



21st Century Power Partnership

An Initiative of the Clean Energy Ministerial

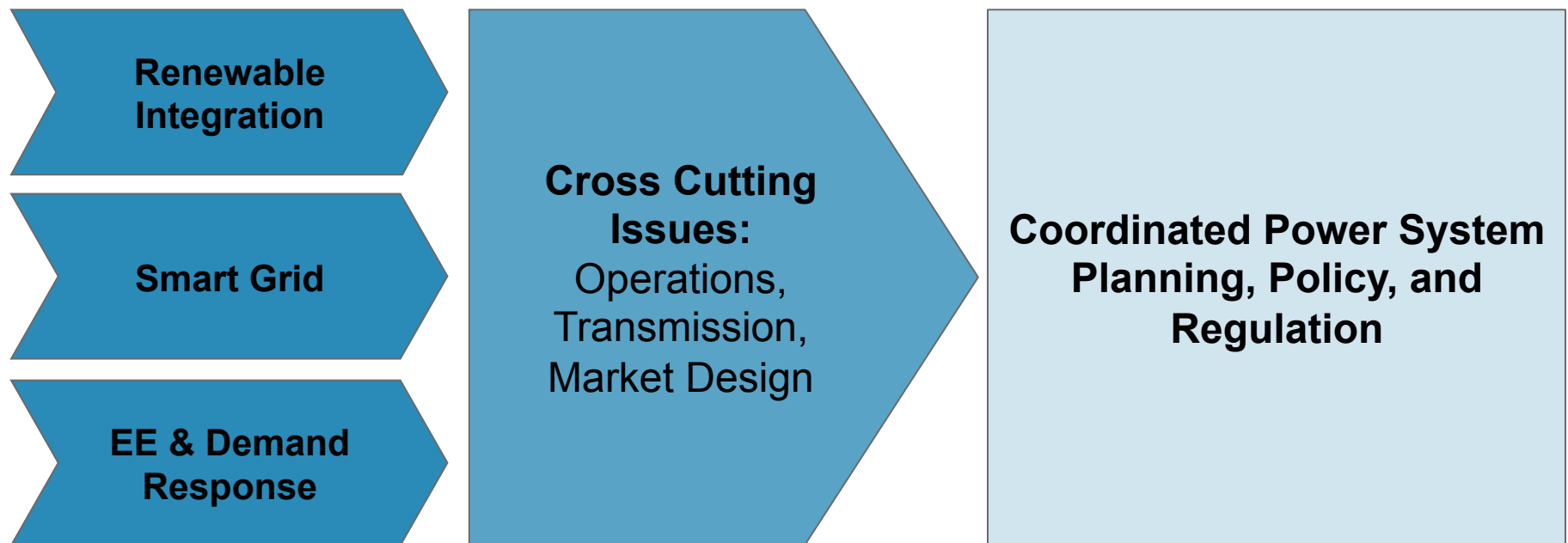
An Overview and Key Activities

National Renewable Energy Laboratory

Operating Agent for the 21CPP



Accelerating the transition to clean, efficient, reliable, and cost-effective power systems.



Elements of Power System Transformation (PST)

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21CPP Activities

The Partnership aims to advance integrated policy development through four areas of activity:

Faster Learning

Developing and sharing knowledge on key topics related to power system transformation.

