NIMBY, Nuclear, and Our Sustainable Energy Future: Modeling Competing Energy Policies

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Fundamentals of Energy Grid Modeling

Generation & Transmission

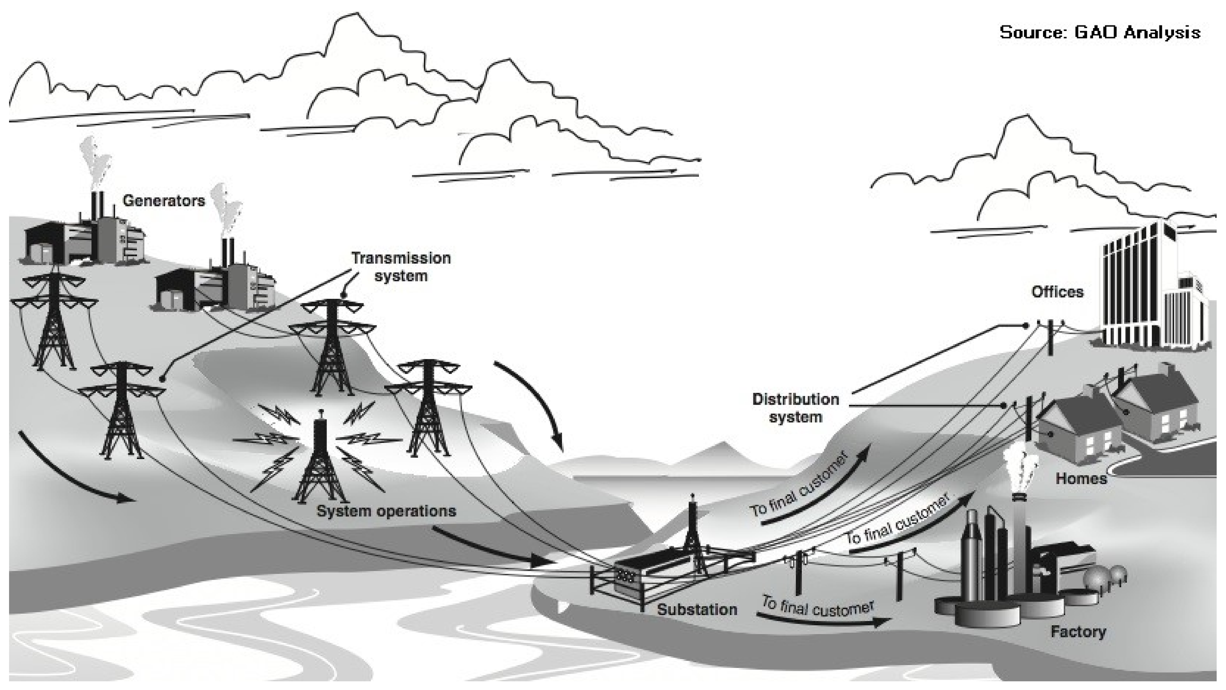

Fig. 1: Power Generation, Transmission, & Consumption

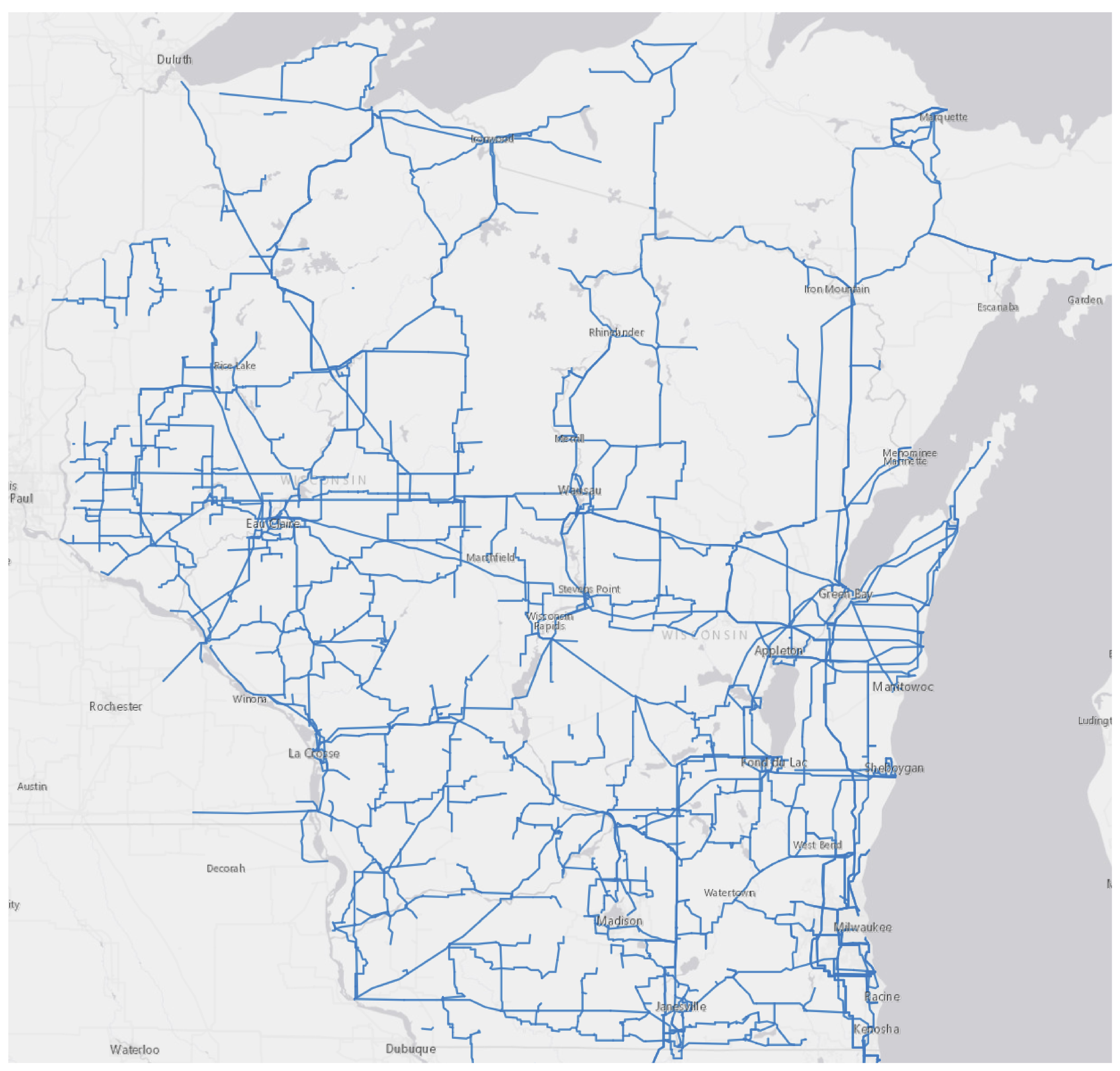

Fig. 2: Filtered View of Wisconsin Transmission Grid [2]

Physical Constraints

- Generation + Shed Load $\geq$ Consumption at all times
- Transmission and Generation both have upper limits
- Transmission between regions has loss
- New Generation is rarely instant response (at all timescales)
- Shed Load is choice to actively not provide electricity

NIMBY As Policy

- Generation & Transmission require building in physical sites
- Some Generation types are disliked by local residents
- Includes both Renewable (Wind) and Non-renewable (Nuclear) Generation
- Not In My Back-Yard (NIMBY) impacts political siting decisions
- Generation siting location impacts efficiency & reliability

