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Air Conditioning Equipment Installation in Singapore, 2012. Photo by RudolfSimon (Permission under CC BY-SA 3.0).

INTRODUCTION

The main theme of this issue is energy efficiency in a low emissions environment in Singapore and the ASEAN region.

The twentieth century witnessed historically unprecedented rates of growth in energy systems, supported by the widespread availability of fossil fuel resources. During the second half of the century, however, concerns associated with the high levels of fossil fuel dependence began to surface. Two issues were of particular significance: the impact of modern energy systems on the environment and security issues associated with fuel supply lines.

Environmental concerns over energy use are not new and have been evident in more localised areas for many centuries. Ancient Rome burned wood and Emperor Nero's tutor, Seneca, complained of the bad effect that smoke had on his health and of smoke damage to temples, whilst anecdotal evidence indicates that air pollution had been a concern in England as early as 1352 when a ban was introduced on the burning of coal in London. Transgressors were hanged! Today, local pollution from energy systems remains a threat to the health of the living environment. However, in the latter decades of the twentieth century, pollution resulting from the combustion of fossil fuels became a global concern, with the publication of credible scientific evidence that the planet's climate was changing as a result of the build-up of so-called greenhouse gases in the atmosphere.

The six contributions that follow reflect a sample of on-going research work within the Energy Economics Division of the Energy Studies Institute (ESI). Either directly or indirectly, all six have a link to energy efficiency in a low emissions environment, focussing particularly on Singapore and the broader ASEAN region.

Globally, the increase in investment in renewable energy technologies for generating electricity has far exceeded projections made just two decades ago. Then, the conventional wisdom was that wind and solar

In this issue ...

power could only be niche technologies due to their intermittent nature and, in any case, they were far too expensive and inflexible to compete with the traditional fuels of coal and gas for meeting the world's growing electricity requirements. However, the drive to lower greenhouse gas emissions from the combustion of fossil fuels, combined with (over?) generous government subsidies in many countries, has delivered significant economies of scale to the solar and wind industries that now permit them to compete with fossil fuel technologies in many of the world's liberalised electricity markets.

The issue of intermittency remains, and in the first contribution to this issue of the ESI Bulletin, Professor Anthony Owen, ESI Principal Fellow and Head of the Energy Economics Division, analyses the costs of intermittency to the power generation sector in a generic context, but with reference to Singapore and its current electricity market structure. Who bears the costs remains an open question, particularly as calculating them is fraught with difficulty. Nevertheless, it is a question that must be addressed with the anticipated higher degrees of penetration of renewables in the grid in the future.

The International Energy Agency (IEA) estimates that investments in power generation and infrastructure in ASEAN will increase by two-thirds by 2040, driven by strong economic and population growth. Liu Yang, ESI Senior Fellow, draws our attention to the fact that ASEAN's renewable energy and energy efficiency programmes should be viewed as complementary and not independent of each other. He addresses the issue of how energy efficiency potential in ASEAN can be unlocked in a cost-effective manner, thus reducing its reliance on meeting anticipated increases in demand with higher cost renewable technologies. He recommends a framework of integrated policy, market design and business models to balance energy demand- and supply-side investments on an equal footing.

Improvements in the efficient use of energy may arise from two sources: either an exogenous increase in energy efficiency or a policy-induced improvement in energy efficiency. Evolving technologies that produce goods which use less energy to deliver the same, or a higher, level of services than their predecessors, often drive the former. Many consumer-based electrical goods, such as television sets, notebook computers, mobile telephones, etc., would fall into this category. The latter are largely driven by government policies that attempt to overcome market barriers or distortions, and often involve a cost to the consumer. Examples would be the setting of minimum levels of energy efficiency for consumer white goods, a ban on the sale of incandescent light bulbs, emission standards for motor vehicles, etc. The degree to which the effective resulting increase in consumer income is spent on goods with an embodied energy content is known as the rebound effect, and was the subject of an ESI study in the context of more efficient air conditioners being installed in Singaporean households. A summary of this study's methodology and results is provided by Brantley Liddle, ESI Senior Research Fellow, in the third contribution.

Green bonds were created to fund projects that have positive environmental and/or climate benefits. The majority of the green bonds issued are green "use of proceeds" or asset-linked bonds. Proceeds from these bonds are earmarked for green projects but are backed by the issuer's entire balance sheet. The green bond market has seen strong growth over recent years. Although the market commenced in 2007, it only really started to take off in 2014 when USD 37 billion was issued. The 2018 issuance reached a record USD 167.3 billion. Dr. Dina Azhgaliyeva, ESI Research Fellow, and Mr. Anant Kapoor, final year Bachelor's student at Singapore Management University, report in detail on green bond issuance in Singapore and the implementation of the Green Bond Grant Scheme by the central bank of Singapore and the projects that they are designed to support.

Large scale deployment of solar photovoltaics and wind energy would require significant amounts of land and significant increases in electricity infrastructure across the Southeast Asian region in order to meet the targets set for renewable energy production to 2040. Dr. Victor Nian, ESI Senior Research Fellow, investigates the prospects for the development of offshore low carbon emissions technologies by considering the business case for offshore wind power production by Singapore. Whilst the levelised cost of energy from the various sites covered by his study was not competitive with the combined cycle gas turbine technology currently supplying the vast bulk of Singapore's electricity requirements, he concluded that cost reductions in submarine power cables were critical for reducing the difference.

The final contribution, by Dr. Kim Jeong Won, ESI Research Fellow, is concerned with access to energy, specifically in sub-Saharan Africa. Globally, around one billion people (or about 14 per cent of the world's population) are without access to electricity, with extreme poverty being one of the major causes of this situation (and hence its high level of occurrence in sub-Saharan Africa). With the decrease in the cost of solar photovoltaic technologies in recent years, off-grid solar PV systems have become a viable source of power for some of the less impoverished nations. However, a number of challenges remain. Clearly, the ability to pay is a major concern and business models have been developed with the intention of resolving this issue that hampers private sector investment. The pay-as-you-go model overcomes many of the obstacles to an individual's inability to meet the upfront investment costs that would otherwise be required, but Dr. Kim concludes that in order for the benefits of off-grid solar to become more widely adopted, improvements are required in consumer awareness and product quality.

We hope you find these articles of interest and welcome your views and comments.

Professor Anthony D. Owen,
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(On behalf of the ESI Bulletin Team)

The Cost of Intermittency in the National Electricity Market of Singapore

Professor Anthony D. OWEN, ESI Principal Fellow and Head of the Economics Division

Singapore City Skyline Dusk Panorama, 2011. Photo by chenisyuan (Permission under CC BY-SA 4.0).

In 2003, electricity trading in Singapore moved to the National Electricity Market of Singapore (NEMS), which is a pool-type wholesale market based on bid-based, security constrained economic dispatch (SCED) with locational marginal pricing (LMP). The NEMS is a real-time energy-only market and does not operate a day-ahead market (DAM) as is the practice in many electricity markets around the world. Rather, it bears a close resemblance to the Australian National Electricity Market (NEM) and the New Zealand wholesale market. Instead of actually clearing the market in advance as in the DAM, a series of indicative scenarios are run at regular intervals based on load forecasts that allow generators to get a sense of the expected market conditions and make their bidding strategies accordingly.

The NEMS co-optimises the procurement of energy and three other ancillary services: primary reserves and contingency reserves for maintaining frequency in times of generator/demand outage; and regulation for maintaining real-time balance with generation and demand. For every half hour dispatch interval, generating units of capacity higher than 10 MW are required to submit ten price-quantity bid pairs for energy, five price-quantity bid pairs for each of the two categories of reserves and five price-quantity bid pairs for regulation.

The Power System Operator (PSO) provides demand forecasts and network data. These datasets are received by the Energy Market Company (EMC) which runs the market clearing engine and produces the least-cost dispatch solution, whilst considering the various constraints such as transmission and systems constraints, generator dynamics and requirements of ancillary services. The market is cleared for a system of more than 700 nodes across the island, although the price differential between different nodes is generally very small.

Other electricity markets have different classes of reserve products that are either fast-responding (catering for battery-type service providers with milli-second response times) and/or bi-directional (upward and downward ramping).

Singapore does not provide special rewards for fast ramping or downward ramping products in its market. Such reserve products, if implemented in Singapore, could be additional levers that would allow Singapore's electricity market to be more efficient (e.g. by reducing the reserve requirements per trading period), better enable solar intermittency integration and better able to maximise the value of batteries at meeting market requirements.

