WORLD ENERGY COUNCIL

Renewable Energy System Integration in Asia

EXECUTIVE SUMMARY

CHALLENGES & MEASURES FOR RENEWABLES PENETRATION

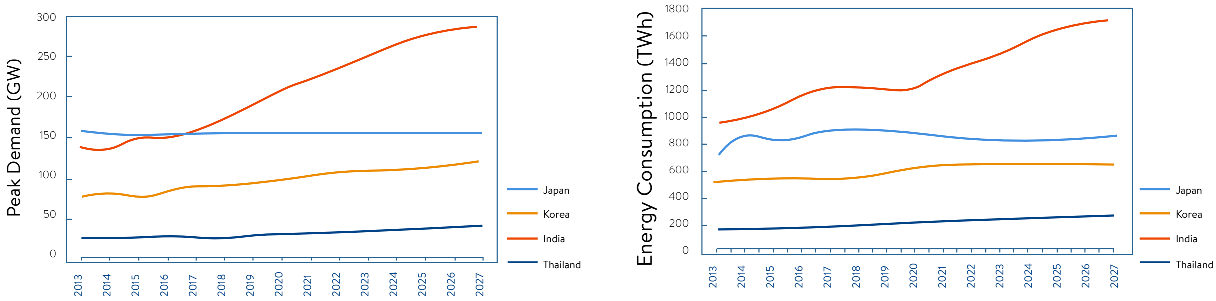
OVERVIEW

A majority of Asian countries are now putting RE at the center of future energy development plans. They have also started R&D in electricity storage technologies, mainly focusing on batteries, which will be an essential tool in order to mitigate RE's output intermittency and maintain grid stability and power quality for customers.
Some Asian countries have already encountered problems due to RE penetration and developed measures to mitigate them. It is also expected that most Asian countries will face new challenges due to greater penetration of RE in the near future.
According to the IEA, RE interconnection levels are categorised into Phase 1 through Phase 4 depending on how much impact is experienced in the power system. Power utilities in Japan, together with some Asian countries such as Australia, India and China, are categorised as Phase 2. Kyushu EPCO is categorised as Phase 3, in which the RE generation determines the operation pattern of the system.

	IMPACT ON THE POWER SYSTEM	PV-WIND GENERATION RATIO	CORRESPONDING COUNTRIES & AREA
Phase 1	RE has no noticeable impact on the system	About 3%	Indonesia, Mexico, South Africa
Phase 2	RE has a minor to moderate effect on the system	About 3 – 15%	Belgium, Australia, India, Sweden, China, Netherland Japan (excluding Kyushu)
Phase 3	RE generation determines the operation pattern of the system	About 10 – 25%	Portugal, Spain, Greece, Germany, Italy, UK, CA(USA), Kyushu
Phase 4	The system experiences periods in which RE makes up all of the generation	About 25 – 50%	Denmark, Ireland

It would be meaningful to share their experiences and best practices, as well as expected future challenges and measures so that they will be able to efficiently integrate renewable energy into the power grids.

1- DEMAND AND SUPPLY BALANCE. An overview of the current situation surrounding electric power business, demand and supply in typical Asian countries is shown in Fig. 1. In these figures, there are two instances of demand and energy consumption increasing and becoming saturated



Peak Demand Trend (GW) (b) Energy consumption trend (TWh)

Fig. 1 Electrical Energy Trend

In terms of supply capacity, thermal power is the main player and the rate of renewables is currently very small, but in the future the main player will shift from thermal power to renewables, as shown in Figs 2 and 3.

