof Basirion, *Palm Oil and Its Global Supply and Demand Prospects*, http://palmoilis.mpob.gov.my/publications/opiejv2n1-1.pdf.

101 Malaysian Palm Oil Council website, http://www.mpoc.org.my/.

102 See the Journal of Oil Palm Research, http://jopr.mpob.gov.my/.

103 The Malaysia Palm Oil Board is a government office charged with regulating and promoting the palm oil industry.

104 Source: Malaysia Palm Oil Board, *Yield Data,*

Sabah's 117 palm oil mills operate year-round. As shown in Figure 2-8, while the mills tend to crush at only about 80% of their rated capacity between October and May, they may operate above capacity between June to September. Thus, over the full course of the 2008 calendar year, Sabah's palm oil mills crushed over 27 million tonnes of FFB, about 93% of the mills' collective rated capacity of 29.3 million tonnes. These figures suggest that palm oil mill waste is available year-round.

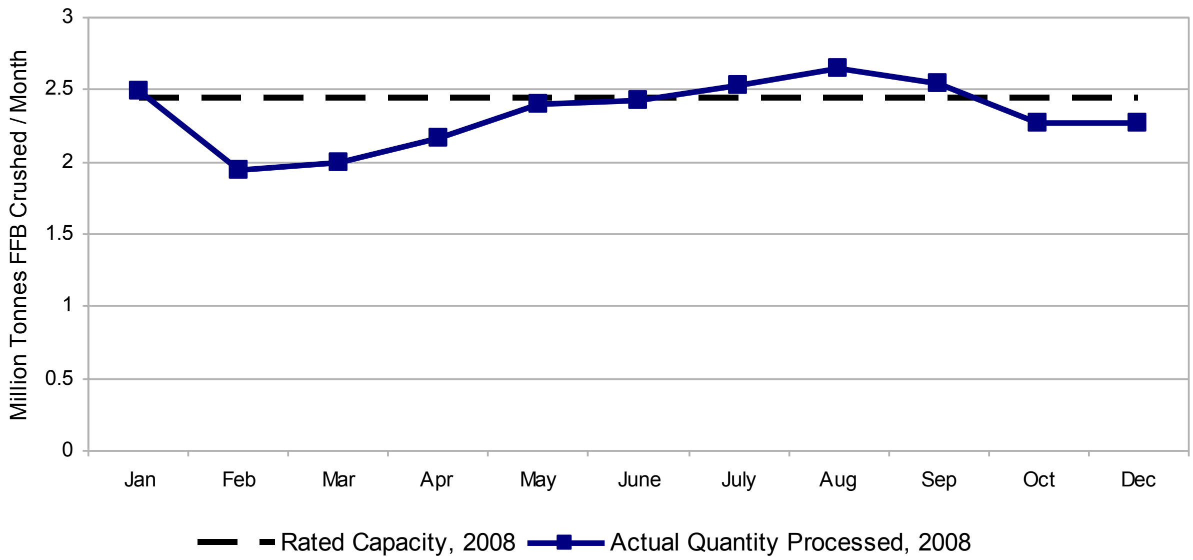

Figure 2-8: Monthly Capacity Utilization of Sabah's Pam Oil Mills (total for 117 mills). [105]

2.3.2 Palm Oil Mill Waste Energy & Emissions Analysis

As shown in Table 2-4, each tonne of fresh fruit bunch processed by a palm oil mill results in approximately 230 kg of empty fruit bunch (EFB) waste, 120 kg of mesocarp fibres, and 60 kg of palm nut shells. All of these solid wastes contain energy that can be recovered by combustion in a boiler. In addition, each ton of FFB processed results in 12.5 cubic metres of palm oil mill effluent (POME). As it decomposes, this effluent releases methane, an energy-containing natural gas.

Most mills manage to run on the relatively dry husks and fibres alone. Empty fruit bunches are typically taken to landfills, spread on the fields for their nutrient value, or, in a few cases, used as an input for paper or fertilizer production. Effluent is traditionally discharged into ponds, though recent environmental legislation is forcing mills to follow certain protocols in handling this waste. Mills do fire their boilers with palm oil waste. However, because the palm oil waste produced by a mill contains more energy than the mill needs, mills are typically

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http://econ.mpob.gov.my/economy/annual/stat2008/EID_statistics08.htm ; Overview of the Malaysian Palm Oil Industry 2009, http://econ.mpob.gov.my/economy/Overview_2009.pdf. The FFB produced figure is the product of the average yield and the number of hectares planted. Actual reported FFB productions statistics are somewhat lower (27.2 million tonnes rather than 30.6 million tonnes). Reported palm oil production growth is higher than FFB production growth because of improvements in palm oil per FFB processing efficiency.

105 Malaysia Palm Oil Board, *Processing Performance Data*, http://econ.mpob.gov.my/economy/annual/stat2008/EID_statistics08.htm.

designed to generate sufficient power cheaply, rather than to maximize the amount of energy produced per tonne of biomass waste.

Therefore, upgrades to mills' electricity generation infrastructure—usually, higher pressure boilers and more efficient steam turbines—combined with fuller utilization of mill waste streams can allow them to generate more electricity than they need for their in-house processing requirements. Table 2-4 shows the amount of surplus energy that can be expected per tonne FFB processed. Even accounting for mill process steam and electricity requirements, full utilization of both biomass waste and POME-derived methane could conceivably allow a mill to produce 160 kWh of electricity energy per tonne of processed FFB.

Table 2-4: Energy Analysis of Palm Oil Waste

Waste Type	% of FFB by weight[106]	Low Calorific Value (MJ/ tonne)[107]	Steam Energy (MJ / tonne FFB)[108]	Mill Steam Use (MJ/ tonne FFB)[109]	Turbine Effic.	electricity / tonne FFB (kWh)[110]	Parasitic load + fuel prep load[111]	mill load (kWh/tonne FFB)[112]	kWh exported to grid
EFB	18%	8590	1314	411	0.30	75			
Fibre	13%	11100	1198	374	0.30	69			
Shells	6%	17300	838	262	0.30	48			
Solid Waste Subtotal	36%	10830	3351	1047	0.30	192	34	21	137
POME Methane[113]	1%	55400			0.3	26	3		23
Total						**218**	**37**	**21**	**160**

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[106] Percent by weight values are from Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ, p. 46. EFB is around 23% by weight at its post-processing moisture content of 60-65%. However, mills that use the fuel typically dry it to 45% moisture content before burning it in boilers; the lost water weight means that the useable fuel is only 18% of FFB by weight.

[107] Calorific values are from Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, p. 46. They are reported for a moisture content of 45% for EFB, 37% for fibre, and 12% for shells. Similar figures are reported in Anders Evald, *DANIDA Renewable Energy Resources Report*, eib.org.my/upload/files/Renewable%20Energy%20Resources.doc, p.7 and PTM Malaysia, *Lecture Note*, http://www.ptm.org.my/biogen/download.aspx, p. 11.

[108] Steam production is based on 85% boiler efficiency reported in the Kunak (Project 2921) CDM application, http://cdm.eib.org.my/useful_materials/Presentation/10.%20Kunak%20CDM%20Project.pdf, p. 9.

[109] Steam diversion is based 25 out of 80 tonnes per hour of high pressure steam for mechanical power requirements of an 80t/h mill. *Id*., see also Henrik Rytter Jensen, Danish Energy Management, *Lessons Learned from the Kunak bio-energy CDM project*.

[110] This column is a calculation based on the columns to the left: (steam produced – steam diverted) * turbine efficiency.

[111] *Id*. The project reports 1.5 MW parasitic load and 1 MW fuel preparation loads and assumes combustion of 32 tonnes/h of biomass.

[112] *Id*. The project reports 1.5 MW of electricity use by an 80 t/h mill.

[113] All information in this row is from Methane Recovery and Utilisation Project at TSH Kunak Oil Palm Mill (Project 0916), *CDM Project Design Document*, http://cdm.unfccc.int/Projects/DB/DNV-CUK1170423084.93/view.

Such projects are attractive on environmental grounds. While some studies have suggested that land conversion for the production of palm oil can cause an increase in the concentration of greenhouse gases in the atmosphere, and that that increase can be large enough to make the use of palm oil-derived bio-diesel "dirtier" than the use of regular diesel, the use of biomass *waste* is a different phenomenon altogether. Currently, byproducts from palm oil processing are disposed of in effluent ponds and landfills. As the waste decays, it releases carbon dioxide and methane, both of which are greenhouse gases that exacerbate global warming.[114] Burning biomass waste in boilers instead releases slightly more carbon dioxide, but it decreases the release of methane, which is a more potent greenhouse gas than carbon dioxide, meaning that on balance the combustion of palm oil waste decreases greenhouse gas emissions vis-à-vis the "business as usual" landfill disposal alternative. Moreover, if the surplus electricity that is generated by burning the waste is sold to the electric grid, it displaces relatively "dirty" electricity derived from diesel, natural gas, and coal.

Together, these reductions in landfill methane emissions and displacement of fossil fuel power add up to significant emissions reductions. Table 2-5 shows net greenhouse gas emissions from a solid waste biomass project and a POME methane capture project. Even after factoring in the emissions from burning of biomass, fossil fuel emissions for transport of biomass and other ancillary energy needs, the projects would reduce emissions by approximately 170 kg CO_2 equivalent and 23 kg CO_2 equivalent for each tonne of fresh fruit bunch processed, respectively.

Table 2-5: Emissions Analysis of Palm Oil Mill Waste Projects[115]

	Emissions Factor of Sabah Grid (tCO2e/ MWh)	Fossil fuel emissions foregone / tonne FFB	tCO2e Methane Reduction / tonne FFB	Project Emissions / Tonne FFB	Total Reductions / tonne FFB	MWh exported / tonne FFB	Total Emissions Reduction /MWh exported
Solid Waste Subtotal (Weighted)	0.40	0.05	0.12	0.01	0.17	0.137	1.22
Methane derived from POME	0.40	0.01	0.17	0.01	0.16	0.023	7.28
Combined	0.4	0.06	0.29	0.02	0.33	0.16	2.08

And biomass generation is attractive for other environmental reasons as well. The disposal of biomass waste in landfills and ponds can be hazardous and malodorous. If properly

114 Of course, to the extent that biomass electricity revenue means that palm oil producers will supply more palm oil at a given price, they could inspire more forest-to-plantation conversion at the margins. We do not account for this possibility in our analysis.

115 Source: Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ; Methane Recovery and Utilisation Project at TSH Kunak Oil Palm Mill (Project 0916), *CDM Project Design Document*, http://cdm.unfccc.int/Projects/DB/DNV-CUK1170423084.93/view. The reported figures have been divided by the Kunak projects' reported production in order to obtain per-MWh figures. We have also replaced the projects' emissions factor of 0.699 tCOCe/MWh with a lower factor of 0.4 tCOCe/MWh (the average or our estimates for 2010 and 2020 in Part III) in order to account for the increased use of natural gas and hydropower in Sabah's grid mix.

managed, combustion of solid biomass waste has the potential to solve this waste disposal problem at the same time it solves the electricity generation problem.

2.3.3 Economic Analysis of Palm Oil Mill Waste Projects

The Small Renewable Energy Power programme (SREP) provides a legal and economic framework for the sale of biomass power from Malaysian mills to Malaysian utilities. Three participating mills are currently exporting 30 MW of power to SESB in East Sabah, with several more projects under development.[116] The experience of these mills, as well as continuing research by the Malaysia Palm Oil Board and international consultants, provides reliable information about the economic viability of mill generation projects.

Table 2-6 shows a simplified economic model of an IPP project at a mill that processes 500,000 tonnes of FFB processed per year. With low efficiency equipment, the mill can generate sufficient steam and electricity by burning about 50% of its palm kernel shells and mesocarp fibre waste and 0% of its EFB waste. If it spends approximately RM 53,000,000 to upgrade its equipment and burns all of its waste, the mill can meet its own electricity and steam needs while also exporting about 66,500 MWh per year to the grid, or 9.5 MW of power at a capacity factor of 80%.[117]

At the typical SREP rate of RM 0.21/kwh, the income from these electricity sales are not quite enough to cover the cost of operating and maintaining the over-sized power equipment and the opportunity cost of using the additional biomass. However, the project can receive monetary compensation for its reduction in greenhouse gas emissions. Under the Kyoto Protocol, emissions reducing projects in Malaysia and other developing nations can sell carbon offset credits to businesses and governments in developed countries who agreed to emissions reductions under the Protocol. Currently, such carbon offsets are trading at a price of about 10 euros per ton of CO_2 reduced. Multiplying this price with the per-MWh emission reduction of 0.177 tCO_2e shows that a large mill project could receive over RM 4,000,000 per year in carbon offset revenue. As shown in Table 2-6, this revenue together with the revenue from electricity sales is sufficient to make the project economically attractive at the SREP tariff of RM 0.21/kwh.

[116] In addition, other significant non-grid connected projects may exist to serve industrial clusters. The Star, *Oil palm players want biomass supply to harness renewable energy*, 29 Dec 2009, http://thestar.com.my/news/story.asp?file=/2009/12/29/nation/5371239&sec=nation (reporting the existence of a 24 MW palm mill waste project in the Lahad Datu Palm Oil Mill Industrial Cluster).

[117] The existing palm oil mill IPPs purchase additional biomass from neighbouring mills in order to export slightly more power.

Table 2-6: Simplified Economics of a Palm Oil Mill Solid Waste Project[118]

	Year 0	Year 1-10	Year 2-20
Capital Expense	(51,200,000)		
O&M Expense		(38,176,062)	(48,868,588)
Fuel Expense		(17,675,652)	(22,626,329)
Debt Paydown		(20,995,173)	(20,995,173)
Electricity Income		98,750,926	98,750,926
Carbon Income		26,952,435	26,952,435
Income Before Taxes		48,856,474	33,213,272
Income Net of Operating Expenses		69,851,647	54,208,445
Interest Deduction		(14,779,433)	(7,575,858)
Depreciation Allowance		(41,327,696)	0
Pioneer Status Allowance		(55,072,214)	0
Corporate Tax Rate		0	0
(Tax Due) / Tax Savings		10,331,924	(11,658,147)
Cash Flow		59,188,398	21,555,126
IRR			49%

The economics of palm oil mill effluent projects are slightly different, but still attractive: at least four Sabah mills have registered methane-capture schemes with the CDM.[119] Even for a large mill receiving a high per-kWh tariff, electricity revenues alone are not sufficient to make the project viable. A mill that crushes 500,000 tonnes of FFB per year might harvest only about 2-3 tonnes of biogas, enough to export about 2.5 MW of power at an 80% capacity factor. On the other hand, because of the strong greenhouse gas mitigation value of preventing the release of methane into the atmosphere, effluent projects can receive higher carbon offset revenues than solid waste projects. At the assumed carbon price of about RM 47/tCO2e and the SREP electricity price of RM 0.21, we estimate an internal rate of return of over 90%.[120]

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[118] Source: Table 2-5; Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ; Methane Recovery and Utilisation Project at TSH Kunak Oil Palm Mill (Project 0916), *CDM Project Design Document*, http://cdm.unfccc.int/Projects/DB/DNV-CUK1170423084.93/view. This example employs the universal assumptions set out in table 2-1 above and the biomass-specific assumptions set out in Table

[119] UNFCCC, http://cdm.unfccc.int/Projects/projsearch.html.

[120] Source: Table 2-5; Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ; Methane Recovery and Utilisation Project at TSH Kunak Oil Palm Mill (Project 0916), *CDM Project Design Document*, http://cdm.unfccc.int/Projects/DB/DNV-CUK1170423084.93/view. The values have been scaled to a mill that crushes approximately 500,000 tonnes of FFB per year.

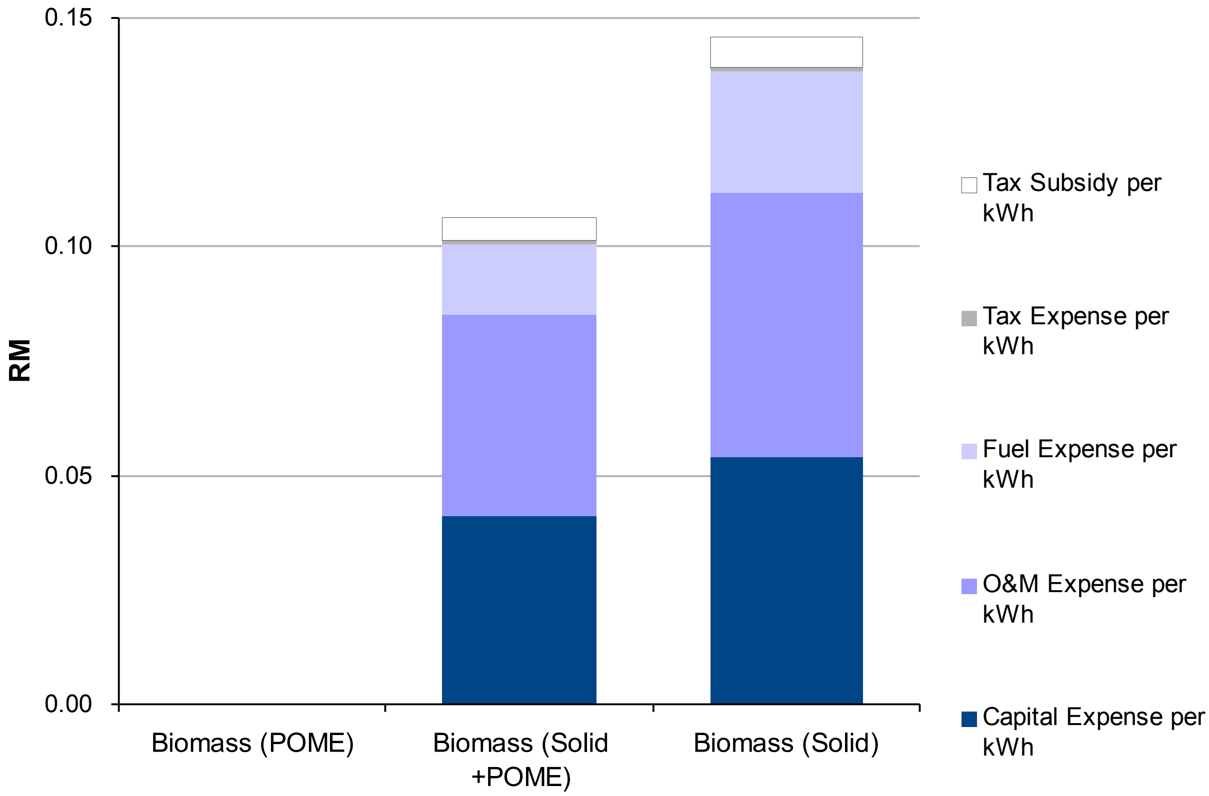
Table 2-7: Simplified Economics of a Palm Oil Mill Methane Capture Project

	Year 0	Year 1-10	Year 2-20
Capital Expense	(16,500,000)		
O&M Expense		(12,212,195)	(15,632,642)
Fuel Expense		0	0
Debt Paydown		(6,766,022)	(6,766,022)
Electricity Income		19,750,185	19,750,185
Carbon Income		32,158,714	32,158,714
Income Before Taxes		32,930,681	29,510,234
Income Net of Operating Expenses		39,696,703	36,276,256
Interest Deduction		(4,762,903)	(2,441,438)
Depreciation Allowance		(13,318,496)	0
Pioneer Status Allowance		(34,933,800)	0
Corporate Tax Rate		0	0
(Tax Due) / Tax Savings		3,329,624	(8,458,704)
Cash Flow		36,260,305	21,051,529
IRR			91%

These results can also be expressed in terms of the levelized cost of electricity framework employed throughout the rest of this report. As shown in Figure 2-8, we estimate the nominal levelized cost of a solid waste biomass projects at RM 0.139/kwh. The low cost results from the significant sales of carbon offset per kWh of electricity produced as well as the 10 year Pioneer Tax Allowance; together, these incentives make it possible for project developers to achieve the benchmark 15% internal rate of return at a relatively low electricity tariff.

