PSERC Project S91
Generating Value from Detailed, Realistic Synthetic Electric Grids

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Kickoff Meeting
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University Team

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IAB Team Members

- Harvey Scribner and Jay Caspary (SPP)
- Jim Price (CAISO)
- Bryan Palmintier (NREL)
- Di Shi (GEIRI),
- Evangelos Farantatos, Paul Myrda (EPRI),
- Cho Wang (AEP)
- Atena Darvishi (NYPA)
- Steven Judd (ISO-NE)
- Alex Lau and David Mercado (CenterPoint)
- Al Engelmann (ComEd)
- Yazhou Jiang and Anil Jampala (GE)
- Mahesh Morjaria (First Solar)
- Patrick Panciatici (RTE)
- Jianzhong Tong (PJM)
- Baj Agrawal (APS)
- Felica Ruiz (MISO)

Agenda

- Introductions
- Overview of the Project
- Specific Tasks
- IAB Feedback on Tasks
- Future Meeting Frequency

Summary and Tasks

- The goal of the project is to work closely with the industrial team to generate value from large-scale, detailed and realistic synthetic electric grids
  - The project builds on recent ARPA-E work by the PIs to develop grids that can be used for research, education, commercial development and public engagement
- The four project tasks are
  1. Developing customized grids
  2. Developing specific grid scenarios
  3. Exploring decision making with uncertainty
  4. Expanding the scope of synthetic grids for coupling with other infrastructures

Project Period and Funding

- The project period is the standard two years, from July 1, 2020 to August 31, 2022
- Total funding is 220K, with the amount split equally between the years
  - 110K per year
- Total funding per researcher is 27.5K per person per year
- TAMU has internal funds that will be used on this project; this includes funding for equipment, data sets, travel and consulting services

Synthetic Electric Grids

- Synthetic electric grids are models of electric grids that were not created to represent any actual electric grid
- The below image shows the five bus synthetic grid I used as an undergraduate

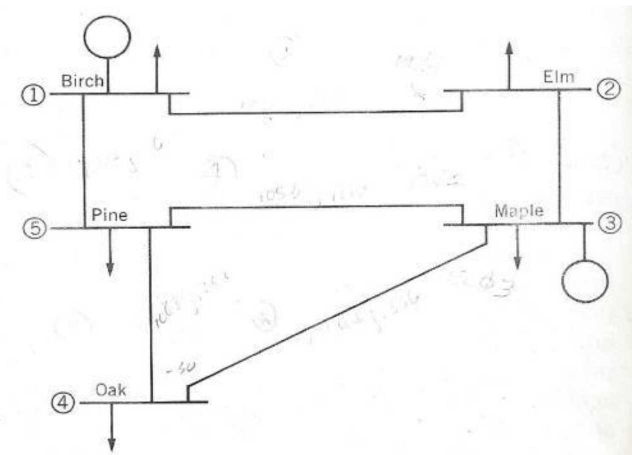
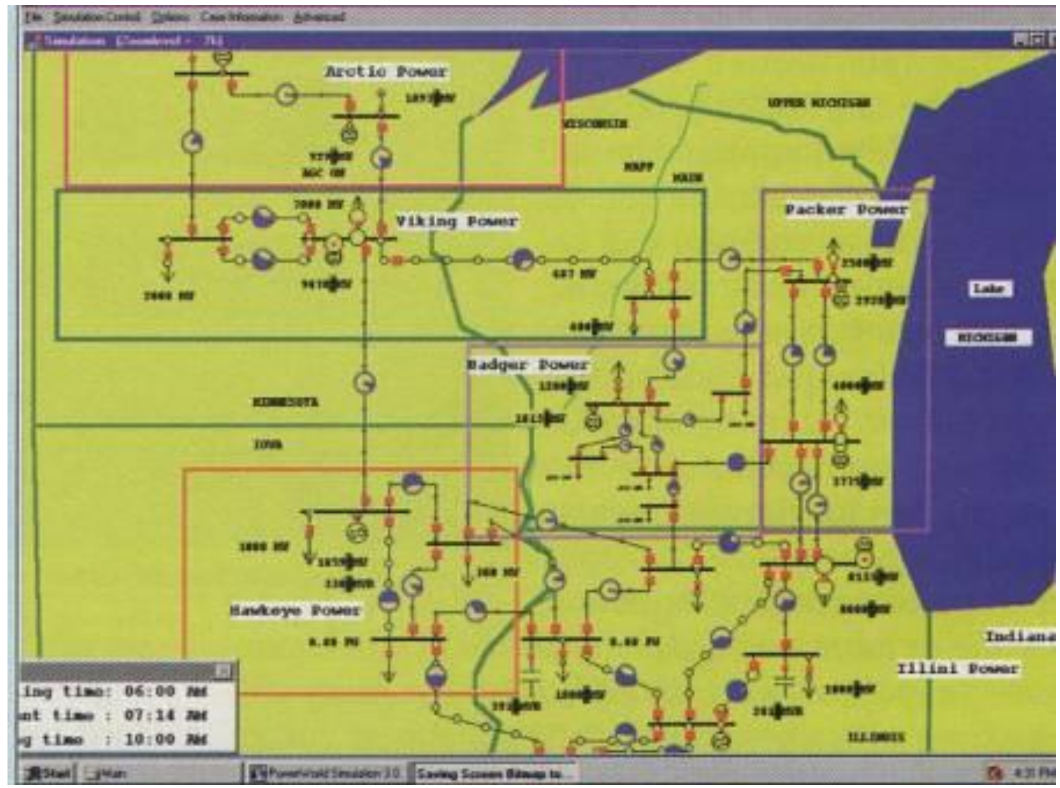


Figure 8.1 One-line diagram for Example 8.1.

Image Source: W.D. Stevenson, *Elements of Power Systems*, Fourth Edition, McGraw-Hill Book Company New York, 1982 (the first edition was in 1955)

Geographical Synthetic Electric Grids

- Synthetic electric grids can be created with or without reference to actual geography
- The image shows an early geographically-based synthetic electric grid



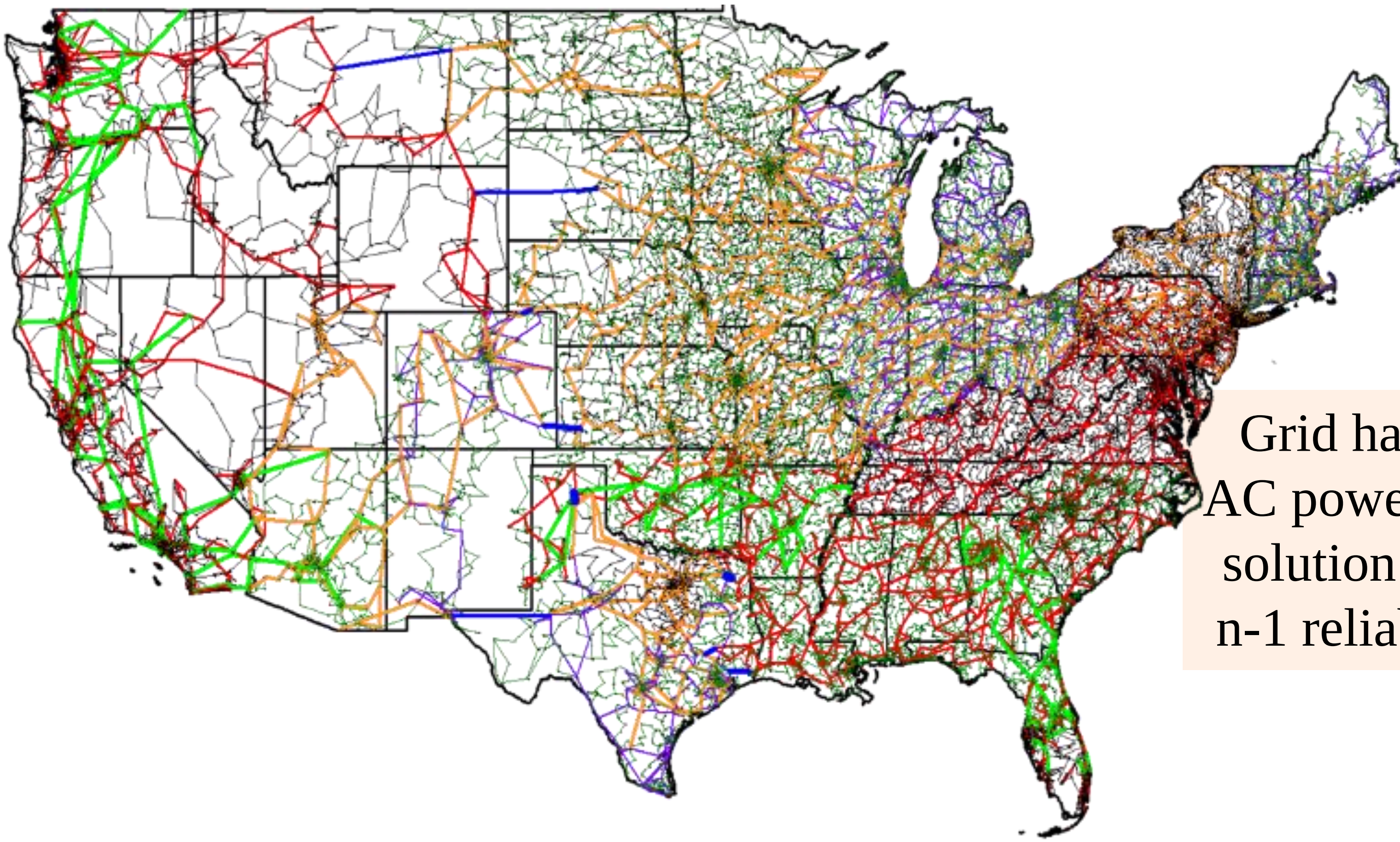
- This grid was designed to show concepts to regulators