Better Tools

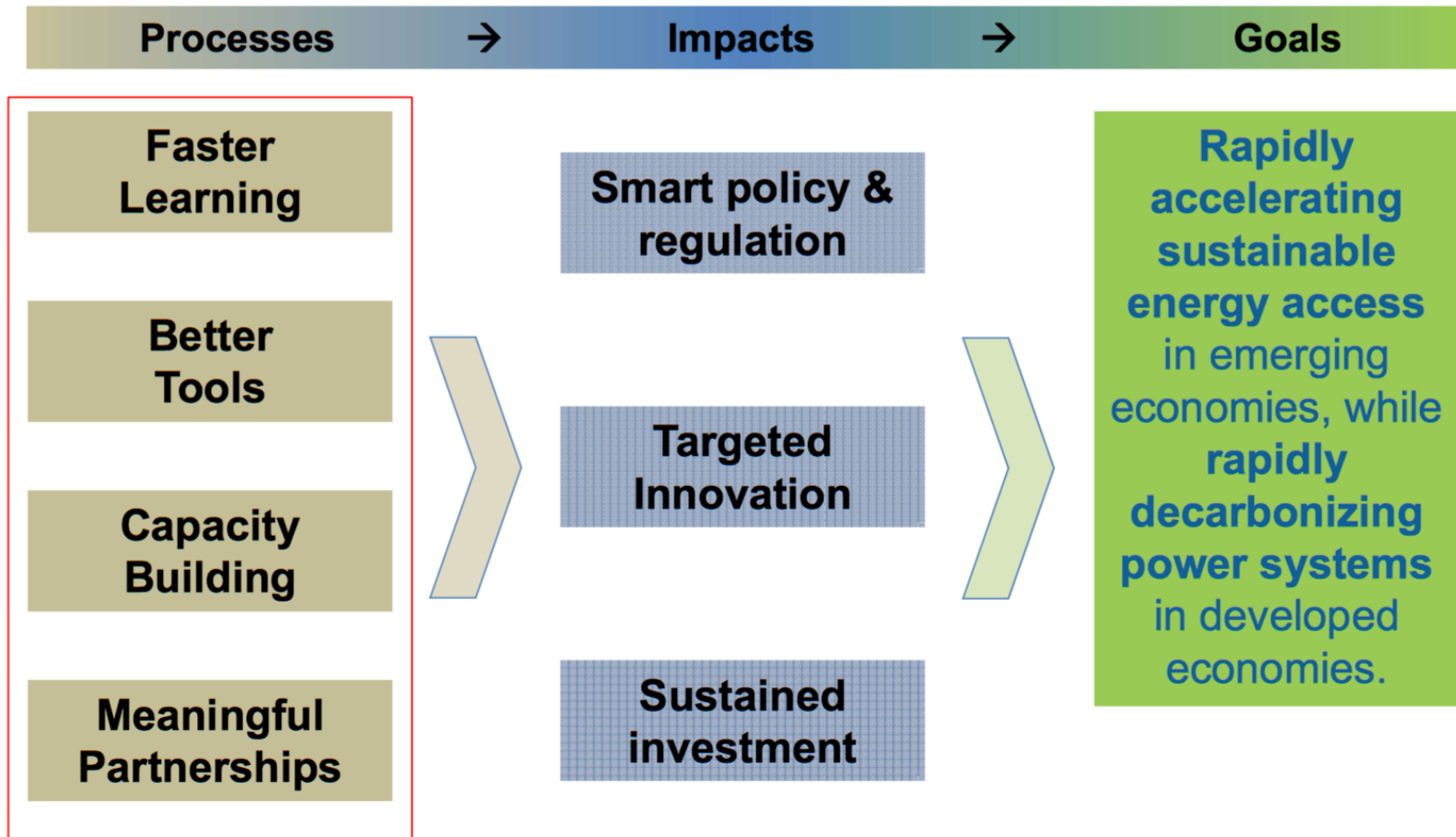
Strengthening and disseminating technical tools to accelerate policy and regulatory analysis.

Capacity Building

Bolstering the capacity of experts to advance the policies, programs, and practices.

Meaningful Partnerships

Establishing applied multilateral partnership engagements to leverage knowledge, tools, and capacity.



KEY AREA OF FOCUS

Clean Energy Ministerial

21st Century Power Partnership Steering Group (PPSG)

Membership open to both CEM- and non-CEM government participation, as well as civic society organizations and private firms. Membership implies in-kind or direct resources to craft and implement annual Program of Work.

Annual Program of Work

Operating Agent
(NREL/JISEA)

Public-Private Leadership Forum (PPLF)

Private sector participation to inform and assist in implementing the Annual Program of Work.