Palm oil effluent capture projects have higher capital costs per kWh; however, because they achieve significant reductions in methane emissions, they receive even higher carbon offset revenues per kWh of electricity produced than the solid waste projects. In fact, incorporating both these revenues and the effects of the Pioneer Tax Allowance into our analysis suggests that a palm oil mill effluent project might be profitable without any electricity revenue, implying a RM 0.00 levelized cost of electricity generation. Thus, a mill that undertakes a comprehensive solid waste + POME waste-to-energy project could be profitable at a tariff lower than the tariff required by a standalone solid waste project.

Finally, it is worth noting that palm oil mill waste projects may benefit from other international incentives not accounted for in the analysis above. At the international level, the Global Environmental Facility and United Nations Development Programme have taken a strong interest in palm oil waste electricity projects, and may provide grants and low interest loans to innovative projects. These additional incentives are not factored into the analysis above, and may increase the attractiveness of palm oil waste projects.



	Biomass (POME)	Biomass (Solid +POME)	Biomass (Solid)
Capital Cost/MW	RM 8,250,000	RM 5,641,667	RM 5,120,000
O&M Cost/MW	RM 825,000	RM 567,333	RM 515,800
Fuel Cost per MWh electric[121]	RM 0	RM 28	RM 34
Typical Plant Size (MW)	2.00	12.00	10.00
Capacity Factor	0.80	0.80	0.80
Levelized Cost per kWh	RM 0.00	RM 0.10	RM 0.14
Tax incentive per kWh	RM 0.00	RM 0.00	RM 0.01
Total cost to Malaysia per kWh	RM 0.00	RM 0.11	RM 0.15

Figure 2-9: Key Assumptions & Results - Palm Oil Mill Waste Levelized Cost Analysis

[121] Our fuel cost assumption is based on the figure of RM 15/tonne for EFB, RM 30/tonne for fibre, and RM 135/tonne for PKS, as reported in Kunak Bio-Energy Project (Project 2921), *CDM Project Design Document*, http://cdm.unfccc.int/UserManagement/FileStorage/P2HETQAD3SFM90U8IY6C4GWOX5KNZJ. However, since palm oil mills burn some waste even when they are not configured to export power, we apply this price only to the additional waste used by the project. Based on information in the Kunak project, we assume that in the absence of a power export project, the mill would meet its own demand for electricity by burning all of its PKS and some of its fibre. Thus, we apply the fuel costs listed above to 100% of the mill's own EFB waste, 50% of its own fibre waste, and 0% of its own PKS waste. (Since most EFB is disposed of in a landfill, we consider the application of these "opportunity costs" to the mill's own waste to be a conservative assumption). We further assume that the mill purchases extra waste equal to 6% of its own waste production in order to have sufficient waste to generate 10 MW of power at a 0.8 capacity factor, and apply the prices listed above to this waste according to the proportion in which EFB, fibre, and PKS occur (i.e. 18%, 13%, 6%). This calculation yields a final average price of RM 9.454 per tonne of waste. The per-MWh price is calculated assuming the energy content and efficiencies shown in Table 2-4.

2.3.4 Potential Size of the Palm Oil Waste Resource

Coupling our per-tonne electricity export estimate to the production statistics and growth estimates reported above allows us to estimate the theoretical size of the palm oil waste generation opportunity. As shown in Figure 2-9, nearly 500 MW of baseload generation capacity is theoretically available currently. Assuming the growth rate projected in Figure 2-6, industry expansion will increase this figure to 700 MW in 2020. Most of this potential (over 85%) is in East Sabah.

However, not all of this theoretical capacity may be economically feasible. In particular, the economics discussed above may not work out for mills that are significantly smaller than the Kunak and Kina mills. Therefore, our estimate of size of the practically-available palm oil waste resource should be guided by mill size. According to the Malaysia Palm Oil Board, there are 117 palm oil mills in Sabah. In addition to the Kunak TSH mill, 10 other Sabah mills have a processing capacity of at least 80 t/h, and 32 more have a processing capacity of at least 60 t/h. At these large mills, TSH-style projects would likely be economically feasible. If all 42 mills undertook projects, they would generate about 3,300 GWh/yr, equivalent to an always-on baseload capacity of about 380 MW. If the number of "large" (> 60 t/h) mills increases at the same rate as total FFB production, this economically-feasible capacity will grow to 510 MW by 2020. Figure 2-10 depicts how IPP developers could take advantage of large-mill biomass waste by developing approximately 4 projects per year between 2010 and 2020. If developers follow this ambitious programme, Sabah could have approximately 500 MW of biomass capacity by 2020.

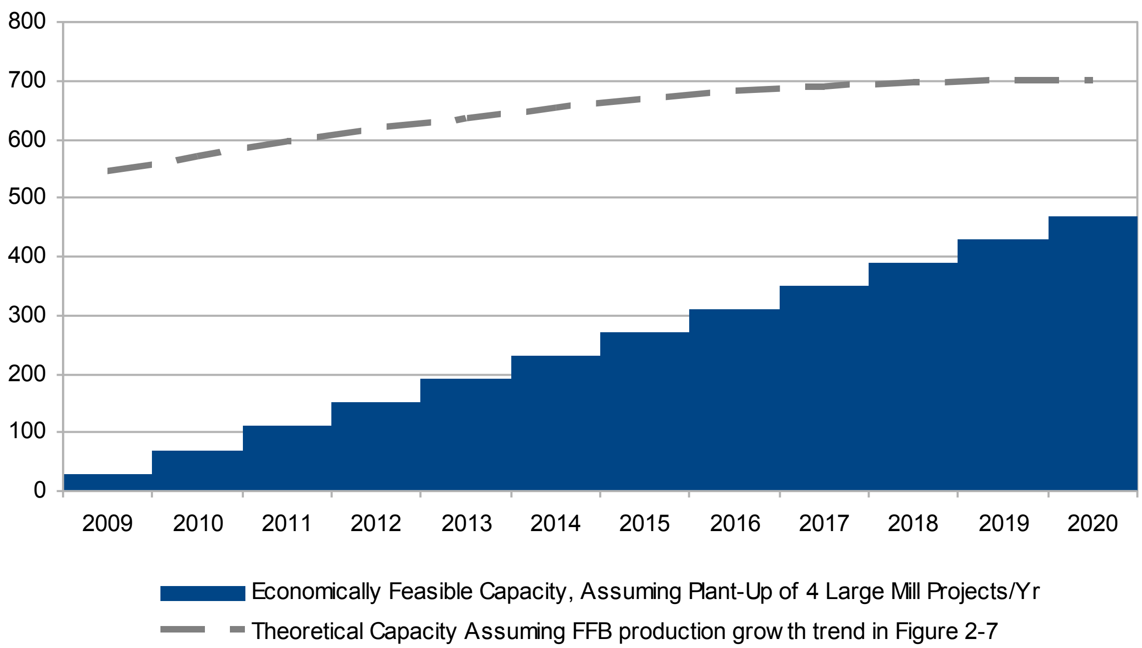


Figure 2-10: Estimate of Size of Palm Oil Mill Waste Resource in Sabah (MW)

Of course, even if projects are not economically attractive at the 65 mills with capacities less than 60 t/h, their biomass may nevertheless be used for electricity generation. Mills that are located near larger mills with electricity projects may sell their excess biomass to the larger mills

(Kunak plans to purchase about 10% of its biomass from other mills). Alternatively, it may be economically feasible for an IPP to aggregate the biomass waste from a number of small mills and set up a centrally located biomass power plant for the sole purpose of selling electricity to SESB. Such plants could conceivably be significantly larger than the 10 MW size chosen by the three existing mill-based plants, and could potentially make a significant contribution to the size of the economically recoverable palm oil waste capacity. A GIS-based estimate of the optimal sizes of such plants given Sabah's highway network, the density of agricultural operations, and transport cost would make an interesting subject for future research.[122]

2.3.5 Other mill waste

Palm oil is not Sabah's only agricultural industry. The state hosts a number of sawmills, of cocoa mills, and of rice mills as well. Rubber production is also important, but sources indicate that most rubber wood "waste" is milled in sawmills and shows up in the sawmill statistics..

Preliminary calculations indicate that that use of sawmill wastes could provide 100-200 MW of baseload power, but that rice and cocoa mill wastes are relatively insignificant(see Table 2-8). The economics of a sawmill electricity project would probably be similar to those of a palm oil mill project, but further analysis is required to determine which, if any, of Sabah's 171 sawmills might be large enough to host a grid-connected power plant.

Table 2-8: Energy Analysis of Other Mill Waste in Sabah

	Hectares Planted[123]	Un-processed crop yield (kg/ha)[124]	Mill waste / crop yield[125]	Total Mill Waste (tonnes)[126]	Energy content of waste (TJ)[127]	Electric Conversion Efficiency (kWh/MJ)[128]	Electricity Potential (MWh/yr)[129]	Baseload capacity (MW)[130]
Rice	36334	5213	70%	85,611	1.3	0.08	110,982	13
Cocoa	9691	823	68%	5,425	0.1	0.08	7,032	0.8
Sawmill	-	-	53%	749,289	14.1	0.08	1,177,949	134

[122] A recent study in Southern Thailand provides a good framework for such an analysis. P. Krukanont and S. Prasertsan, *Geographical distribution of biomass and potential sites of rubber wood fired power plants in Southern Thailand*, Biomass and Bioenergy 26 (2004) 47 – 59.
[123] Department of Statistics Malaysia, Sabah, *Yearbook of Statistics Sabah 2008.*
[124] Department of Statistics Malaysia, Sabah, *Yearbook of Statistics Sabah 2008*.
[125] Rice Source: PTM Malaysia, *Lecture Note*, http://www.ptm.org.my/biogen/download.aspx, p. 13 (20% husk + 50% paddy). Cocoa source: Augustine Ntiamoah & George Afrane, *Environmental impacts of cocoa production and processing in Ghana: life cycle assessment approach*, Journal of Cleaner Production 16 (2008). Sawmill source: Department of Statistics Malaysia, Sabah, *Yearbook of Statistics Sabah 2008* (reporting a 53 % conversion efficiency of logs to sawn timber; other sources suggest 690 kg dry weight per m3 of volume).
[126] Calculated from columns to left.
[127] Assumes 18.85 MJ/kg for sawmill waste and 15.6 MJ/kg for rice and cocoa waste. See PTM Malaysia, *Lecture Note*, http://www.ptm.org.my/biogen/download.aspx, p. 12-16.
[128] 30% conversion efficiency assumed for all wastes.
[129] Calculated based on columns to left.
[130] Calculated based on columns to left.

2.3.6 Non-mill derived biomass resources

Of course, mill waste is only a fraction of total biomass waste. Palm fronds and trunks from replaced oil palms are typically left to decompose in the palm oil plantations. Similarly, large quantities of twigs, branches are left in rubber plantation fields, and branches, bark, and large quantities of sawdust are left behind when logs are brought to sawmills. A recent study came up with a Malaysia-wide inventory of the energy available from such waste. By multiplying these estimates by the ratio between agricultural production in Sabah and agricultural production in all of Malaysia, we can obtain rough figures for the energy potential of these wastes.

Table 2-9: Energy Analysis of Distributed Biomass Waste in Sabah.

	TJ available in Malaysia / yr[131]	TJ available in Sabah / yr[132]	MWh of electricity[133]	MW of baseload power
Pruned Oil Palm Fronds	473,757	142,127	11,853,388	1,353
Oil Palm Replanting Wastes	78,934	23,680	1,974,929	225
Rubber Wood	22,613	6,784	565,770	65
Coconut Fronds	1,000	300	25,030	3
Cocoa Pruning Wastes	102,785	30,836	2,571,681	294
Cocoa Replanting Wastes	3,843	1,153	96,152	11
Logging Residues	116,266	34,880	2,908,975	332
Total				**1,951**

However, unlike mill waste, these agricultural wastes are distributed across the landscape, rather than transported to a central industrial facility. Additionally, the use of these wastes for electricity generation would deprive agricultural land of the organic material that results from their in-situ decomposition, meaning that plantation owners may need to be compensated for their removal. Together, these transport and purchase costs likely make most of the theoretical capacity in Table 2-9 economically unfeasible.

Nevertheless, study of the feasibility of using some fraction of this distributed agricultural waste should continue. For example, geographical analysis of the density of agricultural production around major road networks, transport costs, and estimated nutrient values may reveal locations in which a biomass power plant fired by waste from surrounding agricultural operations may be economically feasible. A GIS-based study concluded that waste from the rubber industry in Southern Thailand could economically support 8 biomass waste-fed power plants with a capacity of roughly 20 MW each.[134]

2.3.7 Conclusion & Policy Recommendations

The size of Sabah's agricultural waste biomass resource is large—so large that the main constraint on expansion of the biomass share of electricity generation is not availability of

[131] All figures are from PTM Malaysia, *Lecture Note*, http://www.ptm.org.my/biogen/download.aspx, p. 10.
[132] Malaysia-wide figures multiplied by 30%, which is Sabah's share of total palm oil production in Malaysia.
[133] Assumes conversion efficiency of .3.
[134] P. Krukanont and S. Prasertsan, *Geographical distribution of biomass and potential sites of rubber wood fired power plants in Southern Thailand*, Biomass and Bioenergy 26 (2004) 47 – 59.

biomass but the economic viability of biomass-based projects. Projects at several large palm oil mills are demonstrably viable under current economic conditions. Some projects that aggregate mill waste from smaller mills, palm fronds and trunks from palm oil plantations, and other biomass waste from decentralized locations are also likely economically viable if optimally sited, though further study is required to confirm this hypothesis.

SREP is a good first step in stimulating the construction of these projects. International grants for research, low-interest loans to project developers, and carbon offset incentives also favour palm oil power developers. However, several more policies can help the industry take off:

- **Raise the SREP electricity tariff**. Currently, SESB pays SREP producers a maximum of 21 sen per kWh. Biomass waste-derived electricity is a "premium" product. It helps mitigate harmful waste streams from agricultural processing, aids Malaysia in achieving its ambitious greenhouse gas emissions targets, and creates local jobs. Therefore, mill IPP projects should receive a higher tariff than fossil fuel IPP projects, not a lower tariff.
- **End 10 MW limit on SREP power plant size**. Under the SREP programme, the maximum allowable power plant size is 10 MW.[135] As a result, some power plants may be sized below their optimal capacity. For example, the waste from a cluster of palm oil mills might be more efficiently used in a 20-30 MW power plant. In order to incentivise the construction of such optimally-sized plants, the SREP capacity limit should be increased.
- **Continue industry research**. The Malaysian Government, the Malaysia Palm Oil Board, academics, and several international institutions have already conducted significant research on the feasibility of palm oil mill electricity generation. Future work should aim to make the existing basic research operationally useful for palm oil power developers. For example, GIS-based research might aid in the optimal siting of power plants.

If these policies are implemented, we predict that Sabah will see the installation of hundreds of MW of clean, biomass-fired electricity.

[135] http://www.ktak.gov.my/template01.asp?contentid=163.

2.4 Solar

Solar energy technologies use energy from the sun to generate electricity. Malaysia receives an average daily solar radiation (“insolation”) of 4-6kWh/m^2, making most of the country a suitable location for solar power. [136] Sabah receives one of the highest insolation levels in the country, and the area around Kota Kinabalu has been identified as especially productive (see Figure 2-10). On average, the state receives an average of 5 kWh/m^2 per day, or approximately 1825 kWh/m^2 per year. In theory, this energy is sufficient to meet Sabah’s entire electricity demand: with an average horizontal solar radiation of 5 kWh/m^2 per day and a typical conversion efficiency of 10%,[137] Sabah’s reported 2007 electricity demand of 3,312 GWh could be met with a solar collection area of 1,815 hectares or 182 km^2.

