Innovations on Power Grid Resilience at the Eversource Energy Center

Emmanouil Anagnostou
Center Director
Alumni Association Distinguished Professor
Endowed Chair in Environmental Engineering
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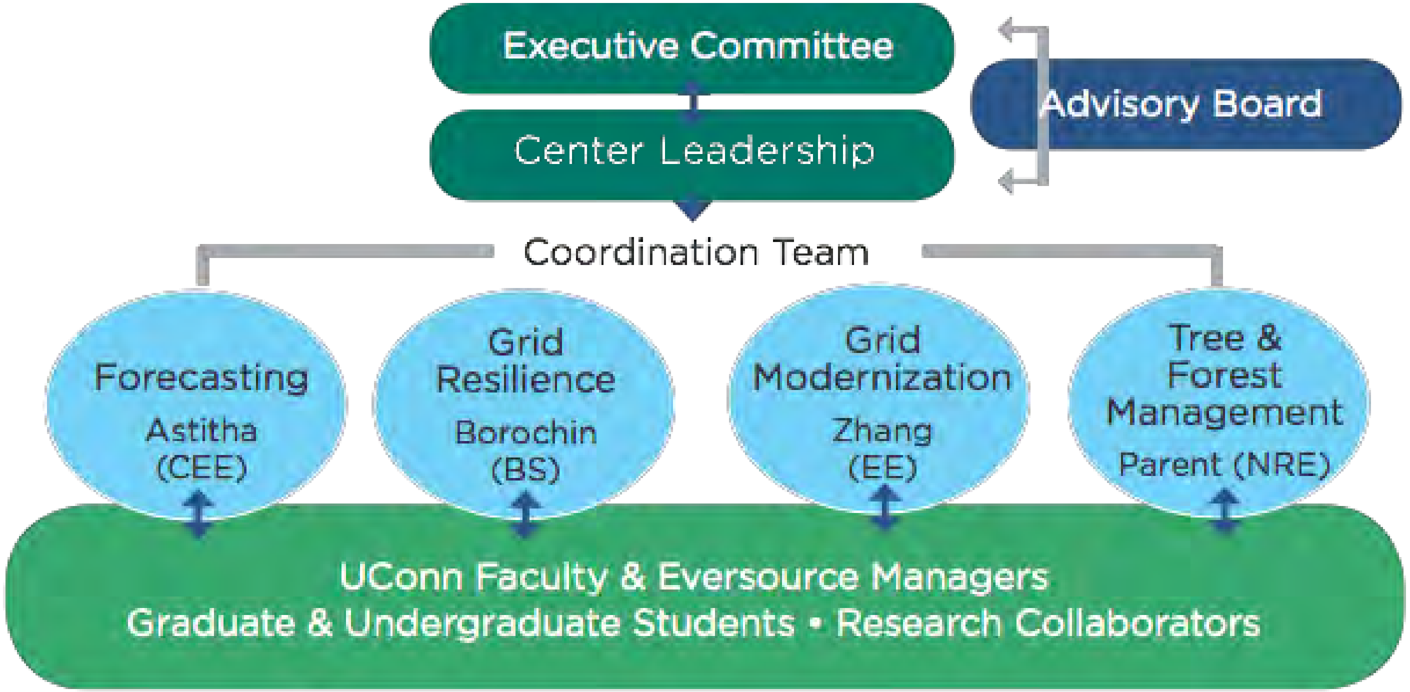
09/12/2018 – IEEE-USA Energy Policy Committee Meeting

Eversource Energy Center

Center Leadership
Director, *E. Anagnostou (CEE)*
Associate Director, *A. Morzillo (NRE)*
Manager, *M. Peña (CEE)*
Eversource, *Rod Kalbfleisch*

Governance
10 Member Executive Committee
10 Member Advisory Board

Team
23 UConn faculty
10 Eversource managers
27 Graduate students
20+ Undergraduate students



Executive Committee

UConn and Eversource Energy leadership are providing real-time insights and governance for our Center activities.


Radenka Maric


Kazem Kazerounian


John Elliott


Cameron Faustman


Craig Kennedy


Rod Powell


Ken Bowes

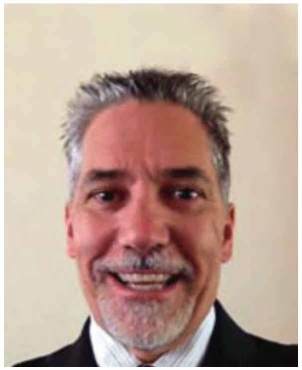

Jim Hunt


Aftab Khan


Roger Kranenburg

Advisory Board

Our Board's expertise in industry, government and academia is recognized regionally and nationally for their utility, technology, policy, cyber and leadership expertise.



Doug Dorr
EPRI

Katie Sharf Dykes
PURA-CT

Bill Hackett
CT-EMHS

Art House
Chief Cyber Security Risk Officer

Rob Klee
CT-DEEP

David Owens
EEI (retired)

Christina Sames
AGA

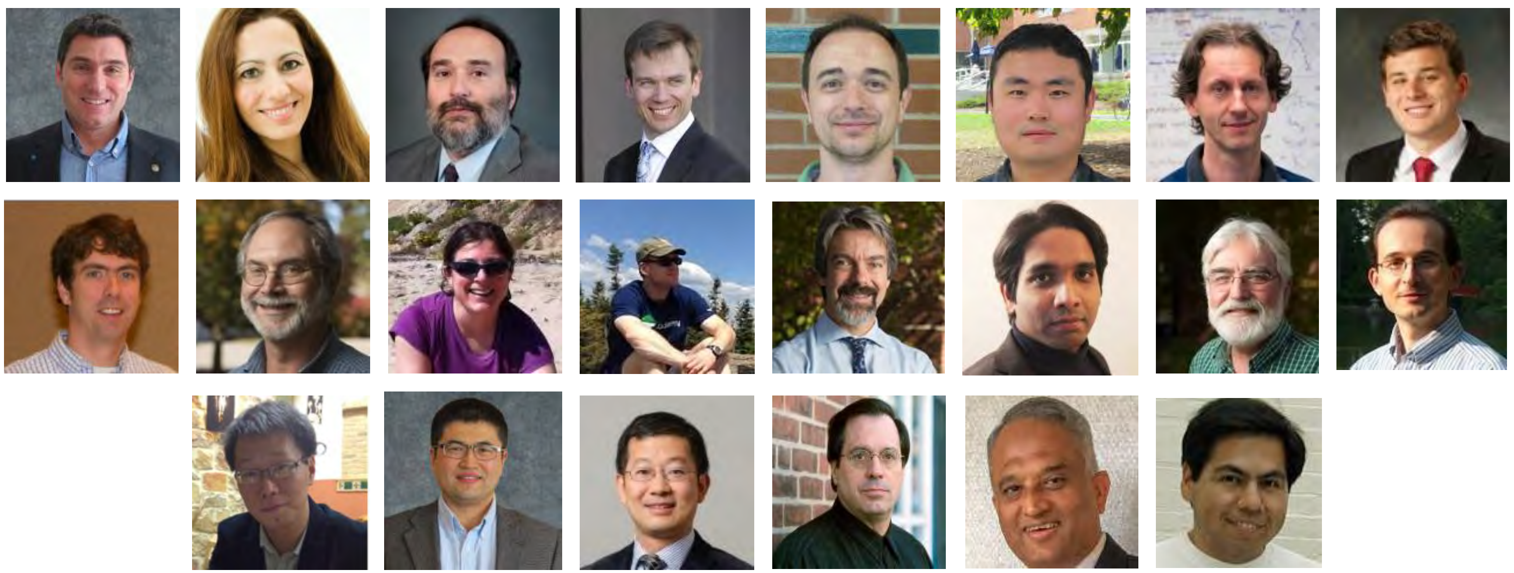
Joe Thomas
AVANGRID

Peter Rothstein
NECEC

Anne George
ISO-NE

Affiliated UConn Faculty Members

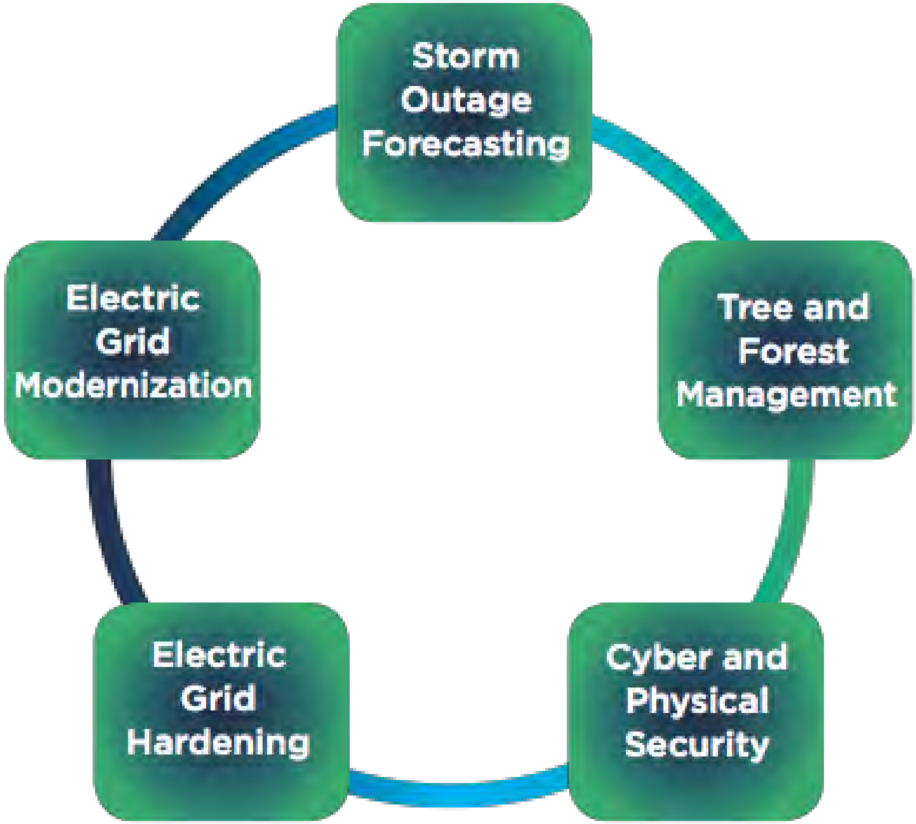
Our Center taps the expertise of 22 faculty members across the UConn School of Business, School of Engineering, and College of Agriculture, Health and Natural Resources.



Mission & Research Goals

Delivering utility industry-relevant technologies and science-based solutions

"To be the foremost energy utility-academia partnership advancing leading-edge interdisciplinary research and technology assuring reliable power during extreme weather and security events"



Key Initiatives Overview

We are driving the innovations and advances that will create the grid of the future – intelligent, interactive, automated, safe.

- Power Grid Storm Readiness *1 & *2
  - High-Resolution Weather Forecasting
  - Outage Prediction Modeling (OPM)
  - Estimated Time of Restoration Modeling
  - Storm Damage Assessment Tools
- Tree and Forest Management *1
  - Tree Risk Mapping from LiDAR
  - Tree Biomechanics Analyses
  - Vegetation Management Best Practices
  - Community Perspectives
- Cyber and Physical Security *1 & *4
  - Anomaly Detection Preventing Malicious Activity in the power grid
  - Unmanned Aerial Vehicles (UAV) Surveillance systems
  - Substation Flooding Protection
- Electric Grid Hardening *1
  - Systems-Based Modeling to Optimize Grid Management
  - Economic Advantages of Improved Reliability and Outage Prevention
  - LiDAR Infrastructure Mapping
- Electric Grid Modernization *1 & *3
  - Safe Integration of Renewables
  - Optimal Storage Technologies & Distributed Generation (micro-pump-storage, CHE, batteries)
  - Forecasting PV Output
  - Grid Analytics – Forecasting loading
  - Electric Vehicles and Pricing
  - Cascading Failures from PV Systems