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PROGRAM OF WORK

Annual Program of Work Includes:

- “Thought-Leadership” studies that focus on generic power system transformation topics across the world
- In-country technical assistance, often as part of a larger development assistance effort, focused on policy, regulatory, and technological progress; grid integration studies often highlight this work.
- Information exchange, capacity building, fellowship programs, and other exercises to share lessons-learned and knowledge transfer.



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SELECT 21CPP THOUGHT- LEADERSHIP REPORTS

Integrating Variable Renewable Energy in Electric Power Markets:

Best Practices from International Experience

Jacquelin Cochran, Lori Bird, Jenny Heeter, and Douglas J. Arent



NREL | **JISEA** | **GLOBAL SOLUTIONS CENTER** | **CLEAN ENERGY**

NREL/TP-6A00-53712
April 2012

2012



Market Evolution: Wholesale Electricity Market Design for 21st Century Power Systems

Jacquelin Cochran, Mackay Miller, Michael Miligan, Erik Ela, Douglas Arent, and Aaron Bloom
National Renewable Energy Laboratory
Matthew Futch
IBM

Juha Kiviluoma and Hannalei Holttinen
VTT Technical Research Centre of Finland
Anjie Orlis
Energinet.dk

Emilio Gómez-Liñán and Sergio Martín-Martínez
Universidad de Castilla La Mancha
Sivven Kukkonen and Glynos Garcia
International Copper Association

Kim Møller Mikkelson
Global Green Growth Institute (GGGI)
Zhao Yanggang and Kaare Sandholt
China National Renewable Energy Center

21stCenturyPower.org

Technical Report
NREL/TP-6A00-51477
October 2013
Contract No. DE-AC36-08OR21400

2013



Flexibility in 21st Century Power Systems

Authors:
National Renewable Energy Laboratory, Jacquelin Cochran, Mackay Miller, Owen Zinaman, Michael Miligan, Doug Arent, Bryan Patterson
University College Dublin, Mark O'Malley, International Energy Agency, Ulfen-Martin Biele, Giovanni Lavezzi, Adam Taylor
Northern Power and Conservation Council, Ben Kavanagh, Akeron-Somner VTT Technical Research Centre of Finland, Hannalei Holttinen, Juha Kiviluoma Power System Operation Corporation, U.S. DoE

Introduction

Flexibility of operation—the ability of a power system to respond to change in demand and supply—is a characteristic of all power systems. Flexibility is especially prized in twenty-first century power systems, with higher levels of grid-connected variable renewable energy (primarily, wind and solar).

All power systems have some inherent level of flexibility—designed to balance supply and demand at all times. Variability and uncertainty are not new to power systems because loads change over time and in sometimes unpredictable ways, and conventional resources fail unexpectedly. Variable renewable energy supply, however, can make this balance harder to achieve. Both wind and solar generation output vary significantly over the course of hours to days, sometimes in a predictable fashion, but often imperfectly forecasted.

It must be supplied by the remaining generators, assuming no curtailment of wind energy. The graph shows that the output level of the remaining generators must change more quickly and be turned to a lower level with wind energy in the system. Solar energy will cause qualitatively similar impacts on the power system.

Because it can take several years to design and build new generators and transmission lines, the planning process is the first critical activity to ensure that the power system of the future possesses sufficient flexibility to accommodate the growth of variable renewable generation. In regulated paradigms, this function may resemble a central-planning model in which some combination of industry and government jointly assesses potential futures. In areas with competitive markets, there must be sufficient investment signals regarding the potential need for flexibility. In the absence of either sufficient planning or investment clarity, the resulting power system may not have sufficient flexibility to operate efficiently.

