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Solar Powered Agri-Rural Communities (SPARC) Bulacan Project on Grasslands and Paddy Fields in Pasong Inchik, San Rafael, Bulacan, Cagayan, Philippines, 2016. Photo by Judgefloro (Permission under CC0 1.0).

INTRODUCTION

The theme of this issue is emerging energy technologies for small-scale grids.

At the *2017 Singapore International Energy Week*, ESI's Roundtable set out to assess three different technologies that hold the promise of being able to provide energy supply to small-scale, community-based grids: different forms of ocean energy, small-scale liquefied natural gas (LNG) and small modular nuclear reactors (SMRs). The aim of the roundtable was to assess the state of development and potential of such technologies and to identify the policies required to support their widespread deployment in Southeast Asia. For this issue of the ESI Bulletin, four of the five speakers have summarised the main points from their presentations.

This topic is particularly relevant to parts of Southeast Asia where significant populations live on islands or in other remote locations. These three technologies are distinct from intermittent renewable energy technologies such as wind and solar that are already widely deployed on a commercial basis. None have been deployed commercially on a large scale in the region.

The first two presentations at the ESI Roundtable provided the Southeast Asian context. Mr. Beni Suryadi, Acting Manager, Policy Research and Analytics, ASEAN Centre for Energy (ACE), outlined the scale of the energy access challenge in the region. In 2015, it was estimated that more

In this issue ...

than 100 million people out of ASEAN's total population of 630 million lived with very unreliable electricity, or even no electricity at all. In addition, different governments categorise connectivity in different ways, which again results in understating the challenge of electricity access. Whilst intermittent renewable energy such as wind and solar PV can play an important role in electrification, it is necessary to introduce technologies that can supply more stable power supplies, both to enhance electrification as well as to replace the ubiquitous diesel generators.

Dr. Maxensius Tri Sambodo, Researcher in the Economic Research Center and Head of the Division for Management and Dissemination of Research at the Indonesian Institute of Sciences (LIPI), discussed the benefits of rural electrification in the ASEAN member states, with a focus on his own findings in Indonesia. His presentation reminded us that electricity is now considered an essential input into raising living standards. Lighting is always the first service to be provided. This not only improves the quality of home life but allows for longer periods of study in the evenings for school children. When lighting is combined with access to the internet, the opportunities for education are boosted even further. Greater access to electricity also enhances wealth, health and resilience to shocks. However, rural electrification is not just a matter of setting up distributed energy generating infrastructure. Projects must be designed to fit the specific circumstances, business models should match the population's ability to pay, and human capacity has to be developed to service and maintain the energy systems.

Mr. Michael Lochinvar Sim Abundo, Managing Director, OceanPixel Pte Ltd., showed how close certain forms of ocean energy are to being deployable in Southeast Asia (no presentation summary included in this Bulletin). Five main forms of ocean energy can be tapped: tidal current, tidal energy from barrages, wave energy, and thermal and salinity gradients. The choice of technology depends on local geographic conditions. The Orkney Islands in northern Scotland have successfully combined tidal and wave energy with wind energy to meet most of the electricity needs from renewable energy. Southeast Asia is at a much earlier stage and the challenge is to adapt these technologies to local conditions and choose the most favourable locations. Tidal current and wave energy, along with ocean thermal, have the best opportunities for deployment in Southeast Asia. A number of projects have already been put into operation, but systematic deployment has yet to begin. The levelised cost of electricity from these projects is certainly cheaper than that from the existing diesel generators, but the long-term sustainability benefits will be achieved only when different forms of renewable energy can be combined to provide reliable, low-carbon electricity.

Liquefied natural gas (LNG) has become a global industry and supposed economies of scale have resulted in ever larger liquefaction facilities, LNG carriers and re-gasification facilities. The drivers for these developments include the energy efficiency of gas-using appliances, the cleanliness of gas compared to coal and oil and the long-term decline in real gas prices. The opportunity exists, in principal, to supply LNG to isolated communities at a much smaller scale than we see in today's LNG market. However, as Mr. Tony Regan, Managing Director of DataFusion Associates Pte Ltd., explained in his presentation, a number of commercial challenges have yet to be overcome. Small-scale LNG industries already exist in countries such as China where small gas fields that have no pipeline connection are commercialised through the construction of small-scale liquefaction plants that produce LNG to be transported by truck to demand centres, usually industrial plants. Such an approach can clearly be applied to maritime transport in order to deliver LNG to Southeast Asia's island communities.

Today, although designs exist on paper, the small-scale, maritime LNG industry suffers from two key challenges. First, the unit cost of the infrastructure will be higher; in other words, there will be dis-economies of scale. Second, there will need to be a sufficient number of orders for systematic production of plants and ships. Even when these challenges have been addressed, great care will have to be taken in the design of each project and the management of the supply chain.

The final technology discussed was the small modular nuclear reactor (SMR). SMRs are claimed to have several advantages over the traditional large-scale reactors. Firstly, by being modular, they can be built in a factory to a common design and through a standardised production process. This should lead to substantial cost reductions once a certain scale of production is achieved. Secondly, SMRs can be deployed to remote communities or locations where the grid capacity is not large. Alternatively, a number of SMRs can be deployed at the same location over a period of time, resulting in a large-scale plant, but with advantages for the project financing. Finally, being smaller, the consequences of an accident should be much less than for a large nuclear plant. As a result of these perceived advantages, a number of governments and companies are pursuing this technology, including the US, UK, India, China and Russia. In his presentation, Professor M.V. Ramana, Simons Chair in Disarmament, Global and Human Security in the Liu Institute for Global Issues at the University of British Columbia, Vancouver, B.C., Canada argued that such optimism is misplaced. As is the case with small-scale LNG, SMRs suffer from the same diseconomies of scale until a substantial production line can be established. In other words, manufacturers need to be confident of receiving hundreds (or maybe thousands) of orders before they invest in industrial facilities. Further, the roll-out of even the most promising designs has been delayed by technical and licensing challenges. In the end, one has to ask the question whether there are enough remote communities in the world where SMRs are technically, economically and environmentally the most suitable energy supply solution; especially given the declining costs of renewable energy.

In conclusion, certain forms of ocean energy are almost ready for widespread deployment in Southeast Asia, small-scale LNG is potentially on the horizon, while SMRs are probably over the horizon, except on an experimental basis.

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

Dr. Philip Andrews-Speed, ESI Senior Principal Fellow
and Head, Energy Security Division

(On behalf of the ESI Bulletin Team)

The Need for New Energy Technologies in ASEAN's Islanded Communities

Mr. Beni Suryadi, Acting Manager, Policy Research and Analytics, ASEAN Centre for Energy (ACE) and Nadhilah Shani,Technical Officer, Policy Research and Analytics, ACE

Community Solar Panel System in Bengkayang District, West Kalimantan Province, Indonesia. (Photo by Dr. Maxensius Tri Sambodo).

ASEAN Member States (AMS) fully understand the urgency of meeting energy demand in the region to improve the quality of life. This is reflected in their efforts to raise the region's electrification ratio. At present, the ASEAN region has an aggregated electrification ratio of 78 per cent with some member states already having 100 per cent electrification. Despite the wide gaps in the ability of the AMS to provide electricity to their citizens, all ten governments have shown continuous efforts.

The high percentage of people with no access to electricity—especially those who live far away from the grid—is a major challenge for ASEAN development. In fact, out of ASEAN's total population of 630 million in 2015, there were still 107 million who did not have access to electricity. Most of these people live in remote areas which cannot be reached by electricity grids. For those who do have access to power, the supply is often not available 24 hours a day.

The main obstacle in electrifying ASEAN's remote areas is related to the fact that the region is composed of numerous islands. There are 13,000 inhabited islands in ASEAN which are in dire need of electricity. As archipelagic countries in ASEAN, both Indonesia and the Philippines need decentralised power generation to improve their citizens' quality of life.