*1 *Eversource & AVANGRID*
*2 *EPRI*
*3 *ISO-NE*
*4 *DoE & NSF*

Power Grid Storm Readiness

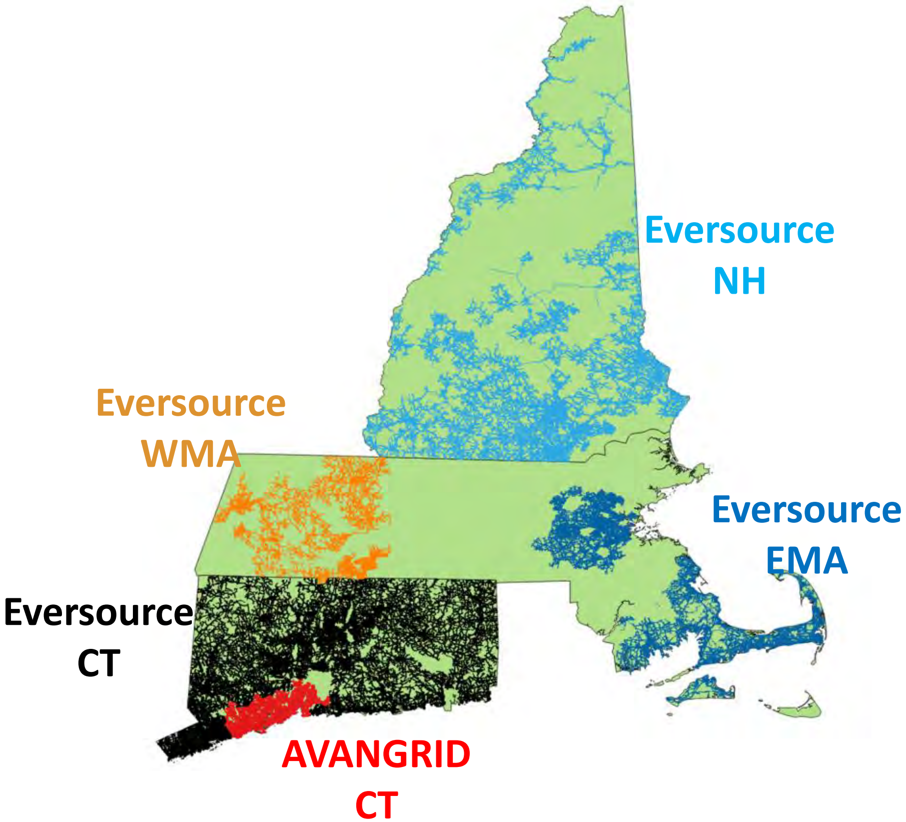
Storm Outage Forecasting

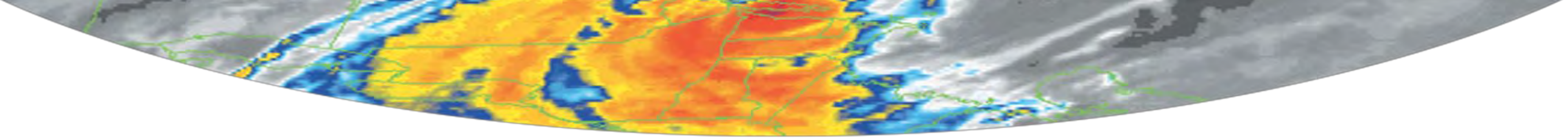
Informed decision making for securing and prepositioning of crews & resources

UConnOPM
OUTAGE PREDICTION MODEL

A computerized intelligence system that combines infrastructure, tree and storm characteristics to:

- predict the likely storm impact and a visualization of where outages are likely to occur.
- provide resiliency insights, such as quantifying the value of vegetation management and other network hardening investments.





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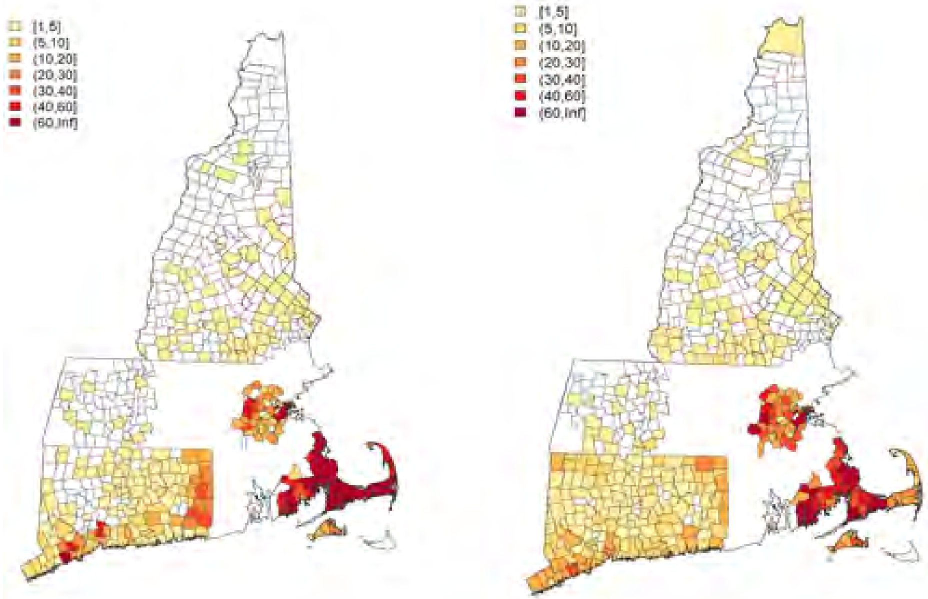
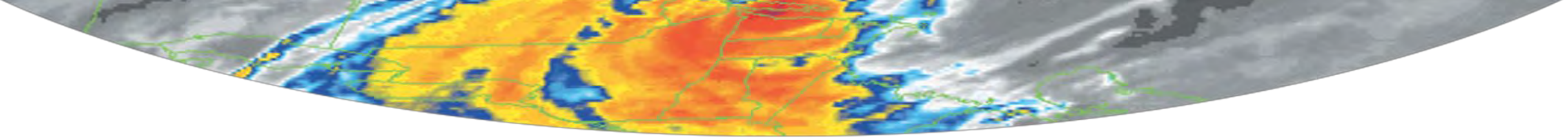
Actual Outages — Predicted Outages by OPM

March 13-14 Nor'easter



TERRITORY	ACTUAL TROUBLE SPOTS	PREDICTED TROUBLE SPOTS
CT	646	500-1000
EMA	4874	2000-3500+
WMA	22	20-40
NH	78	200-400
UI	360	120-250

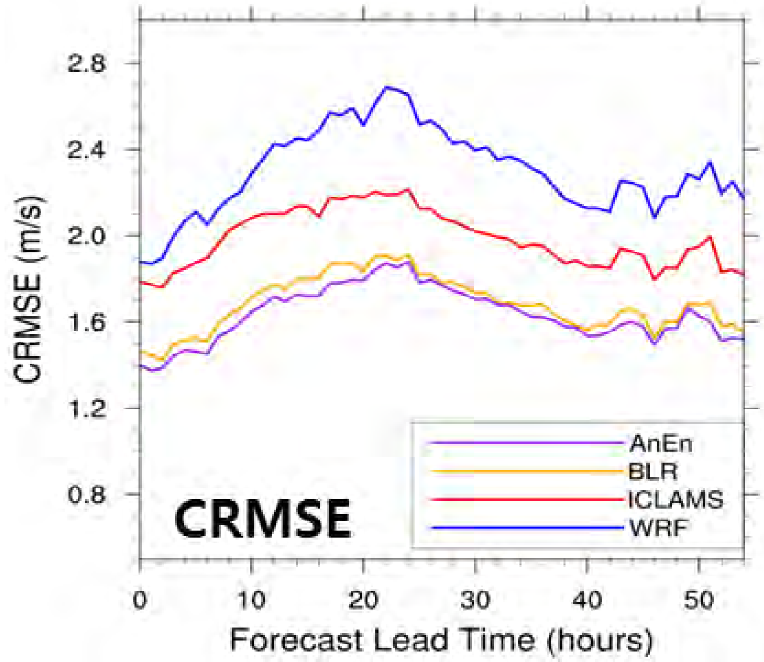


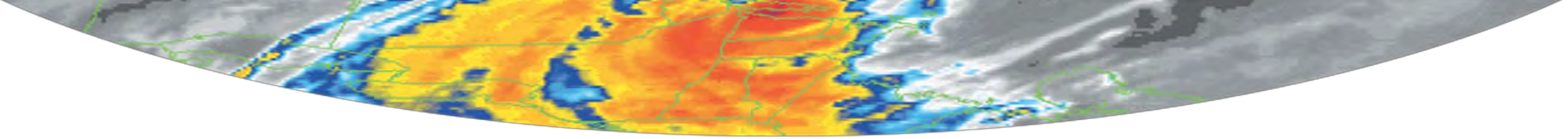
Weather Forecast Improvements

Improved data forcing for outage modeling.

- **Wind speed errors** are reduced by **20-30%** in winter, using various post-processing techniques (*Yang et al., JAMC, 2017*; *Yang et al., MWR 2018*)
- Spatial and temporal errors, both **random and systematic**, are reduced substantially

Random Error Improvement





Weather Forecast Improvements

Improved data forcing for outage modeling.

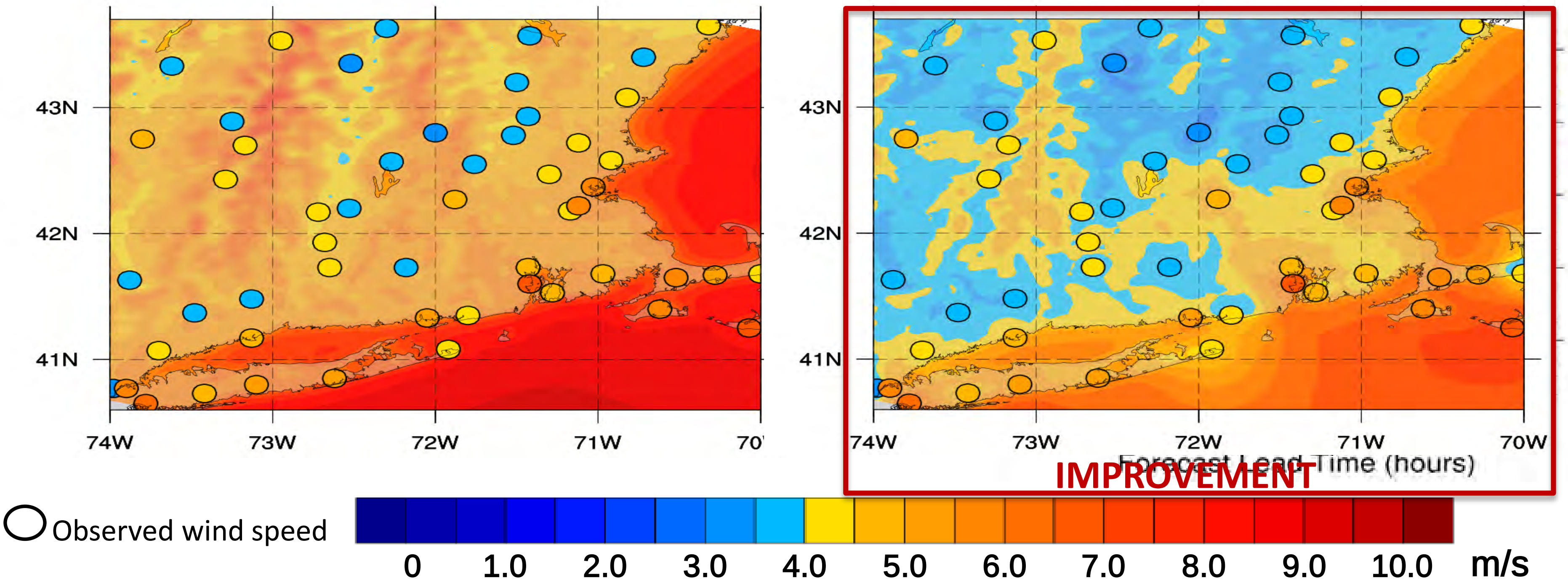
30% error reduction compared to the NCAR ensemble mean

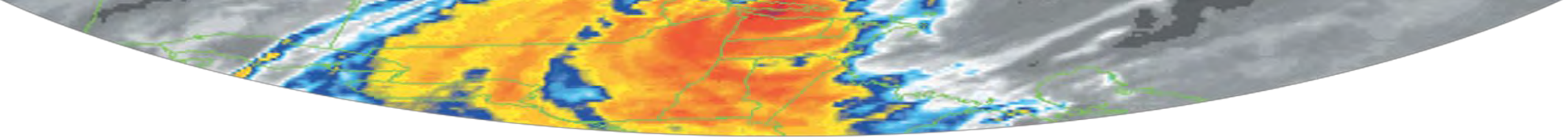
Random Error Improvement

- **Wind speed errors** are reduced by **20-30%** in winter. using various post-

NCAR ENSEMBLE MEAN (original)