High-Quality Synthetic Electric Grids

- High-quality synthetic electric grids are designed to have a wide range of characteristics that are similar to those found in actual electric grids
  - “Realistic but not real” to quote Wisconsin teammates
  - Fictional, but hopefully good fiction
  - **Developed techniques can be applied to real grids**
- However, importantly these grids are not designed to try to duplicate any actual grid
- Over the last three years tremendous progress has been made through ARPA-E at both the transmission and distribution levels

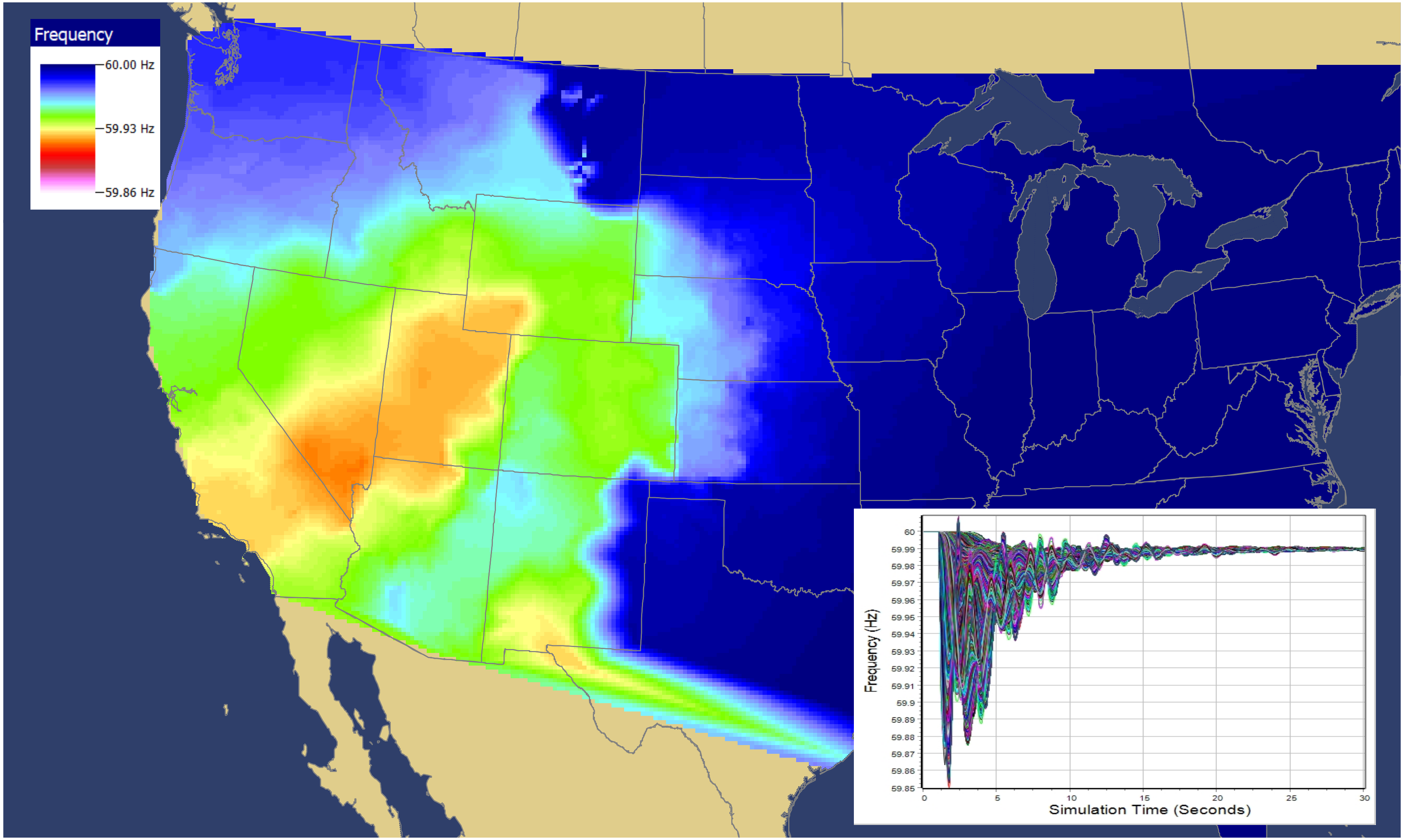
Large-Scale Grids are Now Available

This is an 82,000 bus synthetic model that we publicly released in summer 2018. Both schools have expertise in creating such grids



Grid has an AC power flow solution with n-1 reliability

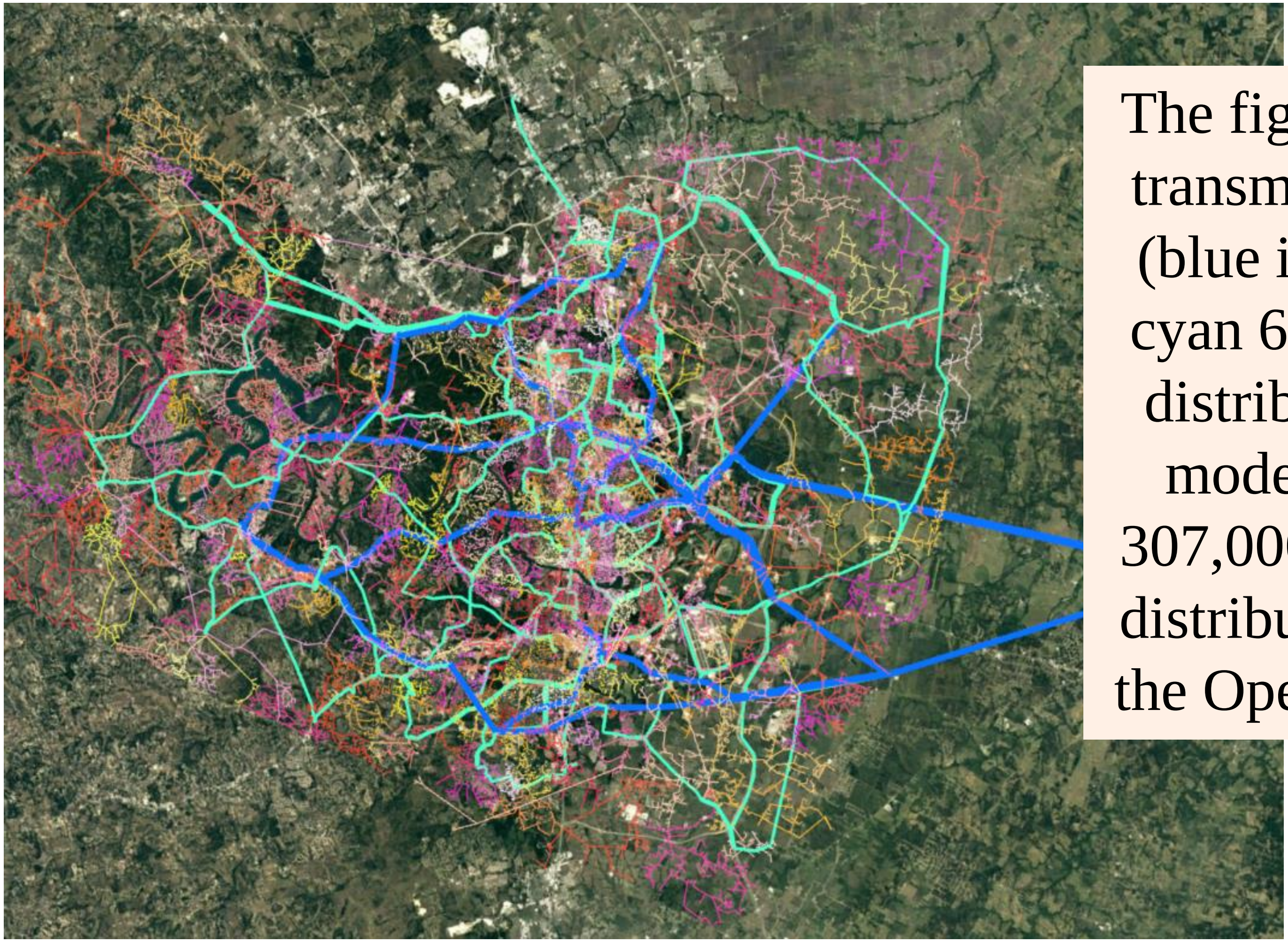
Application for a Grid Interconnect Study



