Research in energy systems at UT Austin

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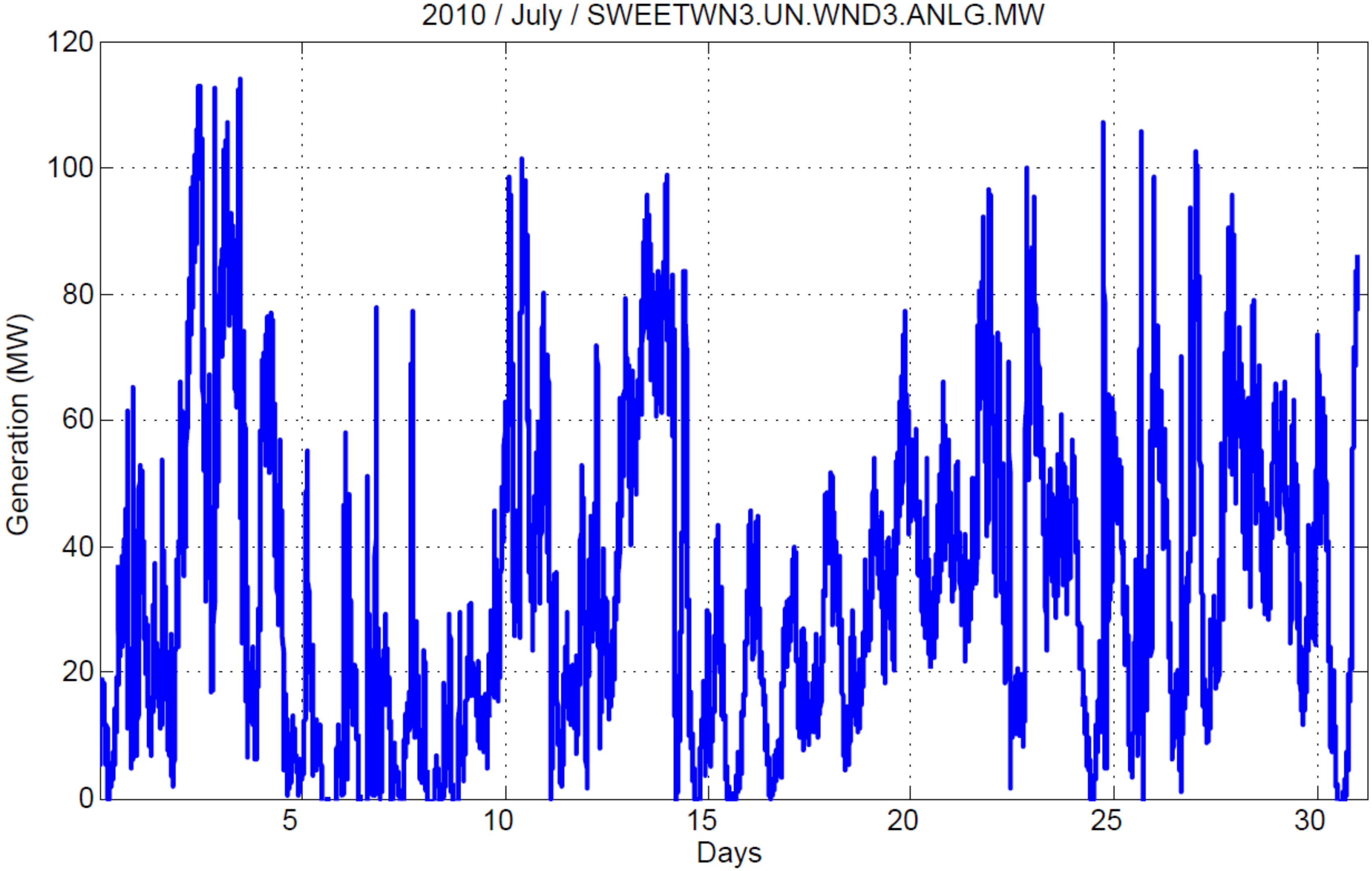
Selected research topics.

