Foundational Resource Planning Concepts; Considerations for Variable Resources, Capacity Expansion, Balancing Reserves, and Adequacy

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Why Planning for Renewables?

- Wind and solar generation
  - Key for decarbonization
  - High interest to increase renewable
  - U.S. fastest growing resources (together with natural gas) [(1)]
  - More than 50% share of global new generation built in the last 8 years [(2)]

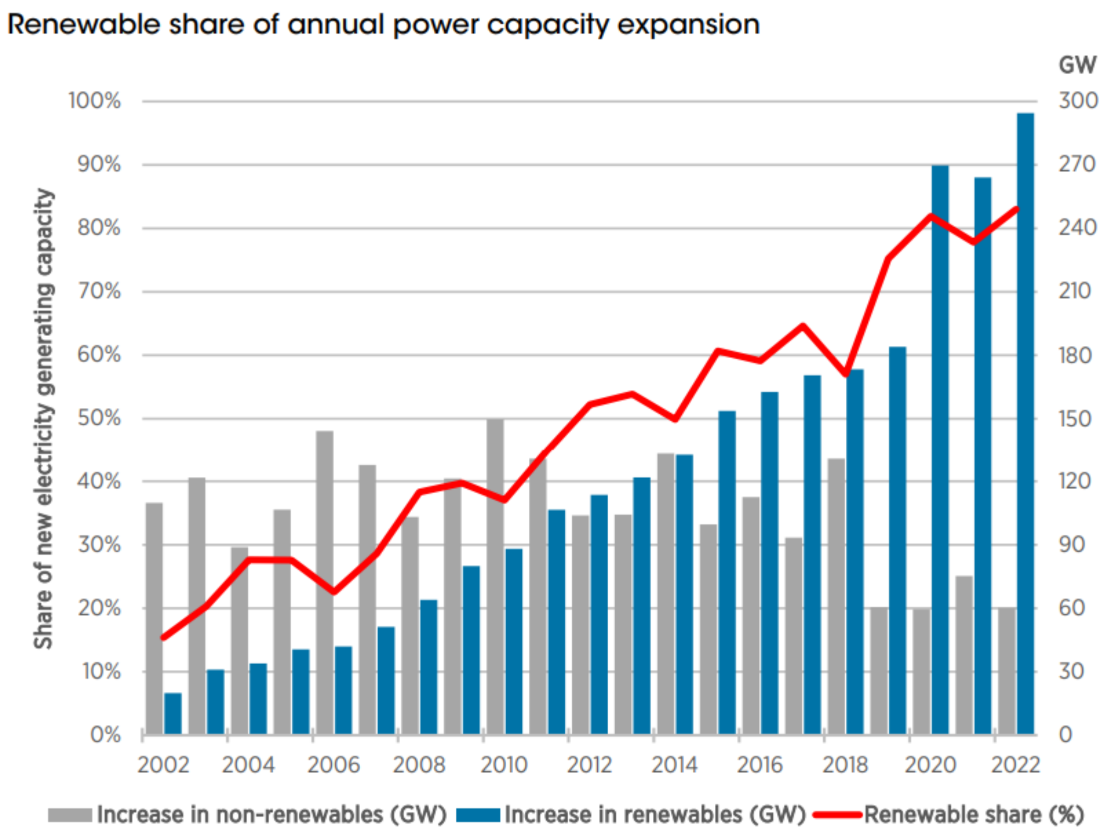


Figure from (2)