Gridded Bayesian Regression

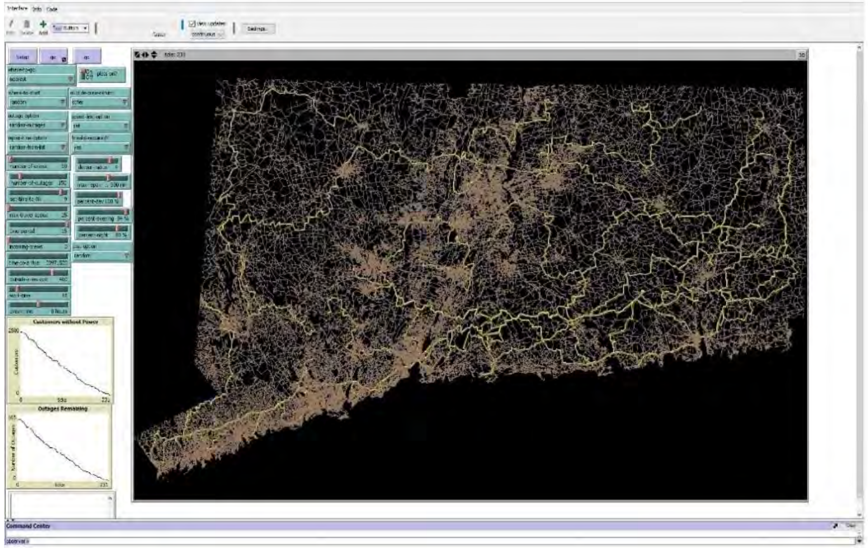


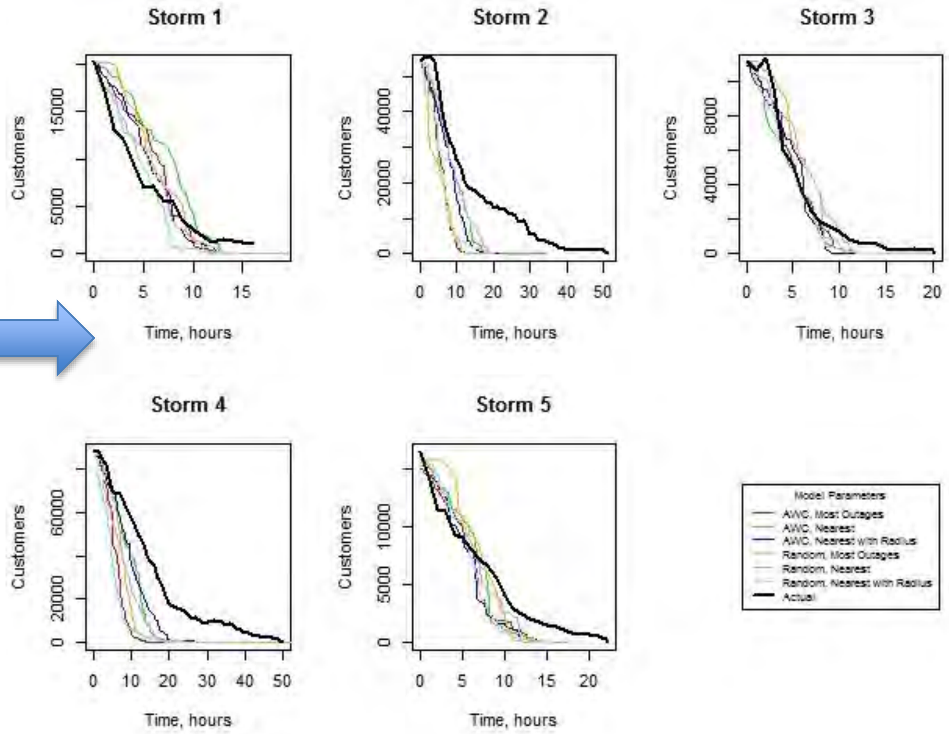


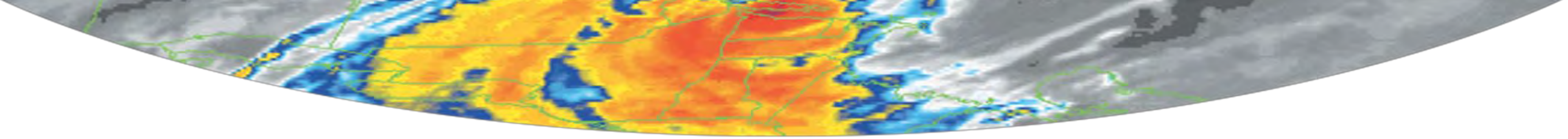
Restoration Time Estimation

Faster and cost-efficient restoration.

Agent Based Model







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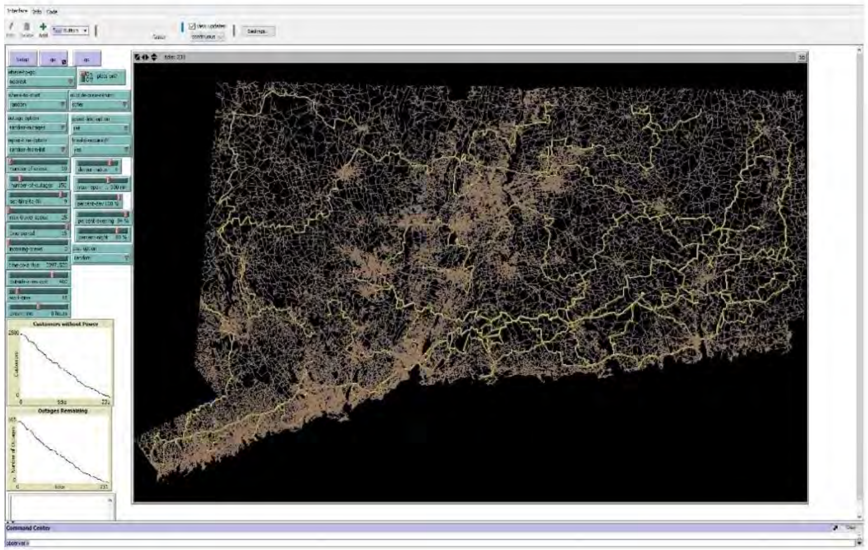
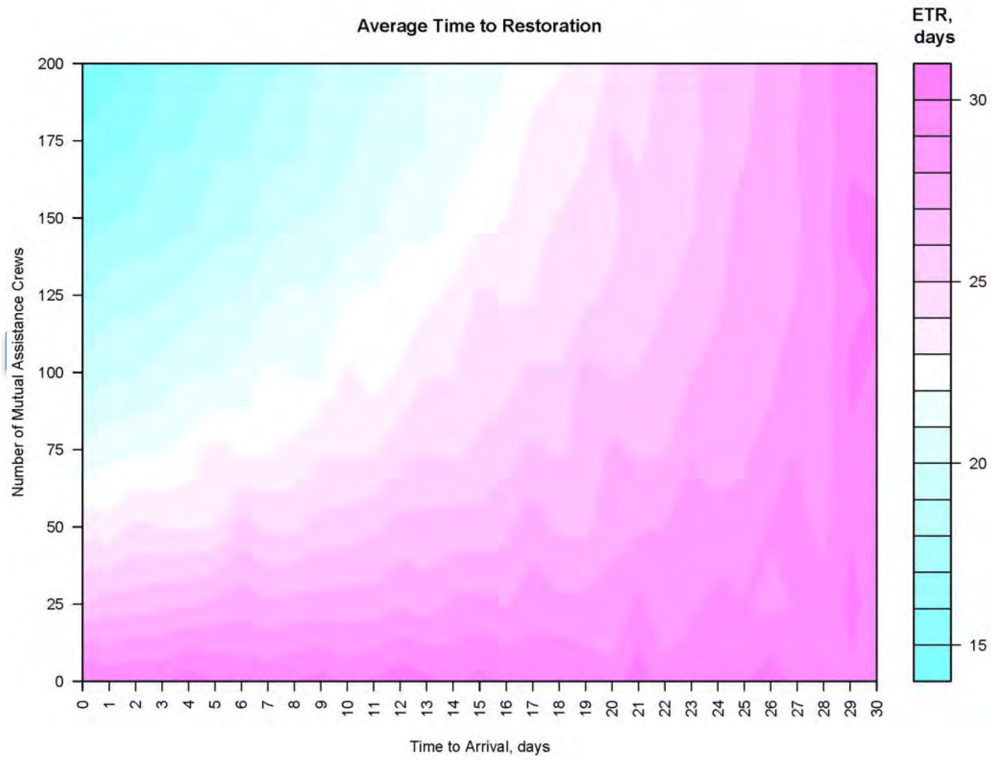
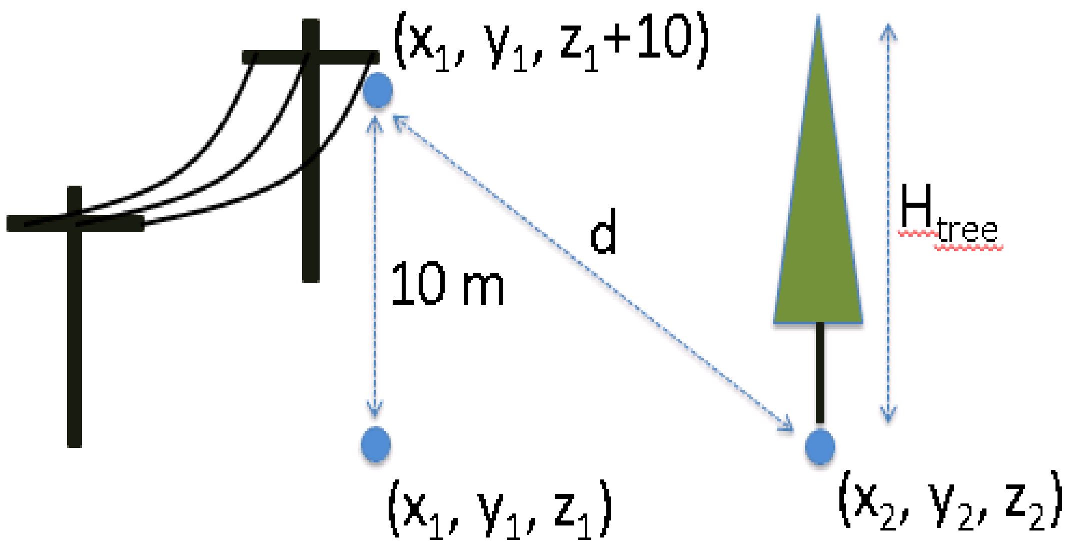




Tree and Forest Management

Identifying tree risk to infrastructure

Use LiDAR to identify locations where trees are capable of striking power lines.

