Whole energy system planning: comparing hydropower and decentralized alternatives for Sarawak (Malaysian Borneo)[101]

Background: Borneo and the Sarawak Corridor of Renewable Energy

The rapid economic growth in Southeast Asia in the new millennium has led to a dramatic increase in the development of large hydropower projects in river basins including the Yangtze and the transboundary Mekong. In Malaysia, the state government of Sarawak is implementing a development program called the Sarawak Corridor of Renewable Energy (SCORE) with a predominant emphasis on hydropower.[102] Sarawak, located along the northern coast of the island of Borneo (Figure 5.10), is the poorest and most rural state in Malaysia. The state government is hoping that inexpensive electricity will attract manufacturing and promote economic development. The current peak annual energy demand in Sarawak is 1,250 MW, met by a mix of diesel, coal and natural gas generation either operated or purchased by the state utility company. At least 12 large hydroelectric dams and two coal power plants, together constituting 9,380 MW of capacity, are scheduled to be built before 2030.[103]

Although those dams could meet energy demand, Sarawak supports globally significant ecological and cultural values and development of the proposed dams would cause significant social and environmental impacts, including the displacement of approximately 100,000 indigenous people and loss of at least 2,425 sqaure kilometers of direct forest cover loss.[104] Six dams are scheduled to be completed by 2020, including three already under different stages of development (see Figure 5.10).[105] In 2012 the 2,400 MW Bakun dam became operational. The dam's reservoir submerged 700 square kilometers of land and displaced about 10,000 people. In 2013, the 944 MW Murum Dam was completed and the 1,200 MW Baram Dam was scheduled for construction.

FIGURE 5.10

Sarawak on Malaysian Borneo.

© TIM LAMAN/NATIONAL GEOGRAPHIC CREATIVE (SARAWAK RIVER, MALAYSIA)

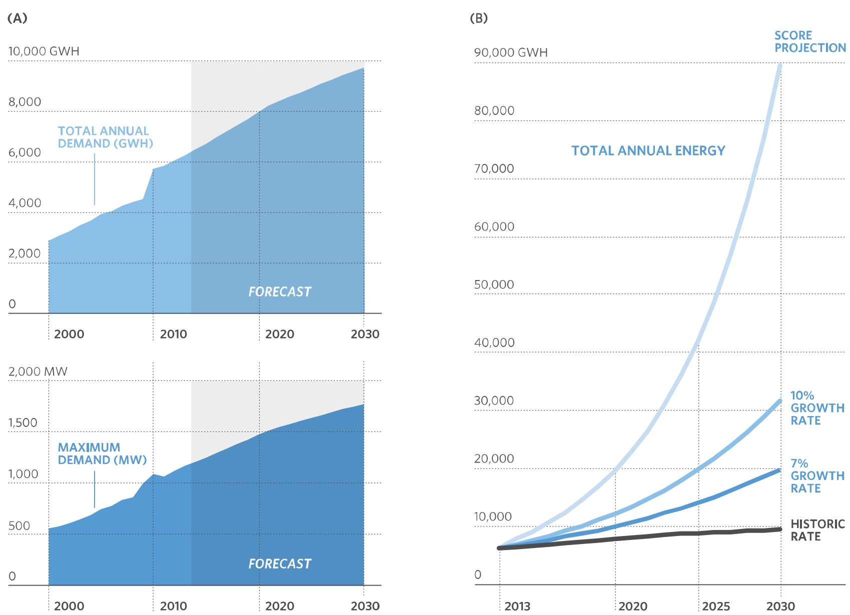
However, the government announced a moratorium against the Baram Dam in September of 2015, largely in response to local and international pressure. On March 21, 2016 a legal decision to solidify this position was announced: the Government of Sarawak reaffirmed indigenous ownership of the land for the dam site, reversing a previous classification that would have allowed the developers to proceed. This decision demonstrated that communities can advocate effectively to protect their interests. It also demonstrated the value of science communication. Research published by the Renewable and Appropriate Energy Laboratory (University of California, Berkeley) had identified financially viable commercial power production alternatives for the state and the government's awareness of realistic energy alternatives facilitated the decision to cancel Baram Dam. This case study summarizes that research and illustrates how expanding the search for options to include other generation sources can reveal alternative pathways that may have a better mix of balanced outcomes and avoid negative impacts that are too high.