Supplying ASEAN Off-Grid Demand: The Fundamental Factors

To enhance off-grid electrification in rural areas, the AMS must incorporate several fundamental factors such as affordability, reliability and sustainability. To reach remote areas, where the purchasing capability of the communities is low, off-grid generation would be a cheaper option than expanding on-grid transmission.

Most AMS currently rely on diesel generation to meet rural electricity demand because it is regarded as the fastest and most practical solution to supply electricity. However, in practice, fuel costs are volatile and transport is costly. This leads to fuel dependency, causing more problems, such as curtailment of service hours and unstable generation costs. For these reasons, it is difficult to justify diesel generation as the most affordable option for ASEAN to meet off-grid demand. Another way to solve the problem would be for islanded communities to independently supply their own demand by using indigenous and abundant sources like micro hydro power, solar, wind or tidal energy. These renewable energy (RE) technologies can be more affordable options than diesel generation in remote places because the price is falling due to technology maturity and low maintenance costs over the lifetime of the equipment. The competitiveness of RE compared to fossil fuels is due to abundant sources which are available locally, thereby eliminating fuel and transport costs.

Additionally, in providing reliable off-grid energy supplies in the long run, the AMS should take into account the growing demand in rural areas. At present, it is still questionable whether it is economically beneficial to attempt to provide 100 per cent electricity access to remote areas where the demand and purchasing capability is low.

However, electricity can open access to other vital necessities such as safe drinking water and sanitation. It can improve people's health and increase communities' well-being. Moreover, access to electricity can drive economic development and tap the potentials of islanded communities since more productive activities can be carried out with the support of electricity. Tourism, fisheries and small- and medium-sized enterprises in islanded communities will have increased energy demand in the future. Therefore, off-grid technology should acquire enough flexibility as well as expandability in accommodating future growing needs. As the reliability of diesel generation supply is still doubted, alternative technologies like RE coupled with energy storage, hybrid systems or even highly flexible smart grids should be explored to address the foreseeable challenges.

In addition, sustainability is an integral part of ASEAN's development goals. There is no point in increasing the off-grid

electrification ratio without ensuring that the energy provided is sustainable, environmentally friendly and beneficial for communities' well-being.

RE and New Technologies as Key Solutions for Off-grid Technology

It is clear that ASEAN needs RE and new technologies to fulfil off-grid energy demand. A comprehensive study on design and feasibility should be conducted prior to implementation to allow RE and new technologies to be harnessed in the most suitable ways to meet the needs of remote areas. The demand and potential of islanded communities can vary widely and have specific geo-characteristics which can lead to different solutions, whether to use RE alone, RE with storage or even hybrid systems. By accurately assessing the indigenous resources, it is possible to utilise more than two renewable energy sources and develop a microgrid or even a smart-grid to achieve energy security in islanded communities.

ASEAN should expand the utilisation of RE and new technologies, and also explore the possibility of converting diesel generation or using it in tandem with other indigenous resources in off-grid areas. If ASEAN can spur the implementation of RE and new technologies for off-grid electrification in the regions, it should be able to meet off-grid electricity demand in order to achieve the regional target of 23 per cent RE in the total electricity production mix in 2025.

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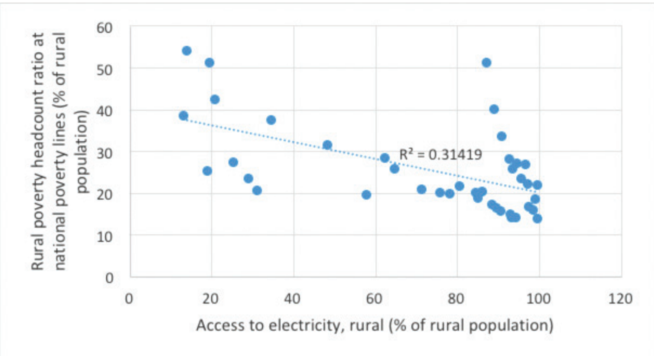
The Socio-Economic Impacts of Rural Electrification Programmes in the ASEAN Region

Dr. Maxensius Tri Sambodo, Researcher in the Economic Research Center and Head of the Division for Management and Dissemination of Research at the Indonesian Institute of Sciences (LIPI)

Many studies have shown that electricity access has a positive impact on income, education, health and the environment. Such studies also indicate that electricity access is strongly correlated with improving the lives of women. There is a positive liner correlation between the percentage of rural population with electricity access and the rural poverty headcount ratio at national poverty lines (see Figure 1).

Figure 1: Access to Electricity and Rural Poverty for Five ASEAN Countries

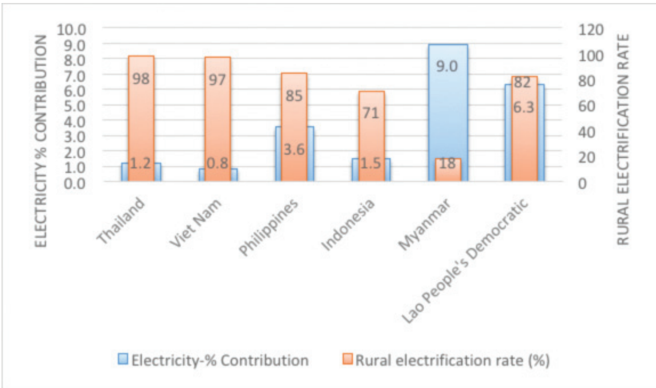


Source: The World Bank. *World Development Indicators* (Washington, D.C.: The World Bank, 2017). See: http://data.worldbank.org/data-catalog/world-development-indicators.

Note: This plots five individual countries: Cambodia, Indonesia, Lao PDR, Philippines and Indonesia. The data cover only some years between 1996 and 2014 because some countries have missing data.

Further, electricity access is one component of the Multidimensional Poverty Index (MPI). MPI identifies three aspects that contribute to poverty deprivation: education, health and standard of living. Electricity access is one component of living standards.[1] According to Alkire and Robles, on average, the percentage contribution of deprivations in electricity access to overall poverty in the ASEAN accounted for about 3.7 per cent. [2]

Figure 2: Rural Electrification Ratio and the Contribution of Electricity Deprivations to Overall Poverty



Source: Drawn by the author based on information from S. Alkire and G. Robles, "Multidimensional Poverty Index Summer 2017: Brief Methodological Note and Results" Oxford Poverty and Human Development Initiative, University of Oxford, OPHI Methodological Notes 45, 2017; and International Energy Agency. *Energy Access Outlook* (Paris: OECD and IEA, 2017).

Figure 2 combines information about the percentage contribution of electricity deprivation to overall poverty and the rural electrification ratio in six ASEAN countries. There is a negative and strong correlation between the two indicators. This implies that in countries with a relatively high rural electrification ratio, the lack of access to electricity makes a small contribution to deprivation.

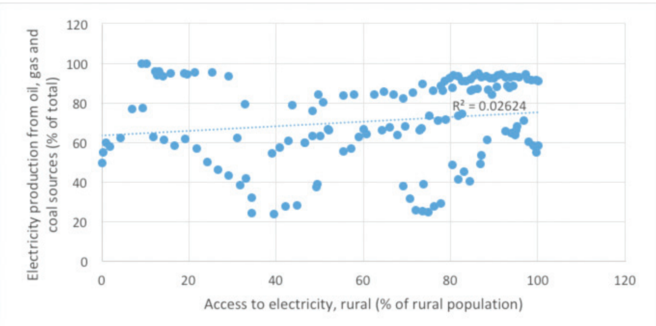
The benefits of electricity access vis-a-vis economic and social standards depend on the initial conditions of household and local infrastructure, the type of grid connection, the source of electricity supply, the size or capacity of electricity access and the nature of socio-economic programmes post connection.