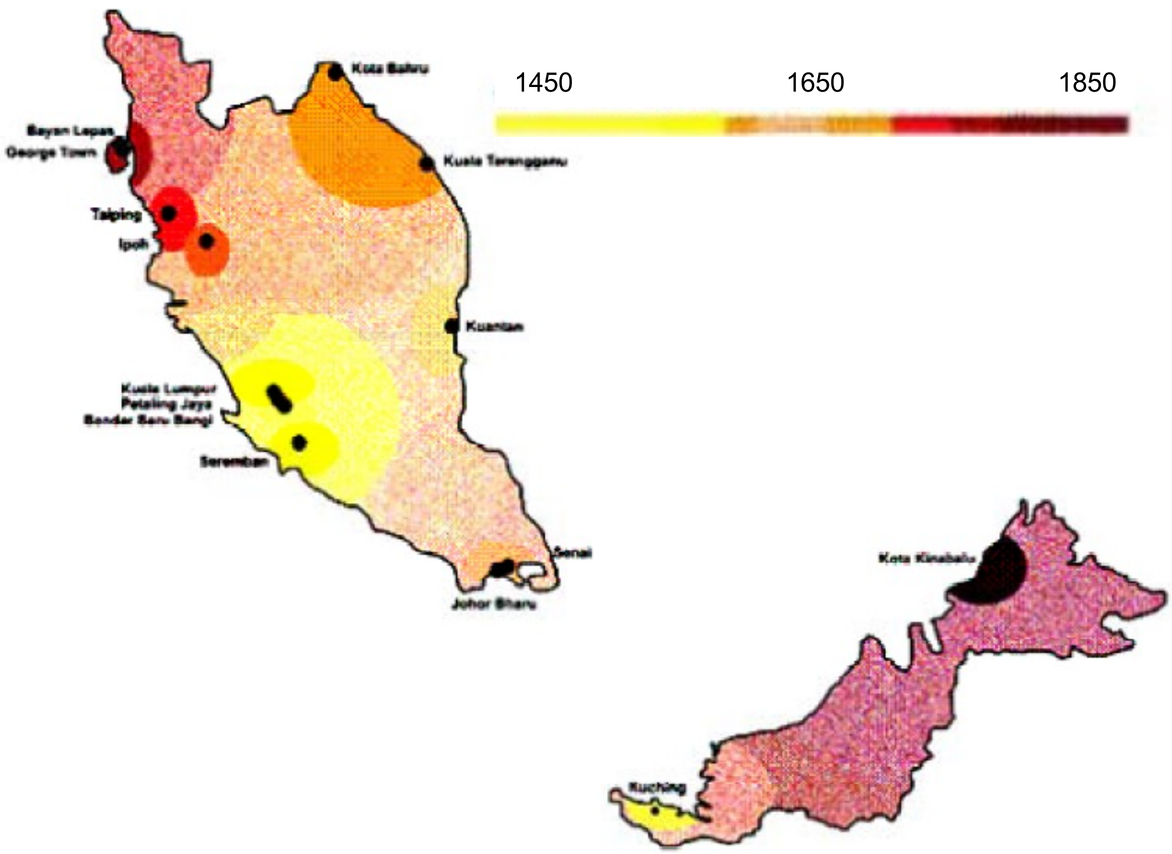


Figure 2-11: Solar Irradiance Map of Malaysia.[138]

[136] Maricar, N.M. et al., *Photovoltaic Solar Energy Technology Overview for Malaysia Scenario*, National Power and Energy Conference (PECon) 2004 Proceedings, Bangi, Malaysia.
Mohamed, A.R. and Lee, K.T., *Energy for Sustainable Development in Malaysia: Energy Policy and Alternative Energy*, Energy Policy 34 (2006): 2388-2397.

[137] Evald, Anders, Feb 2005, *Renewable Energy Resources*, Integrated Resource Planning (Feb 2005).

[138] Source: Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report, p. 16.

Solar energy has many environmental advantages over conventional fossil fuels. The fuel supply (sunlight) is free and non-depletable, and there are no emissions save those that occur during the manufacturing and decommissioning process. Solar panels are silent and have no moving parts, so they require very little maintenance.[139] Even taking into account the emissions during the manufacturing process (due to burning fossil fuels for energy), a solar power system's average 30-year lifespan would yield avoided emissions of 25 tons CO_2, .024 tons SO_2, and .043 tons NO_x per kW compared to reliance on natural gas, the cleanest fossil fuel.[140]

From a capacity planning perspective, however, solar radiation is a more complicated resource than fossil fuels or biomass. As shown in Figure 2-10, solar energy is available only during sunlight hours, and is more intense during the months of the year when the sun is highest in the sky (the "summer" months).[141] The most productive solar hours tend to coincide with peak demand at midday, but off-peak demand continues in the evenings and through the night, meaning that solar is best integrated into a portfolio of energy supply alongside other technologies, or coupled with an energy storage system.

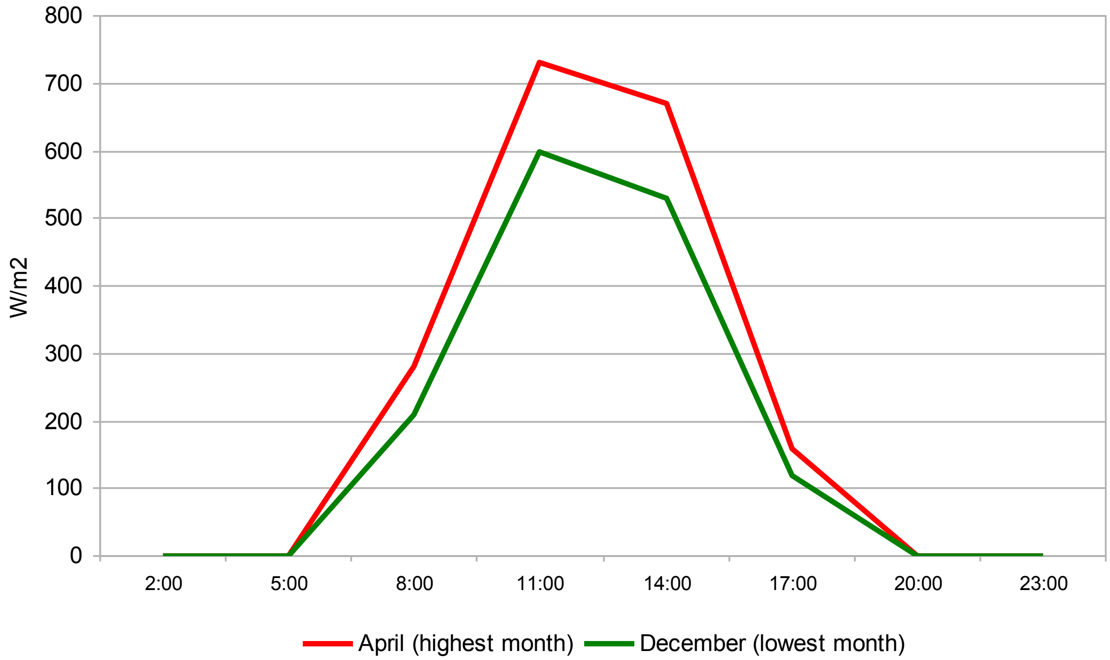


Figure 2-12: Hourly Solar Radiation Profile, Kota Kinabalu[142]

There are two main types of solar power: photovoltaics (PV) and concentrating solar thermal (CST). Below, we analyze three different possibilities for meeting Sabah's electricity demand with these solar technologies: distributed or "building integrated photovoltaic" (BIPV),

[139] Mohamed, A.R. and Lee, K.T., *Energy for Sustainable Development in Malaysia: Energy Policy and Alternative Energy*, Energy Policy 34 (2006): 2388-2397.

[140] Seng, L.Y.; Lalchand, G. and Lin, G.M.S., *Economic, Environmental, and Technical Analysis of Building Integrated Photovoltaic Systems in Malaysia*, Energy Policy 36.6 (2008): 2130-2142.

[141] The scope of the capacity planning problem is reduced somewhat in Sabah, because the state's equatorial location provide it with steady solar radiation throughout the year, rather than high solar radiation in the summer and low radiation in the winter. All else being equal, this means that integration of solar power into Sabah's grid is likely to be easier than in other areas.

[142] Source: U.S. National Aeronautics and Space Agency, http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01#s01.

utility-scale photovoltaic, and utility-scale concentrating solar thermal.

2.4.1 Distributed Photovoltaic

Solar photovoltaic panels use photovoltaic cells to absorb solar radiation and convert it to electric current. PV technology has been used worldwide since the 1970s. In recent years, it has become an increasingly attractive option for energy planners as manufacturing costs have fallen and innovation has increased performance. Current commercial-scale designs have achieved an overall efficiency of over 10%, meaning that 10% of the solar energy that strikes on the surface of a PV panel is converted to electrical energy.

A full photovoltaic system is composed of a photovoltaic module, a mounting structure, an inverter (to convert the DC electricity generated by the module to AC electricity), and possibly a battery for electricity storage. PV systems can be constructed at any scale, from households to power plants, although large PV systems require special modules with higher capacities.[143] There are a number of different types of solar cells, depending on the materials used. Crystalline silicon cells are by far the most common, making up 93% of the global market for PV cells.[144] Thin film cells of various types make up the remaining 7% of the global market. Different cell types have different conversion efficiencies and costs, with monocrystalline silicon cells being the most efficient, and thin film types being the cheapest.

Building-integrated photovoltaic (BIPV) is a form of distributed power – that is, it is an electricity supply strategy that relies on the production of electricity in small amounts at the point of demand, rather than the transport of power to the point of demand from a large centralized plant. Distributed power has several advantages over centralized power. For one thing, it reduces the "line loss" that is inherent in the transmission of power. A study at a commercial property in Petaling Jaya showed a reduction in energy loss on the distribution network of 50% if all custumers) installed a 5 kW PV system.[145] Decentralized power also can be more resistant to the risks of outage, because each power generation resource is separately managed and supervised, reducing the probability of total system failure. Further ancillary service benefits include increased spinning reserve, reduced voltage flicker, and potentially reduced total harmonic distortion.

Distributed solar power has been in use for quite some time in Malaysia for applications where grid connection is not feasible, such as rural telecommunications, sea buoys, and lighthouses. These applications have been focused in Sabah and Sarawak, and as of 2000 their total aggregate capacity was 2.1 MW.[146] In addition, non-grid connected village systems have been estimated to account for 1.5 MW of capacity nationwide.[147]

Recently the Malaysian government has been making a major effort to expand distributed PV through its Malaysia Building Integrated Photovoltaic (MBIPV) Project. MBIPV aims to increase PV coverage by 330% and to lower industry costs by 20% from 2006–2010, with an ultimate goal of creating a self-sustaining market capable of supplying PV systems at prices

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143 Source: PV Resources, http://www.pvresources.com/en/technologies.php.
144 Source: Solarbuzz, http://www.solarbuzz.com/Technologies.htm.
145 Seng, L.Y.; Lalchand, G. and Lin, G.M.S., *Economic, Environmental, and Technical Analysis of Building Integrated Photovoltaic Systems in Malaysia.* Energy Policy 36.6 (2008): 2130-2142.
146 Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report.
147 *Ibid.*

competitive with other countries.[148] In pursuit of these goals, MBIPV offers solar power developers a choice between two different types of tax relief ("Pioneer Status" and "ITA," both described above)[149] Also, the government's SURIA 1000 Programme awards a limited number of direct subsidies worth 40-70% of the costs of PV system installation via a lottery. As of June 2008, the programme was beginning to bear fruit: the total capacity of installed BIPV in Malaysia was 1.3 MW (a 175% increase over 2006 capacity), and the cost of a new BIPV system was US$ 7.269/W (a 14% reduction).[150]

From a resource size perspective, the theoretical potential for electricity generation from BIPV is enormous. Even at a conservative PV capacity value of 1 kW per 10 m^2, the extension of BIPV to all buildings in Malaysia is 11,000 MW, which could provide more than 12,000 GWh/yr and meet 20% of the nation's current energy demand.[151]

However, most of this capacity is not economically recoverable at the current prices of photovoltaic panels and associated equipment. The price of a 1 kW PV system, including panels, power inverter, a battery array, and other associated equipment, in Malaysia is approximately RM 28,000 (US$ 8,000/kWp).[152] Factoring in operations, maintenance, and monitoring (O&M) costs and a capacity factor of 0.18 (1600 kWh electricity produced per year for a 1 kW system, we estimate the un-subsidized levelized cost of distributed solar generation in Sabah at about RM 2.39. Even with the government's generous 100% ITA tax benefit (at a cost of RM 0.14/kwh to Malaysian taxpayers), the levelized cost of PV generation is over RM 2/kWh, significantly higher than SESB's electricity tariffs, which range between RM 0.24 and RM 0.32. Therefore, given our assumptions about inflation and discount rates, most businesses and consumers would be better off buying power from the grid than installing a PV system. Distributed solar to meet residential and commercial needs with systems mounted on roof-tops or in ground-mounted applications are, however, an attractive option should Sabah choose to diversify its energy mix and to work to develop not only local solar energy usage, but also a local manufacturing industry.

2.4.2 Utility-scale Solar Photovoltaic

Utility-scale PV plants consist of large fields of PV arrays, often mounted on single-axis tracking systems that follow the east-west movement of the sun across the sky. Some plants use double-axis tracking systems that also follow the sun from its northernmost orbit in June to its southernmost orbit in December. Currently there are more than 250 PV plants worldwide with peak capacities of 1 MW or more. The largest such plant is located in Olmedilla, Spain, with a peak capacity of 60 MW and annual production of 85 GWh.[153] Even larger farms with 200-500

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[148] Hasan, Ir Ahmaud Fazi, *Energy Efficiency and Renewable Energy in Malaysia,* AFEEC/FAPECA Conference & Meetings (2006), Convention Centre, Kuala Lumpur, http://www.teeam.com/st_paper_15july09.pdf.

[149] Malaysia Building Integrated Photovoltaic Programme, http://www.mbipv.net.my/content.asp?higherID=5&zoneid=4&categoryid=8; Koh Mok Poh and Hoi Why Kong, Renewable energy in Malaysia: a policy analysis, p. 34 (2002).

[150] UNDP EEG and GEF. 2008. *APR/PIR 2008: Malaysia Building Integrated Photovoltaic Project*, 2008, http://www.mbipv.net.my/dload/MBIPV%20Reports/General/Malaysia%20MBIPV%20PIR%202008%20Final.pdf.

[151] Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report.

[152] Seng, L.Y.; Lalchand, G. and Lin, G.M.S., *Economic, Environmental, and Technical Analysis of Building Integrated Photovoltaic Systems in Malaysia*, Energy Policy 36.6 (2008): 2130-2142.

[153] Sources: http://www.pvresources.com/en/top50pv.php.

MW peak capacity are under construction in the U.S. Southwest.

Figure 2-13: A Photovoltaic Farm in the United States

As discussed above, a major advantage of solar plants is that the warm-season and mid-day peak power generation typically coincides with peak demand, meaning that solar decreases the need for expensive "peaker" plants (typically open-cycle gas plants) that must be turned on to serve short-term demand. Moreover, PV plants can be built quickly and expanded incrementally as energy demand increases, making them a flexible resource for system planners.[154]

Solar energy projects have the highest job creation potential of any of the technologies discussed, whether fossil fuel and renewable.[155] They create more than three times as many jobs per MW of plant capacity than coal or gas-fired power plants.

As discussed above, however, solar does have several constraints. Most importantly, solar plants do not produce power at night. Similarly, the output of solar plants usually varies significantly from day to day as a result of cloud conditions. Both of these factors make solar power a technology that is more effective as part of a portfolio that includes wind, hydro, gas or coal fired power than as a stand-alone solution.[156] It also means that power systems with a large share of solar capacity may need a larger reserve margin "cushion" in order to meet demand, though integration of a solar plant into a grid the size of Sabah's is unlikely to prove problematic.

U.S. estimates put the per kW capital cost of solar farms at about RM 17,000 per MW.[157] Since PV systems have few moving parts, fixed operation and maintenance costs are low and variable costs are virtually zero.[158] The plants take up about 66 hectares per MW of capacity, or

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[154] U.S. Department of Energy, Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/solar/utility_scale.html.

[155] Wei, M., Patadia, S. and Kammen, D. M. (2010) "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the U. S.?" *Energy Policy*, 38, 919 - 931.

[156] Solarbuzz, http://www.solarbuzz.com/Utilities.htm

[157] U.S. Department of Energy, Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/solar/pdfs/set_myp_2007-2011_proof_1.pdf.

[158] NREL, *Supporting Data for Energy Technology Costs*, Energy Technology Cost and Performance Data, 2009, http://www.nrel.gov/analysis/costs.html.

about 1.5 times the footprint of a typical coal plant, but can often be sited in unused areas where land costs are low. [159] Based on these numbers, a June 2008 study estimated the levelized cost of energy from large-scale PV in the U.S. at RM 0.43-0.52/kWh.[160]

However, our estimates suggest that PV systems are not likely to be as economically attractive in Malaysia as they are in Spain and the U.S. Southwest. We simulated the performance of a 10 MW solar photovoltaic plant in Malaysia using the U.S. National Renewable Energy Laboratory's "Solar Advisor" model.[161] The model predicted a yearly output of about 12,000 MW (a capacity factor of 13.7%). Factoring in the reported U.S. capital and O&M costs, Malaysia's pioneer investment tax allowance, and revenue from carbon offset sales suggests a levelized cost estimate of RM 1.73/kWh, about 10 times the cost of coal-derived electricity.

2.4.3 Utility-scale Concentrating Solar Thermal (CST)

Concentrating solar thermal (CST) power plants utilize mirrors or lenses to focus sunlight onto a heat transfer fluid, which then produces steam to run a turbine. There are two main types of CST designs: parabolic troughs and power towers.

Parabolic troughs are parabola-shaped solar collectors that focus sunlight onto a linear tube running through the centre of each parabola (Figure 2-14). This tube contains the heat transfer fluid eventually used to generate electricity. Parabolic troughs usually use tracking systems (single-axis or double-axis) to follow the movement of the sun. Parabolic trough technology is currently the most popular and high-capacity solar thermal technology. In the Southwest U.S., power trough plants have been in use since 1984, and there are currently 10 plants ranging in size from 14 to 80 MW, with a total peak capacity of 354 MW.[162] There are also three operational power trough plants in Spain with total peak capacity 200 MW and over 25 in construction, with total peak capacity over 1,000 MW. The decades of aggregated operating experience with such plants reveal low technical and financial risk.[163]

Power tower stations use circular fields of mirrors, called heliostats, to focus sunlight onto a central tower-mounted heat receiver. A heat transfer fluid is pumped from a cold storage tank into the heat receiver, then into a hot storage tank, from which it can be withdrawn later to produce steam. The power tower design is a newer innovation than the trough design, but has been generating significant excitement in the solar power industry. Two power towers with capacities of 10-20 MW have been completed in the last several years in Spain. In the U.S. Southwest, IPP developers are building a number of 200-500 MW power tower plants, each of which contains 2-3 power towers.[164]

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[159] DiPippo, Ronald, *Geothermal Energy: Electricity Generation and Environmental Impact*, Energy Policy (Oct 1991): 798-807.

