

WEREWOLF in London: Minding the Gap with User-Friendly Energy Optimization Tools Informing Policy Makers through the Energy Transition

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(Joint work with Josh Arnold, Adam Christensen, and Andy Philpott)

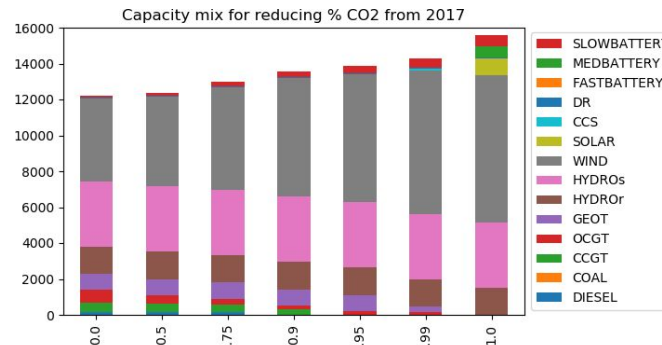
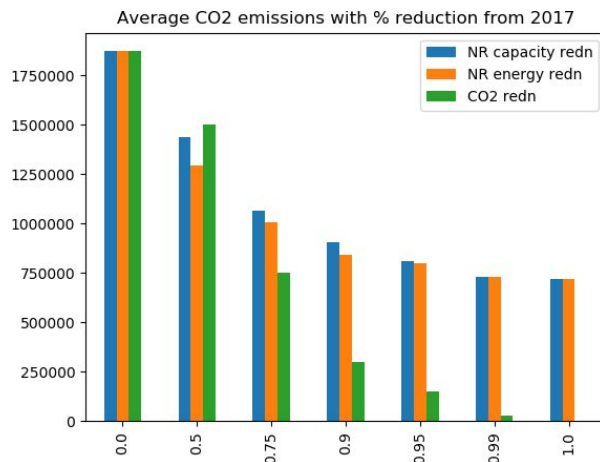
<https://werewolf.discovery.wisc.edu/>

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Energy Evaluation Europe 2021 Virtual Conference
15 March 2021

GEMSTONE model was used to inform New Zealand's Zero Carbon Act

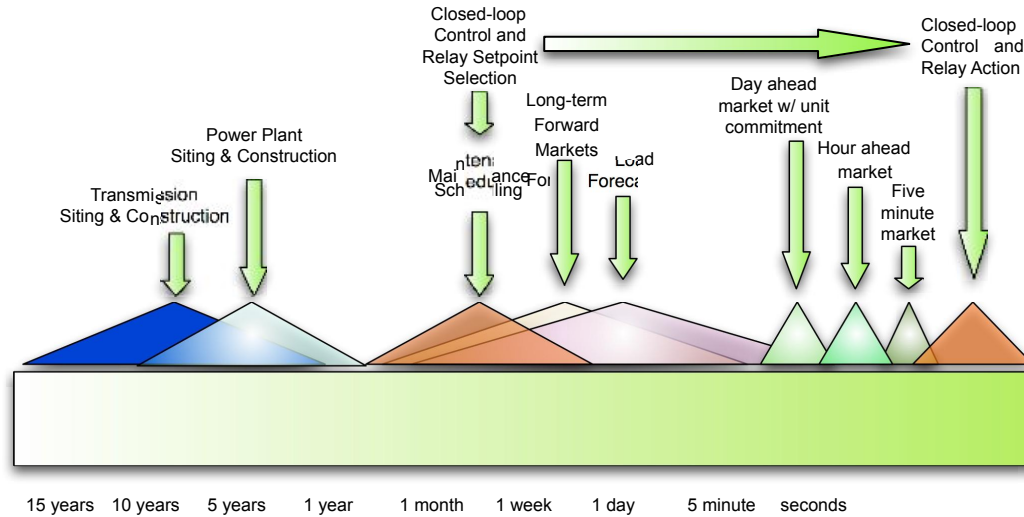
- Zero Carbon Act and new Climate Commission
- Transition to 100% renewable electricity by 2035
- Stimulate new investment



- Policies matter: affects reduction amounts and cost
- Portfolio of required technologies becomes complex as reduction increases
- Uncertainties and incentives key
- November 2019 climate act provides framework for adoption