To illustrate how variable renewable energy can increase the need for flexibility, Figure 1 demonstrates how variable wind output impacts power system operation. The figure introduces the concept of “net load” which represents the demand that must be supplied by the conventional generation fleet if all of the renewable energy is to be utilized. The yellow area in the graph represents demand, and shows the daily variability of demand on an hourly basis for one week. The green shows wind energy, and the orange represents the demand-less-wind energy that

2014



Power Systems of the Future A 21st Century Power Partnership Thought Leadership Report

Owen Zinaman, Mackay Miller, Ali Asli, Douglas Arent, Jacquelin Cochran, and Ravi Vora
National Renewable Energy Laboratory

Sonia Aggarwal
Energy Innovation: Policy and Technology LLC
Minnow Bigham
South Africa National Energy Development Institute

Carl Linzell
Regulatory Assistance Project
Ali David
Columbia University Business School

Richard Kaufman
Office of the Governor, New York
Matt Futch
National Grid

Ethain Villanueva Arocas and José María Valenzuela
Secretaría de Energía (SENER), Mexico
Eric Martinet
Institute for Sustainable Energy Policies

Morgan Italiani
Columbia University, Sustainable Engineering Lab
Raj Kumar Pillai
India Smart Grid Forum

Technical Report
NREL/TP-6A00-52811
February 2015

2015



Clean Restructuring: Design Elements for Low- Carbon Wholesale Markets and Beyond

A 21st Century Power Partnership
Thought Leadership Report

Monisha Shah*, José María Valenzuela†, Hector Alejandro Beltrán Morán, Kim Møller Pion*, Anders Havnslätt*, Sandra Friis-Jensen†, Mette Vangsart*, Fabian Wigand†, Shilpa Tiedemann†, Lori Bird†, Owen Zinaman†, and Jeffrey Logan†

1. National Renewable Energy Laboratory
2. World Wildlife Fund – Mexico
3. Energy Regulatory Commission of Mexico
4. Danish Energy Agency
5. Ecofy

Technical Report
NREL/TP-6A00-56105
May 2016

2016



Status of Power System Transformation 2017

System integration and local grids

2017

Policies for Enabling Corporate Sourcing of Renewable Energy Internationally

- Employed Stakeholder Advisory/review committee
- Interviewed more than a dozen corporations on what policies they need to enable greater purchasing of RE
- Final report completed by May 2017
- Actively seeking follow-on opportunities

Input from: Google, Apple, GM, P&G, Allotrope, APX, Intl Finance Corp., EDF Renewables, Microsoft, Autodesk, Akamai, Facebook, etc.

Paper Contributors:

NREL

IRENA

WRI

CRS

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2017 THOUGHT LEADERSHIP
STUDIES

Next-Generation Performance-based Regulation: Emerging Regulatory Strategies to Leverage Power Sector Innovation

- Continuation of *Power Systems of the Future* report series
- How can PBR be utilized to seize opportunities and mitigation issues presented by emerging technology drivers?
- Review of real-world experiences and proposals
- Final report completed September 2017
- Webinars summarize findings

Paper Contributors:

RAP

NREL

Power System Transformation Status Report

- Updates 2015 PST Status Report work conducted by IEA and NREL in a new collaborative partnership
- Focuses on transformation pathways, implications of variable RE, and local grids in PST
- Provides case studies of Australia, Indonesia, Mexico, and South Africa
- Final report completed June 2017

Paper Contributors:

IEA

NREL

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COUNTRY UPDATES



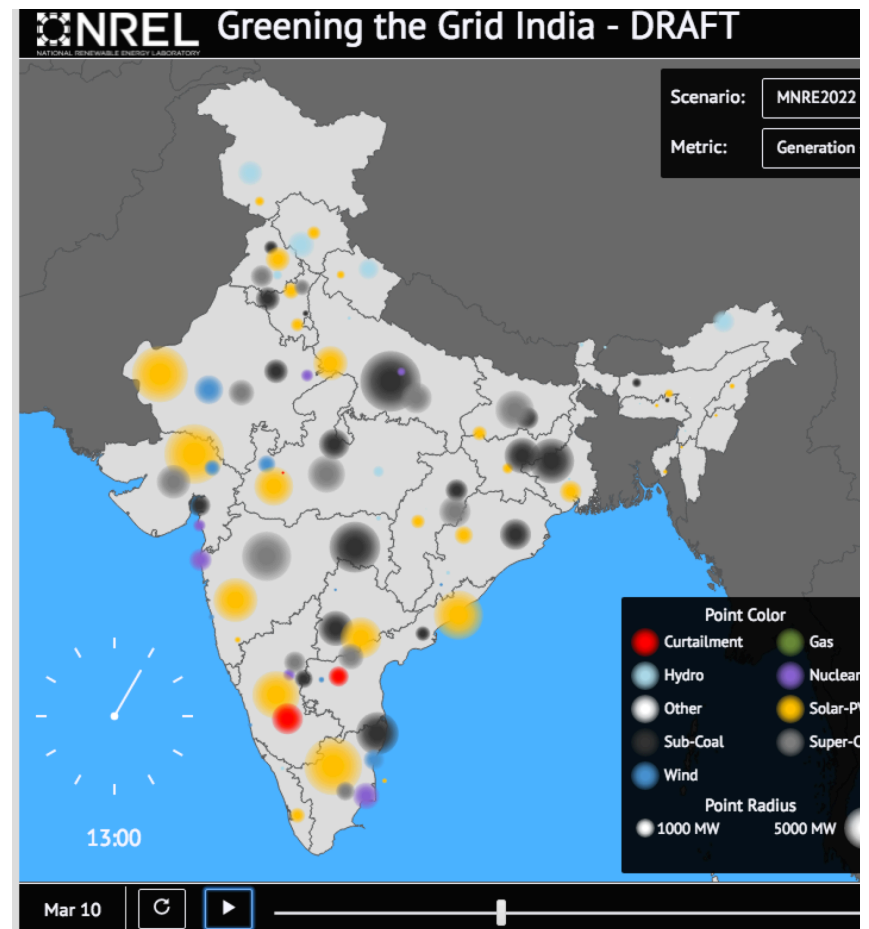
India RE Grid Integration Study

Project Goals:

- Identify impacts of operating India power grid with 175 GW of RE (goal for 2022)
- Inform actions needed to help integrate wind and solar generation

Strong stakeholder engagement:

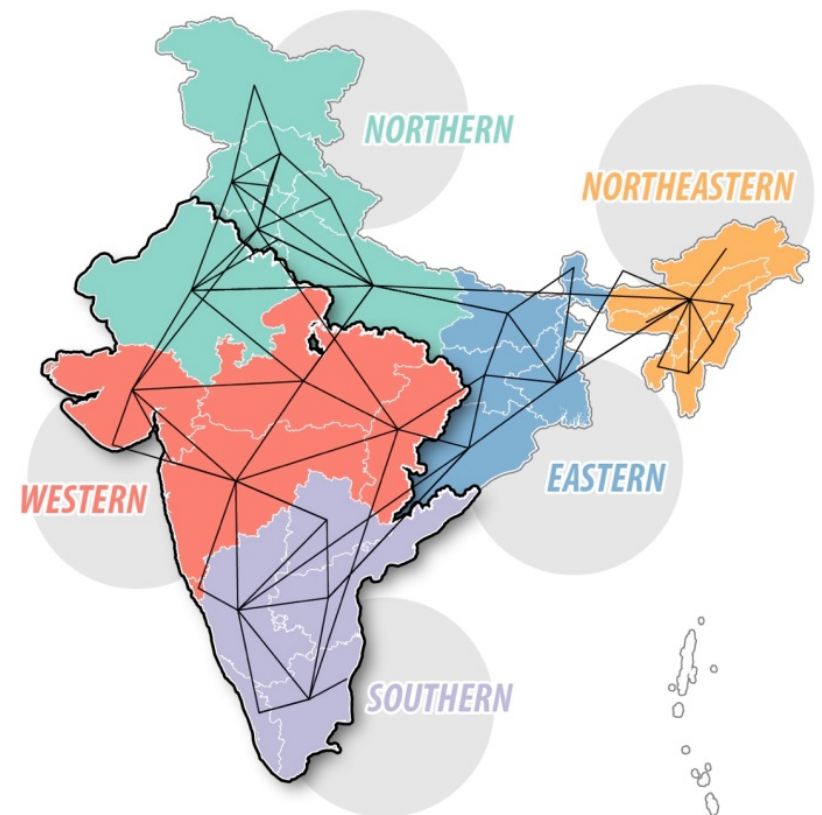
- Capacity building: Modeling team represents 10+ Indian institutions (system operators and planners)
- Three technical stakeholder review committees representing over 150 Indian experts