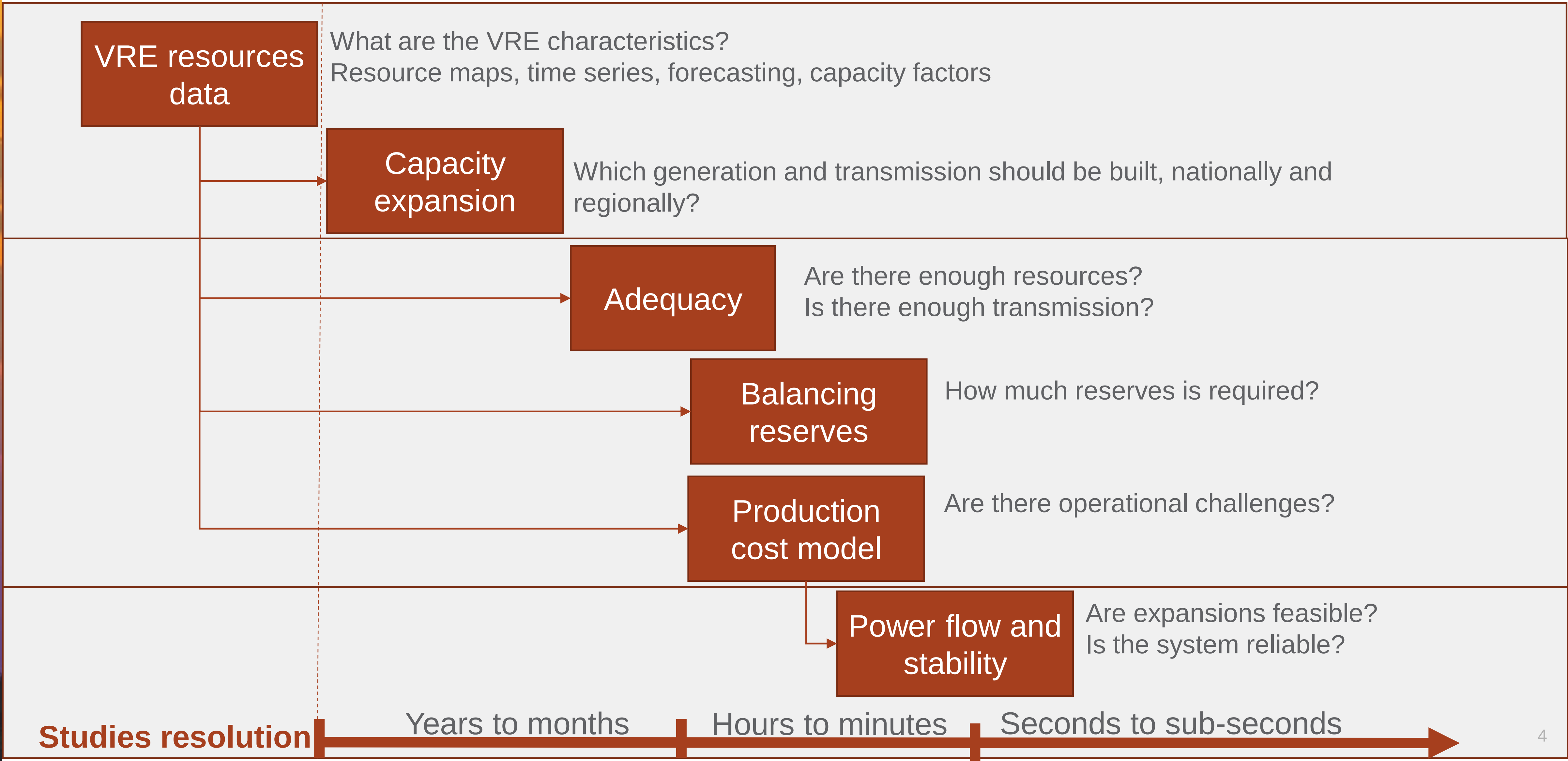
(1) U.S. EIA, "Short Term Energy Outlook," October 2020
(2) IRENA, "Renewable capacity highlights," March 2021

Main Challenges For Integrating Variable Renewable Energy (VRE)