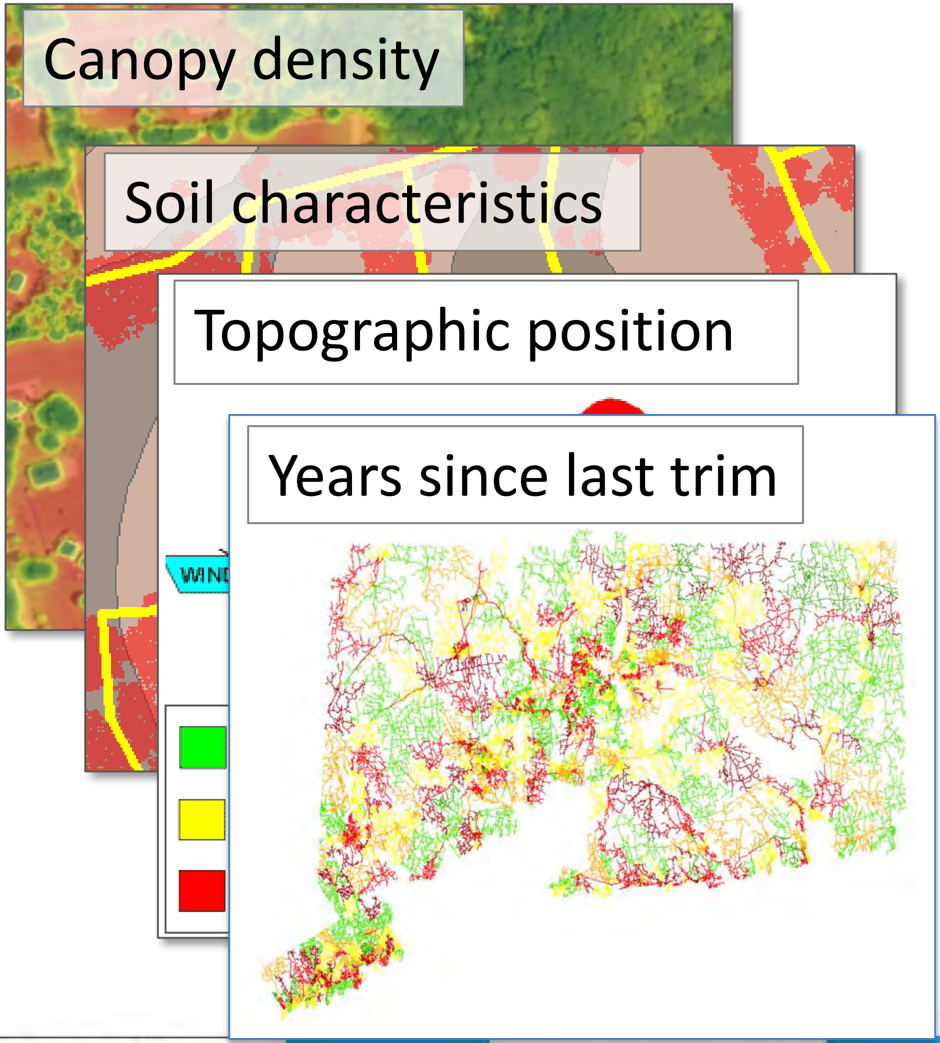


Trees within striking distance of lines

Identifying tree risk to infrastructure

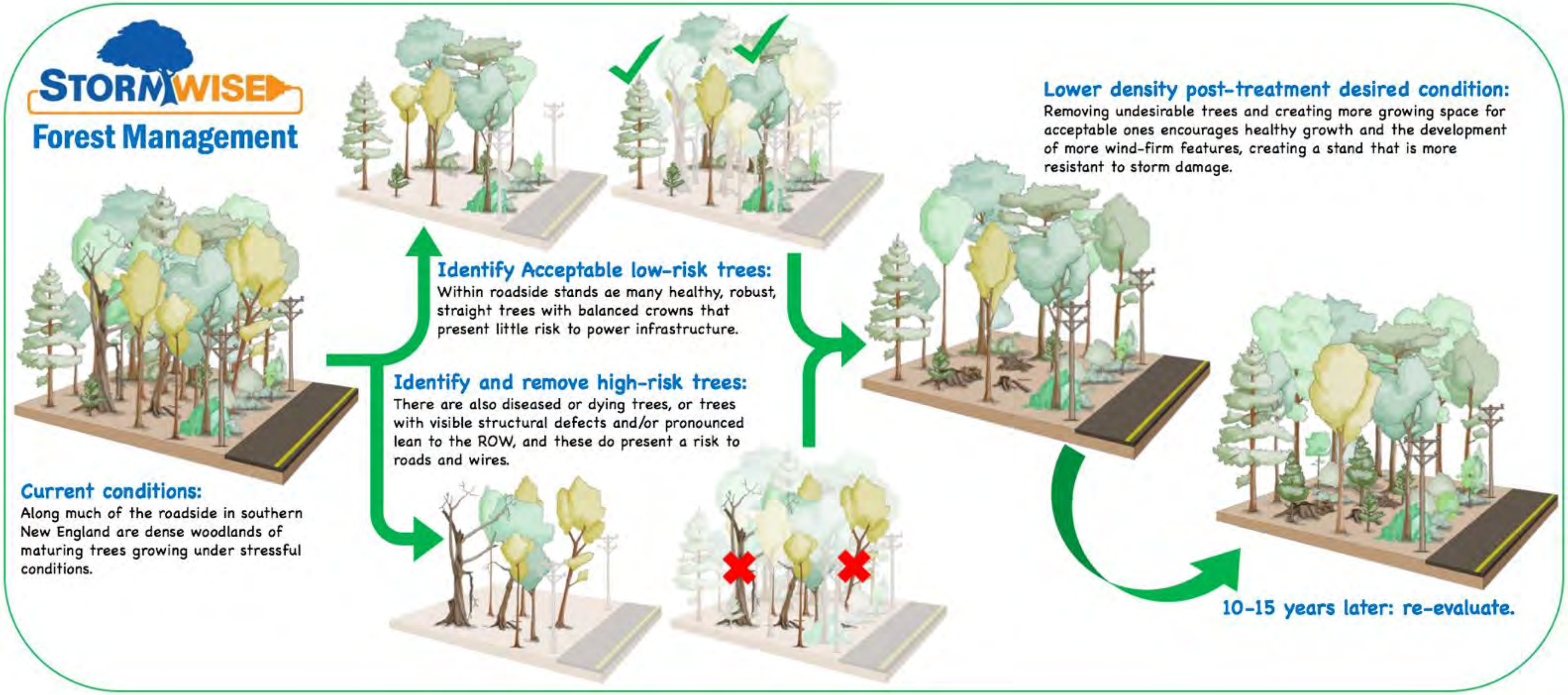
Evaluating tree risk due to environmental conditions.

A vegetation risk model to improve damage prediction and prioritizing vegetation management.



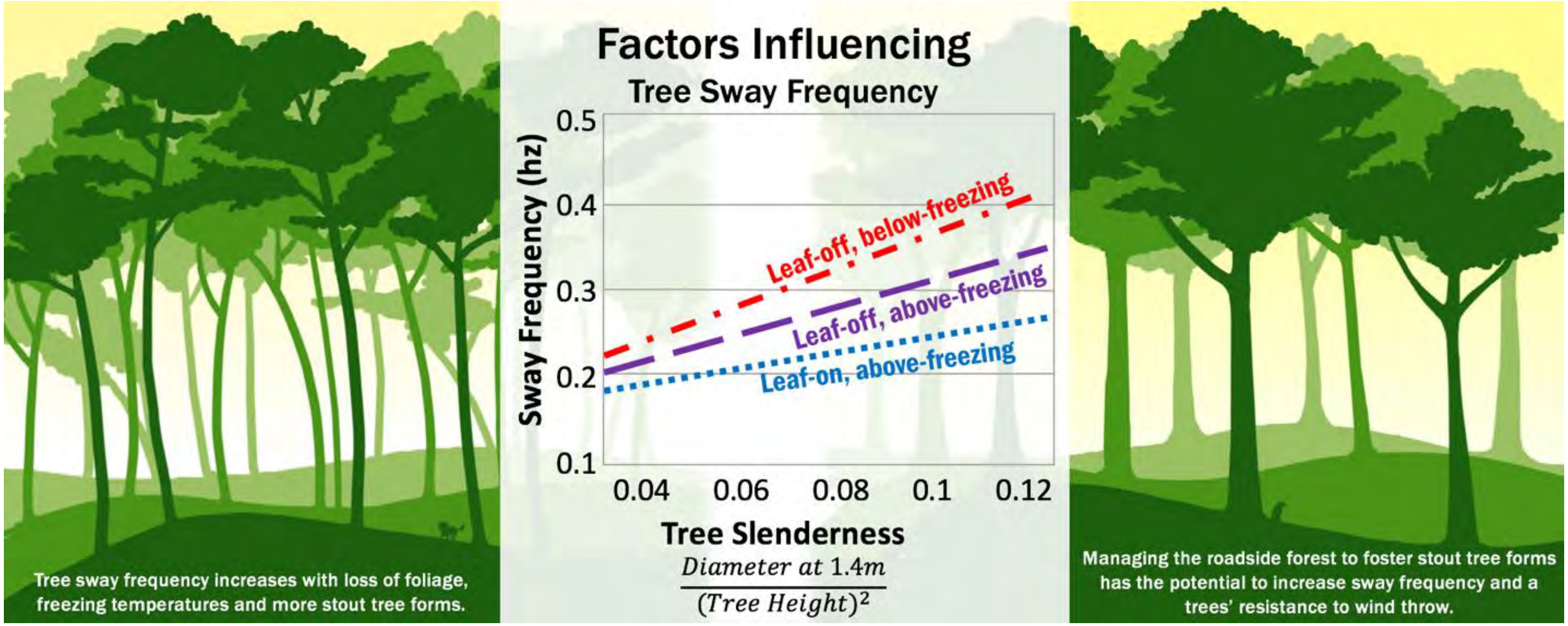
Roadside Management Program

Storm-resistant roadside trees and forests.



Biomechanical Assessment

Improve our understanding of the motion characteristics of trees and changes that take place after a thinning operation.



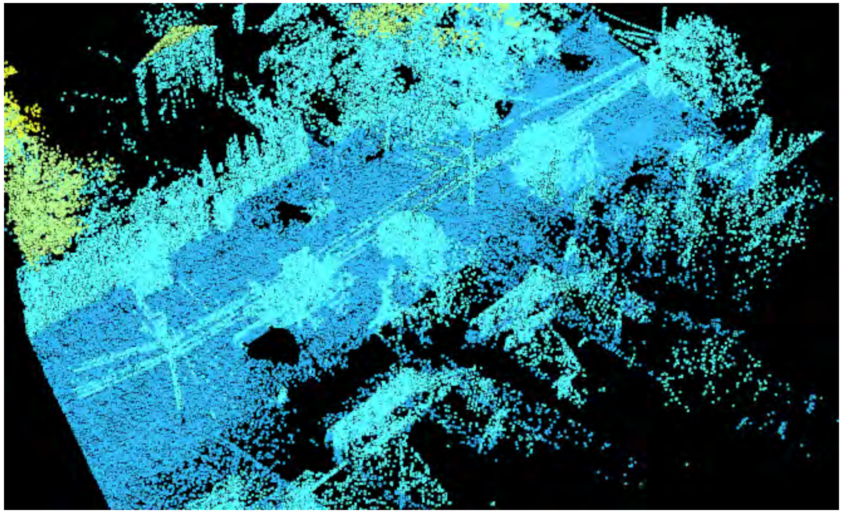
Since 2012, three study sites have been established along roadsides in Connecticut to monitor tree sway under different vegetation management conditions.

Grid Vulnerability Assessment

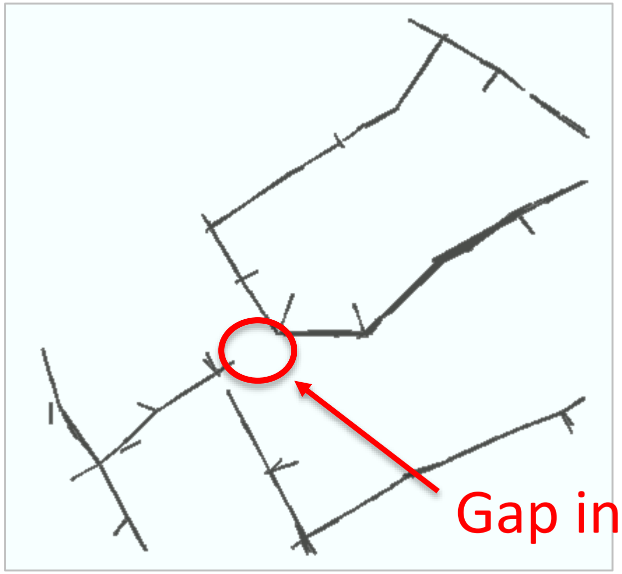
Monitoring Utility Infrastructure

Automated line mapping from mobile LiDAR.

Preliminary algorithm developed to interpolate line locations in areas of vegetation concealment



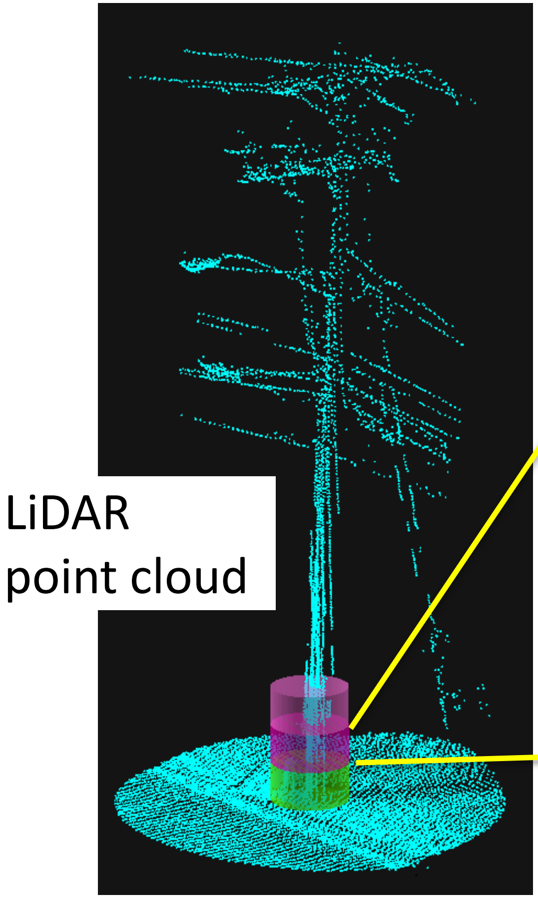
Algorithm results

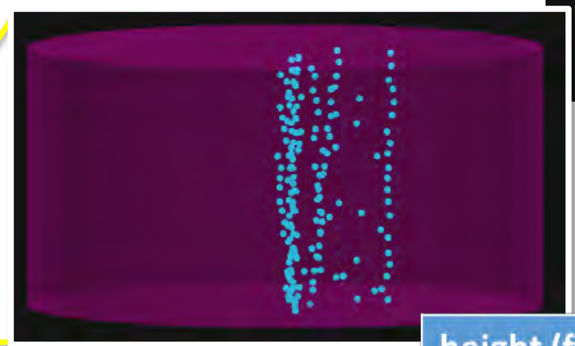


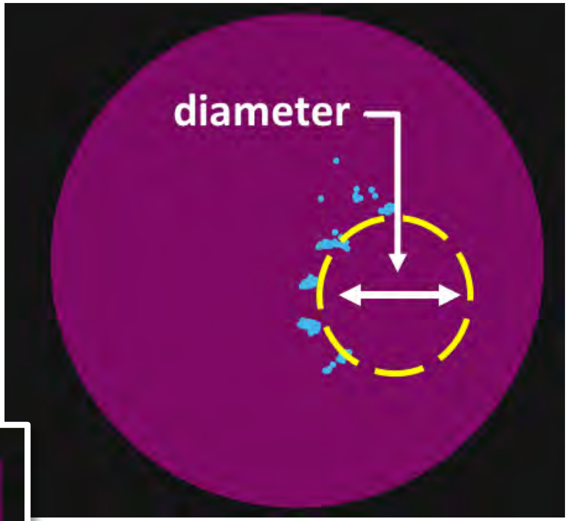
Gap in line coverage

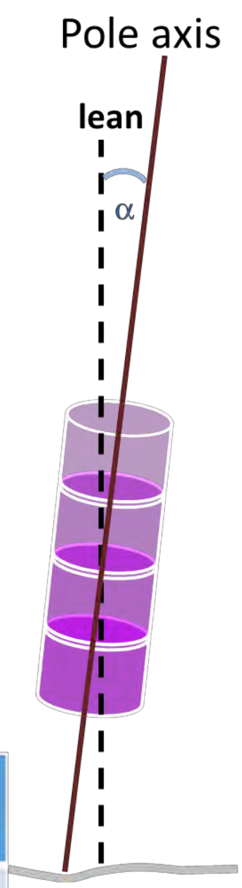
Monitoring Utility Infrastructure

Automated extraction of pole attributes (height, lean, diameter) from LiDAR.









