The Asia-Pacific Journal | Japan Focus
Volume 14 | Issue 24 | Number 6 | Article ID 4987 | Dec 15, 2016

Korea's Greening Strategy: The role of smart microgrids

Sung-Young Kim, John A. Mathews

There are many ways that an economy can be greened. Building vast new renewable energy manufacturing industries is one pathway – as pioneered by China. Deploying extensive renewable power generation systems is another pathway – as demonstrated by Germany with its *Energiewende*. Yet another route is pursuing R&D led strategies and strategic initiatives via the military, as shown by the US. Now Korea demonstrates another pathway, one based on liberalization of its power generation system (to promote competition) and development of the IT-enabling of its electric power grid (smart grid) with a characteristic modular approach to smart grid construction, utilizing microgrids.

One of Korea's great advantages during the era of fossil fuels dominance has been a tightly regulated electric power industry, based on a state-owned electric power quasi-monopoly Korea Electric Power Corporation (KEPCO) which has provided reliable electric power to Korean industry at artificially low (subsidized) prices. According to a 2013 World Bank report, KEPCO retains 95% market share over power generation and 100% market share over transmission and distribution of the electricity industry.[1] This paradigm is under stress as Korea moves slowly to green its economy and power system. Admittedly, Korea's rate of take-up of renewable power sources is slower than in almost all OECD economies. Yet its advance towards a smart grid is characteristically bold and export-business oriented – in a continuation of the industrial policy traditions that have served Korea well in the past.

We have been following the evolution of Korea's greening, from the original 'green growth' strategies developed under the previous president, **Lee Myung-bak**, to the more recent initiatives taken under the presidency of **Park Geun-hye**. It is only with the announcement in August 2016 of a drive to open the electricity generation market to competition, that the greening of Korea's power system has become a serious possibility.

In this article we reflect on these latest developments in Korea's green growth (now subsumed under 'creative economy') strategy, and probe the reasons that have held back the transition to renewable sources of energy. Our argument will focus on the particular niche targeted by Korea, namely the transition to smart grids and in particular modular, self-sufficient microgrids that are suitable for Korea's own islands and as exports to other countries, which are home to large numbers of islands (Indonesia) or geographically remote communities (Canada).[2]

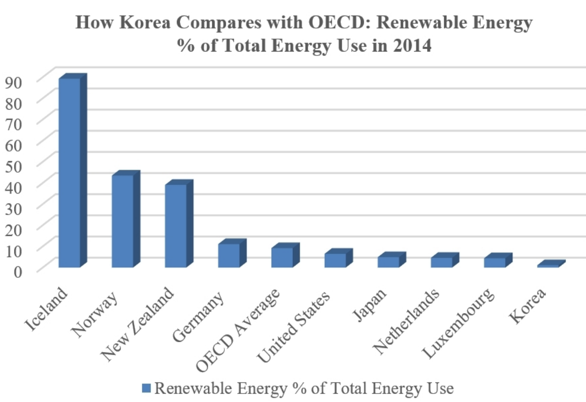
Our argument will be that Korea has a pragmatic and business-oriented green strategy (like Taiwan or China) that involves promoting new home-grown microgrid systems, involving a broad range of Korean companies such as LSIS and Samsung SDI as well as the state-owned power utility KEPCO. We demonstrate that issues to do with liberalization and competition in the electric power sector are closely related to a broader shift to green energy systems, in which an interesting contrast is emerging between Taiwan and Korea.[3] Both countries are grappling with the legacy of a quasi-monopoly in electric power. Taiwan is now moving rapidly towards a post-nuclear era, while Korea remains committed to continuing with its nuclear strategy. We show that cost factors have played an important role in KEPCO's microgrid strategy: the costs for independent and autonomous energy generation and energy storage systems, suitable for island operation, are significantly cheaper than diesel-burning power systems. Our findings suggest that countries which have coordinated early investments in the manufacturing of renewable energy devices stand to reap the greatest benefits in securing techno-economic competitiveness.

Liberalization of Korean power generation sector

In July 2016 the Ministry of Trade, Industry and Energy (MOTIE) revealed detailed investment plans focused on promotion of 'new energy industries' as the next pillar of the Korean economy, combined with early moves to liberalize the market for power generation in Korea.[4] These had been the missing ingredients in previous announcements as KEPCO's monopoly had frustrated efforts to promote the generation of renewable electric power and the manufacturing of renewables. The statement from the Ministry indicates the strongest intention yet to launch a thorough **liberalization** of power generation in Korea, designed by MOTIE to attract new players into the sector. Solar power generators for example will be able to sell electricity to corporate and household customers via the Korea Power Exchange (capped at 10 MW per installation). Renewable energy-based power plants totalling 13 GW of power capacity by 2020 are to be promoted, with an eco-investment of 2 trillion Won (more below).

An earlier announcement from MOTIE in June 2016 stated the intention to open the power generation market in stages to competition, initially allowing the listing of power generating subsidiaries of KEPCO as independent companies on the Korean bourse. The government announced that it would continue to hold a stake in these companies.[5] Six new energy businesses were targeted by officials in the Ministry for promotion – including integrated energy management systems and independent microgrid businesses. The more recent announcement in July 2016 envisages government expenditure of 42 trillion Won (US$ 36 .6 billion) in new energy businesses. This expenditure is to be combined with the commitment that the Ministry "would come up with specific plans to allow renewable energy source-based power generators to participate in the energy sector" – with the clear intention that this would "attract more private companies to join the market".[6] At the same time Korea's Renewable Portfolio Standard (RPS) targets were revised, marginally increasing from 4.5% to 5% by 2018 and from 6% to 7% by 2020. This will require the level of renewable power to be generated by existing power generators to embrace renewable energy at a faster pace.

It is notable that other East Asian industrial giants are grappling with the same issues. In Japan there is under way a 3-stage process for breaking the regional monopolies of power companies (such as Tokyo-based TEPCO), under the terms of the amended Electricity Business Act passed in November 2013 – in the face of powerful opposition from the incumbent generating companies.[7] In Taiwan the newly elected Democratic Progressive Party government headed by the country's first female President, Tsai Ing-wen, is also tackling the monopoly position of Taipower, as prelude to drastically raising levels of competition and renewable energy input into the Taiwanese grid.[8] In Korea similar moves may be seen to be under way – which may belatedly raise renewable energy levels in Korea, which are still the lowest levels of any OECD country (meaning that Korean power generation is more dependent on fossil fuels than any other OECD country; chart below). Liberalization of the Korean power sector has been the missing ingredient, allowing KEPCO to retain its dominance while impeding initiatives to raise the level of renewable power generation. As of December 2015, Korean power production was primarily sourced by such non-renewable, conventional generations as coal (28%), LNG (33%) and nuclear (22.2%).[9] Moreover, these figures highlight the limits of the overall effectiveness of local PR campaigns in Korea such as *Wonjeonhanajurigi* ("One Less Nuclear Power Plant") launched by the metropolitan government of Seoul, which most serious analysts appear to recognise.[10]



Source 'S. Korea's renewable energy use lowest in OECD: report', *Yonhap News Agency*, 2 December 2015, at: http://english.yonhapnews.co.kr/business/2015/12/02/0502000000AEN20151202002600

The MOTIE's July 2016 announcement envisages investment of 42 trillion won (US$36.6 billion) by 2020 in the building of new renewable energy industries. These investments include renewable energy power plants with combined power rating of 13 GW (equivalent of 26 standard coal-fired power plants), along with energy storage systems and smart metering. The principal focus of the new strategy is not just the building of new renewable power plants but the shift to an IT-enabled grid with domestic sales and exports of the key technologies involved, including smart meters, energy management systems and energy storage systems as well as battery systems, electric vehicles (EV) and EV charging infrastructure.