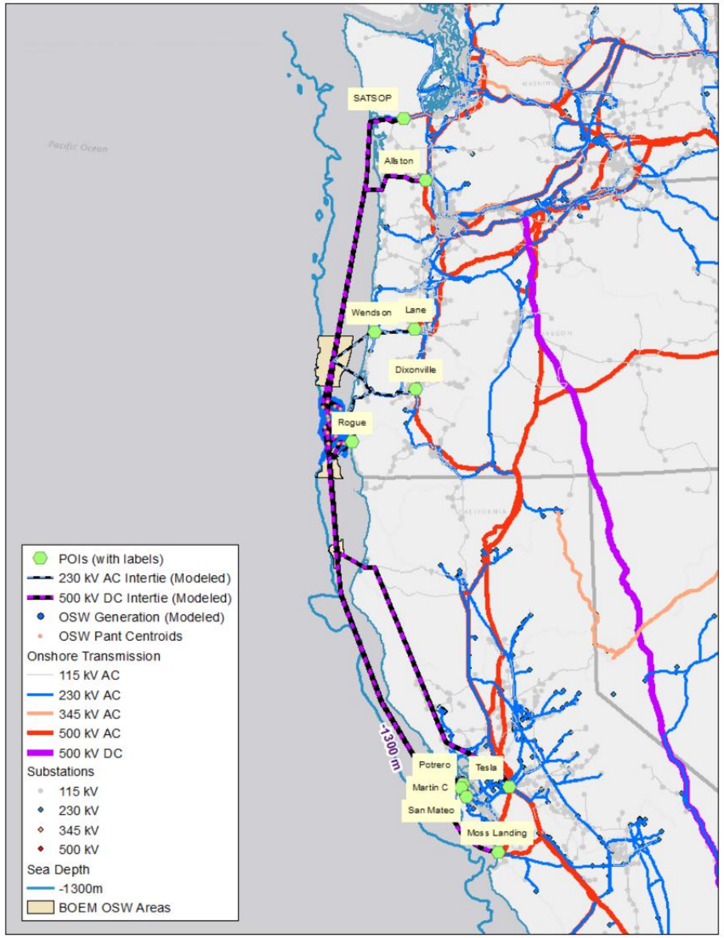
- Variable and uncertain output
  - Forecasts for next day, or hours, have advanced
  - Forecasts for next month, or week, are more inaccurate
- Flexibility needs to deal with load and renewables variability
  - Other flexible generation (hydro, natural gas, retrofitting plants)
  - Energy storage
  - Controlled curtailment of solar and wind
- Developing technologies
  - Costs rapidly decreasing
  - Standards for large-scale integration are being developed

Planning methods have evolved over the last 15 years as more VRE resources are integrated worldwide