The Energy Market Authority (EMA) in 2018 has indicated that an Intermittency Pricing Mechanism (IPM) will be implemented in Singapore "around 2020" when the relevant market rules and information technology systems are in place. The IPM can further stabilise energy storage applications as it incentivises intermittent generation source (IGS) installations to come up with solutions to proactively manage their intermittency. IGS refers to renewable energy generation with fluctuating power output, such as solar and wind energy, where electricity production is determined by weather conditions. Based on current technologies, solar generation, which generates no carbon emissions and requires no fuel imports, offers the greatest potential for deployment in Singapore. The IPM effectively internalises the frequency and magnitude of any output loss occurring for all generation units in each half-hour period and distributes the reserves costs according to their contribution to the intermittency. Known as the "causer-pays principle", the concept has been adopted in other jurisdictions (e.g. Australia, Spain, Denmark, and California).

The IPM will only apply to non-residential consumers with embedded IGS and generators, with the former being exempt where investments in IGS had been connected to the system on or before 31 January 2018. Integrating an energy storage solution with an intermittent generation source, such as solar energy, may reduce the intermittency of output and burden on the system. IGS with energy storage should be treated as separate from the IGS generating unit and allocated a lower Expected Output Reduction Rate (EORR) as the probability of forced power outage is lower. This would lower the cost of reserves for storage installations. As intermittent renewable electricity sources increase, spot market prices are likely to become more volatile, thus giving opportunities for price arbitrage and profitability from energy storage and/or demand management. The system impacts of IGS integration provide both costs and benefits, and the major impacts are outlined below. However, it is important to be aware that these impacts are not mutually exclusive, so it is not appropriate to aggregate them to achieve a single outcome.

• Reserve requirements and costs

The entry of IGS into the system would normally be expected to increase the amount of flexible, dispatchable, generation capacity that must be held in reserve to cope with short-term fluctuations in output that result from varying wind speeds or solar insolation levels. The cost of this additional capacity is likely to be relatively modest at low levels of IGS penetration, whilst international experience at very high levels (say, 50 per cent) varies widely depending upon system flexibility. There is always the possibility of high-cost "outliers" in inflexible systems.

• Curtailment

Output from an IGS source may need to be curtailed if it cannot be accommodated on an electricity system. This may occur because of insufficient transmission grid capacity or where the volume of IGS output at a given time would otherwise have exceeded total demand. It should be noted, however, that some level of curtailment may be both economically rational and sensible from a system operator perspective.

• Capacity credit and costs

Capacity credit is a measure of how much conventional plant can be replaced by IGS generation whilst retaining overall system reliability at peak demand. It is likely to vary significantly, depending upon the country/region being analysed and the technologies involved. However, many studies (based largely upon wind) suggest that capacity credit declines as IGS penetration rises. Capacity costs are derived by calculating the cost of conventional plants which are used to compensate for the lower capacity credit of IGS generators.

• Transmission and network costs

The addition of an IGS plant to a system may impose costs for the electricity transmission infrastructure required to connect the plant to the grid. Reinforcement of other parts of the grid may also be necessary to permit electricity generated to reach load centres. This is not strictly a cost resulting from the variable nature of supply, rather a locational one, and conventional generation plants incur the same costs and may themselves be relatively distant from load centres.

• Thermal plant efficiency

The principal aim of adding IGS generation to a system is to replace the output of fossil fuel plants to secure fuel and emissions savings. However, these savings may be partially offset if the efficiency of the remaining conventional plant is detrimentally affected. In general, improved forecasting of fluctuations in IGS should result in fewer losses since the most efficient mix of plants can be scheduled.

• System inertia

Analyses of the impact of reducing system inertia resulting from adding IGS generation have, to date, focused on the technical challenges that this may pose, rather than assessing any monetary impacts. Additional costs arising from system inertia are likely to become significant only at very high degrees of penetration of IGS (i.e. greater than 50 per cent).

• Who pays for additional costs associated with IGS?

As mentioned earlier, the EMA has proposed an Intermittency Pricing Mechanism that effectively internalises the frequency and magnitude of any output loss occurring for all generation units in each half-hour period and distributes the reserves costs according to their contribution to the intermittency.

• Electricity market impact: the merit order effect in the presence of IGS

The philosophy behind electricity market liberalisation is that by forming a competitive marketplace, wholesale prices will reflect each generator's short run marginal cost (SRMC) of production.[1] As a result, conventional generators are pushed down in the merit order by the entry of negligible SRMC renewable technologies. This is a positive result in terms of emission reductions and fuel savings. However if the effect is to reduce the load factors of these plants to the extent that their long-term profitability is affected, they may cease to operate and/or may deter investment in new conventional plants. To the extent that such plants are required to provide system balancing services, alternative remuneration mechanisms may be required (e.g. capacity or availability credits).

1 However, in practice this may often not be the case and opportunities to exert market power may arise. Market power is a feature of most electricity markets, offering generators the potential for bidding parcels of output at prices significantly higher than their SRMC when capacity is in short supply. Even in the absence of market power, generators are likely to bid parcels of output at a range of prices that reflect (from low to high) minimum technical operating efficiency level, SRMC and rent seeking behaviour.

What Does a More Ambitious Target for Energy Efficiency Mean for ASEAN?

Dr. LIU Yang, ESI Senior Research Fellow

Saint Jude Catholic School, Manila, Philippines, 2009. Photo by Icqgirl (Wikimedia Commons, public domain).

The Growing Challenges of Future Energy Demand in ASEAN

Southeast Asia is playing an increasingly important role in the global energy landscape. Today, ASEAN is the world's seventh largest economy and fifth largest investment destination. The region is projected to become the world's fourth largest economy by 2030. The population is set to rise by more than 10 per cent to 690 million by 2020. As energy will underpin this economic growth, investments in power generation capacity and infrastructure will be needed to meet ASEAN's energy demand, which has grown by 60 per cent over the past 15 years. The International Energy Agency estimates that the investments will continue to grow by another two-thirds by 2040.

Strong economic growth and rising population fuelled an increase in total final energy demand by a factor of 4.5 between 1971 and 2015. Currently, some ten per cent of the ASEAN population (about 65 million people), still do not have access to electricity, and 40 per cent of the ASEAN population rely primarily on the traditional use of biomass.

Policy has an important role in empowering energy efficiency. Both market- and non-market-based policy instruments are required to accelerate energy efficiency improvements in ASEAN. The ASEAN Plan of Action for Energy Cooperation (APAEC) articulates four strategies to attain higher energy efficiencies. These include (a) harmonisation of EE standards for energy-related products, (b) enhancing private sector participation through energy service companies, (c) development of green building codes and (d) increased participation of financial institutions in energy efficiency and conservation.

The ASEAN-wide Energy Intensity Reduction Target is Too Conservative

In 2015, the APAEC designated collective energy targets for all member states. These targets included a 20 per cent reduction in energy intensity by 2020 and a 30 per cent reduction by 2025 based on 2005 levels, as well as a 23 per cent share of renewables in total primary energy supply (TPES) by 2025. ASEAN is on track to meet its collective energy intensity reduction targets. By 2016, ASEAN had already accomplished 21.9 per cent of the desired energy intensity reduction, exceeding its target for 2020. While it is certainly a positive signal, it also raises questions whether the APAEC's targets were rational.

If we assume that the ASEAN member states continue to reduce their energy intensity at a constant rate of approximately 2 per cent per year until 2030, which was the average from 2005 to 2016, there would be an almost 30 per cent reduction in energy intensity by 2020, and an estimated 50 per cent reduction by 2030. This means that ASEAN could achieve its 2025 target five years ahead of schedule. Given the positive showing that ASEAN has demonstrated in the past, higher targets may be necessary to encourage governments to seriously intervene in their domestic markets to promote energy efficiency.

Given that it is likely that the growth rate in energy intensity reduction is exponential, instead of linear across time, the existing gradated targets may also estimate energy intensity reduction rates too conservatively.

As governments implement robust energy policies and endorse green financial instruments, entire ecosystems develop around sustainable energy in these countries. Putting a stronger focus on energy efficiency, and offering more opportunities for new entrants and greater competitiveness in the market will result in a virtuous cycle such that annual energy intensity reduction rates will likely exhibit tremendous growth. APAEC should consider adjusting its future targets to become even more ambitious, such that ASEAN member states will remain active in their pursuit of domestic energy intensity reductions that exceed business-as-usual rates.

Improving Energy Efficiency Can Support a Range of Long-term Energy Targets

It is necessary to examine the interaction of energy efficiency targets with other targets, for example, increasing the uptake of renewable energy, and reducing GHG emissions in order to mitigate climate change.

