# Werewolf and NetZero: the interactions between operations, planning, investments and policies

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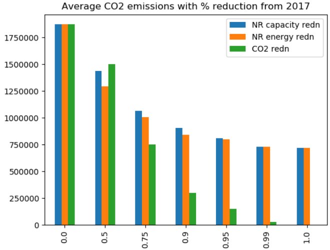
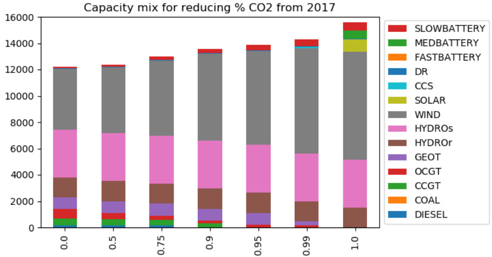
# Jacinda's 2017 election deal

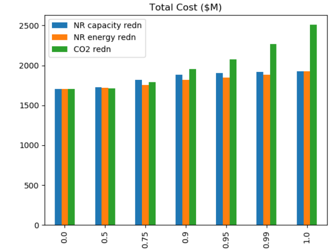
- Introduce a Zero Carbon Act and establish an independent Climate Commission.
- Request the Climate Commission to plan the transition to 100% renewable electricity by 2035 (which includes geothermal) in a normal hydrological year.
- Stimulate up to $1 billion of new investment in low carbon industries by 2020, kick-started by a Government-backed Green Investment fund of $100M.

(Confidence and Supply Agreement between the New Zealand Labour Party and the Green Party of Aoteoroa)
Built model GEMSTONE that was used by New Zealand Climate Commission to help inform this policy

# New Zealand (NetZero)

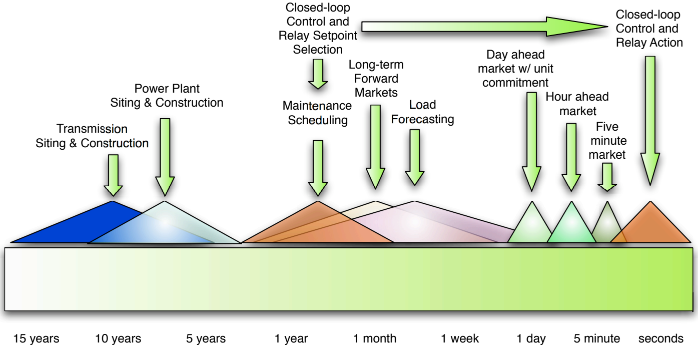



- Policies matter: affects reduction amounts and cost
- Portfolio of required technologies becomes complex as reduction increases
- Uncertainties and incentives key
- November 2019 climate act provides framework

# Werewolf (Wisconsin Expansion of Renewable Electricity with Optimization under Long-term Forecasts)




- Design/policy decisions affecting 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.

# Simplified two-stage stochastic optimization model

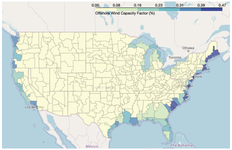
- Capacity decisions are $z$ at cost $K(z)$
- Operating decisions: generation $y$ at cost $C(y)$, loadshedding $q$ at cost $Vq$.
- Scenarios (futures) $\omega$, demand (load curve) is $d(\omega)$.
- Minimize capital cost plus expected operating cost:

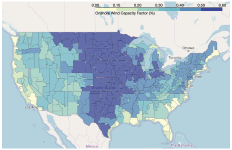
$$\begin{array}{lrcl} \min & K(z) & + & \mathbb{E}_\omega[C(y(\omega)) + Vq(\omega)] \\ \\ \text{s.t.} & y(\omega) & \leq & z \\ & y(\omega) + q(\omega) & \geq & d(\omega) \\ & (z, y, q) & \in & X \end{array}$$

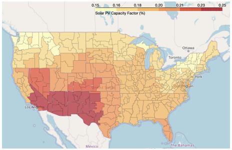
- WEREWOLF populated using data from Wisconsin: develop the model for MISO and look at Wisconsin policies in particular
- Data and structure facilitate any US regional model