Planning Studies for Integration of Variable Renewable Energy



Planning Studies in Offshore Wind Integration Study



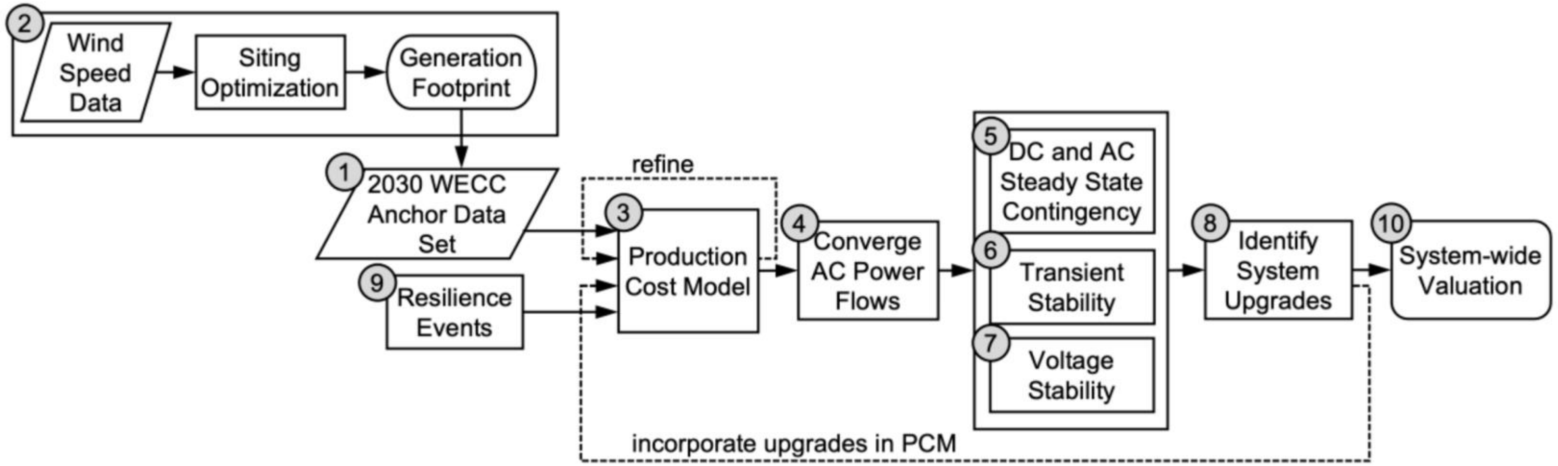
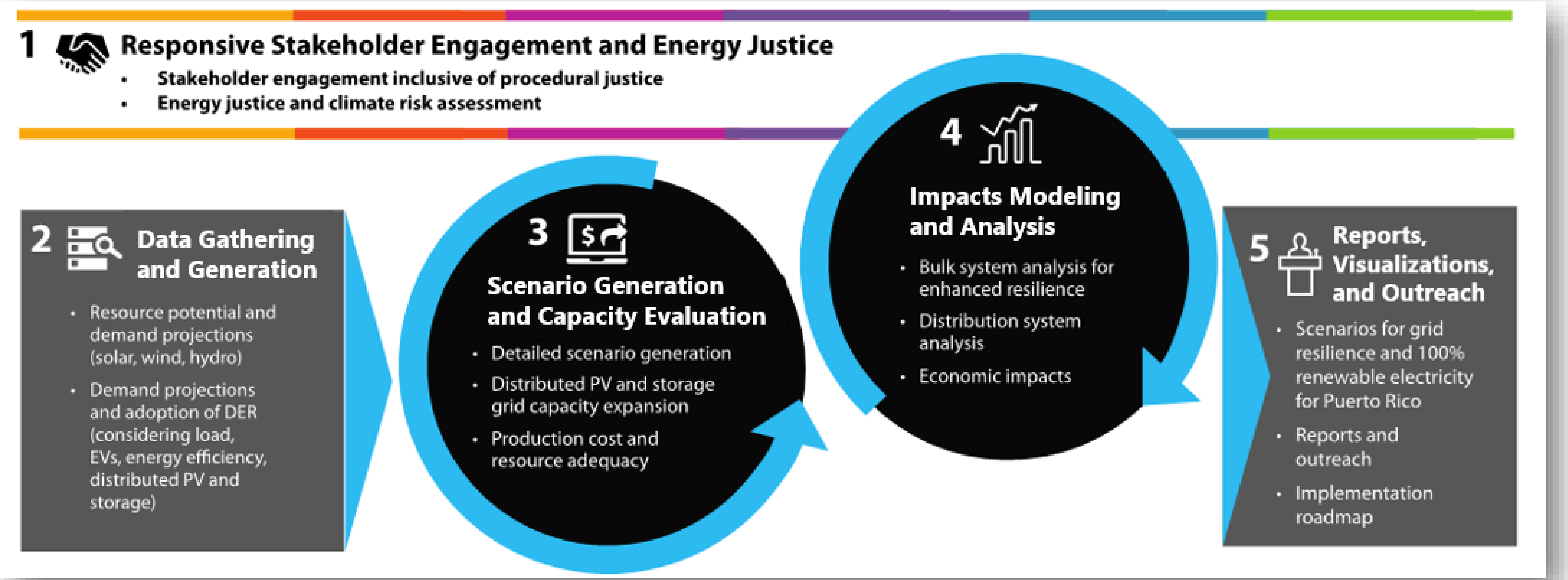