Since ASEAN does not undertake international climate negotiations as a bloc, the region has neither a singular climate policy nor a defined greenhouse gas emissions reduction target. Therefore, ASEAN's climate change mitigation goals are either encompassed by its collective energy intensity reduction target, or by the energy efficiency and/or emissions reduction targets adopted individually by ASEAN member states through their nationally determined contributions.

ASEAN's renewable energy and energy efficiency-related efforts should not be perceived as two separate measures, but as complementary tools to increase the synergy within the policy mix. Increasing ASEAN's energy efficiency, that is reducing the energy intensity further than already committed, will also reduce the region's total energy use. As a result, even with the existing renewable energy capacity, the share of renewable energy will increase in the energy mix and help phase out fossil-fuel energy sources.

Controlling energy consumption through energy efficiency measures is a cost-effective option compared with heavy investments in renewable energy infrastructure. Furthermore, as renewable energy technologies gradually become cheaper in the medium- to long-term, energy efficiency measures can address ASEAN's low-carbon energy transition in the short-term. Therefore, in order for ASEAN to achieve its renewable energy targets, maximising the region's energy efficiency potential is essential.

The financial implications are significant with the optimisation potential of long-term investments driven by energy efficiency improvements. Energy generation, transmission and distribution infrastructure must have the flexibility to cope with both the lowest and highest levels of demand. The electricity infrastructure is typically sized for peak demand which may occur during only a few hours per year. The capacity is underutilised over the majority of off-peak times. Ultimately, the costs of over-investment have to be passed through to the end-consumers. Therefore, in order to make an optimal investment plan, it is particularly important to reduce the growth rate of peak load demand and make the demand curve flatter. Energy efficiency improvements in various sectors can not only reduce the peak demand but also enable better energy system planning and integrate more options for new loads.

The Rebound Effect: An Example for New Air Conditioners in Singapore

Dr. Brantley LIDDLE, ESI Senior Research Fellow

There is a well-recognised phenomenon—sometimes called the rebound effect—that a behavioural-market response to efficiency improvements is increased consumption. A direct rebound effect occurs because improved energy efficiency effectively reduces the price of (an) energy service. We employed 45 months' of energy bills and survey data from Singaporean households and the Fixed Effects (FE) difference-in-differences (DID) estimator to evaluate the actual energy savings from a new air conditioner (AC) purchase and estimated the extent of the direct rebound effect on such a purchase. We focused on ACs since they account for a substantial share of household electricity consumption (e.g., 24 per cent in 2017 according to the NEA).[1] In addition, the market average AC in Singapore is only 56 per cent as efficient as the best available.[2] Hence, the potential for substantial electricity savings for cooling exists.

The direct rebound effect manifests itself in three possible ways: more units, more intense and more frequent. In the case of air conditioning, more units would mean more or larger capacity ACs; more intense would mean setting the desired temperature lower; and more frequent would mean using the AC for more hours. Even though some rebound effect is an inevitable/natural demand response, the finding of a rebound is sometimes seen as a negative occurrence since it means that the achieved savings are less than the best-case technical estimates. Also, if the efficiency policy was motivated by reducing an economic bad (e.g., pollution) and that negative externality is not priced, then the goal will not be accomplished. But the rebound effect is associated with positive developments. For example, it may reflect that previously unfulfilled demand is now met, i.e., welfare has increased.

A common definition of the "rebound effect" is the difference between "expected energy savings" and "actual energy savings" divided by expected energy savings. Expected energy savings should be the energy consumption level with the energy efficiency improvement had there been no behavioural response. "Expected energy savings" are typically based on engineering estimates. The "actual energy savings" are often calculated using household survey data and econometric

HDB Flats at Toa Payoh New Town, Singapore, 2006. Photo by Terence Ong (Permission under CC BY-SA 3.0).

techniques that control for possible fixed effects across different households.

Previous international empirical rebound effect estimates for household heating and cooling lie in the region of around 30 per cent. In other words, improvements in energy efficiency should result in a 70 per cent reduction in energy consumption when compared to engineering estimates. Two recent studies that employed similar methods to ours found little to zero energy savings for ACs in Japan[3] and an overall increase in electricity consumption (i.e., a full take-back or backfire) in Mexico.[4]

The Study

The criteria for participation were that the households must be owners of a dwelling in Singapore and possess an existing AC at the time of their participation. Our contractor reached out to approximately 6,000 households between March and June 2016 to partake in the study and achieved a success rate of approximately one in every 10 households contacted. After dropouts and adjusting for data errors, omissions and discrepancies, the ultimate sample consisted of 571 households. The households were divided into: a control group, i.e., households who purchased an AC before 2008 and had no intention to replace their ACs within the timeframe of the study; and a treatment group, i.e., households who either (i) planned to replace their existing ACs with models that were rated at least 3-ticks under the National Environment Agency's energy rating system within six months of the study or (ii) replaced their ACs a year or less before the start of the study with models that were rated at least 3-ticks.

We combined that household survey data with monthly consumption data (45 months' worth) provided by the Energy Market Authority (EMA) of Singapore. In addition, we collected data on attributes like temperature, rainfall and humidity.

Methods, Results, and Discussion

To estimate electricity savings, we employed a type of fixed effects (FE) estimator called the difference-in-differences model (DID), where electricity savings are calculated based on differences between the treatment group and counterfactual after controlling for other observable factors such as weather variables and socio-demographic characteristics. The control group was meant to act as a baseline that imitates the electricity demand of the treatment group in the counterfactual/hypothetical situation that the treatment group had not purchased a new AC. The DID approach relies heavily on the common trend assumption, i.e., all the households should ideally follow a similar consumption pattern prior to the purchase of new ACs by the treatment group. We confirmed that the difference in trends between the control and treatment group was not significant.

Also, we applied a method that matches the pre-treatment covariates in the treatment group with that of the control group by multidimensional histograms. Trimming our sample in the above way leads to more significant and larger-in-magnitude estimates of energy savings. Using these methods, our best estimate of electricity savings was 7.8 per cent. In addition, we checked for a persistence effect by allowing the electricity savings effect to vary over three months after the month of purchase. While there is evidence that electricity savings decrease over time, long-run savings do persist.

To calculate the expected electricity savings on air conditioning we weighed co-efficient of performance (COP) band values for each tick rating—setting the base value COP for inefficient ACs or those with a 1-tick rating in 2008 at 2.64—by NEA's sales data containing the percentage share for each tick model sold from 2008 to 2014. This approach results in a weighted average expected savings of 29.7 per cent. Because our regressions estimate the total household electricity savings, we need to adjust for the share of household energy/electricity consumption used by ACs. From our sample metered data, ACs account for approximately 36.7 per cent of households' electricity consumption. Hence, our best estimate of expected electricity savings is 11 per cent. These two estimates (of actual and expected savings) suggest a rebound effect or take-back of savings of 27 per cent ((11-8)/11). This estimate of a 27 per cent rebound is (i) roughly similar to other estimates for household heating and cooling[5]; (ii) less than the nearly 100 per cent to over 100 per cent rebound calculated in two recent, similar studies (considering Japan and Mexico, respectively), and in line with the rebound effect that was suggested from our estimate of the price elasticity (which was -0.3). Also, such a less-than-100 per cent of theoretical savings achieved is in line with economic/behavioural theory since after purchasing a new AC, households may (i) use a lower temperature setting, or (ii) use the AC longer in order to (1) fulfil (previously) unmet demand, and/or (2) respond to the effective lower costs of running the AC.

1 Singapore National Environment Agency, *Household Energy Consumption Study 2017* at https://www.e2singapore.gov.sg/households/saving-energy-at-home/households-studies.

2 International Energy Agency. *The Future of Cooling: Opportunities for Energy-efficiency* (Paris: OECD/IEA), 2018.

3 K. Mizobuchi and K. Takeuchi, "Replacement or Additional Purchase: The Impact of Energy-Efficient Appliances on Household Electricity Saving under Public Pressures", *Energy Policy* 93 (2016: 137-48).

4 Lucas W. Davis, Alan Fuchs and Paul Gertler, "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico", *American Economic Journal: Economic Policy*, 6, 4 (2014: 207-38).

5 For example, see S. Sorrell and J. Dimitropoulos, "UKERC Review of Evidence for the Rebound Effect", Technical Report 2: Econometric Studies (London: UK Energy Research Centre, 2007).