Generally speaking, lighting is the main objective of the

Community Solar Panel System in Bengkayang District, West Kalimantan Province, Indonesia. (Photo taken by the author).

electrification programmes, especially in remote and scattered housing. Providing solar home systems (SHS) has become a popular approach in many villages. However, decision-makers are aware that access to electricity needs to support productive uses beyond lighting. Two strategies have been promoted by extending the national grid to end users, or by constructing a mini-grid to serve a group of households. A mini-grid power plant is usually managed by the local community or by the private sector under supervision of the central or local government. Renewable forms of energy, such as solar, hydro, wind and biofuels, have become the major contributors to mini-grids. However, there is a pattern of increasing the rural electrification ratio coinciding with increasing electricity production from fossil fuels, especially from gas and coal (see Figure 3). This indicates that fossil fuels may still be the major source of energy used to eradicate electricity poverty in rural areas.

Figure 3: Electricity Access and Electricity Production from Fossil Fuels for Six ASEAN Countries

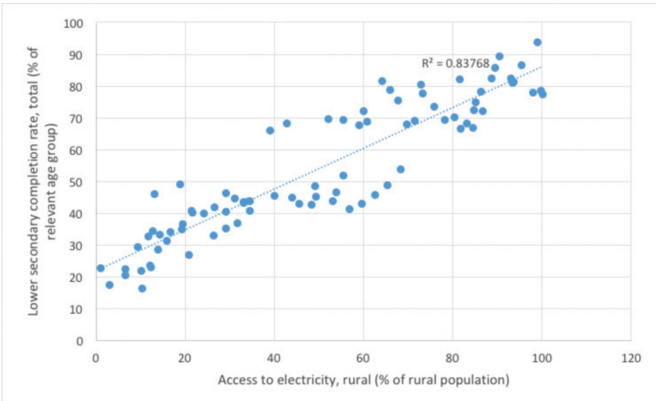


Source: The World Bank. *World Development Indicators* (Washington, D.C.: The World Bank, 2017). See: http://data.worldbank.org/data-catalog/world-development-indicators.

Note: this plots six individual countries: Cambodia, Indonesia, Lao PDR, Philippines, Thailand and Indonesia. The data cover only some years between 1991 and 2014 because some countries have missing data.

Magnani and Vaona found a causal relationship between human capital, represented by the lower secondary school completion rate, and the share of population having access to electricity.[3] In the ASEAN context, there is a positive correlation between human capital and the rural electrification ratio (see Figure 4). Access to electricity has improved the motivation for teachers and students to spend more time studying both at home and school. Further, with electricity, teachers have been able to use computers and provide better materials in their classes. With electricity and internet access, people in rural areas have more opportunities for distance learning, which lowers costs and can expand social networks.

Figure 4: Electricity Access and Education for Six Selected ASEAN Countries



Source: The World Bank. *World Development Indicators* (Washington, D.C.: The World Bank, 2017). See: http://data.worldbank.org/data-catalog/world-development-indicators.

Note: This plots six individual countries: Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Indonesia. The data cover only some years between 1990 and 2014 because some countries have missing data.

Electricity access also provides opportunities for improving economic and social resilience due to the enhanced economic capacity, education, health and social networking.

Diesel Generator in Front of a House in Bengkayang District, West Kalimantan Province, Indonesia (Photo taken by the author).

These assets are necessary to deal with economic shocks or natural disasters.[4] During a flood, solar panels may be more reliable than diesel generators as they are usually installed well above the ground, while diesel plants are placed on the ground, even close to rivers (see photo).

There are two pillars that need to be strengthened in order to ensure the sustainability of the electricity supply. First is good governance. Reaching the "last mile" always needs more resources and capability. There is always the issue of lack of demand and purchasing power in providing electricity in remote areas. Governments need to provide fiscal incentives, but in effective ways. This implies that when considering all rural electrification programmes (on grid and off grid), good project design can create value, and the maximum willingness to pay for the access equals the cost of providing electricity access.

Second, many projects are poorly designed. If project planners focus on the number of households with access, and fail to acknowledge local resources and capability, the project will not be sustainable. Thus, a "one size fits all" policy should be avoided. Project designers need to develop electricity access through an inclusive and gradual approach.

1 Other aspects are sanitation, drinking water, flooring, cooking fuel and asset ownership.

2 S. Alkire and G. Robles, "Multidimensional Poverty Index Summer 2017: Brief Methodological Note and Results" Oxford Poverty and Human Development Initiative, University of Oxford, OPHI Methodological Notes 45, 2017. Data covers Thailand (2012), Vietnam (2013/14), Philippines (2013), Indonesia (2012), Myanmar (2015/16) and Lao (2011/12).

3 N. Magnani and A. Vaona, "Access to Electricity and Socio-economic Characteristics: Panel Data Evidence at the Country Level" *Energy* 103 (2016): 447-55.

4 W. Naude, A.U. Santos-Paulino and M. McGillivray. "Measuring Vulnerability: An Overview and Introduction" *Oxford Development Studies* 37, 3 (2009): 183-91; and M.T. Sambodo, A.H. Fuady, L. Masnun, F.W. Handoyo, E. Mychelisda and R. Novandra, *Peningkatan Akses Listrik Masyarakat Perdesaan dan Daerah Tertinggal: Sebagai Salah Satu Pilar Ketahanan Energi* [Electricity Access in Rural and Remote Areas: A Pillar of Energy Security] (Jakarta: LIPI, 2016).

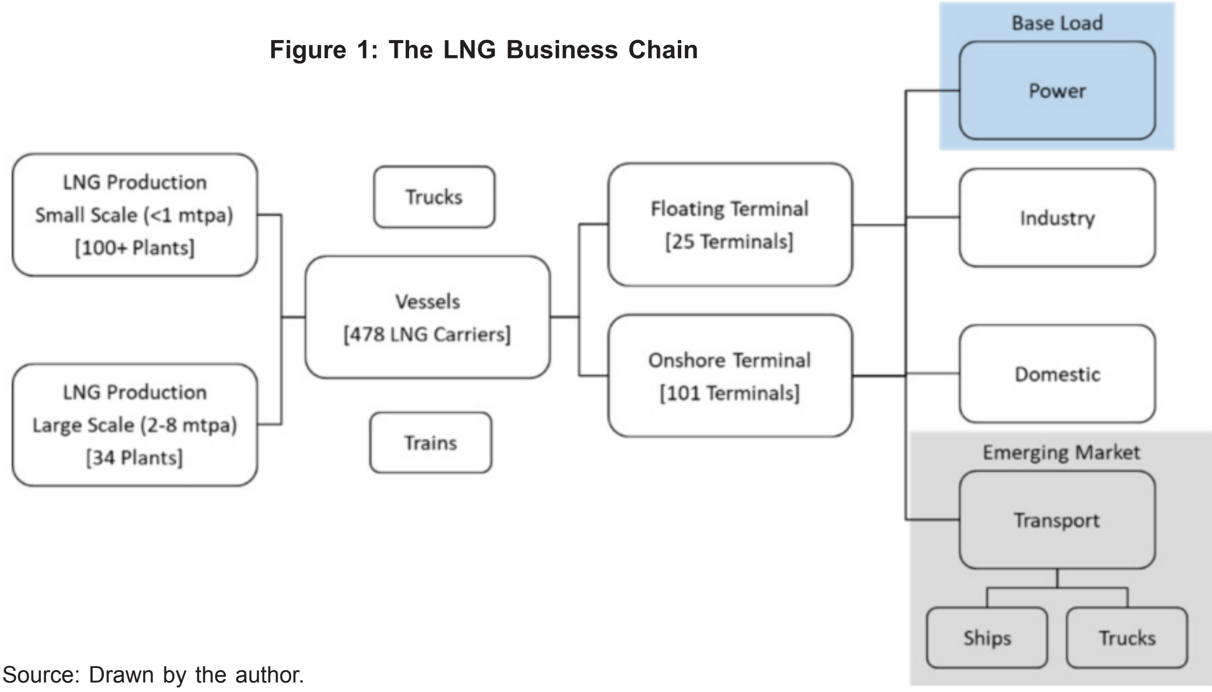
The Potential of Small-Scale LNG Systems in Asia

Mr. Tony Regan, Managing Director, DataFusion Associates Pte Ltd. with contributions from Holger Kelle of INCITIAS Pty Ltd.