Figure 1: Abbreviated study approach to design 3 scenarios

Figure 2: Offshore wind generation (10.1 GW) connected to 6 points

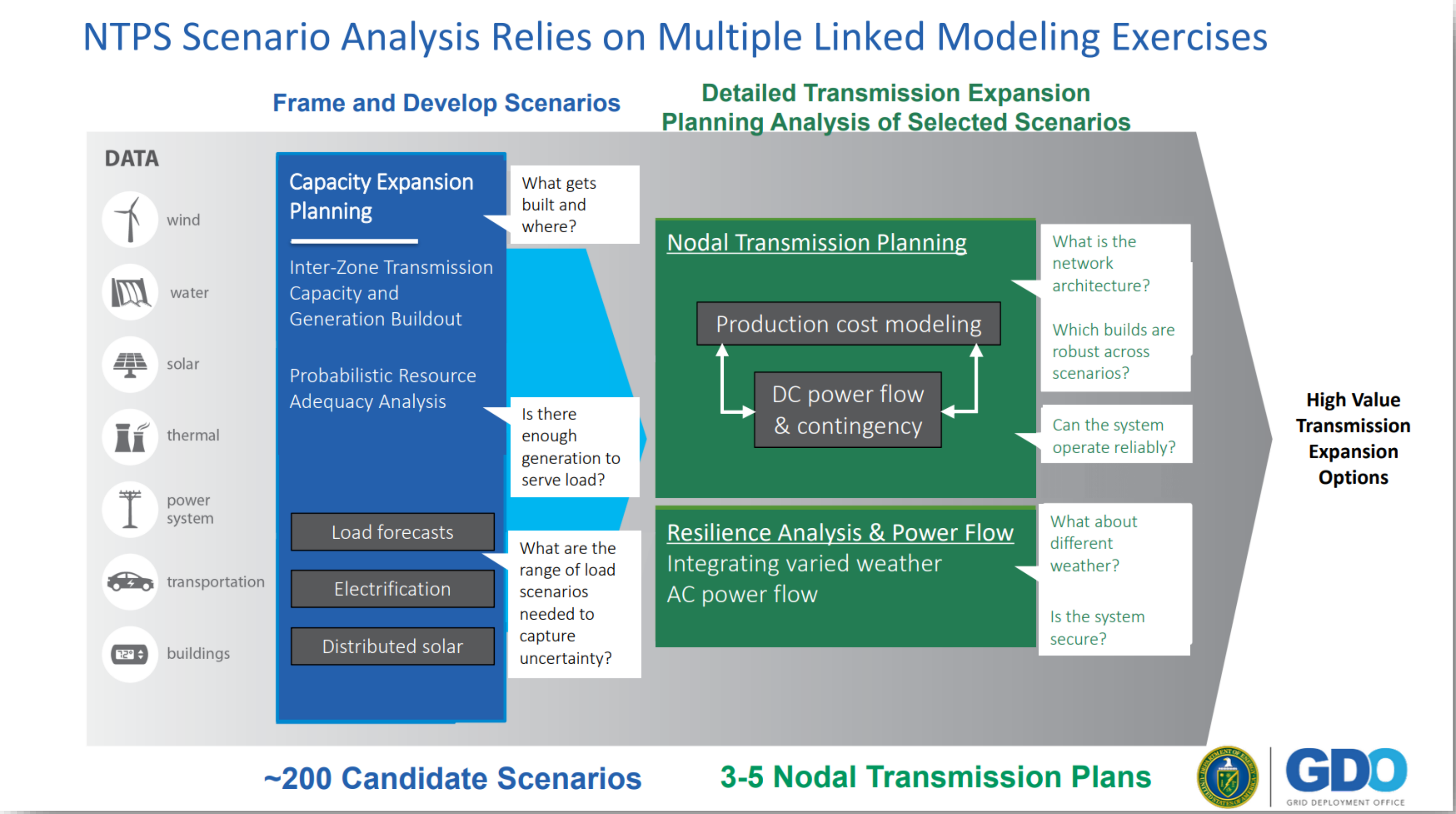
Douville TC, Severy M, Datta S, et al. 2023. “An Offshore Wind Energy Development Strategy to Maximize Electrical System Benefits in Southern Oregon and Northern California.” National Offshore Wind Research and Development Consortium & U.S. Department of the Interior, Bureau of Ocean Energy Management. https://www.boem.gov/sites/default/files/documents/BOEM-2023-067.pdf

Planning Studies Applied in Puerto Rico 100% Renewable Energy Study



More information on PR100 Study funded by FEMA and managed by DOE GDO: NREL, Sandia, PNNL, LBNL, Argonne, ORNL, https://www.energy.gov/gdo/puerto-rico-grid-resilience-and-transitions-100-renewable-energy-study-pr100

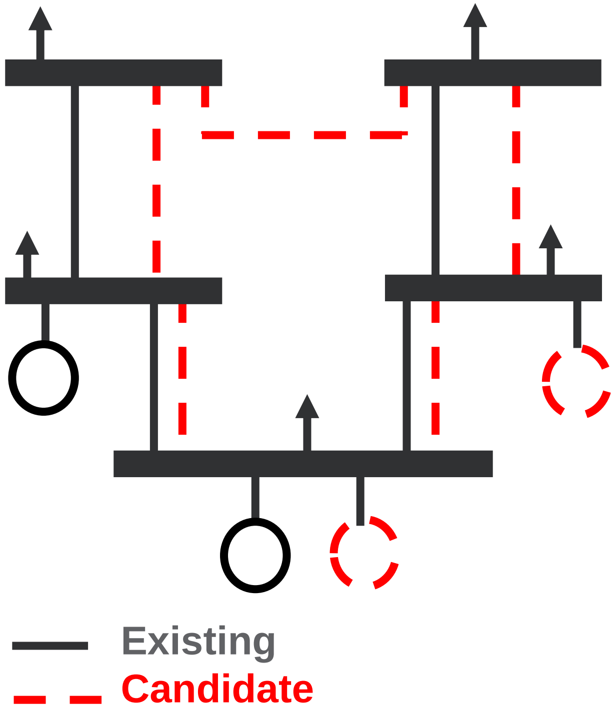
National Transmission Planning Study



NREL and PNNL, National Transmission Planning Study, August 2023, https://www.energy.gov/gdo/events/august-1-national-transmission-planning-study-updates-webinar

What is capacity expansion planning?

