NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Policies and Programs to Integrate High Penetrations of Variable Renewable Energy




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Goals of Project

Photo from Invenergy LLC, NREL/PIX 16037

- Highlight the diverse approaches for enabling high renewable energy penetration
- Synthesize lessons on effective policies and programs
- Present avenues for action to energy ministers and other stakeholders

Approach

Photo by Dennis Schroeder, NREL/PIX 20423

- Case studies
  - Australia
  - Denmark
  - Germany
  - Ireland
  - Spain
  - United States: Colorado & Texas
- Comparative analysis
- Extensive stakeholder consultations

Sponsors and Expert Team

Photo by Dennis Schroeder, NREL/PIX 19887

- Supported by the Clean Energy Ministerial

Australian Government
Department of Resources, Energy and Tourism

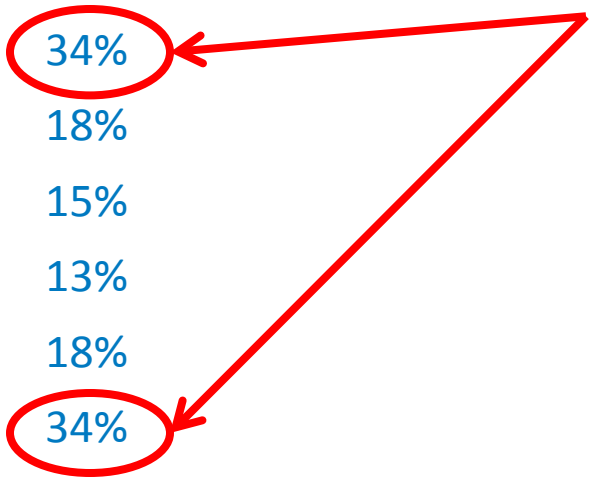
U.S. DEPARTMENT OF ENERGY

- Experts from diverse institutions:

Australian Energy Market Operator, Bloomberg New Energy Finance, Energinet.dk, Global Green Growth Institute, International Energy Agency, Institute for Sustainable Energy Policies, Johns Hopkins University, National Renewable Energy Laboratory, REN21, Risø, Spanish Ministry of Industry, Energy, and Tourism, United Nations Environment Programme, UNIDO, University College Dublin, University New South Wales, Utility Variable Generation Integration Group, VTT Finland, World Economic Forum

RE has achieved varying degrees of penetration

Country	% Renewable Generation (2010)
Australia	8%
China	19%
Denmark	34%
Germany	18%
India	15%
Ireland	13%
Mexico	18%
Spain	34%
Thailand	8%
United Kingdom	7%
United States	11%



Highest penetration on annual basis

Source: U.S. EIA, International Energy Statistics

Challenges: An Overview

- Grids and markets were traditionally not designed to accommodate significant amounts of variable generation
- Variable renewable generation may be
  - located far away from load centers, and require new transmission
  - more distributed and located closer to population centers, and thus more 'visible' to the public

Specific Implementation Challenges

- Legal, market, and institutional barriers—Increasing power system flexibility needed to integrate variable RE (e.g., through larger balancing areas, new market rules) may require significant ecosystem-wide changes
- Coordination—Due to the involvement of multiple agencies and jurisdictions, developing and implementing a shared vision could be challenging
- Public support—The public may not understand or support actions necessary to integrate renewables
- Customizing solutions—There is no one-size-fits-all solution to integrating variable renewables; countries need to determine the most appropriate combination of approaches

Addressing The Challenge

- What approaches from the public and private sectors have most effectively enabled the integration of variable renewables?
- How should countries tailor these approaches for a given market, geographic, and institutional context?
- How can human and institutional capacity be strengthened to meet this challenge?