- Wind power modeling (Dr. Duehee Lee),
- Grid integration of intermittent renewables,
  - Transmission expansion planning (Dr. Heejung Park, Mohammad Majidi),
  - Generation expansion planning (Tong Zhang),
  - Demand response (Dr. Mahdi Kefayati, Dr. Ji Hoon Yoon, Michael Legatt).

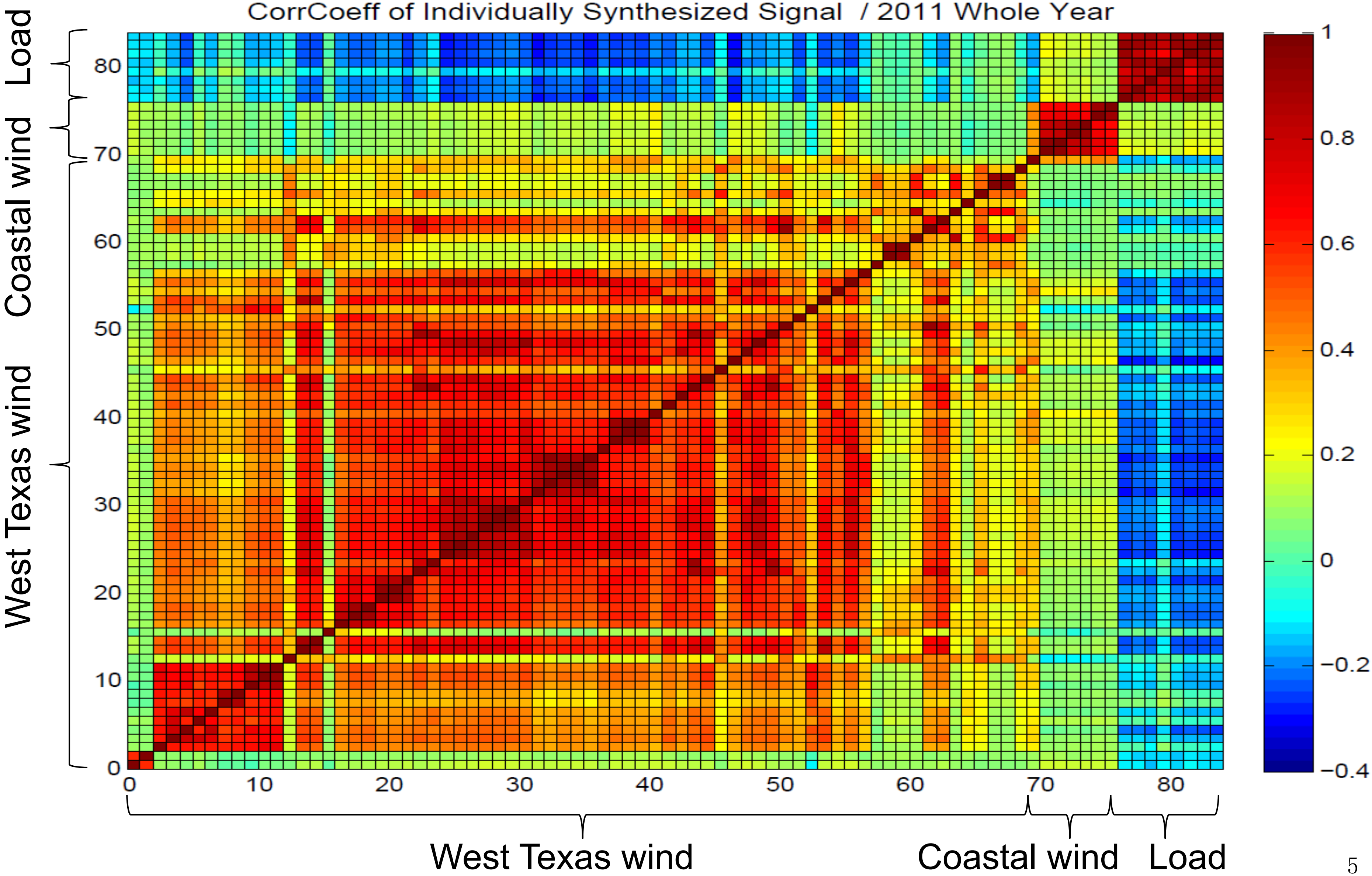
Wind power modeling.