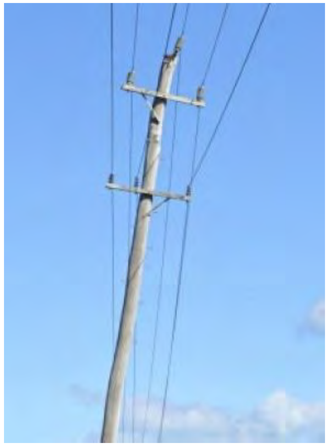
height (ft)	lean	Mean diameter (in)
~ 39	<10°	~ 12

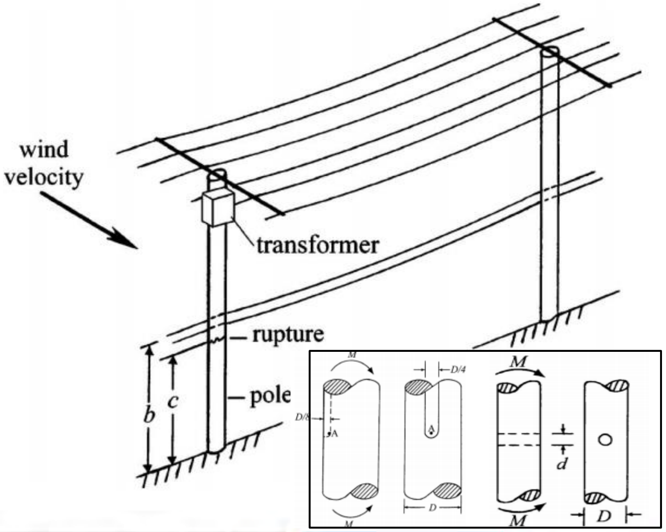
Monitoring Utility Infrastructure

Pole structural integrity model.

Finite element model driven by LiDAR-derived features:

- Pole lean
- Tapered pole
- Reduced cross-sections of pole:
  - (a) line bundle zone
  - (b) equipment attachments

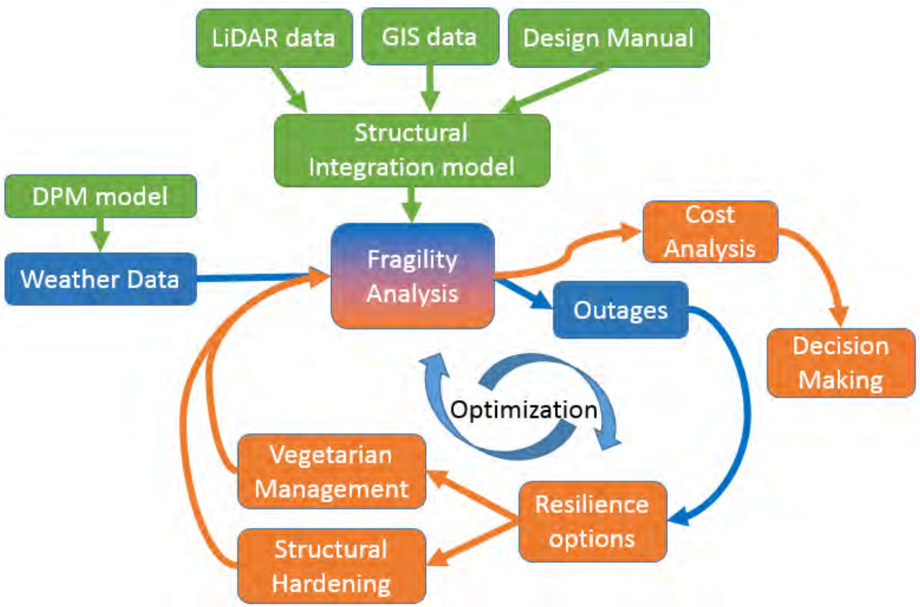


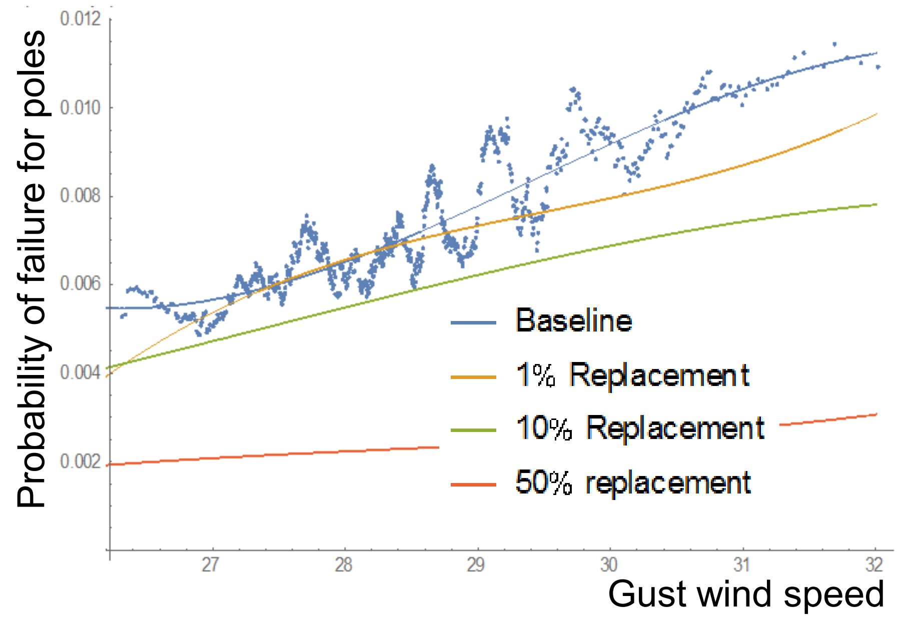


Equivalent reduced cross-section by adding holes or gauges

Total System Assessment Model

Electric Grid Hardening - Systems Approach to Resilience Assessment





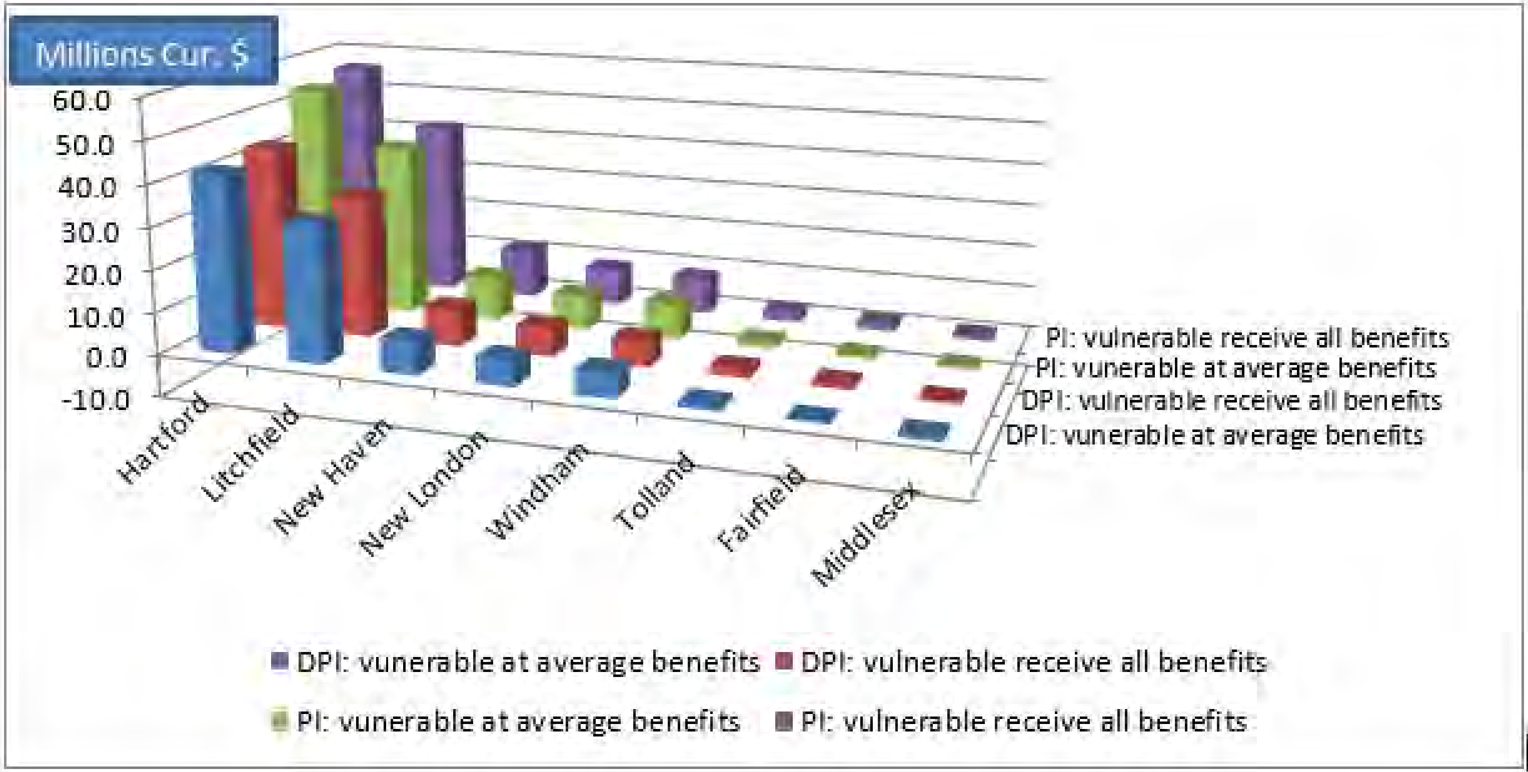
- Tree trimming v.s. replacing poles
  - ✓ Fragility: physics-based/data-informed modeling
  - ✓ 76 storm events to feed the model
  - ✓ Effect of SMT and ETT to reduce outages

Scenario	Predicted Outages	Actual Outages	% Reduction
Baseline	13874	15213	0
1% Reduction	12748	15213	8.12
10% Reduction	10256	15213	26.08
50% Reduction	4438	15213	68.01

Economic Value of Avoided Outages

Average Annual Benefits of Trimming from Outages of More than Five Minutes

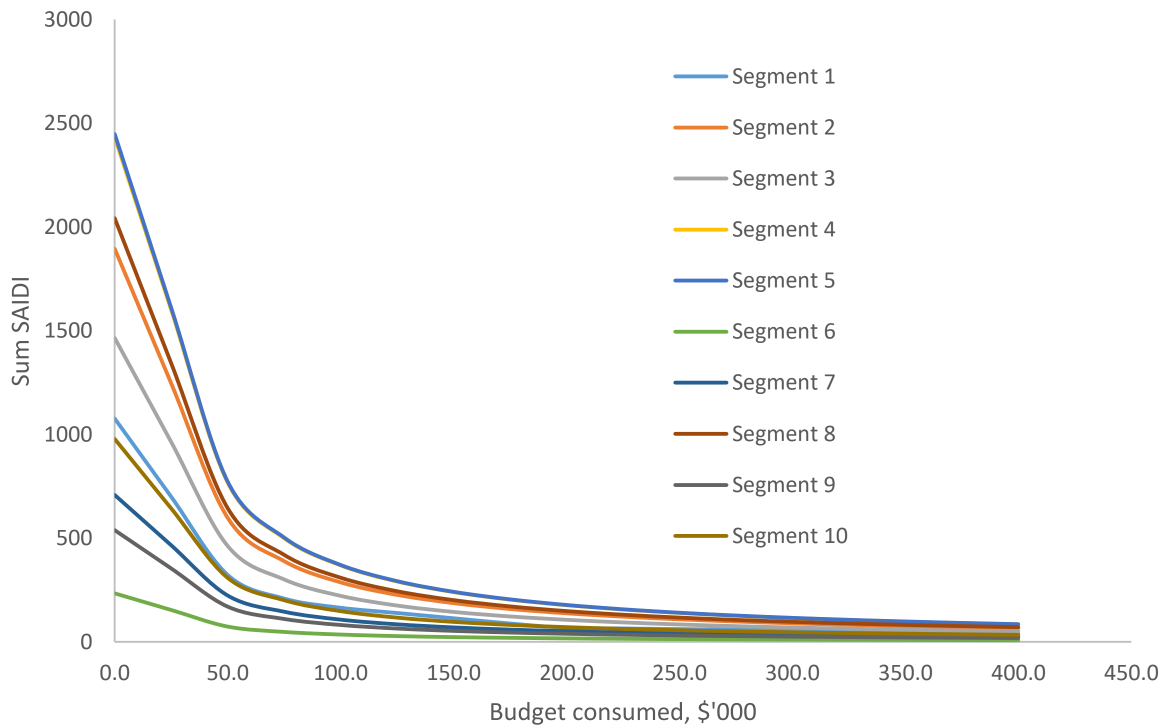
PI and DPI by Connecticut County 2013–18 (Millions Current $)



Utility Resilience Investment Planning

The reduction in SAIDI for a sample of segments of the electrical network, as the budget for resilience increases

Note that similar resilience investments have varying effectiveness for reducing SAIDI on different segments.