Singapore's Green Bond Subsidy Scheme: A Review

Dr. Dina AZHGALIYEVA, ESI Research Fellow, and Mr. Anant KAPOOR, Final year Bachelor's student, Singapore Management University

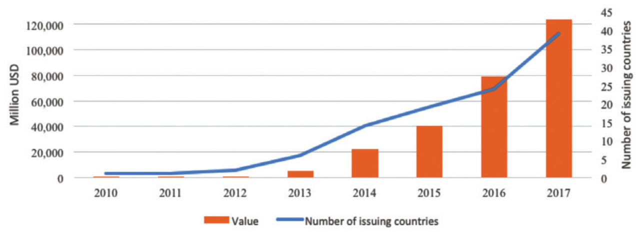
Jurong East, Singapore, 2016. Photo by Edsel Little (Permission under CC BY-SA 2.0).

Background

The Inter-Governmental Panel on Climate Change in their latest report noted that mobilisation of climate finance is critical to limiting global warming to 1.5˚C, and to prevent catastrophic climate change. To fully implement the Paris Agreement, USD 1.5 trillion of green financing is required every year till 2030.[1] Increasing low-carbon investments to the level necessary for the 1.5˚C pathway requires a major shift in investment patterns.[2] This shift would require government policies to redirect financial resources.

Green bonds have been attracting an increasing degree of interest across Asia and the world, as an alternative source to finance low-carbon investments. While the proceedings from generic bonds can be used to fund any legal project, those from green bonds can be used to fund only low-carbon projects such as those that affect climate change mitigation or adaptation, natural resources, biodiversity conservation, or pollution prevention and control.[3] The market for green bonds has grown rapidly, from USD 3 billion in 2012 to over USD 100 billion in 2017 (see Figure 1).

Figure 1: Global Green Bond Issuance

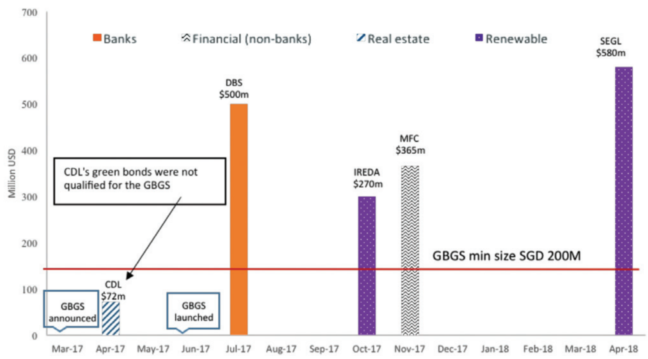


Data source: Bloomberg Terminal.

New Government Policies

New government policies supporting green bonds have recently been implemented, such as green bond guidelines/standards, green bonds disclosure/reporting, public issuance of green bonds and green bond grant schemes. Two years ago, in March 2017, the Monetary Authority of Singapore (MAS), which serves as the central bank of Singapore, announced its intention to implement the *Green Bond Grant Scheme* (GBGS) to promote the development of green bonds in Singapore.[4] The 3-year GBGS was implemented for the period June 2017 to May 2020. The GBGS allows reductions in the cost of issuance of green bonds through subsidisation of the cost of an external review, which is a mandatory requirement for labelling bonds as 'green'. The GBGS can incentivise green bond issuance because the cost of an external review is one of the key barriers in the early stages of green bond issuance.[5] The GBGS covers the entire reviewing cost up to SGD 0.1M (≈USD 0.07M). Similar green bond subsidies covering the cost of an external review are provided in Hong-Kong up to HKD 0.8M (≈USD 0.1M), Japan up to JPY 50M (≈USD 0.5M) and Malaysia 90 per cent up to RM 0.3M (≈USD 0.07). Although Singapore's GBGS does not offer the largest green bond subsidy, it has the least restrictions on eligibility criteria. For example, the GBGS accepts all international green bond standards. In addition, the GBGS is neither limited to local companies nor to local projects (Figure 2 and Table 1):

Figure 2: Green Bonds Issuance in Singapore



Source: Compiled by the author.

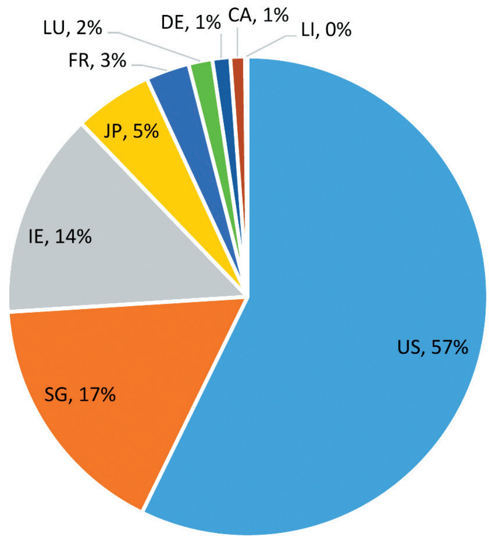
Table 1: Green Bond Issuance in Singapore and the GBGS

Criteria	GBGS Qualification	CDL	DBS	IREDA	Manulife	SEGL
Sector	Any	Real estate	Bank	Government	Life insurance	Energy
Issuance, place	Singapore	Singapore	Singapore	Singapore	Singapore	Singapore
Listing, place	SGX	SGX	SGX	SGX	SGX	SGX
Principal, million	SGD 200	SGD 100	USD 500	INR19,500 (USD 300)	SGD 500	USD 580
Tenure, years	≥3	2	5	5	12	15
Green Bond Standards						
ICMA GBP CBI CBS ASEAN GBS						
Company location	Any	Singapore	Singapore	India	Singapore HQ in Canada	Indonesia
Coupon	Any	1.98 % due in 2019	quarterly coupon of 3-month USD LIBOR + 0.62%	annual coupon of 7.125%.	3% for 7 years, 0.832% 5 - year SGD swap rate after.	semi-annual coupon of 6.75%
Currency	Any	USD	USD	INR	SGD	USD
Project	Green	Green building	Green building	Solar & wind energy	Solar & wind energy	Geothermal energy
Project location	Any	Singapore	Singapore	India	Canada & USA	Indonesia
Impact		6,000 MWh of energy savings and 33% emission reduction per year	11,423 MWh of energy savings and 4,848 tons of CO2 avoided in 2017	831 MW capacity of renewable energy	127 MW capacity of renewable energy	The world's largest geothermal plant

Note: LIBOR - London Interbank Offered Rate, CBI CBS – Climate Bond Initiative's Climate Bond Standard, ICMA GBP – International Capital Market Association's Green Bond Principles, ASEAN GBS – ASEAN Capital Markets Forum's ASEAN Green Bond Standards. Highlighted in grey are those not meeting the GBGS requirements.

Source: Compiled by the author.

Figure 3: Holders of Green Bonds Issued in Singapore



Note: US - United States of America, SG - Singapore, IE - Ireland, JP - Japan, FR - France, LU - Luxembourg, DE - Germany, CA - Canada and LI – Liechtenstein. Data source: Bloomberg Terminal.

- **City Developments Limited** (CDL) used SGD 100 to re-pay a loan which financed energy and water efficiency improvements in the skyscraper, Republic Plaza. This building was awarded the highest Green Mark Platinum Rating by Singapore's Building and Construction Authority (BCA). Each year it saves six million kWh of energy, which is equivalent to 33 per cent emissions reduction.[6]
- **DBS** Bank used USD 500 towards green assets comprising DBS' financing of the Marina Bay Financial Centre Tower Centre 3, a commercial property in Singapore, certified Green Mark Platinum by the BCA. This green building saved 11 million kWh of energy and 4,848 tons of CO_2 emissions in 2017.[7]
- **Manulife Financial Corporation** (Manulife) used SGD 500 to install 127 MW capacity of solar and wind energy in Canada and the US.
- **Star Energy Geothermal Limited** (SEGL) used USD 580 to acquire two geothermal fields in Indonesia, one of which is the world's largest.
- **Indian Renewable Energy Development Agency** (IREDA) used INR 19.5 million to finance 831 MW capacity wind and solar energy in India.

Purchase of Green Bonds

Both local and foreign investors purchased green bonds issued in Singapore. Green bonds listed on the Singapore Stock Exchange (SGX) were purchased by beneficiaries from the US, Singapore, Ireland, Japan, France, Luxembourg, Germany, Canada and Liechtenstein (see Figure 3). The largest share of green bonds listed on the SGX (57 per cent) were purchased by investors from the US. The second largest investment was made by investors from Singapore, which is 17 per cent of all listed green bonds. Around 14 per cent of all green bonds listed on the SGX were purchased by investors from Ireland, followed by Japan (5 per cent), France (3 per cent), Luxembourg (2 per cent), Germany (1 per cent) and Canada (1 per cent). Hence most green bond investments were coming from outside Asia, with investors from Asia, other than from Singapore, investing very little in green bonds listed on the SGX.