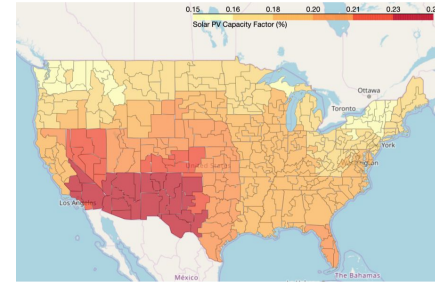
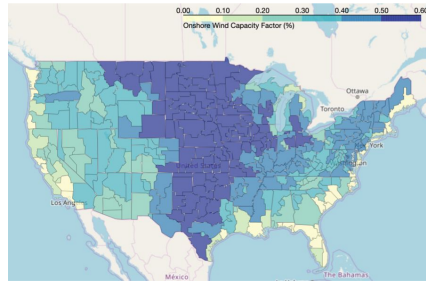
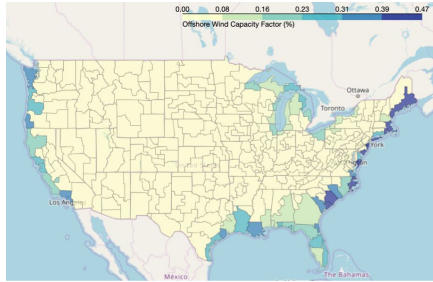
WEREWOLF (Wisconsin Expansion of Renewable Electricity with Optimization under Long-term Forecasts) informs policy....quickly



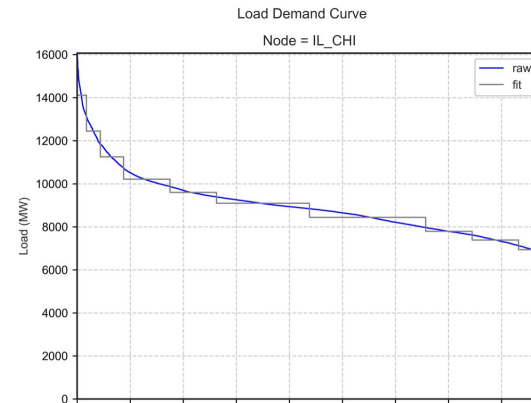
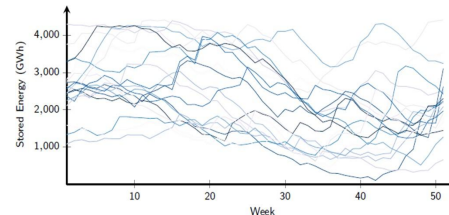
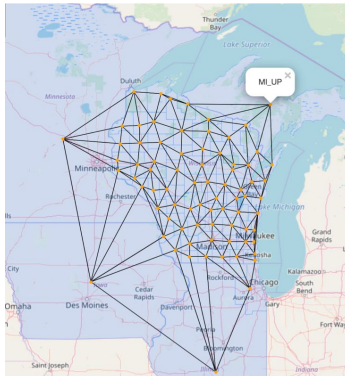
- Design/policy decisions affect operations/reliability and
- vice-versa Goal: to help policy and decision makers ...
 - ▶ to distinguish between objectives and actions;
 - ▶ to understand effects of uncertainty;
 - ▶ to understand effects of incentives;
 - ▶ to explore larger design space, **with quick turnaround**



WEREWOLF uses up to date industry-leading data sources



- (EPA NEEDS/Integrated Planning Model, NREL ReEDS data, NREL Annual Technology Baseline) can be updated regularly as needed
- Data is downscaled to county level - user can customize regions as aggregations of these counties
- Spatial impacts are captured in visualizations