Highly Detailed Combined T &D Grids

- Previous transmission grids were geographic to the zip code level
- On a current ARPA-E project we (with NREL) are developing “down to the meter” synthetic grids
- Actual parcel data is used to determine location of the electric meters. The parcels are connected by a distribution system, and the distribution system by a transmission grid
- Currently we have about 50% of the load in Texas done (southern part of the state including Houston, San Antonio and Austin)

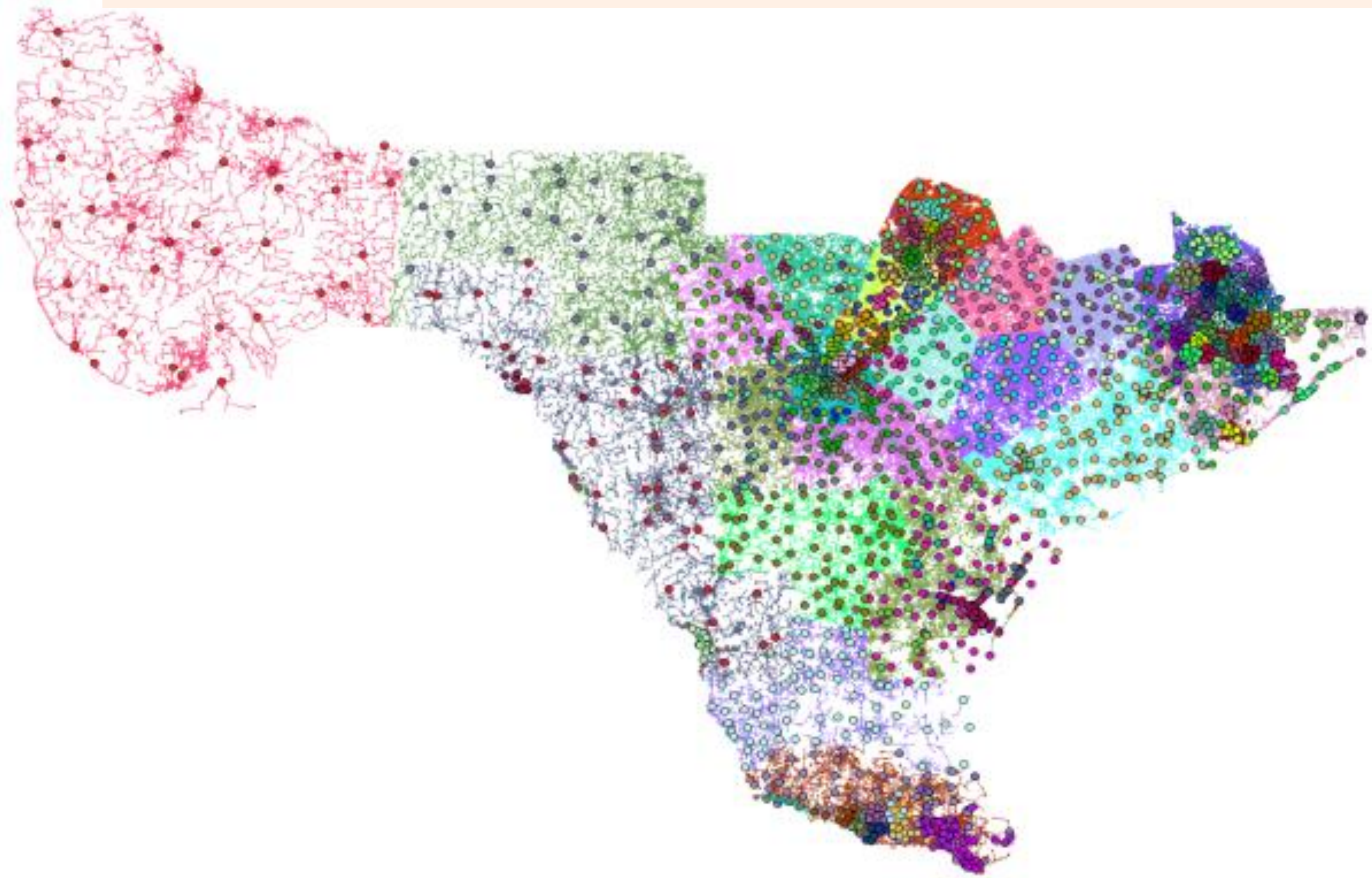
Travis County, TX (Location of Austin)



The figure shows the transmission system (blue is 230 kV and cyan 69 kV) and the distribution system modeled down to 307,000 meters. The distribution data is in the OpenDSS format.

Example Distribution Circuits

The figure shows a synthetic distribution system for South Texas with a total of 8.4 million electric meters and 21.7 million electric nodes.



Different Levels of Modeling

- Just because we have detailed grids, doesn't mean we always simulate the coupled transmission and distribution models. Other options are
  - Transmission only
  - Distribution only
  - Full transmission with distribution topology; this can be quite useful for doing multi-infrastructure simulation in which we just need to know what parts of the distribution system are out-of-service or other data attributes (such as the location of electric vehicles)

The Four Project Tasks and The Work Plan

1. Developing customized grids
2. Developing specific grid scenarios
3. Exploring decision making with uncertainty
4. Expanding the scope of synthetic grids for coupling with other infrastructures

Work Plan: (Q = quarter, KD=Davis, BL=Lesieutre, TO=Overbye, LR=Line Roald)