Balancing the need for large infrastructure with locally appropriate energy solutions presents very real governance and technical challenges. While there is widespread agreement on the need for a planning approach that combines large infrastructure and decentralized systems, most national energy or electrification strategies contain minimal consideration of this integration and little information on the potential for decentralized solutions is available for public discourse.[106] This case study is part of a broader research program to address this gap and contribute to the literature on management of energy transitions. In this study, we adapted a long-term energy simulation and analysis tool and demonstrate its use in comparing energy options in Sarawak, including alternatives to a BaU approach that emphasizes large hydropower. This region provides an illustrative case study for the potential for whole-system energy planning because it is a growing economy making a transition toward industrialization, has a range of generation options, including renewables, and has globally important cultural and environmental values that can be impacted in different ways by different energy development pathways.

101 Lead authors: Rebekah Shirley and Daniel Kammen
102 SCORE. "What is SCORE?"
103 Sovacool and Bulan, 2012.
104 Fonds, 2012.
105 Suruhanjaya Tenaga (Malaysia Energy Commission), 2012.
106 Tenenbaum, et al., 2014.
107 Sarawak Energy Berhad, 2010.

FIGURE 5.11

(A) Growth in demand for total electricity (above) and maximum (below) for Sarawak since 2010 and then projected to 2030 following the same growth rate. (B) Four scenarios of future growth in electricity demand for Sarawak.



Analysis: Using Grid Simulation to Compare Cost and Benefit of Viable Energy Mixes

To date, there has been little quantitative analysis of Sarawak's energy options or cost and benefit tradeoffs and this lack of information and public discussion are major barriers to comprehensive energy planning. This case study addresses the question: What are feasible alternative energy futures for Sarawak that meet future energy demand for the local population given priorities of (a) cost, (b) reliability and (c) environmental impact?

In this case study we describe a model of the proposed energy system simulated under different future scenarios using the commercial energy market software PLEXOS. Using this commercial power-simulation application we prepared a long-term capacity energy expansion model for the state of Sarawak. We first mapped available primary energy resources, existing generation and potential generation options. In addition to the existing plants, these generation sources include hydropower and decentralized sources such as solar photovoltaic (PV), conversion of palm oil mill effluent (POME) and biomass gasification. Using data on these sources, we then analyzed optimal system configurations for Sarawak over the long term, based on existing generation and resource and operability constraints, incorporating metrics for the costs of greenhouse gas emissions. We built four demand-growth scenarios and four policy scenarios to explore a range of economic assumptions and then modeled the resulting cost, performance and environmental tradeoffs through linear optimization.

The SCORE plan assumes a nine-fold increase in electricity demand between 2010 and 2020 (from 5,921 GWh to 54,947 GWh), which represents a 16 percent per annum growth rate. In terms of installed capacity, this translates to an expansion from 1,300 MW in 2010 to between 7,000 MW and 8,500 MW in 2020.[107] We modeled both this SCORE growth assumption and a conservative historic 2 percent per annum growth assumption. We then modeled two intermediate growth rates: 7 percent per annum and a more ambitious 10 percent per annum (see Figure 5.11). We also incorporated policy scenarios such as the establishment of a Renewable Portfolio Standard (RPS) or Feed-in Tariff (FiT), policies happening elsewhere in Malaysia, to observe the effect of policy instruments on the optimal energy mix. For more details, see "Sarawak methods" in Appendix E.