The traditional LNG business has been characterised by very large-scale components. The LNG may be produced in a 7 million ton per annum (mtpa) train, or a 30 mtpa liquefaction plant before being shipped in large LNG carriers with between 125,000 and 244,000 cubic metres of storage. It is delivered into large receiving terminals of between 5 and 10 mtpa prior to being regasified and dispatched by pipeline to major power and utility customers. The three main markets are power, industry and residential. However, over the last few years we have seen the emergence of another market, transportation, i.e. the use of LNG as a truck and marine fuel (see Figure 1).

There are two main drivers — environmental and economic — helping to create new LNG markets. The environmental driver is the requirement for cleaner fuels while the economic driver is the realisation that LNG can be cheaper than petroleum products at "the pump". The introduction of Emission Control Zones in Northern Europe and the coasts of North America has led to the development of LNG bunkering services in these areas whilst in China the new market has been LNG as a truck fuel and the transportation of LNG by truck. However, weaker environmental drivers in Asia (outside China) mean there has been less interest

Figure 1: The LNG Business Chain



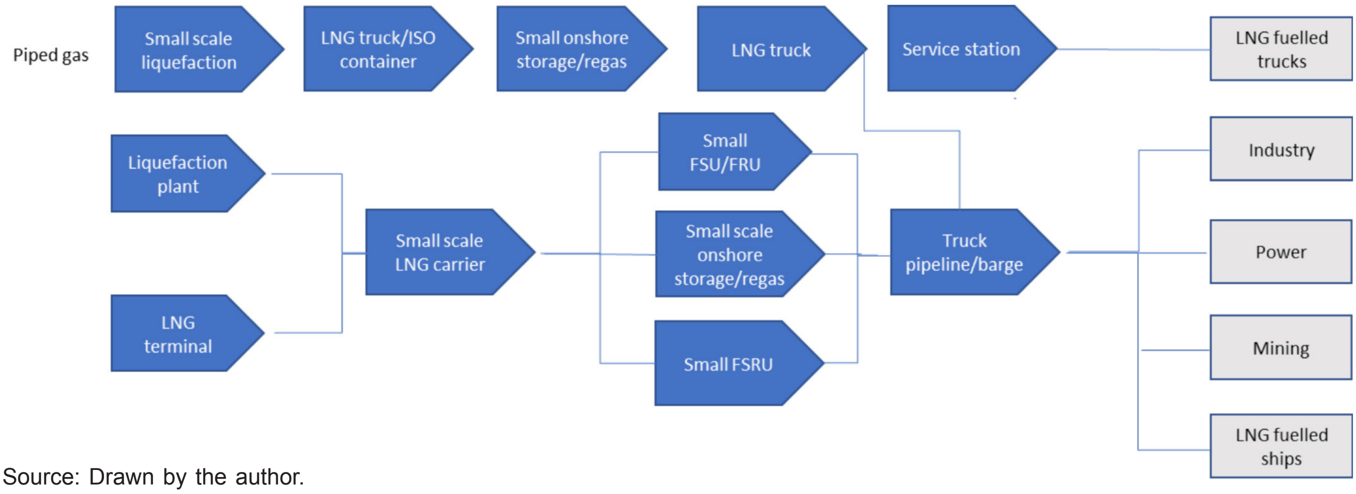
Source: Drawn by the author.

in using LNG as a transportation fuel and here the focus has been on using LNG to support power generation.

Many countries in Southeast and South Asia have major programmes to bring electricity to remote locations. In countries such as Indonesia and the Philippines, with thousands of islands, numerous small power plants are required to provide electricity and replace expensive diesel generators. As it is uneconomic to pipe gas to remote islands, the preferred solution is often LNG. However, the traditional means of delivering LNG, in large LNG carriers, is not economically viable as it must be supported by large berths and storage capacity far in excess of that needed to support a small power plant. Small power plants create the need for a small-scale supply chain, something that in many places does not yet exist.

The small-scale LNG supply chain is different and more complex than the traditional LNG business and there may be more components in the chain (see Figure 2). Instead of shipping LNG in large carriers, it is more likely to be transported in a small LNG carrier, truck, rail tank car or container. Traditional receiving terminals are far too big, so these markets may require small onshore terminals, small floating storage and regasification units (FSRU's) or perhaps small floating storage with regasification onshore or a separate floating unit.

Figure 2: Small-Scale LNG Supply Chain



Source: Drawn by the author.

The LNG systems and supply infrastructures of LNG are more expensive than those required for conventional fuels due to the utilisation of complex technologies and equipment in them. There are few companies with experience operating the equipment and permitting can be more difficult due to the inexperience of licencing authorities.

An initial constraint has been the lack of suitable equipment. Whilst there may be nearly 500 LNG carriers in service worldwide, there are only a handful of small LNG carriers, a handful of small receiving terminals and key equipment such as loading arms suitable for small-scale applications. In some places, solutions have been found, for example, LNG bunkers being supplied to vessels by truck and the construction of purpose-built LNG bunker barges.

Whilst there are 26 floating LNG terminals in operation around the world, we do not yet have any small or medium-size FSRU's. However, the first small-scale floating terminal was recently introduced to Bali in Indonesia, utilising a small floating regasification barge able to handle 0.5 mtpa of LNG and a separate small floating storage vessel.

The potential of these emerging markets has stimulated the research and development of a wide range of new applications and services and brought new vendors into

the business. Designs for a wide range of smaller LNG carriers ranging between 1,000 m³ and 30,000 m³ are on the shelf and ready to build. There are now 24 small LNG carriers in service. The traditional LNG tank made of 9 per cent Ni steel with an outer pre-stressed concrete or carbon steel shell has been shrunk and vendors are now offering small modular tanks with capacity in the 10,000 to 40,000 m³ range. Simpler, cheaper storage is also available using type C tanks, horizontal bullets or iso-containers. An added advantage of containers is that they can be transported by truck, rail or barge and used by the end user as storage, thereby avoiding the need to build static storage at the plant.

Small may be beautiful but it is not necessarily cheap (see Figure 2). A large 170,000m³ LNG carrier costs about USD210 million (a bit more if an FSRU), a mid-scale 30,000 m³ (Type C) carrier about USD105 million and a 12,000 m³ carrier about USD50 million. Storage is expensive - it costs around USD1-1.2million per 1000m³ onshore, or approximately USD2 million/1000 m³ on a small-scale LNG carrier. The unit cost for a 50,000 m³ LNG tank could be up to 50 per cent more than for a 100,000 m³ tank.