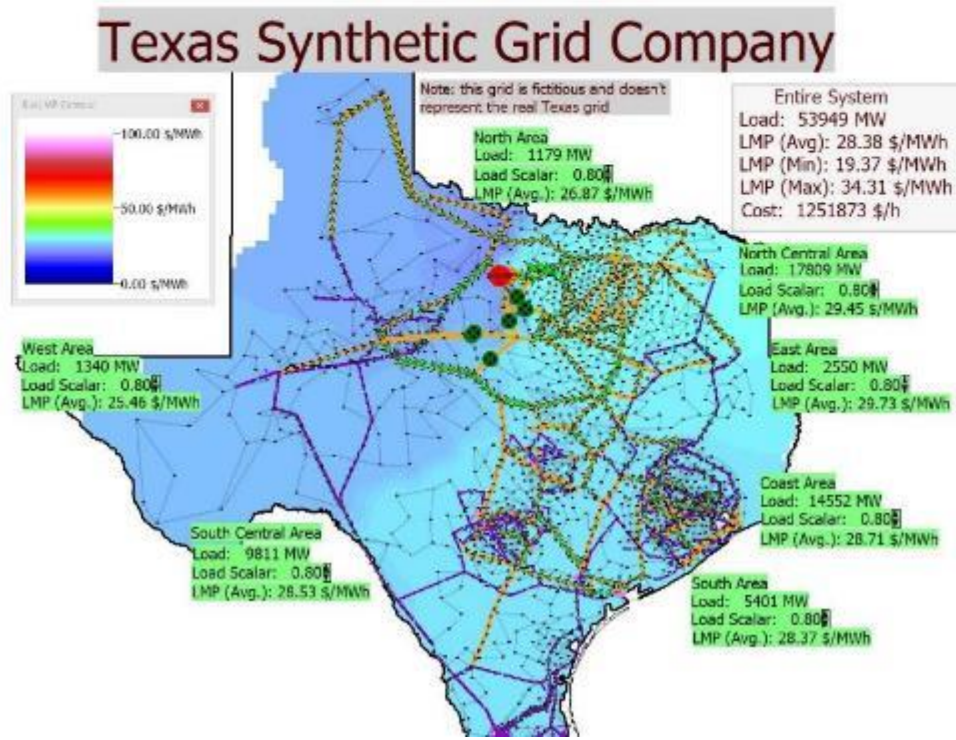
Task	Researchers	Q1	Q2	Q3	Q4	Q5	Q6	Q7	*Q8*
1	BL, TO	x	x						
2	KD, LR		x	x	x	x			
3	KD, LR,TO				x	x	x	x	
4	KD, TO, BL	x	x	x	x	x	x	x	x

Task 1: Developing Customized Grids

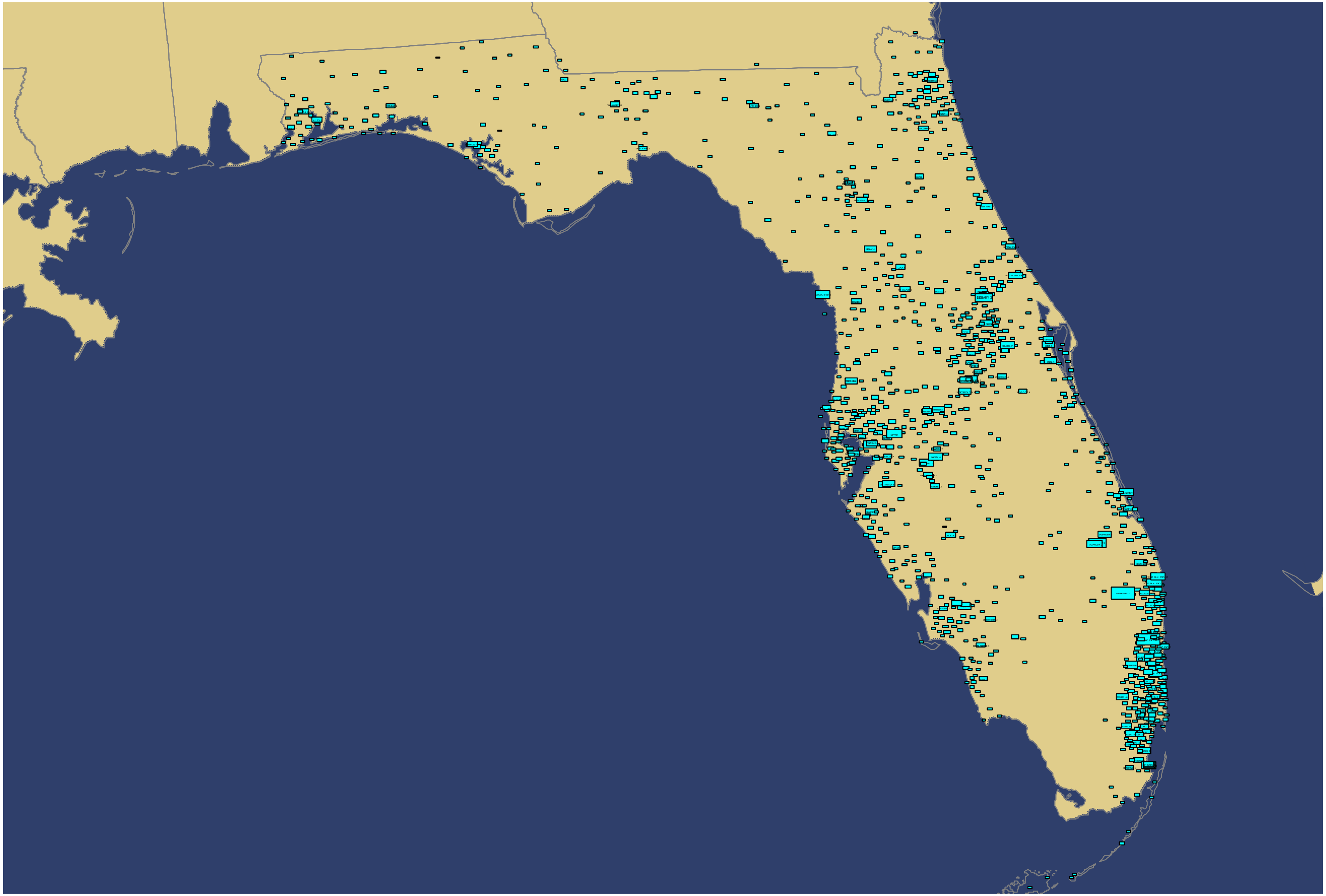
- For this task we will work with our IAB members to build grids on footprints of interest with desired characteristics
  - We have lots of experience doing this!
  - Particular idiosyncrasies can be included in these grids
- These grids can then be used as desired by the IAB members
  - Fully public or not
  - Used by local universities for research and education
  - Provided to potential vendors
- Expected grids sizes up to ten thousands buses

Synthetic Grid Applications: Innovative Electric Power Education

- Lab assignments involving a 2000 bus case have been integrated into Texas A&M's power classes
- Class includes large-system exercises for power flow, economic dispatch, contingency analysis, SCOPF, and transient stability

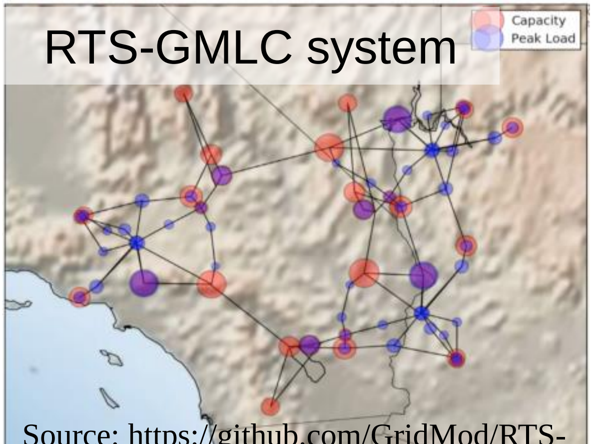


Example of a Custom Case: 2380 Buses



Task 2: Developing Specific Grid Scenarios

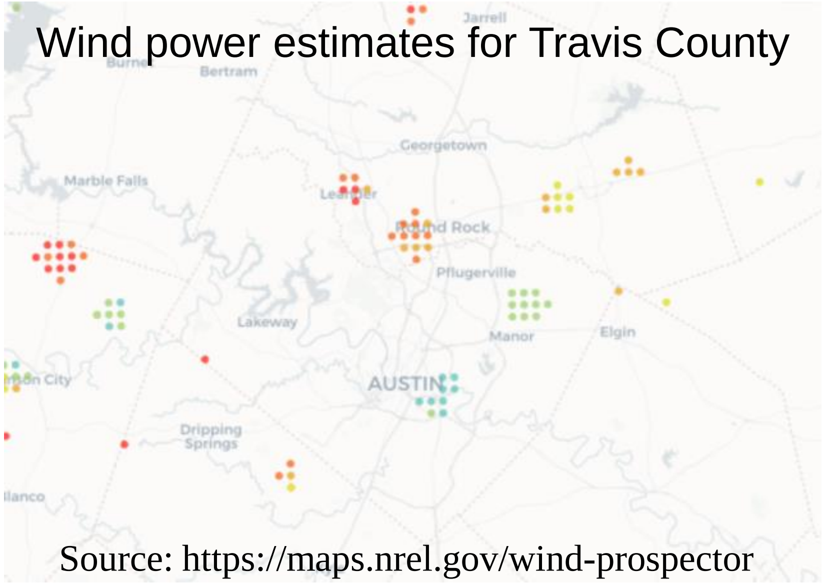
- For this task we will be developing specific scenarios
  - For example synthetic grids based on specific geographic footprints can be combined with data sets describing renewable energy resources
- Recent effort by NREL to update the RTS system with renewable energy generation
  - \+ Very useful!!!!! (**only** easily available data set)
  - \- Limited size
  - \- Grid arbitrarily located
  - \- Only one data set



