ENERGY SECTOR RESILIENCE: DATA, TOOLS, APPLICATIONS

GUENTER CONZELMANN

Argonne National Laboratory
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ARGONNE HAS BROAD ENERGY RESILIENCE CAPABILITIES

From Development of Advanced Algorithms and Models to Commercialization and Deployment

Advanced Algorithms
- Predictive modeling
- Advanced math/solvers
- Scalable solutions for optimization
- Integrative Frameworks

Model Development
- Resource optimization
- Stochastic UC/operations
- Power market tools
- Large-scale grid tools

Model Applications
- Integration studies
- Power market design
- Long-term investment dynamics
- Grid resilience, cascading failures power system restoration
- Storage value/impacts
- Climate change impacts

Deployment
- EPFAST/NGFAST/POLFAST
- HEADOUT, RESTORE, EGRIP
- GTMax/ EMCAS/CHEERS
- EISPC

Useful Useable USED

ARGONNE HAS BROAD ENERGY RESILIENCE CAPABILITIES

From Scenario Definition to System Restoration: EXAMPLE for Electric Power

Scenario Definition

- Describe plausible triggering event, such as weather/climate (hurricanes, ice storms, tornados), earthquakes, cyber, others

Physical Impact Assessment

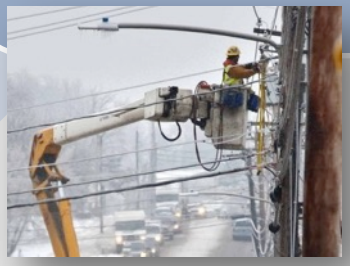
- Using fragility curves, assess physical damage to relevant infrastructure, including generators, towers/poles, wires, substations, fuel infrastructure (natural gas, coal, petroleum, etc.)

System Modeling

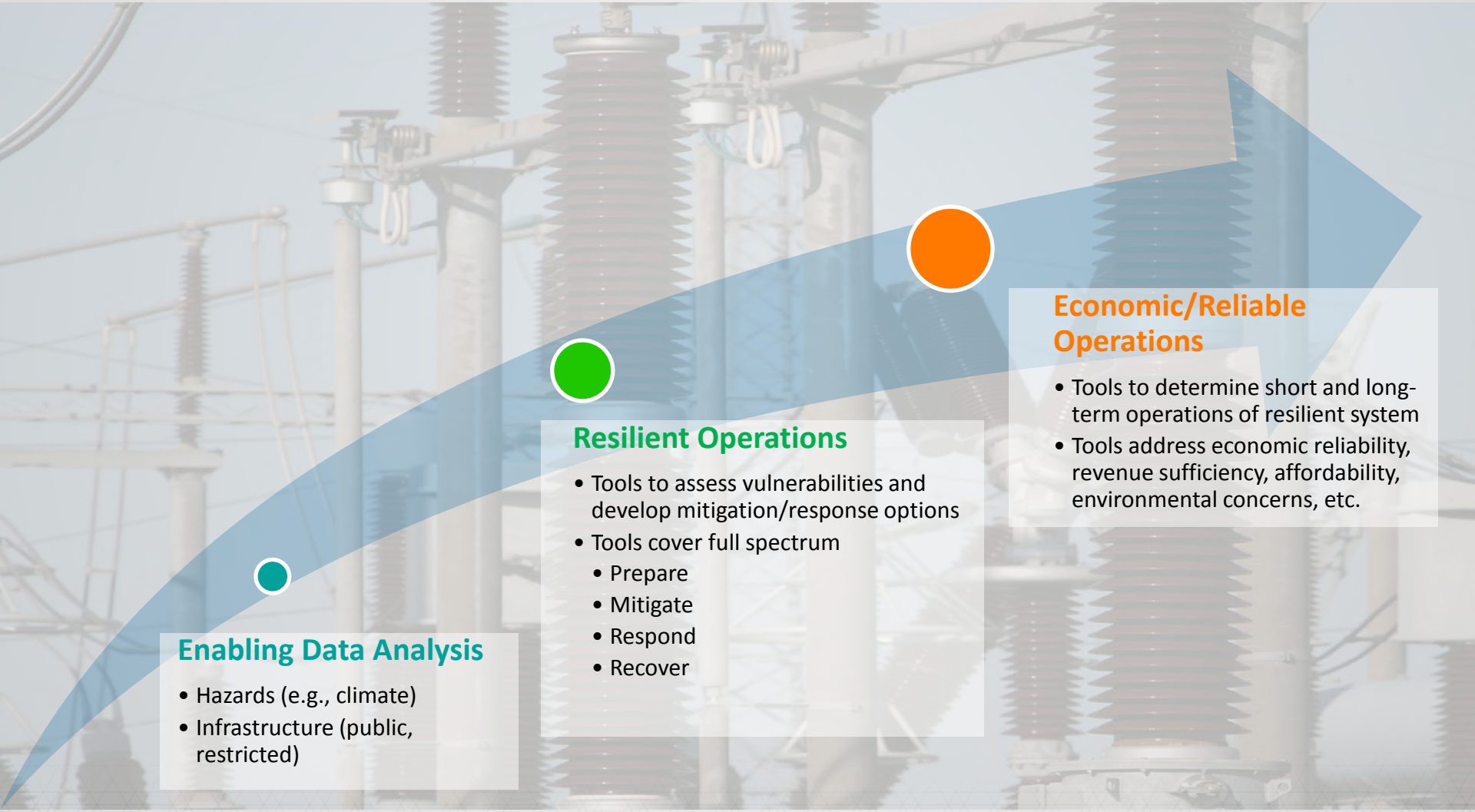
- Model impact of loss of fueling infrastructure
- Model impact of loss of multiple grid assets
- Determine potential islanding and extent of blackout

