Evaluation of micro-reactor requirements and performance in an existing well-characterized micro-grid

Project 20-19693

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Project Purpose:

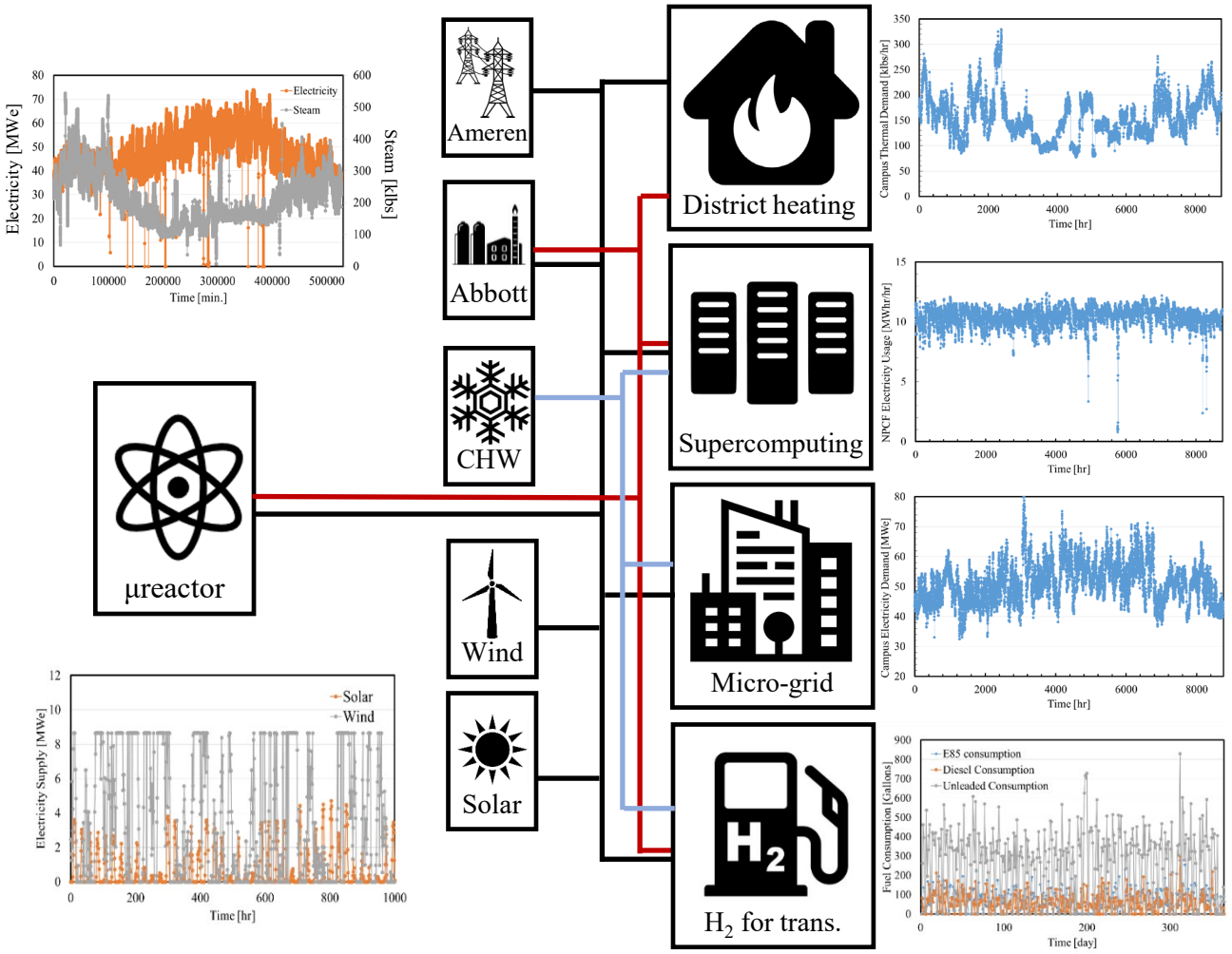
to quantify the opportunities and challenges of operating micro-reactors in populated, decentralized power generation environments and the potential for deployment in established micro-grids with diverse power generation sources.