Network Examples

A Simple Network

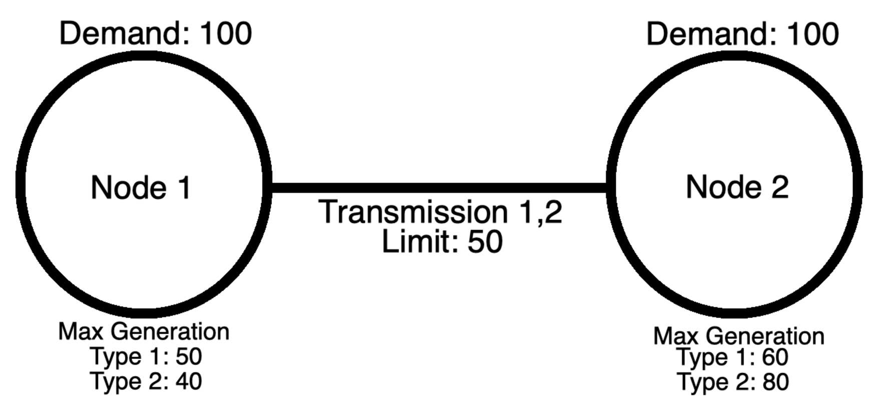

Fig. 3: Two Node Simple Network

For this simple network, all types of generation at all nodes need to be run to varying levels to meet demand. This is true no matter what the actual underlying generation types are.

Networks Extended

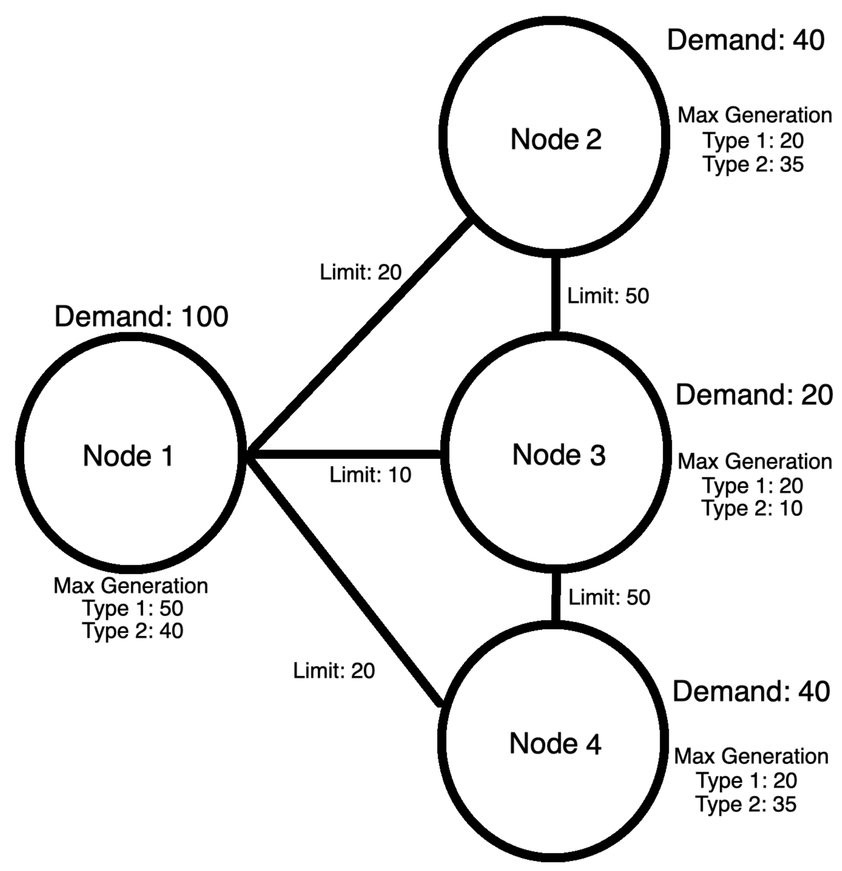

Fig. 4: Four Node Network

In this network, we need to run all types of generation but not necessarily at all nodes to meet demand. This example also becomes the Two Node example if Nodes 2, 3, & 4 are combined together.