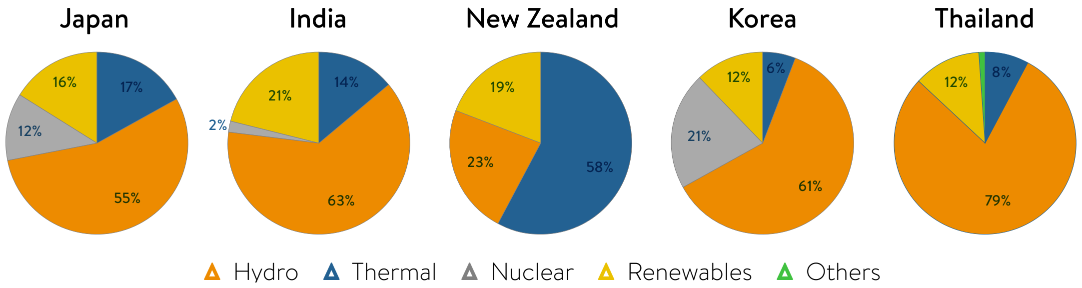


Fig.2 Installed Power Source Capacity

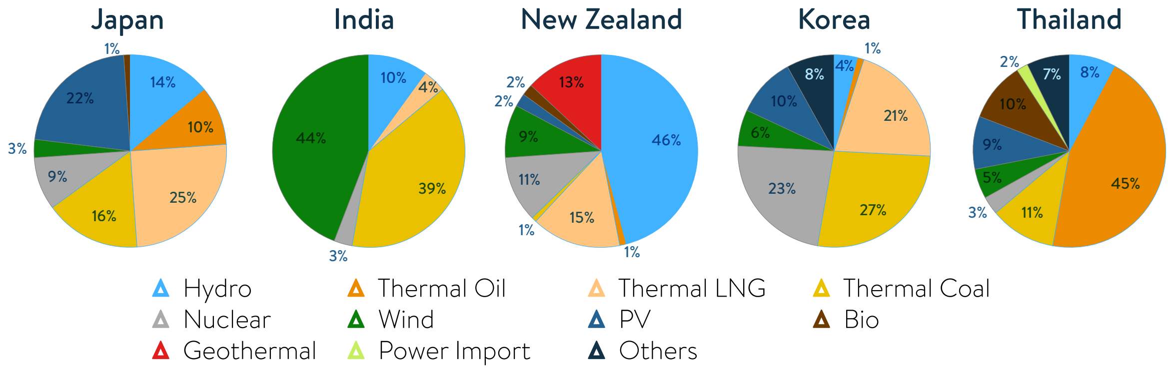


Fig.3 Power Development Plan

2- CHALLENGES (TECHNICAL AND POLITICAL. Various issues due to the renewable integration come to light. As for the technical issues, output fluctuation, duck curve, network congestion, voltage deviation and reverse power flow should be solved. In addition, ancillary services and inertia supply system will be necessary.

Moreover under the satiation that renewables are majors in the energy supply capacity, the political solutions such as to set renewable energy power generation curtailment procedure and connect and manage should be also considered.

Technical Issues

Issue	Countermeasures
Output fluctuation	Thermal power plant Demand response/ VPP Storage facility system (Battery, Pumped storage hydro power)
Duck curve	Demand response/ VPP Storage facility system (Battery, Pumped storage hydro power)
Uncertainty due to DER	Power bidding, capacity market Hydrogen
Ancillary services	Bidding commodities Demand response/ VPP
Forecasting of VER's output	Smart meter Forecasting system
Network congestion	Grid enhancement Dynamic rating

Voltage deviation	Smart meters Batteries Demand response/ VPP
Reverse power flow	LTC with functions to cope with reverse power flow Batteries Demand response/ VPP
Decreasing of system inertia	Flywheels, Synchronous condensers, MG Virtual synchronous generators
Complications of protection	Multifunction PCS Special protection system
Voltage flicker	Adjustment of PCS operation

Political Issues

Issue	Countermeasures
Increase in cost burden	From subsidies to market trading
Termination of subsidies	Design renewable utilisation model for consumers focusing on self-consumption
Market design	Market reform program Future Power System Security program (Australia) Ancillary service market inertia (Australia) Reserves Reguration Ancillary Service (India)
Wide area coordination	Inter-regional planning
Curtailment of VER	Renewable energy power generation curtailment procedure (Japan)

3 - BEST PRACTICES. THIS REPORT provides 14 best practices, both technical and institutional. However, there is no one solution that fits all, as RE penetration levels and economic growth rates in Asian countries differ considerably.