- Production cost model
- High-resolution wind and solar resource data (both forecasts and actuals)
- Unique properties for each generator
- Government projections of new lines and power plants for 2022
- Enforced state-to-state transmission flows
- Interregional transmission limits that adhere to reliability standards
- Final report available here:

<https://www.nrel.gov/analysis/india-renewable-integration-study.html>

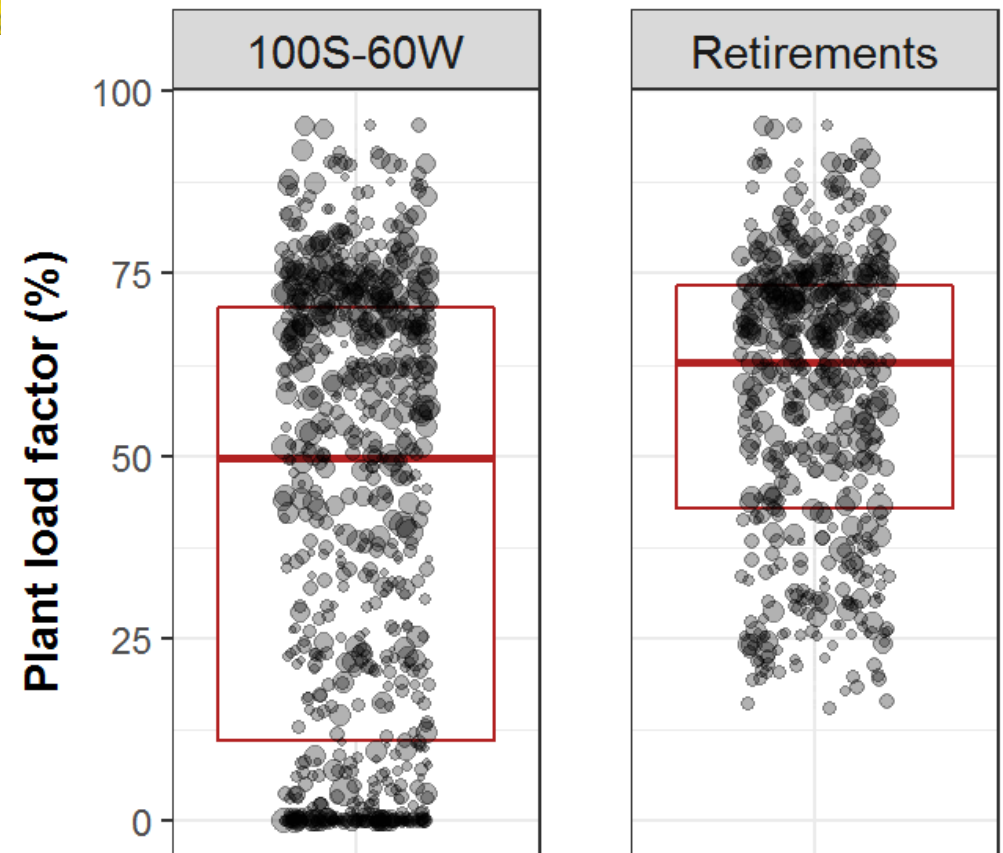
National model features



India: “Greening the Grid” Integration Study

Example finding: Retiring 45 GW of coal in a 2022 system with 175 GW RE does not adversely affect system flexibility

- 45 GW coal (198 plants) operate on average less than 15% capacity and contribute just 1% to annual coal generation
- System still operates effectively without these plants, based on adequate intrastate transmission
- Plant load factors of remaining plants increase from 49% to 61%



Change in coal plant load factors after 45 GW of coal plants are retired

Capacity

- 200 MW
- 400 MW
- 600 MW
- 800 MW

21CPP's South Africa program connects South African government stakeholders with an international network of expertise and a demand-driven technical assistance program with an emphasis on:



- 1) Assisting South Africa's technical capacity to conduct medium- and long-term power system planning
- 2) Address technical, regulatory and policy challenges of distributed energy resources
- 3) Market design and power sector restructuring
- 4) Other high priority topics as identified by key stakeholders such as Eskom, NERSA, SADOE, SANEDI, and National Treasury.

