

# 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?

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***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

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



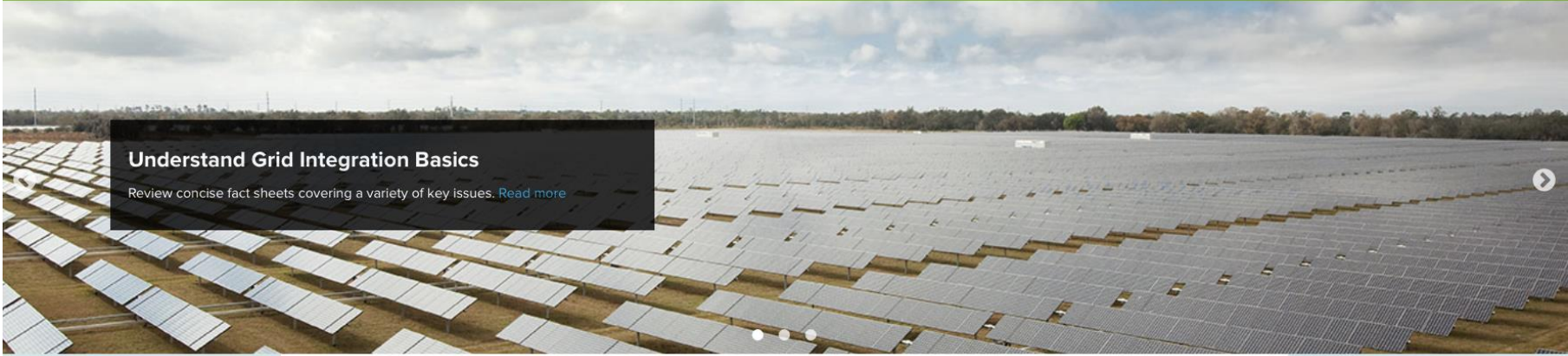
Facilitate direct **technical assistance** tailored to the unique power system characteristics and priorities of each partner country

*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

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



## 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 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'. A call-to-action bubble at the bottom left says 'Download concise factsheets on grid integration issues'.

Download concise factsheets on grid integration issues

# Greening the Grid Factsheets

## Topics Now Available:

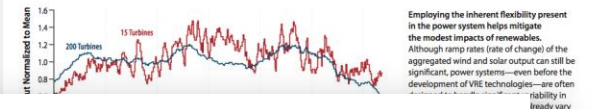
- *Integrating Variable RE into the Grid: Key Issues*
- *Scaling Up Renewable Energy Generation Balancing Area Coordination*
- *Using Wind and Solar to Reliably Meet Electricity Demand*
- *Sources of Operational Flexibility*
- *Methods for Procuring Power System Flexibility*
- *Wind and Solar on the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

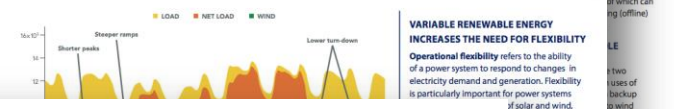
### WIND AND SOLAR ON THE POWER GRID: MYTHS AND MISPERCEPTIONS

GREENING THE GRID



### SOURCES OF OPERATIONAL FLEXIBILITY

GREENING THE GRID



### INTEGRATING VARIABLE RENEWABLE ENERGY INTO THE GRID: KEY ISSUES

GREENING THE GRID



**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.

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 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

Figure 1 shows that variability in solar and wind increases the need for flexibility. This system is dedicated to providing the additional capacity needed to reduce the need for backup power. The first used by. As capacity and increase in this system is dedicated to providing the additional capacity needed to reduce the need for backup power. The first used by. As capacity and increase in this system is dedicated to providing the additional capacity needed to reduce the need for backup power.

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# Access Training

greening the grid

only in current section

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
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

Download materials from previous trainings

Find in-person trainings and webinars

Browse trainings from other organizations

# Explore Integration Topics in Depth

greening the grid

only in current section

HOME OVERVIEW TRAININGS INTEGRATION TOPICS ASK AN EXPERT GLOSSARY RESOURCES

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

**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

Resources:  
Curated  
Reading  
List and  
Examples

Example  
actions to  
address  
challenges  
related to the  
topic

Brief summary  
of the topic



# Integration Topics

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- 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



[Home](#) / [Ask an Expert](#)

## 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

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## 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

The screenshot shows the 'Glossary' page on the Greening the Grid website. The header includes the logo and navigation links: HOME, OVERVIEW, TRAININGS, INTEGRATION TOPICS, ASK AN EXPERT, GLOSSARY, and RESOURCES. A sidebar on the left contains social media icons for Facebook, LinkedIn, Twitter, Email, and a plus sign. The main content area features a 'PDF DOWNLOAD' button, a breadcrumb trail 'Home / Glossary', and the title 'Glossary'. Below the title is an introductory paragraph: '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.' A 'Skip to:' section lists letters A through V. A circular icon with the letter 'A' is highlighted, followed by the definition for 'Active power': 'The portion of electric alternating-current equipment.'

The screenshot shows the 'Resources' page on the Greening the Grid website. The header includes the logo and navigation links: HOME, OVERVIEW, TRAININGS, INTEGRATION TOPICS, ASK AN EXPERT, GLOSSARY, and RESOURCES. A sidebar on the left contains social media icons for Facebook, LinkedIn, Twitter, Email, and a plus sign. The main content area features a 'PUBLICATIONS' button, a breadcrumb trail 'Home / Resources', and the title 'References'. Below the title is an introductory paragraph: '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.' A 'Skip to:' section lists letters A through X. A circular icon with the letter 'A' is highlighted, followed by the first reference: '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

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- 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!

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[greeningthegrid.org](http://greeningthegrid.org)

Email: [greeningthegrid@nrel.gov](mailto:greeningthegrid@nrel.gov)