<table>
<tr><th colspan="2">Category</th><th>Practical use</th><th>Demonstration/Field test</th></tr>
<tr><td rowspan="5">Technical Issues</td><td>Network congestion</td><td>Tender process for accepting application</td><td></td></tr>
<tr><td rowspan="2">Voltage deviation</td><td rowspan="2">Evolution in DMS with Smart Meter data</td><td>Field test of the voltage monitoring and control method in Wakasa, Japan</td></tr>
<tr><td>NEDO R&D Project (Nii-jima Island Project)</td></tr>
<tr><td rowspan="2">Frequency fluctuation</td><td>Demand and Supply balance improvement using large-scale energy storage batteries</td><td rowspan="2">NEDO R&D Project (Nii-jima Island Project)</td></tr>
<tr><td>Renewable Management System</td></tr>
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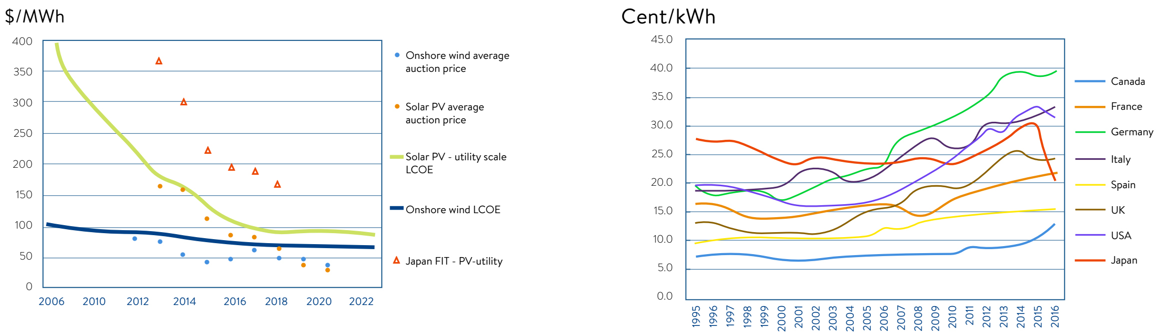
Technical Issues	PV output forecast	Improving the accuracy of PV output forecast	NEDO R&D Project (Nii-jima Island Project)
		The development of PV output forecasting system called Apollon	
		PV Output Forecast System in the Central Dispatching Control Center	
	Mantaining reliability	Development of a new Protection and Control System	
		Expanding the transmission capacity of Kanmon interconnection	
	100% renewable power supply system		100% Renewable Energy for Hahajima Island
Institutional Issues	Political practices	RE curtailment experiences in Kyushu area	
		Connect and manage in Kyushu area	

4- RENEWABLES ALWAYS PROVIDE LOWER electricity price? There are currently reports of a tremendous reduction in PV costs (nearly 3 cents/kWh) in regions with long hours of sunshine, such as Middle Eastern countries.

However, if we thoroughly observe the trend of electricity bills in the countries where the share of renewables have been growing, we should recognise that the bills have been growing as well, instead of decreasing or leveled off.



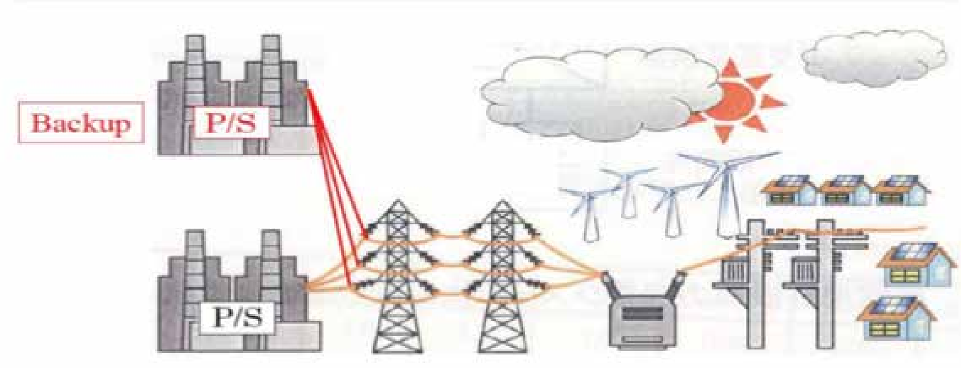
(a) LCOE of renewables [Source: METI, Japan]

(b) Electricity price trends Calculated based on IEA data

Fig. 4 Levelised Cost of Electricity (LCOE) & Electricity price

It is obvious that one of the reasons of rising electricity bill is FIT system, but we must evaluate the total cost of renewable energy integrated in the grid, including so-called “hidden costs” such as backup cost and balancing (frequency regulation) cost, etc. These hidden costs include large scale batteries installed on the grid-side by the utilities. We need to recognise that although no one asks who should pay those hidden costs, they have been borne by the end users (customers) in the end.