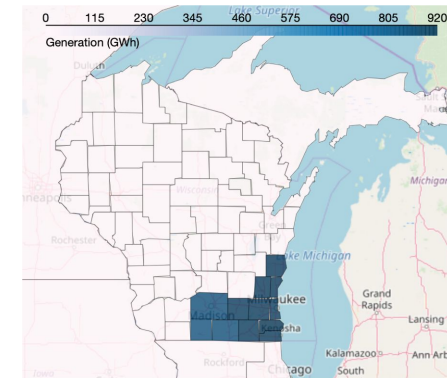
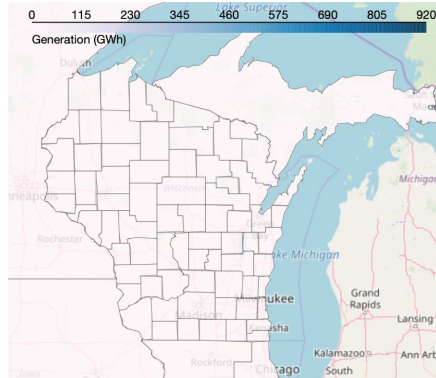
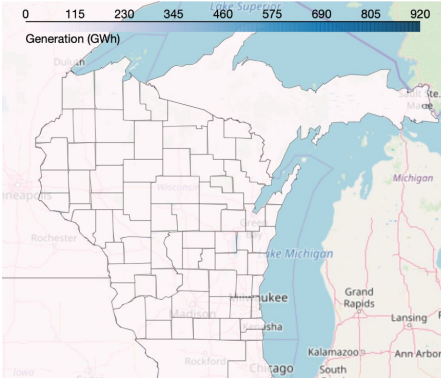
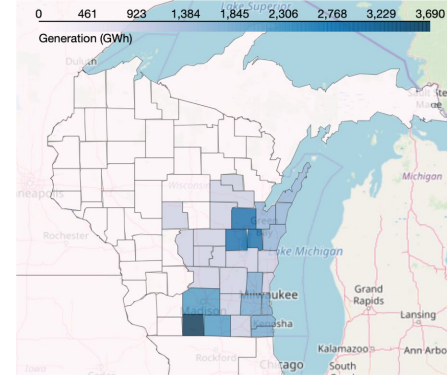
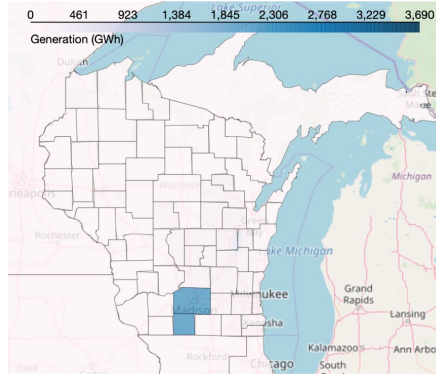
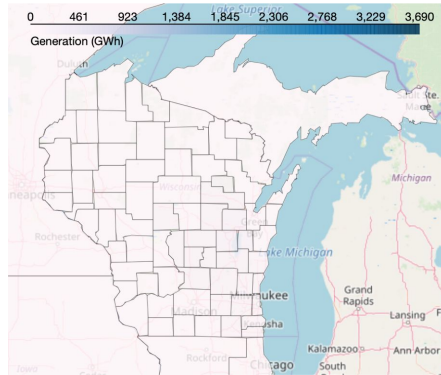


WEREWOLF uses open source code available on github

- Transparency - open source code is on github
- Data is adapted from EPA NEEDS/Integrated Planning Model, NREL ReEDS model data, NREL Annual Technology Baseline and other sources
- After data initialization, each run takes ≈ 5 mins to generate the following results
- Show effects of strategies driving towards 100% carbon free energy by 2050, coal plant closures, rapid deployment of renewables, increase in electric vehicle (EV) uptake, for example
- Demand in 2030 is a data input, what generation portfolio needed for this new demand?
- Model and app exercised with utility executives and state regulators (Wisconsin Public Utility Institute, Public Service Commission of Wisconsin, and WI Office of Sustainability and Clean Energy)



WEREWOLF model outputs: Renewable increases (wind and solar) for 0%, 40%, 80% carbon reduction policy scenarios in State of Wisconsin, USA



