SECOE
SUSTAINABLE ENERGY
CENTER OF EXCELLENCE

"CONNECTING POLICY, TECHNOLOGY & FINANCE THROUGH KNOWLEDGE"

Renewable Energy Grid Integration

7-11 December 2015

Singapore

Contents

Workshop Summary

Background

As world leaders and climate experts worked to forge a climate agreement in Paris during the week of 7-11 December 2015, a total of 49 participants from 15 countries were meeting in Singapore to discuss the technical and policy underpinnings of how to integrate increasingly large amounts of renewable energy generation into the electricity grids of developing Asia. Countries represented at the workshop came from Southeast Asia, South Asia, and Central Asia.

The five-day workshop was the third in a series of training workshops for Asian developing country professionals on important clean energy topics. The workshop is an initiative of the Sustainable Energy Center of Excellence (SECOE), launched earlier this year as a partnership between the Asian Development Bank and the Singapore government.[1]

Workshop Objectives

The workshop was designed to build awareness and knowledge about integrating renewable energy into the electricity grids of developing Asian countries. Given the major drivers of energy security and the need for global action on climate change, the question is not whether RE can be fed into grids in increasing amounts, but how to accomplish this in order to accommodation RE energy targets.

The main questions to be addressed during the workshop were:

- How can electricity grids accommodate increasing amounts of RE, and will the injection of variable RE generation to a grid make it become unstable?
- How much renewable energy can a grid incorporate?
- What are overall strategies and specific technical options for managing grid stability and "flexibility", in order to facilitate integration of variable RE?
- What are the characteristics of solar and wind energy generation, and what are the strategies for managing the intermittency of their generation?
- What is the role of demand management and demand response in managing variations in electricity supply—whether traditional power or renewable power?

How Much Variable RE Can Power Grids Handle?

Experience from a number of countries around the world has shown in recent years that grids can handle high levels of variable RE.

- Denmark had 39% of its electricity from wind in 2014. To balance this RE, it has good interconnections with the Nordic countries and Germany, has flexible generation (including combined heat and power) and good electricity markets

[1] More background on SECOE can be found here.

- Portugal had 25% of its electricity from wind in 2013. . To balance the RE, it has interconnections to Spain, gas and hydro for variable generation, and good electricity markets.
- Spain had 23% of its electricity from wind in 2013. It used variable generation from gas and hydro and good electricity markets for balancing.
- Ireland had 18% of its in electricity from wind in 2013, with gas for variable generation and good electricity markets.

In short, many grids are operating with 20-30% variable renewables (as a share of the electricity supply), and the experts in the workshop indicated that integration of RE into the grid need not be a concern for power planners and system operators at very low levels of RE supply (~5-10%).

In handling increasing amounts of variable RE, proper planning is critical. It is important to understand that Integrating wind and solar resources requires an evolution in power system planning.

Some of the key issues related to RE grid integration are:

- Balancing requires more flexibility
- Existing thermal assets may be used less frequently, and this affects cost recovery
- More reserves are needed
- More transmission and better planning needed
- Voltage control, internal response come at an added cost

Grid Issues

Conventional Grids and Microgrids

Conventional grids operate with the baseload power concept and rely on one-way communication, even if they are decentralized. They are hierarchical in nature. Microgrids allow for the incorporation of distributed generation, demand response, and energy storage, and they can operate independently (island mode), or connected to grid.

The concept of microgrids was introduced in the US in 2004 by the Consortium for Electric Reliability Technology Solutions (CERTS). The objective of introducing microgrids was to improve the reliability of the US power grid system. Microgrids can be scalable, ranging from small, at the consumer and community level, to large, regional grids.

Microgrids enable and facilitate distributed generation. They also can be managed through demand response, which can categorize demand loads as sensitive, adjustable, or sheddable.

Some of the advantages of microgrids are that they are flexible and can incorporate renewable energy (they are green); they are stable, reliable, independent, and extendable; and they are scalable, from small to large size systems

Strong vs. Weak Grids

Not all grids are created equal. When introducing large-scale RE (Wind and PV) integration, it is important to consider the strength of the power grids. For example, the power industry uses the term "short circuit ratio" (SCR), to measure the strength of the power system for connection of power electronic converters. SCR is a metric of the amount of power that can be accepted by power system without affecting power quality. Another indication of grid strength is called the Xgrid/Rgrid ratio. In general, a weak grid is defined as having an SCR of < 0.3, and and Xgrid/Rgrid ratio of < 5. A week grid will be more likely to experience power quality issues when variable generation sources are connected. The problem with a weak grid is that it can accept a limited capacity of RE and is prone to surge impedance loading on long radial transmission lines. It will experience dynamic challenges such as voltage instability and fluctuations.