Liberalization is the critical move that will resolve two of the major blockages standing in the way of Korea's greening of its electric power system. The first blockage has been the continuation of low electric power prices, strongly defended by the Korean government as a source of competitiveness for the manufacturing sector. The second hurdle has been KEPCO's monopoly over power generation. It is worth probing these points because they have relevance to other countries looking to make the renewables transition.

First, as a means to sustain the international export competitiveness of manufacturers, the Korean government has long subsidised electricity prices (rather than allowing market-driven prices). This policy has provided more and cheaper electricity to consumers and businesses and given Korean firms a cost advantage over foreign competitors.[11] According to a November 2013 presentation by **Son Jong-Cheon** of the Korea Smart Grid Institute, Korean electricity prices were half the average for OECD countries – at US 6c/kWh for industry and 8 c/kWh for domestic consumers, compared with 15 c/kWh for industry and 24 c/kWh for domestic consumers in Japan. Korean power prices were even lower than the average in shale-gas rich USA (the Americans burn very little oil for power, so fracking's impact on electricity has primarily been via gas), where industrial consumers pay 7 c/kWh and domestic consumers pay 11 c/kWh.[12] The unsurprising result of such a policy has been a substantial increase in energy consumption by 56% over the 2002-2010 period (or between 3 and 4% a year, exceeding the rate of GDP growth) while the price of electricity has only grown by 15%.[13] As suggested by a June 30, 2013, article in *Korea Times*, the policy of keeping electricity prices so low is now a hurdle on the way to regulatory reform.[14] In addition, the continued use of nuclear power despite concerns over safety especially after the 2011 Fukushima nuclear disaster has only compounded the availability of artificially cheap and plentiful electricity.[15]

The government's subsidisation of electricity (through limiting price increases) has also burdened KEPCO (and its six affiliated generator companies) with increasing levels of debt.[16] This may in part explain why KEPCO's generation of electricity from renewables has been so minor. Of the total 8,618 MW generation capacity utilizing renewable energy sources, privately-owned generators produced at 8,408 MW capacity – as presented by the *Korea Times*. In effect, it's fair to say that KEPCO's contribution to the generation of renewable energy (compared to other OECD countries as mentioned above), was almost next-to-nothing. We view this as the key impediment to Korea's raising its level of renewable power generation.

Second, the weak uptake of renewable energy is also arguably due to KEPCO's maintenance of a virtual monopoly over the generation, distribution and retail segments of the overall electricity industry.[17] This monopoly remains, in spite of attempts to introduce full competition through liberalization and privatization in the early 2000s.[18] While private companies are allowed to participate in the generation of electricity and are responsible for the majority of renewable energy generation in Korea, they have a mere 5 percent share of total electricity generation.[19] The one major area where KEPCO is no longer involved is in the operation of the power market, which since 2001 has been the responsibility of the non-profit body, Korea Power Exchange (KPX). The core function of KPX is to oversee the bidding, metering, settlements, and monitoring of the electricity market. KPX is required to release market information on the volume and cost of electricity on a daily basis and then accept or decline power generation offers by KEPCO and the several private power generator companies. Given KEPCO's monopoly over the retail aspect of the electricity industry, KEPCO is KPX's sole buyer. While KPX is legally an independent body, it is unclear just how impartial this agency is given that KEPCO and private power producers have permanent representation on KPX's executive board.

The government's promotion of a Smart Grid Strategy

The promotion of a smart grid has been a feature of the Korean green growth strategy from its inception (in 2008) – as a way of accommodating (we surmise) the special position of KEPCO. There have been numerous initiatives, including the creation of new institutions such as the **Korea Smart Grid Institute** (KSGI), a new industry association, the **Korea Smart Grid Association** (KSGA), and the formulation of an industrial roadmap, the **Korean Smart Grid Roadmap 2030**.[20]

A special feature of the Korean approach has been a focus on modular microgrids, with the development of an urban-based modular concept called the **Smart Grid Station** (SGS) and island-based microgrids. In this endeavor, the Korean strategy is consistent with US military-led strategy, where the emphasis has been on grid IT-enabling and resilience via microgrids.[21] In December 2008, the government allocated investment funds of Won 76.6 billion, (approximately US$ 66 million) to the construction of a smart grid test-bed on Jeju Island – at the time the largest of its kind worldwide – with investment from the private sector totalling Won172.7 billion (US$ 149 million). The government's aim in providing this seed funding was to accelerate the commercialization and exports of smart grids before foreign competitors could break in.[22]

There were five technological fields under development in the test-bed, which includes:

(1) *Smart Power Grid*, focused on improving the reliability and quality of power supply through intelligent monitoring of demand and automated power grid recovery systems,

(2) *Smart Consumers*, aimed at energy savings for consumers through the development of intelligent home appliances relying on products such as Smart Meters, which provide real-time information

(3) *Smart Transportation* – the building of nationwide electric vehicle recharging infrastructure and Vehicle-to-Grid (V2G) systems (allowing car batteries to be charged off-peak and resale of surplus electricity during peak times)

(4) *Smart Renewables*, aimed at building energy self-sufficiency in homes, buildings and factories through the creation and deployment of microgrids, and

(5) *Smart Electricity Services* focused on reducing energy usage through new business models, increased competition in the electricity market, and real-time electricity trading.

A total of 12 consortia involving 168 companies were involved in developing these five fields – indicating the continuing developmental goals of the Korean government.[23] Let us highlight the case of the Smart Renewables project.[24] Here KEPCO led a consortium of 16 companies to develop microgrids, which includes KEPCO-affiliated utilities such as KOSPO and power systems manufacturers such as Hyosung and LSIS. The efforts were aimed at helping to meet Korea's renewable energy targets under the Renewable Portfolio Standard discussed earlier. A fully integrated and operating smart grid was expected to be completed by May 2013 – and was completed on time. A *National Smart Grid Roadmap* was then developed by 130 public and private experts (of the National Roadmap Sub-Committee). The then Ministry of Knowledge Economy (MKE, now MOTIE) established the Korea Smart Grid Institute (KSGI) to coordinate the implementation of the Smart Grid Roadmap, which set out ambitious step-by-step development goals in the five technological fields established for the test-bed. The initial goal was to verify the technological feasibility of operating microgrids from 2010-2012 while broader efforts were targeted at building a smart grid test-bed. Efforts from 2013-2020 were aimed at building smart grids across selected cities, including Seoul. In terms of microgrids specifically, policymakers seek to deploy demonstration projects to test their commercial feasibility. The full commercialization of microgrid systems is expected to occur from 2021-2030 as part of the completion of a nationwide integrated smart grid.