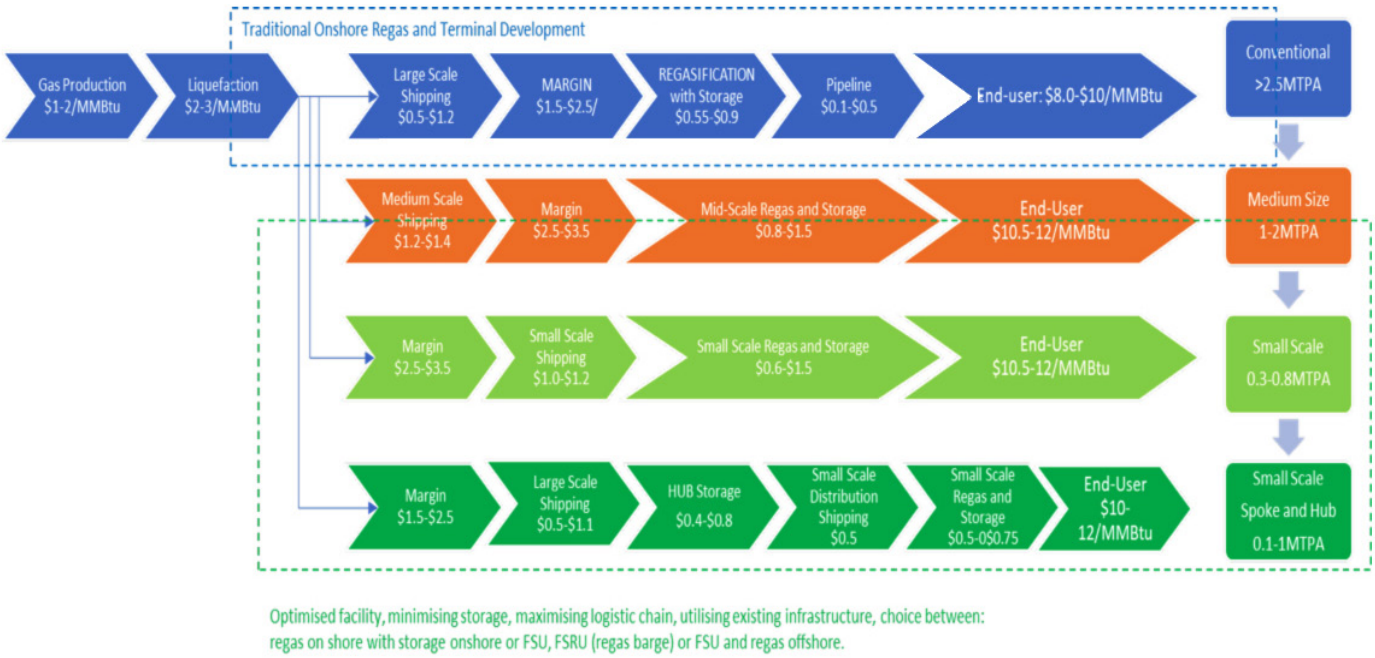
Some LNG to power projects oversize their storage in order to receive full cargoes on a conventional LNG carrier despite the fact that this is far in excess of their needs. A 100 MW combined cycle power station may need only approximately 25,000 m³ of LNG per month. Many of the power plants are smaller than that, sometimes only 10 MW. Excess storage can double the cost of the storage facility. A poorly designed sub-optimal project can result in the cost of LNG to the end user in a small facility being 50-70 per cent higher than via a full-size conventional terminal.

If, however care is taken to optimise all aspects of the project including transportation and storage, and also to site the facility so as to avoid costly dredging and the construction of breakwaters, then the cost of LNG to the end user may be only about 20 per cent higher than via a full-size conventional terminal.

It is also important to note that a small-scale regas developer's focus is most often on the entire logistic chain, while a large-scale developer often has a singular focus on the LNG terminal with the LNG supply left to established shipping companies and the LNG producer, portfolio seller or trader in discrete event simulation (DES) models. Where the small-scale developer is not focused on the logistic chain development, inflated LNG to market prices can be expected. Therefore, small-scale developers often find themselves in the situation of needing not only to develop the terminal but also become a shipping and/or trucking business. This complexity is often seen as a barrier to market, but can, if understood properly, provide significant strategic and commercial benefits.

The base case shown below in blue is the traditional model with onshore storage and regasification with an LNG supply cost to the end user of between USD8 and USD10/MMBtu. By carefully optimising all components in the supply chain and by smart selection of site, technology and contracting strategy — say Build, Operate, Own, Transfer (BOOT) or Engineering, Procurement, Construction, Manage (EPCM) — but also lease, it could then be possible to supply LNG to the end user at between USD10 and USD12/MMBtu in both medium and small-scale modes.

Figure 3: Cost Build-Up



Source: Drawn by the author.

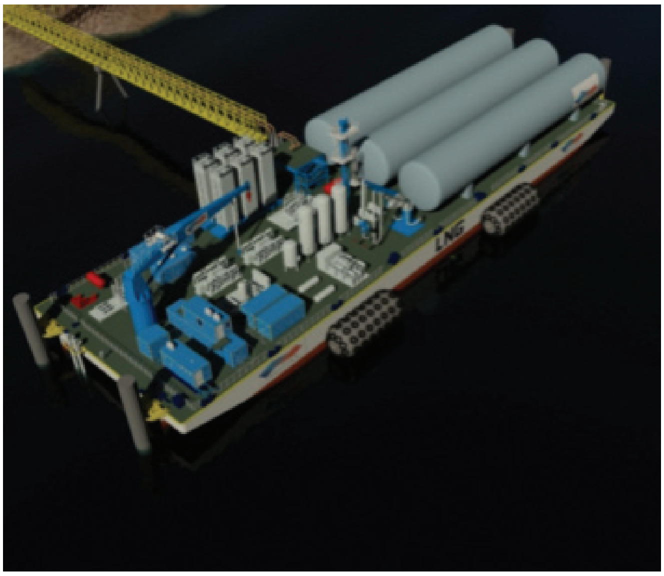
Note: The cost range shown for mid-scale regas and storage is broad enough to cover a regas barge, regas onshore with an FSU or traditional small regas onshore with C-type storage of between 10,000 m3 and 25,000 m3.

Optimisation of logistic chain cost can bring advantage in the order of USD0.5/MMBtu. This may include:

- Storage minimisation.
- Utilisation of existing key infrastructure such as berths.
- Slower steaming of LNG carriers – sailing at 10 knots rather than 14 knots can result in 70 per cent fuel savings.
- Maximisation of LNG carrier utilisation – sharing with other projects.
- LNG supply within a range of approximately 1,000 nautical miles for small-scale and less than 2,500 nm for mid-scale.

An added complication for many of the emerging gas to power projects is shallow water depth which necessitates the need to use small LNG carriers and small FSRU's (if

Figure 4: Small-Scale Floating Storage and Regas Barges



Source: DataFusion Associates Pte Ltd.

Note: SNG™ Barge with 3X 2,270 m^3 storage. Modular regas capacity from 3-30 mmscf/d. Own power generation.

Note: Larger storage – 8 x 2,100 m^3 tanks. Modular regas capacity from 3 to 75 mmscf/d. Own power generation.

Figure 5: Flexible Shallow Water Multi-Modal LNG Distribution System

Source: DataFusion Associates Pte Ltd.

Note: 3x 2,270m^3 LNG storage in C-type tank Transhipment on barge to 20" and 40" ISO Container, to enable sub distribution. Draught: 3.4m; LOA: 95m; beam: 30m; speed: 8kn-10kn.

going for floating storage) rather than conventionally-sized vessels (see Figure 4). An alternative is to use barges. Should LNG carriers be used for the transportation and storage of LNG in smaller markets? These are sophisticated vessels with sophisticated propulsion and large crews. Would simpler solutions such as barges suffice? These are much cheaper, can be built in most countries and can support a range of storage options.

