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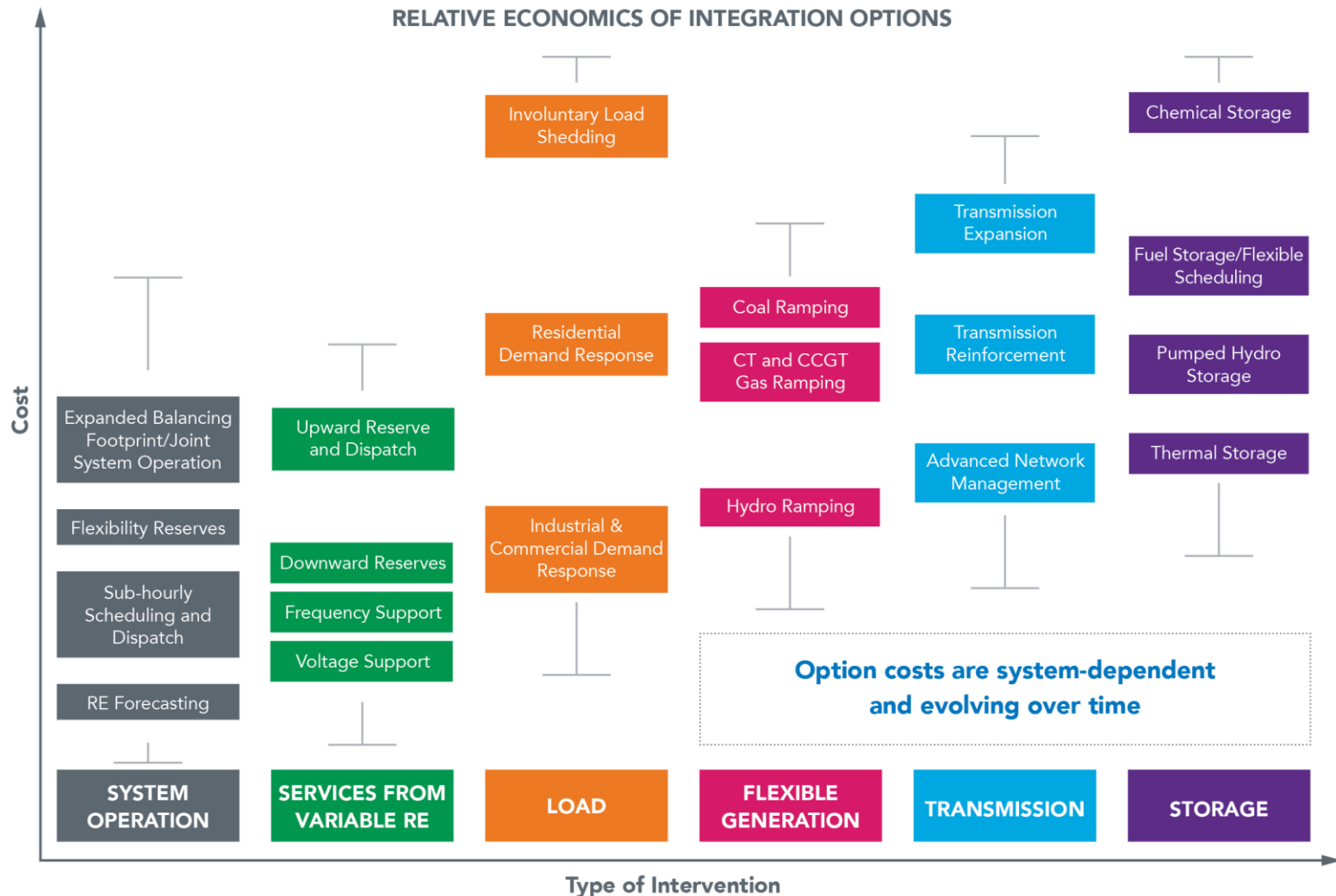
Grid Integration Studies for Identifying Flexibility Solutions

Decision Support Tools to Enable Power System Flexibility

Jessica Katz, NREL | June 2018



Many options for power system flexibility...