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The Prospects for Offshore Energy Resources in Southeast Asia

Dr. Victor NIAN, ESI Senior Research Fellow

Wind Turbine at Laem Phromthep, Phuket, Thailand from a pilot project of the Electricity Generating Authority of Thailand, 2014. Photo by Phuket@photographer.net (Permission under CC BY 2.0).

Introduction

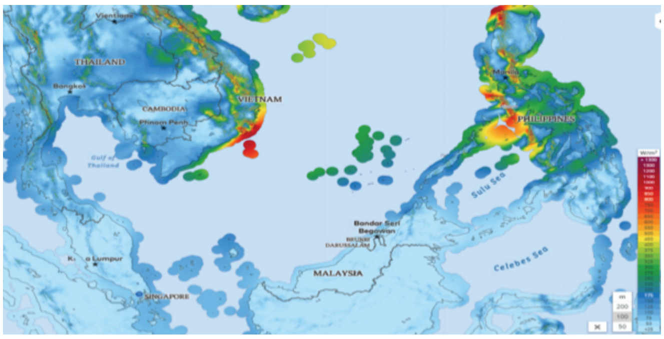
The Southeast Asian region is generally well endowed with fossil and renewable energy resources. In 2010, the International Energy Agency (IEA) found that the technical potential for renewable energy in the Association of Southeast Asian Nations (ASEAN) was approximately 150 GW of hydropower, 90 GW of bioenergy, tens of gigawatts of wind only suitable in Vietnam and the Philippines, and minimum grid connected solar PV.[1] In the IEA's continuous updates on the *Southeast Asia Energy Outlook*, more renewable technologies, especially solar photovoltaic (PV) and potentially wind could be deployed with the right policy and market designs.[2] While Singapore has ruled out the option of nuclear energy for the moment, albeit keeping it as a strategic long-term option, several ASEAN member states, especially Indonesia and Malaysia remain strongly interested in nuclear energy, the advanced Generation IV and small modular reactors in particular.[3]

Deployment of Solar PV and Wind Resources

Large-scale deployment of solar PV and wind requires vast amounts of land, and also significant enhancement to the existing electricity infrastructure. The tropical climatic conditions, contrary to popular belief, are not conducive to the harvesting of solar and wind energy resources in a cost-effective manner. While the costs of PV modules and wind turbines are falling rapidly across the globe, there are persistent technical, policy and financial barriers preventing ASEAN from embracing these energy resources at large scale. While floating PV technologies are gaining momentum, it is still too early to ascertain the overall contributions that floating PV systems could make in ASEAN.

Singapore is completely dependent on energy imports with natural gas being the dominant fuel.[4] In the Industry Transformation Map, Singapore's Ministry of Trade and Industry has identified offshore wind power as an opportunity to sustain long-term growth.[5] Such an announcement by a national government department challenges the traditional view of Southeast Asia's sub-optimal climatic conditions for renewable energy resources, especially offshore wind energy. The wind map of Southeast Asia suggests that the wind conditions in and around Singapore are in fact the least favourable in all of Southeast Asia, especially compared to selected parts of Malaysia, Thailand and Vietnam (see Figure 1).[6] However, channelling offshore wind power from those

Figure 1: Wind Map of Selected Areas in Southeast Asia



Source: Global Wind Atlas 2.0 : https://globalwindatlas.info. Licensed under CC BY 4.0.

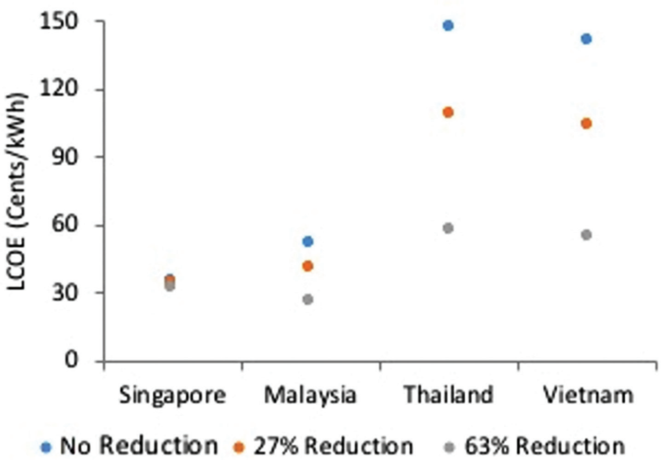
areas near Malaysia, Thailand or Vietnam to Singapore would require long-distance submarine power cables which are much more expensive than overhead and underground power cables. Moreover, the wind conditions in and around Malaysia, Thailand and Vietnam are still not as desirable as those found in Europe, North America and China.

Offshore Renewable Energy Resources

The critical question, therefore, is whether offshore renewable energy resources, in this case offshore wind, has a business case for Singapore. In an attempt to identify the bottom line for offshore wind energy deployment for Singapore, we conducted a cost-benefit analysis of offshore wind power production at selected locations near Malaysia, Thailand, Singapore and Vietnam. The distance at these selected locations is assumed to be 5200, 1500 and 2000 km away from Singapore, respectively. The annual mean wind speed as obtained from the wind map at those locations is 5, 7, 9 and 10 metres per second (m/s). The further the distance from Singapore, the higher the wind speed. This study included a detailed breakdown of main cost components such as turbine generators, transformer substations and submarine power cables so as to estimate the levelised cost of electricity (LCOE). The goal was to evaluate the economic feasibility of ultra-long-distance offshore energy production for Singapore.

The LCOE values of the assumed wind farm at selected locations were found to be driven mainly by the increase in the distance between the assumed location of installation and the location of on-shore grid connections. The

Figure 2: LCOEs of Offshore Wind Energy in Southeast Asia at a 7 Per Cent Discount Rate under the Influence of Distance of Deployment and Submarine Power Cable Cost Reductions



Source: Data compiled by the author.

distance is the main driver for the cost of submarine power cables. The LCOE value is increased from 44.6 to 55.4, and to 148.9 cents/kWh from Singapore to Malaysia, and to Thailand. From Thailand to Vietnam, the LCOE value is reduced from 148.9 to about 143 cents/kWh although the distance increases from 1500 km to 2000 km.[7] This reduction in the LCOE is mainly due to the increase in the assumed wind speed. Regardless of the distance and wind conditions, the LCOEs for the reference wind farm were at least six times higher compared to the LCOE of combined cycle natural gas (CCGT) power generation in Singapore. However, it is evident from the study that cost reductions in submarine power cables are absolutely critical for reducing the LCOE values of offshore wind energy in addition to the falling costs of wind turbine generators and efficiency improvements.

Another important lesson learned from the offshore wind energy study is the importance of the annual availability factor of wind energy resources. There is always a limit on the cost reduction potential of turbine generators and submarine power cables. However, there are significant improvements in the availability factor either through technological innovation or increasing wind speed. In this study we further explored the possibility of vertical-axis wind turbine technologies which can lead to an LCOE value of 18-20 cents/kWh at 5 m/s wind speed assuming a maximum wind energy harvesting efficiency. In other words, technological innovation would eventually encounter physical limits at some stage and increasing wind speed is beyond human control.

The only other offshore energy resource which has a controllable availability factor is floating nuclear power plants. These are the only low-carbon energy resource that can be operated at a distance from the users while assuring the quality of electricity production. As reported in oilprice.com, "Akademik Lomonosov, the first functional floating nuclear power plant, is set to become operational in 2019 and provide energy for the remote port town of Pevek in Chukotka in Russia's far east".[8] While it is highly uncertain if floating nuclear power plants such as Akademik Lomonosov would ever become a mainstream energy producing option, there is no doubt that these technologies could emerge as a strong competitor against offshore renewable energy options in a future carbon-constrained world noting the importance of advanced and safer nuclear power technologies.[9] Perhaps, one day, the Arctic example will reshape attitudes towards offshore nuclear energy in Southeast Asia.

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Off-Grid Electrification to Increase Energy Access in Developing Countries: Success Factors and Challenges from the Experience of Sub-Saharan African Countries

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Kenya Solar-powered Traditional House with Satellite Dish, 2019. Photo by ROYMUNENE (Permission under CC BY-SA 4.0).