Hidden Costs incurred by Distributed Generators



$$C\ wind = FC + O\ \&\ M + \frac{C\ backup}{Hidden\ Cost}$$

Fig.5 Hidden Cost incurred by Distributed Generators

5- **THE BIG QUESTION IS** “Who pays for batteries? There have been frank comments by a senior manager at the Electric Power Research Institute (EPRI), USA.

> “So far, most utilities have got through the issue of accumulating solar power by allowing homeowners with solar arrays to sell some of their power back to the grid. This is a practice called “Net Metering”. You are basically using the grid as a battery. This is why some utilities are a little bit worried about this. The big question is “Who pays for it?” The need for renewable energy storage has emerged recently among the engineers who worry about the health of the grid. But big grid-sised batteries can run into the millions of dollars.”

There is also good news. In Germany, about half of household customers who installed rooftop PV panels installed low cost batteries at the same time. We don’t deny the need for further renewable energy introduction, but we must say that “There is no free lunch.” The costs of large-scale batteries installed at substations by conventional utilities are widely borne by every customer.

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However, what we need to consider is:

- Who should pay these costs?
- Is it fair for only customers to pay?
- Is there no need for mega solar developers and households owing rooftop PV panels to pay a portion?

6 - SYSTEM COSTS ARE DEFINED as the total costs above plant-level costs to supply electricity All power generation technologies cause system effects. By virtue of being connected to the same physical grid and delivering into the same market, they exert impacts on each other as well as on the total load available to satisfy demand at any given time. The interdependencies are heightened by the fact that only small amounts of cost-efficient electricity storage are available. Variable renewables such as wind and solar, however, generate system effects that are at least an order of magnitude greater than those caused by dispatchable technologies.

System costs are defined as the total costs above plant-level costs to supply electricity at a given load and given level of security of supply. In principle, this definition would include costs external to the electricity market, such as environmental costs or impacts on the security of supply.

Focusing primarily on the costs that accrue inside the electricity system for producers, consumers and transport system operators, this subset of system costs that are mediated by the electricity grid are referred to in the following as "grid-level system costs" or "grid costs".

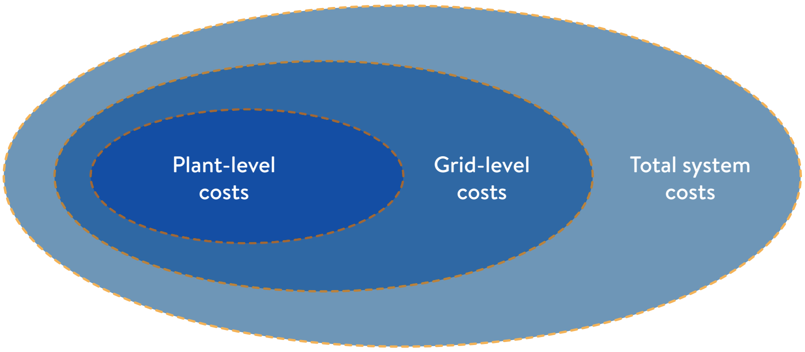

Fig. 6 Plant-level, grid-level and total system costs

Grid-level system costs already constitute real monetary costs. They are incurred as present or future liabilities by producers, consumers, taxpayers or transport grid operators. Such grid-level system costs can be divided broadly into two categories: (1) the costs for additional investments to extend and reinforce transport and distribution grids as well as to connect new capacity to the grid; and (2) the costs for increased short-term balancing and for maintaining the long-term adequacy of the electricity supply in the face of the intermittency of variable renewables.

7 - OECD DEFINED "GRID-LEVEL COSTS" as consisting of four costs. The promotion of renewables is an essential issue in order to realise a low-carbon society. The cost of renewables has reduced significantly in recent years. However, we must recognise that there exist "Hidden Costs" when integrating renewables into the grid.

The OECD defined "Grid-level costs" as consisting of the following four costs.:

1. Backup costs
2. Balancing costs
3. Grid connection costs
4. Grid reinforcement and extension costs

Its trial calculations for six countries (Finland, France, Germany, the Republic of Korea, the United States) indicated that the average grid level cost was 15-80 USD/MWh) depending on the RE penetration level.

8 - TO MAKE IT CLEAR who should bear such costs, and then promote the use of renewable energies based on a public consensus on the hidden cost issue.

In terms of the mitigation of global warming, the popularity of renewable energy has risen worldwide. In fact, CO_2 emissions from wind and solar are quite low.