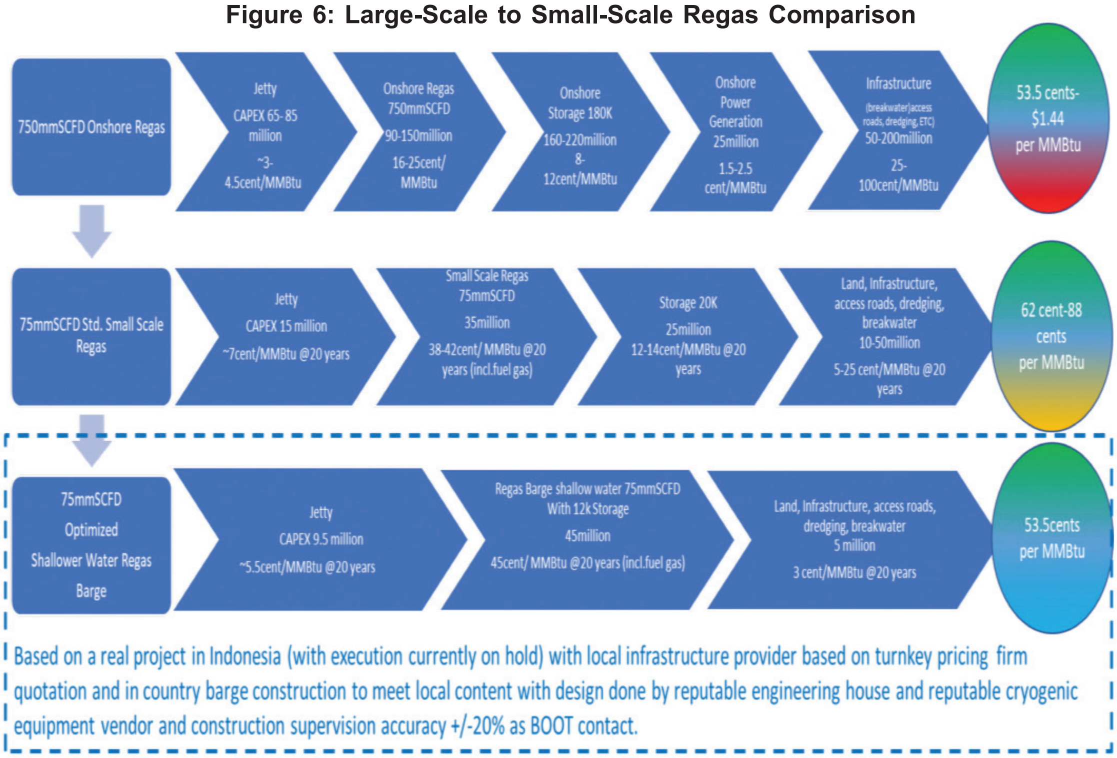
The smaller unit has a draft of less than four metres, a length overall (LOA) of 100m, a beam of 33m and a loading rate of 800m/hour. The larger unit has a draft of less than 4m, an LOA of 120m, a beam of 36m and a loading rate of 1200m/hour. Both are IMO-IGC, SIGTTO, ISGOTT, ISO and ASME Standard compliant.[1] Additional storage can be provided by placing a floating storage unit or barge alongside. A Multi Modal Distribution Concept can further improve costs where ultra-small consumers are part of the distribution chain (<10 mmscf/day) (see Figure 5).

A tug can push and pull, and a barge can moor and offload to standard 5,000DWT wharfs available in most southeast Asian island ports. In addition to delivering ISO containers it can also recover and refill the containers. The latter reduces the number of empty containers in the logistic chain which has significant cost reduction implications for ultra-small facilities such as <10MW power plants, trucking, public transport business and local food processing industries. By utilising barges, costs are brought down and in the worked example shown below, storage and regas costs are USD53.5 cents/MMBtu, the same as the lower end of the range for large-scale facilities.

Although there are not yet any small or medium-sized FSRU's in service, there are now a wide range of transportation and storage options available. With careful supply and project optimisation we do now have economically viable solutions for the small-scale market (see Figure 6).

1 The full terms are: International Maritime Organisation-International Gas Carrier Code (IMO-IGC), Society of International Gas Tanker and Terminal Operator (SIGTTO), International Oil Tanker and Terminal Safety Guide (ISGOTT), International Organization for Standardization (ISO) and American Society of Mechanical Engineers (ASME).

Figure 6: Large-Scale to Small-Scale Regas Comparison



Source: Drawn by the author.

Note: The Optimised Shallower Water Regas Barge is a small-scale floating storage and regas barge, with 12000m^3 Type C-storage.

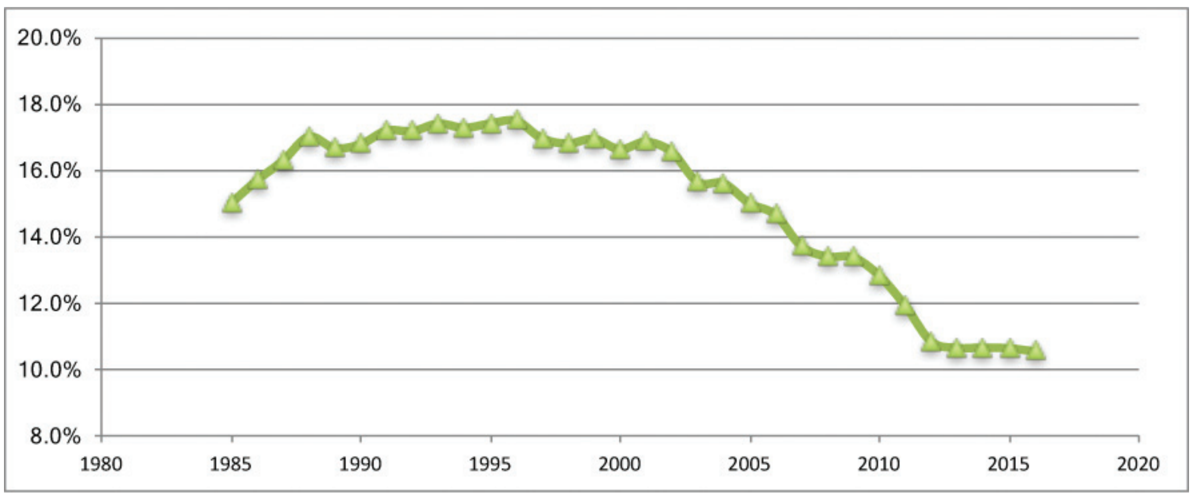
Small Modular Reactors for Nuclear Power: Hope or Mirage?

Professor M. V. Ramana, Simons Chair in Disarmament, Global and Human Security in the Liu Institute for Global Issues at the University of British Columbia, Vancouver, BC, Canada

In October 2017, just after Puerto Rico was battered by Hurricane Maria, U.S. Secretary of Energy, Rick Perry, asked the audience at a conference on clean energy in Washington, D.C.: “Wouldn’t it make abundant good sense if we had small modular reactors that literally you could put in the back of a C-17, transport to an area like Puerto Rico, push it out the back end, crank it up and plug it in?... It could serve hundreds of thousands”.[1] As exemplified by Secretary Perry’s remarks, small modular reactors (SMRs) have been suggested as a way to supply electricity for communities that inhabit islands or in other remote locations.

More generally, many nuclear advocates have suggested that SMRs can deal with all the problems confronting nuclear power, including unfavourable economics, risk of severe accidents, disposing of radioactive waste and the linkage with proliferation. Of these, the key problem responsible for the present status of nuclear energy has been its inability to compete economically with other sources of electricity. As a result, the share of global electricity generated by nuclear power has dropped from 17.5 per cent in 1996 to 10.5 per cent in 2016 (see Figure 1) and is expected to continue falling.

Figure 1: Share of Nuclear Power in Global Electricity Generation



Source: Author’s calculations based on data from *BP Statistical Review of World Energy* (London: BP Co, 2017). See: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

The inability of nuclear power to compete economically results from two related problems. The first problem is that building a nuclear reactor requires high levels of capital, well beyond the financial capacity of a typical electricity utility, or a small country. This is less difficult for state-owned entities in large countries like China and India, but it does limit how much nuclear power even they can install. The second problem is that, largely because of high construction costs, nuclear energy is expensive. Electricity from fossil fuels, such as coal and natural gas, has been cheaper historically—especially when costs of natural gas have been low, and no price is imposed on carbon. But, in the last decade, wind and solar energy, which do not emit carbon dioxide either, have become significantly cheaper than nuclear power. As a result, installed renewables have grown tremendously, in drastic contrast to nuclear energy.[2]

How are SMRs supposed to change this picture? As the name suggests, SMRs produce smaller amounts of electricity compared to currently common nuclear power reactors. A smaller reactor is expected to cost less to build. This allows, in principle, smaller private utilities and countries with smaller GDPs to invest in nuclear power. While this may help deal with the first problem, it actually worsens the second problem because small reactors lose out on economies of scale. Larger reactors are cheaper on a per megawatt basis because their material and work requirements do not scale linearly with generation capacity.