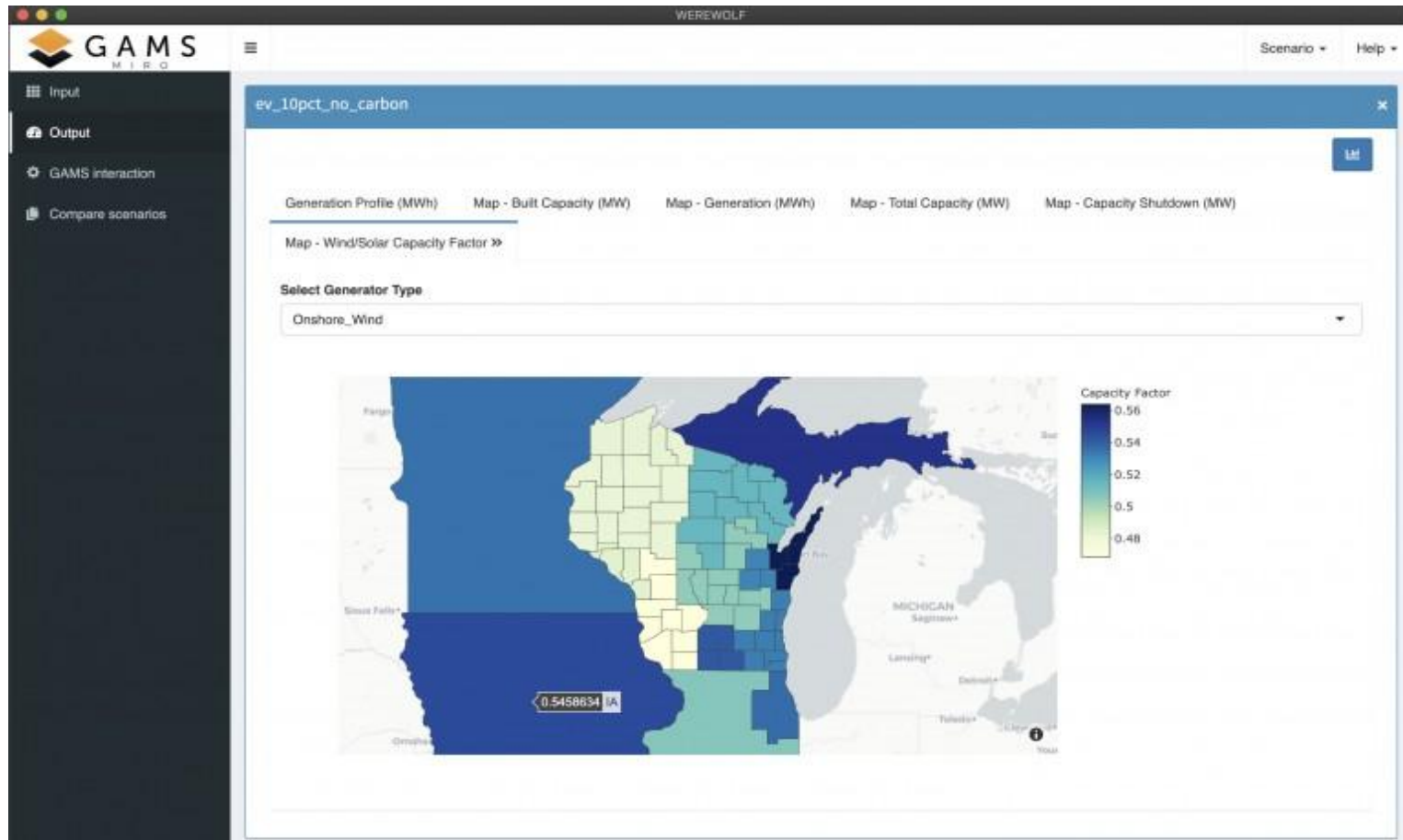
WEREWOLF: User-friendly configuration using interactive GAMS MIRO app

The screenshot displays the WEREWOLF GAMS MIRO app interface. The top bar shows the GAMS logo and the title 'WEREWOLF'. A sidebar on the left contains navigation options: 'Input', 'Output', 'GAMS interaction', and 'Compare scenarios', along with 'Load data' and 'Solve model' buttons. The main panel is titled 'ev_10pct_no_carbon' and features several interactive widgets:

- Input widgets**: A tabbed interface with options like 'Generator Data', 'Additional generation capacity (units: MW)', 'Transmission line capacity (units: MW)', 'Input Scalars', and 'More >>'.
- Fraction of light duty transport to become EV (units: unitless)**: A slider ranging from 0 to 0.5, with a current value of 0.1.
- Annual demand growth for electricity (units: %/yr)**: A slider ranging from 0 to 5, with a current value of 0.5.
- Allow capacity investment in projected year**: A toggle switch that is currently turned on.
- Limit capacity investment to control region only**: A toggle switch that is currently turned off.
- Scale NREL capacity data**: A slider ranging from 0 to 2, with a current value of 1.
- Allow only non-renewable generators to shutdown**: A toggle switch that is currently turned off.
- Allow both renewable/non-renewable generators to shutdown**: A toggle switch that is currently turned on.
- Use NREL Data for Wind/Solar Capacity Potential (region-specific)**: A toggle switch that is currently turned off.



