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An overview of renewable energy development in Kyoto, Seoul, and Hong Kong

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This paper summarized an overview on renewable energy (RE) development in three Asian cities, namely Kyoto, Seoul, and Hong Kong. These three cities share similarities in urban development and RE development. Table 1 illustrated the energy background of the three cities with highlights on liberalization status of electricity market, energy targets, RE policies, and local case communities.

The city population of Kyoto was 1,115,00 in the 2nd quarter of 2021. Seoul accumulated population of 9,828,094 in the 1st quarter 2021. The population of Hong Kong reached 7,394,700 in the 2nd quarter of 2021.

In 2018, Kyoto's GDP was US$ 58.2 billion. Seoul has gained US$ 364.7 billion. Up till 2020, GDP of Hong Kong was US$ 348.4 billion.

The global ranking of GHG emission by country in 2018 are shown as: Japan ranks for the 7th; South Korea ranks at the 13th; China ranks the 1st. In specific, Japan emitted 1,155 $MtCO_2e$; South Korea emitted 673 $MtCO_2e$; China emitted 11,706 $MtCO_2e$.

Up till 2020, the distribution of energy mix of Japan was indicated as natural gas 42%, coal 32%, RE 11%, nuclear 4%, and solar 2%. In South Korea, the energy mix was distributed as coal 36%, nuclear 29%, natural gas 26%, RE 7%, solar 3%, hydro and pumping 2%, and oil 0.4%. In Hong Kong, energy mix was shown as natural gas 48%, coal 24%, nuclear and RE 28%, and solar less than 0.1%.

The national governance mode in Japan is at a developmental state which adopts democratic and deliberative model. In South Korea, the governance mode is also at a developmental state, but the orientation is technocratic yet participatory. In China, the nation adopts authoritarian state. But for city-level, neoliberal market is allowed.

Three cities take different prosumer business models respectively. Kyoto used "prosumer-embrace model", which is a post-FiT model that the Kansai Electric engages with prosumers for changes. In Seoul, "prosumer-challenge model" is applied. It relates to FiT phasing-out business models as the KEPCO (Korea Electric Power Corporation) has announced for their reduced involvement but not limited to sudden and occasional changes such as blackouts. Prosumers hold more flexibility in the operation and decision-making process. In Hong Kong, the local government adopted "basic prosumer model" by introducing the basic Fit-in-Tariff to be the RE subsidy and make it to be a FiT (subsidy)-dependent business model. The two electricity monopolies, CLP and Hong Kong Electric, will take incremental traditionalist changes for the scheme.

For solar installation capacity goal, three cities have set respective targets. Kyoto set the target of meeting 140 MW of solar installation capacity by the quarter I of 2020. Seoul aimed to achieve 305.3 MW by 2020. Hong Kong pursued to attain 6.29 MW by 2017.

For the current stage of electricity market liberalization status, Kyoto is fully liberalized; power market in Seoul is working under a moderately liberalized mode; and Hong Kong performs vertical monopolized utilities thus it has no liberalization in its energy market.

In terms of energy target in meeting carbon neutral, developing solar, and executing energy saving, three cities have set the following commitment.

For solar target, Kyoto plans to achieve 250 MW of solar installation capacity by 2030; Seoul aims for reaching 5GW by 2050; Hong Kong government plans that the capacity could be sufficient to supply 1% to 2% of electricity demand by 2035. For energy saving goal, Kyoto government set a long-term goal of 12 years (from 2018 till 2030) that the energy saving could attain 18.1% more comparing to 2018 as the base. Seoul government announced that newly built buildings will be equipped with solar system. In Hong Kong, reduction of energy consumption in commercial buildings will have to minimize within 30 to 40% and for residential buildings will need to reduce 20% to 30% by 2050.

On the other hand, there are five RE policies that we can examine the progression of energy transition. They include feed-in tariff (FiT), net metering, renewable energy certificates (RECs), power purchase agreement (PPA), and renewable portfolio standards (RPS).

Feed-in tariff policy in Kyoto city is executed at a transitional stage as it is starting to be phasing out. In Seoul and Hong Kong, feed-in tariff is still applicable. For net metering, Kyoto is still adopting this policy. In Seoul, net metering is exercised at national level. While in Hong Kong, it is not implemented. Apart from FiT and net metering, RECs is implemented in the three cities.

Particularly, for the power purchase agreement, Kyoto government introduced the "Kyoto 0 Yen Solar Platform Business". This scheme features 0-yen initial cost for installing solar panel. The installation area includes private residence rooftop, office, factories, and stores (Kyoto Photovoltaics Platform, 2021).

In Seoul, the government executes PPA at national level and name it the "National PPA with KEPCO". In Hong Kong, power purchase agreement is not applicable. Finally, renewable portfolio standards (RPS) of Kyoto and Seoul perform at national level. In Hong Kong, RPS is not implemented.