Source: https://github.com/GridMod/RTS-GMLC/blob/master/RTS-GMLC.pdf

Task 2: Developing Specific Grid Scenarios

- Synthetic grids with renewable resources
  - Synthetic grid for a give geographical footprint
  - Open resources with wind and solar data (available from NREL)
  - Publicly available aggregated data on total renewable energy production (available from system operators)



Source: https://maps.nrel.gov/wind-prospector

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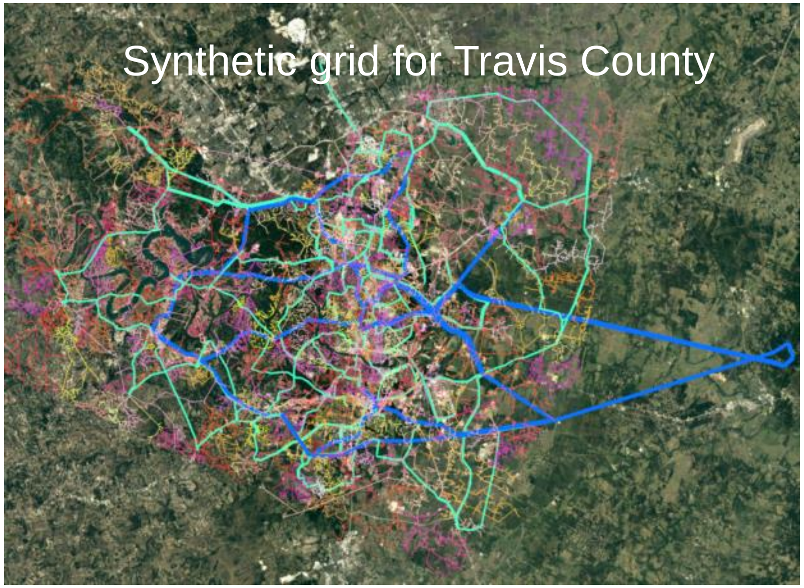
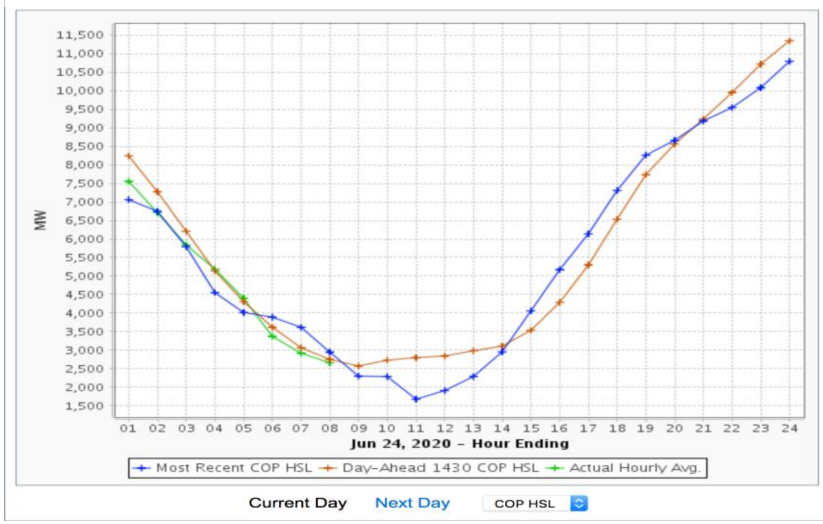


Task 2: Developing Specific Grid Scenarios

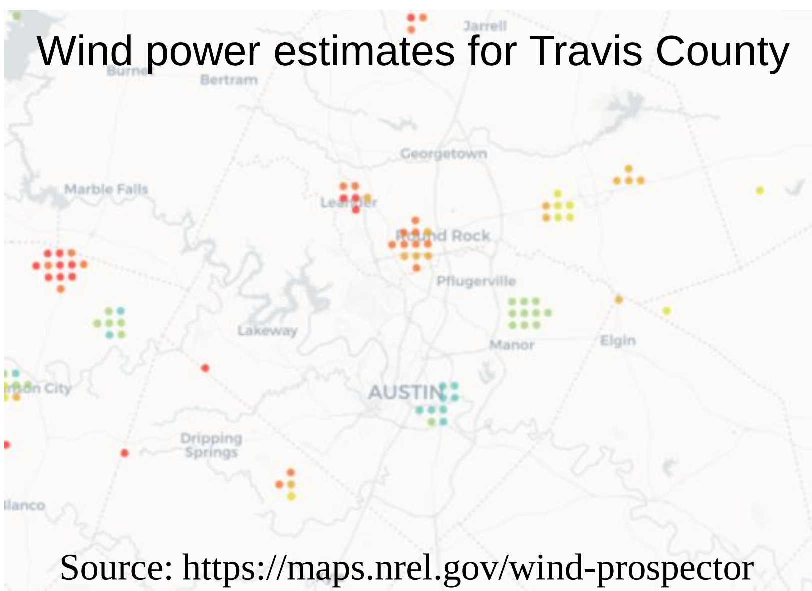
ERCOT Wind Power Production



\+ Other data of interest

...

Wind power estimates for Travis County



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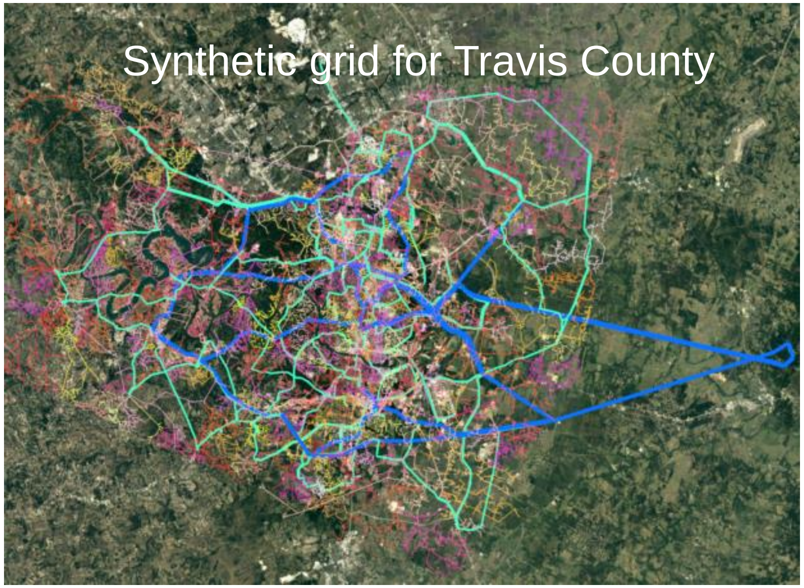
Synthetic grid for Travis County



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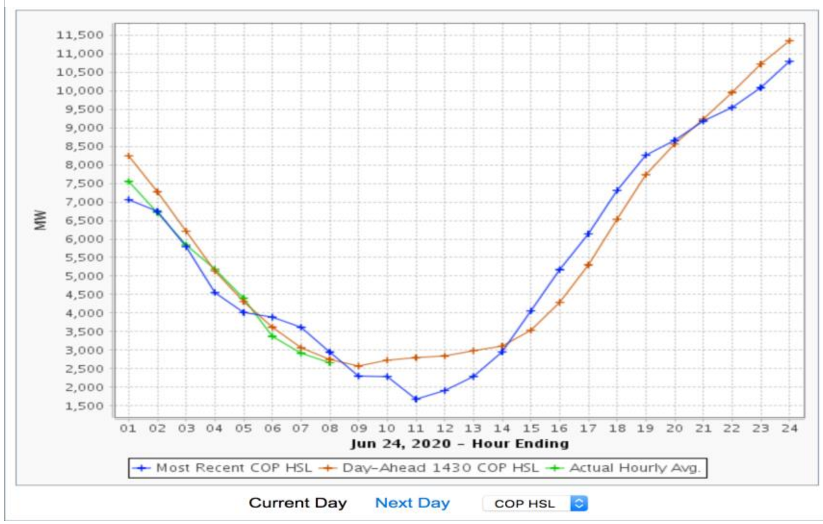