# The data

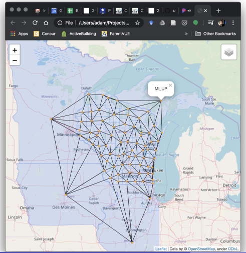
- WEREWOLF is data rich (EPA NEEDS/Integrated Planning Model, NREL ReEDS model data, NREL Annual Technology Baseline)

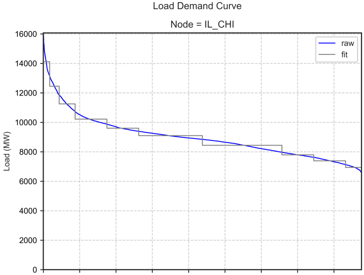


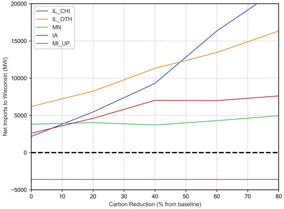

- Data is downscaled to county level - *user can customize regions as aggregations of these counties*
- Spatial impacts are captured in visualizations

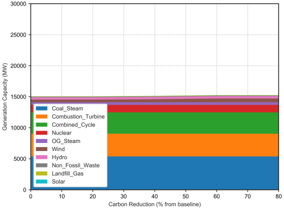


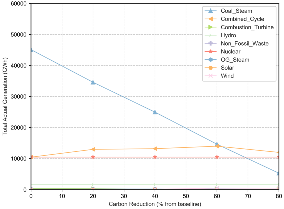



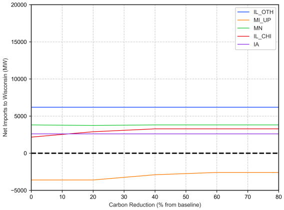
# Carbon reductions (increasing or flat imports)

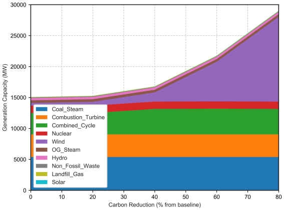
- Demand in 2030 is a data input, what generation portfolio needed for this new demand under increasing carbon reduction requirement
- Imports, capacity mix (no plant shutdowns), generation

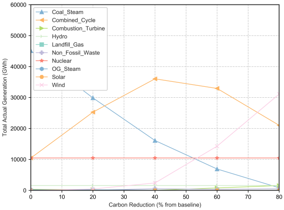


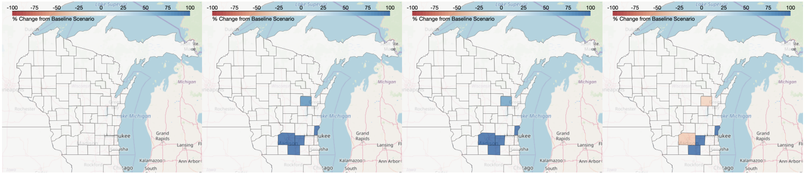



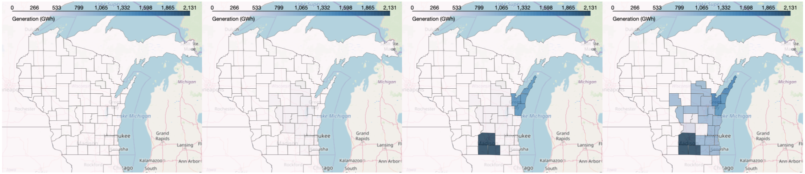



# Carbon reductions – No Plant Shutdowns

Combined Cycle (natgas) ramps up and then down while...