System Restoration Modeling

- Physical restoration/repair time; optimized repair crew scheduling and staging
- Electrical restoration at transmission-level
- Electrical restoration at distribution level



FROM DATA TO RESILIENT AND ECONOMIC/RELIABLE OPERATIONS



Enabling Data Analysis

- Hazards (e.g., climate)
- Infrastructure (public, restricted)

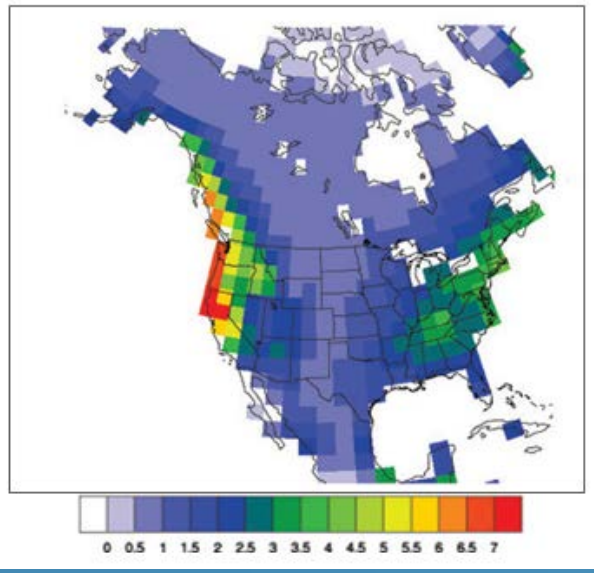
Resilient Operations

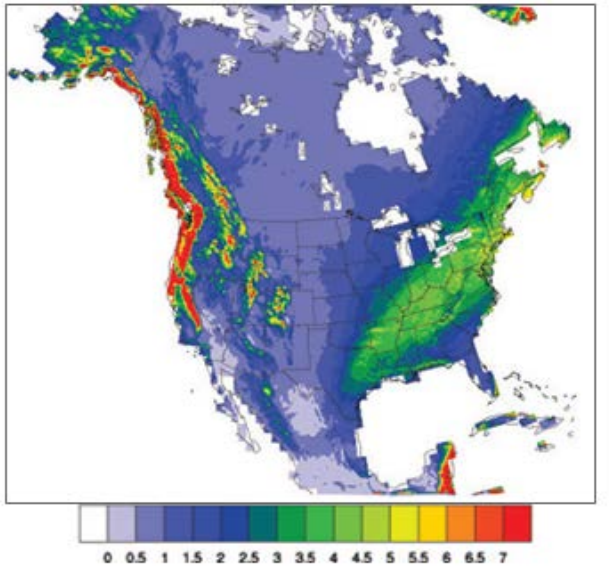
- Tools to assess vulnerabilities and develop mitigation/response options
- Tools cover full spectrum
  - Prepare
  - Mitigate
  - Respond
  - Recover

