CAMBODIA 2040

ECONOMIC DEVELOPMENT

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Chapter 7 | Energy

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Can we see a future Cambodia as a society that has reduced its energy demand and dependence on imported fuels such as oil and coal and moved towards forms of renewable energy such as solar, wind, and biogas? We can view this society in 040 through the eyes of Phnom Penh resident Sothy, who works with a university, teaching students in the department of energy futures. Sothy travels to work on public transport, among the busy foray of cyclists on the dedicated bike paths, street vendors using biogas to cook, electric motorbikes and people engaged in car-pooling. On his way to work, Sothy admires the beautiful architecture in the city with buildings that are surrounded by cool green trees and shade, and the use of insulation in the buildings with louvers on the windows to increase air flow. The building that Sothy works in is four storeys high, is surrounded by tall shady trees and provides an environment in which to work that feels close to nature. His favourite bird, the Great Hornbill is often seen outside his office in the trees that surround the building. The building has a 0kW solar photovoltaic system on the roof, a nd includes battery storage to provide electricity for use in the building. The solar power system is also connected to the national grid, which allows for supply of electricity to the grid at peak times during the day when energy is needed the most. Many buildings and industries in Phnom Penh now use solar PV and batteries, which has the

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added benefit of providing support for the grid, which is needed with the recent installation of wind energy production in Kampot province.

I. Energy: The Ideal Scenario

In 2040, Cambodia's energy sector reflects the transformation that occurred in the prior decades with the realization of 35 percent of renewable energy on the national grid, comprising mostly of solar photovoltaics (PV) and wind energy. Biomass generation was also increased off grid using agricultural residues, as well as an increase in the use of biogas for cooking and to replace diesel fuels in the agriculture industry. A Renewable Portfolio Standard (RPS) was implemented to achieve an additional 35 percent of renewable energy in Cambodia. The RPS as a policy mechanism, provided the investment incentive and a market for increased renewable energy generation in Cambodia. The percentage of renewable energy in Cambodia increased over time and included intermediate targets, such as 20 percent of renewable energy in 2025, from a base of one percent of renewable energy in 2018-2019. The benefits of increasing the percentage of renewable energy over time allowed for the introduction of solar and wind energy forecasting in Cambodia's network to maintain security and reliability of the grid. In addition, storage costs reduced significantly in the previous two decades, which enabled Cambodia to install storage on the national grid to provide further support for renewable energy on the network.

Another significant factor that occurred to increase reliability, enable frequency control, and allow for additional intermittent generation on the national grid in Cambodia was the integration and trading of electricity between Cambodia, Laos, Thailand, and Vietnam through the ASEAN Power Grid. Having additional support for the national network in the form of a larger, regionally connected grid was crucial in allowing for increased solar PV and wind energy in Cambodia. As Cambodia is now generating enough solar and wind energy to meet national demand, along with the legacy of coal, hydroelectricity, gas and fuel oil, Cambodia was able to begin exporting excess generation to Thailand and Vietnam. This has allowed for increased revenue, as well as reducing the need for the building of additional coal-fired power plants in Vietnam and Thailand.

Another factor that led to reduced demand, and thus the follow on effect of lessening the need for additional generation capacity, was theimplementation of energy efficiency in the building sector in Cambodia. The introduction of regulations for energy efficiency standards in new buildings, including insulation, shading and airflow requirements reduced the use of air conditioning in Phnom Penh, which led to significant reductions of energy use in this sector. In addition, a program to assess the effects of solar hot water systems on energy use was trialled in Phnom Penh, with promising results. The trial resulted in energy reductions from the use of solar hot water and lower electricity bills in the trial households and it is likely that the Royal Government of Cambodia will develop and implement a program of incentives for many more households to switch from electric to solar hot water.

Cambodia also saw 100 percent of households in the country electrified in 2030, which was achieved through the extension of the national grid where feasible and through incentives and reduced tariffs that were provided by the government for the provision of affordable remote area power supplies, including the use of solar micro and mini grids in areas that were located too far from the national grid. Rural Electrification Enterprises (REEs) in the country, also began installing solar PV on their distribution networks in areas of high demand, such as at transformer sites to reduce costs. This had the added benefit of making the extension of distribution lines to some areas more affordable for REEs, thus leading to increased electrification in areas where this was feasible. The combination of grid and off grid electricity, increased diversity of supply and the increased reliability of the national grid led to all households in Cambodia having at least 23 hours of electricity per day, with at least 2000 watts of power, enough to power most appliances, such as fans, washing machines, and refrigerators. All households in Cambodia also transitioned to the use of gas, biogas and improved cookstoves, which has led to reduced wood fuel use in cooking and improved health outcomes for the population as a whole.

II. Scenario Space and Key Factors for Energy

The Royal Government of Cambodia's priorities for energy include: ensuring sufficient supply; increasing electrification and accessibility; reliability; and a

reduction of tariffs with minimal impact to the environment (Economic Research Institute for ASEAN and East Asia, 2019, p. 15; Keo, 2019). These priorities are worthy goals for the energy sector in Cambodia and this chapter will discuss potential ways to meet these priorities with a focus on security, equity and sustainability. The four key factors listed below will influence the path of development in the energy sector and will be crucial for Cambodia to ensure a secure, equitable and sustainable energy future in 2040.