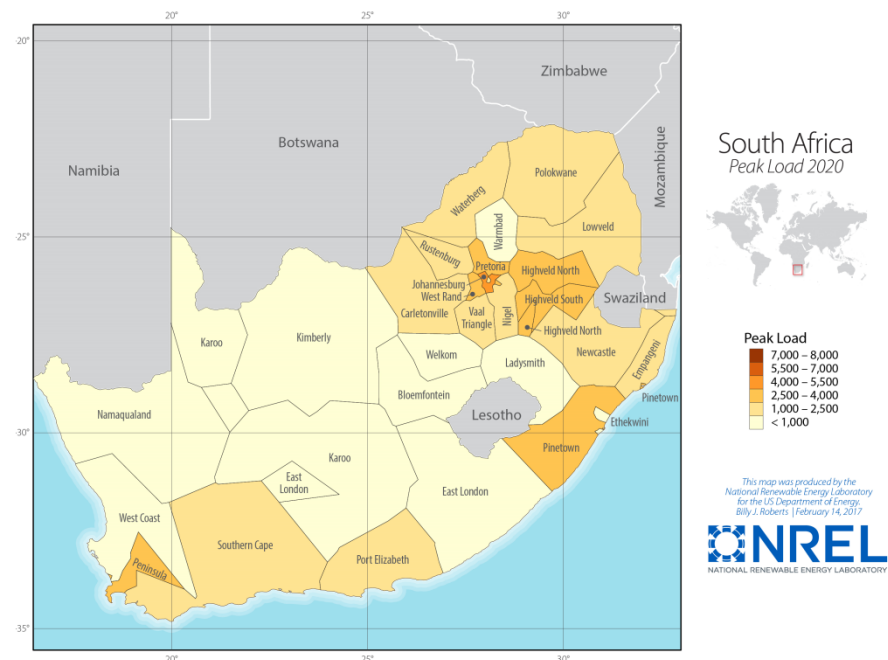
Comprehensive South Africa Grid Integration Study

State-of-the-art, multi-component grid integration study to examine the South African grid's ability to support high penetrations of variable renewable energy.

Developing advanced medium- and long term planning capabilities with Eskom in line with international best practice

Hosted Eskom technical team at NREL
September 2016 and February 2017

Creating first-of-its-kind renewable energy "supply curve" data set for South Africa with Council for Scientific and Industrial Research



*Future Activities

Eskom-NREL Technical Collaboration Agreement; Forthcoming MOU with SA-DOE;
SAPP regional planning exchanges; NREL-CSIR Technical Collaboration Agreement



Accelerate “next generation” power system planning for 2030.

Providing technical assistance to Mexico for the integration of variable, intermittent renewable energies into the grid to meet its clean energy 35% goal by 2024

- Renewable Energy Grid Integration Studies
- Analysis of Priority RE Zones
- Evaluation of Expansion plans

Provide operational policy and regulatory support for grid integration

- Renewable Energy Forecasting Models
- Use of Storage Technologies
- Demand Control Technologies

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MEXICO: LONG-RANGE PLANNING

- Drive the development of a strategic policy framework to support the high penetration of renewables, and to support the acceleration of “next generation” planning around scale-up and integration of renewables”



Mexico’s Regulatory Engagement in Bulk Electric Power System Planning: An Overview of U.S. Practices and Tools

Barbara O’Neill, David Hurlbut, Ivonne Pena,
Douglas Gagne, Jeff Cook, and Ricardo Bracho
National Renewable Energy Laboratory

**NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC**

This report is available at no cost from the National Renewable Energy
Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-5D00-66103
June 2016