Comprehensive studies are required to guarantee the successful integration of large RE integration, and these should be take before injecting large amounts of RE into the grid. (However, at levels of less than 5 or 10% RE, there are not likely to be issues with grid stability.)

The challenges faced by weak grids when integrating RE can be managed through proper control strategies. In cases where the grid is weak (nor not strong), It is important for grid operators, planners, developers, and OEMs to collaborate closely and understanding and take potential remediation measures to mitigate the operation of RE plants. It is important to understand that hooking a large RE source up to a weak grid doesn't necessarily make the grid weaker. In fact, if properly managed, it may be possible for it to strengthen the grid

Challenges of grid integration: Technical Issues

The four main challenges of RE grid integration are:

- Non-controllable variability (Fluctuation). Wind and solar output varies in a way that generation operators cannot control.
- Partial unpredictability. The availability of wind and sunlight is partially unpredictable
- Location dependence. The best wind and solar resources are based in specific locations.
- Grid Capacity. Can the grid withstand more and more RE generation without reinforcement?

In a conventional power network, the frequency balance between generation and load is achieved by controlling power. As load increases, frequency decreases; and as load decreases, frequency increases.

With increasing amounts of distributed RE feeding into the grid, the power flow in the system is no longer one direction. High penetrations of RE such as PV could reverse the power flow of the system. When power flow reversed, voltage drop could be "reversed" too. An area in the grid with high RE penetration could face an "over-voltage" problem.

In a conventional network, the generator controls system frequency by adjusting power output. Large scale fluctuations of RE power (e.g. solar) in the system would cause fluctuations in the system frequency. Frequency fluctuations could cause tripping of renewable inverters, which could expand to a larger scale. If there is an instantaneous loss in generation, this could create instantaneous frequency drops and could trip renewable inverters.

One good solution for dealing with such fluctuations is electrical energy storage, which can help with power quality and stability, frequency regulation, spinning reserves, and load following and ramping.

One case study presented covered the use of energy storage for frequency regulation in Germany. The issue in Germany is that the high levels of renewable energy (solar & wind) in Germany's grid cause high frequency fluctuations. Moreover, since Germany exports RE to other European countries, this could potentially affect the European grid. The solution applied in Germany has been to apply battery storage to smooth the grid frequency fluctuations caused by solar and wind. (See section below on energy storage.)

Challenges of Grid Integration: Best Practices in Conducting Grid Integration Studies

The need for integration of large amounts of RE is driven by the establishment of ambitious RE targets. Some examples include:

- Turkey: 25 GW of wind by 2023
- China: 300 GW of wind and solar by 2020
- India: 160 GW of wind and solar by 2022
- Kenya: 635 MW of wind by 2016
- South Africa: 14 GW of wind and solar by 2020

A grid integration study is an analytical framework or evaluating a power system with high levels of variable RE. In principle, it should do the following things:

- Simulate operation of power system under different future power scenarios
- Identify reliability constraints
- Determine relative costs of actions to help integrate RE
- Address system operation concerns that the system can work reliably and cost effectively
- Examine impacts of high RE on capacity expansion (generation and transmission).

The study should also look at macro issues such as market design, as well as detailed technical issues such as hourly system balancing, costs, emissions; operational dispatch at sub-hourly timeframes; availability an type of ancillary services that can be provided; potential impacts on the thermal fleet of cycling to balance the load; and grid stability following a disturbance

The four main steps in a grid integration study are:

- Step 1: Collect data
- Step 2: Develop scenarios (resource, transmission, system management)
- Step 3: Simulate the power system (production cost simulation and flexibility assessment, dynamics, load flow, capacity value/reliability)
- Step 4: Analyze and report (data analysis and output synthesis)

A typical grid integration report will analyze the following outputs and metrics:

- Production costs
- Capacity and generation by plant type, including RE curtailments
- Fuel consumption
- Energy transfers and power flows
- Operational feasibility (including solutions to infeasibilities)
- Cost/benefit of specific integration options, including options aimed at mitigating negative effects of RE integration.