SMR proponents argue that they can make up for the lost economies of scale by savings through mass manufacture in factories and resultant learning. But, to achieve such savings, these reactors have to be manufactured by the thousands, even under very optimistic assumptions about rates of learning.[3] Rates of learning in nuclear power plant manufacturing have been extremely low; indeed, in both the United States and France, the two countries with the highest number of nuclear plants, costs rose with construction experience. For high learning rates to be achieved, there must be a standardised reactor built in large quantities. Currently dozens of SMR designs are at various stages of development; it is very unlikely that one, or even a few designs, will be chosen by different countries and private entities, discarding the vast majority of designs that are currently being invested in. All of these unlikely occurrences must materialise if small reactors are to become competitive with large nuclear power plants, which are themselves not competitive.

There is a further hurdle to be overcome before these large numbers of SMRs can be built. For a company to invest in a factory to manufacture reactors, it would have to be confident that there is a market for them. This has not been the case and hence no company has invested large sums of its own money to commercialise SMRs. An example is the Westinghouse Electric Company, which worked on two SMR designs, and tried to get funding from the U.S. Department of Energy (DOE). When it failed in that effort, Westinghouse stopped working on SMRs and decided to focus its efforts on marketing the AP1000 reactor and the decommissioning business. Explaining this decision, Danny Roderick, then president and CEO of Westinghouse, announced: “The problem I have with SMRs is not the technology, it’s not the deployment -- it’s that there’s no customers... The worst thing to do is get ahead of the market”.[4]

Given this state of affairs, it should not be surprising that no SMR has been commercialised. Timelines have been routinely set back. In 2001, for example, a DOE report on prevalent SMR designs concluded that “the most technically mature small modular reactor (SMR) designs and concepts have the potential to be economical and could be made available for deployment before the end of the decade, provided that certain technical and licensing issues are addressed”. Nothing of that sort happened; there is no SMR design available for deployment in the United States so far.

Similar delays have been experienced in other countries too. In Russia, the first SMR that is expected to be deployed is the KLT-40S, which is based on the design of reactors used in the small fleet of nuclear-powered icebreakers that Russia has operated for decades. This programme, too, has been delayed by more than a decade and the estimated costs have ballooned.[5]

South Korea even licensed an SMR for construction in 2012 but no utility has been interested in constructing one, most likely because of the realisation that the reactor is too expensive on a per-unit generating-capacity basis. Even the World Nuclear Association stated: “KAERI planned to build a 90 MWe demonstration plant to operate from 2017, but *this is not practical or economic in South Korea*” (my emphasis). Likewise, China’s plans for constructing a series of High Temperature Reactors (HTR-PM) appear to have been cancelled, in part because the cost of generating electricity at these is significantly higher than the generation cost at standard-sized light water reactors.

On the demand side, many developing countries claim to be interested in SMRs but few seem to be willing to invest in the construction of one. Although many agreements and memoranda of understanding have been signed, there are still no plans for actual construction. Good examples are the cases of Jordan, Ghana and Indonesia, all of which have been touted as promising markets for SMRs, but none of which are buying one.

Another potential market that is often proffered as a reason for developing SMRs is small and remote communities. There again, the problem is one of numbers. There are simply not enough remote communities, with adequate purchasing capacity, to be able to make it financially viable to manufacture SMRs by the thousands so as to make them competitive with large reactors, let alone other sources of power. Neither nuclear reactor companies, nor any governments that back nuclear power, are willing to spend the hundreds of millions, if not a few billions, of dollars to set up SMRs just so that these small and remote communities will have nuclear electricity.

Meanwhile, other sources of electricity supply, in particular combinations of renewables and storage technologies such as batteries, are fast becoming cheaper. It is likely that they will become cheap enough to produce reliable and affordable electricity, even for these remote and small communities never mind larger, grid-connected areas, well before SMRs are deployable, let alone economically competitive.

1 Ron Adams, “Perry’s Vision of Nuclear Generator Movable by Cargo Plane Successfully Tested During Kennedy Admin”, *Forbes*, 29 September 2017.

2 Mycle Schneider and Antony Froggatt, *The World Nuclear Industry Status Report 2017* (Paris: Mycle Schneider Consulting, 2017). See: https://www.worldnuclearreport.org/-2017-.html.

3 Alexander Glaser et al., “Small Modular Reactors: A Window on Nuclear Energy” *Energy Technology Distillate*, no. 2 (Princeton, N.J.: Andlinger Center for Energy and the Environment at Princeton University, June 2015), See: http://acee.princeton.edu/distillates/distillates/small-modular-reactors/.

4 Anya Litvak, “Westinghouse Backs off Small Nuclear Plants”, *Pittsburgh Post-Gazette*, 1 February 2014. See: http://www.post-gazette.com/business/2014/02/02/Westinghouse-backs-off-small-nuclear-plants/stories/201402020074.

5 Mycle Schneider and Antony Froggatt, op. cit.

Staff Publications

Internationally Refereed Journal Articles

Allan Loi and Ng Jia Le, "Analyzing Households' Responsiveness towards Socio-Economic Determinants of Residential Electricity Consumption in Singapore" *Energy Policy* 112 (2017): 415-26.

Wei T. and **Liu Y.**, "Estimation of Global Rebound Effect Caused by Energy Efficiency Improvement" *Energy Economics* 66 (2017): 27-34.

Books/Book Chapters

Hari M. P., Gautam Jindal and Jacqueline Tao, "Best Practices in Cross Border Power Investments with ASEAN Perspective" in *Connectivity and Trading in Power and Energy: A Regional and International Dimension,* ed. Syed Munir Khasru, Institute for Policy Advocacy and Governance, Dhaka, Bangladesh, 2017.

Other Publications

Brantley Liddle, "The Urbanization, Development, Environment, and Inequality Nexus: Stylized Facts and Empirical Relationships" Asian Development Bank Institute Working Paper 788, 2017.

Allan Loi, "Assessing the Benefits of an Open Electricity Market for Households and Small Businesses", *Channel News Asia*, 31 October 2017.

Melissa Low, "The One Item to Pay Attention to at COP 23", *Eco-business.com*, 27 October 2017.

Staff Presentations and Moderating

26 October Liu Yang presented "Charting the ASEAN Energy Efficient Future" at *Unlocking ASEAN's Energy Efficiency Potential*, a roundtable organised by the ASEAN Centre for Energy at *Singapore International Energy Week 2017*, Sands Expo and Convention Centre, Singapore.

26 October Liu Yang moderated the session "Utility Transformation" in the *Innovations in Energy Services: Utility Transformation* event organised by SIEW and Asian Utility Week at *Singapore International Energy Week 2017*, Sands Expo and Convention Centre, Singapore.

19 October Philip Andrews-Speed presented "Energy Connectivity in Southeast Asia" *at Insular and Divided Energy Cities: Between Autarky and (Re)Integration*, a KOSMOS workshop organised by the IRI THESys, Berlin, Germany.

13 October Gautam Jindal presented "Singapore's Carbon Tax: Implementation and Implications", at the *Changi Airport Environment Forum*, Singapore.

06 October Melissa Low presented "Climate Change and Singapore", at the NUS Geography Department, Singapore.

29 September Christopher Len presented "Political Cooperation and Science Diplomacy in the Arctic?" at *Arctic Frontiers Overseas Seminar*, Singapore.