Actions to Accommodate High RE

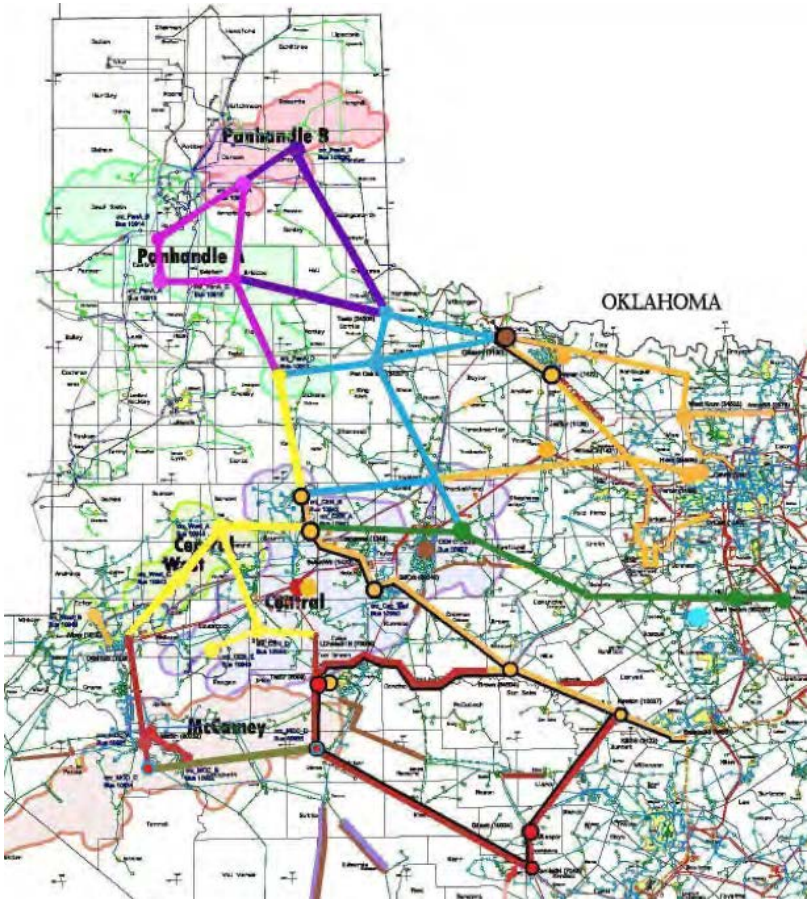
A. Lead public engagement, particularly for new transmission
B. Coordinate and integrate planning
C. Develop rules for market evolution that enable system flexibility
D. Expand access to diverse resources and geographic footprint of operations
E. Improve system operations

Actions Reflect Market Status

	Public Outreach	Planning	Market Rules	Expanded Access	System Operations
At LOW RE Penetrations	Involve public stakeholders in planning	Evaluate system flexibility, penetration scenarios, transmission needs, and future flexibility needs	Evaluate market design and implications for higher penetrations of RE	Assess renewable energy resources and options for encouraging geographic diversity	Build capacity of grid operator staff; review regulatory changes needed to require advanced forecasting
At MEDIUM RE Penetrations	Communicate to public why new transmission is essential	Regulatory and legislative changes needed to accommodate revised scenario planning, such as laws to support renewable energy zones (REZs)	Ensure that market design and pricing environment aligns with technical needs, such as accessing flexibility, minimizing uncertainty, and managing risk	Make necessary regulatory, market, or institutional changes	Implement grid codes to accommodate high penetrations of variable RE
At HIGH RE Penetrations		Monitor and review effectiveness of actions; revise	Ensure broad systems solutions are sought, including smart grid/demand response, storage, and complementary flexible generators		

Source: NREL

A. Lead Public Engagement, New Transmission



Source: Public Utility Commission of Texas, Docket No. 35665, Nov. 14, 2008. Public domain.

Examples

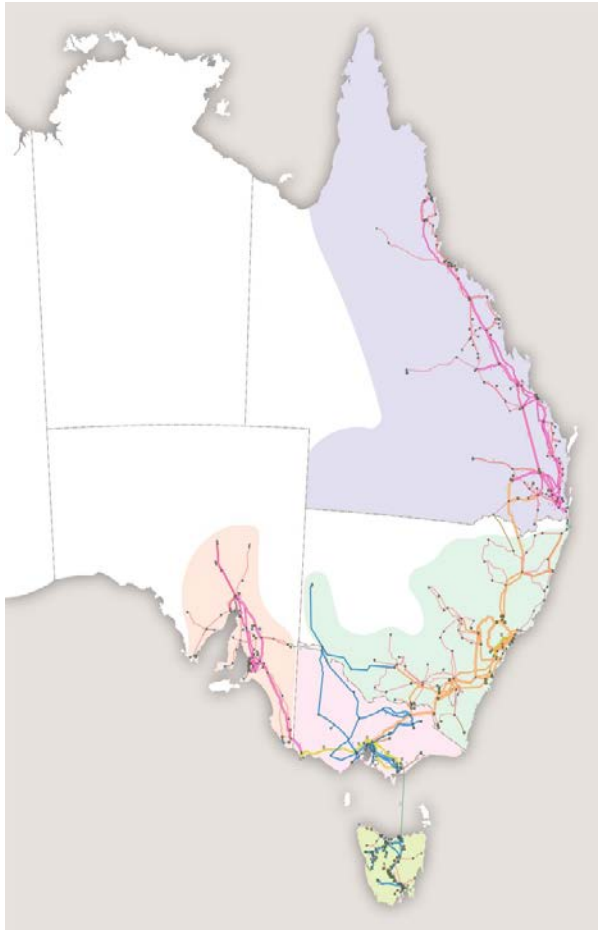
Texas: New transmission lines were key to integration; line construction, often resisted, was successful due to extensive and varied opportunities for public feedback