In designing a grid integration study, stakeholder engagement is critical. This engagement can be handled through a Technical Review Committee, which can:

- Assist modelers in guiding study objectives, scenarios, and sensitivities
- Reviews study assumptions and results on multiple occasions throughout course of study.
- Endorses technical rigor of the study.

Typically, the stakeholder members in a Technical Review Committee can include system operators; utilities (if distinct from system operator); owners, operators, and developers of both conventional and RE power plants; transmission developers; regulators; and a public advocate stakeholder.

Sources of Grid Flexibility to Facilitate Integration of RE

Power grid operation is by necessity dynamic, not static. Grid operators have been managing supply to meet variable demand for years. And all power systems have variability and outages in supply, transmission, and distribution.

Variable renewable energy introduces more variability on the supply side, compared to baseload plants, but it can be managed through a range of grid flexibility mechanisms.

RE grid integration is the practice of developing efficient ways to accommodate higher penetration levels of variable RE to the grid. The more flexibility there is in the power system, the easier it is to manage the variability and intermittency of RE power sources

This section of the workshop addressed how we can design and operate the power system so that we can more efficiently integrate RE. It is important to do the integration at the least cost, and to meet reliability targets

The Flexibility Supply Curve

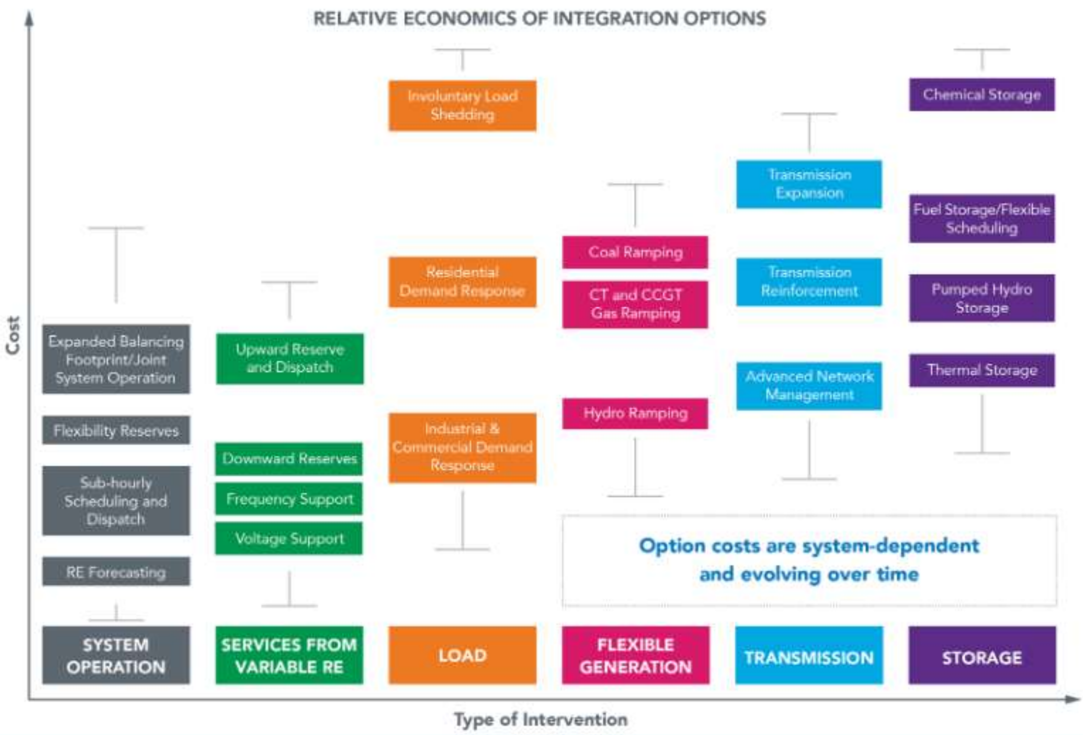
As noted above, “grid flexibility” refers to the ability of a power system to respond to changes in demand and supply. There are numerous options for increasing flexibility in any power system. Flexibility reflects not just physical systems, but also institutional frameworks.

The US National Renewable Energy Laboratory (NREL) has developed a “flexibility supply curve”, which provides a good framework for understanding how different options can be used to provide flexibility and enable integration of RE into the grid.

