

Greening the Grid

A Toolkit for Integrating Variable Renewable Energy to the Grid

Asia Clean Energy Forum
Grid Integration Deep Dive Workshop
June 16, 2015

What is Greening the Grid?



Greening the Grid provides technical assistance to energy system planners, regulators, and grid operators to overcome challenges associated with integrating variable renewable energy to the grid.

What We Do



Offer a **toolkit** of information and guidance materials to inform the development and implementation of grid integration roadmaps



Facilitate direct **technical assistance** tailored to the unique power system characteristics and priorities of each partner country

Greening the Grid is a component of the U.S. Government's Enhancing Capacity for Low Emission Development Strategies (EC-LEDS) program)

The Greening the Grid Toolkit



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Understand Grid Integration Basics

Review concise fact sheets covering a variety of key issues. [Read more](#)

Greening the Grid

What is Grid Integration?

The Challenge:
Large-Scale, Grid Connected Clean Energy

Power grids are complex networks that balance electricity supply and demand around the clock, every day of the year. Renewable energy, such as solar and wind, can significantly reduce greenhouse gas emissions from electricity generation.

[Read more](#)



What We Do

Technical Assistance and Collaboration

Greening the Grid offers a toolkit of information, guidance materials, and technical assistance to support countries in significantly scaling up the amount of variable renewable energy connected to the electricity grid.

[Read more](#)



Ask an Expert

Request information and assistance

Greening the Grid connects power system stakeholders to experts from our grid integration expert network to provide no-cost, remote consultation and advice.

[Submit a Request](#)



Understand Grid Integration Basics

The screenshot shows the website's header with the logo 'greening the grid' and a navigation menu: HOME, OVERVIEW, TRAININGS, INTEGRATION TOPICS, ASK AN EXPERT, GLOSSARY, RESOURCES. Below the menu is a banner image of power lines. The main content area has a breadcrumb 'Home / Overview' and a title 'Overview of Key Issues: Integrating Variable Renewable Energy into the Grid'. The text explains that many countries are setting ambitious renewable energy targets, and grid integration is the practice of developing efficient ways to deliver variable renewable energy (RE) to the grid. It notes that robust integration methods maximize the cost-effectiveness of incorporating variable RE while maintaining system stability and reliability. A key point is that 'Policymakers, regulators, and system operators consider a variety of grid integration issues, which can be organized into four broad topics:'. The first topic is '1. New Renewable Energy Generation', with a sub-point that power system planners can secure and sustain investment in new variable RE generation by *aligning targets*. A sidebar on the left contains social media icons (Facebook, LinkedIn, Twitter, Email, Plus) and a 'QUICKLINKS' section with 'Overview' and 'About Greening the Grid'. Below that is a 'PUBLICATIONS' section with three items: 'Scaling Up Renewable Energy Generation: Aligning Targets and Incentives With Grid Integration Considerations', 'Using Wind and Solar to Reliably Meet Electricity Demand', and 'Sources of Operational Flexibility'.

Download concise factsheets on grid integration issues

Greening the Grid Factsheets

Topics Now Available:

- *Integrating Variable RE into the Grid: Key Issues*
- *Scaling Up Renewable Energy Generation Balancing Area Coordination*
- *Using Wind and Solar to Reliably Meet Electricity Demand*
- *Sources of Operational Flexibility*
- *Methods for Procuring Power System Flexibility*
- *Wind and Solar on the Power Grid: Myths and Misperceptions*
- *Grid Integration Studies: Data Requirements*

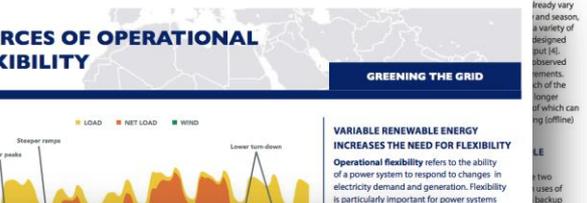
Coming Soon:

- *The Evolution of Power System Planning*
- *Grid Expansion and Upgrades*
- *Demand Response and Storage*
- *Integrating Distributed Solar*
- *Evaluating Costs of Grid Integration*

WIND AND SOLAR ON THE POWER GRID: MYTHS AND MISPERCEPTIONS

GREENING THE GRID

Employing the inherent flexibility present in the power system helps mitigate the most impacts of renewables. Although ramp rates (rate of change) of the aggregated wind and solar output can still be significant, power systems—even before the development of VRE technologies—are often naturally flexible. Variability in renewable output is not a problem in itself, but the longer the duration of which it occurs, the more difficult it is to manage. In heavily variable and seasonal, a variety of designed and dispatched (e.g., observed) resources, such as hydro, are often needed to meet the longer duration of which it occurs (offline).