Project Objectives:

1) Develop integrated system modeling of micro-reactor applications,
2) Incorporate available data to validate modeling,
3) Simulate normal and bounding events
4) Determine economic performance requirements across applications,
5) Identify operational requirements and opportunities across applications.
6) Determine the scalability of micro-reactor deployment at campuses and other existing micro-grids.

Overview of UIUC Campus Microgrid

- Electrical
  - 55 MW_e average demand(Peak 80 MW_e)
  - Blue Waters Supercomputer up to 15 MW_e
  - Wind: ~25,000 MWhr/yr
  - Solar: ~27,200 MWhr/yr
  - Chillers: ~20 MW_e peak
- Thermal
  - >50 MW_{th} average demand
  - High P steam relatively constant,
  - Low P steam varies with Temp and RH
  - 6 Chilled water plants (2 steam, 21 electric)
  - Energy storage (6.5 million gallons chilled water)
- Transportation
  - Campus fleet ~ 800 gallons/day
  - Campus bus system: up to 3,400 gallons/day
  - Bus system already investing in 10 new H_2 busses



Data Overview

Table 1: Summary of Currently Available Data

Data	Resolution	Span	Supply/Demand	Units	Source
Abbott Electricity Generation	Hourly	Fiscal[a] Years [2015, 2019]	Supply	kW	UIUC F&S[c]
Campus Electricity Demand	Hourly	Fiscal Years [2014, 2019]	Demand	kW	UIUC F&S
Wind Energy to Campus	Hourly	Fiscal Years [2016, 2019]	Supply	kW	UIUC F&S
UIUC Solar Farm 1.0	15-minute	Calendar Years (2015, 2019]	Supply	kW	AlsoEnergy [3]
Solar Irradiance	30-minute	Calendar Years [2013, 2018]	[-]	W/m^2	OpenEI [4]
Campus Steam Demand	Hourly	Fiscal Years [2015, 2019]	Supply	Klbs	UIUC F&S
Lincoln Weather Data[b]	Hourly	Calendar Years [2010,2019]	[-]	Varied	NOAA [5]
Champaign Weather Data [b]	Hourly	Calendar Years [2010,2019]	[-]	Varied	NOAA [5]
UIUC Fleet Fuel Demand	Daily	Calendar Year [2019]	Demand	Gallons, Dollars	UIUC F&S
CU-MTD Fuel Demand	Daily	Calendar Year [2019]	Demand	Gallons, Dollars	CU-MTD[c]
Abbott: Low Pressure Steam	Minute	Calendar Year [2019]	Supply	Klbs	UIUC F&S
Abbott: High Pressure Steam	Minute	Calendar Year [2019]	Supply	Klbs	UIUC F&S
Campus Electricity Demand	Minute	Calendar Year [2019]	Demand	kW	UIUC F&S
Chilled Water System	Minute	Calendar Year [2019]	Supply/Demand	Tons	UIUC F&S
Thermal Energy Storage	Minute	Calendar Year [2019]	Storage	Tons	UIUC F&S
UIUC Solar Farm	Minute	Calendar Year [2019]	Supply	kW	UIUC F&S
UIUC Total Natural Gas	Minute	Calendar Year [2019]	Demand	BTU	UIUC F&S
Bluewaters Supercomputer	Hourly	Fiscal Years [2014,2018]	Demand	kW	UIUC F&S

(a) The UIUC fiscal year runs from August 1 to July 31

(b) See Table 2 for further breakdown of weather data.

(c) This data is proprietary *unsure about citation*.