In 2012, the Presidential Committee on Green Growth (PCGG) finalised the *First Five-Year-Master Plan for the Smart Grid* (2012-2016) in accordance with the *Special Act on Promoting Smart Grid Establishment and Usage*. The government committed itself to contributing to a total of Won 3.6 trillion (approximately USD$3.1 billion), which was expected to be provided from a mix of public and private sources.[25] According to the Director of the Policy Planning Team at the KSGI, **Son Jong-Cheon**, this plan set out clear technological and infrastructure deployment targets focused on a shift from testing the feasibility of new smart grid technologies (such as microgrids) through 'test-beds' and their eventual commercialization via 'pilot' projects.[26] Institutions such as Seoul National University are cooperating in providing the campus as a microgrid test area.[27] The attainment of the goals in the Five Year Master Plan will depend critically on the creation of new service delivery business models utilising Advanced Metering Infrastructure (AMI), Demand Response (DR), Energy Management Systems (EMS), Energy Storage Systems (ESS), Electric Vehicle (EV) Charging, Vehicle-to-Grid (V2G), and Renewable to Grid devices and systems. A total of eight proposed consortia involving 14 provinces, service providers, system integration firms, device manufactures were expected to drive these pilot technology deployment projects. Importantly, the pilot projects would be targeted at major cities throughout the country; a logical step in light of the fact that cities consume the majority of energy with 46% of the national population and 46% of national GDP centred in the seven largest cities.

Policymakers involved in the promotion of these new products, technologies and systems are well aware of the risks associated with governments ‘picking winning technologies’ such as selections based upon special interests in the private sector, the unpredictability of success or failure, and the failure to cease support even after dismal results. However, as argued by the third and current Chairman of the Prime-Ministerial Green Growth Committee, **Lee Jisoon**, there are conditions when industry policy is warranted such as the presence of externalities (e.g. environmental pollution), the likelihood of coordination failures if economic activities are left purely to the private sector, and the likelihood of large markets for new products, which may not currently exist due to high start-up costs (e.g. green batteries).[28] Governments can step in especially in the initial stages of promotion to overcome such shortcomings. According to Chairman Lee, the success of industry policies including those targeted at green technologies rest on several ‘prerequisites’:

> ‘First, potential winners should be selected using market signals. When relevant domestic markets do not exist, then policy makers can get useful information by surveying global markets. Second, the supports should be given almost automatically, once the right candidates are chosen. Third, supports should be terminated when it becomes evident that a wrong choice is made. Fourth, when a firm becomes successful thanks to the assistance, a portion of the fruits must be recouped’.

Even if such conditions are met after extensive consultations with experts in industry and research, Chairman Lee makes clear that ‘nobody is sure, however, whether they [green technologies selected for promotion] are the right ones. It is highly likely that several of them are mistakenly chosen’.

The extent to which Korean efforts to develop smart grid technologies will result in success is an open question and will only be clearer in the longer-term given that the foundational *National Strategy for Green Growth* had a time horizon of over forty years (2009-2050).[29] What is clear in the present is that for Korean policymakers smart grid technologies remain a key pillar of the *Second Five-Year Plan for Green Growth* (2014-2018). What is especially noteworthy about the Second FYP is the explicit focus on the targeted implementation of GG plans introduced under the First FYP. While the thrust of the First FYP is on a government-led push for the building of the institutional infrastructure for governing GG, the Second FYP is focused on encouraging the private sector to lead greening efforts and to achieve concrete industry development results.

Global strategy

The shift from a ‘dumb’ electric power grid to a ‘smart grid’ enabled by IT, is now already under way globally, and emerging as a site of intense competition between the US, Europe, Japan, China – and Korea.[30] The continued focus on smart grids is driven by various considerations as presented in the detailed analysis of the *Second FYP for Green Growth*.[31] This includes a global market for smart grid technologies, which is expected to grow by an average of 7 percent per year from 2013 to 2020, so that by 2020, the global market value of smart grid technologies (including ESS, EMS, smart plugs, smart appliances, wind turbines, power lines and power transistors) will be worth around US$ 350 billion (or Won 400 trillion). In Korea alone, the domestic market for smart grid technologies such as ESS and microgrids is expected to grow from just Won 3.9 billion (US$ 3.4 million) in 2012 to Won 2.5 trillion (US$ 2.1 billion) by 2020. It is no surprise then, as the *Second FYP* shows, that there are national green development plans being developed and promoted in the United States, Japan, European Union, Germany and China, all of which undoubtedly seek to gain a competitive edge in this strategic industry.

Of course, challenges remain in the development of this strategic growth area in Korea such as technological short-comings of domestic players and delays in private sector investments as mentioned in the *Second FYP*. However, the recognition of such obstacles has been less an impediment for the government's guiding role and more a key driver. According to **Cheong Seung Il**, the Director-General for Energy Industry Policy at the MOTIE, the fact that smart grid technologies are in their 'infancy and are not yet ready for commercialization' is the driving rationale behind the government's commitment to 'establish smart grid technologies as a fledgling industry in South Korea'.[32]

In accordance with the focus on smart grid technologies targeted for promotion such as microgrids in the MOTIE's *Second National Energy Plan*, in July of the same year the Ministry re-affirmed the government's commitment to promoting remote island microgrids as one of six strategic areas.[33] However, we note that this initiative has had minimal impact on the uptake of renewable energies because of its failure to address the critical issue of KEPCO's dominance of the power generation sector. Importantly, as the major thrust of the *Second FYP* for GG shows, the Ministry also set the goal of increasing the commercialization of R&D and to close a perceived technology gap with leading countries in fields such as demand-response driven ESS – a core technology in microgrids.[34]

Smart grid initiatives

As noted earlier, part of the first phase of Korea's green growth strategy saw a smart grid project launched on Jeju Island, the largest of Korea's islands off the south coast. This project sought to test the ingredients of a smart grid strategy in real time and in a real, integrated and self-contained setting. The Jeju Smart Grid Demonstration project, launched in 2009 and concluded in 2013, involved 168 Korean and foreign companies in a series of consortia – the world's biggest smart grid stand-alone project, following the *National Smart Grid Roadmap* launched in June 2009.

KEPCO's leadership of one of the consortia in the Jeju island test-bed involved a total of 246.5 billion won (US$ 216 million), which was used to develop and test a total smart grid solution.[35] In addition to its achievements in the Smart Renewables field, KEPCO made important progress in the Smart Power Grid field (one of five as discussed earlier), the company successfully developed a two-way electric power transmission and automated restoration technology in the event of system failures, real-time monitoring of the electrical substation system, and smart meters to help consumers respond more effectively to peak demand and prices.