1. Access and affordability of sufficient electricity for people in Cambodia that includes at least 23 hours of electricity per day at an affordable tariff.
2. National supply of electricity, which includes 35 percent of renewable energy by 2040 (excluding large-scale hydroelectricity).
3. Achievement of energy security that reduces energy imports such as coal and oil; encompasses a diversity of energy sources for electricity supply; and ensures reliability of the national grid.
4. Reduction of energy demand in Cambodia through the implementation of energy efficiency across sectors, in particular the building and residential sector.

These goals will be discussed further in this chapter; however, the authors also suggest that the ideal scenario for Cambodia with growing energy demand is to not only increase renewable energy generation but to actively avoid the need to build additional coal and hydro-electricity through demand reduction. As discussed by York and Bell (2019), historically when new energy sources are added to an energy mix, this does not necessarily replace traditional sources of energy, such as coal, oil or in the case of Cambodia, wood fuel. Although globally, renewable energy sources such as wind and solar are increasing, they still only comprise about two percent of the global energy supply (York & Bell, 2019, p. 41). We can see this trend on a smaller scale occurring in Cambodia. Over the last ten years in Cambodia, energy generation capacity has been increasing with economic growth and increasing electrification. What has been found however, is that although many areas are becoming electrified, the use of wood fuel is still prevalent and makes up a significant amount (up to 60 percent) of primary energy use in the country (Participant 20, 2019; Luukkanen et al., 2015). With

only 33 percent of the population using clean fuels (such as gas) for cooking - wood fuel and charcoal are still the dominant energy sources for cooking in Cambodia.

Cambodia's energy trajectory is one of growing demand and increasing electrification with the expansion of the national grid. At the time of writing, the total installed generation capacity in Cambodia was approximately 2500 megawatts (MW). This consists of approximately 35 percent from coal, 48 percent from hydroelectricity, 2 percent from fuel oil and less than 1 percent from renewable energy (other than hydro). Remaining power usage (approximately 14 percent) is imported electricity from Thailand, Vietnam and Laos (Electricity Authority of Cambodia, 2018b). With increasing economic growth, rising electrification rates, and continued urban population growth in Cambodia, electricity demand has been increasing at a rate of approximately 18 percent per year during the period from 2010 to 2016 (Economic Research Institute for ASEAN and East Asia, 2019; Intelligent Energy Systems & Mekong Economics, 2016, p. 14). Projections of electricity demand into the future are that demand will increase by 7.5 times to 2040 (Economic Research Institute for ASEAN and East Asia, 2019, p. xviii). The residential sector traditionally consumes the highest proportion of electricity at 50 percent, with commercial and services at 28 percent and industrial use constituting 18 percent of demand (Intelligent Energy Systems & Mekong Economics, 2016, p. 14). The trend of increasing energy demand for Cambodia and many other count ries within ASEAN, such as Vietnam and Thailand is a reality that appears set to continue with the pursuit of development that relies on high levels of energy consumption.

Electrification in Cambodia is growing with latest figures stating that 81 percent of households were electrified in 2018 (Economic Research Institute for ASEAN and East Asia, 2019, p. 37). This has exceeded the target of 70 percent of households electrified by 2030, however the levels of energy access and hours of supply for households in Cambodia could be improved. A World Bank study examining 3,300 households in Cambodia found that 63 percent of households in the kingdom have approximately 8 hours of electricity access per day, which equates to tier 3 access under the multi-tier framework (Dave et al., 2018, p. 29). Tier 3 access can power medium load appliances, or provide approximately 200-

799 watts of power (Dave et al., 2018, pp. 3-4). Households that are located off grid and using other sources of energy such as a solar home system or a rechargeable battery are mostly in tiers 0-2, which equates to approximately four hours of electricity per day or enough to power load appliances up to 200 watts (Dave et al., 2018). A simple solar home system in Cambodia traditionally ranged from 60 to 250 watts. Research undertaken by den Heeten et al. (2017, p. 8) exploring patterns among over one hundred solar home system users in Cambodia showed that mean energy consumption was 310Wh per day with most energy consumed at night. Under the multi-tier framework this would be considered tier 3 access.

Cambodia is relatively self-sufficient in traditional biomass sources, with wood fuel making up a significant percentage of the primary energy supply, with figures varying from 45 to 60 percent (Asian Development Bank, 2018, p. 2; Participant 20, 2019). Firewood is the dominant fuel used for cooking in the country, with 62 percent of households reliant on wood fuel; 5 percent using charcoal; and 31 percent use gas. Approximately 33 percent of households use a clean fuel stove, which is mostly Liquefied Petroleum Gas (LPG) or biogas. A small percentage of the population, 2 percent, use electricity for cooking (Asian Development Bank, 2018). The remaining primary energy supply consists of 38.5 percent of oil and petroleum products; 10.7 percent of coal; 3.6 percent of hydropower; and 2.8 percent of electricity imports (Asian Development Bank, 2018, p. 2). Biomass and oil are the most dominant fuels, with oil used mostly in the transport sector (Economic Research Institute for ASEAN and East Asia, 2019). Oil imports for transport fuel are projected to increase quickly in the future leading to further dependence on imports (Luukkanen et al., 2015, p.874). Oil and gas exploration is occurring both offshore in Cambodian waters and onshore, however there does not appear to be certainty of domestic supply from this early stage exploration (Asian Development Bank, 2018, p. 3).