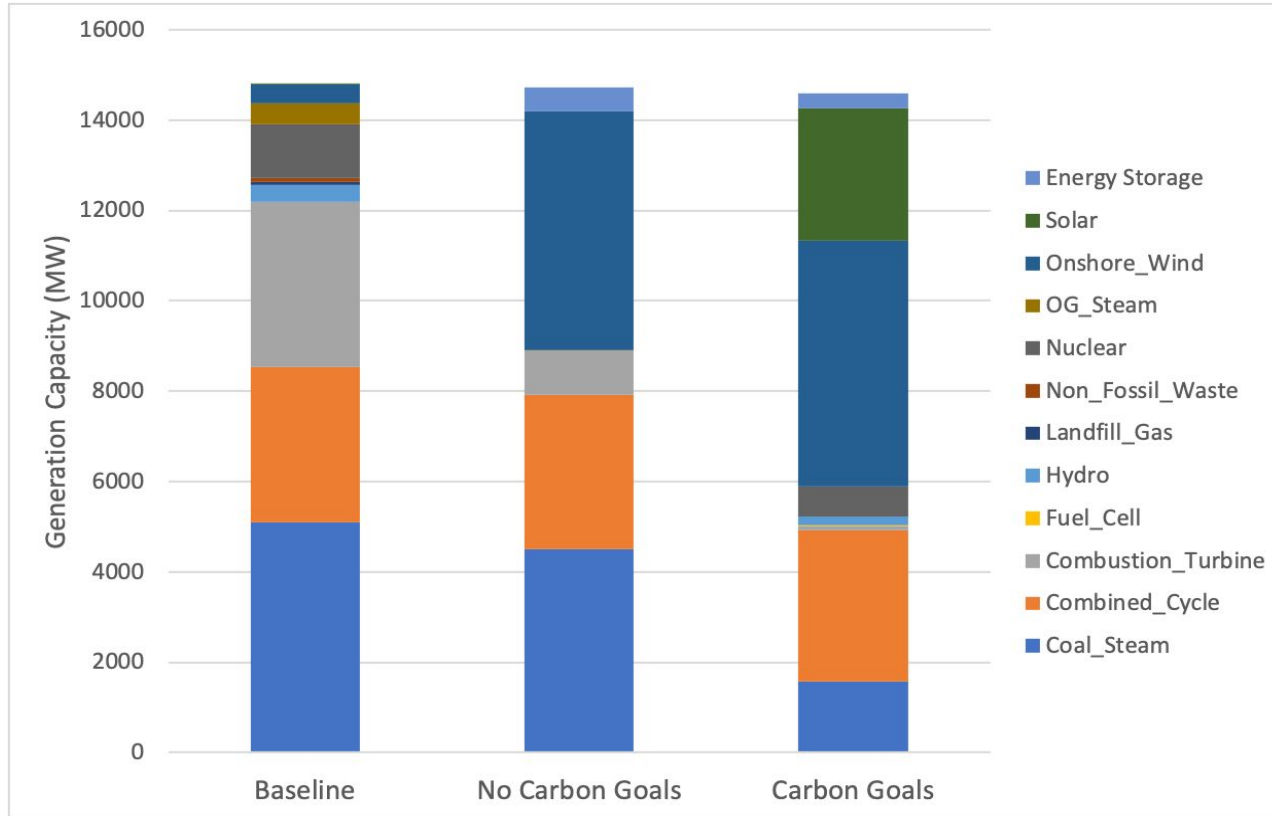
WEREWOLF MIRO model generator selection example: onshore wind