After the conclusion of the test-bed project, in 2014 KEPCO announced its intention of investing US$ 155 million between 2015 and 2017 on furthering the development of smart grid technologies.[36] In July 2016, KEPCO announced its intention to roll-out its smart grid solution throughout the country by 2018.[37] This ambition appears achievable considering the company's steady progress in implementing new technological advances gained from the Jeju test-bed including the 'Smart Grid Station' (SGS) project – a type of microgrid centred on buildings in cities.[38] The project, launched in 2014, involved 39 SMEs and was aimed at developing an EMS, which monitors and controls renewable energy resources such as solar modules, ESS, EV chargers, and smart metering devices inside buildings. The project also involves the development of hybrid Power Conversion Systems (PCS), which convert energy generated from renewable energies to charge the system's battery and provide electricity. In 2014, KEPCO installed SGSs in 29 of its own offices. In 2015, with a budget of US$ 13.5 million, KEPCO launched a further 75 SGSs in 75 of its buildings, and six SGSs in the buildings of various public and private organisations.[39] In total, KEPCO's SGS projects demonstrated 10% reductions in power consumption (equalling 10 GW) and 5% cuts to peak demand (totalling 4MW) for consumers. These reductions meant KEPCO was able to save US$ 4.6 million in transmission, generation and distribution costs as well as achieve 5% reductions in CO_2 emissions. The value of this modular approach to the construction of smart grids has been recognised internationally. In October 2015, KEPCO concluded the first of many foreseeable SGS pilot projects with Middle Eastern governments when it signed a US$ 3 million construction project with the Dubai Electricity & Water Authority to support plans to turn Dubai into a 'Smart City' by 2021.[40]

The global race to develop standards for smart and microgrid technologies is being spearheaded by national authorities established by various countries. Standards are being developed in the US (by NIST and IEEE), in Europe, in Japan, and elsewhere. For a country like Korea, the challenge is to keep abreast of these standards and develop products that are compatible with them – as in previous experiences such as telecommunications where Korea's early adoption of the Qualcomm CDMA standard turned out to be a winning strategy.[41] In the development of national standards related to microgrid technologies, Korea's approach has been coordinated by public and private participants of the 'Korea Smart Grid Standardization Forum' as outlined in a presentation by Director **Kim Eung-sang** of the Korea Electrotechnology Research Institute (KERI).[42] The MOTIE established this Forum under the Korean Agency for Technology and Standards (KATS) in 2010 to lead the national standardization of smart grid technologies arising from the Jeju Island test-bed. The Korea Smart Grid Association – a body representing the interests of 143 companies involved in smart grid technologies (and government research institutes such as KERI) – acts as the Secretariat of the Forum. The Forum initially focused on national standards for intelligent power devices (2010-11) and power monitoring and control (2012-13). Since 2014, efforts have been focused on national and international standards for integrated EMS amongst other technologies. National standards for microgrid technologies have so far aligned with those developed in the International Electrotechnical Commission (IEC) and the International Organization for Standardization (ISO), amongst other global bodies in which Korean authorities have been active participants.[43] Of particular relevance is that Korean companies such as LG CNS have aligned new smart grid devices such as Advanced Metering Infrastructure (AMI) with Open Smart Grid Protocol (OSGP), an open security standard, as part of an export offensive in the European market.[44]

Microgrids and energy self-sufficient islands

Gasa Island, a tiny island off Jindo in South Jeolla province, is home to the world's first independent microgrid using a Korean-built Energy Management System (EMS). According to our interview with **Chae Wookyu**, a Senior Researcher at KEPCO Research Institute and designer of the Gasa Island microgrid system, KEPCO purchased all necessary devices including wind turbines, PV modules, batteries, computer systems and other components, while the EMS was developed in-house.[45] Housed in a 'Microgrid Monitoring Center' on the Island, the EMS automatically limits the supply of energy, based on variables such as the level of energy being consumed in real-time (see picture below). Any excess electricity is stored in high capacity batteries (up to 24 hours) and released for usage during periods of short power supply. KEPCO and the MOTIE shared the costs involved equally in developing the microgrid system and the Gasa island trials. According to one report, KEPCO spent a total of 9.2 billion Won (US$8 million).[46] The EMS takes power generated from four wind turbines (400 kW), four solar panel installations (320 kW), three diesel power units (450 kW) and an energy storage system (lithium ion batteries) with 3 MW capacity – or 4.17 MW in all (see picture below). The project has been in full operation since October 2015. While the goal initially was to run a trial based purely on renewable energy sources, due to fluctuating weather conditions the wind turbines and PV module generators operated at 79.4 percent capacity, which is why a diesel generator producing 20.6 percent of total power was necessary.[47]

The Gasa island project is a prototype for as many as 86 other island-based projects planned by KEPCO. The company is planning to roll out the microgrid on the much larger Ulleong Island with just over 10,000 residents (and five other island locations) in the East Sea by late 2017/early 2018. The microgrid system of these islands will be constructed by private firms such as Korea Telecom (Deokjeok Island), Woojin Industrial Systems (Sapsi Island), POSCO (Chuja Island), LG CNS (Geomun Island), and by KEPCO (with LG CNS) on Ulleung Island and Geocha Island (KEPCO).[48] It is envisaged that private energy producers will form Power Purchase Agreements to sell electricity to KEPCO.[49] One of the main goals in the next development phase of these microgrid projects is to increase the renewable make-up of energy sources on islands such as Ulleung to 100 percent by 2021.[50] It is noteworthy that for companies such as LG CNS, their ability to provide microgrid solutions was based on the company's experiences in the Jeju Island Smart Grid testbed.[51]

Wind turbines and solar panels used in Microgrid on Gasa Island: Courtesy of KEPCO.

Costs of generating power in remote microgrids

Perhaps the most significant markers of success of the Gasa Island trial were the cost savings achieved from using the new microgrid system. During October 2015-March 2016, no less than 82% of power used in the remote microgrid was sourced from renewable energy, meaning that there was a reduction of 80 percent in the use of diesel.[52] During the six months a total of 150 million won (about US$ 149,000) was saved in fuel costs from the 700 million Won (US$ 629,000) required on average annually in operating the diesel power plant.[53]

In terms of the actual cost per kW/h of generating electricity on Gasa Island, according to a senior member of the Prime-Ministerial Green Growth Committee, the Gasa Island microgrid project was able to produce electricity at approximately 300 won/kW, representing a saving of 200 won/kW for KEPCO from using diesel generators.[54] From this perspective, this figure would likely have played a significant role in convincing KEPCO executives of the merits of investing even further in microgrids.