Economic/Reliable Operations

- Tools to determine short and long-term operations of resilient system
- Tools address economic reliability, revenue sufficiency, affordability, environmental concerns, etc.

DOWN-SCALED CLIMATE DATA FOR REGIONAL ASSESSMENTS





- For DOD's Environmental Research Program (SERDP), generated high-resolution (12-km) climate projections/probability distributions of downscaled climate variables for North America (1980-2010, 2045-2054, 2085-2095, in 3-hour time steps, 200 TB of data)
- Allows comprehensive analysis of uncertainty of climate projections at regional scale and ability to quantify/plan for impacts of future climate change at specific locations; used in DHS regional resiliency assessments
- Currently transferring data to web portal; will be available in 1-2 months
- Next-generation (4x4km) resolution data will be available next year

DOWN-SCALED CLIMATE DATA FOR REGIONAL ASSESSMENTS

- Provides information for selecting climate information and downscaled climate products
- Describes how to incorporate these into vulnerability and impact assessments, climate resilience and preparedness, and adaptation planning, at an actionable, impact-relevant scale
- https://www.serdp-estcp.org/Program-Areas/Resource-Conservation-and-Climate-Change/Climate-Change/

SERDP
DOD • EPA • DOE

DOWN-SCALED CLIMATE DATA FOR REGIONAL ASSESSMENTS

STATISTICAL DOWNSCALING

- More computationally affordable than dynamic
- Can provide a large ensemble of projections quickly
- Should be used with caution for applications over complex terrain and coastal region

DYNAMIC DOWNSCALING

- Based on Regional Climate Models (RCMs)
- Computationally expensive
- Vastly improves modeling over mountainous regions or other variable terrain
- Provides climate variables beyond daily average temperature and precipitation
- Often the only method that provides enough data to understand precipitation and temperature extremes (key point for engineers)

COMPREHENSIVE INFRASTRUCTURE DATA

- Ongoing work by National Geospatial Intelligence Agency (NGA) to prepare and deliver infrastructure datasets for various energy sectors

- New efforts by APRA-E to develop synthetic grid datasets for transmission and distribution (ARPA-E GRID-DATA)

ARGONNE RESILIENCE AND RESTORATION TOOLS

Prepare

- Self-assessment/ maturity (**ERAP-D**)
- Emergency planning (**onVCP/ SyncMatrix, SpecialPop, LPAT**)
- EP/PSR exercise/ drill (**Scenarios, Threat-Damage, Impact Models**)

Mitigate

- Mitigation assessment (**EPfast, NGfast, POLfast, others**)
- Resource mitigation measures, dependencies (**IST-RMI**)
- Power system restoration planning (**EGRIP**)
- Blackstart resource planning (**EGRIP**)