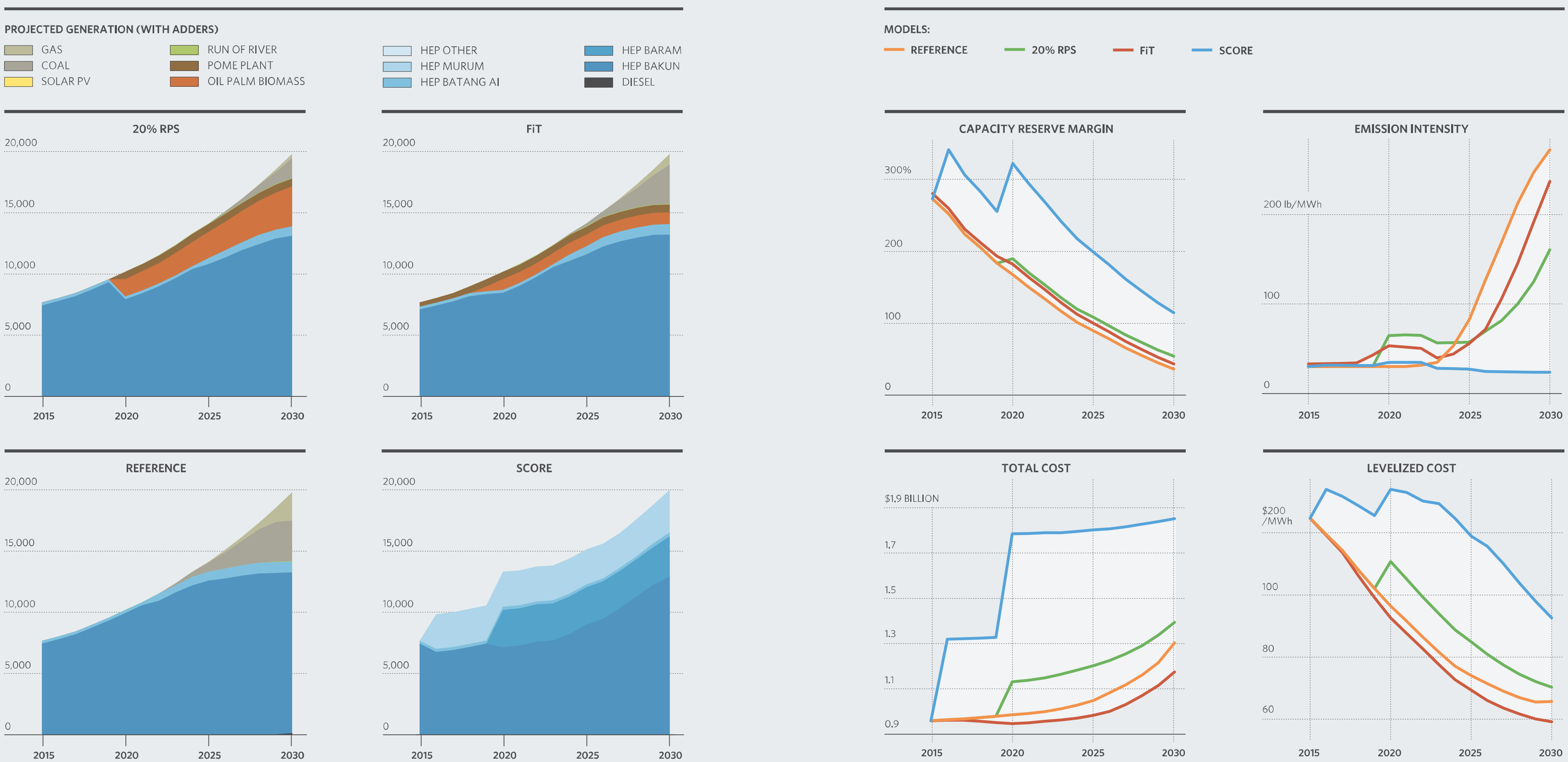
Results: Incentive Schemes Can Significantly Influence Most Optimal Energy Mix

We found that Sarawak's current installed capacity, including Bakun, already exceeds expected demand in 2030 under the historic growth assumption. So, using this growth forecast, the results showed no additional buildout and no investment differences across policy scenarios. The Bakun Dam itself can provide more than 10,000 GWh per annum. Under a 7 percent electricity demand growth assumption, Bakun's generation could meet half of expected demand by 2030. Even under the more aggressive 10 percent growth assumption, Bakun alone would satisfy a third of demand in 2030. Completion of the two additional dams currently under construction (Murum and Baram) would result in an oversupply relative to 2030 demand projected with 7 percent growth, leading to a large excess capacity. Under the 10 percent growth projection, this level of generation would require a marginal amount of additional generation.

The other scenarios show that decentralized generation sources, including PV, biomass gasification and POME conversion, can all contribute to meeting future demand. Both the FiT and RPS scenarios call for the buildout of over 450 MW of biomass waste capacity. The overall total cost per year is quite similar across the other scenarios, though the various cost components differ. We find the Reference and FiT scenarios have the lowest total cost and levelized costs across the fifteen-year time horizon (Figure 5.12).

FIGURE 5.12

Generation profile, cost components and generation characteristics of scenarios under 7 percent demand growth.



The SCORE scenario has a higher total cost and a higher levelized cost than all other scenarios. While it has a low fuel cost and emissions cost, the high annual build cost and associated fixed costs are high. This is because the system is over-built. Building three dams causes the Capacity Reserve Margin to rise to over 300 percent and the reserve margin stays well above 100 percent in 2030, much higher than the 15 percent minimum constraint imposed. The SCORE scenario has 6 GW installed capacity by 2030, almost 33 percent greater than any of the other scenarios which each have roughly 4 GW installed. Nevertheless, the SCORE scenario has one of the lowest emissions production and emission intensity rates. The overall total cost per year is quite similar across the other scenarios, though the various cost components differ. We find the Reference and FiT scenarios have the lowest total cost and levelized costs across the fifteen-year time horizon.