The Y axis shows the relative cost of the options. The X axis shows categories of options, roughly in increasing cost, from left to right.

The broad categories of flexibility control are:

- System operation
- Services from variable RE
- Load (demand)
- Flexible generation
- Transmission
- Storage



System Operation Issues and Flexibility

System operation approaches can include things such as better forecasting. Improved variable RE forecasting can reduce uncertainty and costs. For example, Exel Energy is the largest wind generator in the US, and wind energy accounts for 15% of its energy generation. Wind energy can spike up to 60% of its electricity supply at times. Exel developed a state-of-the-art forecasting model that reduced the forecast error for wind from 17% to 10% between 2009 to 2014. This helped with the ability to manage the wind energy integration and saved ratepayers USD 49 million

Faster dispatch can also reduce the reliance on expensive reserves. For example, sub-hourly dispatch can be applied instead of hourly dispatch of supply resources. All utilities in US now use 5-minute dispatch; and some are considering going to 3-minute dispatch. And India modified bidding time block from one hour to 15 minutes in 2012

Having RE resources distributed across a larger geographic area can reduce system variability and the need for reserves. This is called having a larger "balancing footprint". As a simple example, a wind farm with 200 turbines will have a lot less variability than a farm with just 15 turbines, since the addition of more turbines reduces the relative peaks and valleys of the overall wind energy generation.

Integrating More Large-capacity RE: Energy Storage Solutions

While energy storage is one of the most expensive of the grid flexibility mechanisms, it still has an important role to play.

Here is a list of energy storage technologies, in descending order from higher power to higher energy:

- Pumped storage
- Compressed air energy storage
- Sodium sulfur (NaS) battery
- Vanadium redox battery
- Advanced lead acid batteries
- Zinc bromine flow battery
- Sodium nickel chloride battery
- Li-ion – High Power
- Li-ion – High Energy
- Flywheels
- Double layer capacitors (super capacitors)

These are the value areas where storage can make a difference:

  - Energy
  - Power (capacity—both active and reactive power)
  - Power (variability)
  - Service reliability

One of the important things to remember about ESS is that there is no silver bullet—i.e. there is no single best storage technology for all applications. Different technologies have their strengths and weakness. For example, a flywheel has short duration, but can ramp up very quickly. And Mongolia has a lot of RE potential but a weak grid. They are assessing energy storage as an option for strengthening the capacity of the grid to accept more RE from distributed wind generation.

It is important to match the each storage technology with an appropriate application(s), and the main body of this report provides a table matching storage technologies with different stationary applications.

Another thing that is important to remember about storage is that although it is the most expensive strategy for grid flexibility, it has an important role in combination with other approaches in different applications

It is difficult to assess the market for energy storage, because it is so diverse, but experts estimate that the storage market will achieve a value of at least USD 30 billion annually by 2020. Currently, the dominant use of storage in markets around world is for PV systems. But it is also used for wind energy, including for community storage and substation support.

Demand Response and Grid Flexibility

Demand response (DR) was introduced in Singapore in 2004, when interruptible loads were accepted as a source of spinning reserve for the ancillary services market. There is now an active market for DR in Singapore, and it could replace as many of 2 of the 7 peaking power plants envisioned in Singapore's Power Development Plan

DR has a number of clear benefits:

- when appropriately designed and implemented, DR programs can yield significant benefits to the electricity system;
- DR is not intended to replace existing generation resources already in operation but rather complement them;
- DR enables diversification of the supply mix to include more renewables;
- DR can assist in managing intermittent generation sources such as solar and enhance the resilience of the power system; and
- DR is a versatile resource, and is quickly deployable.

DR is a good solution to ease the impacts of distributed generation (DG). In the US, direct control ("dispatchable") DR programs account for 62% of total programs; customer voluntary response to signals account for = 27% of total; retail programs ;and just 8% of programs are for residential customers.

DR has a number of benefits, including the following:

- DR improves system reliability
    - Can provide dispatchable peak load reductions (e.g., incentives for factories)
- Improve system efficiency
    - E.g., no-crisis peak shaving
- Improve system flexibility, through demand-side balancing services

The market for "spinning reserves", including interruptible loads, in Singapore was SGD 51 million (~USD 36 million) in 2014, as part of the ancillary services program. In addition, DR is now being introduced into the Singapore Energy Market as part of a price response program in the broader energy market.