[160] Lazard., *Levelized Cost of Energy Analysis–Version 2.0.*, June 2008, http://www.nrel.gov/analysis/costs.html under "sources."

[161] National Renewable Energy Laboratory, Solar Advisor Model (SAM), https://www.nrel.gov/analysis/sam/

[162] U.S. National Renewable Energy Laboratory, http://www.nrel.gov/csp/troughnet/power_plant_data.html.

[163] Qu Hang, Zhao Jun, Feasibility and Potential of Concentrating Solar Power in China, http://www.springerlink.com/content/q8674461k5w86wm7/fulltext.pdf p. 4.

[164] Bri*ghtSource and Bechtel Partner on 440 MW Ivanpah CSP* Project, RenewableEnergy.com (Sep. 2009), http://www.renewableenergyworld.com/rea/news/article/2009/09/brightsource-bechtel-partner-on-440-mw-ivanpah-csp-project?cmpid=SolarNL-Tuesday-September15-2009

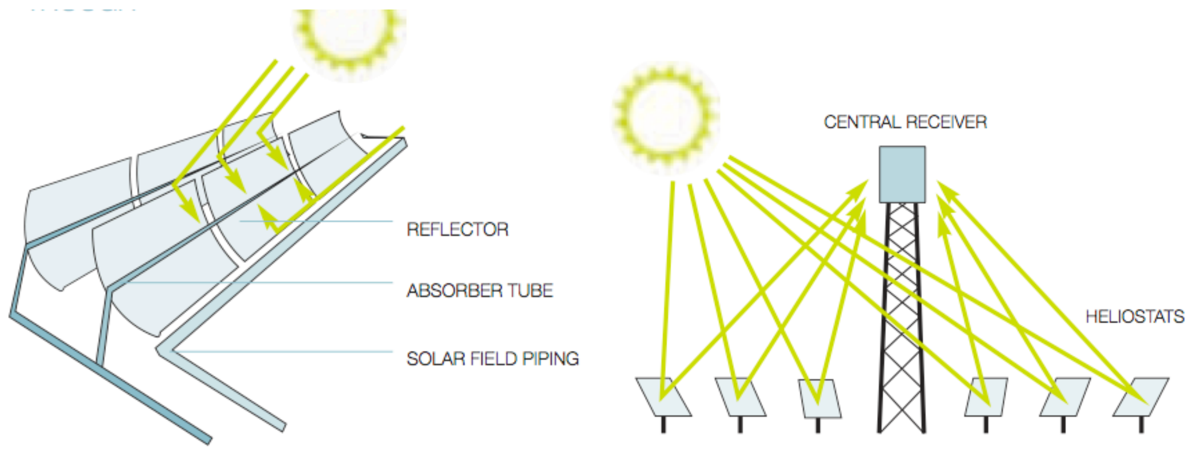

Figure 2-14: Leading Solar thermal designs: parabolic trough (left) and power tower (right)..[165]

Both parabolic trough plants and power towers can store thermal energy in their heat transfer fluid (HTF). Older CST plants using water/steam as the HTF can store 30 minutes worth of power, but newer CST plants using molten nitrate salt can store up to 7 hours worth of power. This storage tends to make solar thermal plants more "dispatchable" than PV plants, with power system managers able to call on the plant for power when it is most needed, rather than being forced to accept power as it is produced. It also helps solar thermal installations to achieve an average capacity factor of about 30%, with designers hoping that progress in storage technologies will increase that figure to over 50% by 2020.[166]

Solar thermal plants achieve these relatively high capacity factors with capital costs that already match those of photovoltaic farms (about RM 17,000 per MW) and are falling rapidly. Furthermore, at 28 hectares per MW, solar thermal plants are significantly more compact than photovoltaic farms and slightly more compact than some fossil fuel plants.

Based on the cost figures reported above, a 2003 NREL study estimated the levelized cost of energy for parabolic troughs located in desert regions of the U.S. at RM 0.34/kWh, and predicted that costs would fall to RM 0.14-0.20/kWh by 2020.[167] The same study estimated the levelized energy cost of power towers at RM 0.38-0.46/kWh, and predicted that costs would continue to decrease significantly through 2020 as more plants are built.[168]

However, performance of photovoltaic farms and solar thermal plants in a particular geographic location can diverge widely, with solar thermal being unsuitable in some areas where

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[165] Greenpeace, Concentrating Solar Power (2009), http://www.greenpeace.org/raw/content/international/press/reports/concentrating-solar-power-2009.pdf, p. 18.

[166] NREL, *Supporting Data for Energy Technology Cost*s, Energy Technology Cost and Performance Data, 2009, www.nrel.gov. Accessed 5 Jan 2010 <http://www.nrel.gov/analysis/costs.html. http://www.greenpeace.org/raw/content/international/press/reports/concentrating-solar-power-2009.pdf, p. 66.

[167] Sargent & Lundy LLC Consulting Group, *Assessment of Parabolic Trough and Power Tower Solar Technology Costs and Performance Forecasts*, National Renewable Energy Laboratory (Oct 2003), http://www.nrel.gov/csp/pdfs/34440.pdf.

[168] Sargent & Lundy LLC Consulting Group, *Assessment of Parabolic Trough and Power Tower Solar Technology Costs and Performance Forecasts*, National Renewable Energy Laboratory (Oct 2003), http://www.nrel.gov/csp/pdfs/34440.pdf.

photovoltaic output is high. The divergence results from the fact that solar radiation can be divided into two components: direct beam and diffuse. Direct beam radiation arrives at the earth's surface directly from the sun, whereas diffuse radiation is scattered by clouds and other components of the atmosphere, causing it to arrive from all directions. Solar thermal collectors can only utilize direct beam radiation, whereas photovoltaic panels can utilize both direct and diffuse radiation (which are sometimes referred to collectively as global radiation).

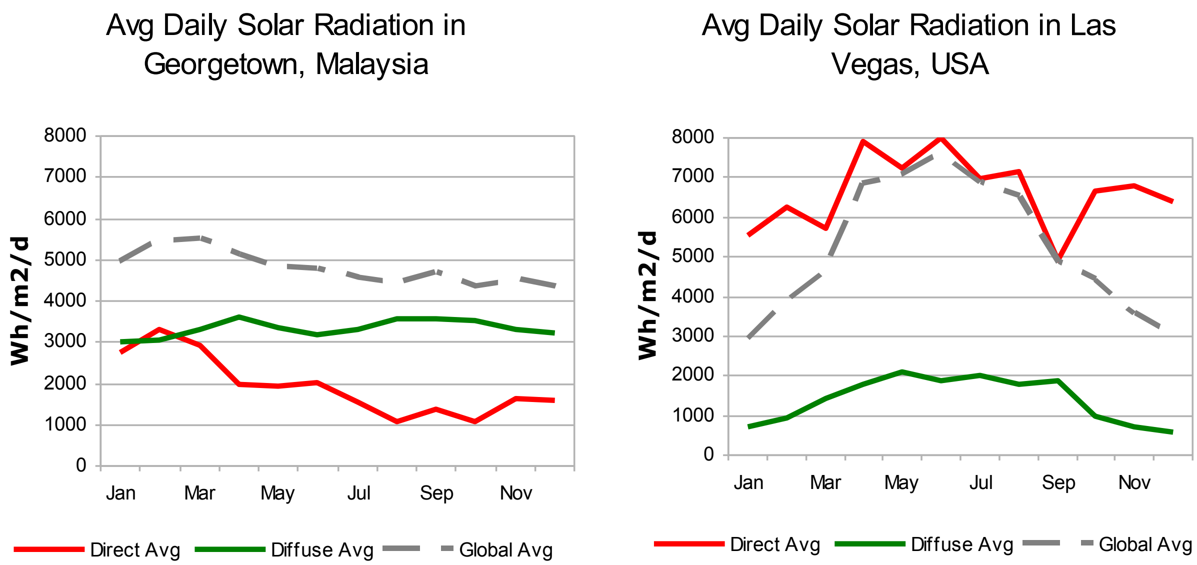

Figure 2-15: Although Malaysia receives levels of global radiation that are comparable on a yearly average basis to commercially viable utility-scale solar regions like the U.S. SW, it receives relatively low levels of direct beam radiation.[169]

Unlike regions where commercially-viable solar thermal is under development, most of Malaysia's solar radiation is diffuse radiation (see Figure 2-15). As a result, our simulations indicate that utility-scale solar thermal is not as cost competitive in Sabah as it is the areas of the U.S. and Europe where existing plants have been sited. Loading Malaysian solar data into the U.S. National Renewable Energy Laboratory’s calculator yielded a capacity factor estimate of just 8.7%, implying that a system with a nameplate capacity of 40 MW would yield about 30,000 MWh of electricity per year. At an expected capital cost of RM 367 million for a 40 MW system,[170] and a yearly O&M cost of about RM 3.3 million, such a system’s per-kWh levelized cost would be about RM 1.76, even after factoring in both a 10-year Pioneer Tax Allowance and carbon offset revenue.[171]

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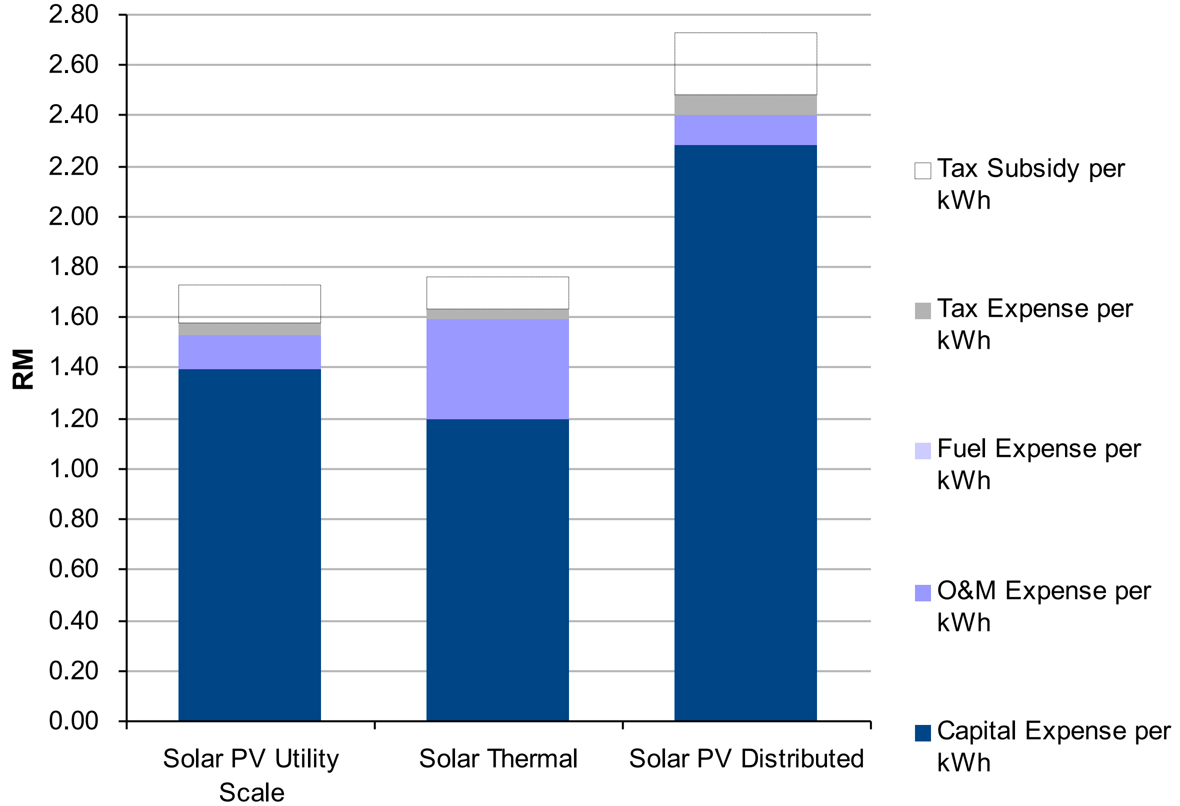
[169] Source: http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm. We use Georgetown data because Kota Kinabalu data for direct & diffuse radiation is not available, and because of those sites with available data, Georgetown’s global solar radiation level and pattern appears closest to reported global values for Kota Kinabalu.

[170] Source: Bill Gross, eSolar, Inc.

[171] See also Evald, Anders, *Renewable Energy Resources*, Integrated Resource Planning (Feb 2005) (noting that solar thermal has not yet been implemented in Malaysia).

2.4.4 Summary & Policy Recommendations

Figure 2-16 pulls together our levelized estimates of the cost of the three types of solar discussed above. None of the three options are currently cost-competitive with fossil fuels, hydropower, or palm-oil waste. However, distributed photovoltaic generation and utility-scale PV has strong potential given Malaysia's vast solar resource. .



	Solar PV Utility Scale	Solar Thermal	Solar PV Distributed
Capital Cost/MW	RM 17,132,260	RM 9,180,000	RM 28,000,000
O&M Cost/MW	RM 156,721	RM 287,300	RM 140,000
Fuel Cost per MWh electric	RM 0	RM 0	RM 0
Typical Plant Size (MW)	10.00	40.00	0.00
Capacity Factor	0.14	0.09	0.14
Levelized Cost per kWh	RM 1.58	RM 1.63	RM 2.48
Tax incentive per kWh	RM 0.15	RM 0.13	RM 0.24
Total cost to Malaysia per kWh	RM 1.73	RM 1.76	RM 2.73

Figure 2-16: Key Assumptions & Results - Levelized Cost of Solar

The MBIPV programme's tax incentives, subsidies, and information dissemination has made headway in creating the demand conditions necessary to further lower the cost of solar power in Sabah.[172] The next step may be to establish feed-in tariffs to allow distributed solar

[172] Malaysia Building Integrated Photo-Voltaic Programme, http://www.mbipv.net.my/content.asp?zoneid=4&categoryid=12.

producers to sell power back to the grid at rates that reflect solar's future importance.[173] In a study on BIPV in Malaysia, Professor Lim Yun Seng recommends a combination of feed-in tariffs (i.e. utilities would buy electricity from BIPV owners at a higher price than fossil fuels) and low subsidies to achieve further expansion of BIPV, rather than high subsidies standing alone. This is because feed-in tariffs increase the Net Present Value of BIPV systems more than subsidies, offering a stronger incentive for consumers to install BIPV systems.[174]

Both the Malaysian government and private industry may have a more direct role to play in reducing the costs of solar equipment. Photovoltaic panels, like computer chips, use silicon wafer technology. As one of the world's largest producers of computer chips, Malaysia thus has the potential to become a major producer of PV panels. Malaysia's well-established electronics industry, with its abundant supply of state-of-the-art materials, also makes large-scale production of PV inverters (necessary to convert the electricity generated by PV panels from Direct Current to Alternate Current) easily achievable. Malaysia also has an established manufacturing sector in electronic assemblies and sub-assemblies, components, moulds, tools and dies, metals and plastics, making local production of PV mounting structures feasible.[175]

Indeed, international solar players are already manoeuvring for position in the Malaysian market. For instance, BP Solar has a manufacturing plant in Malaysia with a maximum production capacity of 5 MW of solar panels per year, though the facility has yet to produce at capacity. First Solar also opened a manufacturing plant in Kedah, and production was expected to begin at the end of 2008.[176] The Malaysian government has supported this investment by providing tax exemptions for the import of solar equipment.[177] It has also given tax holidays to international firms investing in domestic solar manufacturing capacity. It should continue to use these policies to support the growth of PV in Malaysia.

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[173] Daniel Ruoss, *From Watts to Gigawatts*, (Powerpoint Presentation 2008) http://www.st.gov.my/ecom/images/publication/p3%20photovoltaics%20-%20from%20watt%20to%20gigawatt.pdf, p. 18.

[174] Seng, L.Y.; Lalchand, G. and Lin, G.M.S., *Economic, Environmental, and Technical Analysis of Building Integrated Photovoltaic Systems in Malaysia*, Energy Policy 36.6 (2008): 2130-2142. Seng calculated that a 40% subsidy and a feed-in tariff of RM 1.495/kWh (the current tariff is RM 0.28/kWh) would allow BIPV owners to make a 40% profit. However, this feed-in tariff would have to be paid for by levying a tax on all electricity users. At small BIPV capacities (the study uses the figure 2 MW), the tax would be unnoticeably small. But at large scales (360 MW, or 2% of electricity demand), consumers would find the tax unacceptably high (8% increase in electricity bills).

[175] Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report.

[176] Seng, L.Y.; Lalchand, G. and Lin, G.M.S., *Economic, Environmental, and Technical Analysis of Building Integrated Photovoltaic Systems in Malaysia*, Energy Policy 36.6 (2008): 2130-2142

[177] Electricity Information Board, http://eib.org.my/index.php?page=article&item=99,126.

2.5 Wind

Wind turbines convert the kinetic energy of wind into electricity. Wind turbines are typically constructed at least 30m above ground, where air moves faster and with less turbulence. A single wind turbine can have a peak capacity of up to several MW, but several turbines are typically grouped together in utility-scale wind farms to make power plants with a capacity in the tens to hundreds of MW.

Wind energy consumes no fuel, produces no emissions, and the energy required for manufacturing is usually recouped within a few months. Some environmentalists have raised concerns about danger to birds and bats, especially during key movement periods, but one important study has shown that fossil fuels kill twenty times the number of birds per unit of energy than wind turbines.[178] Although wind farms cover large areas of land, the land beneath the turbines can still be used for agriculture and other purposes, meaning that the actual geographic footprint of wind generation is small. Wind farms have also been sited offshore, where wind speeds are often higher than they are over land.

Wind turbines' main disadvantages are that they are is non-dispatchable (electricity output must be consumed immediately) and that their production is intermittent. Like solar, this makes wind a poor choice for baseload power. Moreover, the highest wind speeds in many areas occur during off-peak hours, making wind slightly more difficult than solar to integrate into a grid power generation mix.

Wind power is one of the cheapest of all renewable technologies. The capital cost of a wind farm has been estimated at RM 5,600,000 per MW, about 1/3 the capital cost of utility-scale solar, and on par with that of coal. However, the per kWh cost of wind electricity depends on an installation's capacity factor, which depends in turn on the location's wind speeds and frequencies. For onshore turbines, wind speeds of more than 6 m/s at 80m height are considered most desirable for wind power development. For offshore turbines, which have higher capital and O&M costs, wind speeds of 8.6 m/s or more are typically required.[179] The current average capacity factor for wind projects in the US is 41%.[180] At that level of production, the levelized cost of wind power has been estimated at between RM 0.149-0.308/kWh .