INTEGRATING VARIABLE RENEWABLE ENERGY INTO THE GRID: KEY ISSUES



"Greening the Grid" aims to modernize the power system so that it can accommodate large-scale integration of variable renewable energy resources. Photo from <https://www.foxphoto.com/17722781-and-17722782>.

To foster sustainable, low-emission development, many countries are establishing ambitious renewable energy targets for their electricity supply. Because solar and wind tend to be more variable and uncertain than conventional sources, meeting these targets will involve changes to power system planning and operations. Grid integration is the practice of developing efficient ways to deliver variable renewable energy (VRE) to the grid. Good integration methods maximize the cost-effectiveness of incorporating VRE into the power system while maintaining or increasing system stability and reliability.

When considering grid integration, policymakers, regulators, and system operators consider a variety of issues, which can be organized into four broad topics:

- New renewable energy generation
- New transmission
- Increased system flexibility
- Planning for a high RE future.

NEW RENEWABLE ENERGY GENERATION

Power system planners can secure and sustain investment in new VRE generation by aligning targets and incentives with grid integration considerations. Long-

term, aspirational renewable energy targets establish a vision that can drive innovation in the policies and system operations that support clean energy. Also critical are "grid-aware" incentives (e.g., rewarding wind and solar generators that incorporate technologies that contribute to grid stability), which both motivate investment in renewable energy and mitigate negative impacts of integrating these resources to the grid.

As planners consider scaling up VRE generation, the inherent variability of wind and solar resources complicates evaluations of whether a system with significant VRE has adequate supply to meet long-term electricity demand. A variety of approaches exist for estimating the capacity value of VRE, as well as techniques that enable utilities and power system operators to use wind and solar to reliably meet electricity demand.

Integrating distributed photovoltaic (PV) solar power results in unique benefits and challenges compared to the integration of utility-scale wind and solar power. Significant localized growth in PV can raise concerns such as voltage violations and reverse power flow in low-voltage distribution systems. However, various studies have shown that positive impacts (e.g., reduced line losses and avoided generation costs) can also result

GRID INTEGRATION TERMINOLOGY

Balancing area: the collection of generation, transmission, and loads within the metered boundaries of the responsible entity (i.e., the balancing authority) that maintains balance between electricity supply and demand within this boundary.

Capacity value: the contribution of a power plant to reliably meet demand, measured either in terms of physical capacity (kW, MW, or GW) or as a fraction of the power plant's nameplate capacity (%).

Flexibility: the ability of a power system to respond to changes in electricity demand and supply.

Demand response: voluntary (and compensated) load reduction used as a system reliability resource.

Grid integration of renewable energy: the practice of power system planning, interconnection, and operation that enables efficient and cost-effective use of renewable energy while maintaining the stability and reliability of electricity delivery.

Grid integration study: an analysis of a set of scenarios and sensitivities that seeks to inform the stakeholders on the ability and needs of a power system to accommodate significant VRE.

Storage: technologies capable of storing electricity generated at one time and for use at a later time.

Variable renewable energy (VRE): electricity generation technologies whose primary energy source varies over time and cannot easily be stored. VRE sources include solar, wind, ocean, and some hydropower generation technologies.

Variability: the changes in power demand and/or the output of a generator due to underlying fluctuations in resource or load.

Uncertainty: the inability to perfectly predict electricity demand and/or generator output.

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Access Training

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HOME OVERVIEW **TRAININGS** INTEGRATION TOPICS ASK AN EXPERT GLOSSARY RESOURCES

TRAINING MATERIALS

Home / Trainings

Trainings

Skip to:

- Upcoming trainings
- Greening the Grid training materials
- Grid integration trainings from other organizations

Greening the Grid seeks to connect power system stakeholders with the training they need to understand and address the issues associated with integrating significant variable renewable energy to the grid. Scroll through the materials below to find upcoming events, materials from previous Greening the Grid trainings, and links to training on grid integration topics offered by other organizations.