Of course, as with all new technological advances, challenges remain. The most significant is that in the short-term, the initial outlay of costs in installing a microgrid system is substantially higher than investing in diesel power plants. However, in Chae Wookyu's view (the chief engineer in the Gasa Island project), the initial cost of approximately 4.2 billion Won for a microgrid system could be recouped within 16 years of operation.[55] He expects these savings would arise from lower fuel and management costs while providing electricity at the cheaper rates mentioned above. Doing away with the exorbitant costs of transporting barrels of diesel alone, could arguably achieve significant cost savings. Separate reports by foreign competitors such as Caterpillar in 2016 estimate a payback period of only 5 to 6 years.[56] Independent commentary by Navigant Research estimates an even more ambitious figure of four years or less to gain a Return On Investment (ROI) (assuming cost of diesel at $1/L), up to three years at $1.36/L and up to two years at $1.64/L.[57]

Gasa Island Microgrid Control Centre: Courtesy of KEPCO.

The focus on remote island-type microgrids (and KEPCO's building-centred microgrids as discussed earlier) is part of a wider push to develop nation-wide smart grids through modular architecture. Take for instance, the idea of 'energy block platforms' that are being trialled throughout industrial complexes in Korea.[58] With a budget of US$ 100 million (64% public sources with 34% funding matched by private firms), from 2011-2013, the MKE/MOTIE sponsored the 'Korea Micro Energy Grid' (K-MEG) consortium led by Samsung C&T.[59] There are a total of 11 large companies in addition to Samsung C&T such as KT and Hyosung, 33 SMEs, 12 R&D Centres and universities and five foreign partner organisations involved in the project. The aim of the project is to develop a total solution for blocks of industrial-scale, independent and self-sufficient energy grids, which can be targeted at both domestic and export markets.[60] The full commercial details of such a project will undoubtedly be revealed in the near future. In terms of the business models for a nation-wide smart grid (the ultimate aim) – which is critical to the rapid diffusion of new technological services – agencies such as KPX have already developed sophisticated plans, including the establishment of a Northeast Asia electricity trading system by 2030.[61]

Meetings with officials of Korea Power Exchange emphasised just how important the formulation of new business models will be since even the best technologies will have little future unless a *market* exists for such products.[62] From their perspective, KEPCO's monopoly is proving to be an obstacle to the wide deployment of smart grid technologies by limiting competition. Of course, the issue is not that interest from new potential entrants is not present – indeed, Korea's major telecommunications carriers have expressed considerable interest[63] – but that meaningful competition is needed to create a market for new smart grid technologies.

The Push to Export Microgrids

After various studies of the technological and economic feasibility of the Gasa Island Remote Microgrid, the system is now ready for commercial export – according to Chae Wookyu.[64] And as the Koreans have shown time and again in the past, they are able to move aggressively into world markets with their now proven technology. In July 2015, KEPCO concluded its (and indeed Korea's), first-ever deal to export a total microgrid solution. The contract was provided by Canada's fourth-largest power utility, PowerStream, to collaborate in the construction of microgrids in Toronto and elsewhere in the province of Ontario to replace aging and unstable electricity grids.[65] Importantly, the agreement involves the application of KEPCO's in-house EMS technologies in the construction of microgrids and upgrading of existing energy management systems at a cost of US$15 million. The Korean firm POSCO ICT will also be involved in these projects as a manufacturer of ESS products.

Approximately one year later, KEPCO and PowerStream officially launched a completed microgrid to supply 400 residents in the small community town of Penetanguishene, Ontario. The two companies agreed on plans to construct microgrids elsewhere in Canada. In PowerStream's words 'at the heart of this cutting-edge solution is the Microgrid Distributed Energy Resource Automation System (MiDAS), an advanced microgrid controller that can operate autonomously and optimize the way in which power is delivered'.[66] The CEO and President of KEPCO, **Cho Hwan-Eik**, also made clear the value of KEPCO's EMS solution in the Ontario microgrid:

> "The successful completion of the Microgrid demonstration project in Canada and signing of a Joint Development Agreement prove that our technologies are of global standards and are globally competitive…This success will create a momentum for KEPCO's advance to the North American market and the establishment of the global KEPCO energy belt that connects Americas, Africa, Middle East, and Asia."

LSIS is another private firm which, as mentioned earlier, was a participant in the MOTIE-sponsored microgrids R&D project (2010-2013) and in the Jeju Island smart grid test-bed; it has recently sought to conclude export contracts with the Indonesian government for its own microgrid solutions.[67] Countries such as Indonesia pose a potentially enormous export market considering that the country is an archipelago of 18,000 islands. On a separate note, Korean ESS manufacturers such as LG Chemical and Samsung SDI have excelled in supplying global markets for electric vehicles (e.g. with Volkswagen, Ford, GM and Daimler) and utility-scale solutions (e.g. Germany's STEAG Gmbh), contending with Japan's Panasonic (which supplies Tesla) for dominant market share.

Discussion: Remote microgrids as stepping stones to full transition to renewable energies?

Our findings have shown that the Korean state's role in implementing key programmes first forged under the national smart grid plans included in the *First FYP* for GG have relied heavily on the economic benefits to utilities such as KEPCO. To be clear, the Koreans did not wait for the costs of renewable energy generating devices such as PV and wind generators to fall or wait for a foreign company to develop an EMS technology pending the emergence of an international standard. Through successive political administrations since the early 2000s and especially since 2008, the government's efforts to support the creation and commercialization of remote microgrids (the most important being the development of an in-house EMS) has been critical to positioning KEPCO to play a leading role in commercialization and export since 2014. However, the key reason KEPCO has invested so aggressively in this new and emerging strategic technology cannot be explained without acknowledging the fact that the economic benefits of investing in microgrids simply outweighed the benefits of sticking with diesel-powered generators in remote island locations.

What might our study of smart microgrids tell us about the makings of a wider renewables transition? According to Lee Seung-Hoon, a broader and more encompassing transition is dependent as much, if not more, on political calculations rather than economic rationality. Efforts to reform KEPCO's pricing structure and monopoly depend heavily on the wider political environment. Interest groups opposed to any changes to the subsidisation of electricity are supported by the political elite and the general public, whose perceptions of KEPCO are highly positive.[68] From Lee's perspective, the public's positive view comes from the availability of cheap electricity (which many believe is possible even without the state's subsidies) and by "many efficiency measures KEPCO is indeed an excellent utility". This might explain why more recent attempts to enact reforms to the electricity industry are incremental at best. In June 2016, the Deputy Finance Minister for Fiscal Affairs at the Ministry of Strategy and Finance, **Noh Hyeong-ouk**, announced a plan to float KEPCO and its affiliates on the stock market although management will remain in the hands of the government.[69] As noted in the Introduction, this plan will also allow privately-owned power generating companies, especially those involved in renewable energy projects, to sell electricity directly to consumers, which would mean by-passing KEPCO in the process. Introducing competition at the retail level would indeed be an important step forward in introducing a nation-wide NRE transition. To be sure, such discussions are nothing new and would appear limited in their effectiveness without the phasing out of subsidisation of electricity prices.