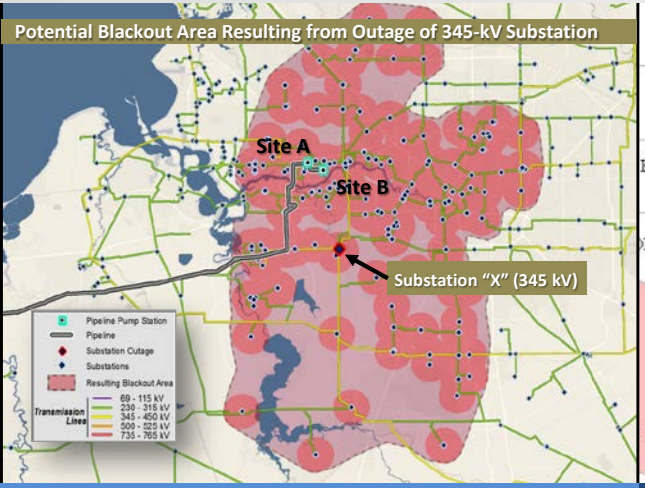
Respond

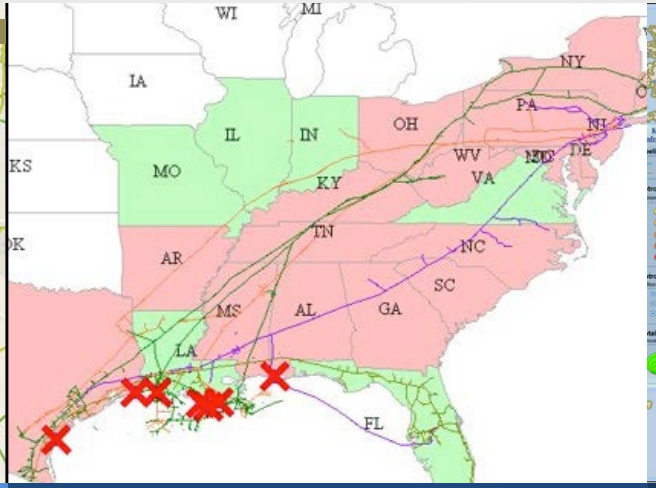
- Impact assessment (**Threat-Damage, Impact Models**)
- Hurricane assessment (**HEADOUT**)
- Emergency management/resp onse (**onVCP, vBEOC**)

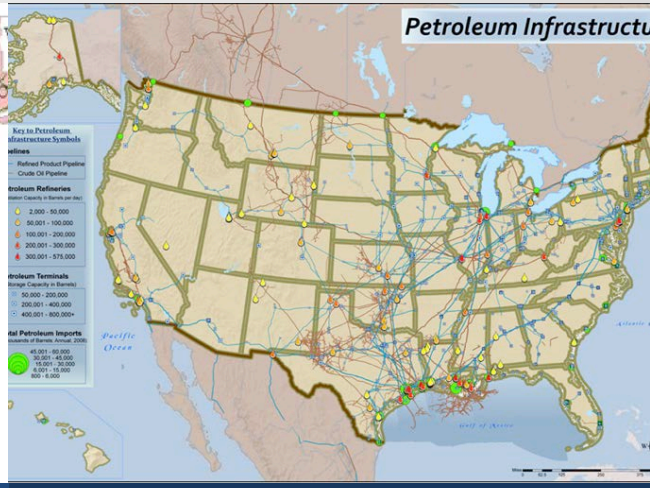
Recover

- Real-time PSR analysis (**EGRIP**)
- Emerge-Manage., Communication, Collaboration (**onVCP/vBEOC**)

ARGONNE'S ENERGY SECTOR RESILIENCE MODELING TOOLS





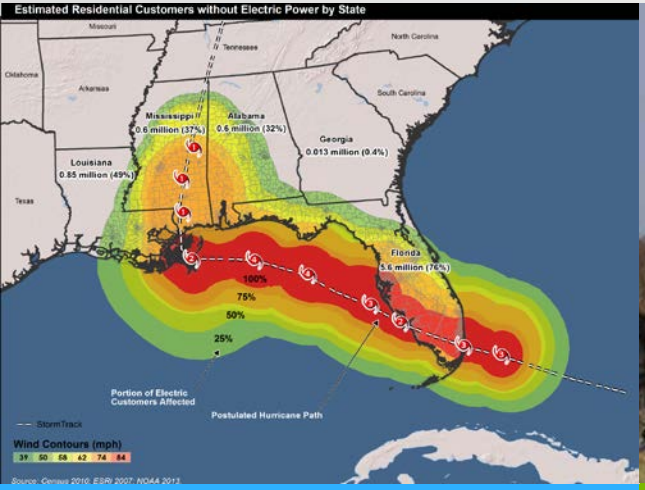


- **EPFAST** examines the impacts of power outages on large electric grid systems
- Models the tendency of power systems to "island" after either man-made or natural disturbances, which can lead to regional power disruptions