Table 2: Description of available weather data

Variable	Units
Dry Bulb Temp	°F
Wet Bulb Temp	°F
Precipitation	inches
Relative Humididty	%
Wind Direction	°
Wind Speed	m/s
Station Pressure	in. Hg

Overview of UIUC Campus Grid Emissions

Scope	Scope Definition	Emissions (MTCO2e; %)	Campus Energy Source %	Campus Electricity %
1	Emissions produced on campus within UIUC control	195,459; 45.1%	80%*	43.10%
2	Emissions from purchased electricity	183,595; 42.3%	20%	56.90%
3	Emissions from off campus university activities	54,743; 12.6%	N/A	N/A

*Calculated from fuel consumption

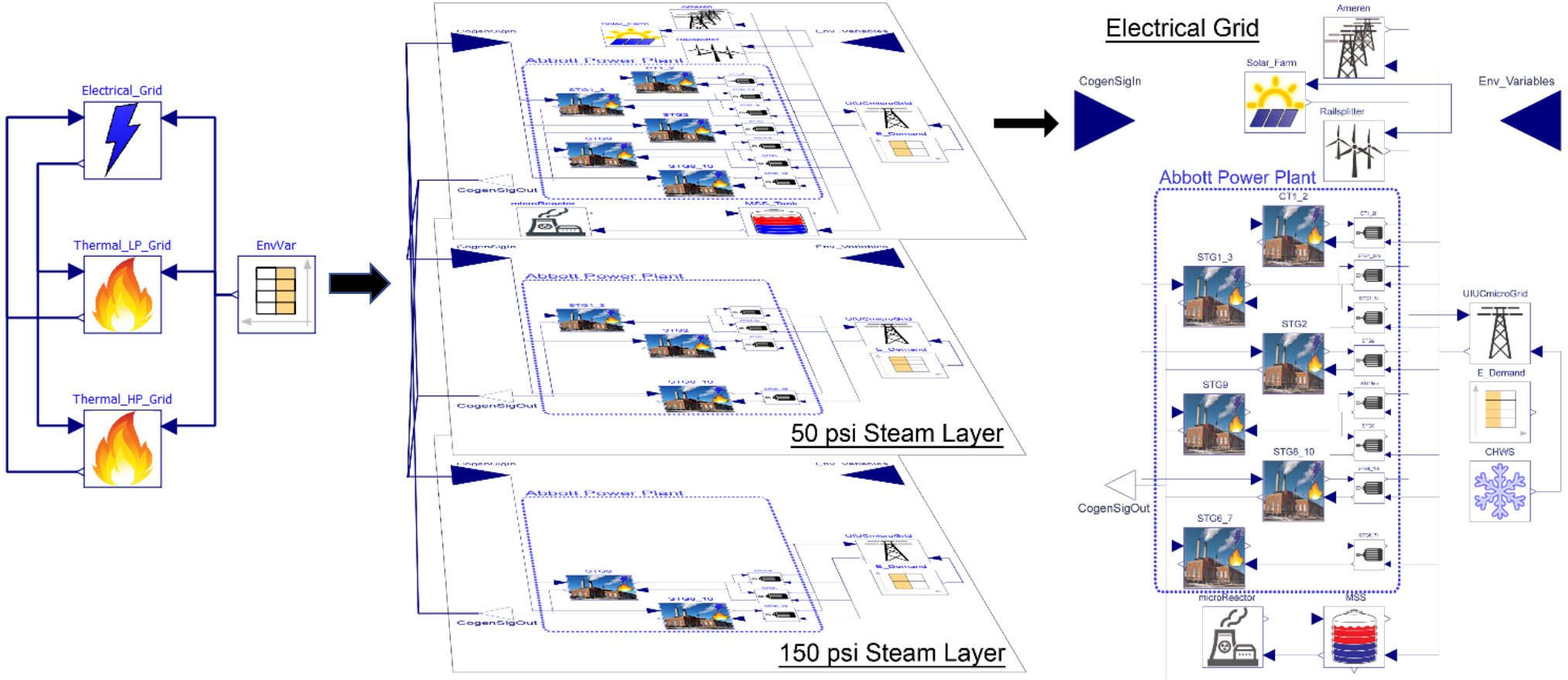
Ameren Energy mix:

Coal	Nuclear	Renewables	Natural Gas
69%	25%	5%	1%

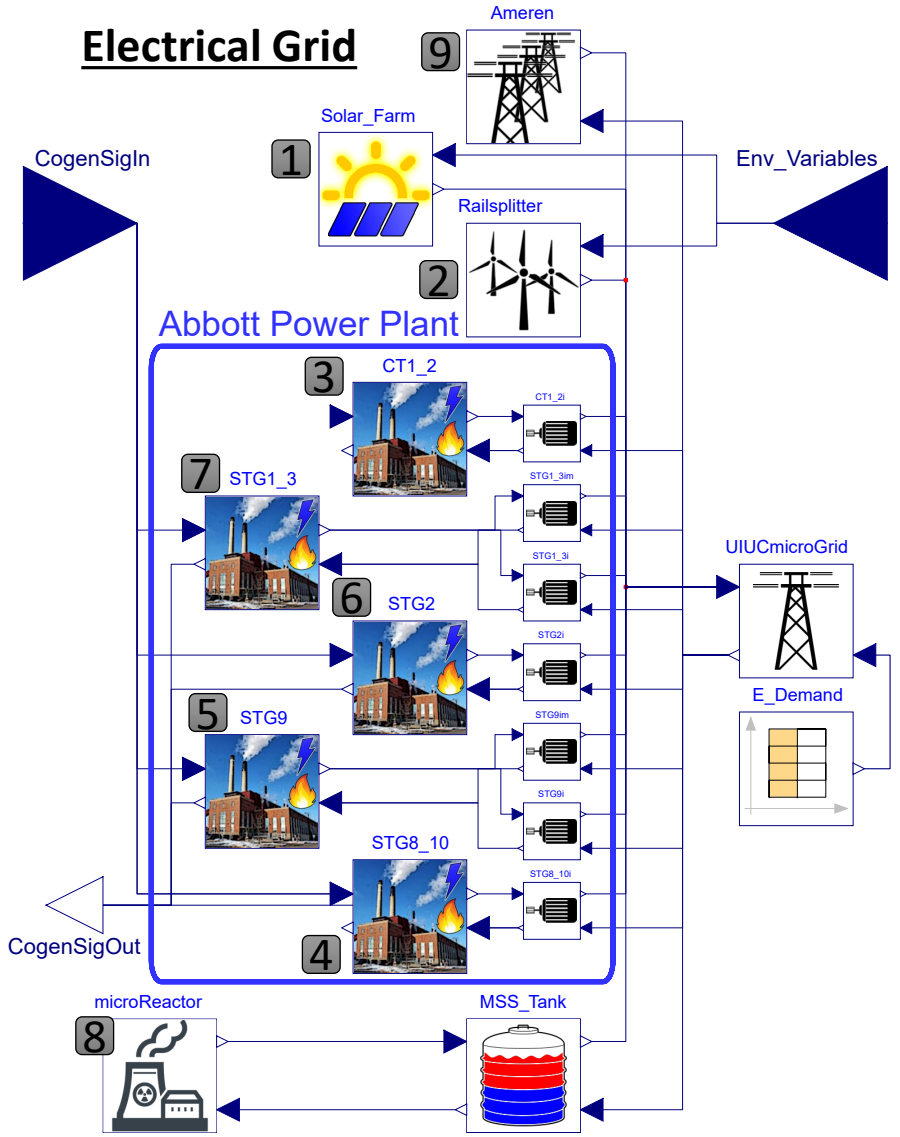
Campus Energy mix:

Natural Gas	Coal	Solar	Wind
89%	6%	2.5%	2.5%

Microgrid Model

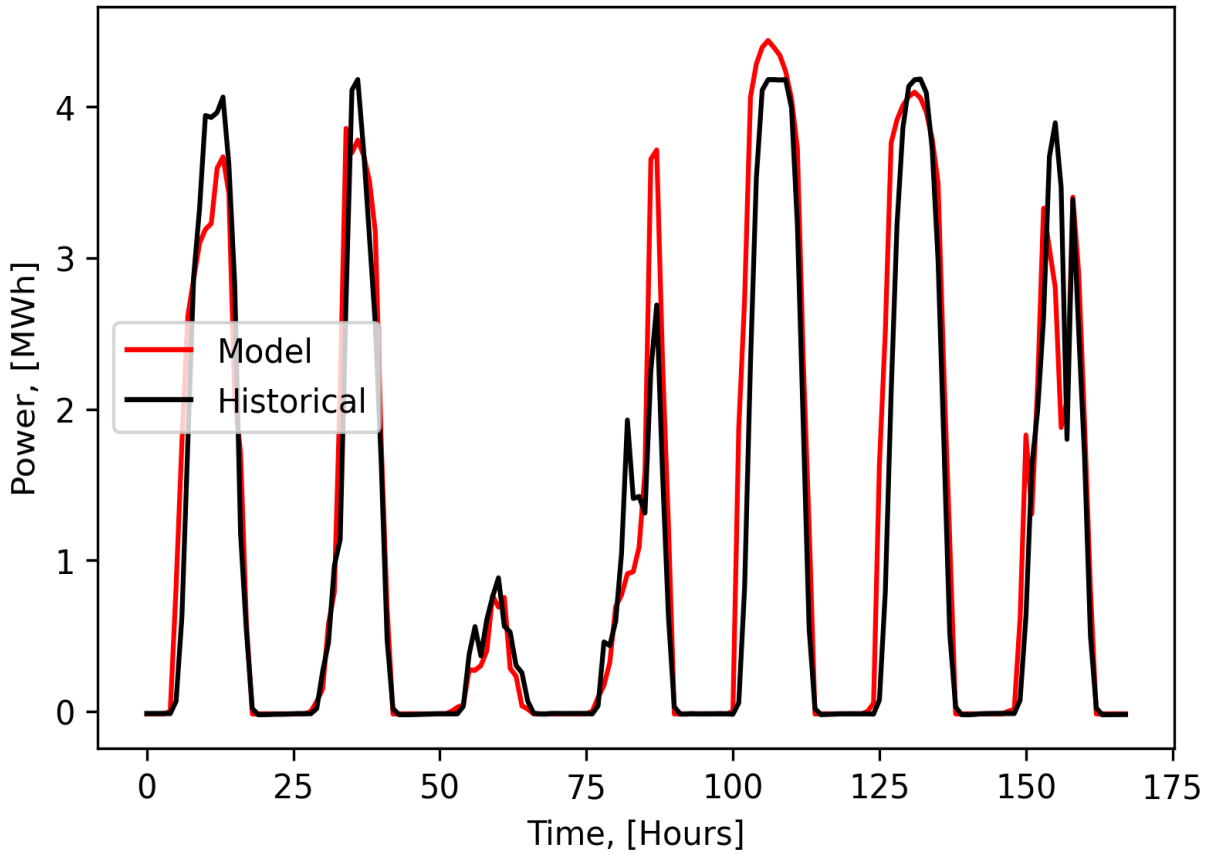


Microgrid Model



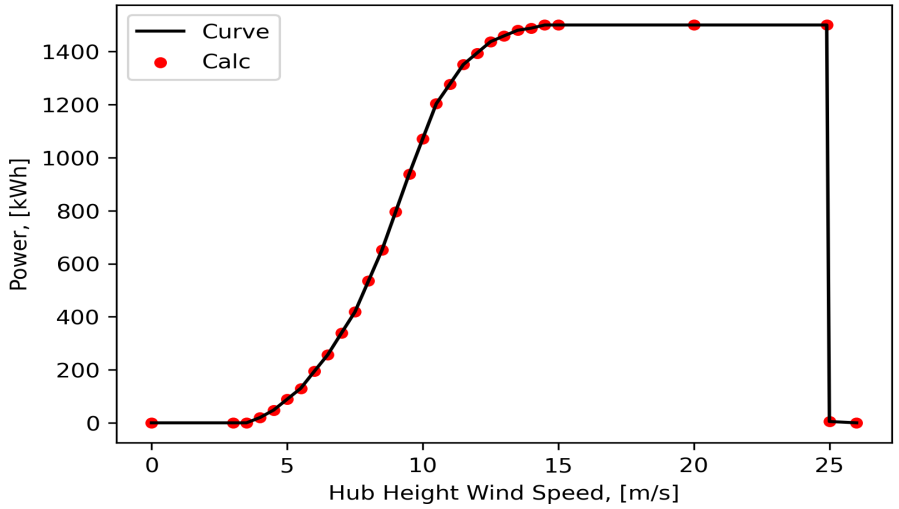
Modeling Renewables - Solar

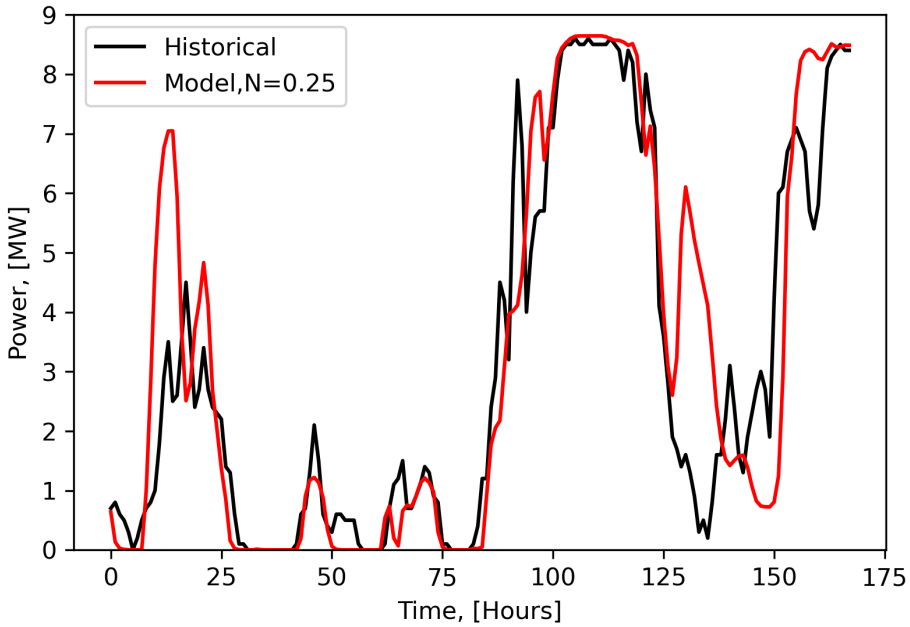
- Solar farm 1.0, 2.0
  - Fixed and East-West Tracking
  - 27,200 MWhr/yr
- Modeling parameters:
  i. Capacity (& rated intensity)
  ii. Latitude
  iii. North-South tilt
- Inputs
  i. Efficiency
  ii. Area
  iii. Transmissivity
  iv. Temperature Coefficient
  v. Day-of-year, Hour-of-day
  vi. Cell Temperature (based on climate data)
  vii. Direct Normal Intensity (DNI)
  viii. Diffused Horizontal Intensity (DHI)



Modeling Renewables - Wind

- Wind
  - PPA with Rail Splitter Wind farm
  - 8.6% of real-time generation
  - ~25,000 MWhr/yr
- Modeling parameters:
  i. Turbine power curve (from manufacturer)
  ii. Wind speed correction (ground to hub height-power extrapolation)
- Inputs
  i. Number of turbines
  ii. Turbine capacity
  iii. Weather data (wind speed from NSRDB)





Modeling - Abbott Power Plant

- Steam
  - 50MWth average demand
  - 150 and 50 psig
  - 100% of campus needs
- Electricity
  - ~45% of campus electricity
  - Biproduct of steam demand
  - CT provide base load to electricity demand (13.5 MWe each)
- Modeling parameters:
  i. Capacity
  ii. Ramp Rates
  iii. Cogeneration Ratio
- Inputs
  i. Electricity Demand
  ii. Steam Demand