Introduction

The world has been stepping up efforts to ensure universal access to modern energy and consequently has achieved a remarkable increase in the electrification rate. The proportion of the population with access to electricity in developing countries increased from 68.9 per cent in 2005 to 83.1 per cent in 2017. Off-grid electrification based on renewable energy, particularly solar PV generation, is regarded as one of the most significant ways to accelerate global access to electricity due to its cost competitiveness, innovative business models and rapid deployment. By the end of 2017, approximately 130 million off-grid solar PV systems had been installed and approximately 360 million people were supplied with electricity from them.[1]

Off-grid solar PV systems have enjoyed considerable success in East Africa. East Africa is the birthplace of the pay-as-you-go (PAYG) model for off-grid solar electrification. In 2016, it accounted for about 70 per cent of all sales of pico-PV and solar home systems (SHS) in sub-Saharan Africa. Kenya and Tanzania, in particular, have shown conspicuous growth in the off-grid energy sector. It is estimated that more than 50 per cent of the off-grid population in both countries benefit from off-grid solar PV systems. In 2016, they recorded the second highest and the fifth highest sales of off-grid solar systems. Out of 8.1 million off-grid solar products sold throughout the world in 2016, 1.2 million and 0.4 million products were sold in Kenya and Tanzania, respectively.[2,3] West African countries show a relatively lower performance in renewable energy expansion and have a smaller off-grid solar PV market than East African countries, but have recently been making efforts to catch up.

Key Factors for Electrification Trends

Without doubt, the precondition for success in renewable energy-powered off-grid electrification is cost decreases in renewable energy technologies and the availability of more efficient technologies. As the cost of solar PV has fallen to a fifth of the cost that it was in 2010, it has become an appropriate means to be scaled up with cost competitiveness. For example, in Kenya it cost USD 40 to buy a single fluorescent bulb and a lead-acid battery in 2009, but now residents there can enjoy four times the light they had in 2009 for the same price with LED bulbs and lithium-ion batteries. Also, they had to pay around USD 1,000 for a radio, a cell phone charger and a residential solar system in 2009, but now they pay only USD 350 for the same products.[4]

The growth of the electrification rate in sub-Saharan African countries is also partly attributable to the willingness to expand renewable energy and the support of the government. The Kenyan and Tanzanian governments established the Rural Electrification Authority and have implemented not only grid extension projects, but also various off-grid electrification projects. They have also implemented policies favourable to renewable energy including VAT and tariffs exemption on solar panels to provide fiscal incentives for the renewable energy sector.[5]

The primary driving force in the off-grid solar PV market growth in sub-Saharan Africa has been aggressive marketing and active operation of the private sector using the PAYG model. In West Africa, the role of the private sector has been more obvious because the governments still focus on providing on-grid energy solutions. Due to the spread of cell phones, the development of mobile payment technologies and the partnership with telecom operators, the off-grid solar PV providers introduced the innovative PAYG model. Customers receive a telephone credit check, sign a contract, make a payment in instalments using mobile money and own the system after certain periods of payments. Solar panels had already existed in sub-Saharan Africa before the recent off-grid market leaders ran their businesses, but they were not prevalent because customers had to bear high upfront costs. However, monthly payments through mobile money eased the financial burden of people who are willing to install SHS. Based on this business model, M-Kopa (Kenya, Tanzania and Uganda), Mobisol (Kenya, Rwanda and Tanzania) and Zola Electric (Rwanda, Tanzania and Uganda) have installed SHS in more than 600,000 households in Kenya, Rwanda, Tanzania and Uganda since 2012, and PEG Africa (Cote d'Ivoire and Ghana) and Lumos (Cote d'Ivoire and Nigeria) have sold around 90,000 SHS in Cote d'Ivoire, Ghana and Nigeria since 2013.

Participation of the private sector has enabled better and more varied services. Unlike the government-led projects which often lack after-service, the PAYG companies emphasise customer service. They provide door-to-door service and run customer care departments and service centres. Customers can call the service centre whenever they have a problem. The service agents are responsible for dealing with the customers' requests and have financial incentives for prompt handling.[6] The companies also provide other financial incentives for their customers. Customers of M-Kopa and PEG Africa can use their SHS as collateral for further loans which allows them to finance larger solar equipment or more expensive appliances including clean cookstoves, smartphones and refrigerators. PEG Africa and Mobisol offer the option of adding health insurance to their SHS services as an incentive for good customers. With the significant demand, Mobisol provided more than 5,000 SHS in combination with health insurance and approximately 11,000 families took up health insurance from PEG Africa's pilot project.[7,8]

Key Challenges

Despite the rapid growth in the off-grid solar PV market in sub-Saharan Africa, several challenges still exist. The most fundamental problem is the absolute poverty of potential customers. Even though the technology development brought significant cost reductions in solar PV products and the financial burden of customers has been relieved due to the monthly payments, they are still far beyond the ability of many off-grid residents to pay for them. A number of people earn their income irregularly and live on about USD 2 per day. Even people who can cover daily or monthly payments may not be able to pay an upfront deposit. Thus, one of the biggest challenges for off-grid electrification is creating a business model that is affordable for poor customers. Companies are also hindered by a lack of access to capital and other investment barriers. The lack of proven business models and the unavailability of reliable data and information increases the uncertainty of off-grid electrification projects, and consequently, makes securing bank funding and private investment more difficult due to their risk aversion. The PAYG model is regarded as a dominant business model, but the specific plans to guarantee its success have not been standardised and companies are therefore constantly experimenting with different plans.[9] Lastly, the awareness of consumers is low and the quality of products should be guaranteed.

Conclusion

Despite remarkable progress in raising the global electrification rate over the last decade, approximately 1.06 billion people in developing countries, or around 14 per cent of the global population, remain without access to electricity. Off-grid electrification based on renewable energy should be expanded in order to improve their quality of life and achieve the United Nation's Sustainable Development Goal 7 (SDG 7) (Ensure access to affordable, reliable, sustainable and modern energy for all). Other developing countries should note the experience of the sub-Saharan African countries in designing their own policies and business models for off-grid electrification.

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Victor Nian and Hari M. P., "A New Business Model for Encouraging the Adoption of Electric Vehicles in the Absence of Policy Support", *Applied Energy* 235 (2019): 1106-117.

Raimund Bleischwitz, Catalina Spataru, Stacy D. VanDeveer, Michael Obresteiner, Ester van der Voet, Corey Johnson, **Philip Andrews-Speed**, Tim Boersma, Holger Hoff and Detlef P. van Vuuren, "The Resource Nexus: A Perspective towards the UN Sustainable Development Goals", *Nature Sustainability* 1 (2018): 737-43.

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Dina Azhgaliyeva, "Energy Storage and Renewable Energy Deployment: Empirical Evidence from OECD countries", *Energy Procedia* 158 (2019): 3647-51.

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Melissa Low, Eric Bea and Sarah Lu, "Katowice Climate Package: Operationalising the Climate Change Regime in the Paris Agreement", *ESI Policy Brief 27* (3 January 2019).

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Anthony D. Owen, Anton Finenko and Jacqueline Tao, *Power Interconnection in Southeast Asia: Lessons Learned from International Experience* (London: Routledge, 2019).

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Other Publications

Gautam Jindal, "Retailer's Exit from Singapore's Electricity Market: No Need for Warning Bells", *Singapore Business Review,* 7 March 2019.

Gautam Jindal, "Retailer's Exit from Singapore's Electricity Market: No Need for Warning Bells", *Asian Power,* 6 March 2019.

Liu Yang, "Powering Prodigy: How to Unlock Electricity System Transformation and Solar Energy for Smart Cities", *Envision, National Environment Agency of Singapore*, December 2018.

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Staff Presentations and Moderating

28 March Shi Xunpeng presented "Frontier Issues in Gas Pricing Transition", at College of Economics and Management, Nanjing University of Aeronautics and Astronautics, Nanjing, China.

27 March Philip Andrews-Speed presented "Controversial Energy Technologies in China" at Yale-NUS College, Singapore.

27 March Christopher Len presented "Advancing Resource Cooperation and Fostering Community-Building Along the Lancang-Mekong" at the *2nd Think Tank Forum of the Global Center for Mekong Studies (GCMS)*, Vientiane, Lao People's Democratic Republic.

27 March Shi Xunpeng presented "Frontier Issues in Gas Pricing Transition", at the School of Politics and Economics, Nanjing Audit University, Nanjing, China.

25-26 March Liu Yang presented and moderated the workshop "Roundtable on Financing Energy Efficiency in the Manufacturing Sector: Insights from International Experience and Implications for Singapore" organised by ESI, Singapore.