Energy security is discussed here in relation to primary energy supply, which includes transport fuels and biomass, as well as in relation to electricity. Energy security based on availability, affordability, reliability, efficiency and environmental sustainability is a significant issue for Cambodia. A study undertaken by Sovacool et al. (2011) assessed the energy security of the

European Union, United States, China, India, Japan, South Korea, Australia and all countries of the Association of South East Asian Nations, including Cambodia. Energy security was assessed based on the factors mentioned above, which go beyond the security of fossil fuel supplies and include an analysis of areas such as energy efficiency, affordable electricity, stability of electricity prices, land use and the percentage of households dependent on traditional fuels such as wood and charcoal. The study found that Cambodia's energy security has declined over the decades from 1990 to 2010. Cambodia rated the fourth lowest on the energy security index for the decades studied. Vietnam, India and Myanmar were considered the least energy secure countries in the study with Japan, Brunei and the US rating highest (Sovacool et al., 2011, p. 5850).

A later study by Kanchana and Unesaki (2014) evaluated the energy security of nine ASEAN member nations (excluding Laos). This particular study used indicators relating to supply security – that includes a reliance on imported fuels and diversification of energy sources as well as socioeconomic and environmental dimensions, including energy efficiency and issues related to carbon emissions. The main emphasis however to determine energy security in this study relates to the availability of energy sources and "energy import dependency" (Kanchana & Unesaki, 2014, pp. 164-165). "Self-sufficiency of energy resources" is conceptualized as the capacity to meet energy demand using domestic resources, excluding renewable energy sources such as hydroelectricity, but including coal, oil and natural gas. Cambodia is not self - sufficient in oil, gas or coal and imports 100 percent of its petroleum products. In the near future, it is expected that Cambodia will increase its demand for oil faster than its economic growth rate, which will create a worsening of the trade balance (Economic Research Institute for ASEAN and East Asia, 2019, p. 3). Cambodia sources most of its oil imports from Thailand, Vietnam and Singapore (ibid, p.5).

From a cost perspective, the Royal Government of Cambodia prioritizes keeping tariffs low to provide affordable electricity. Providing affordable electricity is a worthy goal to ensure energy access and provides another incentive for Cambodia to avoid the building of too much additional coal or hydroelectric generation that may increase costs in the future. There have been instances in

other countries such as Ghana that saw the government increase the amount of additional generation as a response to power outages and they are now finding themselves in the situation of having excess energy with high costs as a result of take or pay contracts and a reliance on the private sector for energy infrastructure (Sarkodie, 2019).

Cambodia appears to be wary of take or pay contracts and has so far managed to avoid investing in additional generation that would see the country in a similar situation. However, a recent announcement to purchase 2400 MW of power from Laos, extending out to 2027 (Chea, 2019), could create a situation of excess energy and high costs in the future, depending on the type of contract signed. Given the recent power outages in Cambodia, the experience in Ghana as discussed by Sarkodie (2019), is a cautionary tale for Cambodia to plan and effectively provide projections of their energy needs for industry and the population to increase investment in generation, proportionally to growing demand. In addition to costs over time, Cambodia would be wise to consider the import costs of fuels over time and avoid an overreliance on imported coal and oil.

III. Policy Initiatives to Achieve the Ideal Scenario

Access and affordability

For rural electrification, the rate of electrification does not reveal the complete story about availability in terms of hours per day, quality aspects such as voltage and frequency and what people are using electricity for (Sovacool et al., 2011, p. 5849). Innovative projects such as those from Okra Solar could assist Cambodia to focus more on the energy needs of communities and ensure sufficient energy access. The technology developed by Okra Solar is a direct current (DC) distributed micro grid system. Although the power capacity of Okra's initial demonstration site is still considered to be low by global standards, for example approximately 5kW of solar PV for 40 households, Okra Solar aims to provide 24 hours of electricity per day for households through power sharing in the system. There has been no independent study undertaken on energy access levels for households using the Okra Solar system in Cambodia, therefore determining

the tier level under the multi-tier framework is not appropriate. However, it is more likely to meet tier 4 access based solely on hours of electricity available per day to meet household needs. The system is also more efficient due to the use of DC electricity and the sharing of power among houses. Okra Solar also considered the power needs of households in detail and ensure that energy efficiency is considered in the purchase and use of appliances on the system. The load that the distributed micro grid can meet at this stage is still lower than grid electricity, with the grid providing around 2300 watts on average, which is enough to power high load appliances such as air conditioning.

Thus, the Okra system is a vast improvement on simple solar home technologies in terms of availability of electricity per day, loads and efficiency, but high load appliances are still limited on the current demonstration system. Okra Solar however had indicated that the system is modular and scalable over time, so additional capacity can be added to the system (Participant 14, 2018 & 2019).

These types of innovative energy projects are worth supporting through government policy mechanisms such as those referred to by Kivimaa and Kern (2016) as "price performance improvements". These can include subsidies to increase the competitiveness of innovations that meet specific criteria, for example providing minimum standards of energy access (tiers 4 or 5) to communities located off the national grid. Other criteria for subsidies to private companies could also include the implementation of a knowledge sharing arrangement, where firms are required to provide data about their respective projects and energy use in provinces to government officials to enable better service planning. If the Royal Government of Cambodia were to provide tariff subsidies for rural electrification, it is recommended that companies providing the energy service meet minimum standards of energy access as well as providing information to the government to facilitate better future energy planning in the kingdom. Although some success has been gained from the solar home system market in providing electricity to households in rural areas, what has been found is that when people have access to electricity, their energy use grows. Thus, the small scale solar home systems, over the longer term, often do not meet the needs of households when additional load is added to the system. As discussed by den Heeten et al. (2017, p. 9), to resolve the issue of under sizing

of systems, there is a need for up to date user load profiles with a view to the future energy needs of users as the aspirations of people's energy needs often increases, particularly if income increases. In addition, the needs of households in relation to cooking should also be considered and a program to implement clean cooking solutions across rural Cambodia where wood fuel is dominant is recommended.