Contract No. DE-AC36-08GO28308

Capacity Expansion Studies

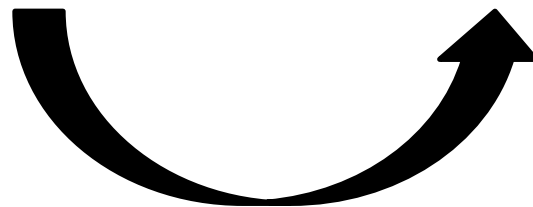
Optimization of capacity, localization and operation of generation and transmission to meet with future demand and system restrictions

Production Cost Modeling

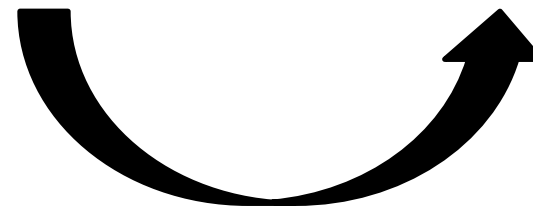
Simulation of the operation of the power system (optimization of production costs)

Power Flow Studies

Technical viability and analysis of reliability



Future generation and transmission scenarios



Periods of stress in the power system



Assist the government of Mexico with the implementation of its energy reform directives.

- Structure of MMU Options
- Market Analysis Tools
- Real Time Information Systems
- Surveillance and Reporting
- New Regulation
- Market Manuals
- Fuel Indices

Workshop
Market Monitoring Issues & Concerns
Concepts of Market Monitoring

Secretaría de Energía (SENER)
Comisión Reguladora de Energía (CRE)
Centro Nacional de Control de Energía (CENACE)

Sponsored by
21st Century Power Partnership
National Renewable Energy Laboratory

By:
Parviz Adib, Ph.D.
ESTA International

Workshop - Market Monitoring in Mexico
Module 4 - Concepts of Market Monitoring

INTELLIGENCE . STRATEGY . TECHNOLOGY
www.ESTAInternational.com

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Evaluate and expand smart grid and distributed generation deployment via enhancement of public policies and regulation

- DG Policy Paper
- Smart Grid Deployment Pathways for Mexico



Designing Distributed Generation Policies and Tariffs Well in Mexico

**Period of Performance:
December 2014–June 2015**

Carl Linvill and Donna Brutkoski
*Regulatory Assistance Project
Montpelier, Vermont*

NREL Technical Monitor: Ricardo Bracho

DRAFT – NOT FOR PUBLICATION, QUOTATION, OR CITATION

Subcontract Report
NREL/SR-6A50-66026
March 2016 DRAFT

Contract No. DE-AC36-08GO28308

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COUNTRY UPDATES: CHINA

Boosting Renewable Energy as Part of China's Energy System Revolution

- Five-year program with work streams on power system modeling, grid development, power system flexibility, and distributed generation
- China Renewable Energy Outlook (CREO) 2016 released in September 2016
- CREO 2017 released in October 2017, with model improvements, updates on China's power sector reform and carbon policies, and regional power markets

Key partners:

NREL

CNREC


DEA

GIZ

AGORA

DENA

Energinet




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FELLOWSHIPS AND KNOWLEDGE SHARING

- The 21st Century Power Partnership has hosted dozens of fellowships, study tours, and technical events focused on building capacity, sharing lessons-learned, and enabling power system transformation.
- Visit <https://www.21stcenturypower.org/fellowship.html> to find out more about potential fellowships.



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POTENTIAL COLLABORATION

We'd Like to Hear From You:

1. *Extending Partnership to New Countries*

Opportunities to partner are always welcome.

2. *Joint Development and Enhancement of Analytical Tools*

In conjunction with private-sector partners, the Partnership aims to identify and address needs for new tools (or for enhancements to existing tools) commonly used for analysis, planning, and management in the electricity sector.

3. *Innovating Policies to Support Novel, Viable Power System Business Models*

Opportunities for existing businesses and new entrepreneurs will be significantly enabled (or possibly constrained) by local and regional policy regimes.

Understanding policy regimes that support and accelerate the transition to clean, smart, efficient, affordable, and reliable electricity will help inform decisions that enable innovative solutions (and in some cases disruptive innovations).



Please visit us at: www.21stCenturyPower.org

Or

21stCenturyPower@nrel.gov