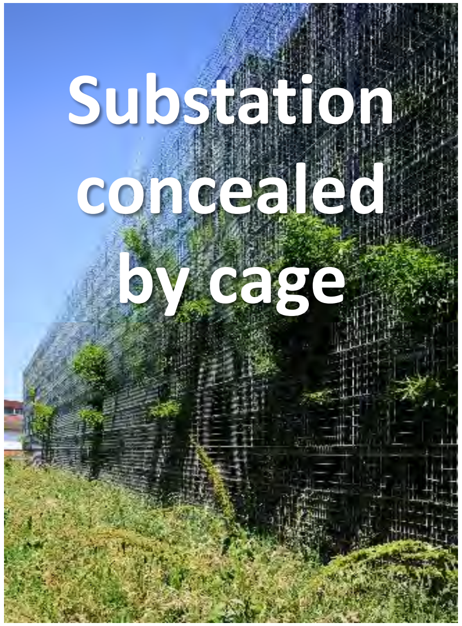


Cyber and Physical Security

Substation Physical Security

Securing substations from potential UAV attacks.

- Evaluate commercial systems (radar, acoustic, LiDAR, optical/thermal) for detecting different types of UAVs
- Explore cost efficient and easily-implemented methods for neutralizing UAV threats:
    - Equipment or facility cages
    - Localized GPS or radio interference
    - Geofence



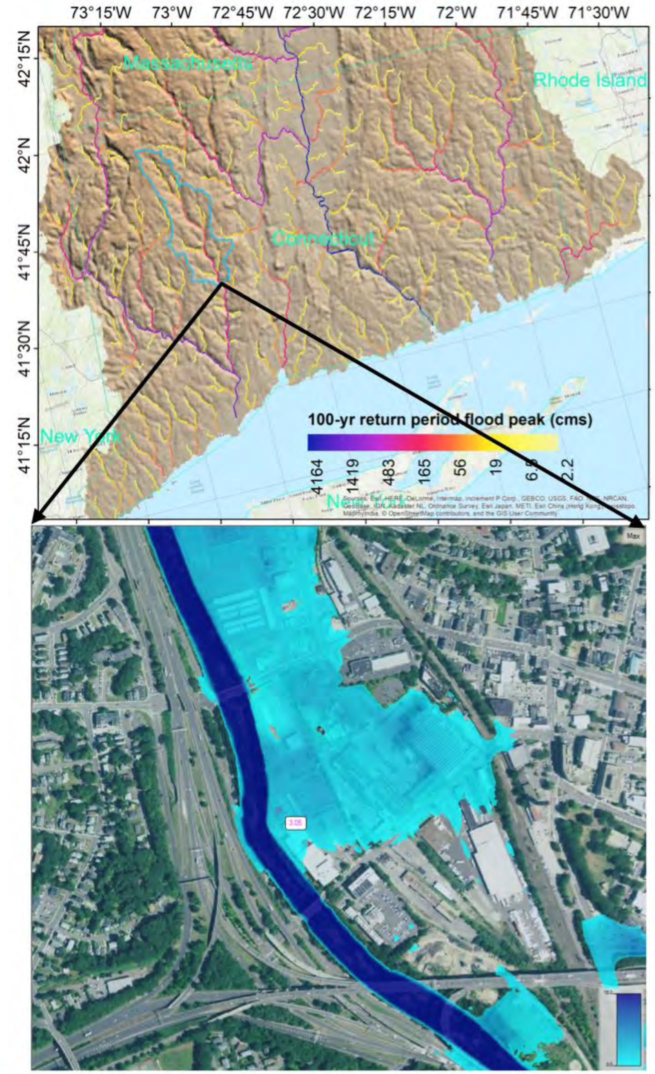
https://www.detail-online.com/article/disappearing-act-electrical-substation-extension-in-lyons-28616/

Substations’ Risk of Flooding

Estimating flood risk of critical power infrastructure.

Predicting floods up to three days in advance and issuing warnings when they are expected to rise above a substation’s critical level, using:

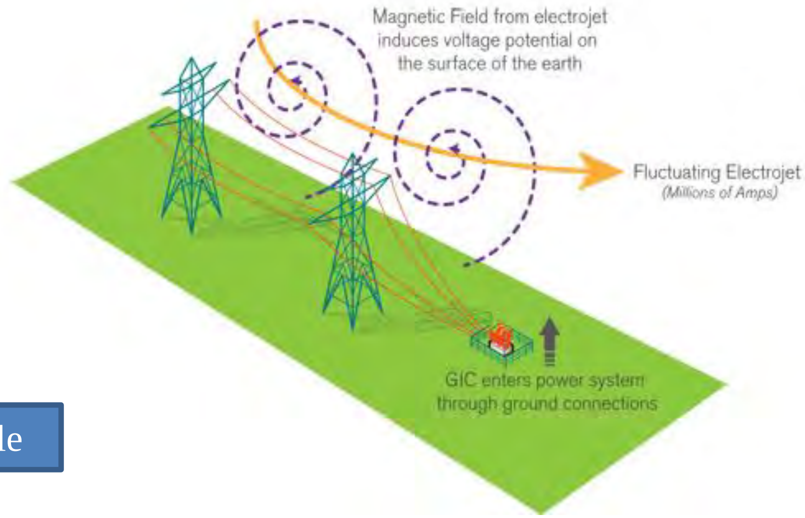
- weather forecasts
- hourly precipitation data from radar
- distributed hydrologic and hydro-dynamic models



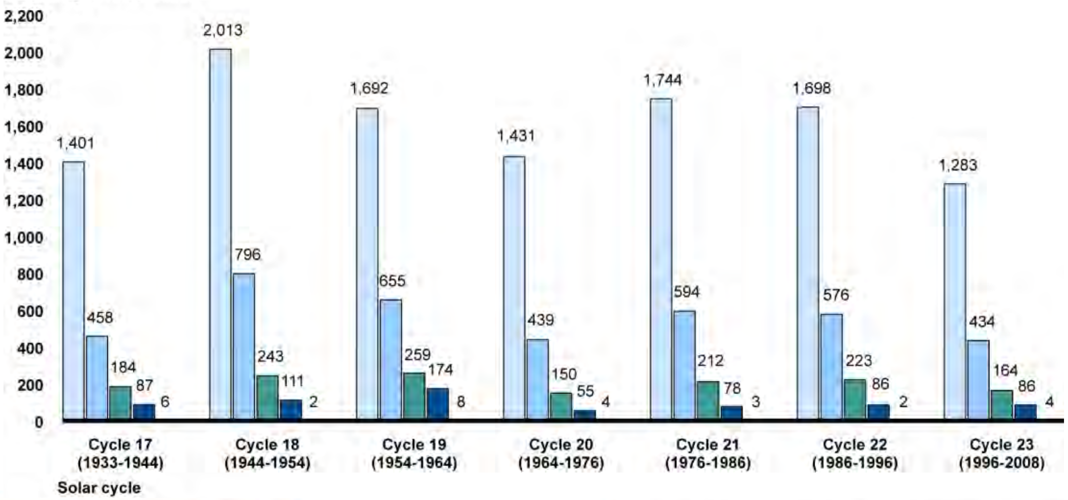
Geomagnetic Disturbances

Understanding GMD impact on HVDC grids.

Solar wind-high energy charged particles streaming outward from the sun can affect earth's magnetic field



Planetary Geomagnetic Disturbance (GMD) Intensity by Solar Cycle

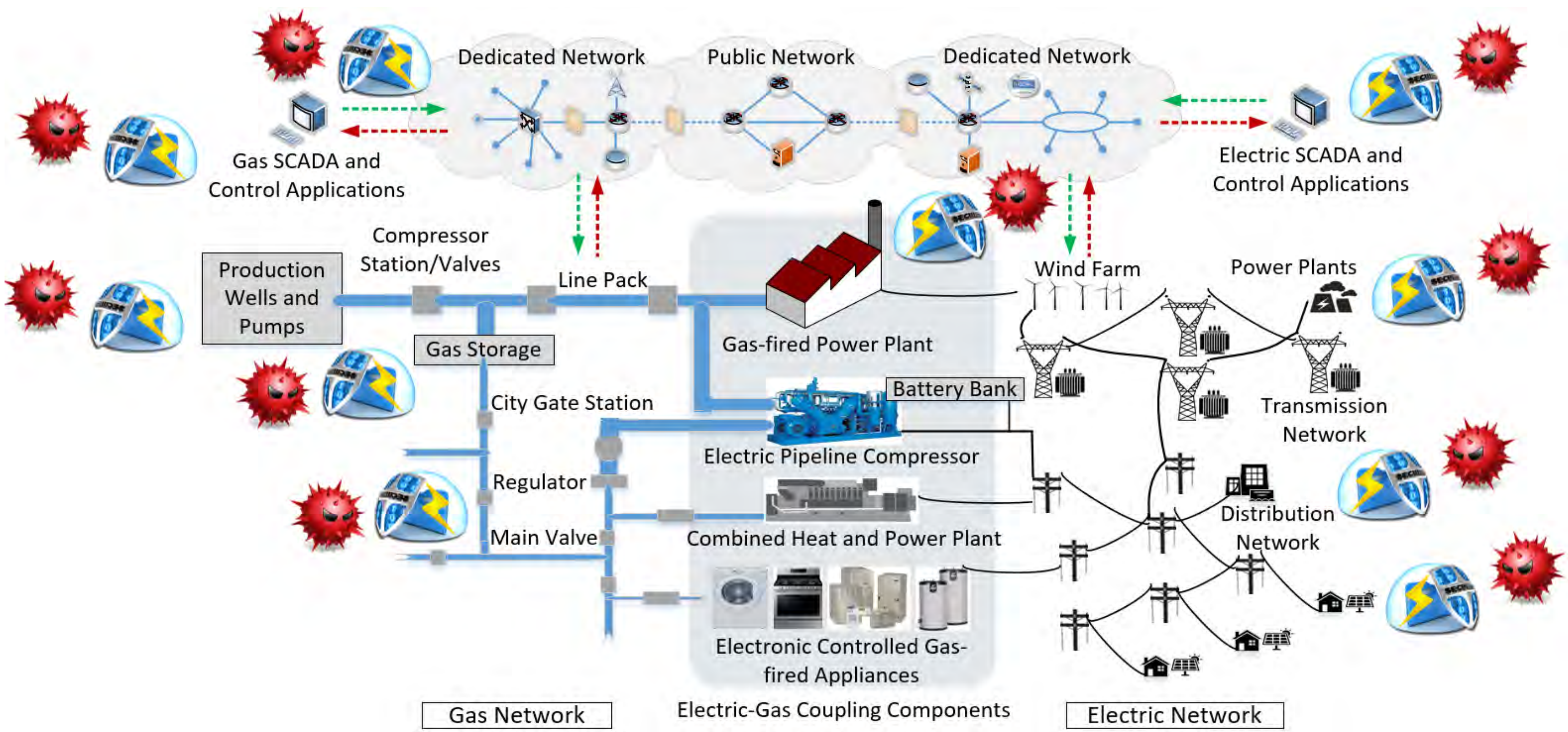


Sun's magnetic polarity reverses every 11 years, solar activities follow 11 year cycle.

large geomagnetic storms generally have not occurred around the peaks of sunspot activity.