- Statistical models:
  - Mainly for long-term (planning) applications:
    - Understand relationship between time/season of maximum wind production and time of maximum load,
    - Understand variability,
    - Understand implications for “residual” thermal system.
  - Also some short-term forecasting applications.
- Challenges in modeling:
  - Intermittency,
  - Correlation between wind and load.

Intermittent wind power production.



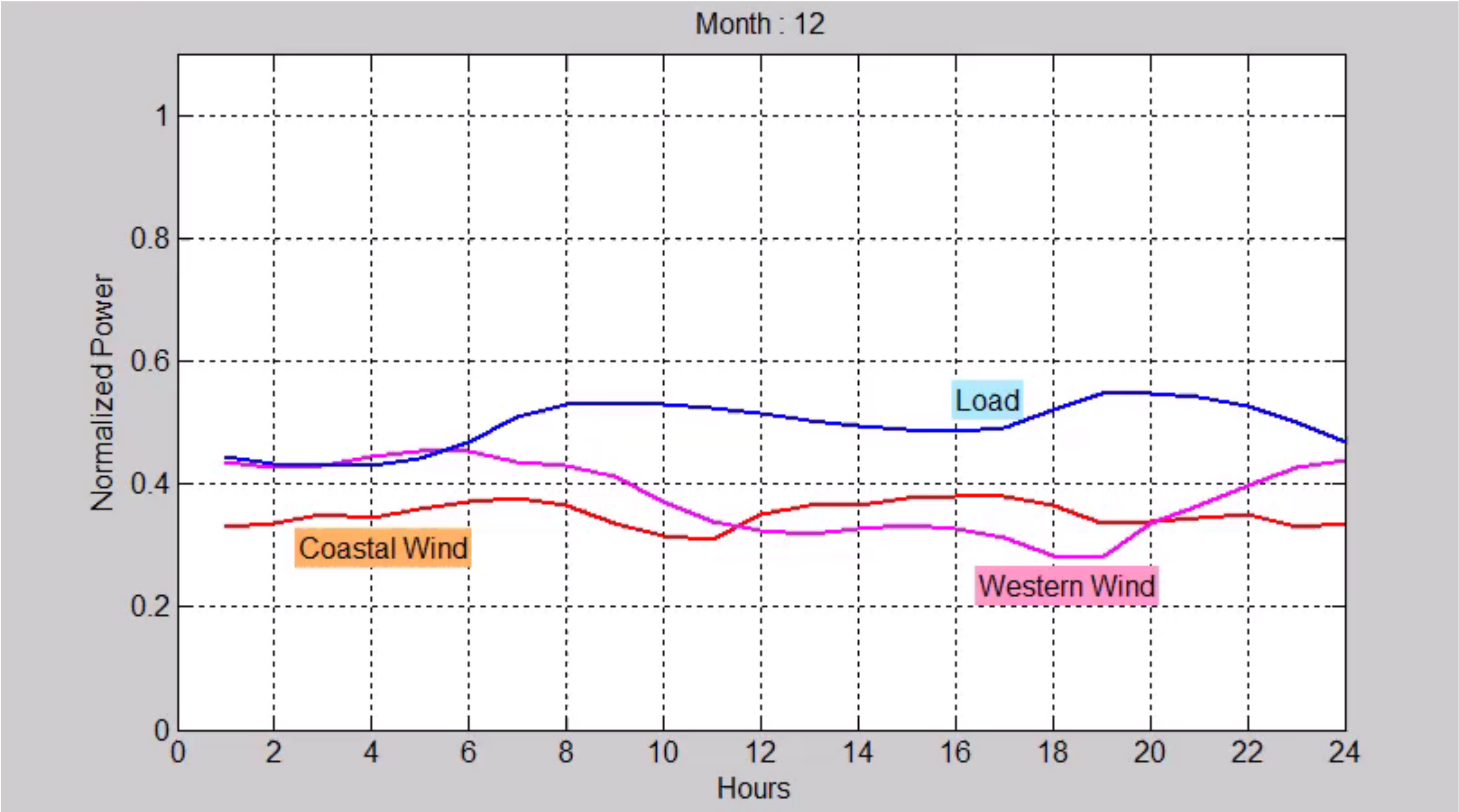
ERCOT wind and load.