A final aspect of ensuring that energy remains affordable is related to REEs in Cambodia. In April, 2019 a dialogue was held with the renewable energy industry in Phnom Penh and it was discussed at this event that REEs in Cambodia are looking to reduce their operating costs and some would be willing to invest in solar PV for self-consumption at transformer locations on the grid. REEs are currently unable to integrate solar into the grid, however if solar was used for self-consumption (and not exported), this may assist REEs and support the grid by reducing the load and improving reliability in areas of high energy use. To ensure reliability is maintained, the allowance of solar PV for use by REEs on the national grid could start as a trial or the amount of solar PV could also be capped by Electricite du Cambodge (EDC). Allowing REEs to reduce their overall costs with the use of solar PV in areas of high demand, could also ensure lower tariffs in rural Cambodia over the longer term.

National supply of electricity to include 35 percent renewable energy by 2040

Renewable energy targets need to be ambitious, but also realistic and to consider that many renewable energy sources, such as solar and wind have lower energy densities than fossil fuels (Braun & Glidden, 2014, p.17). This is important to consider in planning for energy generation in Cambodia as energy productivity (doing more with less energy) is just as important. Another aspect to consider is the future of energy technologies and not ruling out that affordable future technologies may exist in 2040, or indeed in 2030, that make a sustainable future much more likely. Intermediate milestones that will provide an estimate of how fast renewable energy markets are expected to develop for investors (Heng, 2018) should accompany any targets for renewable energy. This will take some foresight; however, we know that energy demand is growing

incredibly quickly in Cambodia and it makes sense to incorporate renewable energy technologies that are affordable and exist now into the supply mix.

A supportive policy instrument in place such as a Renewable Portfolio Standard (RPS) would assist to transition Cambodia's energy sector towards renewable energy and is an effective way to quantify the amount of renewable energy that is being installed in Cambodia. An RPS is a policy mechanism used by states globally to increase the amount of renewable energy generation within the energy mix. The RPS usually hasa minimum percentage obligation, for example, the authors recommend a minimum of 35 percent by 2040 for Cambodia. The percentage of renewable energy in the national grid increases over time and can include intermediate targets, such as 20 percent by 2025. The targets can include both new renewable energy generation and existing generation; however, the authors would not recommend including existing generation as this can weaken the target and result in profits over and above that which is reasonable to utilities and companies already owning renewable energy generation assets (Yin & Powers, 2010, pp. 1141-1143).

In Cambodia, the target would also need to exclude large scale hydroelectricity, which is also classified as a renewable energy source. The RPS targets can be met by one, or a combination of additional renewable energy generation, purchasing renewable energy generation from another supplier or purchasing renewable energy certificates or credits (Economic Research Institute for ASEAN and East Asia, 2019, p. 62). The latter approach could potentially be implemented through the purchase of credits from household and industrial solar PV that could add to the generation mix and assist in meeting the overall RPS target. The Australian based Renewable Energy Target (RET) utilizes renewable energy certificates from household PV systems named Small-scale Technology Certificates (STC) and larger renewable energy projects utilising Large Generation Certificates (LGC) from projects such as wind farms and utility scale solar. All certificates contribute to meeting the nationwide RET of 20 percent of electricity or 9500 gigawatt hours (GWh) from renewable energy sources by 2020 and has the added benefit of accounting for energy generation from renewable energy sources in the country. Each renewable energy certificate is equal to one megawatt hour (MWh) of electricity of anticipated

generation over the life of the renewable energy system. Other states in Australia have independent renewable energy targets, such as South Australia's 50 percent of renewable energy by 2025 (Chapman et al., 2016, p. 1266).

Research undertaken by Ritzenhofen et al. (2016) assessed three mechanisms for increasing renewable energy generation; feed in tariffs (FIT), RPS mechanisms, and market premia. The researchers assessed these mechanisms according to affordability, reliability and sustainability. The model that Ritzenhofen et al. (2016) used to assess the mechanisms accounted for investor behaviour and the reaction of customers and was not a "generation focused" perspective (Ritzenhofen et al., 2016, p. 226).Their study found that there was less volatility in the price of electricity under a RPS scheme than under a FIT scheme. They also found that FIT rates, when improperly set can result in over or under investment in renewable energy sources and distort the electricity market (Sarkodie, 2019, pp. 236-237). The authors also note that if a focus on reliability is required by policy makers, RPS is favourable as FITs do not improve market integration of renewable energy sources. In addition, increasing renewable energy generation can be achieved at a lower cost under a RPS scheme than with FITs (Ritzenhofen et al., 2016, p. 237). FITs have also be shown to increase inequitable outcomes in Australia on household electricity prices for homes without solar (Chapman et al., 2016, p. 1278). A study by Yin and Powers (2010) on the effectiveness of RPS mechanisms in the United States confirms that there is a "significant and positive effect" on renewable energy development within states of the US with the use of RPS policies. Nevertheless, they caution against the trading of renewable energy certificates across jurisdictions as it can weaken the mechanism (Yin & Powers, 2010, p. 1149).