All the above suggests, as we have argued, that liberalization of the electricity industry is key to actualising the government's plans for the nation-wide deployment of smart grids by 2030. In this sense, the freeing-up of markets in the Korean context is not about running a neo-liberal agenda; it is about pursuing environmentalism as an extension of the country's long developmentalist tradition – 'developmental environmentalism' as some have called it.[70]

This work was supported by the Academy of Korean Studies Grant funded by the Korean Government (MEST) (AKS-2012-BAA-2101)

References

Bunker, K., S. Doig, K. Hawley, J. Morris 2015: Renewable Microgrids: Profiles from Islands and Remote Communities Across the Globe (http://www.rmi.org/Content/Files/RMI-Islands-RenewableMicrogrids-FINAL-20151103.pdf). Rocky Mountain Institute, November.

Chae, W., H. Lee, J. Won, J. Park and J. Kim 2015: 'Design and Field Tests of an Inverted Based Remote MicroGrid on a Korean Island', *Energies*, 8, 8193-8210.

Cheong, Seung-Il 2013, 'South Korea as a Paradigm Shift in Energy Policy', *Living Energy*, 8 (July): 76-81.

Global Green Growth Institute 2015: *Korea's Green Growth Experience: Process, Outcomes and Lessons Learned*. Seoul: GGGI.

Kim, Sung-Young & Elizabeth Thurbon 2015: 'Developmental Environmentalism: Explaining South Korea's Ambitious Pursuit of Green

Growth', *Politics & Society*, 43(2): 213-240.

Korea Electric Power Corporation 2016: *Annual Report 2016*. Naju, Jeollanamdo: KEPCO.

Korea Power Exchange 2011: *Smart KPX Brochure*. Seoul: KPX

Korea Smart Grid Institute (KSGI) 2015: *Smart Grid, An Energy Revolution in Our Daily Lives*. Seoul: KSGI.

Lee, Jisoon 2010: *Green Growth: Korean Initiatives for Green Civilization*. Seoul, Korea: National Research Council for Economics, Humanities and Social Sciences & Random House Korea.

Lee, Seung-Hoon 2014: 'Electricity in Korea'. In Christopher Findlay (ed.): *Priorities and Pathways in Services Reform. Part II, Political Economy Studies*. New Jersey: World Scientific, pp. 111-127.

Lee, T., T. Lee, Y. Lee 2014: 'An Experiment for Urban Energy Autonomy in Seoul: The One "Less" Nuclear Power Plant Policy'. *Energy Policy*, 74: 311–318.

Liu, Zhenya 2015: *Global Energy Interconnection*. London: Academic Press.

Mah, D.N., J.M. van der Vleuten, P.R. Hills and J. Tao 2012. Governing the Transition of Socio-Technical Systems: A Case Study of the Development of Smart Grids in Korea, *Energy Policy*, 45: 133-141.

Mathews, John A. 2015: T*he Greening of Capitalism: How Asia is Driving the Next Great Transformation*. Stanford: Stanford University Press.

Ministry of Trade, Industry and Energy 2014: *Jae 2 Cha Aeneojigibongyaehoek [Second National Energy Plan*, Seoul: MOTIE.

Pittman, Russell 2013: 'Which Direction for South Korean Electricity Policy?', *Korean Energy Economic Review*, 13(1), 145-178.

Presidential Committee on Green Growth 2009: *Road to Our Future: Green Growth, National Strategy and the Five-Year Plan (2009–2013)*. Seoul: PCGG.

Prime-Ministerial Committee on Green Growth 2014: *Jae 2 Cha Noksaek Seongjang 5 Gaenyeon Gyaehoek (Second Five-Year-Plan for Green Growth)*. Seoul: PCGG.

Saury, Francois-Xavier & Craig Tomlinson 2016: Hybrid Microgrids: The Time is Now (http://www.cat.com/en_US/articles/white-paper-hybrid-microgrids-the-time-is-now.html). Caterpillar Incorporated Electric Power White Paper, February.

Tuballa, M.L. and Abundo, M.L. 2016. A Review of the Development of Smart Grid Technologies, *Renewable and Sustainable Energy Reviews*, 59: 710-725.

Vagliasindi, Maria & John Besant-Jones 2013: *Power Market Structure: Revisiting Policy Options*. Washington, D.C.: The World Bank.

Sung-Young Kim was until recently Lecturer in Politics & International Relations, School of Social Sciences at The University of Auckland. His research is in international political economy and more specifically on the roles of public and private actors in the creation of global high-technology industries in East Asia. He is particularly interested in the sources of state capacity for the promotion of new technological products, systems, and innovations. His work has focused on the roles of "developmental states" in building industries related to

Information and Communication Technologies and Renewable Energy Technologies. His articles include "Transitioning from Fast-Follower to Innovator" *Review of International Political Economy*, 2012, 19(1); "The Politics of Technological Upgrading in South Korea" *New Political Economy*, 2012, 17(3); "The Rise of East Asia's Global Companies" *Global Policy*, 2013, 4(2); and "Developmental Environmentalism" (with E. Thurbon) *Politics & Society*, 2015, 43(2).

John A. Mathews is Professor Emeritus in the Macquarie Business School, Macquarie University, Sydney. He was Professor of Strategy for many years at Macquarie Graduate School of Management, Sydney, and concurrently the Eni Chair of Competitive Dynamics and Global Strategy at LUISS Guido Carli University in Rome. His research focuses on the competitive dynamics of international business, the evolution of technologies and their strategic management, and the rise of new high technology industries. His work has centered in recent years on the emergence of the 'green economy' and the transition to renewable energies, and the institutional changes needed to provide industrial capitalism with long-term sustainability. He is the author of *Strategizing, Disequilibrium, and Profit, Global Green Shift: When Ceres Meets Gaia (https://www.amazon.com/Strategizing-Disequilibrium-Profit-John-Mathews/dp/0804754837/?tag=theasipacjo0b-20)* published by Anthem Press and *Greening of Capitalism: How Asia is Driving the Next Great Transformation (https://www.amazon.com/Greening-Capitalism-Driving-Great-Transformation/dp/0804791503/?tag=theasipacjo0b-20)* published by Stanford University Press.

Notes

[1] See Vagliasindi & Besant-Jones (2013), 194.
[2] As various studies have begun to show, smart micro grids utilizing clean energy sources have many potential advantages over traditional diesel or oil powered systems including system resilience, stability, energy efficiency and lower costs. See Bunker *et al* (2015), 9.
[3] See the companion article on Taiwan's green energy strategies, by Mei-Chih Hu and John A. Mathews, 'Taiwan's green shift: Prospects and challenges' (http://apjjf.org/2016/19/Hu.html)`, *Asia-Pacific Journal: Japan Focus*, 1 October 2016.
[4] See 'New energy industry: Korea's next growth engine' (http://www.koreatimes.co.kr/www/news/nation/2016/08/197_211128.html), *Korea Times*, 4 August 2016; and press release from MOTIE, 'Korea to invest 42 trillion Won in new energy businesses by 2020' (http://english.motie.go.kr/?p=6657&paged=0), 6 July 2016.
[5] See 'Power supply market will open to private companies' (http://www.koreatimes.co.kr/www/news/biz/2016/07/488_206976.html), *Korea Times*, 14 June 2016.
[6] See the MOTIE press release (http://english.motie.go.kr/?p=6657&paged=0), 6 July 2016.
[7] See the report on 'Electricity system reform in Japan'

(https://www.amt-law.com/en/pdf/bulletins9_pdf/140106.pdf), by the law firm Anderson, Mori and Tomotsune, Jan 2014.