It is said that if the availability of blowing wind is more than 2000 hours a year, a project could sufficiently pay off. Considering the high price of oil currently, the break-even point may be less than 2000 hours. Positive use of renewable energy is a requirement of the age. Its share will increase through being pushed by strong supporters among policy makers and citiz v ens.

On the contrary, the quality of power required by consumers has become higher and higher. Unfortunately, many renewable energy technologies such as wind and solar rely on favorable weather conditions, making them an unstable source of energy. In short, they cannot meet the needs of society without compensation. Stand-alone use in an isolated private network is not realistic due to the uncertainty of power output. Inevitably, they need to be connected with the conventional power grid.

It is necessary for power grid engineers to technically evaluate the impact of the renewable energy connections on power flows through transmission lines, including international tie-lines, as well as the stability of the whole network. If there are unfavorable impacts, they must take the necessary measures.

The opinion from the grid side is as below:

Once connected with the power grid, output fluctuation of renewable energy can be compensated for. This means that backup power can be easily obtained by virtue of the unique features of the electric power system. Generally speaking, renewable energy can be fully utilised as a clean alternative energy to fossil fuel power plants when it is connected to the power grid. In other words, the power system must prepare reserve margin and provide ancillary services. According to a Japanese researcher, the cost of backup and stabilisation for renewable energies could amount to 10 to 14 Yen/kWh. In Japan, this “Hidden Cost” is now charged in the electricity rate paid by every customer.

However, in spite of the hidden costs, the great value of renewable energies will not decrease. Thus, it is essential for us to make it clear who should bear such costs, and then to promote the use of renewable energies based on a public consensus on the hidden cost issue.

As far as some renewables, for examples, Mega-Solar business gets a big profit, such profit should be back to cost payers, who silently shoulder it. Renewables never give big merits to one side, but should be fair and be justice for everyone.

9 - RECOMMENDATIONS AND BEST PRACTICES - Among the 14 best practices, we recommend the following ones to be commonly shared regardless of RE penetration level:

TECHNICAL

- Balancing supply and demand using large-capacity energy storage batteries
- Improving the accuracy of PV output forecasting
- 100% RE supply systems for remote islands

INSTITUTIONAL

- RE output curtailment rules (procedures)
- Connect & Manage

NEED FOR HIDDEN (GRID-LEVEL) COST REDUCTION

In order to promote renewables further, we need to reduce the total costs, including these grid-level costs, using the following emerging measures.

- Output curtailment
- Connect & Manage
- Utilisation of smart meter data
- Frequency regulation via V2G

METHOD OF HIDDEN COST SHARING

We have now entered an era of “Grand Energy Transition” featuring the new trends of the “three Ds” (digitalisation, decentralisation and decarbonisation), where a large amount of renewables are integrated into the “downstream” (demand) side of electric power systems.

In light of this paradigm shift, we should reconsider the method of hidden cost sharing, 100% of which has traditionally been borne by end-users.

From the literature survey we conducted, we have identified the following two main issues for discussion:

Evaluation of renewables’ role and location in the grid

- It is true that renewables are power sources that supply electricity to all customers

- It is also true that renewables contribute to national and/or global aims to reduce CO_2 emissions

- However, there is a clear distinction between decentralised renewables and conventional centralised power stations in terms of position in the electric power supply chain. Conventional power stations are located on the upstream side, but renewables are located on the downstream, namely the demand side.

METHOD OF INCREMENTAL COST SHARING TO MAINTAIN POWER QUALITY IN THE FACE OF RENEWABLE INTEGRATION

- Traditionally, all costs regarding power sources have been borne by customers. However, we have also witnessed large industrial customers causing voltage flicker mitigating this phenomenon at their own expense based on the principle of cost causation

- As mentioned above, we can think of renewables as either “power sources” or “negative loads”

- However, it would be inappropriate to make this issue a straight choice between two things, “power sources” or “negative loads”

- Rather, we should aim for the best balancing point in a way that stakeholders such as existing utilities, renewable developers, end-users and government feel their burdens to be fair and transparent

ABOUT THE WORLD ENERGY COUNCIL

The World Energy Council is the principal impartial network of energy leaders and practitioners promoting an affordable, stable and environmentally sensitive energy system for the greatest benefit of all.

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Published by the World Energy Council 2020

www.worldenergy.org

World Energy Council
Registered in England and Wales
No. 4184478

VAT Reg. No. GB 123 3802 48

Registered Office
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