As a result of these low costs, global capacity increased more than fourfold from 2000-2006. Currently, the U.S., Germany, and Spain have the largest wind power capacities, ranging from 16,000-25,000 MW, and China and India are rapidly approaching these levels.[181] The world's largest wind farm, located in the Southern U.S., has a peak capacity of 780 MW and covers 100,000 acres (400 km^2).[182]

"Sabah" means "land below the wind." This epithet most likely refers to its position South

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[178] Sovacool, B. K. , *Contextualizing avian mortality: A preliminary appraisal of bird and bat fatalities from wind, fossil-fuel, and nuclear electricity*, Energy Policy 37 (2009): 2241–2248.

[179] Archer, Cristina L and Jacobson, Mark Z, *Supplying Baseload Power and Reducing Transmission Requirements by Interconnecting Wind Farms*, Journal of Applied Meteorology and Climatology 46 (Nov 2007):1701-1717, http://www.stanford.edu/group/efmh/winds/aj07_jamc.pdf.

[180] NREL, *Supporting Data for Energy Technology Costs*, Energy Technology Cost and Performance Data (2009), http://www.nrel.gov/analysis/costs.html.

[181] U.S. Department of Energy, Energy Efficiency & Renewable Energy, *2008 Renewable Energy Data Book* (August 2009), http://www1.eere.energy.gov/maps_data/pdfs/eere_databook.pdf.

[182] CBS, *World's Largest Wind Farm Churns in Texas* (Oct 2009), http://www.cbsnews.com/stories/2009/10/02/tech/livinggreen/main5358287.shtml.

of the typhoon belt, but many interviewees used it to describe the low wind speeds over the state in general. Several studies confirm this anecdotal evidence:

- A 1994 study by Universiti Kebangsaan Malaysia measured wind speeds and calculated wind power densities for Kota Kinabalu, Tawau, and Labuan.[183] None of the three locations had wind speeds greater than 3 m/s or a wind power density of greater than 50 W/m.^{2} As a result, the study classified the wind potential as a 3 on the NREL 1-7 scale, corresponding to a judgment that wind investment was not likely to be feasible.
- Low-resolution wind speeds for any latitude and longitude in Sabah are available from the U.S. National Aeronautics and Space Agency.[184] We investigated several spots that interviewees suggested might experience higher-than-average wind speeds, including the site of the proposed coal plant, without finding any promising locations.
- A 2003 study of wind speeds off the various Malaysian coasts at 80m height found wind speeds of 1.2-4.1 m/s throughout the year, too low for effective use of wind power.[185] Stronger winds occur during the Northeast and Southwest Monsoons, especially off the East Coast of Peninsular Malaysia and in certain areas off the coast of Sarawak and Sabah.[186] One region off the coast of Sabah, spanning 6-8° latitude and 114-116° longitude, was found to receive wind speeds exceeding 5mph during the northeast monsoon season (3 months) but falling between 1.6 and 4.4 mph for the rest of the year. This is most likely not optimal for wind power.[187]

Nevertheless, wind power may be commercially feasible in certain scattered locations throughout Sabah. In 2009, a private study was conducted of wind speeds in Kudat division, the most promising location for onshore wind in Sabah of which we are aware.[188] The study found wind speeds of 5 m/s all along the coast in Kudat district, and found wind speeds of up to 8 m/s on the ridgelines above the Kudat peninsula. It is possible to imagine wind farms of 10-20 MW being commercially feasible on these ridgelines.

As the study itself indicates, a great deal of further study is required before recommending these locations as commercially viable. Energy output is disproportionately higher at high wind speeds than low ones, meaning that average wind speeds do not fully capture a location's potential for wind power. Moreover, the variability of wind speeds would need to be observed over several years in order to reduce the uncertainty of any estimate of power output from a wind turbine. At the same time, at least some basic information about the distance of the most promising sites from existing road networks is required to estimate construction cost within

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[183] Sopian, K; Othman, M.Y. Hj. and Wirsat, A. 10 Nov 1994. "The wind energy potential of Malaysia." *Renewable Energy* 6.8: 1005-1016.

[184] U.S. National Aeronautics and Space Agency, http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?+s01#s01.

[185] Chiang, E.P. et al. 2003. "Potential of Renewable Wave and Offshore Wind Energy Sources in Malaysia." Marine Tech. 2003 Seminar. Accessed 6 Jan 2010 <http://eprints.usm.my/9180/1/Potential_of_Renewable_Wave_and_Offshore_Wind_Energy_Sources_in_Malaysia_(PPKMekanikal).pdf>.

[186] Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report.

[187] Chiang, E.P. et al. 2003. "Potential of Renewable Wave and Offshore Wind Energy Sources in Malaysia." Marine Tech. 2003 Seminar. Accessed 6 Jan 2010 <http://eprints.usm.my/9180/1/Potential_of_Renewable_Wave_and_Offshore_Wind_Energy_Sources_in_Malaysia_(PPKMekanikal).pdf>.

[188] Garad Hassan Pacific Pty Ltd. 16 March 2009. "Mesoscale and Microscale Wind Mapping in Kudat Province, Malaysia." Issue: A (Draft).

a reasonable range. For those reasons, we do not consider it productive to report a Sabah-specific levelized cost estimate for wind electricity at this time.

2.6 Geothermal

Geothermal power plants utilize hot water and steam from underground reservoirs to drive a turbine that generates electricity. There are three types of geothermal power plants: dry steam, flash steam, and binary cycle. Dry steam plants use steam directly from underground reservoirs to operate a turbine. Flash steam plants extract very hot water (>182°C) that depressurizes as it flows upwards and "flashes" into steam. Binary cycle power plants use semi-hot water (107-182°C) to heat a working fluid, such as an organic compound, which is then vaporized and used to run a turbine.

The U.S. is the world's largest user of geothermal energy with 3,000 MW total capacity, 2,600 of which is located in the state of California.[189] The Philippines and Indonesia are the 2nd and 3rd largest users; in 2007 they generated 12,000 and 6,000 GWh of geothermal electricity, respectively.[190]

Although geothermal plants do emit CO_2 and H_2S that are brought to the surface along with the underground steam, emissions levels are negligible compared to fossil fuels – geothermal steam plants emit only 5% as much CO_2 as coal plants per kWh, and H_2S emissions can be reduced up to 90% using abatement systems.[191] Also, land use requirements are only 1,200 m^2/MW, far below the land requirements for other renewable and fossil fuel sources. Finally, the heat and water used by geothermal plants replenish naturally, so they are renewable as long as extraction rates do not exceed replenishment rates.

In 2008, the average capital costs of geothermal in the U.S. have been estimated at RM 12,100,000 per MW. Geothermal has an extraordinarily high capacity factor of 84%, making it an excellent source of baseload power.[192] At this capacity factor, the average levelized cost in the U.S. was estimated at RM 0.142-0.233/kWh, making geothermal competitive with fossil fuel sources where it is available.

Geothermal resources are often found in the geologically-active areas along the edges of tectonic plates, where high temperature liquids and gas are close to the surface. Malaysia is located on the geologically active Pacific "ring of fire," near the border of the Eurasian and Australian tectonic plates. This makes it highly likely that some areas of the country are suitable for geothermal energy. Indeed, as shown in Figure 2-17, preliminary geothermal prospecting has revealed several locations that may have geothermal potential in Sabah. For instance, hot springs, a common indicia of geothermal activity, are abundant in Poring-Ranau and the Semporna Peninsula in Sabah.

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[189] Gelman, Rachel and Hockett, Steve, *2008 Renewable Energy Data Book*, U.S. Department of Energy (July 2009), http://www1.eere.energy.gov/maps_data/pdfs/eere_databook.pdf.

[190] Gelman, Rachel and Hockett, Steve, *2008 Renewable Energy Data Book*, U.S. Department of Energy (July 2009), http://www1.eere.energy.gov/maps_data/pdfs/eere_databook.pdf

[191] DiPippo, *Ronald, Geothermal Energy: Electricity Generation and Environmental Impact*, Energy Policy (Oct 1991): 798-807.

[192] NREL, *Supporting Data for Energy Technology Costs*, Energy Technology Cost and Performance Data (2009), http://www.nrel.gov/analysis/costs.html.

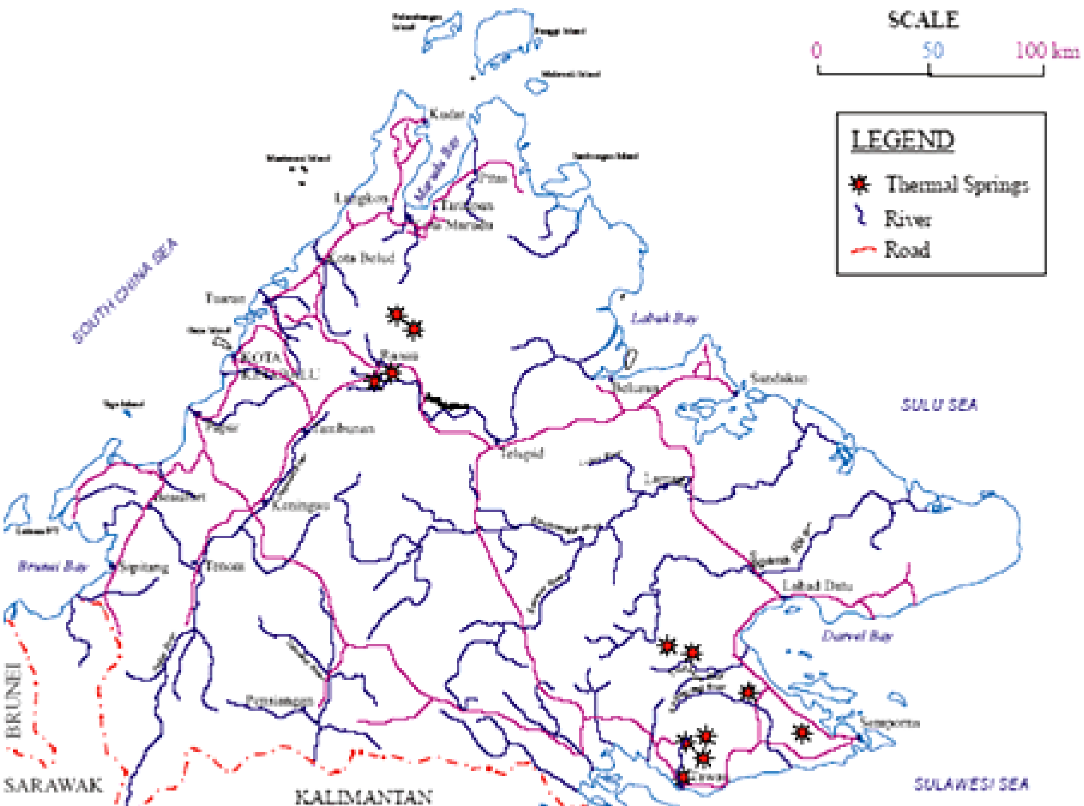

***Figure 2-17: Thermal springs in Sabah, Malaysia*.**[193]

Researchers recently began a more extensive study of one of these sites, the Apas Kiri hot spring near Tawau.[194] In July 2009, the Mineral and Geoscience Department concluded that a 67 MW power plant would be feasible at the site. If the site can be developed at the average capital costs, O&M costs, and capacity factories reported for similar projects in the literature, it might be economically feasible at a levelized cost of RM 0.172 per kWh. If it receives carbon offset revenues in proportion to its emissions reductions, our estimate would fall to RM 0.157, making geothermal's levelized cost comparable to that of hydro, cheaper than natural gas and only slightly more expensive than that of coal.

[193] Source: Overview of Policy Instruments for the Promotion of Renewable Energy and Energy Efficiency in Malaysia: Background Report, p. 35.

[194] Lim, P. S., 1988. "Geology and Geothermal Potential of the Tawau Area, Sabah." *Geological Survey Malaysia 1987 Annual Report*: 402-413; Lim, P. S.; Intang, F. and F. O. Chan, 1991. "Geothermal Prospecting in the Semporna Peninsula with Emphasis on the Tawau Area." *Geological Society Malaysia, Bulletin 29*: 135-155.

2.7 Demand-Side Energy Efficiency

Studies of the comparative cost of electricity generation almost invariably find that the cheapest electricity supply option is actually reduction of electricity demand. By establishing prices and policies that incentivise reductions in electricity use, utilities can forgo entirely the need for new power plant investments. For example, in the residential sector, technology standards can require certain efficiency levels for consumer appliances like washers, dryers and light bulbs, and building codes can prescribe insulation requirements that reduce the electricity consumed by air conditioners. In the industrial sector, industry regulation can reduce the electricity consumed in factory processes. And in every sector, a higher electricity price provides a very powerful incentive for electricity users to voluntarily improve efficiency in whatever way they can.

A major study of energy efficiency in the U.S. shows that almost all of these types of policies cost less to implement than the price of electricity. Figure 2-18 shows the study's estimates of the cost per unit of energy for a number of energy efficiency options as well as the amount of electricity that could be saved nationwide by implementation of each option. A similar study specific to the U.S. Southwest region found that energy efficiency could reduce projected electricity consumption by 18% over the next 7 years and 33% over 17 years, eliminating the need for thirty-four 500 MW power plants.[195]

[195] Southwest Energy Efficiency Project, http://www.swenergy.org/.

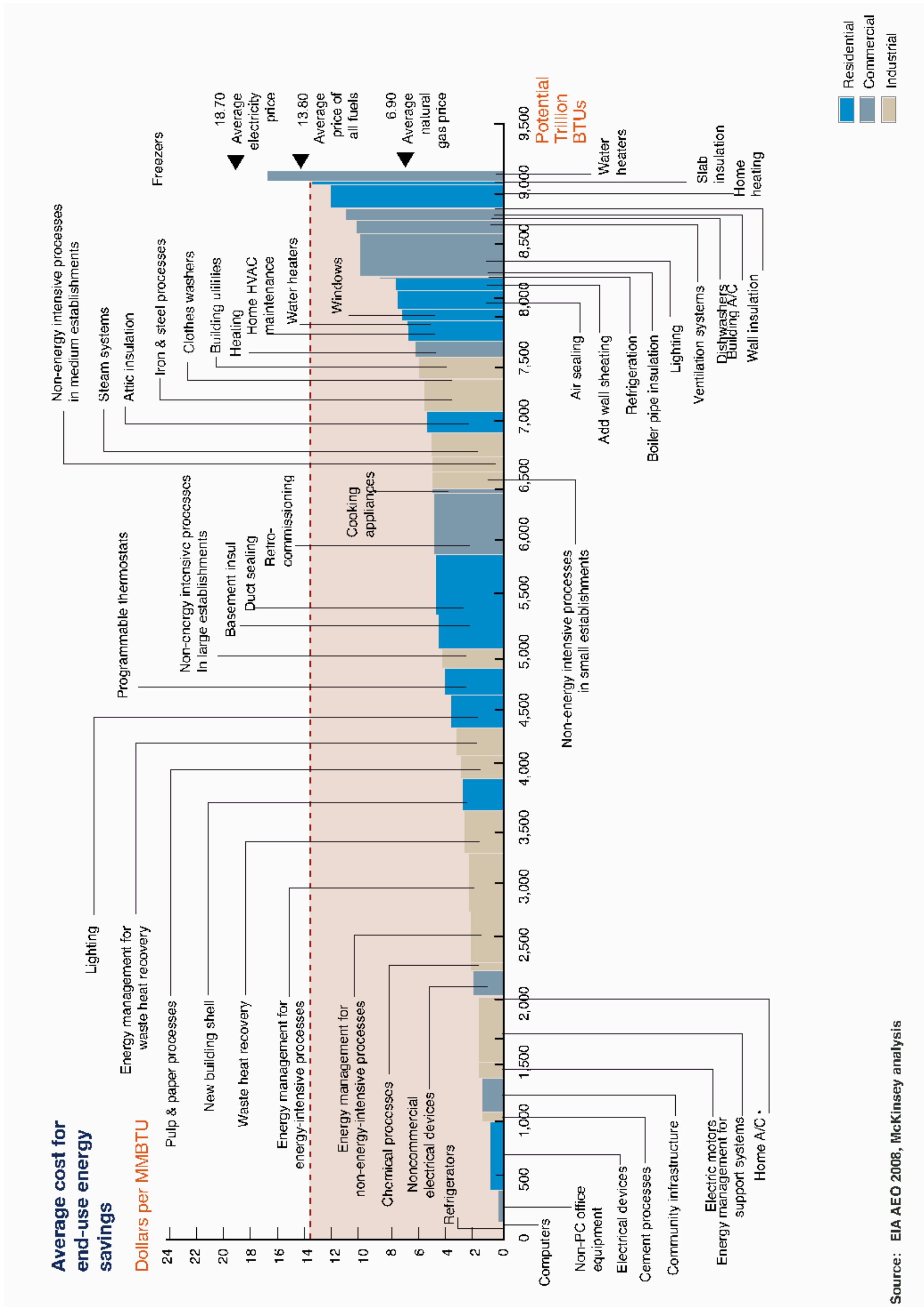

Figure 2-18: McKinsey & Company Estimate of Energy Efficiency Potential in the U.S.[196]

[196] McKinsey & Company, Unlocking the Energy Efficiency Potential in the U.S. (2009).

The U.S. state of California provides an instructive example of how energy efficiency policies can work in the real world. California began promoting energy efficiency in the mid-1970s. The success of these programmes allowed the state's electricity demand to remain essentially flat through 2000, despite sustained economic growth and population growth during that period. As a result, California's per capita electricity demand was about 40% less than that of the U.S. as a whole by the year 2000.