- **NGfast** is a natural gas – electric interdependency tool
- Estimates impacts to natural gas sector from user-defined hazards and determines gas-fired power plants at-risk of fuel disruptions

- **POLfast** estimates impacts to petroleum sector (crude oil and refined products) from disruptions in production, storage, and transportation

ARGONNE'S ENERGY SECTOR RESILIENCE MODELING TOOLS

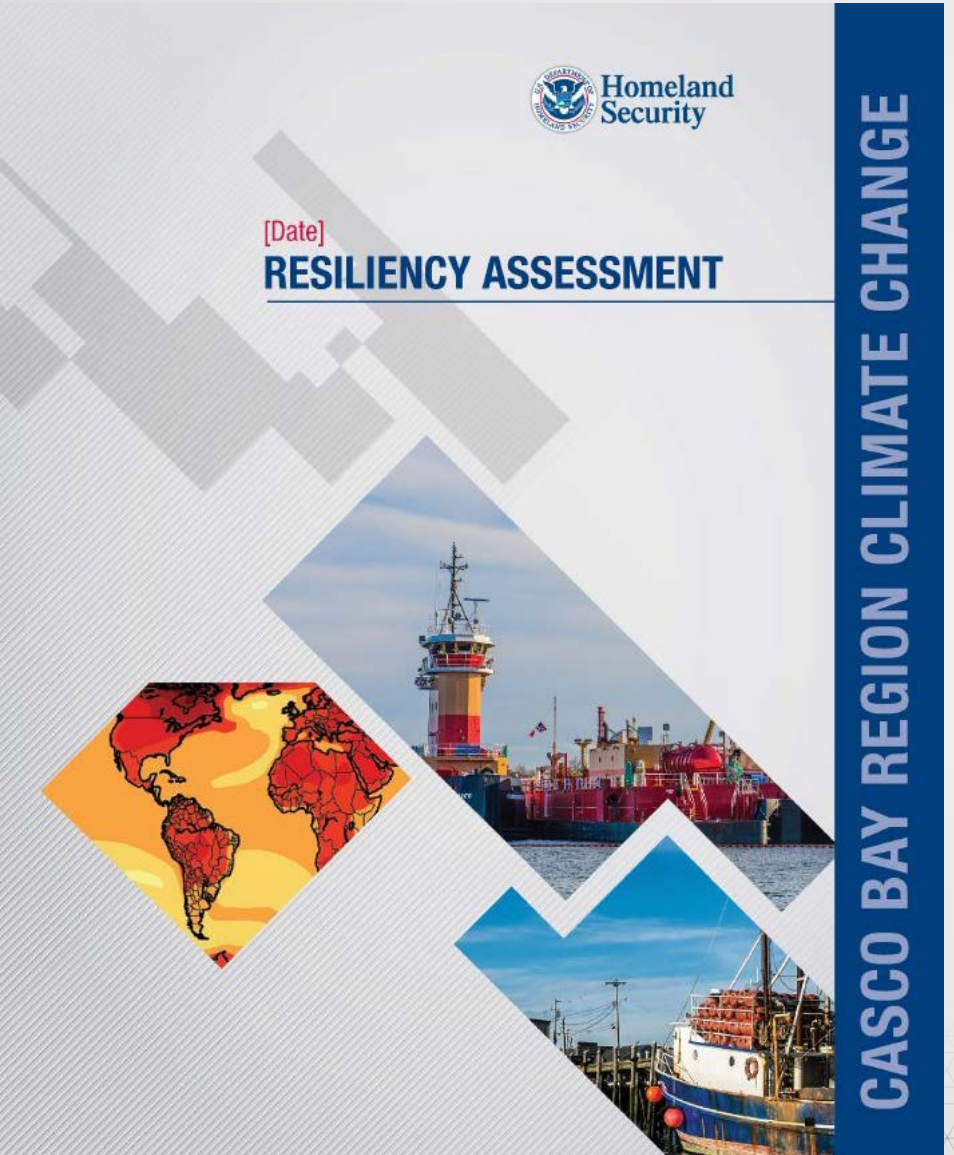


- **HEADOUT** produces an estimation of the potential number of electric customers that will experience a loss of commercial electrical power as a tropical cyclone makes landfall