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
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28	29	30				

Download materials from previous trainings

Find in-person trainings and webinars

Browse trainings from other organizations

Explore Integration Topics in Depth

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HOME OVERVIEW TRAININGS INTEGRATION TOPICS ASK AN EXPERT GLOSSARY RESOURCES

QUICKLINKS

- Integration Topics
- Ancillary Services
- Balancing Area
- Coordination
- Demand Response and
- Renewable Generation
- Forecasting
- Integration Studies
- System Operations Improvements

FACT SHEET

Sources of Operational Flexibility

Home / Integration Topics / System Operations Improvements

System Operations Improvements

Skip to:

- Example Interventions
- Reading List and Case Studies
- Regulatory and Policy Examples

Operational flexibility is the ability of a power system to respond to changes in electricity demand and generation. Operational flexibility is a prized characteristic in power systems, particularly those with significant variable renewable energy (RE). While system operators have many tools at their disposal to unlock flexibility (e.g., flexible generation, transmission, storage, demand response, and power markets), changes to operational practices are among the most readily accessible interventions. Well-designed system operations to extract flexibility from the existing physical infrastructure and can often be implemented at lower economic costs than options that require changes to the physical power system.

For example, adjusting day-ahead generation scheduling practices to allow changes closer to real time and dispatch decisions to be made based on improved forecasts of both variable RE output and demand. This

Resources:
Curated
Reading
List and
Examples

Example
actions to
address
challenges
related to the
topic

Brief summary
of the topic

Integration Topics

- Ancillary Services
- Balancing Area Coordination
- Demand Response and Storage
- Flexible Generation
- Forecasting
- Grid Integration Studies
- System Operations Improvements

Coming Soon

- Resource Adequacy
- Distributed Generation
- Target-Setting

Resources in the Toolkit:

- *Background information*
 - *Tools*
 - *Methodologies*
 - *Videos*
- *Technical reports*
- *Case studies*
- *Model policies and regulations*
- *Example grid integration studies*

Ask An Expert



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HOME OVERVIEW TRAININGS INTEGRATION TOPICS **ASK AN EXPERT** GLOSSARY RESOURCES

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Ask an Expert

Through the Ask an Expert service, Greening the Grid connects power system stakeholders in developing countries to experts from our grid integration expert network to provide remote consultation and advice. Our experts provide these services via phone and/or email at no cost to the requester.

Submit a
request



Eligibility for Assistance

The Greening the Grid Ask an Expert service supports requests from developing country government agencies, power system operators, utilities, and regulators—as well as their consultants, technical institutions, and nongovernment organizations—working to significantly increase the proportion of renewable energy in their electricity supply.

Example Questions

Greening the Grid experts can answer specific questions, provide high-level review of drafts of measures and



Greening the Grid Technical Assistance Opportunities

Ask an Expert Service

- No cost, remote expert consultation on grid integration questions
- High-level guidance; review of drafts of strategies; examples from other systems
- Supported by experts from the National Renewable Energy Laboratory and the Clean Energy Solutions Center expert network

Demonstration Projects

- In-depth USAID-funded direct assistance to partner countries to identify and implement actions to increase variable RE penetration
- Examples:
 - Support for grid integration studies and roadmaps
 - Integrating forecasting into system operation controls
 - Addressing technical and regulatory challenges of distributed solar PV

We welcome requests!

Glossary and Resources

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HOME OVERVIEW TRAININGS INTEGRATION TOPICS ASK AN EXPERT GLOSSARY RESOURCES

PDF DOWNLOAD

Home / Glossary

Glossary

The Greening the Grid Glossary includes terms and definitions that are commonly used in discussion of grid integration issues. The definitions are adapted in part from the Federal Energy Regulatory Commission, the North American Electric Reliability Commission (NERC), and the National Renewable Energy Laboratory's Transmission Grid Integration Glossary.

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- A B C D E F G I L M N O P R S T U V

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Active power The portion of electric alternating-current equipment.

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References

The following references include technical reports, policy and regulatory documents, case studies, and other resources that are either cited within the toolkit or included as recommended readings.

Skip to:

- A B C E F G I L M N P S W X

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Clean Energy Solutions Center
The Clean Energy Solutions Center, an initiative of the Clean Energy Ministerial, facilitates deployment of renewable energy and energy efficiency

Scaling Up Renewable Energy Generation: Aligning Targets and Incentives With Grid Integration Considerations

Using Wind and Solar to Reliably Meet Electricity Demand Greening

AF-Mercados EMI. (2012). "Development of Western African Power Pool Market Design and Market Rules." <http://www.erera.arrec.org/getattachment/News-Events/News-archive/Proposed-Regional-Market-Design-and-Market-Rules/WAPP-Market-Rules-last-Final.pdf.aspx>.

Association for Demand Response & Smart Grid (2013). "Pacific Gas & Electric Company (PG&E) SmartRate:

Coming Soon

- Additional factsheets and integration topics
- Webinar series
- Integration demonstration projects with partner countries
- More case studies and examples from developing countries
 - Please let us know if you know of resources that you would like to see highlighted!

Thank you!

greeningthegrid.org

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