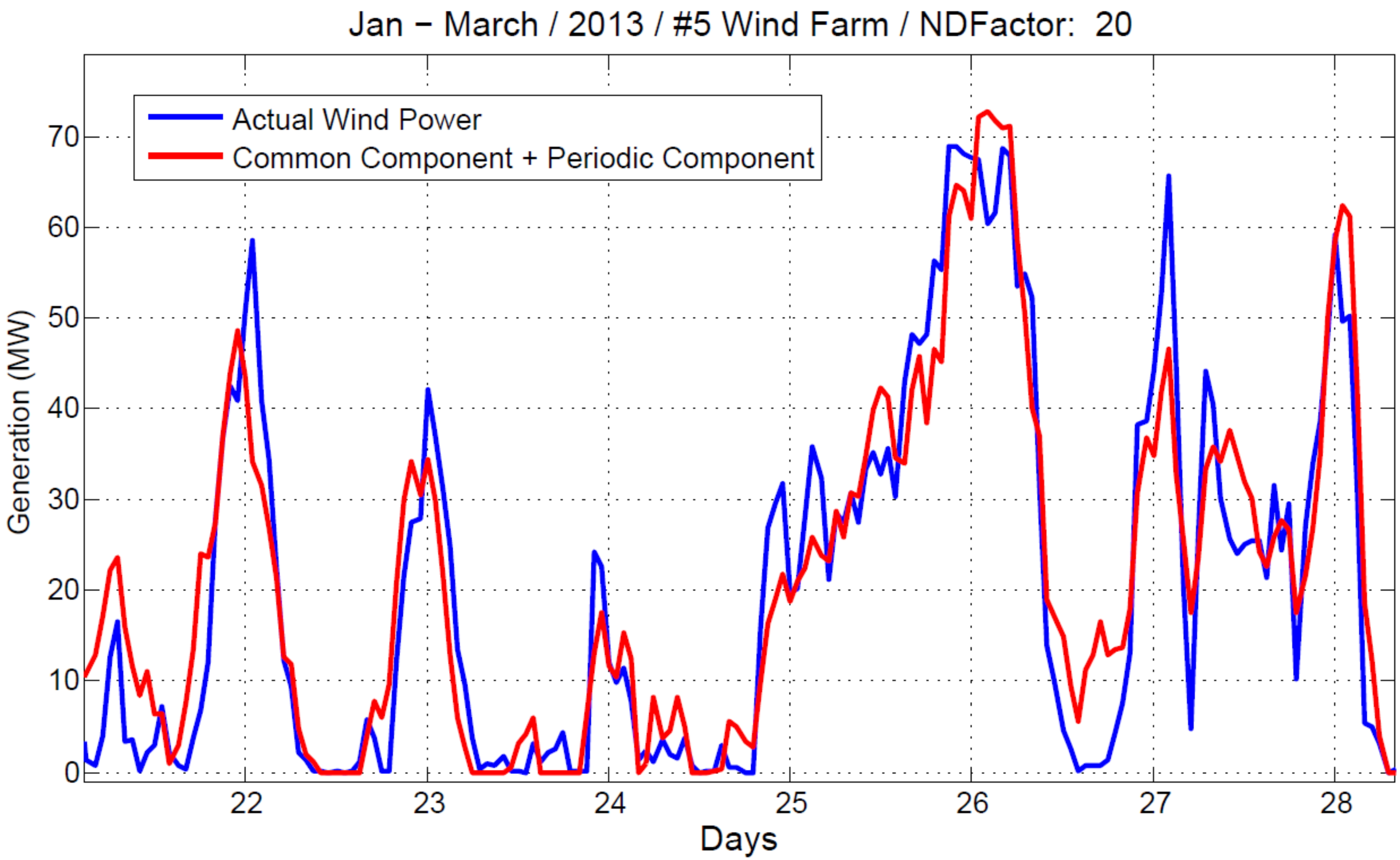
Statistical wind power model.