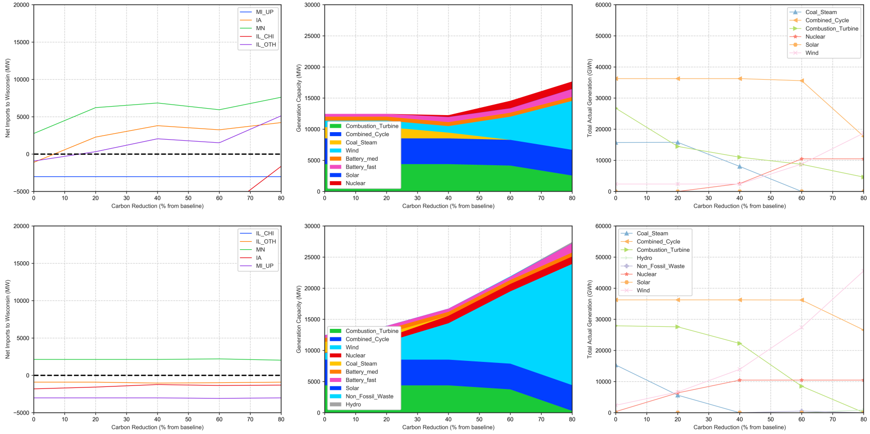



Onshore wind ramps up.



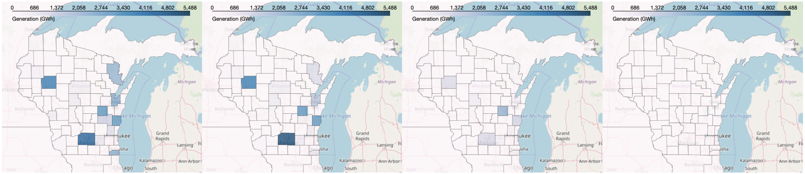
# Carbon reductions (increasing or flat imports)

- Reductions in coal, increase in gas
- Imports, capacity mix (shutdowns allowed), generation



# Carbon reductions – Shutdowns Allowed

Combustion Turbine (natgas) ramps down while...

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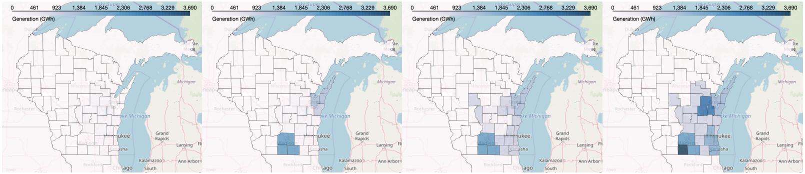
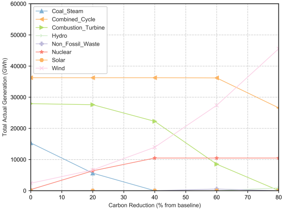
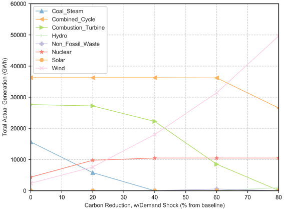
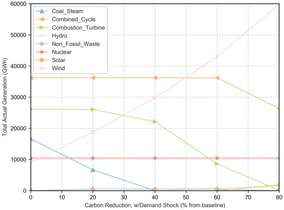


# Increased demand – Shutdowns Allowed

- 5% and 20% increase in demand for WI only (beyond the growth factor for 2030)
- Wind still dominates the low carbon fuel, but the demand shock incentivizes nuclear to come in back in earlier ($> 20\%$)

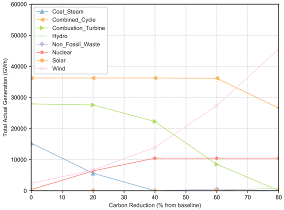


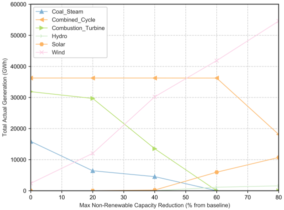



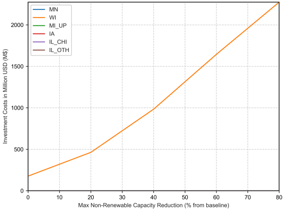



# Limit non-renewable capacity

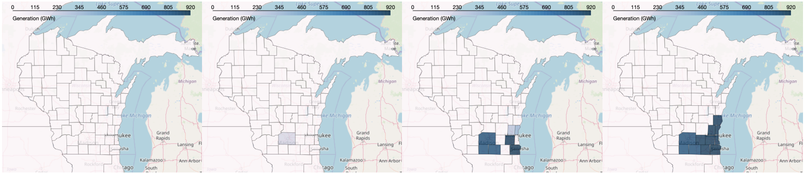
Expansion of combustion turbines for 2030, but then they ramp down as nonrenewable capacity allowed shrinks, cost increase significant




Solar deployment ramps up is specific locations...