When we applied low future renewable energy technology costs (Biomass: US$1,500/kW; POME: US$2,000/kW, Solar PV: US$1,100/kW and Wind: US$2,210/kW) it changed the resulting generation matrix in the FiT scenario and called for as much Palm Oil Biomass generation and PV generation as possible, with no conventional generation chosen. These results show that renewable resources, including solar and biomass waste, can contribute to the generation mix at lower cost and environmental impact than additional dam construction over the long term and especially when supported by incentive schemes.

We considered the additional cost of environmental impacts, including greenhouse gas (GHG) emissions and direct loss of forest land, as follows: We applied emissions factors to generation and assumed that a carbon price of US$10/tonne CO_2-eq is applied in 2015. A charge based on Forestland Value (FLV) was applied as a fixed charge per kW-year. We found that inclusion of the carbon adder changed the optimal configurations selected, while the land-value adder had little significant impact on the choices made. Emissions caused total annual cost in 2030 to be 4 percent greater for the SCORE scenario while increasing the total cost by a much larger margin for other scenarios. The FLV adder caused no observable change in any cost property for any scenario. Inclusion of the environmental-cost adders also caused fuel switching: the 20 percent 2020 RPS scenario again built out 490 MW of biomass gasification and POME biogas capacity while the FiT scenario switched to 596 MW of Solar PV.

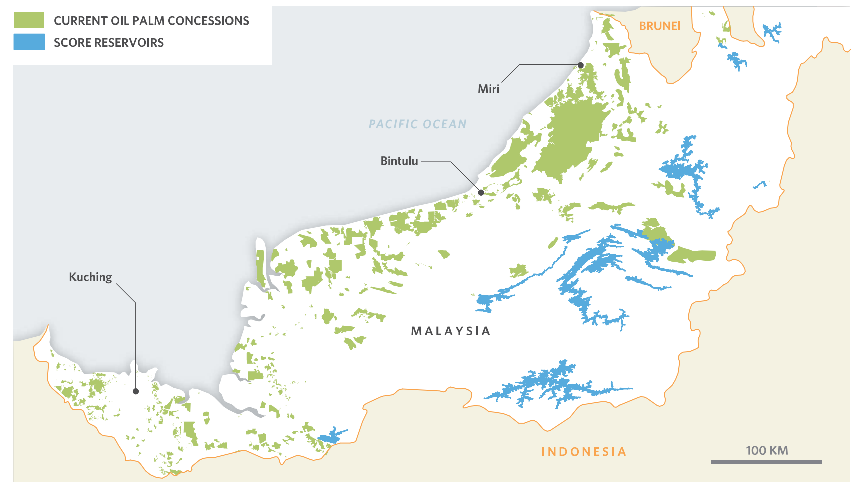
The oil palm industry in Sarawak represents a particularly high quality biomass waste resource. Sarawak alone represents 45 percent of Malaysian crude oil production with an average of 8.5 million tonnes annually. There are forty-one palm oil refineries across Sarawak and a number of these refineries are near major load areas allowing palm oil waste-to-energy to be a feasible option for energy production. The process of extracting crude oil and palm kernel from fresh fruit bunches (FFB) generates considerable amounts of residue. These include solid residues such as shells, fibers and empty fruit bunches (EFB), as well as liquid wastes including palm oil mill effluent (POME). A number of studies find the economics of oil palm waste to energy conversion to be feasible in Malaysia and Sarawak particularly.[108] Common energy conversion technologies explored for EFBs include ethanol production, methane recovery, compression and briquette production, and cogeneration or combined heat and power production. However, studies find that less than 30 percent of palm oil mills in Malaysia are involved in some sort of recycling activity for EFB or POME.[109] Thus, palm oil wastes represent a readily available resource in need of an innovative and efficient means of utilization.