For these reasons, the authors believe that a RPS mechanism is the best policy instrument to increase the percentage of renewable energy over time as energy generation assets increase in Cambodia. However, we would also recommend that if the Royal Government of Cambodia chooses to develop a policy mechanism, such as RPS to increase renewable energy, that an independent study is undertaken to determine the effect on long term electricity prices, the cost of infrastructure investments to accommodate renewable energy and interactions with current regulations such as the *General Conditions for*

connecting Solar PV Generation sources to the Electricity Supply System of National Grid(Electricity Authority of Cambodia, 2018a). Inaddition, carefulconsideration should be given to whether Cambodia allows the purchasing of renewable energy certificates or credits from household solar PV to form part of a RPS mechanism as it may not be the best option from an electricity generation point of view (Chapman et al., 2016, p. 1277). It is also important to avoid cross subsidization of renewable energy such as solar PV. If a feed in tariff was introduced along with a RPS mechanism, this could have the long term effect of increasing electricity prices for customers without solar PV (Chapman et al., 2016, p. 1267 & 1275). There are several lessons from Australia's implementation of the RET mechanism for increasing renewable energy generation as detailed in the paper by Chapman et al. (2016). However, Cambodia can avoid many of these mistakes and reduce the complexity that occurred in Australia as a result of separate state governance and regulatory regimes in the Australian electricity market.

It is also acknowledged by the authors that the Cambodia Basic Energy Plan does not recommend a FIT or RPS mechanism for solar PV in Cambodia, but instead recommends opening the market to local, foreign entities, the private sector and the Asian Development Bank (Economic Research Institute for ASEAN and East Asia, 2019, p. xix). However this advice is then contradicted in the Basic Energy Plan, and it is recommended over the longer term that a study on FIT is conducted, while also acknowledging that it is likely to increase electricity prices (Economic Research Institute for ASEAN and East Asia, 2019, p. 64 & 69). The impetus for a FIT mechanism appears to be more focused on attracting investors to the renewable energy sector in Cambodia, however from a policy perspective and in consideration of the priorities of the government to have reliable, secure and affordable electricity, we would recommend that the focus remains on these priorities, and thus an RPS mechanism as discussed here is favoured over a FIT mechanism.

Achieving Energy Security, Reliability and Diversity of Supply in 2040

Cambodia is not yet entirely comfortable with intermittent solar and wind generation on the national grid and this is a valid concern for EDC as variability with wind and solar PV generation exists that can threaten the reliability of centralised power systems (Akrami et al., 2019). However, the risks related to reliability can be mitigated, as will be discussed, and Cambodia is in need of additional electricity generation that is not prone to drought, as the power outages and load shedding that occurred in Cambodia from mid-March to end of May 2019 showed. The current national grid in Cambodia has been set up to prefer dispatchable energy (i.e., coal, gas, oil and hydro generation). Thus from a technical perspective, better planning and focus on actual energy needs in the country would be preferable to building a great deal more dispatchable generation that is a focus of centralized energy systems.

To ensure energy security, reliability and diversity of supply, Cambodia will need to increase the diversity of energy supply in the country to reduce the use of imported fuels such as oil and coal. It is feasible for Cambodia to meet more of its energy demand with solar PV and wind energy and the recent announcement of additional solar PV to the national grid is highly welcome (Keo, 2019). Options for ensuring reliability and frequency control on the national grid with the introduction of variable solar and wind systems include: smart grids utilising bidirectional communication links; energy storage systems; interconnection of the national grid regionally; ancillary services such as load following; improving market design; flexible conventional units; and maintaining greater control over renewable generation (Akrami et al., 2019).

The authors are aware that EDC is starting to look at some aspects of increasing the flexibility of the grid with the European Union co-funded grid modernization project and ensuring flexible conventional units, such as the recently announced 400MW liquefied natural gas (LNG) and heavy fuel oil (HFO) plant. Cambodia could increase the flexibility of the grid by considering some of the other measures noted here, such as storage, solar energy forecasting, and better integration of the national grid in Cambodia to other countries in the region that

form part of the ASEAN Power Grid. Solar energy forecasting has the potential to be a cost effective measure for Cambodia to increase grid flexibility and reliability. The Philippines currently uses solar and wind energy forecasting on its network and this places the country in an advantageous position for the integration of renewable energy to other ASEAN nations due to their ability to predict electricity generation (Huang et al., 2019, p. 719).

Regional and market integration with Laos and Thailand is a strength for Cambodia and this integration could be improved within the region to ensure secure energy supply (Huang et al., 2019). Clearly some of the interventions noted here to increase flexibility on the national grid - particularly storage - would be costly initially. However, storage costs are likely to reduce in the near future. Also incorporating mechanisms to create more flexibility in the grid now with the use of renewable energy, is likely to reduce the need for additional costly generation in the future. Cambodia also has the advantage of having less infrastructure than other countries in ASEAN, which may provide an advantage to incorporate renewable energy sources (Huang et al., 2019, p. 719). With support in place for additional solar energy on the national network, Cambodia may also want to consider the option of wind energy, with enough wind resources in southern Cambodia to validate investment from the private sector (Promsen et al., 2014). The private sector in Cambodia is already undertaking significant steps towards wind energy in the country.