California's Renewable Energy Transmission Initiative—diverse, credible 30 person steering committee committed to achieving consensus and publicly supporting outcomes

Denmark, to address public concerns about aesthetics, plans to bury its entire high voltage grid by 2030

What Worked: Communicated to the public why new transmission is essential

B. Coordinate and Integrate Planning



Source: Australian Energy Market Operator

Examples

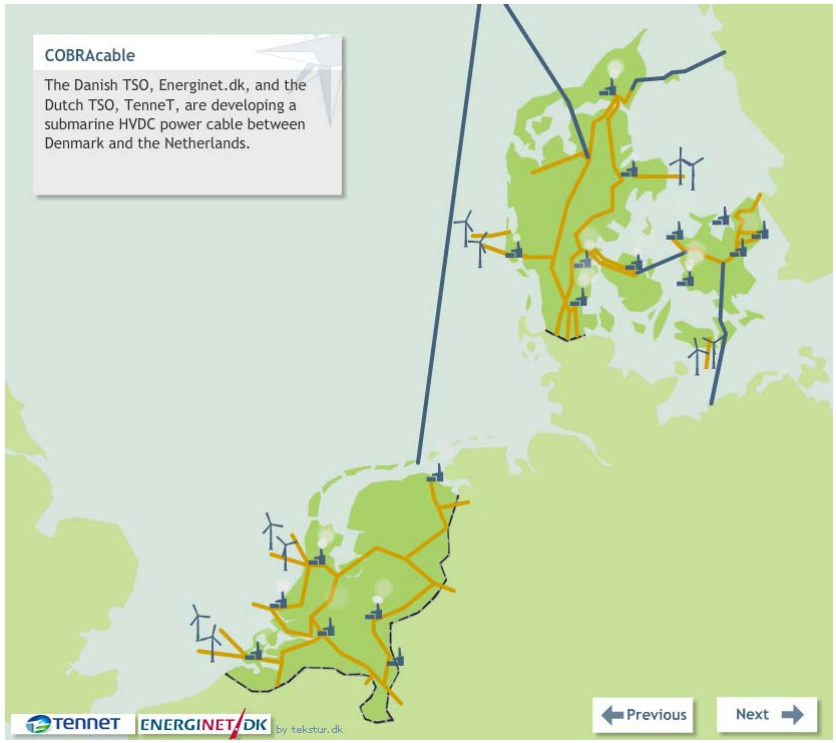
Australia: National-scale studies provide information, but complex spot market pricing has guided investment in both generation and transmission. Pricing includes

- Location-specific multiplier on regional price to reflect losses
- Connection costs
- Congestion-based pricing

Texas: Centralized planning has guided decisions. Competitive Renewable Energy Zones (CREZ) allow generation and transmission to be developed in coordination. Rate payers, not developers, absorb financial risk.