28 September Christopher Len co-moderated the National University of Singapore-University of Tromso *Workshop on Collaboration Opportunities between NUS and UiT, Singapore*.

27 September Philip Andrews-Speed presented "Electrical Power Connectivity in Southeast Asia" at *Harvard Project on Climate Agreements Workshop*, Shanghai, China.

27 September Liu Yang presented "Unlocking the Value of Smart Storage" at the *8th International Smart Grid Conference*, Seoul, South Korea.

26 September Brantley Liddle presented "Consumption-Based Accounting and the Trade-Carbon Emissions Nexus in Asia" at the *ADBI-World Economy Workshop on Globalization and Environment*, Tokyo, Japan.

19 September Christopher Len presented "Capacity-Building for Sustainable Energy Access in Remote Locations: Common Challenges and International Opportunities" at the *Arctic Energy Summit 2017*, Helsinki, Finland.

19 September Christopher Len moderated "Panel on Sustainable Development and the Southeast Asian Experience" at the *Arctic Energy Summit 2017*, Helsinki, Finland.

13 September Brantley Liddle presented "Consumption-Based Accounting and the Trade-Carbon Emissions Nexus in Asia" at a joint seminar organised by the Department of Geography and Resource Management and Institute of Environment, Energy and Sustainability at The Chinese University of Hong Kong, Hong Kong.

5 September Alan Loi presented "How Much Do Labels Actually Matter for Electricity Savings?: Singapore's Case for Residential Air-Conditioner Purchases and Usage Behavior", at the *12th International Association for Energy Economics European Conference*, Hofburg Congress Center, Vienna, Austria.

Staff Media Contributions

Allan Loi quoted in "The Big Read: As Electricity Market Opens Up, Experts Foresee Payoffs for S'pore and Marked Change in Power Change Habits", *Todayonline*, 31 October 2017.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on China's winter gas shortages, 28 October 2017.

Philip Andrews-Speed was quoted by *Energy Intelligence* on local-central tensions in China's energy sector, 17 October 2017.

Melissa Low was interviewed by *The Business Times* on climate change adaptation, 4 October 2017.

Philip Andrews-Speed was interviewed by *Radio Free Asia* on the Shenhua-Guodian merger in China, 13 September 2017.

Christopher Len was interviewed by *Reuters* on China's 19th Party Congress, 11 September 2017.

Allan Loi was quoted in "Diesel Vehicles May Be on Their Way Out", *Straits Times*, 3 September 2017.

Recent Events

Dr. Philip Andrews-Speed, Mr. Beni Suryadi, Dr. Michael Abundo, Mr. Tony Regan, Professor M.V. Ramana and Dr. Maxensius Sambodo (Photo by ESI).

27 October, "Emerging Technologies for Small-Scale Grids" (Singapore International Energy Week Roundtable)

Consistent with SIEW 2017's focus on seizing opportunities, this roundtable examined a selection of technologies that hold the promise of being able to provide energy supply to small-scale, community-based grids. This is particularly relevant to parts of Southeast Asia where significant populations live on islands or in other remote locations. Speakers from the ASEAN Centre for Energy, OceanPixel Pte Ltd., DataFusion Associates Pte Ltd. and the University of British Columbia addressed a variety of issues, including but not limited to small-scale liquefied natural gas (LNG), small modular nuclear reactors (SMRs) and different forms of marine energy. Although all of these technologies are under demonstration, none have been deployed commercially on a large scale in the region, if at all. The presenters assessed the various technologies' state of development and potential, and identified the policies required to support their widespread deployment in Southeast Asia. This event was moderated by ESI's Dr. Philip Andrews-Speed, Senior Principal Fellow and Head of the Energy Security Division.

16 October, "Market-Based Measures for Reducing CO_2 Emissions in International Shipping" (ESI Seminar)

Ms. Lee Xin Ni, Research Engineer at the Centre of Maritime Studies, National University of Singapore presented research currently being undertaken jointly between CMS and ESI. The research primarily focuses on market-based measures (MBMs) and their suitability in emissions reduction in international shipping. Her analysis began with a systems perspective of how MBMs may lead to CO_2 reduction, followed by definitions of the two fundamental types of MBMs – bunker levies (a form of tax on fuel) and emission trading systems. She then explained how key criteria was


Participants at the SIEW 2017 Roundtable (Photo by ESI)

used to assess MBMs in terms of their suitability to the sector. The findings show that a bunker levy is easier to implement than an emissions trading system. Thus the research currently argues that international shipping should adopt a bunker levy in the immediate term while searching for a suitable MBM in the long term.

9 October, "Singapore's Long-Term Energy Future: PV, Storage and Virtual Power Plants" (Expert Consultation)

This event was organised by ESI and gathered key stakeholders to discuss the long term outlook for Singapore's electricity sector, with a particular focus on how developments in solar, energy storage technologies, as well as potential business innovations such as prosumage and virtual power plants will help forge the future electricity landscape. While barriers such as intermittency and limited land space


Participants at ESI's Solar PV Workshop (Photo by ESI)


Professor Ang Delivering the Opening Remarks at the Solar PV Workshop (Photo by ESI)

Mr. Mark Leslie (Photo by ESI)


Mr. Christophe Inglin (Photo by ESI)


Dr. Jenny Riesz (Photo by ESI)

Participants at the ESI's Solar PV Workshop (Photo by ESI)

Ms. Stephanie Bashir (Photo by ESI)

were recognised, recent technological advancements in energy storage systems and innovative deployments of PV installations such as floating PV, have opened up new opportunities for solar in Singapore. Local stakeholders discussed shifts in policies that help facilitate a change in how the energy is consumed, not only through the use of smart devices, but also through innovative ways for consumers to interact with energy through demand response capabilities.

4 October, "Who Sets the Agenda on Economic Diversification in Kazakhstan? An Emphasis on Energy Diversification" (ESI Seminar)

Mr. Mergen Dyussenov, a PhD student at the NUS Lee Kuan Yew School of Public Policy, presented a paper on agenda-setting for energy diversification policy in the broader context of economic diversification in Kazakhstan. He noted that among the major actors in Kazakhstan, the government (including the Prime Minister's office and President) tend to exert predominant influence, though other actors may also play a role, such as media and academia. His research revealed that think tanks seem to set the government's agenda for economic diversification policy in Kazakhstan and that the government, while exhibiting the larger agenda-setting magnitude vis-à-vis the other actors, shapes subsequent debates as measured by the number of relevant references in the media, think tanks and academic publications.

20 September, "Charting an Energy Efficient Future" (ESI Seminar)

Dr. Liu Yang, Senior Research Fellow at the Energy Studies Institute discussed global trends in energy efficiency. Specifically, he analysed global investment in energy efficiency for the year 2016 and the drivers that underpinned much of it. He highlighted the growing market for energy efficiency services and the various business models that have helped drive efficiency. He noted that despite great improvements in energy efficiency, the economic growth of developing countries does not seem less energy-intensive than previous growth in industrialised countries. As such, he underscored the importance of new energy technology leapfrogging opportunities that developing countries should harness in order to decouple emissions and economic growth.

6 September, "The Role of Technological Trajectories in Catching-Up-Based Development: An Application to Energy Efficiency Technologies" (ESI Seminar)

Dr. Zhong Sheng, Research Fellow at the Energy Studies Institute presented a paper that he co-wrote on technological trajectories applied to energy efficiency technologies. The paper argues that the analysis level of a technological trajectory is suitable for analysing the decisions of latecomer countries with regard to the technological area that they should focus on. Using the OECD's ENV-TECH list and patent data from the European Patent Office, the authors identified and investigated how countries active in three fields of energy efficiency technologies are classified as either latecomer or incumbent countries. He noted the use of an explorative regression model to establish that latecomer countries tend to contribute to a lesser extent than incumbents to the main technological trajectories in the fields under consideration.

Contact

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