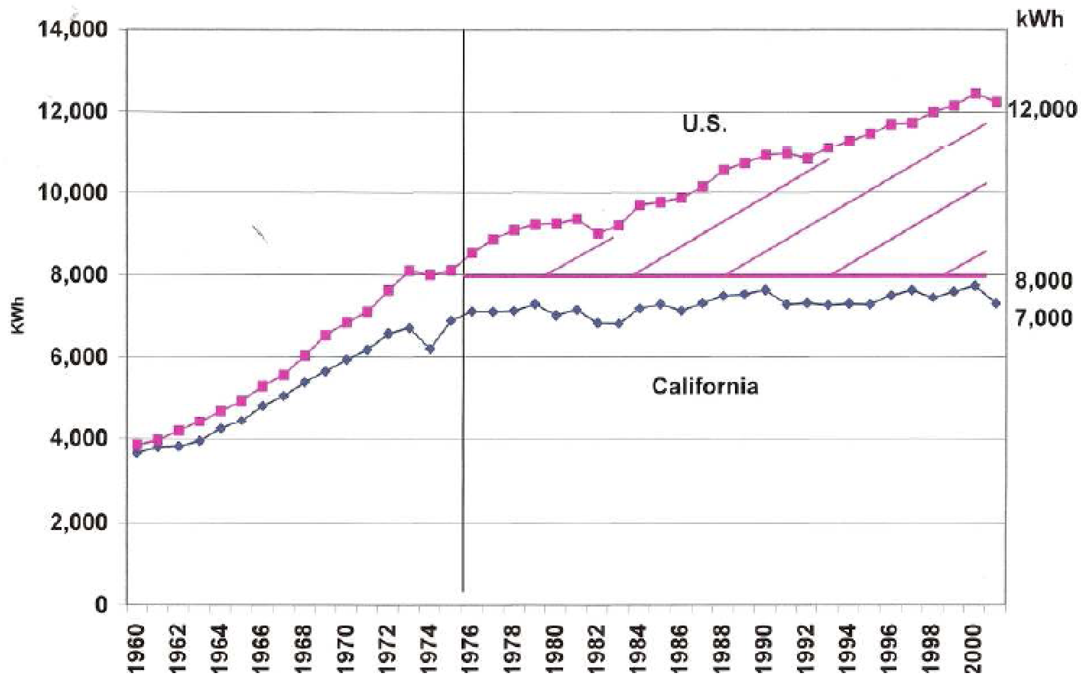

Figure 2-19: Electricity demand per capita in California vs. entire U.S., 1960-2000[197]

Energy efficiency efforts are already underway in Malaysia. The Malaysia Industrial Energy Efficiency Improvement Project (MIEEP) was launched in 1989. This initiative disseminates best practices, benchmarks, and general information about energy efficiency, targeting improvements in 8 major industries.[198] Beginning in 2000, the government of Malaysia bolstered this effort with a more comprehensive energy efficiency policy architecture, promulgating energy efficiency regulations and binding technology standards. These policies affect or potentially affect the electricity demand of the commercial, industrial, and residential sectors. The government also began offering tax incentives for the development of renewable energy infrastructure.[199]

In spite of these efforts, however, per capita electricity consumption in Malaysia has continued to rise over the last decade, as it has in other countries in the region (see Figure 2-20). Malaysians currently consume 200% more electricity per person than Indonesians and Chinese,

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[197] Source: Dato Engr Lee Yee Cheong, Lighting the Way Toward a Sustainable Energy Future (2008), http://www.st.gov.my/ecom/images/publication/p3%20lighting%20the%20way%20-%20toward%20a%20sustainable%20energy%20future.pdf, p. 15.

[198] Energy Information Bureau, Energy Efficiency, http://eib.org.my/index.php?page=article&id=1.

[199] Energy Information Bureau, Energy Efficiency – Incentives and Regulations, http://eib.org.my/index.php?page=article&item=98,117.

and about 50% more per unit of GDP.

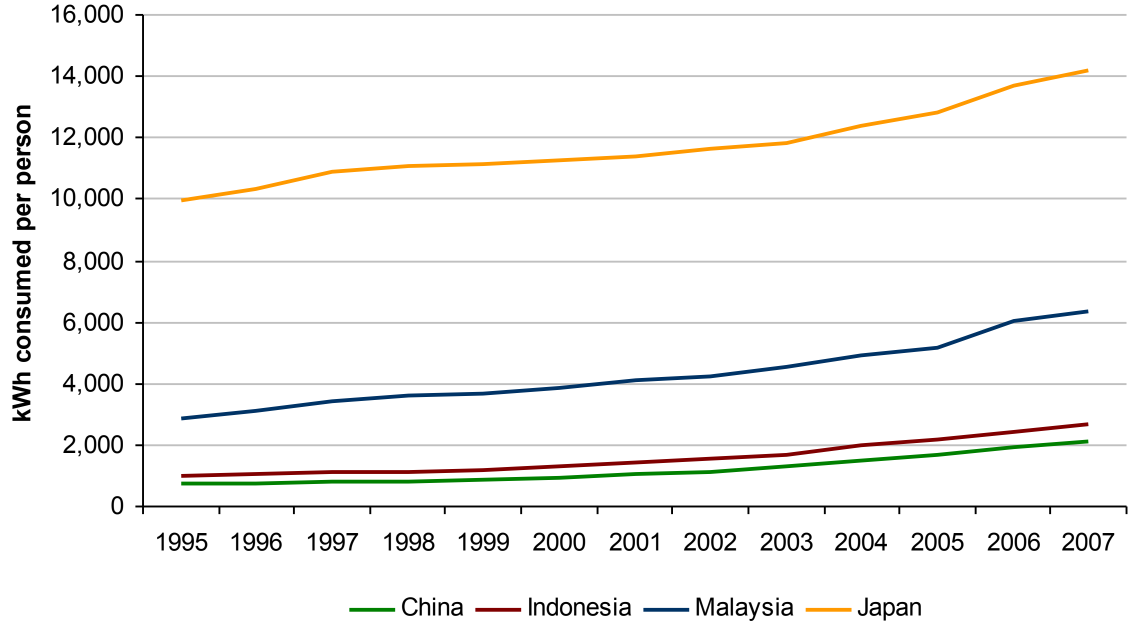

Figure 2-20: Electricity Consumption per unit of economic output[200]

Therefore, assuming that Sabah's per-capita consumption is comparable to that of Malaysia as a whole, the State likely has the potential to make significant improvements in energy efficiency. Estimating the potential size and levelized cost of such improvements would require detailed information about the technologies employed in a number of different sectors, a task that is beyond the scope of this report. However, the detailed research from other countries and regions discussed above, combined with Malaysia's overall observed efficiency level, suggests that demand-side energy efficiency is almost certain to be cheaper per kWh than any electricity supply option, including coal and palm oil waste projects. It is also almost certain to be a very large resource. If Sabah makes a ten-year energy efficiency improvement equivalent to the amount the SWEEP report predicted was feasible for the Southwest United States (25%), it would reduce the average demand of 900 MW forecast for 2020 to 620 MW. This type of savings would eliminate the need to build 280 MW of new baseload capacity.

2.8 Summary of All Estimates; Sensitivity Analysis

Our levelized cost estimates for each type of technology are presented together in Figure 2-21, and can be briefly summarized as follows:

- Factoring in tax incentives and revenue from international carbon offset sales, two renewable technologies—Biomass and Mini/Small Run-of-the-River Hydro—are estimated to be cheaper than coal.

[200] Source: GDP and population data from Asian Development Bank, Key indicators 2009, http://www.adb.org/Documents/Books/Key_Indicators/2009/Part-III.asp#economy. Electricity consumption data from the U.S. Energy Information Agency, http://tonto.eia.doe.gov/cfapps/ipdbproject/iedindex3.cfm?tid=2&pid=2&aid=2&cid=&syid=1980&eyid=2008&unit=BKWH&products=2.

- Geothermal is slightly more expensive than coal, but is cost competitive with natural gas. In fact, because of high taxpayer-funded subsidies to natural gas IPPs, geothermal's cost to Malaysia as a whole is much cheaper than that of natural gas.
- Solar power is still more expensive than traditional supply options, though it is rapidly approaching parity with diesel generation if the cost of the diesel fuel subsidy is taken into account.
- The energy efficiency potential is not directly addressed in this report, but is almost certainly very large.

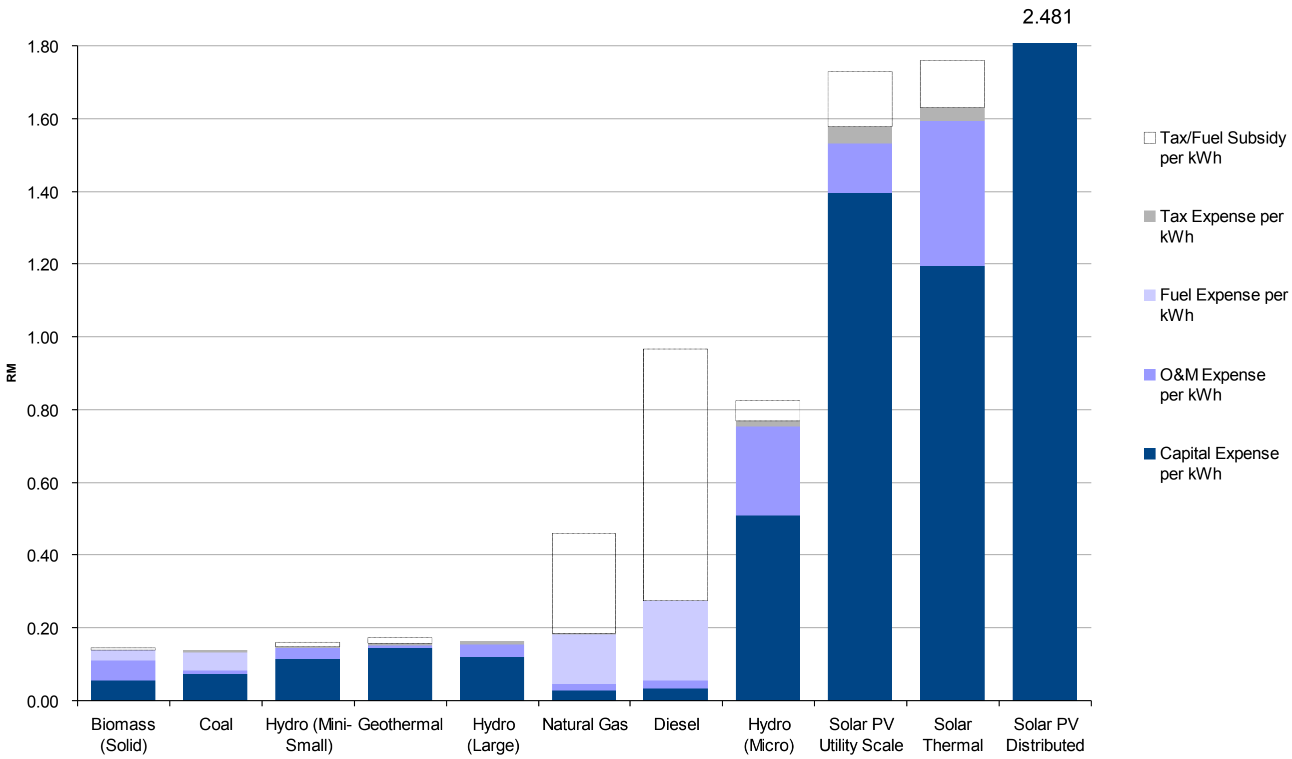

Figure 2-21: Comparison of all levelized cost estimates

As we noted in the introduction to this section, our estimates factor in the international "Clean Development Mechanism" price incentive paid by businesses in Kyoto Protocol Annex I ("developed") nations to businesses in Kyoto Protocol non-Annex I ("developing") nations that invest in emissions-reducing projects such as clean energy projects. The continued availability of that incentive it is current form depends on the negotiation of a replacement treaty by 2012, when the Kyoto Protocol expires. However, even if the world does not reach agreement on an international protocol, demand for carbon offsets of some kind is almost certain to continue from national level cap and trade systems. The vast majority of CDM demand today comes from the European Union's cap and trade system. If the U.S. implements cap and trade legislation, as many observers expect it will within a year, this demand will likely more than double.

Another possibility is that negotiators will sign an international treaty, but that Malaysia will join the Annex I nations by committing to specified level of emissions reductions. If so, Malaysian businesses might no longer be eligible for international incentive payments for renewable energy development. If Malaysia does make such a commitment, however, it will have to stimulate renewable energy development on its own account, either by providing domestic incentives to renewable power producers or by providing a disincentive (e.g. a tax or cap and trade system) to fossil fuel producers. As in the no-treaty scenario, therefore, some form of carbon price—whether positive or negative—will likely augment renewables' cost competitiveness with fossil fuels, but the size of that incentive is difficult to predict.

However, while it is virtually certain that some form of international or national subsidy will continue, the size of that subsidy is much less certain. For example, the prices paid for each t CO_2e of carbon offsets will depend on both market conditions and the terms of any international agreement or national law. A relatively strict cap will increase the demand for the carbon offsets sold by emissions reducing projects in nations like Malaysia, putting upward pressure on the prices at which Malaysian renewable IPPs can sell their emissions reductions. On the other hand, a loose cap, or continued slow economic growth, will decrease the demand, and put downward pressure on prices.

In order to account for this uncertainty, we conducted a sensitivity analysis that shows how the levelized costs of selected renewable options vary with the international carbon price. (See figure 2-22). As for the levelized cost estimates above, the levelized cost estimate can be interpreted as the PPA price that an IPP would need to receive to obtain a 15% internal rate of return. The necessary price increases as the carbon incentive decreases, because the developer will need more electricity revenue to compensate itself for smaller carbon revenue. Hydro and geothermal become cost-competitive with coal at a carbon price of around 14 euros (RM 64.40).

The palm oil waste projects are particularly sensitive to the price of carbon because their methane reductions give them more total carbon-equivalent greenhouse gas emissions reductions per kWh than the other renewable options. At high carbon prices, their levelized cost estimate is in about RM 0.08-RM 0.10. However, at a carbon price of zero—i.e. in the no incentive scenario—the palm oil waste projects are more expensive than both coal and natural gas, and are no longer even the cheapest renewable option.

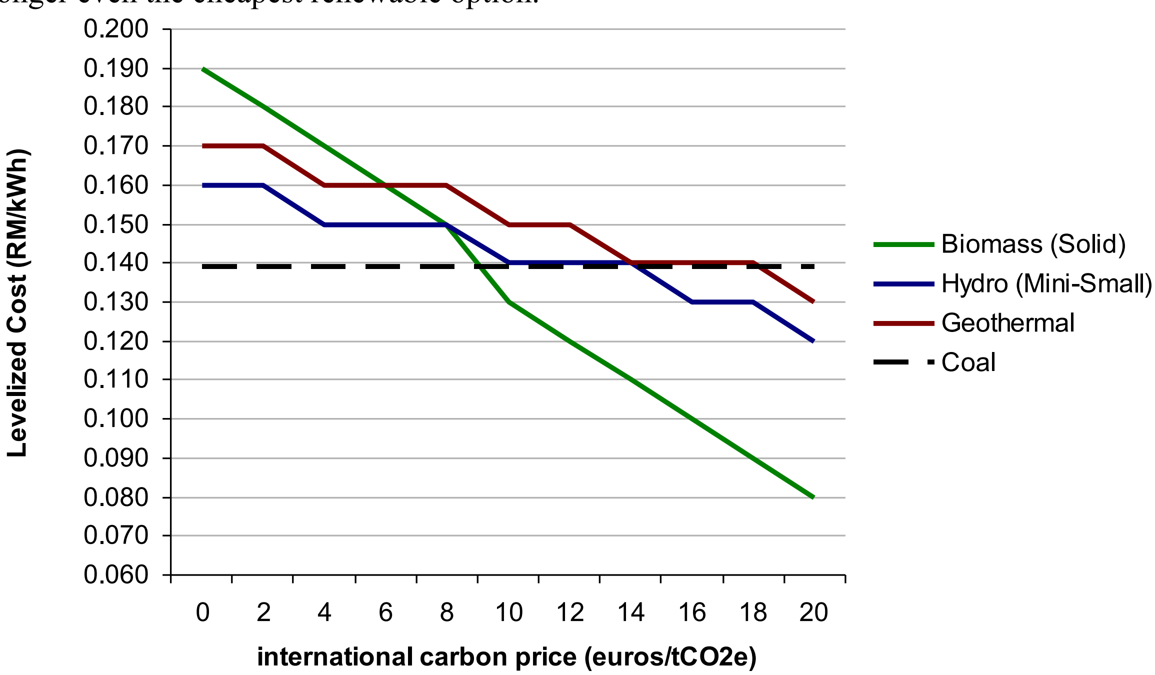

Figure 2-22: Sensitivity of renewable options to the international price of carbon offsets.

3. Power Supply Simulation Analysis

In this section, we examine whether several alternative portfolios of electricity supply options can meet Sabah's electricity demand on an hour-by-hour and month-by-month basis. This analysis is important because the availability of some renewable energy sources—especially hydro, solar, and wind—vary, and may not match the hourly and monthly pattern of demand.

We used the HOMER model to simulate the production of electricity in Sabah against expected demand during the 2010, 2015, and 2020 calendar years. We tested four separate scenarios: a baseline scenario based on SESB's current publicly-reported plant-up plan, a SREP scenario based on the accelerated expansion of small biomass and hydro production, and a utility-scale renewables scenario solar and geothermal investments. For each scenario, we simulated the production of each grid-attached power plant over the course of an 8760 hour year based on a low-cost dispatch model.

The results allow us to determine whether each proposed portfolio of capacity additions can meet Sabah's demand profile, and to report simulated electricity production and emissions by fuel/technology type. We also multiplied the electricity production figures by the levelized cost estimates reported above to obtain an overall per-kWh "price tag" for each scenario.

It goes without saying that these price estimates are highly unrealistic as an estimate of the actual costs of electricity supply in Sabah, both because of the simplifying assumptions used in the per-kWh cost estimates (see above) and because many plants are owned by SESB or are built by IPPs in years other than 2010. However, the primary goal of our exercise is neither to calculate SESB's actual costs of electricity supply nor to provide a basis for detailed infrastructure planning—those are tasks for which only SESB is qualified. Rather, our goal is to show how relatively low-cost portfolios can meet demand on an hour-by-hour and month-by-month basis. Similar analyses have been conducted by PTM and by the Malaysian - Danish Environmental Cooperation Programme.[201]

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[201] Pusat Tenaga Malaysia, RE: Road to Energy Independence? (Powerpoint Presentation 2008), http://www.st.gov.my/ecom/images/publication/p6%20renewable%20energy%20-%20road%20to%20energy%20independence.pdf; Henrik Jacobsen and Morten Blark, Malaysian - Danish Environmental Cooperation Programme Renewable Energy and Energy Efficiency Component, *LEAP: Reference Scenario Assumption and Results* (2005), eib.org.my/upload/.../Reference%20Scenario%20for%20Energy%20sector.doc.