# How can we help?

- Models can inform policy
- Models can show effects and costs of constraints
- Investment is coupled to reliability
- The model is currently being refined, and we are interested to get feedback from utility and policy experts about how this model would be useful in your utility and regulatory planning efforts (by April-May)
- One-on-one demonstrations of model, suggestions of possible policy interventions
- Contact at: ferris@cs.wisc.edu

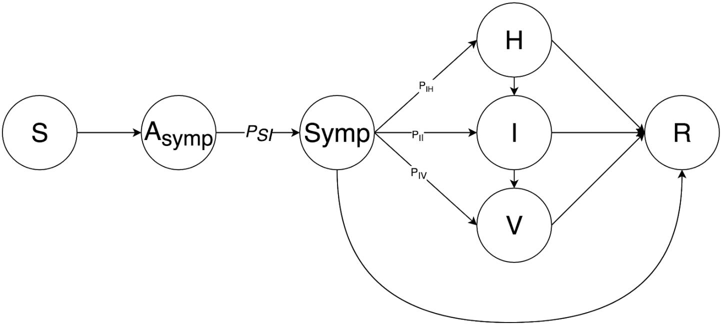
# Aside: using operations research to illuminate decisions

- How can mathematical modeling help in understanding physical phenomena and provide information to decision makers to improve decisions?
- Lots of models generate information about (exponential) growth of infections (in coronavirus pandemic)
- Models are based on data at different scales (both spatially, physically and temporally)
  - Spatial scale: worldwide, country, state, county models to convey information about the system at a given level of detail.
  - Temporal: the number of people in some health state at different intervals: yearly, monthly, daily, hourly
  - Physical: ventilators, masks, virus, microbes

# Aside: using operations research to illuminate decisions

- Simulation or agent based models provide predictions moving forward based on estimated parameters, often calibrated to existing data collected
  - Starting from assumptions and using data to predict what is going to happen in the future.
  - Using estimated parameters. e.g. the infected rate of nurses within the hospital.
  - Calibration: Use the simulation model by setting back in time and moving forward to corroborate existing data.
- These models are informative - how to improve?
  - The main focus of the lecture
- Sensitivity analysis can help with uncertainties in estimated parameters
  - Varying the estimated parameters over some range, defined by variance and standard deviation of those parameters and do sensitivity and analysis and look at the outcomes to somehow get how good or sensitive those predictions are to the assumption of the data

# Adapted SHINE model picture




Additional information in `SIRmodelOutline.pdf`

# What can we do with the predictions?

- Simulations provide the numbers of people in each circle (population model not agent - individual model) over time
- Susceptible, Asymptomatic, Symptomatic, Hospitalized, Intensive Care, Ventilator, Recovered
- The simulation generates values for counties (spatial resolution) as days increase (possibly by age cohort) based on the parameters that are encoded in the model (prediction)
- Parameters relate to resources (beds, masks, nurses, ventilators, etc) and how those affect the outcomes or transitions
- Questions/analysis:
  - Which resources at which locations become critical, and at what time?
  - Can we deploy new resources, or move resources from one location to another to improve outcomes?
- This redeployment changes the parameters for the simulation - rerun to see its effects (validation)

# Linear programming can help determine the critical resource/location information

- Which resources at which locations become critical, and at what time?
- Show model in GAMS (wimodel.gms)
  - The main focus is to find what to deploy and when.
  - The data is randomized.
  - E.g.: The number of masks at a particular location and at a particular time is counted by today's mask and yesterday's unused mask minus the masks nurses use today
  - Utilize information on population sizes in each category at each time from simulation.
  - Connect to data sources regarding resources, both existing and newly arriving. Use marginal prices to determine value of additional resources at each location and at each time.