...which of these will be most effective in my power system?

Understanding system-specific impacts and opportunities

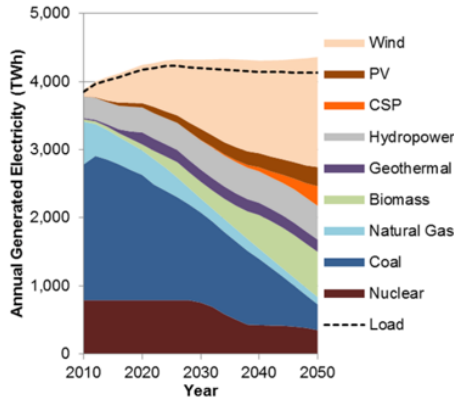
Grid integration study: an analytical framework to quantitatively evaluate how a power system will perform with large amounts of wind and/or solar

Outcomes

- Simulates operation of the power system under different future scenarios.
- Identifies operational, economic, and reliability constraints.
- Determines relative costs of actions to help integrate RE.
- Addresses stakeholder concerns that the system can work reliably and cost-effectively with high variable RE.

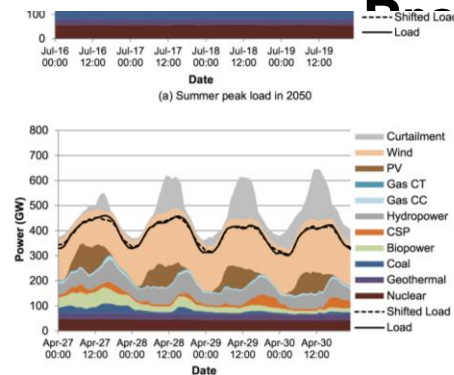
Not the same as a ***grid impact study***, which assesses impacts of individual solar or wind installations.

Different analyses for different questions



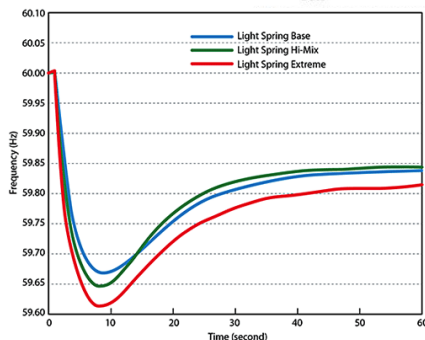
Capacity Expansion

Where, when, how much, and what types of generation and/or transmission infrastructure would achieve variable RE targets at least cost?



Dispatch Cost

What are the relative system-wide operating costs and impacts associated with different RE expansion scenarios and flexibility?



Power Flow and Dynamics

Does the system meet reliability criteria? How does the power system respond to a disturbance under various variable RE deployment scenarios?