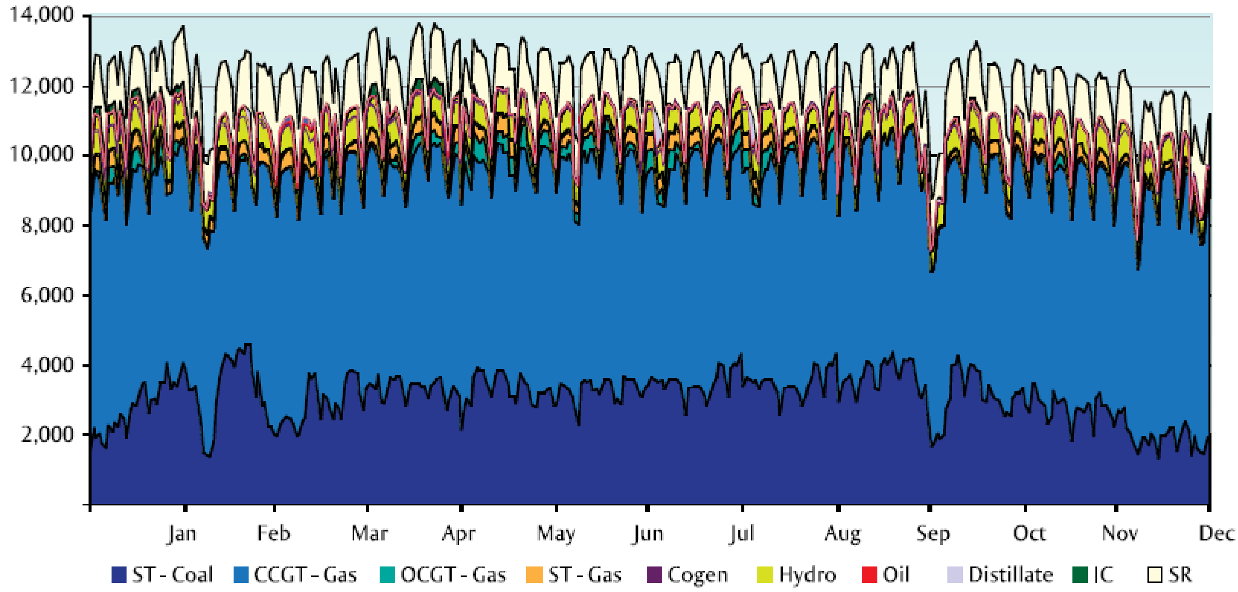

Figure 3-1: Actual grid production by fuel/technology type during 2008, Malaysia-wide.[202] ***The simulations we report below predict what the actual production pattern in Sabah might look like for each hypothetical future scenario***.

3.1 Baseline Scenario

Our baseline scenario is based on the plant-up programme described in Section 1. This scenario starts with the estimated 2010 installed capacity of 30 MW of biomass power, 46 MW of hydro capacity, 411 MW of diesel capacity, and 416 MW of natural gas capacity. It assumes the addition by 2020 of about 600 MW of natural gas-fired capacity, over 500 MW of hydro capacity, 15MW of additional biomass capacity, and 300 MW of coal-fired capacity.
In our simulation, power plants are dispatched according to fuel costs. As fuel costs for hydroelectric plants are 0, they are dispatched first. Biomass has the next-lowest costs, so it is dispatched next, followed by coal, natural gas, and finally diesel.[203]

Figure 3-2 shows the pattern of dispatched plants during an average day in 2010. During off-peak hours, hydro, biomass, and a small portion of natural gas capacity are enough to satisfy demand. During peak hours, the gas plants are used up to their full capacity, and some of the diesel plants come online.

[202] Source: Suruhanjaya Tenaga, Laporan Tahunan 2008, http://www.st.gov.my/index.php?option=com_docman&task=doc_view&gid=593&Itemid=660.

[203] This corresponds to the dispatch order provided by TNB. Azman Ezraie Ariffin, *Transmission Planning and Project Implementation, Powerpoint Presentation* (23 May 2008), p. 19, on file with the author and available upon request.

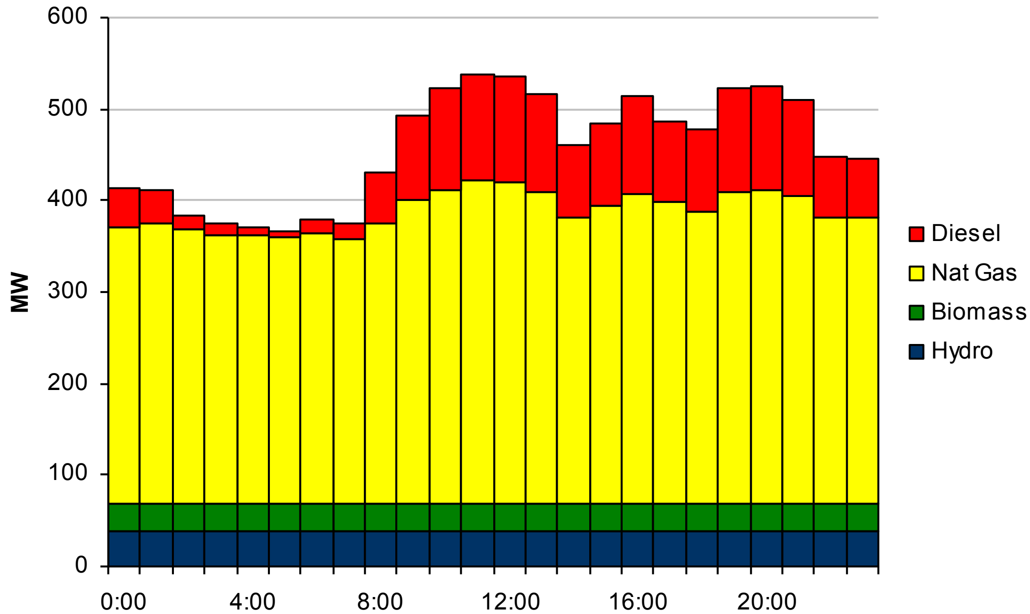

Figure 3-2: Simulated Hourly Profile of Load Serving, 2010.

However, these hour-by-hour patterns also vary from month-to-month, and for two reasons. First, power demand varies somewhat by month (see Section 1 of this report). Second, the availability of the hydropower resource varies by month. Thus, in August, when hydropower availability is predicted to be low and demand is predicted to be high, a greater share of diesel capacity must be brought online than in January, when hydropower is abundant and demand is low. Figure 3-3 shows the monthly variation of power plant usage in the 2010 baseline scenario.

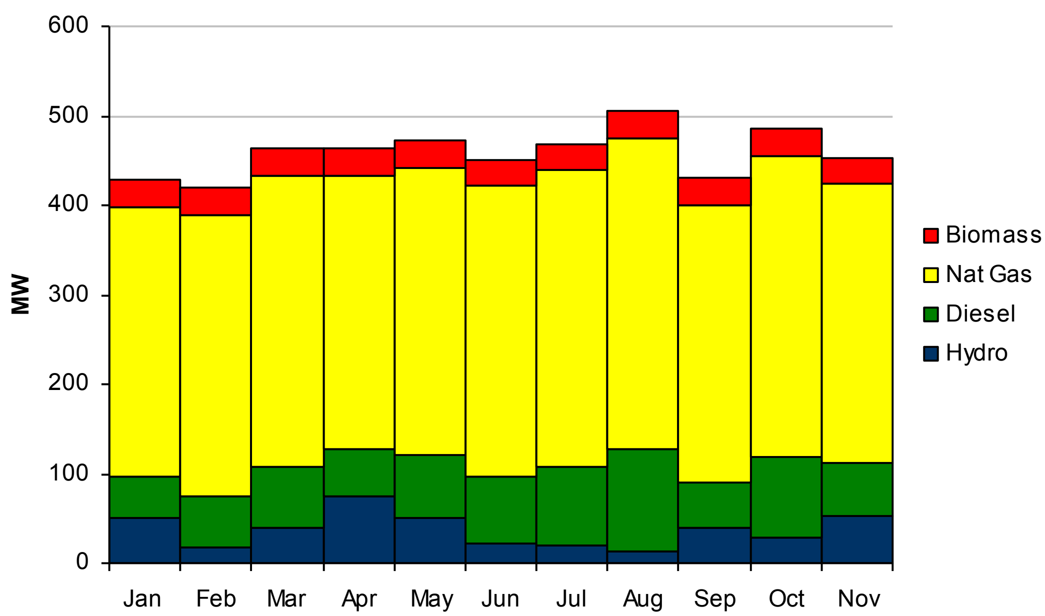

Figure 3-3: Simulated Monthly Load Serving Power 2010 Baseline Scenario

In this scenario, as in other scenarios, the power required from the thermal power plants is determined largely by the availability of hydropower. The blue (bottom) section of the columns in Figure 3-3 shows our assumption about the stream flows by month, which is extrapolated from recorded flows at the Tenom Pangi site.[204] We have scaled up the monthly index values for the available Tenom Pangi data to yield a 70% capacity factor in 2010 – a conservative estimate based on Tenom Pangi's typical capacity factor of 73% and Esajadi's predicted capacity factor of 77%. In 2015, we assume an even more conservative capacity factor of 60%, on the assumption that the Lawas and Upper Padas projects may have lower capacity factors than Tenom Pangi and the Esajadi projects.

Given these assumptions, the model predicts that most of the power in the 2010 baseline scenario would come from natural gas. Despite the fact that diesel plants are still 45% of installed capacity in this scenario, the model predicts that only 15% of Sabah's power would have to be obtained from diesel. In fact, in 2015 and 2020, when expanded hydropower, gas, and coal capacity is online, the model predicts that no diesel power whatsoever would need to be deployed.

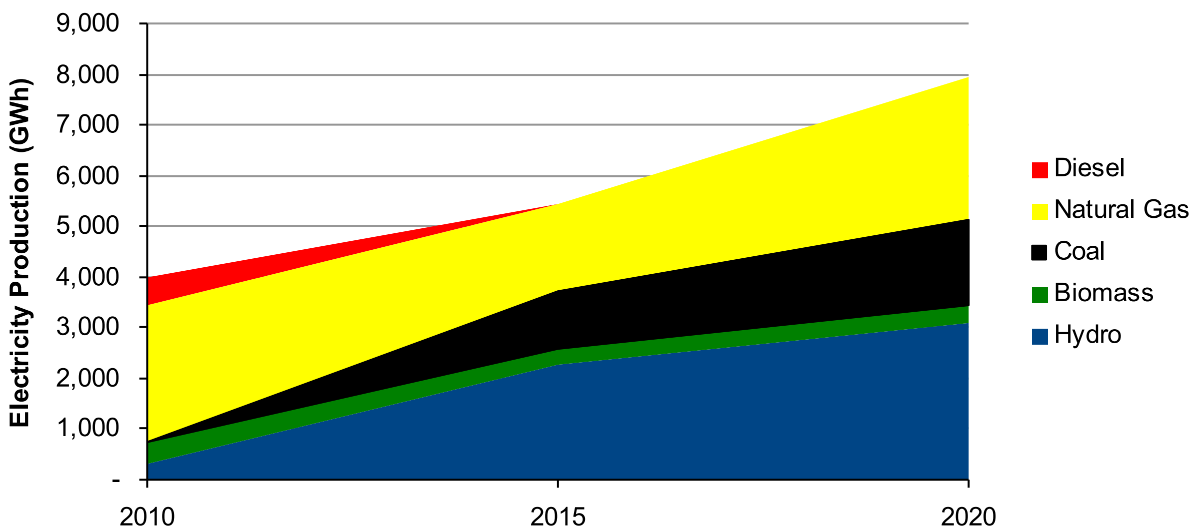

Figure 3-4: Fuel Technology Shares in the Baseline Scenario.

Coupled with the lower utilization of natural gas capacity in 2015 and 2020, this fuel shift decreases dramatically the average costs of power supply. Assuming the levelized costs calculated in Section 2 above, we estimate a total levelized cost of generation in this scenario of about RM 0.165/kWh in 2015 and 2020, as compared to a cost of 0.25/kWh in 2010.

As a result of the increasing share of zero-emissions hydropower and relatively low-emissions natural gas, the simulation predicts that total per-kWh emissions by Sabah's electricity sector decreases from 0.545 tCO2e/kWh in 2010 to 0.35 tCO2e/kWh in 2015. However, from 2015 to 2020, the emissions intensity increases back up to 0.41 tCO2e/kWh due to the fact that coal assumes a larger stare of total electricity generation after 2015. In fact, emissions from coal

[204] Because our attempts to obtain stream flow data were unsuccessful, we rely on values reported in Tenaga Ewbank Perunding (M) Sdn Bhd, *Sabah Power Development Master Plan Study, Draft Final Report Volume One.* It goes without saying that these figures are extremely out-of-date and unrepresentative of stream flows in other rivers.

are so high that they more than offset the emissions-lowering effect of increased hydroelectric power.

Additionally, a real question exists as to the efficiency of timing of capital investment in the baseline scenario. Specifically, the heavy investments in power between 2010 and 2015 create a large reserve margin and result in the under-utilization of installed capacity. Under the simulations low-cost dispatch assumption, the planned 300 MW coal plant only produces at 42% of capacity in 2015, and the natural gas plants at 20%.[205] Even in 2020, only 34% of the natural gas plants' total capacity and 69% of the coal plant's total capacity is utilized. Delaying the construction of some plants until the latter part of this decade, or perhaps even forgoing the construction of the coal plant entirely, can therefore be expected to lower the total cost of electricity production as well as the emissions per unit of electricity.

Table 3-1: Key Assumptions & Results – Baseline Scenario

	2010	2015	2020
Peak Demand (MW)	754 MW	1012 MW	1499 MW
Total Electricity Production (GWh)	3,985 GWh	5,400 GWh	7,947 GWh
Hydro Capacity (MW) / Capacity Factor	52.5 MW / 72%	440.5 MW / 59%	590.5 MW / 60%
Biomass Capacity (MW) /Capacity Factor	45 MW / 67%	45 MW / 75%	225 MW / 86%
Coal Capacity / Capacity Factor	-	300 MW / 53%	300 MW / 71%
Natural Gas Capacity / Capacity Factor	606 MW / 51%	1006 MW / 20%	1006 MW / 32%
Diesel Capacity / Capacity Factor	411.5 MW / 15%	198.5 MW / 0%	148.5 MW / 0%
Reserve Margin	52%	96%	39%
Levelized Cost (RM/kWh)	0.186	0.162	0.164
Emissions (tCO2e/MWh)[206]	0.443	0.351	0.397

3.2 SREP Palm Oil Waste Plant-Up Scenario

Our "palm oil waste" scenario makes two deviations from the baseline scenario. First, it eliminates the construction of the 300 MW coal plant. Second, it replaces much, but not all, of the coal plant's 300 MW of capacity with biomass-fired capacity at palm oil mills.

In this scenario, we assume the completion of two new 10 MW palm oil waste projects per year between 2011 and 2020, yielding 80 MW of additional capacity in 2015 and 180 MW of additional capacity in 2020.[207] The natural gas and hydro plant-up programme is the same as described in the baseline scenario, as is the diesel decommissioning plan. Altogether, this programme would result in a reserve margin of 42% in 2015 and 20% in 2020. Because most of the palm oil mills are on the East Coast, most of the additional capacity would be added to that region.

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205 The economic inefficiency of idle capacity is not taken into account in our levelized cost estimates for gas and coal, which assume a capacity factor of 80%-95%. At lower capacity factors, IPPs would have to receive a higher electricity price to give them the desired 15% internal rate of return on their investment.

206 Fridleifsson,, Ingvar B.; Bertani, Ruggero; Huenges, Ernst; Lund, John W.; Ragnarsson, Arni; Rybach, Ladislaus; O. Hohmeyer and T. Trittin. Ed; *The possible role and contribution of geothermal energy to the mitigation of climate change*, Luebeck, Germany. pp. 59–80.

207 Based on our findings in Section 2, we assume that about 10 out of 12 MW of capacity would come from solid palm oil waste projects and that 2 out of 10 MW of capacity would come from POME methane-capture projects.

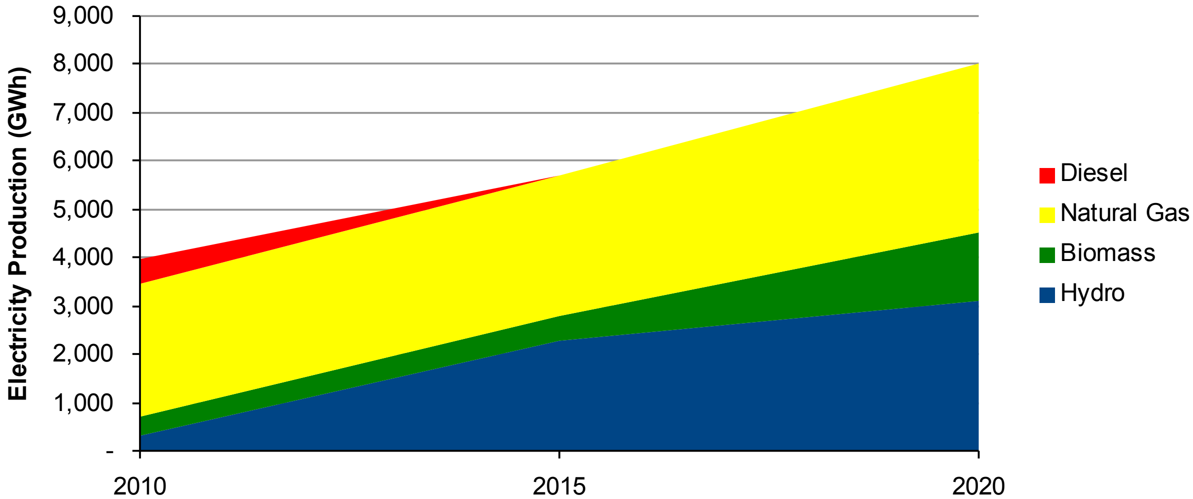


Figure 3-5: Fuel Technology Shares in Palm Oil Waste Scenario

Figure 3-5 shows the resulting resource shares of total electricity generation. As in the baseline scenario, the need for diesel is eliminated by 2015. However, steady plant-up of palm oil SREP plants and a more efficient utilization of the new gas plants displaces the need for coal-fired power entirely. As shown in Table 3-2, this plan matches the cost performance of the baseline scenario: levelized cost in 2015 is estimated at RM 0.172 and we estimate levelized cost in 2020 at RM 0.168, roughly equal to the baseline scenario's 2020 levelized cost of 0.165.