The Singapore power market is fully deregulated, with bidding on both the demand and supply side. On the demand side, the market has DR "aggregators". Who have clients that agree to be paid for the right for some of their loads to be interrupted? The interruptible loads are dispersed throughout grid, to provide an additional layer of resiliency. There are three classes of interruptible load in the Singapore DR market: primary (8 second response time); secondary (30 second response time); and contingency (10-minute response time). When the DR aggregator assumes coordination of the loads and interrupts the load when an

"Activation Event" (ranging from a few MW to a few hundred MW) is initiated by the Singapore Independent System Operator (ISO).

Introduction to Smart Grids & Their Potential

A Smart Grid is an electric power network that utilizes two-way communication and control technologies to cost efficiently integrate the behaviour and actions of all users connected to it – in order to ensure an economically efficient sustainable power system with low losses and high levels of quality, security of supply and safety.[2]

The key factors driving smart grids are the need to improve the reliability and quality of energy supply; to improve power system operation and customer satisfaction; and to reduce the environmental impact of the power system, by increasing the use of RE resources, utilizing DR, and as a result reducing emissions of GHG emissions.

There are a number of myths and impressions about smart grids that are incorrect. A Smart grid is not any of the following:

- smart grids are not new "super grids";
- smart grids are not a revolution but rather an evolution;
- Smart grids relate to the electricity network only;
- there will not (and cannot) be any "rollout" of smart grids; and
- smart metering does not create a smart grid; and
- solar arrays, wind turbines, and plug-in hybrid electric vehicles are not part of the smart grid

The key factors enabling smart grids are a combination of good policies, people, and technology.

- The policy framework depends on effective regulatory incentives (such as time of day pricing, and incentives for interruptible loads, etc.)
- Having good people depends on operational capabilities and business processes of the regulator, the utilities, and market players (equipment suppliers and market aggregators)
- For smart grids to work properly, there need to be a range of effective technologies: information/system integration and interoperability; data processing analysis and intelligent applications; data communications; grid design and configuration; intelligent devices; demand side automation; and distributed generation technologies.

Some of the core smart grid technologies include:

- advanced Metering Infrastructure (AMI) integration of smart meters and two-way communication;
- advanced sensing and measurement technologies to support faster and more accurate response such as remote monitoring, time of-use pricing and demand-side management;

[2] IEC and The European Technology Platform on Smart Grids

- advanced components to apply the latest research in storage, power electronics, diagnostics and superconductivity;
- advanced control methods to monitor essential components, enabling rapid diagnosis and precise solutions appropriate to any event; and
- improved interfaces and decision support to amplify the decision-making of grid operators and managers

A number of electrical studies and simulations are needed for effective integration of RE into the grid. These include:

- power flow studies,
- dynamic stability assessments
- short circuit studies
- frequency assessments, and
- connection facility assessments

Challenges in Financing Weak Grids to Make them Stronger

In many countries in South Asia, the transmission system remains the last public monopoly. Countries such as Pakistan are coming to grips with how to integrate RE, how to finance the investments, and how to recover the investment and operating costs.

ADB provide an overview of some issues related to finanginc grids to strengthen them in order to accommodate larger amounts of RE.
Funding from ADB

The three pillars of ADB's Energy Policy (2009) are to promote RE, provide energy access for all (Energy for All) and to promote energy sector reforms and capacity building in government.

ADB invests about $3bn a year in clean energy, through a combination of sovereign loans, technical assistance grants, and private sector loans and investment

The challenges that ADB sees for RE in its dealings with its clients is the perception of risk or RE projects and the impact that this has on the cost and tenor of debt. There is often a question of whether the RE infrastructure should be financed by public or private sectored debt.

The Types of MDB financial assistance include the following:

- bonds (international, domestic, and "masala");
- loans (through financial institutions, and these can be either sovereign or non-sovereign)
- guarantees, including partial risk mechanisms, foreign exchange hedging, partial credit guarantees; and
- equity and grant investments, including technical assistance.