Networks in Layers

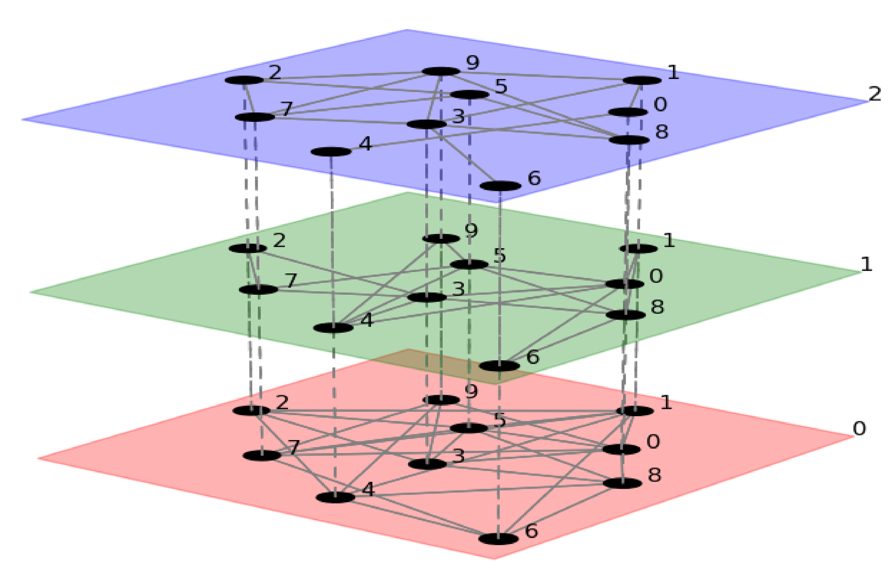

Fig. 5: Multiple Layer Network [3]

Our ability to analyze the obvious impacts of policies breaks down when the networks become hard to visualize either in complexity (e.g. layers) or size (e.g. 72 Wisconsin counties).

Complex policies also can counter-intuitively interact with cost incentives, modeling decisions, and other policy demands.

Applications and Policy

Applications Types

This Energy Grid Modeling impacts a range of applications including:

- Short Term Full Knowledge Economic Dispatch
- Stochastic Economic Dispatch
- Generation Capacity Expansion Planning
- Long Term Air Pollution Forecasting

Policy Considerations

A variety of policy considerations can be directly built into these models including:

- NIMBY/Resource Placement Limitations
- Impact of Mandated Build-outs
- Absolute Carbon Limits
- Probabilistic Carbon Limits
- Carbon Taxes

Post-processing of model results can include additional items like health concerns with interaction through external tools like EPA COBRA. [1]

Optimal Cost Considerations

Once we have feasible solutions to our models, we have to decide how to choose between solutions.
This choice is made by having a cost notion that our tools minimize.
This cost notion is separate from constraints but can be directly relevant to them.
Options for possible cost functions to minimize for these problems include:

- Economic Cost to Provide Power
- Amount of Unmet Demand (Shed Load)
- Carbon Generation
- Scale Combinations of All of the Above

Modeling for Policy Developments

All of these discussions form questions directly considered or adjacent to the tools as part of WEREWOLF (Wisconsin Expansion of Renewable Electricity with Optimization under Long-term Forecasts) [4].
We are actively extending WEREWOLF to consider more circumstances including:

- Multiple Time-step Capacity Expansion Planning
- Python-GAMS API version of Tool
- Enumeration of Multiple Cost-Optimal Solutions

References

[1] *COBRA Web Edition.* `https://cobra.epa.gov/`. Accessed: 2023-11-19.

[2] *Electric Power Transmission Lines.* `https://hifld-geoplatform.opendata.arcgis.com/datasets/geoplatform::electric-power-transmission-lines/explore`. Accessed: 2022-04-19, Filtered to Wisconsin Data.

[3] *Pymnet Multiple Layer Network Example.* `http://www.mkivela.com/pymnet/visualizing.html`. Accessed: 2023-11-19.

[4] *WEREWOLF.* `https://werewolf.discovery.wisc.edu/`. Accessed: 2023-11-19.