In addition to solar and wind energy, Luukkanen et al. (2015) discuss the use of agricultural waste, such as rice husk and straw as potential sources of fuel available in Cambodia and Laos for electricity generation. In particular, they note the use of diesel in rice mills and sugarcane processing that could be replaced with other biomass fuels such as rice husks (Luukkanen et al., 2015, p.875). However, the potential for the use of rice husks in Cambodia for electricity generation is limited at this time due to several factors, including the use of rice husks for paddy drying in large mills; export of excess residues from rice harvesting to Thailand; and the lack of technology and financing in Cambodia to make electricity generation from rice husks viable (Participant 16, 2018).

The government of Thailand implemented a program for Very Small Power Productions to generate electricity from renewable energy materials (in thiscase rice husks), which increased support in Thailand for this form of generation and it now forms an important source of fuel in the energy sector in Thailand (Ueasin et al., 2015). If Cambodia wishes to utilize the extensive resource of agricultural waste in the country, such as rice husk for electricity generation, it would be beneficial for the Royal Government of Cambodia to provide research and development funds toward that end, due to the high capital investment cost and to improve efficiencies as well as ensuring the most efficient application of the technology (Ueasin et al., 2015, p.2760; Verbong et al., 2010, p.277). The potential for the use of agricultural waste for electricity generation exists in Cambodia and it may prove to be an important source of dispatchable power in the country for use on the national grid, yet government research and development support will be crucial if this technology is to be utilized to itsfull potential.

Benefits that are noted here to ensure grid reliability; integrate additional renewable energy on the national grid; increase diversity in Cambodia's energy supply and work towards greater regional interconnection through the ASEAN Power Grid has the potential to reduce Cambodia's reliance on fuel imports. However, this would need tooccur in conjunction withtargetedenergy efficiency measures, particularly in the building and residential sector to avoid simply adding renewable energy generation, while traditional sources of fuel such as coal and oil continue to increase.

Energy efficiency

The residential and building sector in Cambodia is contributing to additional energy demand in the country and there are many gains that could be made by 2040 through implementing energy efficiency in these sectors. The Ministry of Mines and Energy have an action plan and strategy for energy efficiency, with a goal to reduce energy demand in Cambodia by 20 percent compared to business as usual. The plan also prioritizes decreasing dependency on imported fuels, as well as energy efficiency in industry such as rice mills, garment and brick

factories, commercial buildings, domestic cooking, line losses from REEs and household appliances (Ministry of Industry Mines and Energy, 2013).

Energy efficiency in buildings and the residential sector in Cambodia could also be approached more in the sense of "wellness" that is created with buildings. Many of the newer apartments and buildings being constructed in Phnom Penh adhere to a global vision of modernity, however the particular climate of Cambodia is not considered within the design (Kishnani, 2012, p. 47). Throughout the 2019 power outages in Cambodia, it was not possible to stay indoors in many buildings in Phnom Penh without electricity to power fans or air conditioners, as it was simply too hot. The comfort and well-being of residents are barely considered in the design of buildings and they mostly have limited access or consideration of nature, such as trees, light, air flow or views to have a connection with the outdoors (Kishnani, 2012, p. 79). Traditional architecture in Cambodia is likely to have these aspects, however the modern development path that Cambodia is following with buildings in Phnom Penh, is not conducive to energy efficiency or a connection with nature. Consideration of these aspects of buildings in Phnom Penh would also assist in reducing energy demand through natural cooling.

A further aspect of energy efficiency in the residential sector is the use of solar hot water, which is underutilized at preesnt in Cambodia. Given that many houses and apartments in the capital use electric hot water, there is a case to be made for solar hot water. There are reliable, local suppliers of solar hot water systems in Cambodia that could be engaged to supply and install these systems on residential homes, hotels and businesses in Cambodia. In addition, the use of solar water pumping in rural areas is another area that the government could incentivize for farmers.

Energy efficiency in the transport sector is also required in Cambodia with an increased demand for petroleum products, and an increase of petroleum imports. Diesel oil, gasoline, and LPG demand increased by 7.2 percent per year from 2012 to 2016. The growth rate of LPG grew the most at 23 percent. The growth of petroleum products is projected to continue to increase until 2040 (Economic Research Institute for ASEAN and East Asia, 2019, p.2). Energy savings

in the transport sector could occur from import restrictions on old cars; a preferred tax system for fuel-efficient cars; and fuel consumption regulation by type of vehicle. Other options for reducing energy use in the transport sector include electric vehicles, electric bikes, and compressed natural gas – all of which have the effect of decreasing oil demand. In addition, public transport routes or car-pooling services for common journeys within the city would also assist in reducing oil demand from the use of cars and motorbikes. The use of more communal transport also could reduce congestion on roads in Phnom Penh at peak times if more people were using public transport or car-pooling services.

IV. Energy Under the Baseline Scenario: Business as Usual in 2040

With the current trajectory in Cambodia of rapid industrial development and increasing energy demand, intervention across the four key factors noted in sections two and three is required. The interventions required in energy access and affordability, national supply, energy security and energy demand that have been discussed in this chapter will avoid a business as usual scenario that could lead Cambodia into a precarious situation in relation to electricity costs, reliability and pollution.