What Worked: Improved capacity of planners to handle added complexity

C. Market Design for System Flexibility



Source: Energinet.dk

Examples

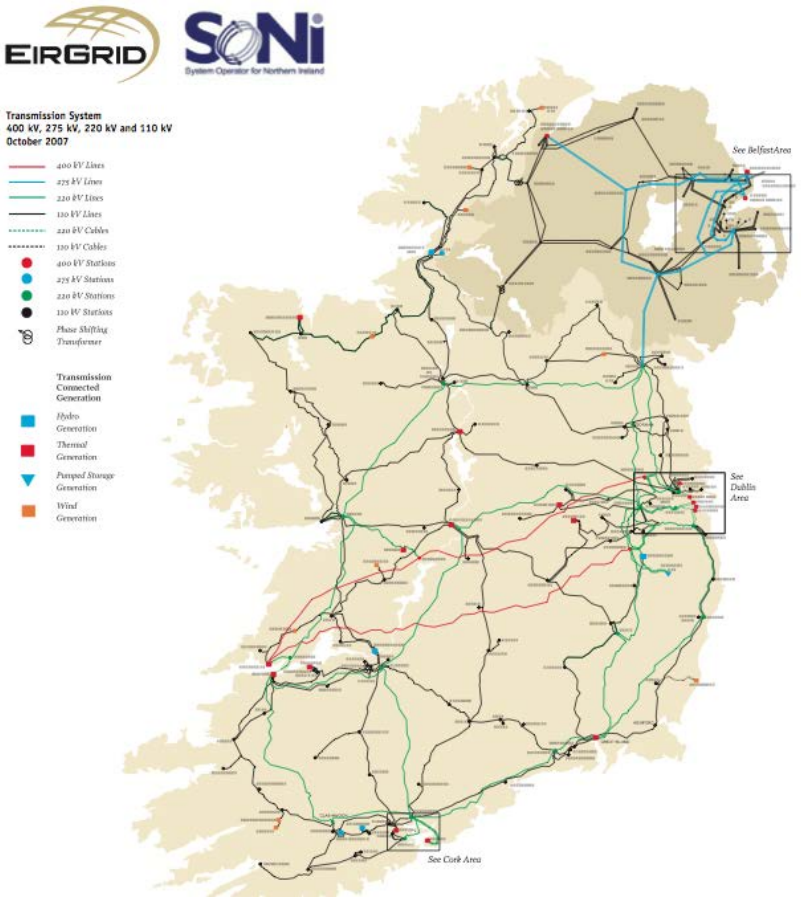
Denmark:

- Large power pool provides greater flexibility, e.g., Norway's hydro is critical to accommodating high wind penetrations
- Regulating Power Market operates up to 15 minutes before delivery
- Negative pricing provides economically efficient way to reduce output during excess generation
- Combined heat and power (CHP) required to participate in spot power market

Australia: Subhourly (5 min) dispatch intervals reduce need for ramping and improve forecast accuracy. Nodal and negative pricing encourage market efficient location strategies.

What Worked: Identified potential impacts of variable generation on electricity markets and generator compensation

D. Expand Diversity, Geographic Footprint



Source: Global Energy Network Institute

Examples

Ireland—has twice sought both to reduce its vulnerability to weather variability and also to strengthen its power system through expanding regional integration

- Single Electricity Market with Northern Ireland: required for all electricity >10 MW sold and bought in Ireland; no bilateral transactions permitted
- 500 MW East-west interconnector to U.K. (under construction)

U.S. West lacks an organized wholesale electric market, but an Energy Imbalance Market has been proposed to allow balancing areas to share reserves, and—through this broader diversity—reduce the system-wide variability of RE

What Worked: Evaluated options to overcome institutional challenges in merging or increasing cooperation among balancing areas