- Model wind power production as sum of (slowly varying) diurnal periodic component plus stochastic component.
- Use "generalized dynamic factor model" (GDFM) for stochastic component:
  - Decompose into sum of "common" component and "idiosyncratic" component.
  - Common component for wind and load powers expressed in terms of fewer underlying independent stochastic processes, the "factors,"
  - Idiosyncratic component different for each farm.

Diurnal periodic component varies over year.



Periodic plus common accounts for most variation.



Statistical model summary.

- Periodic component plus GDFM provides good match to empirical data.
- Enables synthesis of future wind production and load scenarios for planning.
- Currently investigating analogous models for wind speed and cloud effects:
  - Wind speed more useful for predicting future power production at new farms,
  - Cloud effects for predicting solar production.

Grid integration of intermittent renewables.

- Much renewable resource is remote from load centers.
- Together with need to replace aging transmission infrastructure, has made transmission increasingly significant expenditure.
- Transmission planning has traditionally focused on peak load periods.

Transmission planning.

- With increased renewables, peak flow on some transmission elements not at time of peak load:
  - West Texas wind and load.
  - Grid integration of intermittent renewables requires representation of wind and load.
- Developing optimization-based system to consider distribution of wind and load, select least-cost portfolio of lines based on candidates extracted from geographical information system.

Grid integration of intermittent renewables.

- Increasing renewable capacity also has implications for "residual" thermal system (and storage) providing for "net load,"
  - difference between load and renewable production.
- Responses include:
  - Long-term economic adaptation of thermal generation,
  - Storage,
  - Increased demand response.

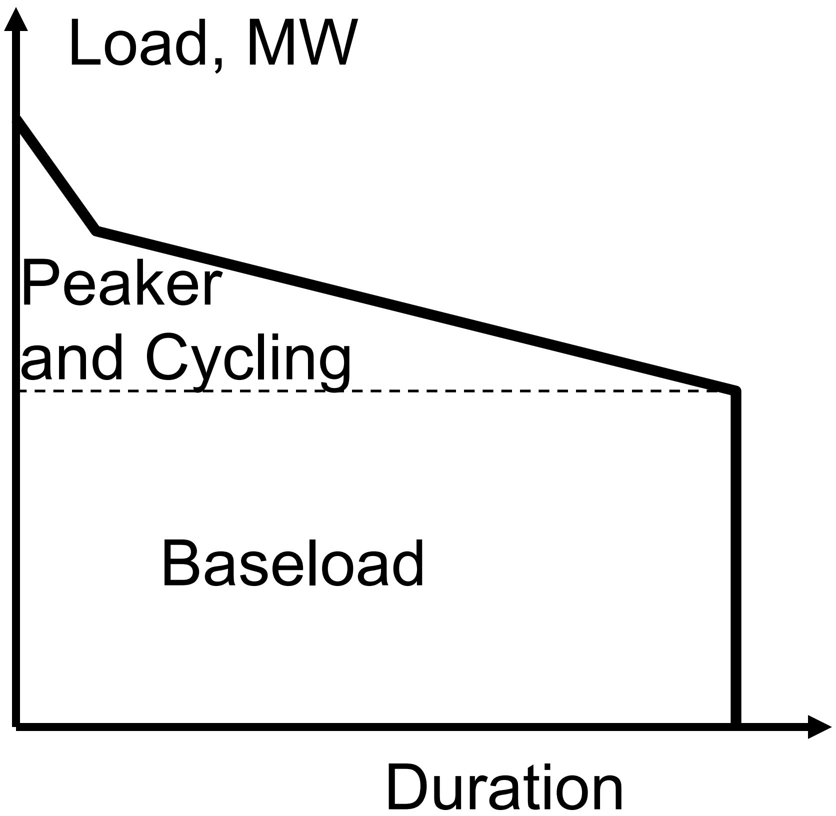
Generation expansion planning.