For key factor one - energy access and affordability, further incentives need to be provided for the private sector and REEs to provide sufficient electricity to households that are located in areas that do not provide sufficient return on investment due to low demand and high costs to extend the distribution network. In a business as usual scenario, if incentives, such as tariff subsidies are not provided for areas without energy access, it is likely by 2040 that all households will have access to some electricity in Cambodia; but reliability and quality of supply will remain an issue if households are reliant on simple home solar systems at best, or car batteries at worst. Not having access to sufficient electricity to meet daily needs can affect people's educational and employment prospects. As discussed above, with appropriate incentives and ensuring that the quality of energy supply is at a minimum of tier 4 or 5 supply, the government can be confident that the population will receive affordable energy services to meet their needs. In addition, sufficient hours, reliability and quality

of energy services in rural areas will assist people to access opportunities for income generation and education. Ensuring that all households have access to clean cooking solutions, such as biogas or gas will also assist in reducing pollution, deforestation and improving health outcomes for people that are no longer required to cook on traditional fuel stoves.

Under a business as usual scenario for key factor two, relating to national supply, Cambodia's energy use will continue to grow rapidly, with further coal and heavy fuel oil generation assets potentially built, as well as increased electricity imports to meet growing demand from Laos in particular. Cambodia has already begun to develop solar PV utility scale generation, which is promising, however this needs to be planned, staged and integrated into the national grid to ensure stability and prevent solar PV being dismissed as unreliable if potential issues arise due to an unplanned increase of renewable energy generation. Preventing solar PV on the network is not the solution as costs for solar PV generation are competitive; however, ensuring that the national grid is effectively able to absorb intermittent generation on the network, will have longer term benefits. These benefits include a staged, planned and regionally connected network that incorporates 35 percent renewable energy by 2040. Providing a policy directive of 35 percent renewable energy by 2040, with a market mechanism such as RPS to encourage investment, along with supporting grid functions as outlined, would provide more far reaching benefits than simply relying on the private sector for energy infrastructure. In addition, the growth of renewable energy could be controlled by the government over time by setting intermediate renewable energy targets.

In relation to energy security, key factor three, Cambodia's total primary energy supply (TPES) is projected to increase to almost 13 million tonnes of oil equivalent (Mtoe) in 2030 at an average rate of almost 4 percent per year. Fossil fuels would also dominate Cambodia's future and increase to 60 percent in 2030. An increasing share of fossil fuels in the TPES would occur due to an increase in coal for power generation in the country. Oil consumption will also continue to increase in the future due to the continued growth in the ownership of cars and motorbikes in Cambodia. With a continued reliance on imported fuels in Cambodia, emissions from the energy sector are likely to increase with

the increased consumption of coal and oil, and renewable energy is likely to contribute less than 15 percent of the total energy mix. Along with a smaller amount of renewable energy generation, if steps are not taken now to integrate variable sources of energy such as wind and solar into the network, the flexibility and reliability of the network could be compromised.

The final key factor of energy demand is crucial and interrelated with all of the other key factors. Without some form of energy efficiency in the building sector, many of the current residential buildings being constructed in Cambodia, particularly in Phnom Penh will increase energy demand significantly in order to maintain internal comfort levels. In addition, transport options in Cambodia need to be drastically improved to prevent ever increasing oil consumption, road congestion, air pollution and safety. Without intervention in the transport sector and the increasing use of private vehicles, road congestion in major cities like Phnom Penh is likely to become significantly worse and potentially unmanageable. Public transport options that are frequent and on major routes, electric bikes, and vehicles and car-pooling initiatives can assist with road congestion and pollution.

Overall, Cambodia is developing rapidly with increasing energy demand and electrification. Now is the time for Cambodia to plan effectively for a 2040 that includes renewable energy sources and an openness to future technologies. A key to achieving this will be integrating viable renewable energy options available now, such as solar PV into the national grid and planning for how energy demand in the country can be met in the most efficient, affordable and sustainable way for the future.

References

Akrami, A., Doostizadeh, M., & Aminifar, F. (2019). Power system flexibility: an overview of emergence to evolution. *Journal of Modern Power Systems and Clean Energy*. doi:10.1007/s40565-019-0527-4

Asian Development Bank. (2018). *Cambodia Energy Sector Assessment, Strategy, and Road Map*. Retrieved from Manila, Philippines

Braun, T., & Glidden, L. (2014). *Understanding Energy and Energy Policy* Retrieved from https://ebookcentral.proquest.com/lib/curtin/detail.action?docID=1833661

Chapman, A. J., McLellan, B., & Tezuka, T. (2016). Residential solar PV policy: An analysis of impacts, successes and failures in the Australian case. *Renewable Energy, 86*, 1265-1279. doi:10.1016/j.renene.2015.09.061

Chea, V. (2019). Cambodia and Laos to sign 2,400-megawatt power deal today. *Khmer Times*. Retrieved from https://www.khmertimeskh.com/50642313/cambodia-and-laos-to-sign-2400-megawatt-power-deal-today/

Dave, R., Keller, S. O., Koo, B., Fleurantin, G., Portale, E., & Rysankova, D. (2018). *Cambodia - Beyond connections: energy access diagnostic report based on the multi-tier framework*. Retrieved from Washington DC: http://documents.worldbank.org/curated/en/141011521693254478/Cambodia -Beyond-connections-energy-access-diagnostic-report-based-on-the-multi-tier-framework

den Heeten, T., Narayan, N., Diehl, J.-C., Verschelling, J., Silvester, S., Popovic-Gerber, J., Bauer, P., & Zeman, M. (2017). Understanding the present and the future electricity needs: Consequences for design of future Solar Home Systems for off-grid rural electrification. 8-15. doi:10.23919/due.2017.7931816

Economic Research Institute for ASEAN and East Asia. (2019). *Cambodia Basic Energy Plan*. Retrieved from Jakarta, Indonesia:

Electricity Authority of Cambodia. (2018a). *Regulations: On General Conditions for connecting Solar PV Generation sources to the Electricity Supply System of National Grid or to the Electrical System of a Consumer connected to the Electricity Supply System of National Grid*. Phnom Penh Retrieved from https://eac.gov.kh/site/regulation?lang=en.