Some recent examples of ADB investments in clean energy in South Asia include:

- Gujarat Solar Park, India. This was planned to be a 500 MW project, with an FiT mechanism. The FiT rate was front loaded—about INR 13 (US 20 cents) for first several years, then dropped by 3-4 INR (US cents 4.5-6).
- Simpa Networks. Investment into the India operations of a pay as you go scheme for providing solar home PV energy access across India.
- Maldives
    - RE and clean energy to about 200 inhabited islands
- Green Energy Corridor (India). This project will have an overall investment of USD 6-8 billion, of which ADB will provide USD 500 million sovereign debt and USD 500 million of non-sovereign debt.
- RE Guarantee Facility (India). IIFCL, which is a broad based infrastructure financing intermediary will provide credit enhancement for RE companies and assist them in issuing corporate bonds.
- CSP in India. ADB is investing in a 100 MW CSP project in Rajasthan, through its Private Sector Operations Division.
- Maldives POISED (Preparing Outer Islands for Sustainable Energy Development) Project. The Maldives has 1,192 islands, of which just 194 are inhabited. The installed capacity is 141 MW, and the cost of electricity is US 30-70 cents/kWh.
    - In its [project design, ADB has developed a typology for different islands:
        - Type A: Large islands–moderate RE (10% of energy and 30-40% of peak)
        - Type B: Medium sized islands–medium RE (10-30% of energy and up to 80% of peak load, Need storage as backup for security, grid support)
        - Type C: Very small islands–full RE (RE penetration close to 100 , peak < 20 kW, storage backup for security, grid support, load following)
    - The project will provide investment of $110m including private sector financing.

Technical Assistance Resources to Support Grid Integration Initiatives

A number of different TA resources are available in the public domain to support countries that are seeking to scale up their implementation of clean energy to meet national climate change and energy security targets, and that need to integrate increasing amounts of RE into their grids. Some of these presented at the workshop are presented below

Clean Energy Solutions Center (CESC). CESC was launched in April 2011 to support the Clean Energy Ministerial. It is one of several CEM Initiatives, which include the Global Superior Energy Performance Partnership (GSEPP); the Super Efficient Equipment and Appliance Deployment (SEAD) initiative ; and the Global Lighting and Energy Access Partnership. CESC helps governments design and adopt policies and programs that support the deployment of clean energy technologies It has more than 35 partners, including IRENA, IEA, IPEEC, Sustainable Energy for All, Bloomberg New Energy Finance and Leonardo Energy

The goals of CESC are:

- Serve as a principal clearinghouse of clean energy policy and program resources.
- Share clean energy policy best practices, data, and analysis tools across countries

- Deliver dynamic, customized services that will enable expert assistance, learning, and peer to peer sharing of experiences.
- Foster dialogue on emerging policy issues and innovation across the globe.
- Serve as a primary resource for project financing options and information to expand markets for clean energy

Clean Energy Grid Integration Network (CEGIN). The objective of CEGIN are to help strengthen policies and programs to enable high levels of renewable energy generation for electricity systems, along with related demand response, smart grid, and storage solutions. CEGIN partners include the Clean Energy Solutions Center; the 21st Century Power Partnership; the US Agency for International Development (USAID); the Asia Low Emission Development Strategies Partnership (ALP); and the Greening the Grid initiative.

CEGIN resources and services include:

- Expert technical assistance
- Training and knowledge exchange
- Technical resources and good practices
- Regional and global networks

Clean Energy Regulators Initiative (CERI). CERI focuses on improving the effectiveness of regulation and is a collaboration between Leonardo Energy, the Clean Energy Solutions Center, the and 21st Century Power Partnership. CERI serves as a knowledge provider on clean energy topics including current developments; regulations and best practices; and capacity building for utility regulators on EE, demand-side management, smart grids, and RE deployment/integration. The CERI webinar programme delivers a series of sessions around major challenges in energy markets. CERI is developing a curated library of clean energy resources important to regulators.

International Smart Grid Action Network (ISGAN). ISGAN is a strategic platform to support high-level attention and action for the accelerated development and deployment of smarter, cleaner electricity grids around the world. ISGAN activities include building a global understanding of smart grids, addressing gaps in knowledge and tools, improving peer to peer exchange, and recognizing excellence. ISGANIncludes representatives of governments, national laboratories and research institutions, transmission and distribution system operators, power generators, and others from 24 countries and the European Commission.