- **RESTORE** offers insights into *physical* outage restoration times at critical infrastructure facilities
- Identifies the dependencies of the affected infrastructure and its impact on the restoration process

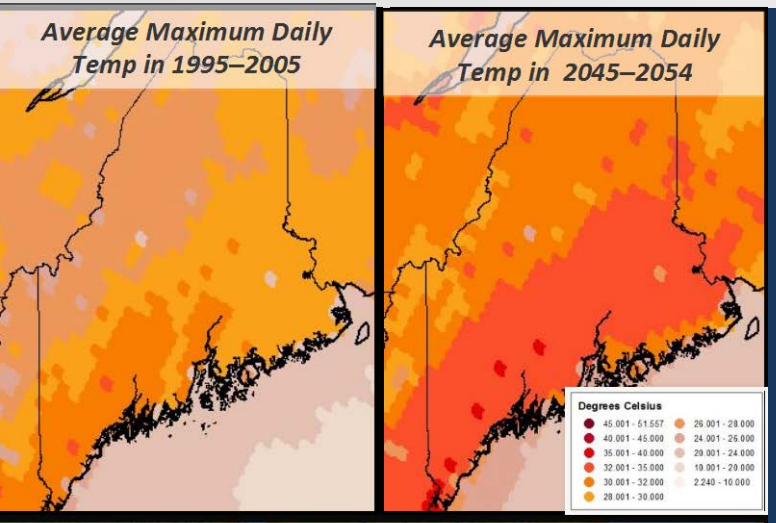
- **EGRIP** is an AC power flow based cascading failure/outage and integrated power system restoration optimization tool
- The *electric* restoration module supports restoration planning and operational decision-making in both T&D

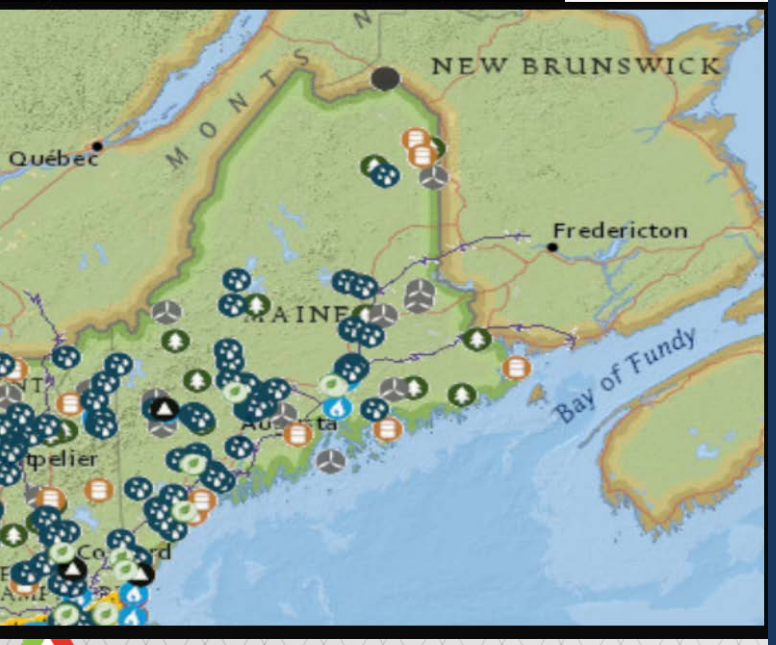
TOOL APPLICATION: REGIONAL ENERGY RESILIENCE FOR DHS



- DHS Regional Resilience Assessment Program (RRAP)
- RRAP process identifies critical infrastructure security and resilience gaps; dependencies; interdependencies; cascading effects; and State, local, tribal, and territorial government capability gaps
- Presents results of the assessment phase of the RRAP in the form of Key Findings and Resilience Enhancement Options
- Sets the stage for follow-on Implementation Activities
- Argonne has completed 60 RRAPs (2009-2016)