After examining the status of electricity market liberalization, energy targets, and city renewable policies, establishing community-based demonstration site is also a vital component to examine the progress of RE transition. In Kyoto, Seikadai, is a government-led high income smart solar demonstration community. At city context, the Keihanna Science City is used as a demonstration site for encouraging smart solar prosumers and emerging new prosumers market opportunities of blockchain-based distributed energy market with Kansai

Electric as a key actor. In Seoul, the representative case community Sungdaegol serves as a local peer-to-peer energy trading platform. It is also an energy cooperative which promotes solar prosumption. The participants in the community are mostly grassroots. The idea of being a prosumer energy community is supported by the city government. Moreover, WATTMALL, a community-based energy trading market of a social enterprise is also offering support to the demonstration site. One of the successes is identified as their community-based peer-to-peer market being set up. In Hong Kong, the case community is Fairview Park. It owns 5,000 high income low-rise flats which are situated with rich solar resources. In the city context, the government responded to low-carbon future and take involvement in the Greater Bay Area which is designated to be the regional energy development area. The scope includes Hong Kong and 10 neighboring cities in the southern part of China.

Table 1. An overview of renewable energy development in Kyoto, Seoul, and Hong Kong.

City		**Kyoto, Japan**	**Seoul, South Korea**	**Hong Kong, China**
Population by city		1,115,000 (Q2 2021)	9,828,094 (Q1 2021)	7,394,700 (Q2 2021)
City GDP (billion US$)		58.2 (2018)	364.7 (2018)	348.4 (2020)
Global rank of GHG emission by country (2018)		7th	13th	1st
Total GHG emissions by country (2018)		1,155 $MtCO_2e$	673 $MtCO_2e$	11,706 $MtCO_2e$
Electricity mix by country (2020)		Natural Gas (42%); Coal (32%); RE (11%); Nuclear (4%); Solar (2%)	Coal (36%); Nuclear (29%); Natural Gas (26%); RE (7%); Solar (3%); Hydro and pumping (2%); Oil (0.4%)	Natural Gas (48%); Coal (24%); Nuclear and RE (28%); Solar (<0.1%)
National governance mode		Developmental state; Democratic and deliberative	Developmental state; Technocratic yet participatory	Authoritarian state with a neoliberal market at city-level
Prosumer business models (prosumer-utility relationships)		"*Prosumer-Embracer Model*": Post-FiT business models in which Kansai Electric engages prosumers for changes.	"*Prosumer-Challenger Model*": FiT Phasing-out business models, with KEPCO introduces changes only in face of major challenges such as blackouts.	"*Basic Prosumer Model*": Basic, FiT (subsidy)-dependent business model with which the two electricity monopolies adopt incremental traditionalist changes.
Solar installation capacity		140 MW (Q1 2020)	305.3 MW (2020)	6.29 MW (2017)
Electricity market Liberalisation status (●full; ◖ moderate; ○ null)		●	◖ (generation liberalisation)	○ (no liberalisation; vertical monopolised utilities)
Targets (●yes; ◖ depends)	City carbon neutral targets	● (by 2050)	● (by 2050)	● (by 2050)
	City solar targets	● (250 MW by 2030)	● (5GW by 2050)	● (1~2% of electricity demand by 2035)
	City energy saving targets	● (-18.1% by 2030 compared to 2018)	◖ (for new buildings)	● (-30~40% from commercials; -20~30% from residentials by 2050)
City RE policies (●yes; ◖ depends; ○no)	Feed-in tariff (FiT)	◖ (phasing-out)	●	●
	Net metering	●	● (National)	○
	Renewable energy certificates (RECs)	●	●	●
	Power purchase agreement (PPA)	● ("Kyoto 0 Yen Solar Platform Business")	◖ (National PPA with KEPCO)	○
	Renewable portfolio standards (RPS)	● (National)	● (National)	○
Case communities		Case Community: Seikadai (精華台; government-led high income smart solar community demonstration) City-context: Government-led Keihanna Science city as a demonstration project for smart solar prosumers Emerging new prosumer market opportunities of blockchain-based distributed energy markets with Kansai Electric as a key actor	Case Community: Sungdaegol (Local P2P energy trading platform; active *energy co-operatives* promoting solar prosumption City context: Grassroots prosumers' communities supported by city government •WATTMALL, a community-based energy trading market (a social enterprise) Community-based P2P market being set up	Case Community: Fairview Park (5,000 flats high income low-rise housing estate with rich solar resources) City context: role of HK initatives on low-carbon city in the greater regional energy development in the Greater Bay Area that consist of Hong Kong and 10 neighbouring cities in southern part of China

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Seoul (Kan, 2021, September 1; Kang, 2018, November 27; KEEI, 2020; Seoul Metropolitan Government, 2020; Seoul Solution, 2021)

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