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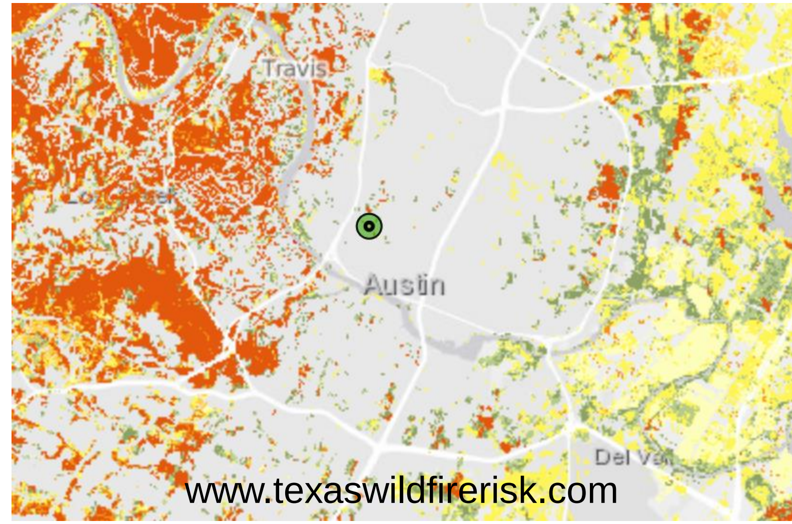
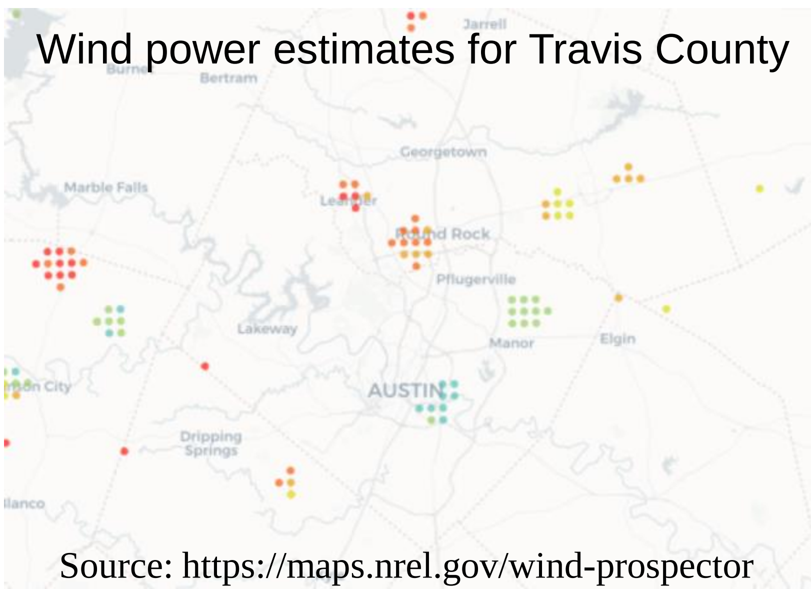
Travis county wildfire risk



www.texaswildfirerisk.com

Wind power estimates for Travis County



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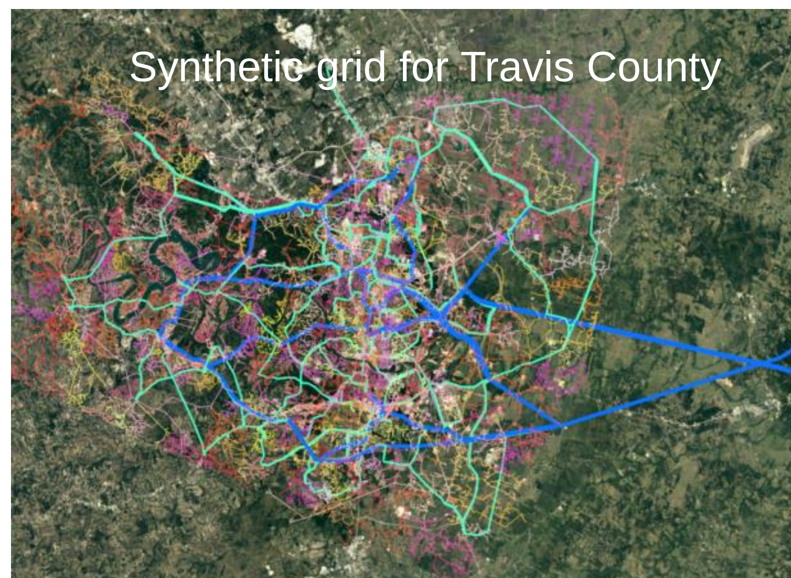
Synthetic grid for Travis County



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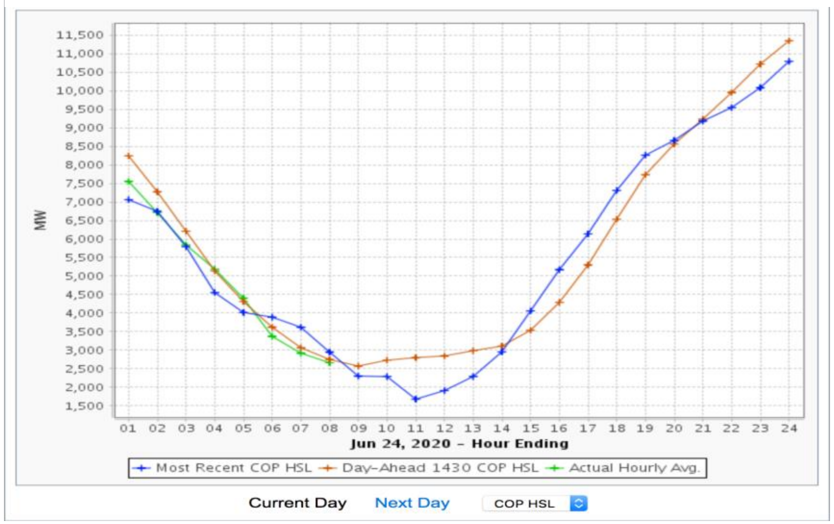

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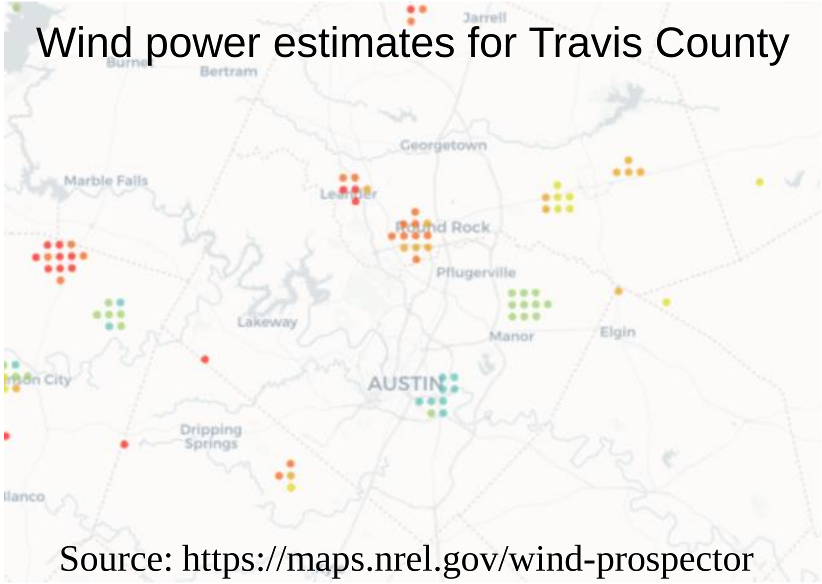
Model technology