E. Improve System Operations

Photo from Red Eléctrica Española

Examples

Spain's Control Centre for Renewable Energies

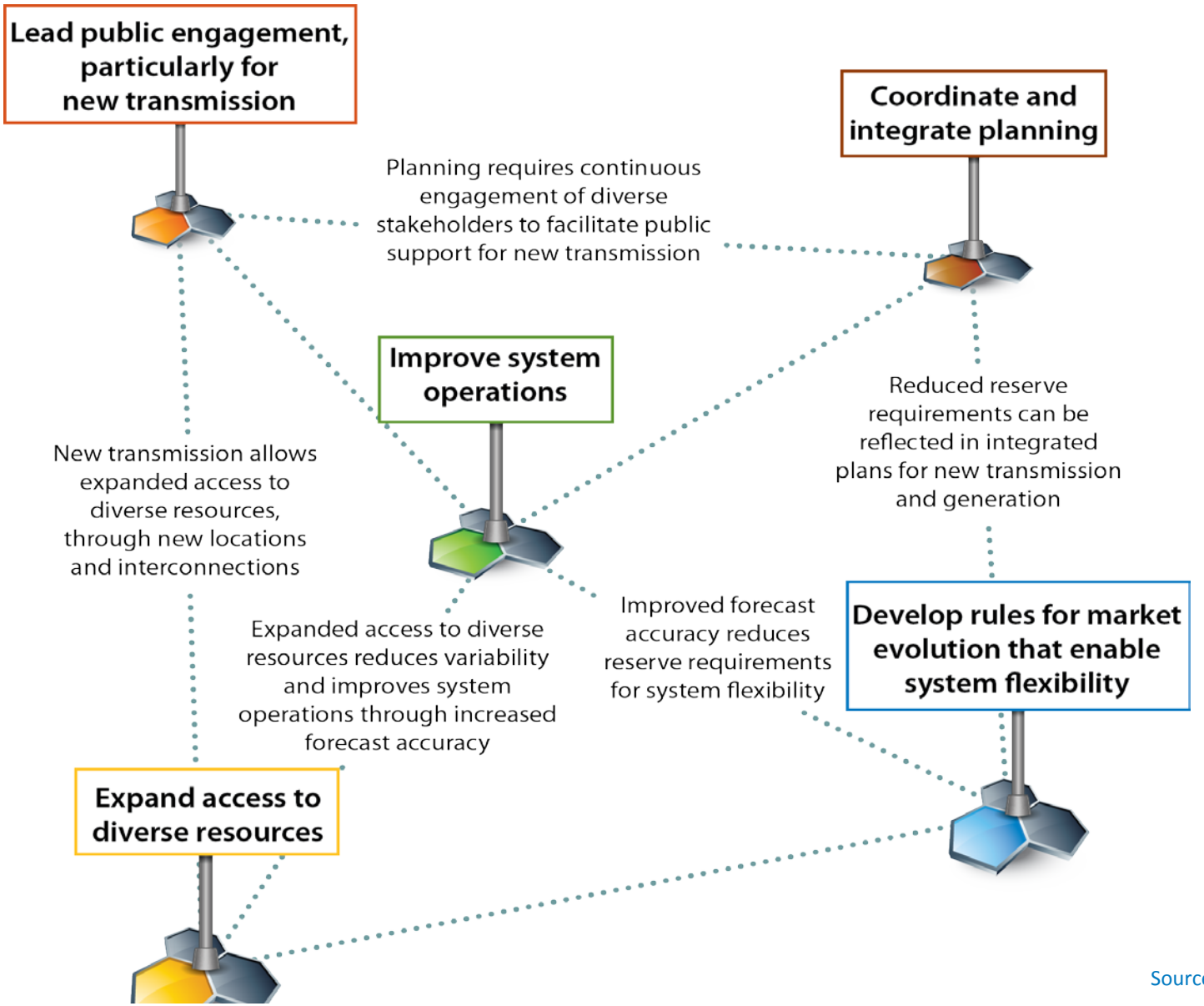
- Monitors RE installations real-time
- Wind farms >10 MW & PV>2MW provide reactive power support
- 97.5% of wind farms have fault-ride through capability
- New operational procedures proposed to maintain optimal voltage control

Australia: Market operators use forecasting model that integrates forecasts from a variety of sources

Denmark: System operator uses multiple, advanced forecasts in planning, congestion management, dispatch, and to assess need for regulating power

What Worked: Supported use of forecasting best practices; training on best practices for grid operators

System-wide Approach More Effective



Source: NREL

Key Findings—Leadership Actions to Consider

1. Lead the advancement of the technical, institutional, human capital, and market institutions required to enable renewable energy integration
2. Develop visionary goals and plans at national and regional levels, and empower appropriate leadership to bring the visions to fruition
3. Lead the public engagement to communicate goals and needed actions to attain them
4. Engage in international coordination to share best practices and strengthen technical, human and institutional capabilities to achieve higher levels of renewable energy penetration

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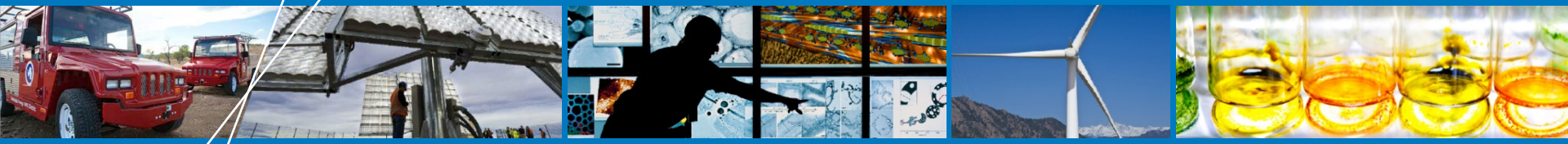

Thank you

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