[8] See Hu and Mathews 2016, *op cit.*

[9] See KEPCO (2016), 56.

[10] Analysts revealed the impressive success in reducing overall energy use equivalent to that produced by one nuclear power reactor. However, as of 2014 (two years after the launch of the campaign), renewable energy targets were still below projected goals and the use of nuclear energy remained constant. See Lee *et al* (2014), 316-317.

[11] See Global Green Growth Institute (2015), 88.

[12] The OECD average is 11 c/kWh for industrial consumers and 15 c/kWh for domestic consumers. See Cheong Son Jong, 'Smart grid in Korea' (http://www.iea.org/media/training/bangkoknov13/session_7c_ksgi_korea_smart_grids.pdf), IEA Conference, Bangkok, 26 Nov 2013.

[13] See Global Green Growth Institute (2015), 338.

[14] See 'Cheap electricity backfires' (http://www.koreatimes.co.kr/www/news/nation/2013/06/328_138344.html), *Korea Times*, 30 June 2013.

[15] The key point as articulated by Mark Halle, Vice-President of the International Institute for Sustainable Development, is that the subsidisation of fossil-fuel generated electricity is '…actually paying people to use more fossil-fuel[s], therefore, making it hard for renewable energy to compete on the same playing field'. See the *Korea Times* article above.

[16] See Global Green Growth Institute (2015), 88. KEPCO's accumulated debts are largely a product of government caps on electricity prices at a time when imported fossil-fuels were at their peak (before the price drop in fossil-fuels 5-6 years ago) and even now when KEPCO is carrying enormous levels of debt.

[17] In an important study of reforms to the Korean electricity industry, Pittman (2013: 166-167) questions whether an effort to reform the vertical (KEPCO-centred) organisation into a more horizontal and privately-owned structure would achieve its intended effects. Instead, Pittman suggests that amongst other recommendations, more urgent and effective means to ensure energy stability and security include the introduction of smart grids (to control demand via real-time pricing) and an end to subsidisation of electricity prices especially to manufacturers. For further background on Korean reforms and strategy for creation of a smart grid, see Mah *et al*. (2012).

[18] In his reflections on the politics of reforms to the electricity industry during his tenure as the Chairman of the Korean Electricity Commission (2001-2004), Seung-Hoon Lee, discusses a combination of factors. These include a lack of wide public awareness of the benefits of competition in the electricity industry, a highly resistant labor union, and ultimately the change in political leadership from the reform-minded Kim Dae-Jung to the more sceptical Roh Moo-Hyun. See Lee (2014), 117.

[19] See Vagliasindi & Besant-Jones (2013), 196.

[20] See Cheong (2013).

[21] See Andrew DeWit, 'The US military, green energy, and the SPIDERS at Pearl Harbor' (http://apjjf.org/2013/11/6/Andrew-DeWit/3909/article.html), *Asia-Pacific Journal: Japan Focus*, 11 (6), Feb 2013. For a more recent exposition, see 'Military marches forward with

microgrids' (http://insideenergy.org/2015/07/09/military-marches-forward-with-microgrids/), *Inside Energy*, 9 July 2015.

[22] See Korea Smart Grid Institute (2015), 10.

[23] See Kim and Thurbon (2015) for a deeper examination of drivers and mechanisms in instituting 'developmental environmentalism'.

[24] See Korea Smart Grid Institute (2015), 10-13.

[25] See Korea Smart Grid Institute (2015), 18.

[26] See Jong-Cheon Son 'Smart Grid in Korea' (http://www.iea.org/media/training/bangkoknov13/session_7c_ksgi_korea_smart_grids.pdf). Presentation at the 'Sustainable Energy Training: Electricity Generation and Supply - Challenges and Opportunities for Asia' workshop, Bangkok, 25-29 November 2013.

[27] See 'SNU launches microgrid project' (http://pulsenews.co.kr/view.php?year=2015&no=691033), *Pulse (Maeil Business News Korea)*, 19 July 2015.

[28] See Lee (2010), 116.

[29] See Presidential Committee on Green Growth (2009), 5.

[30] The Korean Smart Grid Institute defines a smart grid as 'a next generation network that integrates information technology into the existing power grid to optimize power efficiency through a two-way exchange of electricity information between suppliers and consumers in real time' (Tuballa and Abundo 2016: 712).

[31] See Prime-Ministerial Committee on Green Growth (2014), 86-87.

[32] See 'South Korea: a Paradigm Shift in Energy Policy' (http://www.energy.siemens.com/ru/pool/hq/energy-topics/living-energy/issue-8/essay-south-korea-SeungIlCheong-Living-Energy-8.pdf), *Living Energy* (July 2013), 8: 76-81.

[33] See MOTIE (2014) and the MOTIE press release (in all its brevity) can be found here (http://english.motie.go.kr/?p=862&paged=0).

[34] See 'Korean Gov't to Invest 20 Trillion Won in Energy Tech Development for next 10 Years' (http://www.businesskorea.co.kr/english/news/industry/8201-energy-tech-korean-govt-invest-20-trillion-won-energy-tech-development-next-10), *Business Korea*, 24 December 2014.

[35] This figure includes funding from the Korean government (73.9 billion won), KEPCO (23.9 billion won) and private firms (148.7 billion won). See 'KEPCO's "smart grid" tech leaves the test site' (http://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3021498&cloc=joongangdaily%7Chome%7Cnewslist1), *Korea Joongang Daily*, 20 July 2016.

[36] See 'South Korea's KEPCO ready to export smart grid technologies' (https://www.metering.com/s-koreas-kepco-ready-to-export-smart-grid-technologies/), 28 October 2014.

[37] See 'KEPCO plans nationwide rollout of smart grid tech', 20 July 2016, *op cit*.

[38] See the mention of KEPCO's SGS Project in the 2015 ISGAN Award of Excellence -Award Winners (http://www.iea-isgan.org/?c=395/397/403).

[39] See 'KEPCO Smart Grid Station Project' (http://www.globalsmartgridfederation.org/2015/07/06/kepco-smart-grid-station-project/), Global Smart Grid Federation Newsletter, 6 July 2015.

[40] See 'KEPCO to Build Smart Grid Systems in Dubai'

(http://www.businesskorea.co.kr/english/news/industry/12693-pilot-project-kepco-build-smart-grid-systems-dubai), 30 October 2015.

[41] The National Institute of Standards and Technology (NIST) and the International Institute of Electrical and Electronics Engineers (IEEE).