- Decide what, when, and where to make generation and transmission investments
- Drivers of new investments: load growth, retirements
- Time horizons : 10-50 years
- Generation and Transmission solved serially
  - Generation more expensive
  - Different assets owned by different organizations



Bottom Figure adapted from James McCalley's EE 552 course materials (http://home.engineering.iastate.edu/~jdm/ee552/Cooptimization.pdf)

Slide credit:
Patrick Malloney, PNNL

Example of Capacity Expansion Planning Tools

- Modeling Tools (specifically for CEP/TEP/GEP)
  - Commercial Tools
    - ✓ Energy Exemplar Aurora (CEP)
    - ✓ PSR Netplan (TEP), OptGen (GEP)
  - Free
    - ✓ NREL ReEDS (GAMS)
    - ✓ GridPath (Python)
    - ✓ E3 Resolve (Python)

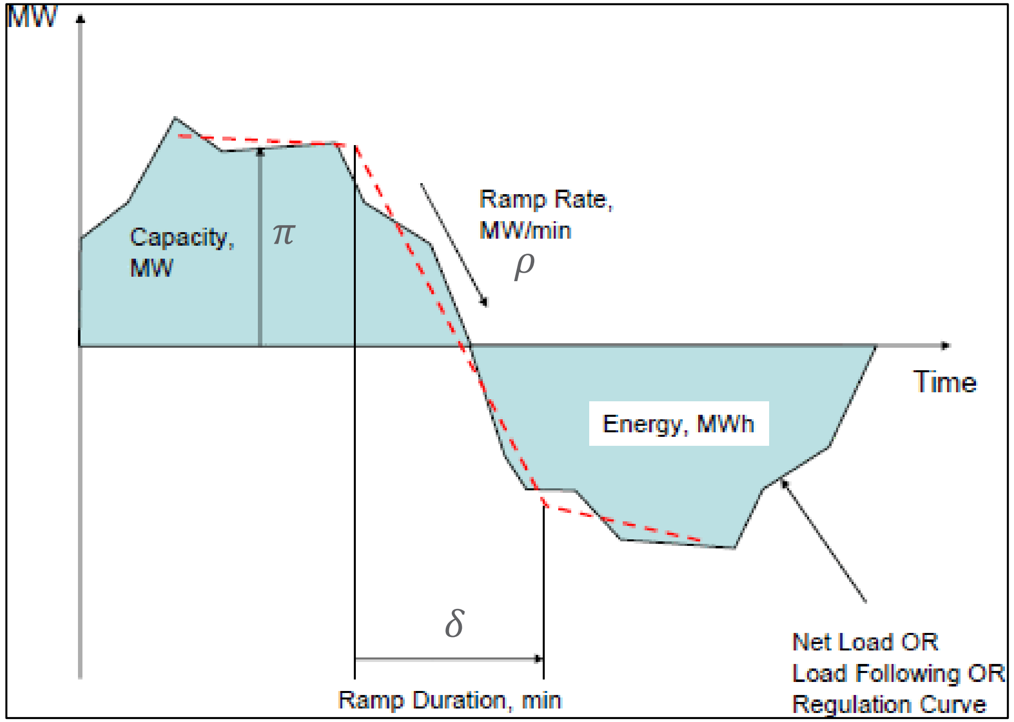
Resource Adequacy

- Are there enough generation resources and transmission to supply electricity?
- Resource adequacy should consider
  - Consider both generation and transmission availability
  - Failure probability
  - Chronological hourly operation
  - Weather datasets for several years, influencing both generation and load
  - Seasonal, yearly, and long-term study horizons
- Extreme weather events (e.g.; heatwaves, droughts, wildfires)