- energy storage
- HVDC / Low-freq. AC
- other technology



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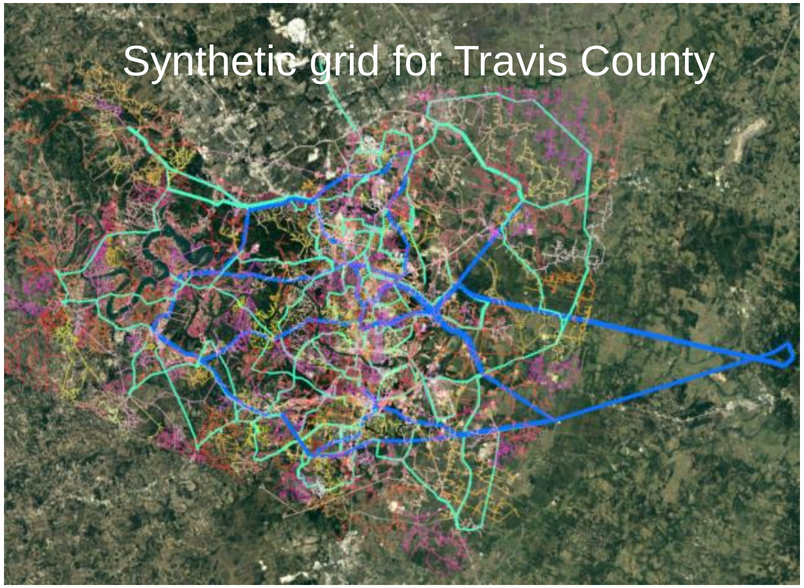
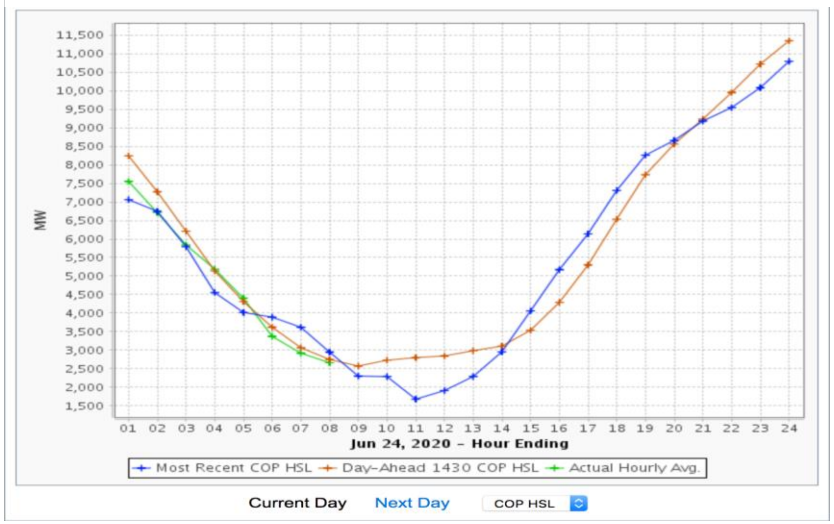


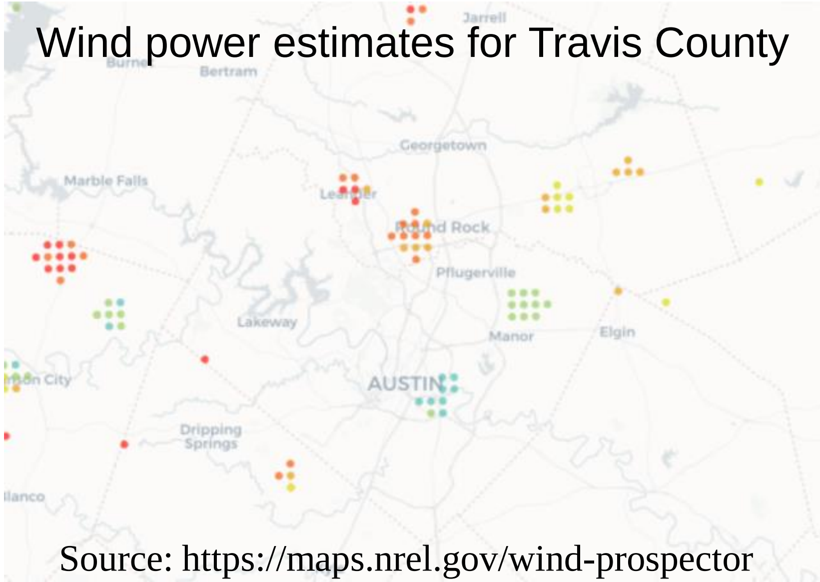
Synthetic grid for Travis County

Task 2: Developing Specific Grid Scenarios

ERCOT Wind Power Production



Scenarios, data and
\+ technologies of interest to
industry team members?



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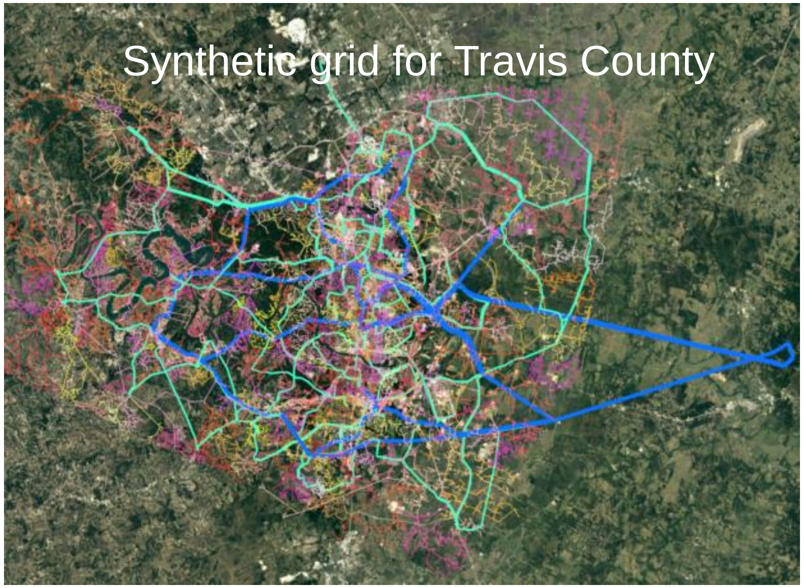
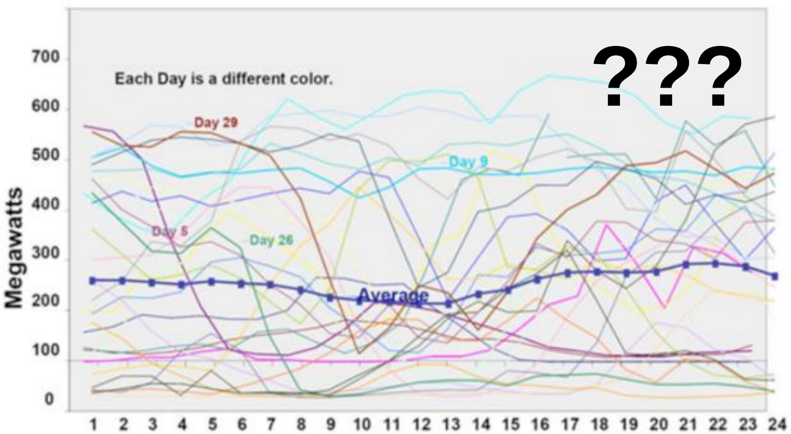


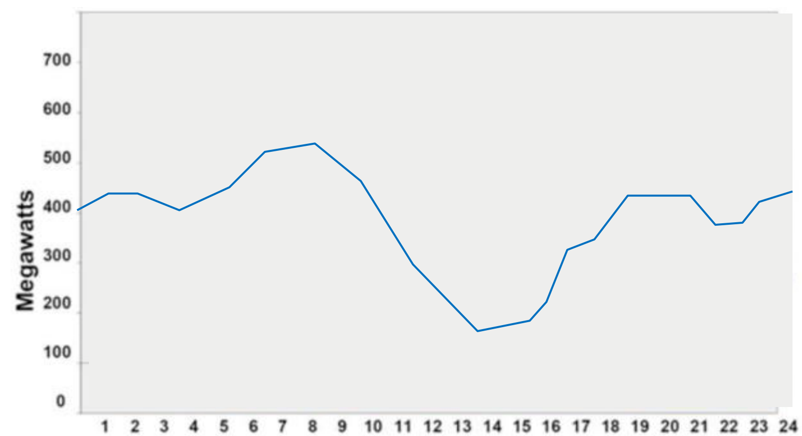
Task 3: Exploring Decision Making with Uncertainty

- Decisions taken with uncertain information might often seem like **bad decisions** in hindsight

Optimal dispatch given uncertain renewable generation ≠ Optimal dispatch given actual renewable generation



Source: Wind energy from CAISO (2007)



Task 3: Exploring Decision Making with Uncertainty

- How to manage different kinds of uncertainty?
  - Component failures
  - Renewable variability
  - …

N-1 doesn't cut it…

Update how we think about and teach power system security

- How is this done now? What are open needs?
- How can our research help?