25 March Melissa Low moderated "Roundtable on Financing Energy Efficiency in the Manufacturing Sector: Insights from International Experience and Implications for Singapore", organised by ESI, Singapore.

25 March Shi Xunpeng, presented "Water and Carbon Footprints of Hydrogen from Electrolysis: A Tale of Two Countries", 绿色"一带一路"与能源经济国际合作 *(Green Belt and Road and International Energy Cooperation)*, Wuhan University, Wuhan, China.

24 March Shi Xunpeng presented "Natural Gas in Energy Transition", 碳市场与能源转型*(Carbon Market and Energy Transition)*, Hubei University of Economics, Wuhan, China.

20-21 March Liu Yang participated as a discussant in the workshop "Carbon Markets and the Electricity Sector: Issues, Opportunities, and Priorities for East Asia" organised by the Konrad-Adenauer-Stiftung, the Chinese University of Hong Kong, Chulalungkorn University and the International Carbon Action Partnership and the Thailand Greenhouse Gas Management Organization in Bangkok, Thailand.

15 March Dina Azhgaliyeva presented "Green Bonds: Policies and Regulations" at the International Workshop on *Green Climate Financing* organised by MFA and NTU, Singapore.

15 March Liu Yang moderated the *CEO Forum* organised by the Energy Market Company of Singapore.

15 March Nur Azha Putra presented "Global Nuclear Power Governance and the ASEAN Nuclear Power Cooperation Framework: Issues, Challenges and Opportunities for the ASEAN Nuclear Power Safety Research Network" at *the 3rd Annual ASEAN Nuclear Power Safety Research Network Meeting,* Bangkok, Thailand.

12 March Anthony D. Owen presented "Cross-Border Electricity Interconnections: Lessons Learned from International Experience" at the *7th International Association for Energy Economics Latin American Conference*, Buenos Aires, Argentina.

8 March Melissa Low presented "Outcomes of Katowice COP24", at the Yale-NUS College, Singapore.

6 March Melissa Low delivered opening remarks at the "Fireside Chat with Singapore's Chief Negotiator for Climate Change", organised by ESI and the National Youth Council Singapore, MediaHub at Scape, Singapore.

4 March Philip Andrews-Speed presented "China's Low Carbon Energy Transition" at a Roundtable on *The Global Implications of China's Energy Revolution* at Chatham House, London.

3 March Philip Andrews-Speed presented "Asia's Carbon Options" at the Annual Conference of the Windsor Energy Group, Windsor, UK.

28 February Dina Azhgaliyeva presented "Financing Energy Efficiency in South-East Asia", at the *European Energy Efficiency Conference* during the World Sustainable Energy Days (WSED) organised by OÖ Energiesparverband, Wels, Austria.

26 February Brantley Liddle presented "Revisiting the Income Elasticity of Energy Consumption and Energy Leapfrogging" at The *Economics of World Energy Markets*, School of Accounting and Finance, Hong Kong Polytechnic University.

18-22 February Zhong Sheng presented "EV Impacts on Singapore's Energy Demand and Emissions" in the first ERIA working group meeting on energy outlook and energy saving potential in East Asia region, Jakarta, Indonesia.

21 February Christopher Len presented "Contextualising Just Transition: Energy Access for Developing Countries and Remote Communities" at the *Conference on Global Climate Governance and China's Role: Between Katowice and New York*, Shanghai, China.

13 February Melissa Low presented “Outcomes of COP24: Katowice Climate Package”, at *The Worst Has Been Predicted: Now What?,* organized by Fossil Free Yale-NUS, Singapore.

1 February Melissa Low presented “Katowice Climate Package”, at a *Masters of Environmental Management Seminar*, NUS, Singapore.

29 January Melissa Low presented “What’s Up with the Paris Agreement?”, at *Eco-Fest @ U-Town*, NUS, Singapore.

28 January Dina Azhgaliyeva presented “Green Finance: New Opportunities for Government Support and Regulation” and chaired the session “Behavior, Economic and Policy Implications for Energy Use”, at *the International Workshop on Putting Sustainability into Convergence: Connecting Data, People, and Systems* organised by NSF RCN-SEES: Predictive Modelling Network for Sustainable Human-Building Ecosystems (SHBE), Singapore.

22 January Philip Andrews-Speed presented “The Sustainable Energy Transition in ASEAN” at the ESADE Center for Global Economy and Geopolitics, Barcelona, Spain.

22 January Philip Andrews-Speed presented “China’s Low Carbon Energy Transition” at the ESADE Center for Global Economy and Geopolitics, Barcelona, Spain.

13 January Victor Nian presented “UNi-LAB on Integrated Systems Analysis Tools” at Beijing University of Posts and Telecommunications, Beijing, China.

14 December Elena Reshetova presented “Institutional Analysis of Energy Securitization: Oil and Gas Supply Chains in Canada, China, and Russia” at *the Ronald Coase Institute Workshop on Institutional Analysis*, Bratislava, Slovakia.

8 December Yao Lixia presented “ASEAN Electricity Market Integration: How Can the Belt and Road Initiative Bring New Life to It?” at *International Conference on Singapore as a Nexus of the Maritime Silk Road: Knowledge Exchanges and Capacity Building,* organised by NCPA of NTU, Singapore.

6 December Philip Andrews-Speed presented “The Sustainable Energy Transition in ASEAN” at *Encarta Dialogue Session*, Singapore.

5 December Victor Nian presented “The Outlook for China’s Nuclear Power Industry: Technology and Safety”, at the seminar on the *Future of Nuclear Industry Development in China: An Historical Perspective*, ESI Seminar.

5 December Philip Andrews-Speed participated in a panel on “Investing in Green Technology” at *121 Tech Investmen*t, Singapore.

3 December Dina Azhgaliyeva presented “Green Bonds: Policies and Regulations”, at the International Workshop on *Green Climate Financing* organised by MFA and NTU, Singapore.

Staff Media Contributions

Philip Andrews-Speed interviewed by Damon Evans, freelance energy journalist, on the implications of the US-China trade negotiations on China’s oil and gas sector, 29 March 2019.

Philip Andrews-Speed interviewed by *S&P Global Platts* on coal-fired power stations along the China-Pakistan Economic Corridor, 27 March 2019.

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Recent Events

Visit from the University of Calgary 29 March 2019

Professor Janaka Ruwanpura, Vice Provost (International) of the University of Calgary, Alberta in Canada (fourth from left) and Ms. Uli Mg, Regional Manager, for Asia-Pacific International Relations also from the University of Calgary (first on the left).

Professor Janaka Ruwanpura, Vice Provost (International) of the University of Calgary, Alberta in Canada and Ms. Uli Mg, Regional Manager, for Asia-Pacific International Relations also from the University of Calgary visited ESI. Professor Ruwanpura explained that energy forms one of the main pillars of the University's current research strategy. Apart from unconventional resources, the key priority areas relate to managing the low-carbon transition, a central focus also for ESI. In addition, the University of Calgary hosts the Arctic Institute of North America, another area of shared interest.

Roundtable on Financing Energy Efficiency in the Manufacturing Sector – Insights from International Experience and Implications on Singapore 25-26 March 2019

Participants of the Roundtable on Financing Energy Efficiency in the Manufacturing Sector held at ESI (Photo by ESI Staff).

ESI organised an expert roundtable on financing energy efficiency in the manufacturing sector for Singapore government officials at the Grand Copthorne Waterfront Hotel and ESI Conference Room. The event was an opportunity for dialogue among government officials, industry experts and academia. It was attended by officials from five different ministries and agencies, as well as key stakeholders from industry and financial institutions. The experts were from Asia Clean Energy Partners, the Asian Development Bank, Asian Development Bank Institute, Asia-Pacific ESCO Industry Alliance, Bangladesh Institute of Development Studies, Copenhagen Centre for Energy Efficiency, National Development and Reform Commission of China, Lawrence Berkeley National Laboratory, Griffith University Australia and European Commission.

The participants at the roundtable discussed financing programmes, the market barriers that continue to impede access to energy efficiency finance in the manufacturing sector, obtaining recommendations for existing programme designs, and identifying the next steps towards the design and implementation of new government and private sector interventions. The information and feedback drawn from this roundtable will inform a study undertaken by ESI entitled, "Promoting Energy Efficiency for the Manufacturing Sector in Singapore – Outlook for Economic Instruments and Energy Services Market.

Visit from the Head of the Centre for Energy Research at NUPI and Ambassador of Norway to ASEAN 21 March 2019

Dr. Indra Øverland (with bag) and H.E. Morten Høglund, Ambassador of Norway to ASEAN (wearing a tie) with ESI staff. (Photo by ESI staff.)