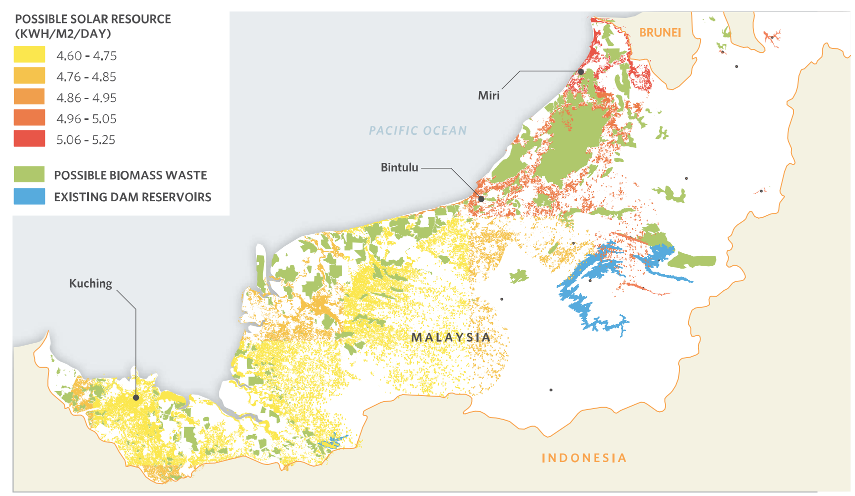
Further, Sarawak has considerable potential for solar energy (Figure 5.13). The minimum monthly average for insolation in Sarawak is found in the month of January at 3.26 kWh per square meter per day and maximum monthly value in April at 6.91 kWh per square meter per day with the annual average being 5.00 kWh per square meter per day. Though a good quality resource, according to the Malaysia Energy Commission, there are only 10 MW of photovoltaic capacity installed in Peninsula Malaysia through small SPPs ranging in size from 0.5 MW to 5 MW.[110] Thus there is also significant opportunity to develop the solar sector.

We estimate the size of the biomass waste resource from oil palm through correlation with total land area under palm oil plantation and standard yield rates. We estimate solar resource based on selection of zones that receive significant annual insolation (monthly averaged insolation above 5 kWh per m2 per day more than nine months of the year). Selecting only mill sites or solar resource within 50 kilometers of existing HV transmission and conservatively assuming only 3 percent of selected solar area can be used for PV, we find there is over 1 GW photovoltaic potential and 450 MW of biomass waste energy potential across the state, currently undeveloped. Future work will feature a more detailed study of the interactions between electricity sources, including how operations of existing hydropower facilities can support greater proportion of variable generation in the grid.

FIGURE 5.13

Spatial distribution of generation resources under different development scenarios. The top map shows distribution of reservoirs with hydropower development under the SCORE scenario. The lower map shows the distribution of decentralized generation sources (solar and POME).





108 Bursa Malaysia Market, "Research Repository."
109 Chiew, et al., 2011
110 Suruhanjaya Tenaga (Malaysia Energy Commission), 2012.

Discussion: High-Level Energy System Planning Tools Can Reveal Sustainable Alternatives

Energy infrastructure is critical to the future of any rapidly developing economy. Unprecedented rates of growth in the global South have quickly raised the stakes for finding optimal energy technology mixes to keep pace with development needs, where the term "optimal'"usually derives from a techno-economic perspective. Yet the number of projects deployed in developing countries over the last two decades that perform poorly in terms of broader economic and environmental resources and public support, the environmental and public support, illustrates a major disconnect between planners, their tools and their project stakeholders.

Our application of a capacity-expansion methodology has implications for many other regions where the need for assessment of alternatives to large-scale energy infrastructure may exist. The Lower Mekong River Basin, for instance, is currently undergoing massive hydropower development (see case study earlier in this chapter). Similar large-scale energy infrastructure projects are underway across Africa and Latin America. These development pathways are often characterized by limited information, unrealistic assumptions of future demand and narrow definitions of cost (focused on technical and financial with oft-limited consideration of social and environmental costs) that impede broader evaluation of risk and tradeoff. In this case study, we demonstrated a simple and effective framework for assessing critical assumptions embedded in energy-infrastructure development strategy while also providing directionality for appropriate solutions.

Our results highlight that projections of future demand can be grossly overestimated, leading to unnecessarily high projections for needed growth in generation capacity. We also found that decentralized solar and biomass waste technologies can contribute significant capacity to the state's energy portfolio and can meet realistic electricity demands at a lower financial cost than through development of additional large hydropower dams. These findings are consistent with other studies finding solar and biomass waste to be effective solutions for Borneo given their large resource potential.[111] The development pathways that include decentralized alternatives also would have dramatically lower impacts on indigenous communities, forests and rivers, although they also have higher emissions of GHG.

111 Shuit, et al., 2009; Sulaiman, et al., 2011.