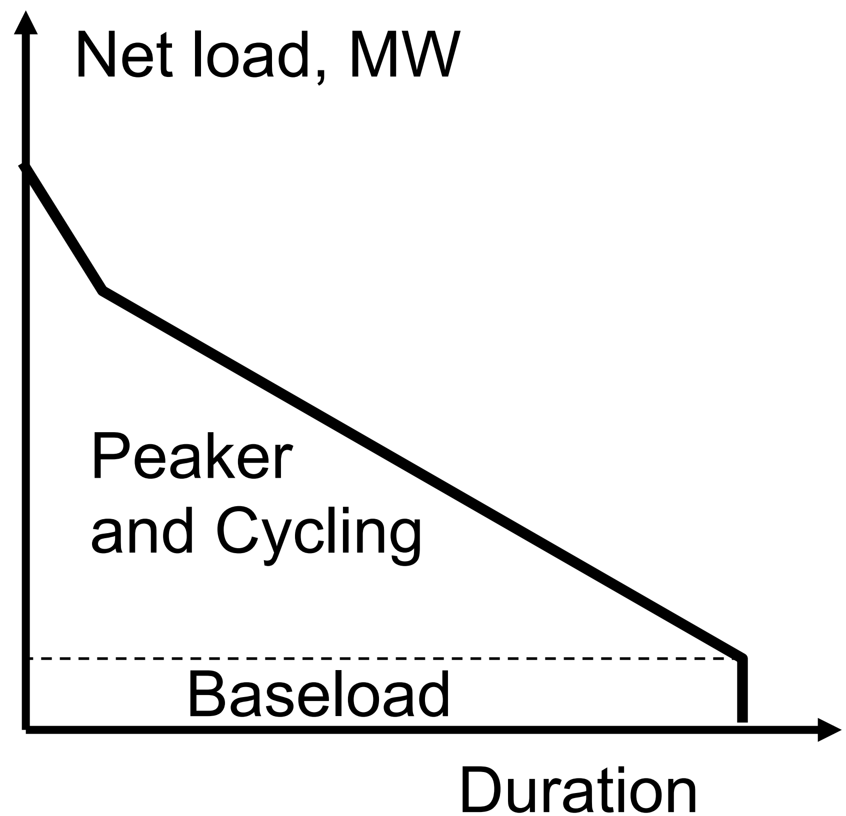
- Off-peak wind production tends to *decrease* need for thermal generation off-peak.
- Also *increases* need for flexibility, such as ramping capability, of thermal system.
- In longer-term, generation portfolio might adapt to “peakier” net load and greater ramps by increasing fraction of peaker and cycling capacity.

Generation expansion planning.

Load-duration without wind.

Net Load-duration with wind.
Net load = load minus wind.