WEREWOLF MIRO generation profile: renewable generation

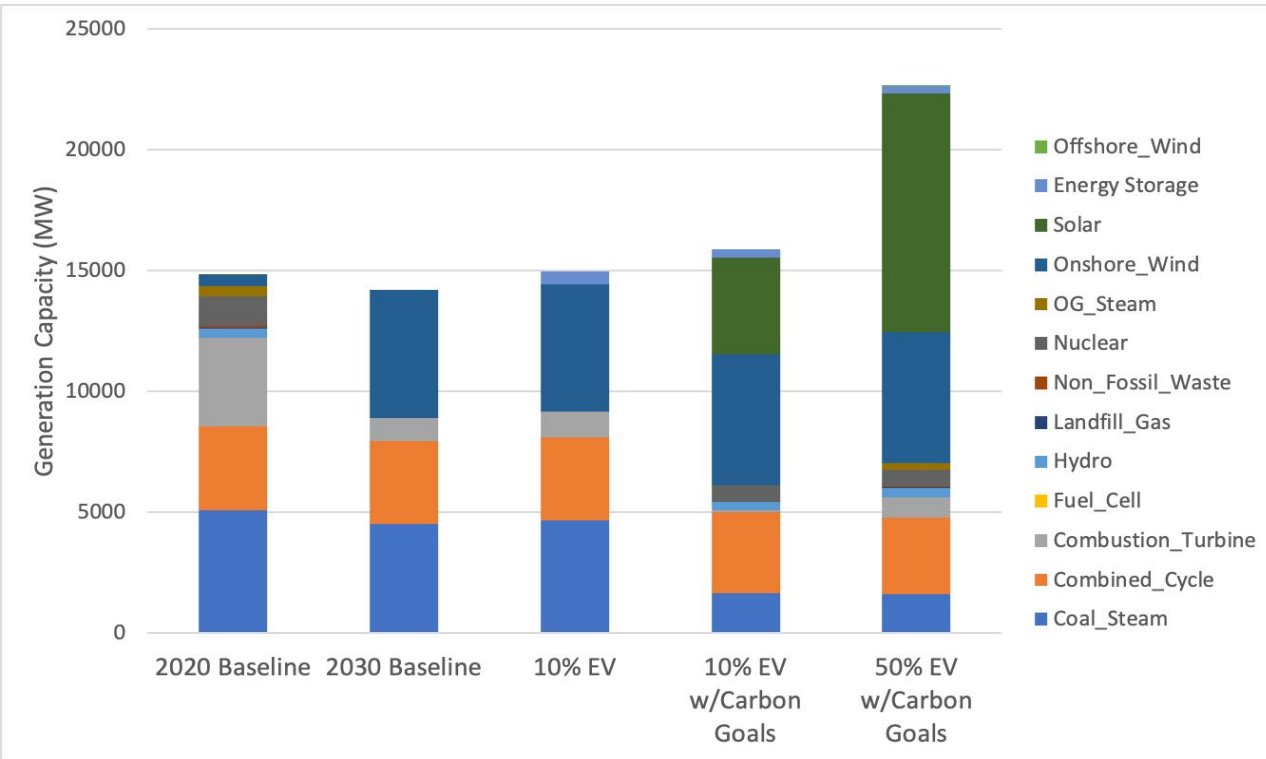


Generation capacity mix in 2020/2030 for different policy scenarios



- ❖ No Carbon Goals: overall system costs are minimized, without a carbon constraint
- ❖ Carbon Goals: 60% reduction on in-state carbon emissions by 2030
- ❖ Nuclear (low-carbon) used when deep carbon reductions are necessary
- ❖ Coal steam generators are shut down, supplanted by renewables
- ❖ Storage to arbitrage across time slices
- ❖ Caps on investment are modifiable

Impact of Electric Vehicle Deployment on Generator Investments



- ❖ Model widespread adoption of light duty electric vehicles (EVs)
- ❖ Additional 180,000 MWh demand per year
- ❖ Storage investment needed
- ❖ No significant CO2 reduction
- ❖ Additional demand and/or imposing carbon goals necessary for more dramatic effects

How can WEREWOLF add value to your next energy decision?

- Models can and should inform policy
- Models demonstrate effects and costs of constraints
- Investment is coupled to reliability
- Run high level scenarios in close to real-time – quick and interactive
- We are interested to get feedback from utility and policy experts about how this model/app would be useful in your utility and regulatory planning and evaluation efforts
- One-on-one demonstrations of model, suggestions of possible policy interventions
- Contact at: ferris@cs.wisc.edu or see <https://werewolf.discovery.wisc.edu>



WEREWOLF: two-stage stochastic optimization model (simplified)

- Capacity decisions are z at cost $K(z)$
- Operating decisions: generation y at cost $C(y)$, loadshedding q at cost Vq .
- Scenarios (futures) ω , demand (load curve) is $d(\omega)$.
- Minimize capital cost plus expected operating cost:

$$\begin{aligned} \min \quad & K(z) + E_{\omega} [C(y(\omega)) + Vq(\omega)] \\ \text{s.t.} \quad & y(\omega) \leq z \\ & y(\omega) + q(\omega) \geq d(\omega) \\ & (z, y, q) \in X \end{aligned}$$

- WEREWOLF populated using data from Wisconsin: develop the model for MISO and look at Wisconsin policies in particular
- Data and structure facilitate any US regional model or EU model