Typical approach for a grid integration study

Build an operations model of today's power system

For future year, forecast load and necessary capacity to meet load

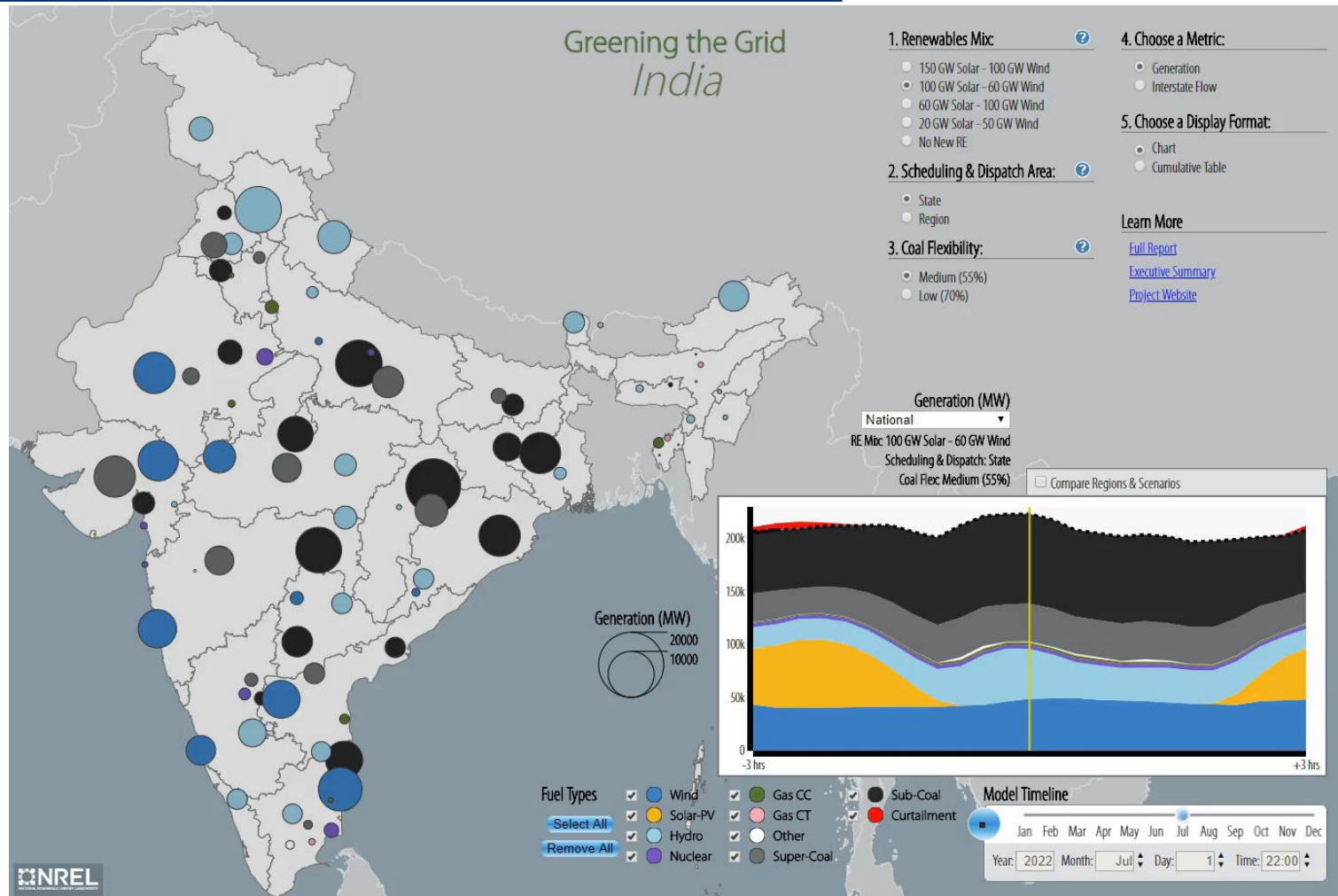
Simulate power system operations in the future year

Best practice: engage stakeholders (e.g., via modeling working groups and technical review committees) at all phases to ensure decision-relevant analysis



Modeling Working Group for the solar and wind integration study for the Luzon-Visayas power system of the Philippines 5

Example: India's power system with 160 GW wind and solar—Achieving system balance every 15 minutes



India: What can policy makers do to more efficiently integrate RE?