Michael Mulligan, "Resource Adequacy: How did we get here (and where are we going)?" NARUC/NASEU Training, May 2021
Derek Stenclik, "Probabilistic Resource Adequacy Methods," ESIG Presentation, October 2022, https://www.esig.energy/event/g-pst-esig-webinar-series-probabilistic-resource-adequacy-methods/
Elaine Hart, Ana Mileva, "Advancing resource adequacy analysis with the GridPath RA Toolkit - A Case Study of the Western US," October 2022, https://gridlab.org/GridPathRAToolkit/
NREL PRAS: Probabilistic Resource Adequacy Suite, https://www.nrel.gov/analysis/pras.html

Three Dimensions of Balancing Reserve Requirements

- Reserve requirements have three dimensions:
  - capacity requirements -- π
  - ramp rate -- ρ
  - ramp duration -- δ
- For analysis of:
  - Load Following
  - Regulation



Y.V. Makarov, C. Loutan, J. Ma, and P. De Mello. “Operational impacts of wind generation on California power systems,” IEEE Transactions on Power Systems, vol. 24, pp.1039–1050, May, 2009

Balancing Reserves: Generation Flexibility Requirements and Assessments

Scenarios of wind and solar generation – existing + planned (meteorological models)

Operational practices – dispatch, scheduling, and reserves

Characteristics of **flexible resources**

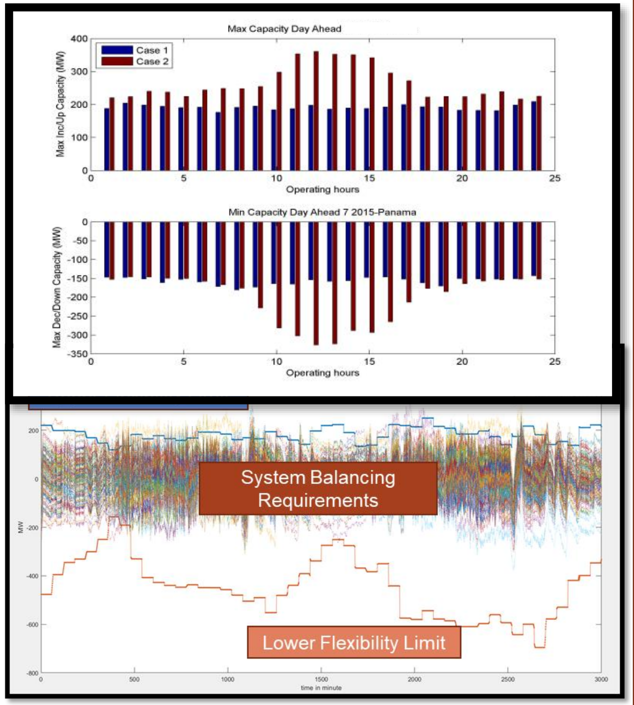
Forecast and operation model

- Minute by minute load, wind, and solar data
- Forecasting practices for wind, solar, and loads
- Available flexible generation

➢ Balancing timeseries signal
➢ Swinging-door algorithm

Calculation of flexibility **requirements**
- Capacity
- Ramp rate
- Ramp duration

Estimation of Flexibility **Exceedances**
- Can flexible resources cover needs?

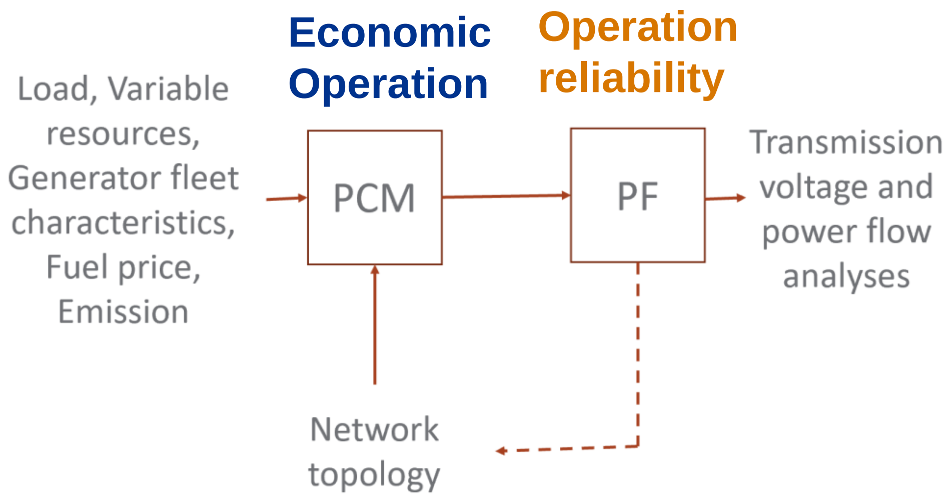


PNNL's Grid Reserve And Flexibility Planning Tool (GRAF-Plan)