21st Century Power Partnership. The Partnership is a multilateral effort under the umbrella of the Clean Energy Ministerial. The Partnership has (1) *country level programs*, through which it teams with key stakeholders in India, Mexico, and South Africa to support power system transformation activities such as modeling, road-mapping and integration; (2) *knowledge development and sharing*, which involves knowledge development and dissemination, including reviewing, researching and developing case studies of policy-relevant power sector issues; and (3) *organizing global networks of expertise*, including platforms for multilateral expert consultations, workshops, and fellowships.

Key web resources. Two of the key web clearinghouses for information on RE grid integration are:

- *Clean Energy Solutions Center*
    - cleanenergysolutions.org
    - Contact: https://cleanenergysolutions.org/contact
- *Greening the Grid initiative*
        - greeningthegrid.org
        - Email: greeningthegrid@nrel.gov

Final Session: Country Working Groups and Conclusions

In the final session of the workshop, participants spent several hours in group work, reviewing the main lessons learned and discussing how to take the knowledge and information forward for possible application in each of their countries.

Participants were asked to address the following questions:

- What are the key things they have learned during the week?
- What are some of the key strategies for handling the intermittency of RE supply?
- How can they apply some of the learnings from the workshop in their country?
- Identify priority list for public and private sector action in their country to support research and action to support successful grid integration of RE

Key Take-Aways

Here is a list of the most common take-away lessons, as presented by the workshop participants:

- update on the status of RE developments and trends around the world;
- overview of grid Integration issues, including RE forecasting, strong vs. weak grids, managing RE variability;
- approaches to financing RE integration and related efforts to improve grid strength and flexibility;
- knowledge of metrics for grid strength, including SCR and Xgrid/Rgrid ratio;
- use of improved forecasting methods to improve reduce the margins needed in managing RE intermittency;
- NREL concept of the “Flexibility Supply Curve”, showing the catagories of grid flexibility measures and their relative costs;
- familiarity with a number of frequently used options to increase grid flexibility, including:
    - system operation (e.g., Sub hourly forecasting and scheduling);
    - ancillary Services from variable RE (e.g., upward and downward reserves, frequency and voltage support);
    - demand response measures and strategies (and especially the DR market mechanism being applied in Singapore;
    - power electronic controls in wind turbines, and the ways they can be connected to the grid;

    - application of battery storage to smooth grid frequency fluctuations; and
    - the diversity of types of energy storage and the need to match the storage technology to the particular application;
- concept of rooftop leasing as a way of scaing up distributed generation using solar PV;
- mechanisms for ADB sector-level financing, including support instruments such as technical assistance (TA) packages, bonds, loans, and government guarantees;
- overview of Singapore energy market and the essential role played by Singapore's Energy Markets Authority.

Next steps

Participants also presented lists of priority topics to pursue and next steps in moving forward to build capacity for RE grid management and integration in their countries.

Here is a list of the most commonly referenced next steps:

- *design and implementation of RE grid integration studies* (drawing on the examples presented by the international experts and also by the Sri Lankan delegation of the grid integration assessment it has done in its country);
- *public-privates sector collaboration* on research, design, investment in measures to understand and implement grid flexibility mechanisms;
- *improved forecasting of RE resources*, to reduce wasteful investment in excess operating reserves;
- *introduction of regulatory framework, technologies, and tools for implementing demand response* as a grid flexibility mechanism to help manage RE grid integration;
- *detailed analysis of storage options and applications* (e.g., pumped storage, battery storage, etc.); and
- *implementation of demand side management, smart grids, and energy storage* to help manage achievement of aggressive country RE targets,