**Coordinated operations
across states**



**Lower technical
minimums for
coal plants**

Cost savings

RE curtailment

State

Scheduling and dispatch

**As operated in
2014**

70%

Technical minimum

USD
980
million
annually

3.5%

1.4%

Regional

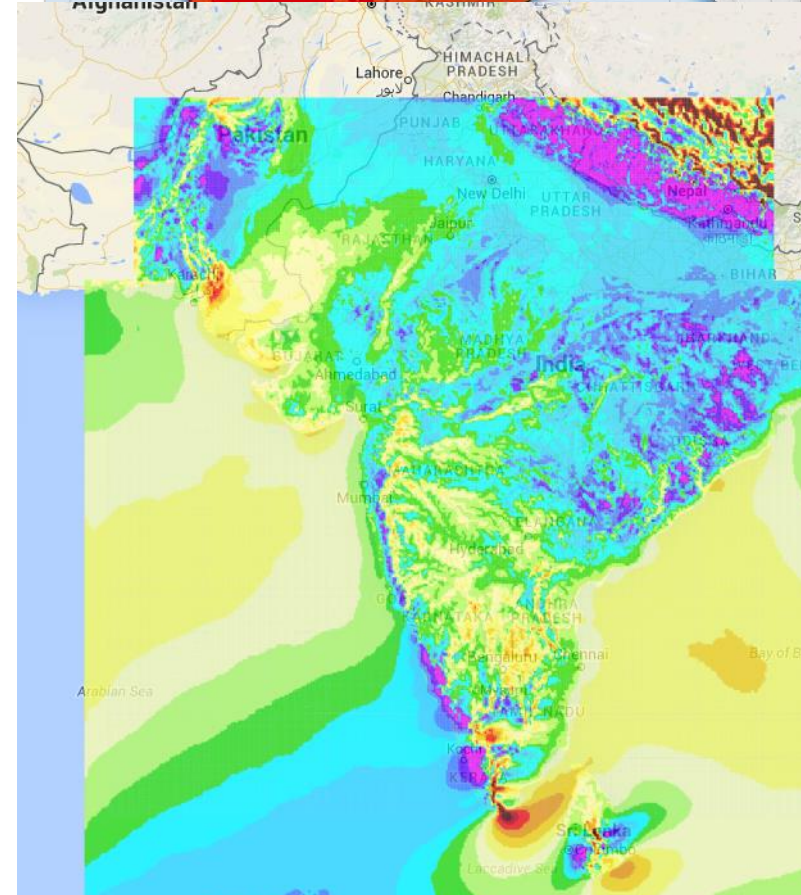
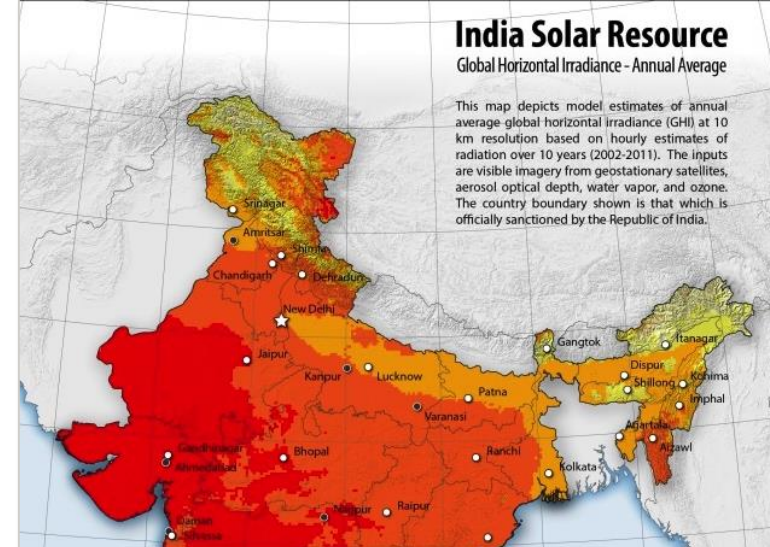
Scheduling and dispatch