The palm oil waste scenario is also a very low emissions scenario. Emissions are cut from 0.45 tCO2e/kWh in 2010 to 0.20 tCO2e/kWh in 2015 and to a remarkably low 0.04 tCO2e/kWh in 2020. Most of the emissions reduction is achieved by avoiding coal-fired power, but a major contribution is also made by the palm oil waste projects. As shown in Table 2-5, the additional emissions from the burning of biomass waste are more than offset by the reduction in methane emissions, making the per kWh emissions effect of biomass power negative.

Table 3-2: Key Assumptions & Results – Palm Oil Scenario

	2010	2015	2020
Peak Demand	754 MW	1012 MW	1499 MW
Total Electricity Production	3,985 GWh	5,400 GWh	7,947 GWh
Hydro Capacity / Capacity Factor	52.5 MW / 72%	440.5 MW / 59%	590.5 MW / 60%
Biomass Capacity / Capacity Factor	45 MW / 67%	125 MW / 48%	225 MW / 71%
Coal Capacity / Capacity Factor	-	-	-
Natural Gas Capacity / Capacity Factor	606 MW / 52%	1006 MW / 33%	1006 MW / 39%
Diesel Capacity / Capacity Factor	411.5 MW / 17%	198.5 MW / 0%	148.5 MW / 0%
Reserve Margin	52%	74%	31%
Levelized Cost (RM/kWh)	0.191	0.172	0.168
Emissions (tCO2e/MWh)	0.443	0.203	0.039

3.3 Geothermal + Hydro Scenario

In this scenario, we estimate the feasibility of meeting Sabah's electricity demand with utility-scale investments in renewable power plants. Specifically, we assume the construction by 2015 of a 67 MW geothermal plant (the size deemed feasible at the geothermal site near Tawau) and the construction by 2020 of a 30 MW run-of-the river hydro plant. Together, these plants would be just enough to maintain a 25% reserve margin through the year 2020, assuming that all other power plant investment is the same as in the baseline scenario, except for the elimination of the construction of the planned 300 MW plant.

Figure 3-6 and Table 3-3 show the results for this scenario. Emissions are reduced compared to the baseline, but not as much as in the palm oil waste scenario. Costs are slightly higher than in either the baseline scenario or the palm oil waste scenario.

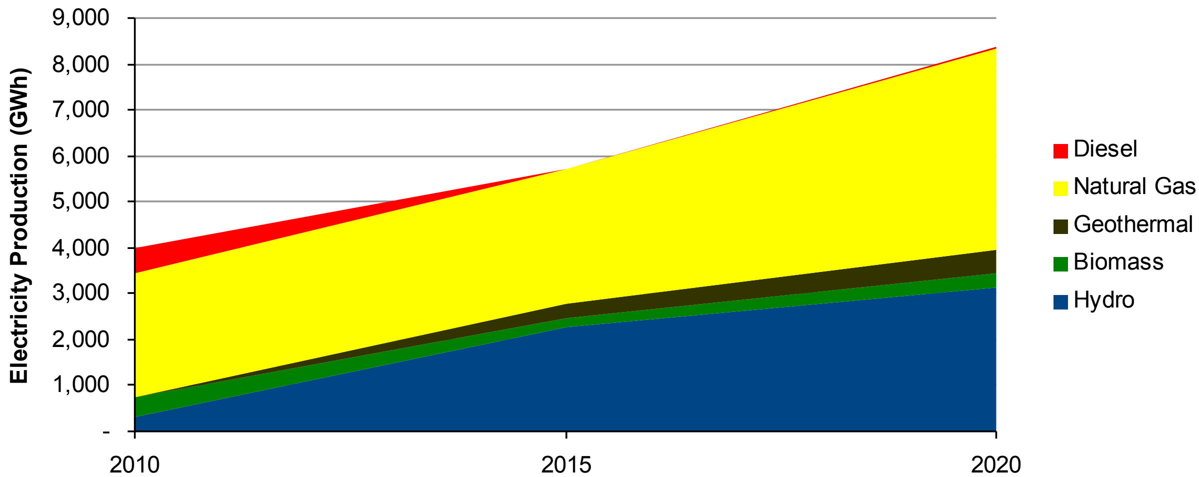


Figure 3-6: Technology Shares in the Geothermal & Hydro Scenario

Table 3-3: Key Assumptions & Results – Palm Oil Scenario

	2010	2015	2020
Peak Demand	754 MW	1012 MW	1499 MW
Total Electricity Production	3,985 GWh	5,400 GWh	7,947 GWh
Hydro Capacity / Capacity Factor	52.5 MW / 72%	440.5 MW / 59%	620.5 MW / 58%
Biomass Capacity / Capacity Factor	45 MW / 67%	125 MW / 41%	225 MW / 78%
Coal Capacity / Capacity Factor	-	67 MW / 56%	67 MW / 85%
Natural Gas Capacity / Capacity Factor	606 MW / 52%	1006 MW / 33%	1006 MW / 50%
Diesel Capacity / Capacity Factor	411.5 MW / 17%	198.5 MW / 0%	148.5 MW / 2%
Reserve Margin	52%	74%	31%
Levelized Cost (RM/kWh)	0.191	0.173	0.174
Emissions (tCO2e/MWh)	0.443	0.290	0.295

3.4 Solar + Biomass Scenario

Our final scenario is based on a mix of solar and biomass power plants. We assume a slightly slower biomass plant-up than in scenario 3.1—40 MW of additional power between 2010 and 2015 and another 60 MW of additional power between 2015 and 2020. The remainder of the gap to the desired reserve margin is closed with a 40 MW PV solar plant built between 2010 and 2015 and a second 40 MW PV solar plant added between 2015 and 2020.

The daily load profile changes somewhat with the addition of the solar capacity. As shown in Figure 3-7, the simulation predicts that geothermal would serve as another baseload power source. Solar, on the other hand, is available only during peak hours, which will partially, but not entirely level the peak that would otherwise need to be met by natural gas. Moreover, because of the relatively low capacity factor of solar predicted by the solar radiation data, some diesel capacity would need to come online during peak hours in order to meet demand.

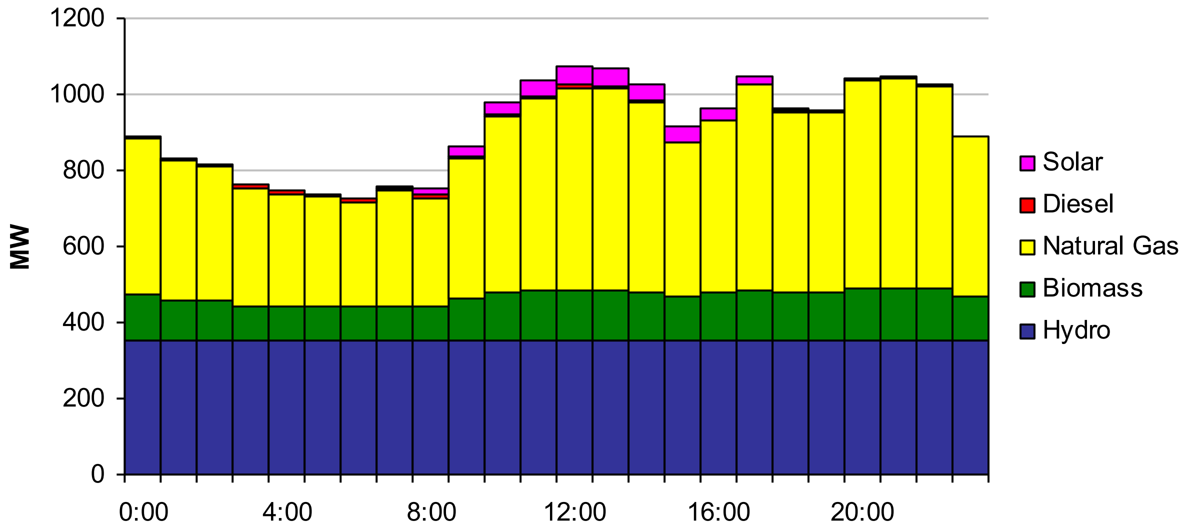


Figure 3-7: Solar & Biomass Scenario Load Serving (2015 simulation)

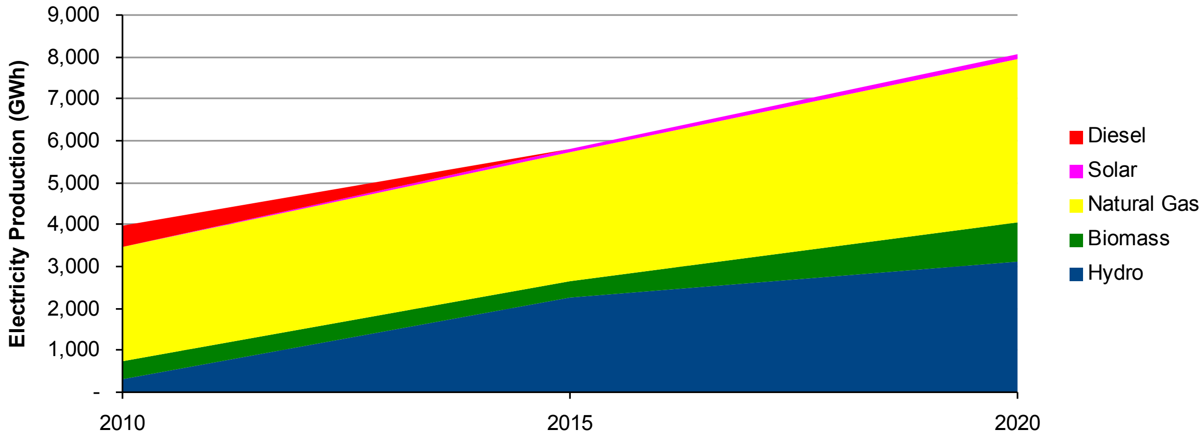


Figure 3-8: Technology Shares – Solar & Biomass Scenario

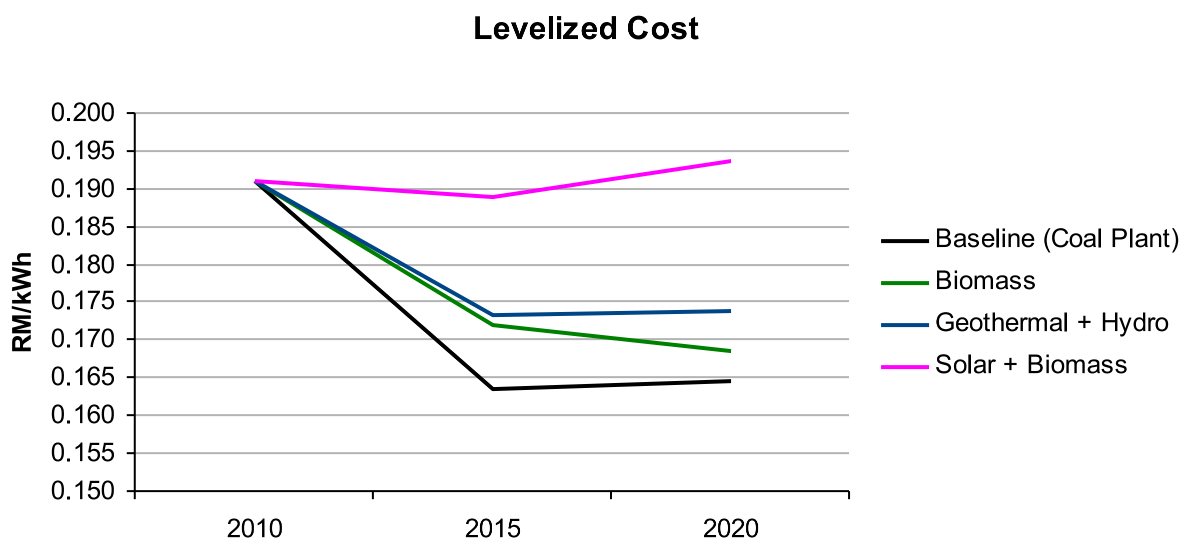
As shown in Table 3-4, this scenario manages to more or less match the present-day cost performance of Sabah's electricity sector, and reduces emissions dramatically. However, neither the cost performance nor the emissions reductions match those of the pure biomass scenario. The major advantage of the solar scenario would be to build local experience with solar generation and stimulate solar markets, in order to take advantage of falling solar prices in the future and position Sabah as a renewable energy leader.

Table 3-4: Key Assumptions & Results – Solar & Biomass Scenario

	2010	2015	2020
Peak Demand (MW)	754 MW	1012 MW	1499 MW
Total Electricity Production (GWh)	3,985 GWh	5,400 GWh	7,947 GWh
Hydro Capacity / Capacity Factor	52.5 MW / 72%	440.5 MW / 59%	590.5 MW / 60%
Biomass Capacity /Capacity Factor	45 MW / 67%	85 MW / 52%	145 MW / 74%
Geothermal Capacity / Capacity Factor	-	40 MW / 18%	80 MW / 18%
Natural Gas Capacity / Capacity Factor	606 MW / 53%	1006 MW / 35%	1006 MW / 44%
Diesel Capacity / Capacity Factor	411.5 MW / 17%	198.5 MW / 0%	148.5 MW / 1%
Solar Capacity /Capacity Factor	52%	74%	31%
Reserve Margin	0.191	0.189	0.194
Levelized Cost (RM/kWh)	0.443	0.255	0.152
Emissions (tCO2e/MWh)	754 MW	1012 MW	1499 MW

3.4 Comparison of all Scenarios

Figure 3-8 compares emissions and cost for all three scenarios over the 2010-2020 time period. The palm oil waste scenario achieves the greatest emissions reductions, and does so at a cost that is nearly as low as the baseline cost. The geothermal + hydro and solar + biomass scenarios do not perform as well on either cost or emissions grounds, but the simulation proves that they are feasible, in terms of both supplying power that matches Sabah's load profiles and in terms of doing so at a reasonable cost.



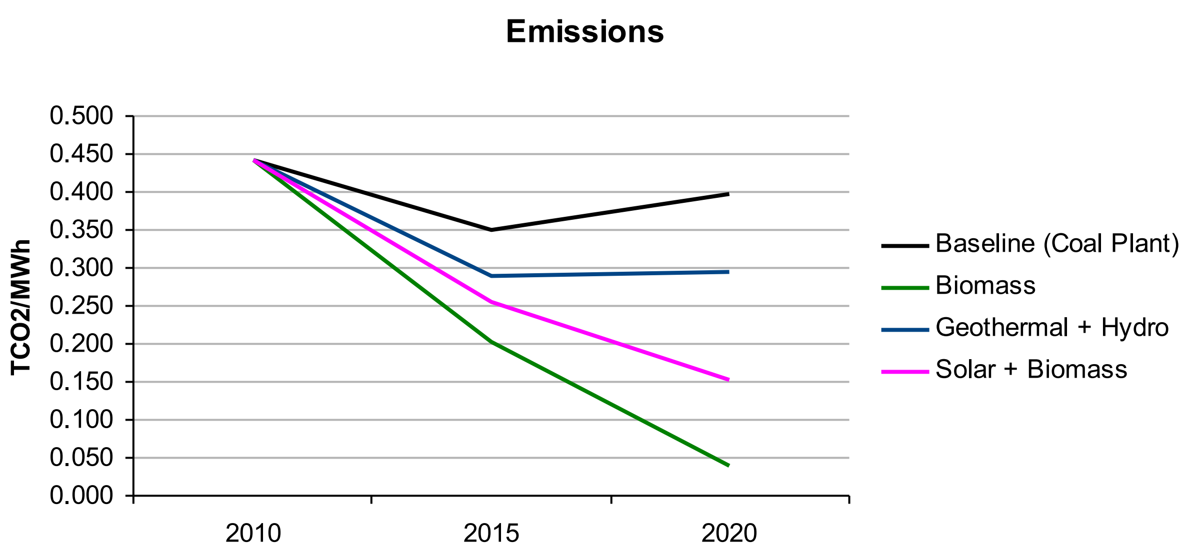


Figure 3-8: Comparison of Emissions and Levelized Costs for the 3 Scenarios

Conclusions & Recommendations

As we have emphasized repeatedly throughout this report, our findings are preliminary estimates based on the best information available at this time, and should be used as the basis for investment and policy decisions only with great caution. That said, our work does justify several conclusions:

- The current capacity additions planned for Sabah may be larger than necessary given SESB's stated goal of a 25% capacity margin.
- Palm oil mill waste projects can feasibly replace the 300 MW coal plant planned for the East Coast of Sabah. These projects present a very attractive electricity supply option, and should continue to be supported by utilities and the government.
- Geothermal and small hydropower investments can also feasibly clean replacement for the proposed coal plant, though at slightly higher cost.
- Solar is an attractive long-term option in Sabah, and the government should continue to support programmes that aim to bring down PV capital costs. Integration of solar "peaker" plants into a larger portfolio of renewables—perhaps by using waste biomass as a backup fuel for steam turbines at solar thermal plants—is highly recommended.
- The wind energy resource in Sabah is likely smaller than in many other areas of the world, but certain higher wind-speed areas deserve further study.

To maximize the integration of renewable power into Sabah's energy mix, policy makers may consider:

- Advocating the phase-out of the costly fossil-fuel subsidies that distort energy markets and make fossil fuels unfairly competitive with other options;
- Recognizing clean energy's status as a "premium product" with significant external benefits to Sabah and Malaysia as a whole by raising the SREP tariff paid to renewable energy producers over the current RM 0.21 limit,
- Encouraging optimal sizing of renewable power investments by removing the SREP programme's 10 MW cap on IPP renewable energy development;
- Establishing a state-level solar commission to explore the best means of stimulating investment in both solar manufacturing and solar power production;
- Continuing to study the potential of the known geothermal sites in Sabah;
- Continuing to study and publicize the feasibility of environmentally-friendly run of the river hydro schemes at the sites identified by Sabah's earlier hydropower prospecting activities.
- Continuing to study and publicize the wind energy potential at certain windy sites in Sabah.