- GRAF-Plan methodology has been applied to several utilities in North America, including WECC 2028 and 2030 studies (covering all balancing authorities), as well as internationally in 6 Central American countries and Vietnam
- GRAF-Plan reserve requirement method integrated with Hitachi GridView

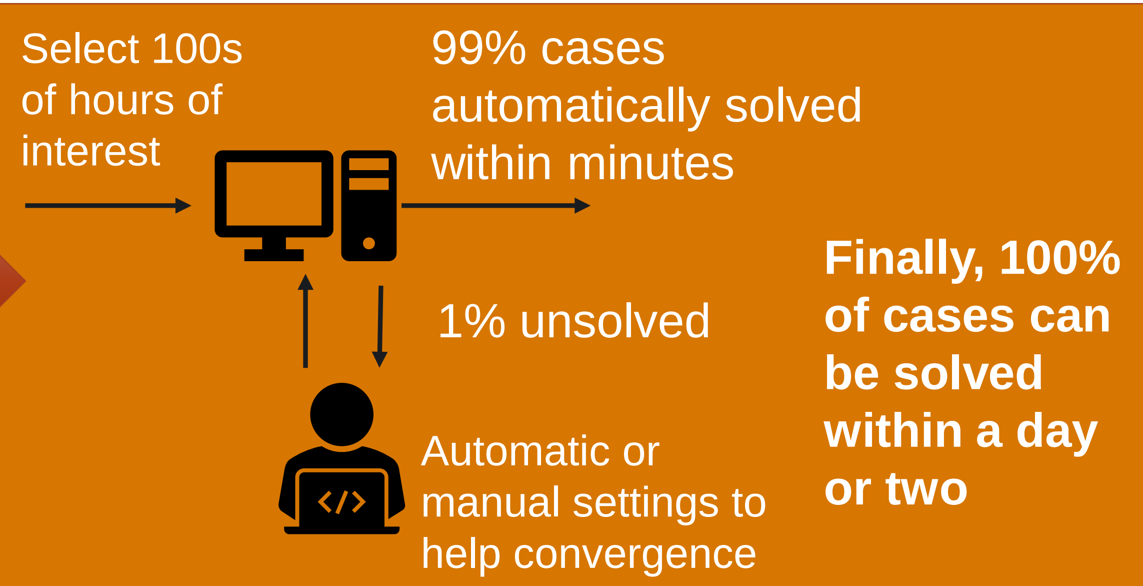
M. Ghosal, A. Campbell, et al., "Grid Reserve and Flexibility Planning Tool (GRAF-Plan) for Assessing Resource Balancing Capability under High Renewable Penetration," in IEEE Open Access Journal of Power and Energy, 2022, doi: 10.1109/OAJPE.2022.3169729.

Chronological AC Power Flow Analysis



- **Why round trip (PCM to PF) :** Planning issues that cannot be dealt with only PCM or PF
  - PCM: cannot deal with voltage stability
  - PF: cannot deal with resource adequacy, flexibility requirement
- **Challenges to perform round trip**
  - DC to AC power flow conversion
  - Time consuming: Typically, it takes several days to months to create a base AC power flow case from PCM data

- **Chronological AC Power Flow Automated Generation Tool (C-PAGE),**
- Used in several projects, such as the Atlantic and Pacific offshore wind studies, PR100, DOE HydroWIRES initiative



B. Vyakaranam, Q. H. Nguyen, T. B. Nguyen, N. A. Samaan and R. Huang, "Automated Tool to Create Chronological AC Power Flow Cases for Large Interconnected Systems," in IEEE Open Access Journal of Power and Energy, vol. 8, pp. 166-174, 2021, doi: 10.1109/OAJPE.2021.3075659.

Summary

- Key aspects of planning:
  - Generation and transmission expansion, resource adequacy, production cost modeling (simulation of operation), and balancing reserves planning
  - Power flow, stability, and contingency analysis
  - Model multi-year weather data
  - Model effects of extreme weather events
- Power system planning has evolved and needs to continue evolving to study grid transformation

Thank you