Cybersecurity for Attack-Resilient Electric and Gas Networks

A DOE CEDS Proposal Submitted by: UConn, Argonne & Brookhaven National Labs



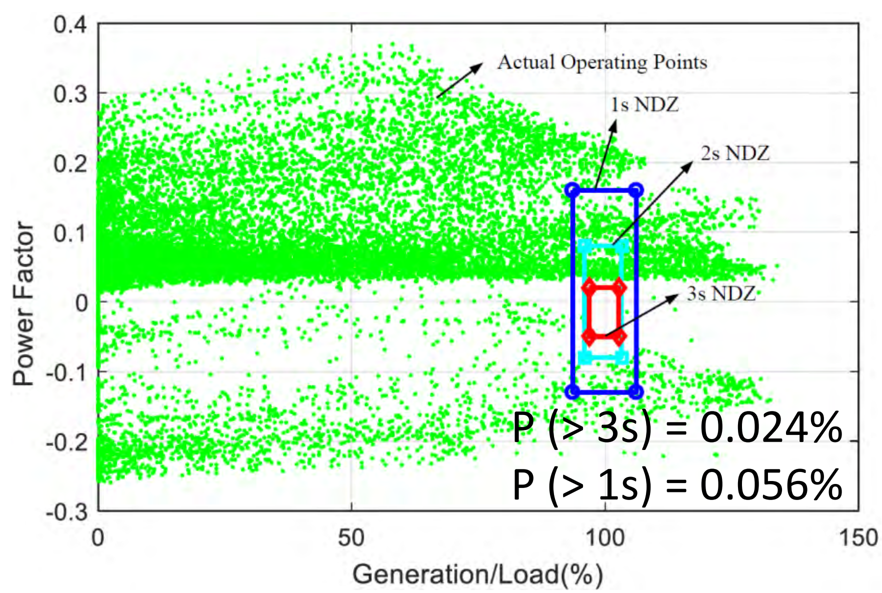

Electric Grid
Modernization

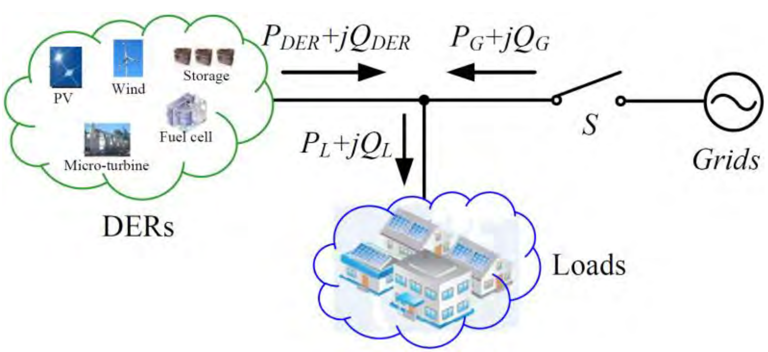
Integration of PVs in the Power Grid

Unintentional Islanding Evaluation

A method for quantifying regions in which islanding detection schemes fail to detect the abnormal islanding mode:

- Software tool developed reduces utilities engineer's case study time from months to just a few minutes
- Towards a pure data-driven, machine learning approach

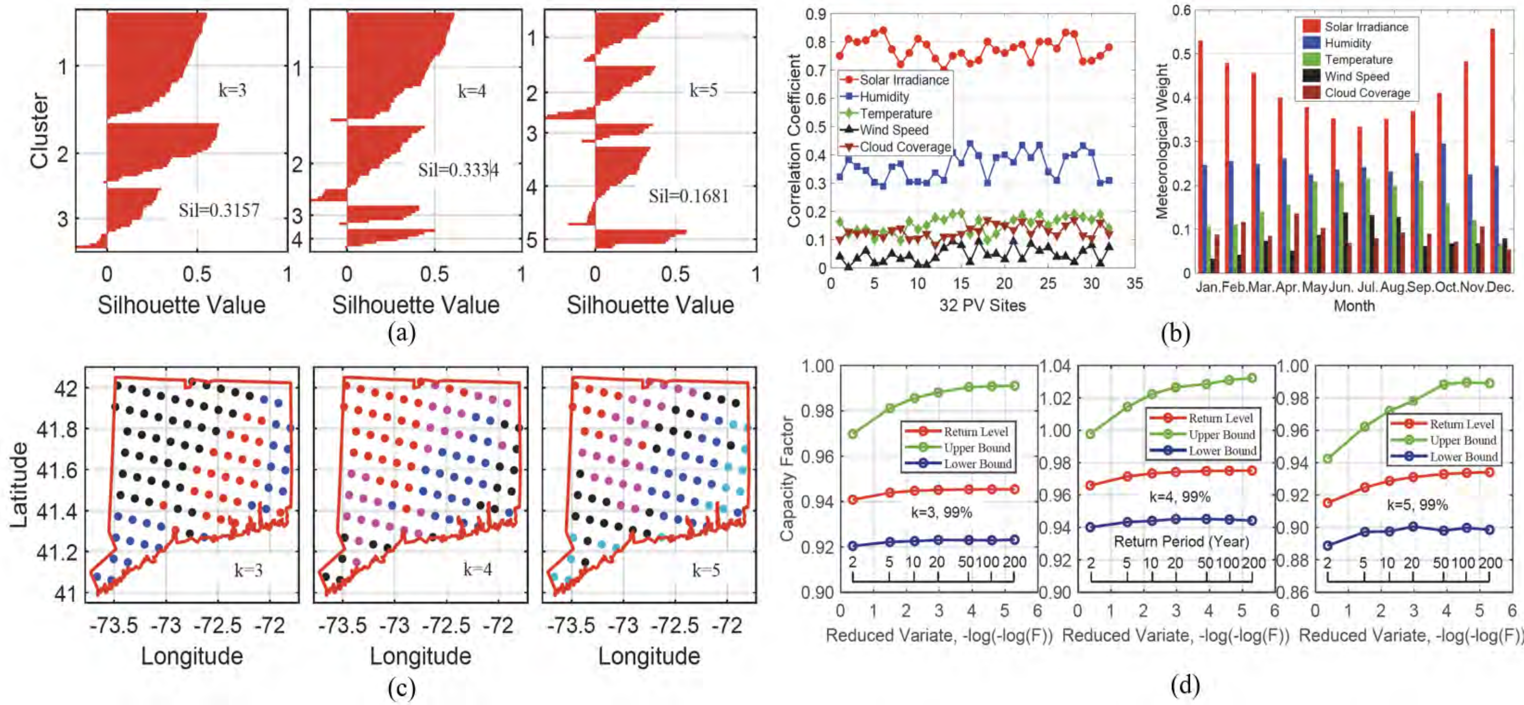




Integration of PVs in the Power Grid

Extreme PV power analytics

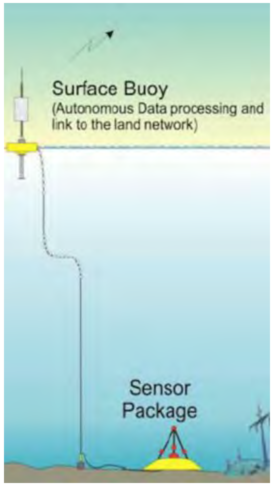
- Explore how extreme PV is related to weather parameters
- The utility service territory is divided into several clusters at a given time interval, such that PV systems homogeneous in terms of the extreme output.

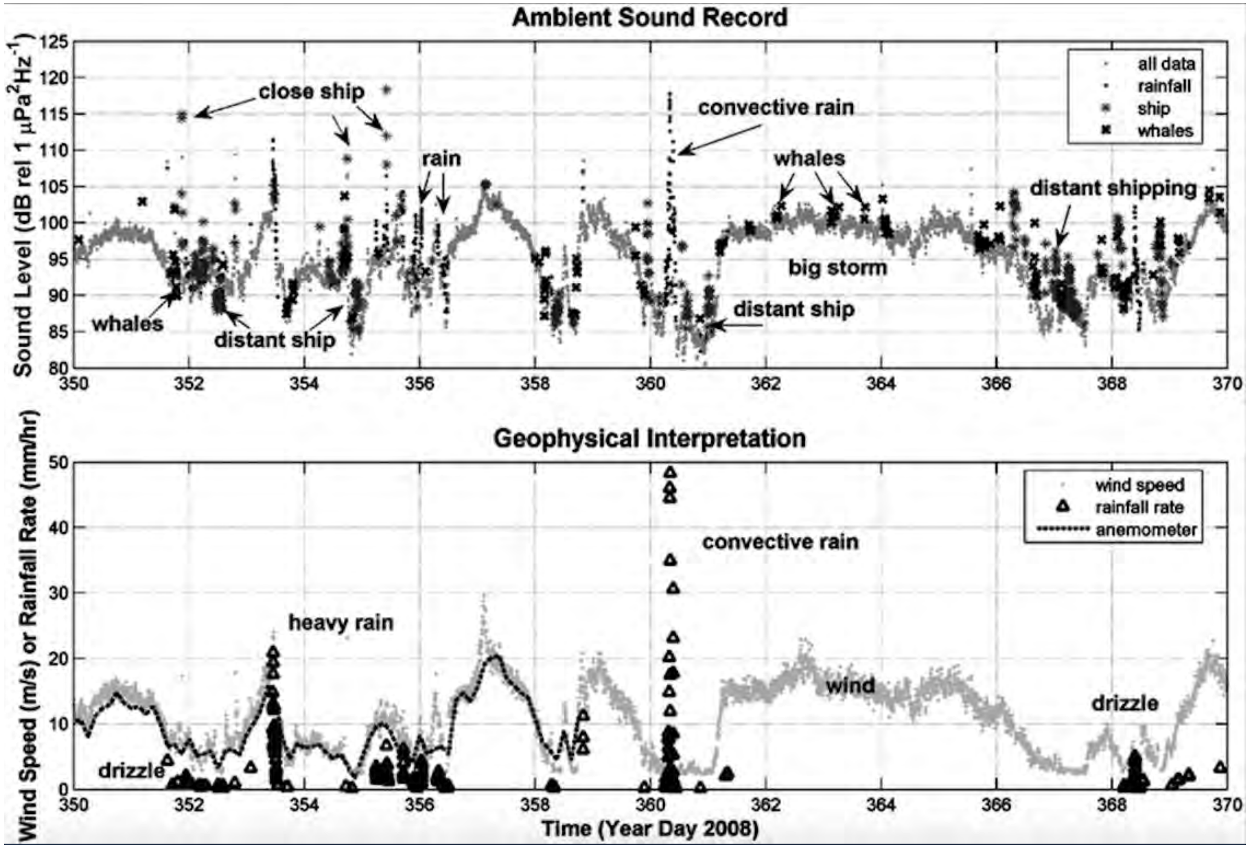


Offshore wind energy

Towards real-time high-resolution modeling & observing system

Underwater Acoustic sensors

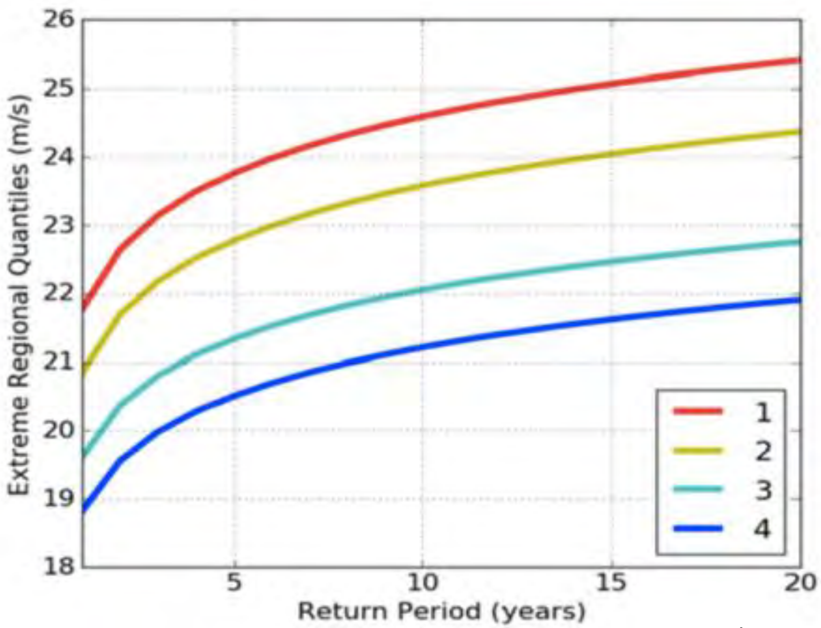


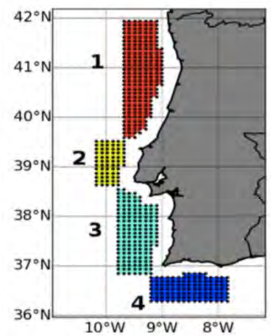


Offshore wind energy

Towards real-time high-resolution modeling & observing system

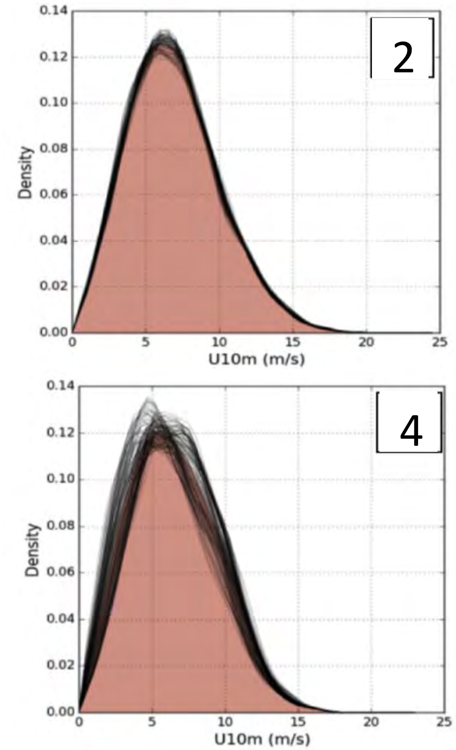
Statistics of Wind Extremes and Impact





Extreme wind frequency analysis and its geographical dependence.