Dr. Indra Øverland (with bag) and H.E. Morten Høglund, Ambassador of Norway to ASEAN (wearing a tie) with ESI staff. (Photo by ESI staff.)

ESI received a visit from Dr. Indra Øverland, Research Professor and Head of the Energy Programme at the Norwegian Institute of International Affairs (NUPI), and H.E. Morten Høglund, Ambassador of Norway to ASEAN.

Participants of the Roundtable on Financing Energy Efficiency in the Manufacturing Sector holding discussions at the Grand Copthorne Waterfront Hotel (Photo by ESI Staff).

Dr. Øverland and Mr. Høglund presented to ESI research staff the details of the ASEAN Climate Change and Energy Project (ACCEPT) and discussed major energy issues relevant to ASEAN.

ACCEPT is a three-year joint project which aims to produce valuable analysis and actionable recommendations for ASEAN energy policies. The project will be carried out by the ASEAN Centre for Energy (ACE) in cooperation with NUPI and with support from the Royal Norwegian Ministry of Foreign Affairs via the Royal Norwegian Embassy in Jakarta.

Fireside Chat with Singapore's Chief Negotiator for Climate Change 6 March 2019

ESI and the National Youth Council Singapore (NYC) co-hosted a Fireside Chat with Singapore's Chief Negotiator for Climate Change, Mr. Joseph Teo. The event was part of INSPIRIT, a community platform initiated by the NYC in 2012, to bring young working adults together to advocate for youth interest on national issues. Supported by Singapore Youth for Climate Action (SYCA), the Environmental Law Students Association at NUS Law (ELSA) and Climate Conversations, the event provided an opportunity for youths to learn more about the UN Climate Change Conference that was held in Katowice, Poland from 2-15 December 2018, and how Singapore has galvanised regional climate action.

Mr. David Chua, Chief Executive Officer of the NYC and Ms. Melissa Low, ESI Research Fellow, delivered brief opening remarks, highlighting how collaborative action and partnerships are critical for more meaningful consultation and an overall better understanding of the Government's environmental policy consideration. Mr. Teo outlined the components of the Paris Agreement and the Katowice Climate Package, and shared what Singapore is doing on the international, regional and national fronts to address climate change. Following this, a youth panel session was held which featured two representatives who attended the last UN Climate Change Conference. Then, Ms. Carol Yuen from ELSA who was a representative of NUS at COP24 and Ms. Swati Mandloi from SYCA both spoke. The session was moderated by Mr. Kok Ann Ng, who represented Climate Conversations. The event was attended by 60 participants, mainly youth leaders and young working professionals.

Offshore Renewable Energy: Seeing the Industry Through the Eyes of Those Underwriting the Risk 7 February 2019

Professor Alan Lowdon addressing the audience gathered in the ESI Conference Room (Photo by ESI staff).

Professor Alan Lowdon, Advisor of Offshore Renewable Energy Catapult and Visiting Professor of the Durham Energy Institute (UK) gave a presentation on the Capital Asset Pricing Model (CAPM) beta of offshore wind generation. CAPM betas form the basis of discount factors used in financial models used to examine investment decisions and competition for capital. He compared the financing of mature technologies, such as onshore wind, with less mature technologies, such as offshore wind and wave and tidal. Professor Lowdon noted that the levelised cost of offshore wind energy is driven by risk perceptions, making uncertainty a key contributor to the cost of offshore wind energy. He explained how to construct CAPM beta and provided recommendations for better risk assessment of offshore wind projects. He provided 10 recommendations on how to reduce CAPM beta, adding that access to operational performance data for offshore wind project assets such as blades, towers, cables, power electronics, etc. is needed for risk assessment.

Participants at the Fireside Chat with Singapore's Chief Negotiator for Climate Change, Mr. Joseph Teo (second from the left) (Photo courtesy of the National Youth Council Singapore).

Explaining Spatial Variation in Small-scale Solar Uptake across Australia 15 January 2019

Dr. Paul Burke delivering his presentation (Photo by ESI staff).

Dr. Paul Burke, an Associate Professor at the Australian National University's Crawford School of Public Policy, presented "Explaining Spatial Variation in Small-Scale Solar Uptake Across Australia", a project co-authored with Rohan Best of Macquarie University in Australia and Shuhei Nishitateno of Kwansei Gakuin University in Japan. This project used postcode-level data to quantify the impact of Australia's spatially-differentiated *Small-scale Renewable Energy Scheme* on solar uptake. The goals of this project are to inform grid management planning in Australia and to learn how uptake might proceed in other countries. After the presentation, Dr. Burke met with several ESI researchers to discuss his work in Indonesia.

New Staff

HOO Poh Ying, Rachel

Research Fellow

Ms. Rachel Hoo joined ESI as a Research Fellow in December 2018. She holds a Bachelor of Chemical Engineering (Bioprocess) degree from the University of Technology, Malaysia (UTM). At ESI, her research is primarily focused on techno-economic and policy analysis of energy storage systems (ESS). At the same time, she is pursuing her PhD in Chemical Engineering, also from the UTM (expected graduation in early 2020). Ms. Hoo's thesis focuses on spatial-economic optimisation of waste to biogas planning in Malaysia. During her PhD studies, she was one of the participants at the IIASA Young Scientist Summer Program at the International Institute of Applied System Analysis (IIASA), Laxenburg, Austria in 2016. Her research interests include life cycle and cost-benefit analysis of energy storage technologies, policy and regulation of Elastic Storage Server (ESS) deployment, renewable energy and circular economies.

Dr. KIM Jeong Won

Research Fellow

Dr. Kim Jeong Won joined ESI in March 2019. Jeong Won brings several years of research and project management experience. She holds a PhD in Energy and Environmental Policy from the Green School (Graduate School of Energy and Environment), Korea University, an MPA from Korea University and an MPP from the Harris School of Public Policy Studies at the University of Chicago. Dr. Kim has participated in writing several policy reports for the South Korean government as a researcher at the Korea Environment Institute (KEI), implemented various international development projects serving as a project manager at the UNWTO ST-EP Foundation, and conducted research on renewable energy policy and funding in developing countries as a research intern at the Global Green Growth Institute (GGGI). Her major research areas are renewable energy policy and climate change policy at the national and local levels. She is particularly interested in vertical and horizontal policy diffusion among governments in the energy and climate change sectors.

Contact

- Collaboration as a Partner of ESI (research, events, etc)
- Media Enquiries
- ESI Upcoming Events
- Join ESI Mailing List

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Special Issue Call for Papers

Journal of Sustainable Finance & Investment by Taylor & Francis

The *Journal of Sustainable Finance & Investment* is an international, peer-reviewed journal which publishes high quality, original research contributions to scientific knowledge. The Journal is supported by an editorial board of leading researchers and professionals in sustainable finance from top universities such as the University of Oxford, Harvard University and Stanford University.

Scaling up Green Finance in Asia: The Role of Policies and Regulations

In their latest report, the Inter-Governmental Panel on Climate Change noted that the mobilisation of climate finance is critical to limiting global warming to 1.5°C, and preventing catastrophic climate change. To fully implement the Paris Agreement, USD 1.5 trillion of green financing is required annually till 2030. Raising green finance is also important in Asia for meeting energy demand, which is growing fast due to economic growth, population growth and improvements in energy access. Increasing low-carbon investments to the level necessary for the 1.5°C pathway requires a major shift in investment patterns, a shift that would require government policies to redirect financial resources. Government policies are playing an increasingly important role in efforts to mainstream green finance. Recently, new government policies supporting green finance were implemented in Asia. Such policies include green bond standards, green bond grant schemes, green loans, sustainability disclosure and reporting requirements, etc.

We invite submissions addressing issues related to green finance, in particular addressing the following (as well as other relevant) themes with a focus on Asia:

- National policies supporting green finance
- Market barriers for green finance
- The role of governments in promoting green finance
- Green finance and its development
- Definitions, standards and guidance for green finance at the international, national and corporate levels
- Sustainability disclosure and reporting, including international, national and corporate
- The role of public green finance in promoting private finance
- National policies boosting demand for green finance
- Green finance market development.

Submission Guidelines

We welcome all methodologies and theoretical orientations. Please format and reference your paper according to the requirements of the Journal of Sustainable Finance and Investment. Please select "special issue submission" in manuscript type (Step 1) when submitting your paper to the journal https://mc.manuscriptcentral.com/jsfi. Please include at least two potential reviewers (full name, position, affiliation and email address) in the cover letter.

Submission deadline: 31 August 2019

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