Electricity Authority of Cambodia. (2018b). *Salient Features of Power Development in Kingdom of Cambodia until December 2018*. Cambodia Retrieved from https://www.eac.gov.kh/site/index?lang=en.

Heng, P. (2018). *Toward a low carbon energy transition in Cambodia*. Retrieved from Phnom Penh: https://www.kas.de/web/recap/publikationen/einzeltitel/-/content/toward-a-low-carbon-energy-transition-in-cambodia

Huang, Y. W., Kittner, N., & Kammen, D. M. (2019). ASEAN grid flexibility: Preparedness for grid integration of renewable energy. *Energy Policy, 128*, 711-726. doi:10.1016/j.enpol.2019.01.025

Intelligent Energy Systems, & Mekong Economics. (2016). Alternatives for Power Generation in the Greater Mekong Subregion. Power Sector Vision for the Kingdom of Cambodia. Retrieved from http://wwf.panda.org/what_we_do/where_we_work/greatermekong/our_solutions/2050powersectorvision/

Kanchana, K., & Unesaki, H. (2014). ASEAN Energy Security: An Indicator-based Assessment. *Energy Procedia, 56*, 163-171. doi:10.1016/j.egypro.2014.07.145

Keo, R. (2019). *Energy 2020 Vision*. Public event. Electricite du Cambodge. Raffles Hotel Le Royal, Phnom Penh.

Kishnani, N. (2012). *Greening Asia : emerging principles for sustainable architecture*. Singapore: BCI Asia.

Kivimaa, P., & Kern, F. (2016). Creative destruction or mere niche support? Innovation policy mixes for sustainability transitions. *Research Policy, 45*(1), 205-217. doi:10.1016/j.respol.2015.09.008

Luukkanen, J., Akgün, O., Kaivo-oja, J., Korkeakoski, M., Pasanen, T., Panula-Ontto, J., & Vehmas, J. (2015). *Long-run energy scenarios for Cambodia and Laos: Building an integrated techno-economic and environmental modelling framework for scenario analyses*. *Energy, 91*, 866-881. doi:10.1016/j.energy.2015.08.091

Ministry of Industry Mines and Energy. (2013). *National Policy, Strategy and Action Plan on Energy Efficiency in Cambodia*. Phnom Penh, Cambodia Retrieved from http://www.euei-pdf.org/sites/default/files/field_publication_file/EUEI_PDF_Cambodia_Energy_Efficiency_May2013_EN.pdf.

Participant 14. (2018 & 2019) *Technology company/Interviewer: M. Boyle*.

Participant 16. (2018, 23 February 2018) *Start up business/Interviewer: M. Boyle*.

Participant 20. (2019, 12 April 2019) *Non profit environmental organisation/Interviewer: M. Boyle*.

Promsen, W., Janjai, S., & Tantalechon, T. (2014). *An Analysis of Wind Energy Potential of Kampot Province, Southern Cambodia*. *Energy Procedia, 52*, 633-641. doi:10.1016/j.egypro.2014.07.119

Ritzenhofen, I., Birge, J. R., & Spinler, S. (2016). The structural impact of renewable portfolio standards and feed-in tariffs on electricity markets. *European Journal of Operational Research, 255*(1), 224-242. doi:10.1016/j.ejor.2016.04.061

Sarkodie, S. A. (2019). Lessons to be learnt from Ghana's excess electricity shambles. Retrieved from: https://theconversation.com/lessons-to-be-learnt-from-ghanas-excess-electricity-shambles-121257

Sovacool, B. K., Mukherjee, I., Drupady, I. M., & D'Agostino, A. L. (2011). *Evaluating energy security performance from 1990 to 2010 for eighteen countries*. *Energy, 36*(10), 5846-5853. doi:10.1016/j.energy.2011.08.040

Ueasin, N., Liao, S.-Y., & Wongchai, A. (2015). The Technical Efficiency of Rice Husk Power Generation in Thailand: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis. *Energy Procedia, 75*, 2757-2763. doi:10.1016/j.egypro.2015.07.518

Tun, Juchelkova, Win, Thu, & Puchor. (2019). Biomass Energy: An Overview of Biomass Sources, Energy Potential, and Management in Southeast Asian Countries. *Resources, 8*(2), 81. doi:10.3390/resources8020081

Ueasin, N., Liao, S.-Y., & Wongchai, A. (2015). The Technical Efficiency of Rice Husk Power Generation in Thailand: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis. *Energy Procedia, 75*, 2757-2763. doi:10.1016/j.egypro.2015.07.518

Verbong, G., Christiaens, W., Raven, R., & Balkema, A. (2010). Strategic Niche Management in an unstable regime: Biomass gasification in India. *Environmental Science & Policy, 13*(4), 272-281. doi:10.1016/j.envsci.2010.01.004

Yin, H., & Powers, N. (2010). Do state renewable portfolio standards promote in-state renewable generation?. *Energy Policy, 38*(2), 1140-1149. doi:10.1016/j.enpol.2009.10.067

York, R., & Bell, S. E. (2019). Energy transitions or additions? *Energy Research & Social Science, 51*, 40-43. doi:10.1016/j.erss.2019.01.00

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