55%

Technical minimum

Reliable results are based on detailed input data

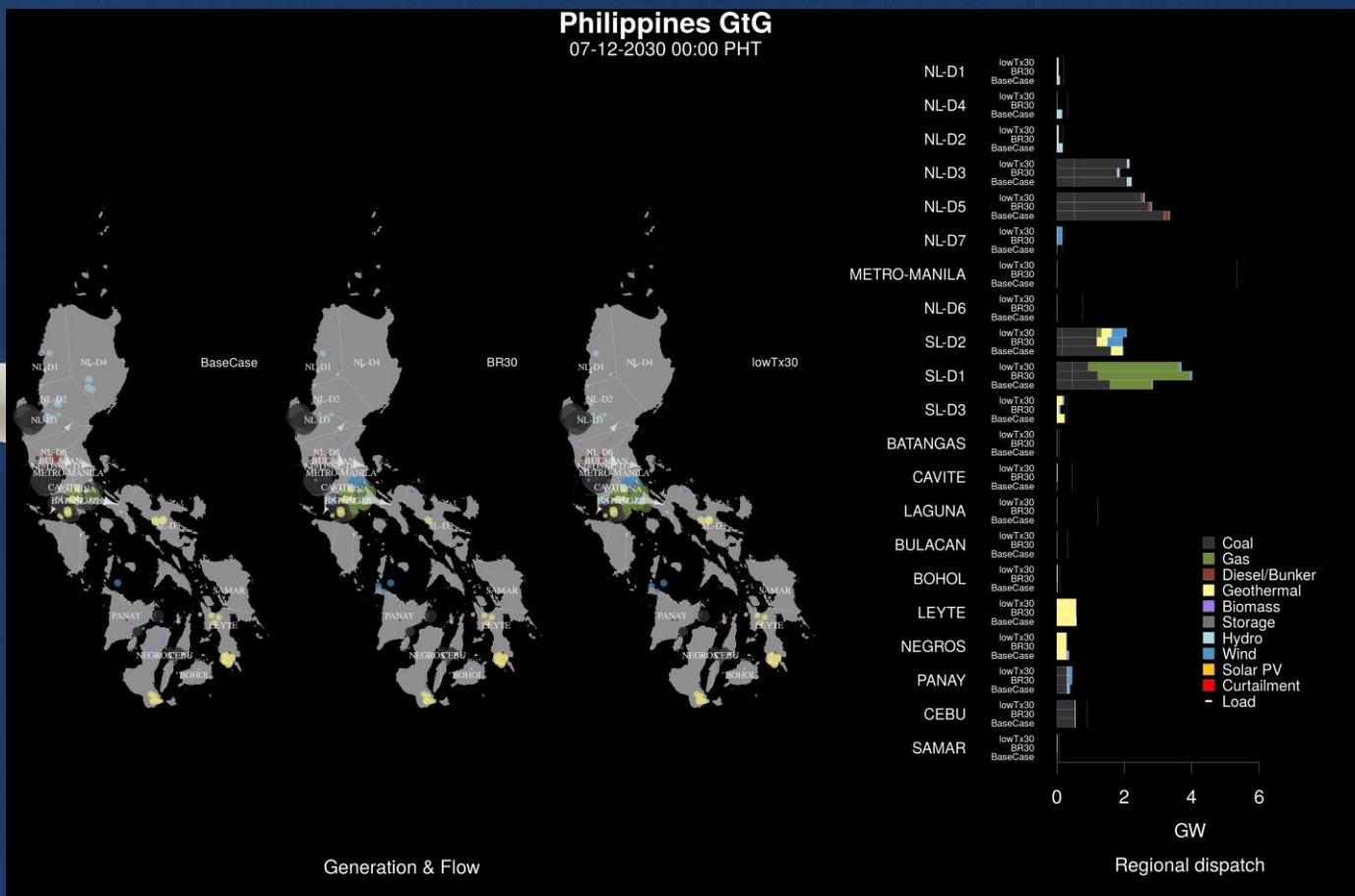
- High-resolution wind and solar resource data (ideally, both forecasts and actuals)
 - Wind data for India study: 5-minute weather profiles for each $3 \times 3 \text{ km}^2$ area
 - Solar data for India study: 1-hour weather profiles for each $10 \times 10 \text{ km}^2$ area, including impact of aerosols
- Unique properties for each generating unit (e.g. ramp rate, minimum generation level, outage rates, costs)
- Unique properties of each transmission element (nodes, lines, interfaces)
- Load data: magnitude and profile



Tips for your own studies

- Clearly defined study questions
 - What is it that you want to learn?
- Best tools for the question
 - Are the right models being used to answer your questions?
- Data
 - Is data quality sufficient to answer your questions?
- Transparency
 - Is the process for developing methods and assumptions for analysis transparent? Are results publicly available?
- Peer reviewed
 - Do impartial external experts review the results?

For more information: <http://greeningthegrid.org>



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

Full study: Barrows et al. 2018. *Greening the Grid: Solar and Wind Grid Integration Study for the Luzon-Visayas System of the Philippines*. NREL/TP-6A20-68594.
<https://www.nrel.gov/docs/fy18osti/68594.pdf>.