TOOL APPLICATION: CLIMATE CHANGE IMPACTS IN MAINE

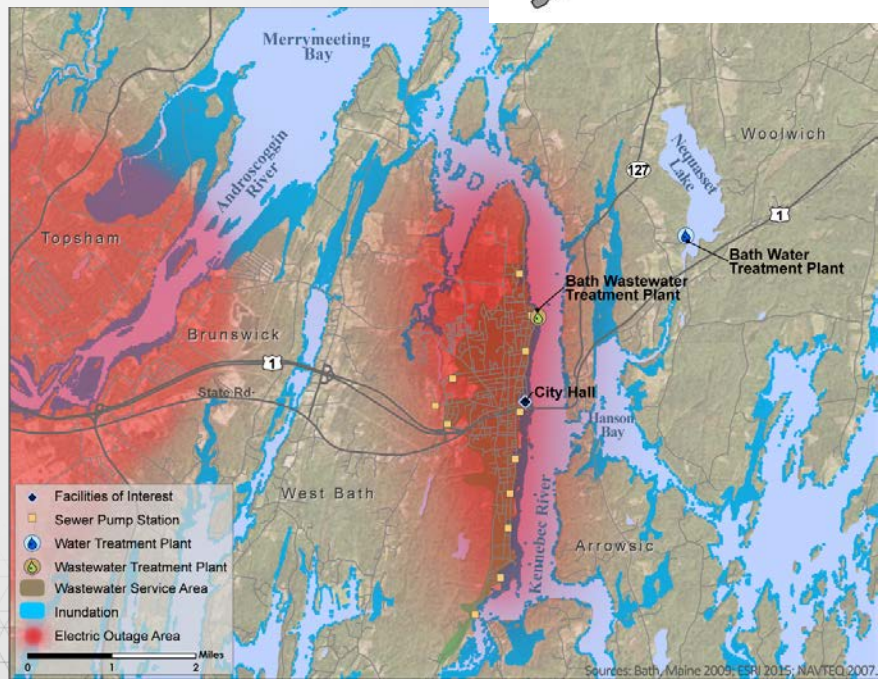




- Part of DHS RRAP
- Investigate the impacts to Maine's electric system from climate change hazards, including higher storm surge and increased ambient temperatures
- Impose 2050 storm surge and ambient temperature projections on the 2011 electric system in Maine
- Identify impacts on capacity of power plants, transmission lines, transformers and growth in demand
- Determine implications on overall grid performance via load-flow simulation

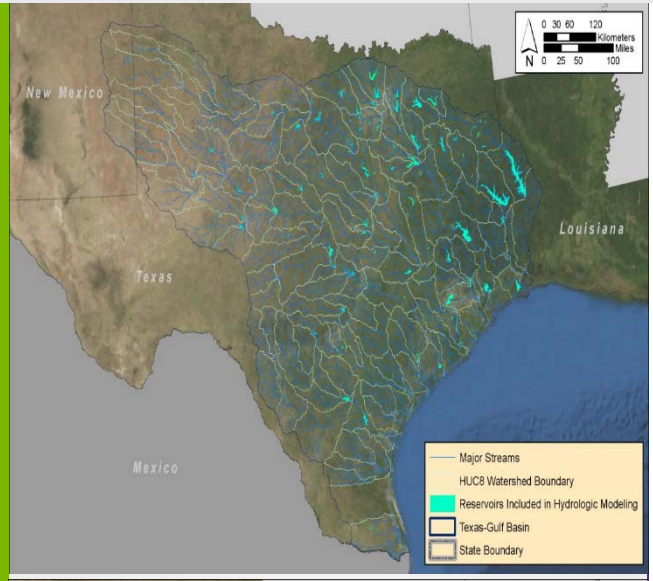
TOOL APPLICATION: CLIMATE CHANGE IMPACTS NEW ENGLAND