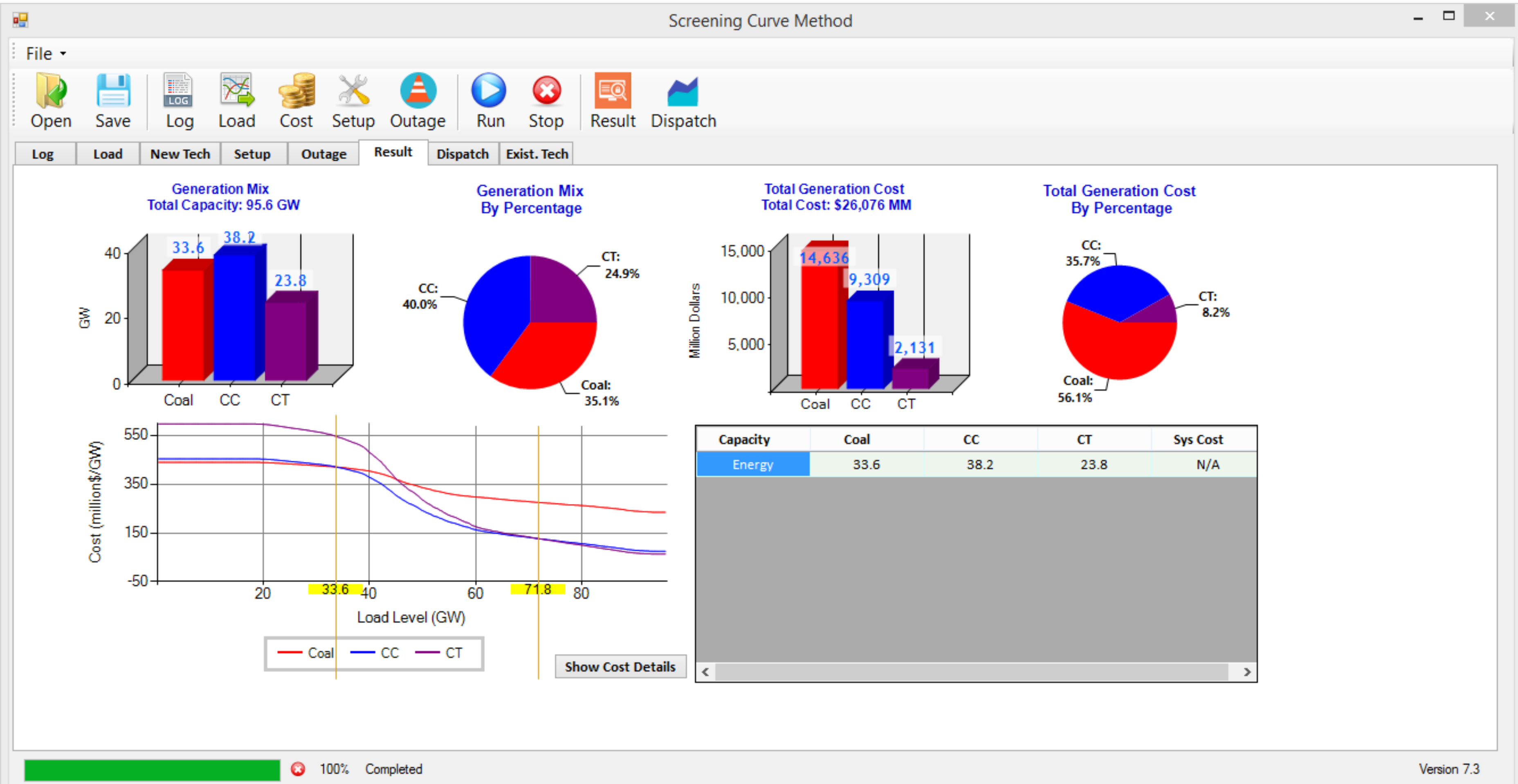
Generation expansion planning.

- Added features to "screening curve methods,"
  - "Old fashioned" approach to generation expansion to find portfolio with least annualized capital plus operating costs,
  - Fast simulation compared to models such as Aurora, and with less parameters.
- Better understand how increased wind will affect thermal generation portfolio through effect on net load.

Screening curve methods.

- Original formulation does not represent issues that become more significant as net load becomes peakier with wind.
- Added several features to provide relatively fast evaluation of economically adapted portfolio:
  - Approximation of unit commitment and operation at part loading,
  - Representation of existing generation,
  - Representation of retirement.