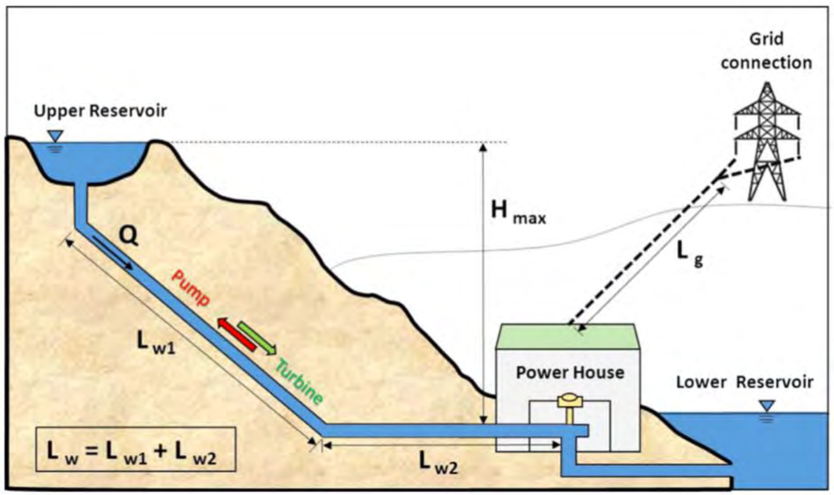
Empirical wind distributions



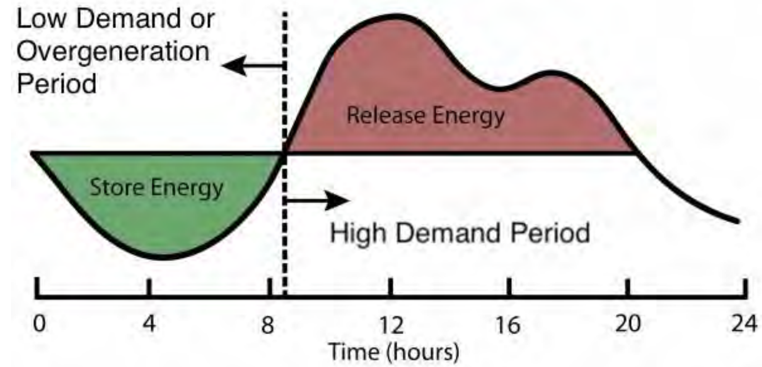
R.M. Campos, C. Guedes Soares / Renewable Energy 123 (2018) 806-816

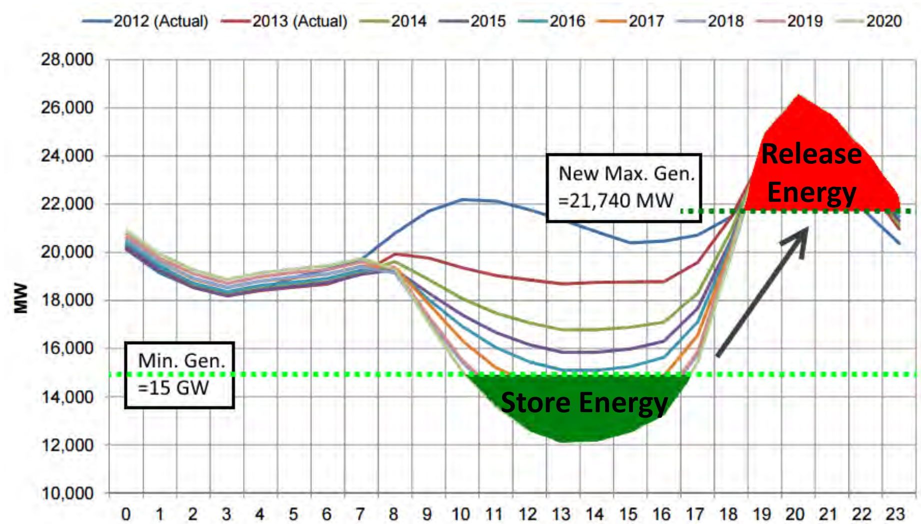
Grid Balancing Solutions for deep penetration of intermittent renewables

Pumped hydroelectric energy storage



Source: Kucukali, S., 2014. Finding the most suitable existing hydropower reservoirs for the development of pumped-storage schemes: an integrated approach. *Renewable and Sustainable Energy Reviews*, *37*.

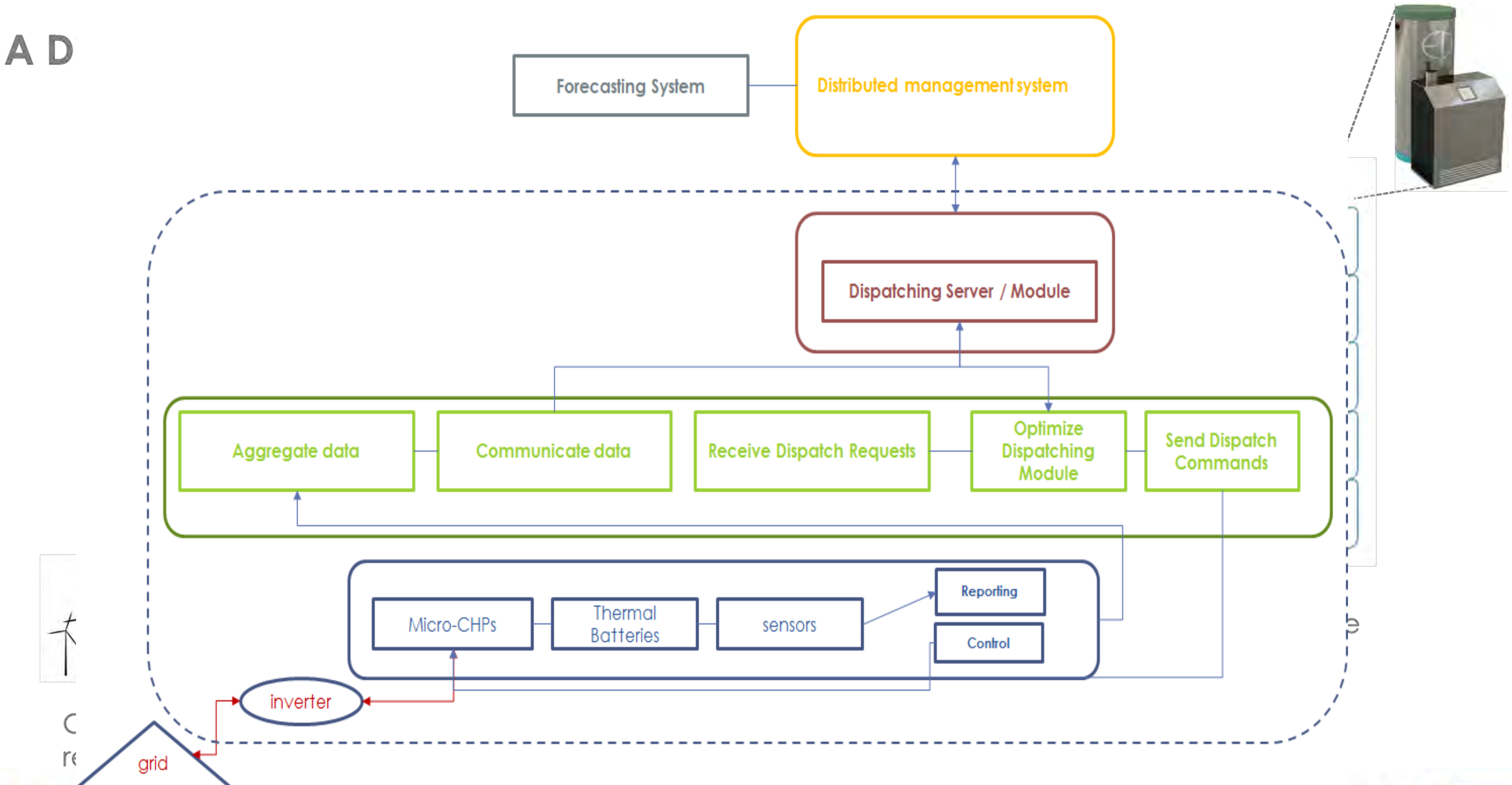




Source: http://large.stanford.edu/courses/2015/ph240/burnett2/images/f3big.png.

Grid Balancing Solutions for deep penetration of intermittent renewables

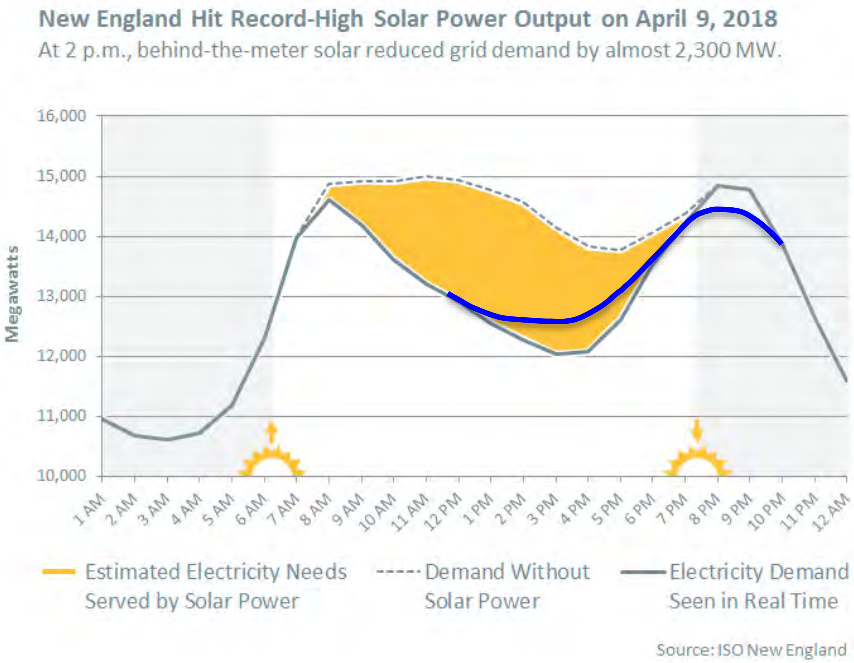
DOE ARPA-e Proposal led by EnviroPower LLC



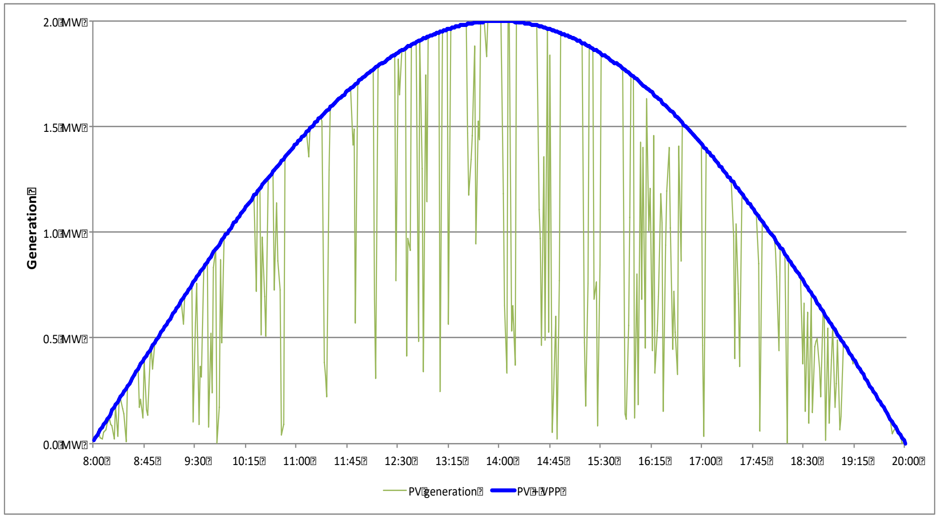
Grid Balancing Solutions for deep penetration of intermittent renewables

DOE ARPA-e Proposal led by EnviroPower LLC

PEAK SHAVING



SMOOTH INTERMETTENCY



Annual Workshop

Three years of utility-academia partnership in tackling real-world challenges where weather, resilience and energy intersect.

NOVEMBER 9, 2018
9:00 A.M. - 1:00 P.M.
INNOVATION PARTNERSHIP BUILDING
UNIVERSITY OF CONNECTICUT

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THE UNIVERSITY OF CONNECTICUT CORDIALLY INVITES YOU TO ATTEND THE EVERSOURCE ENERGY CENTER'S ANNUAL MEETING.

Please join us for research updates from our faculty and students, and to meet our Center's Advisory Board members.

DOUG DORR
PROGRAM MANAGER,
ELECTRIC POWER RESEARCH INSTITUTE

KATIE SCHARF DYKES
CHAIR, CT PUBLIC UTILITIES
REGULATORY AUTHORITY

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Please RSVP by Friday October 26, 2018
EversourceEnergyCenter@UConn.edu
or by calling (860) 486-3785.

Click here for directions to the Storrs campus and parking in **North Garage**.

EVERSOURCE

Thank you!