[42] As Kim's presentation shows, American smart grid standardization efforts have been coordinated under the 'Grid 2030' initiative, the European Union under the 'Climate & Energy Package 20-20-20' and Japan's under the 2010 'Smart Grid Standards Roadmap'. See Kim, Eung-sang 'Standardization of Micro-grid and Energy Storage System of Korea' (http://www.ksgw.or.kr/ver2014_eng/conference/conference03.php), presentation at the SGIP-SGSF Joint Workshop, COEX, Seoul, Korea, 16 October 2014.

[43] Such as the Society of Automotive Engineers (SAE), IEEE, and the International Telecommunications Union (ITU).

[44] See 'LG CNS signs US $ 45 million AMI contract with Polish utility, Tauron' (https://www.lgcns.com/Views/News/NewsDetail?SERIAL_NO=1516), *LG CNS News*, 23 September 2014.

[45] Author interview (Kim) via email communication with Senior Researcher, KEPCO Research Institute, Wookyu Chae, 28 December 2015.

[46] See 'Global sustainable energy starts on Korea's islands' (http://koreajoongangdaily.joins.com/news/article/article.aspx?aid=3004894), *Korea Joongang Daily*, June 3 2015.

[47] See Chae *et al* (2015), 8200.

[48] See Chae, Woo-Kyu 'Design and Field Test Results of High Renewable Penetration at a Korean Island Remote Microgrid' (http://microgrid-symposiums.org/wp-content/uploads/2015/09/13-Chae-Design-and-Field-Test-20150812.pdf), Presentation at the Aalborg 2015 Symposium on Microgrids, Aalborg, Denmark, 27-28 August 2015.

[49] See Ja-Kyun Koo 'Smart Grid: Futuring Smart Energy' (https://d2oc0ihd6a5bt.cloudfront.net/wp-content/uploads/sites/837/2015/06/Ja-Kyun-Koo_GBI_ACEF_CEO-Keynote-Presentation_Final.pdf), Keynote speech presented at The 10th Asia Clean Energy Forum, ADB Headquarters, Manila, 17 June 2015.

[50] 'Aeneojijaribseomeun Mirae Meoggeori Saeob…20jo gyeongjae Hyogwa' [Self-Sufficient Energy Islands to Provide 20 trillion [Won] in Economic Benefits]' (http://thekpm.hankyung.com/news/articleView.html?idxno=2873), *Qompass News*, 27 October 2015.

[51] See 'LG CNS Released "Micro Grid"' (http://english.etnews.com/news/article.html?id=20130716200007), *etnews*, 16 July 2013.

[52] See Chae *et al* (2015), 8204.

[53] See 'Global sustainable energy starts on Korea's islands', *Korea Joongang Daily*, June 3 2015.

[54] Author interview (Kim) with Senior Member, Prime-Ministerial Green Growth Committee, Seoul, 17 December.

[55] See 'Global sustainable energy starts on Korea's islands', *Korea Joongang Daily*, June 3 2015.

[56] The analysis presented in Caterpillar's White Paper shows that a microgrid system

combining diesel with just solar panels (producing 670 kW) would be paid back in just over six years (Saury & Tomlinson 2016: 8-9). If an energy storage unit of 250kW capacity is used additionally, the investment in such a system would be recuperated in less than five years.

[57] The analyst also assumes that the batteries in microgrid systems will be replaced after seven years and that the cost of diesel is roughly 33 cents/kW. Considering the substantially higher cost of diesel per kW assumed in Chae's (2015: 4) presentation, the estimates on the years required to gain a ROI appear to be conservative. See the Navigant Research Blog 'Energy Storage Reduces Diesel Use in Microgrids' (https://www.navigantresearch.com/blog/energy-storage-reduces-diesel-use-in-microgrids), 6 June 2014.

[58] See Youngmin Kwon 'Business-oriented Korea's Flagship R&D Program: Korea Micro Energy Grid (K-MEG) Project' (http://www.ieadsm.org/wp/files/Content/7.JejuIsland_Young-minKwon.pdf).

[59] As part of 'Korea's Future Flagship Program – Project in Energy Field'.

[60] See Park, Jee-Sik 2012 'Korean Activities on Smart Grid and Energy Storage System' (http://www.standard.no/Global/externalSites/iec2012/Presentation%20Jee-Sik%20Park%20-%20Final.pdf).

[61] See Korea Power Exchange (2011), 20. Of course, such an ambitious goal will depend on the agreement of neighbouring countries. If the views of the Chairman of China's State Grid Corporation (SGC), Zhenya Liu, carry any weight then the makings of a regional and eventually worldwide electricity trading system is already being promoted through the concept of a 'Global Energy Interconnection' (Liu 2015). The founder of Softbank, Son Masayoshi, through the work of the Japan Renewable Energy Foundation has proposed a similarly ambitious project called the 'Asian Super Grid' (Mathews 2015: 92). This idea now appears to have gained more concrete traction through the signing of a MOU in Tokyo (in September 2016) between the Japan-based Renewable Energy Institute, KEPCO, SGC and Russia's PSJC Rosseti to construct the Asian Super Grid. See 'China, Japan, Russia, & South Korea Plan Renewable Energy Super Grid' (https://cleantechnica.com/2016/09/21/china-japan-russia-south-korea-plan-renewable-energy-super-grid/), 21 September 2016.

[62] Author interview (Kim) with Senior Officials, Smart Grid Team and Power Planning Team, Korea Power Exchange, Seoul, 19 November 2013.

[63] See 'SKT, KEPCO to Collaborate For Smart Grid, IoT' (http://www.koreatimes.co.kr/www/news/tech/2015/09/133_186155.html), *Korea Times*, 3 September 2015.

[64] Author interview (Kim) via email communication with Senior Researcher, KEPCO Research Institute, Wookyu Chae, 28 December 2015.

[65] See 'POSCO ICT to export micro-grid technology to Canada' (http://pulsenews.co.kr/view.php?year=2015&no=702634), *Pulse News*, 22 July 2015.

[66] See 'PowerStream's Utility-Scaled Microgrid Becomes Operational' (https://blog.powerstream.ca/2016/06/powerstreams-utility-scaled-microgrid-operational/), *PowerStream Corporate Communications News Release*, 29 June 2015.

[67] See 'LSIS Eyes Indonesia as Smart Grid Hub' (http://www.koreatimes.co.kr/www/news/tech/2015/09/133_186723.html), *Korea Times*, 13

September 2015.

[68] See Lee (2014), 127. Similar challenges can be seen in ambitions to liberalize the Taiwan electricity industry where labour unions have continued to block revisions to the Electricity Act. Revision to the Act would introduce competition and break the monopoly held by Taiwan Power Corporation (Taipower). See 'DPP, Cabinet to discuss priorities for legislation' (http://www.taipeitimes.com/News/taiwan/archives/2016/09/12/2003654989), *Taipei Times*, 12 September 2016.

[69] See 'Power Supply Market Will Open To Private Companies' (http://www.koreatimes.co.kr/www/news/biz/2016/06/488_206976.html), *Korea Times*, 14 June 2016.

[70] See Kim and Thurbon (2015)