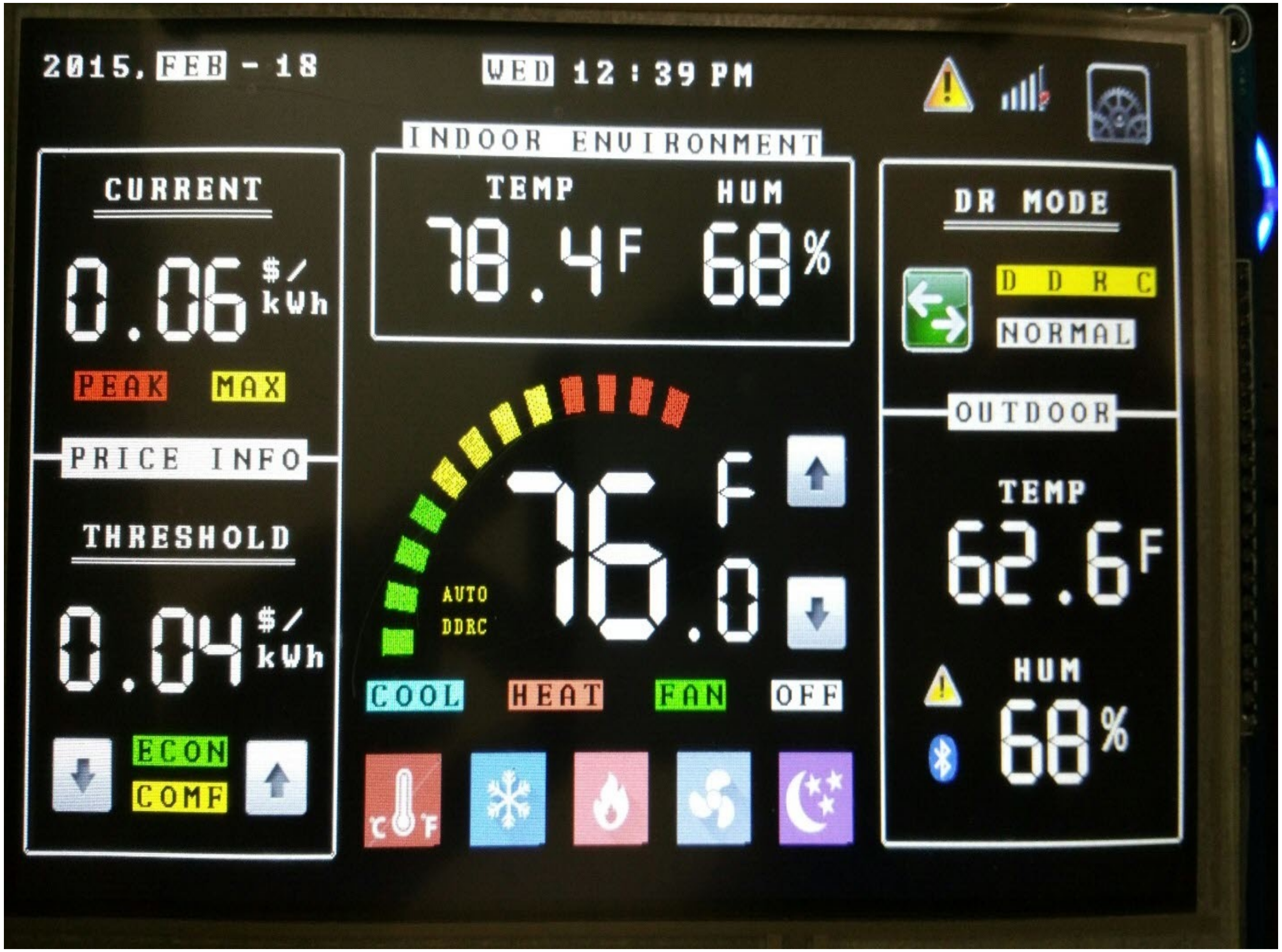
Screening curve tool.



Grid integration of intermittent renewables.

- Increasing intermittent generation suggests need for paradigm shift from “generation follows demand” to “(some) demand follows generation.”
- Price-based air-conditioning control.
- Electric vehicle charging typically has timing flexibility, which can be leveraged to help with wind integration:
  - Even if power flow from grid is always to the car!

Demand response: Price-based AC control.



Demand response: Electric vehicle charging.

- Testbed at Electric Reliability Council of Texas (ERCOT) Taylor and Austin facility parking lots.
- Investigating incentives/desires of drivers and the flexibility to use controlled charging of EV batteries to facilitate renewable integration.

Demand response: Electric vehicle charging.

Charging testbed at ERCOT Taylor offices (photo courtesy Michael Legatt).

Summary.

- Wind power modeling,
- Grid integration of intermittent renewables,
  - Transmission expansion planning,
  - Generation expansion planning,
  - Demand response.
- Increasing renewable capacity will increase variability of net load and necessitate increased flexibility of thermal system/storage/demand.