Annex 1: Participant List

No.	Role	Full Name	Agency/Ministry	Country
1	Delegate	Mrs Donara Vardanyan	Ministry of Energy and Natural Resources	Armenia
2	Delegate	Mr Sanan Abbasov	State Agency on Alternative and Renewable Energy Sources	Azerbaijan
3	Delegate	Mr Afsun Alakbar	Azerisig OJSC	Azerbaijan
4	Delegate	Ms Shafa Hajiyeva	Azalternativenergy LLC	Azerbaijan
5	Delegate	Mr Ugyen Tshering	Bhutan Power Corporation Limited	Bhutan
6	Delegate	Mr Nima Tshering C	Bhutan Electricity Authority	Bhutan
7	Delegate	Ms Damchu Dema	Ministry of Economic Affairs	Bhutan
8	Delegate	Mr Zaza Ashotia	Georgian State Electrosystem	Georgia
9	Delegate	Mr Irakli Darchiashvili	Georgian State Electrosystem	Georgia
10	Delegate	Ms Ira Savitri	PT PLN (PERSERO)	Indonesia
11	Delegate	Ms Rizki Wahyuni Asikin	PT PLN (PERSERO)	Indonesia
12	Delegate	Mr Zhandos Nurmaganbetov	Financial Settlements Centez	Kazakhstan
13	Delegate	Mr Samat Aldeev	JSC Electric Power Plants	Kyrgyzstan
14	Delegate	Mr Bapa Zhanybekov	National Electric Grid of Kyrgyzstan	Kyrgyzstan
15	Delegate	Mr Nurlan Kurmanaliev	Ministry of Finance of the Kyrgyz Republic	Kyrgyzstan
16	Delegate	Mr Ibrahim Nashid	State Electric Company Ltd	Maldives
17	Delegate	Ms Asiyath Ibrahim	Fenaka Corporation Limited	Maldives

No.	Role	Full Name	Agency/Ministry	Country
18	Delegate	Mr Masood Abdulrahman	Fenaka Corporation Limited	Maldives
19	Delegate	Mr Aung Moe Myint	Ministry of Electric Power	Myanmar
20	Delegate	Mr Ye Tun Zaw	Ministry of Electric Power	Myanmar
21	Delegate	Mr Tint Soe Win	Ministry of Electric Power	Myanmar
22	Delegate	Mr Mukesh Ghimire	Alternative Energy Promotion Center	Nepal
23	Delegate	Mr Bodha Raj Dhakal	Nepal Electricity Authority	Nepal
24	Delegate	Mr Chirantan Bikram Rana	Nepal Electricity Authority	Nepal
25	Delegate	Mr Imtiaz Hussain	National Electric Power Regulatory Authority (NEPRA)	Pakistan
26	Delegate	Mr Muhammad Waseem Younas	National Transmission Despatch Company (NTDCL)	Pakistan
27	Delegate	Mr Saifan Ahmed Jurri	National Transmission Despatch Company (NTDCL)	Pakistan
28	Delegate	Mrs S.W.A.D.N.Wickramasinghe	Ceylon Electricity Board	Sri Lanka
29	Delegate	Mrs W.M.N.D.Nisansala	Ceylon Electricity Board	Sri Lanka
30	Delegate	Mr Gayan Buddhika Alahendra	Ceylon Electricity Board	Sri Lanka
31	Delegate	Dr H. M. Wijekoon Banda	Ceylon Electricity Board	Sri Lanka

Annex 2 : Resource Speakers List

	Role	Full Name	Agency/Ministry	Country
1	Speaker	Mr Len V. George	ADB	Philippines
2	Speaker	Ms Jessica Katz	National Renewable Energy Laboratory (NREL)	United States
3	Speaker	Dr Peter Du Pont	CLASP	United States
4	Speaker	Mr Roch Drozdowski-Strehl	ERI@N	Singapore
5	Speaker	Mr Dallon Kay	Diamond Energy Group	Singapore
6	Speaker	Dr Loc Nguyen Khanh	DNV GL – Energy	Singapore
7	Speaker	Dr Kelvin Tan	DNV GL – Energy	Singapore
8	Speaker	Mr Tom McInally	DNV GL – Energy	Singapore
9	Speaker	Mr Eugene Toh	Energy Market Authority (EMA)	Singapore
10	Speaker	Mr Daniel Liang	DNV GL Clean Technology Centre	Singapore
11	Speaker	Mr Edwin Khew	Anaergia Pte Ltd	Singapore
12	Speaker	Dr Pushkala Lakshmi Ratan	TUV SUD PSB	Singapore
13	Speaker	Ms Katarina Uherova Hasbani	REN21	Singapore

Annex 3 : ADB List

No	Role	Full Name	Agency/Ministry	Country
1	ADB	Ms Ana Maria Tolentino	ADB	Philippines
2	ADB	Ms Aruna Wanniachchi	ADB	Philippines
3	ADB	Ms Koh Pei Ling	ADB	Philippines
4	ADB	Mr Mirdin Eshnaliev	ADB	Kyrgyzstan
5	ADB	Mr Andre Susanto	ADB	Indonesia