Task 3: Develop Scenarios to Explore Decision Making with Uncertainty

Goals

- Create *scenarios* for exploring decision making under uncertainty
  - These can be simple or quite complex
  - Could consider quite stressed system conditions
- *Develop a platform* for testing and comparing approaches to make operational decisions
- Encourage discussion and sharing of best practices *across regions*

Task 2: Developing Specific Grid Scenarios

- Develop and evaluate cyber-physical grid scenarios that consider DERs and threats involving them
- Use large scale synthetic models of Task 1, particularly coupled T&D models mentioned earlier, and expand them as necessary
- Develop specific hazard and threat scenarios for DERs
- Model interconnected cyber systems
- Generate and analyze data on these threats to develop defenses

Task 2: Developing Specific Grid Scenarios

- Idea is to better answer how to measure and control DER impact on resilience (in a cyber-adversarial environment)
- Student: Shashwat Tripathi (MS)

Task 3: Develop Scenarios to Explore Decision Making with Uncertainty

- Synthetic grids in our testbed allows us to explore user actions taken by different roles (i.e., operators) in a “sandbox” environment
- Using our CIR cyber-physical testbed, we will be researching ways to model and mimic operator actions, i.e., using deep reinforcement learning
  - Inferencing/predicting/recommending adversary/defender actions under uncertainty
  - Develop decision making algorithms
  - Experiments and evaluation of decision support algorithms for the DER hazard scenarios we will be developing in Task 2

Task 3: Develop Scenarios to Explore Decision Making with Uncertainty

- Use our cyber-physical testbed capabilities to help develop a sharable/remotely accessible platform for testing and comparison of these types of approaches for the community

Task 3: Develop Scenarios to Explore Decision Making with Uncertainty

- Conduct live exercises in our testbed, leveraging the models and tools developed in this project
- Allow different classes of users (i.e., this could range from undergraduate students all the way up to experienced operators) hands-on opportunities to interact with these models
  - (Note- I’d like to relate this back to potential work with the human factors experiments faculty member we’d met with a while back on this)
- Generate and analyze data to understand how decisions are made

Task 4: Coupling Synthetic Grids With Other Infrastructures

- Infrastructural dependency modeling for hazards
- Modeling cyber-physical interconnections
  - Cyber communications and control that directly support power systems
  - How to generate and store and manage these in a generic way for any case and scenario
- Extending to other dependencies that may impact power systems under hazards
  - Generation units and their dependencies
  - Natural gas
  - Transportation

Task 4: Coupling Synthetic Grids With Other Infrastructures

- Work on interdependency modeling will relate to the scenarios developed under Task 2

- Specifically, we will consider what infrastructure needs to be modeled to assess research questions about DERs and impact described earlier

Task 4: Coupling Synthetic Grids With Other Infrastructures

- What are the interconnection points between these different infrastructural models?

- How do we properly store and share the information in multi-infrastructure power system models?

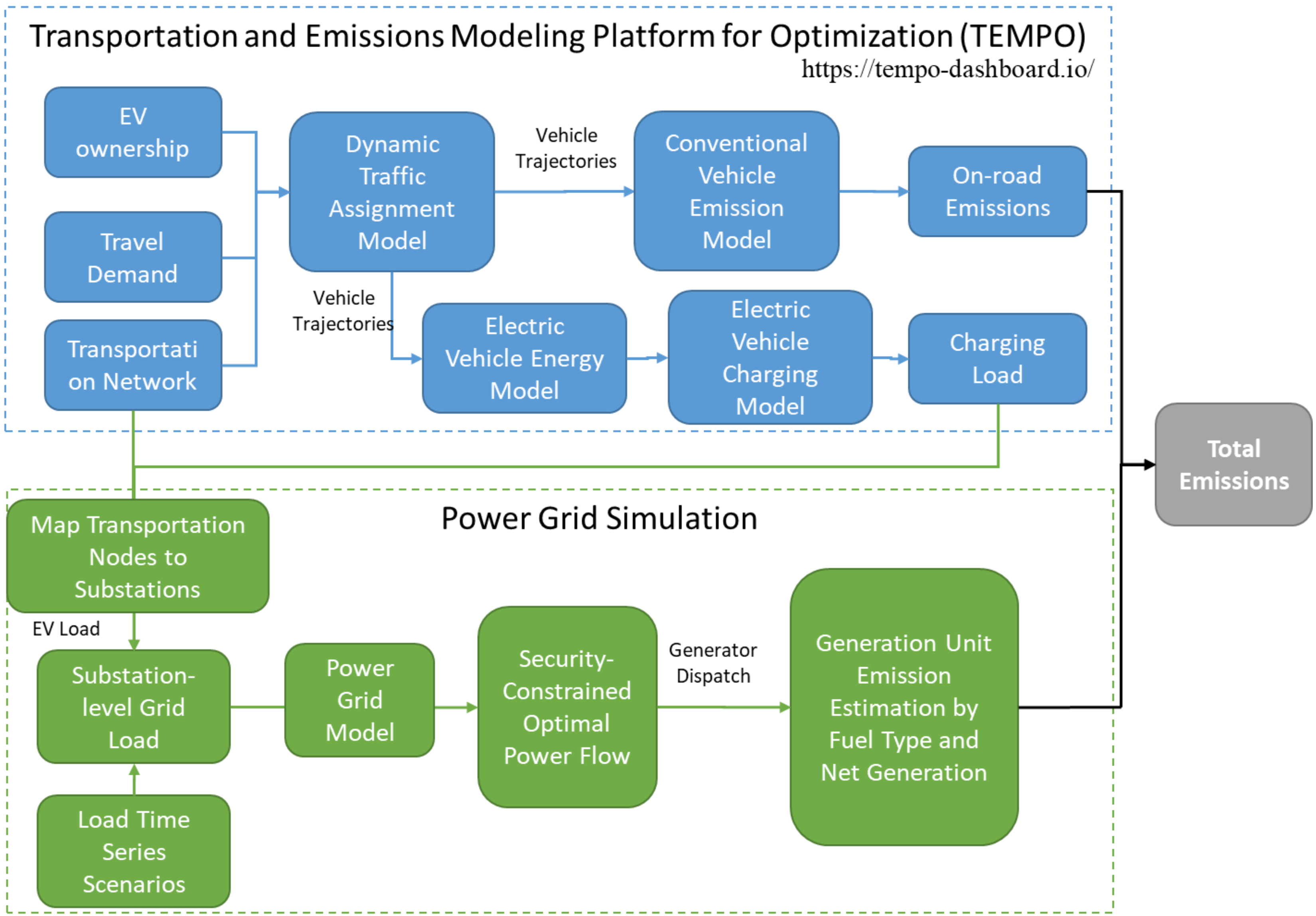
Task 4: Coupling Synthetic Grids With Other Infrastructures

- In this portion of the task we plan on exploring coupling our synthetic grids with other infrastructures
- This leverages the actual, parcel-level geographic coordinates in the highly detailed electric grids
  - Real and synthetic metadata can be used, such as the number of people at a location, the presence of electric vehicles, or the amount of distributed solar
- Our first focus will be on transportation

Task 4: Coupling Synthetic Grids with Transportation

- EV charging is the point of coupling
- EV consumption, and charging patterns calculated with detailed traffic assignment and vehicle models
- Synthetic transmission networks with distribution topology can help map these loads to transmission substations
  - Algorithm implemented on Travis county – can be applied elsewhere where model data is available (T&D network, road networks)
- Applications include emission analysis, or impacts of natural disasters on these coupled networks

Task 4: Coupling Synthetic Grids with Transportation



The Simulation Environment at Texas A&M

Summary

- The goal of the project is to work closely with the industrial team to generate value from large-scale, detailed and realistic synthetic electric grids.
- The four project tasks are
    1. Developing customized grids
    2. Developing specific grid scenarios
    3. Exploring decision making with uncertainty
    4. Coupling the synthetic grids with other infrastructures
- We're very excited to be doing this project and to have such a strong PSERC IAB team!

Thank You! Questions and Discussion