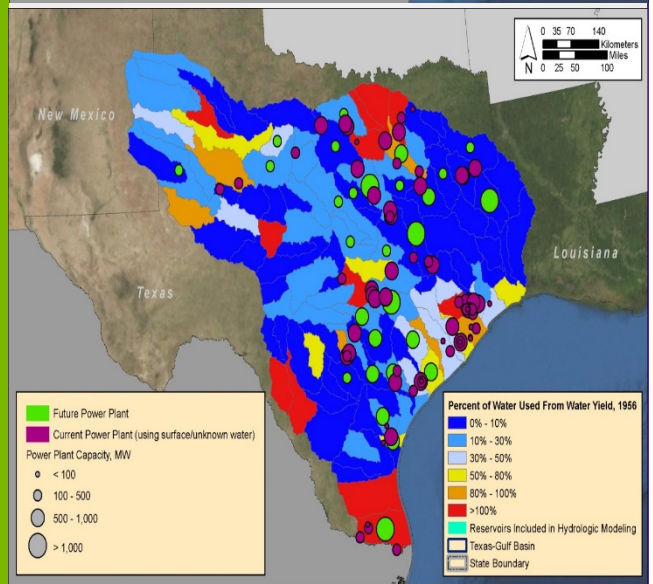
- Builds on Maine analysis, part of 2016 DHS Region 1 RRAP
- Assesses climate impacts on electric infrastructure throughout New England
- Considers flood risk due to sea level rise combined with more intense overland precipitation events
- Identifies high-consequence failure points and potential cascading failure scenarios within the region's electric infrastructure

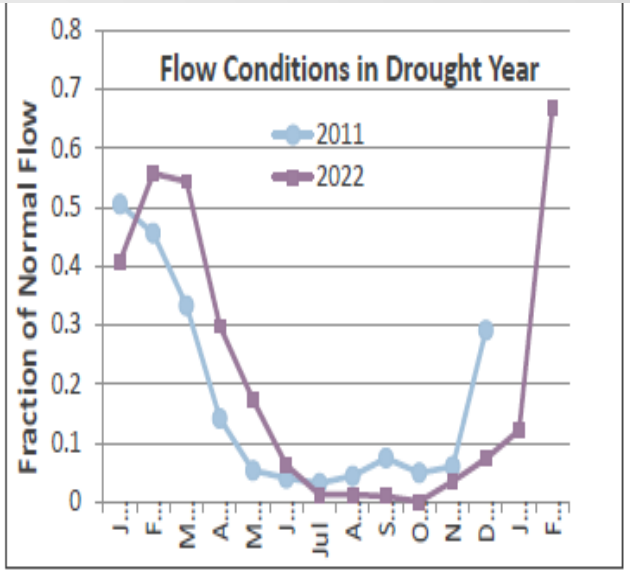


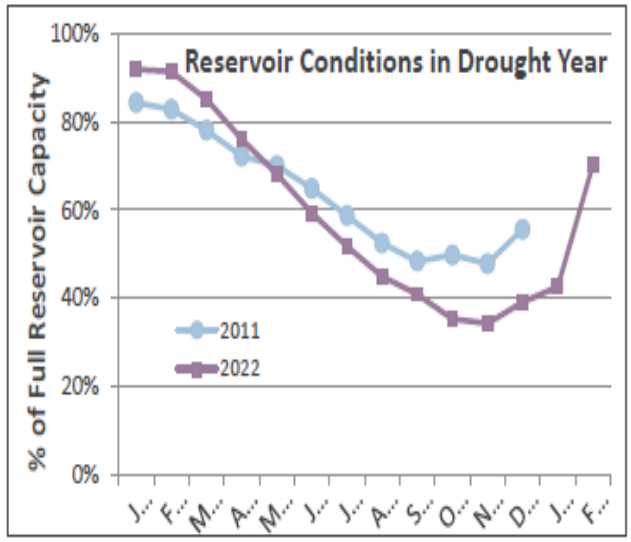
TOOL APPLICATION: CLIMATE CHANGE/DROUGHT IMPACTS

- Using Argonne's downscaled climate data, examined climate variability impact on Texas power generation
  - Impacts on water availability
  - Potential reduction or curtailment of power generation
- Supports long-range transmission planning in Texas and Western U.S.

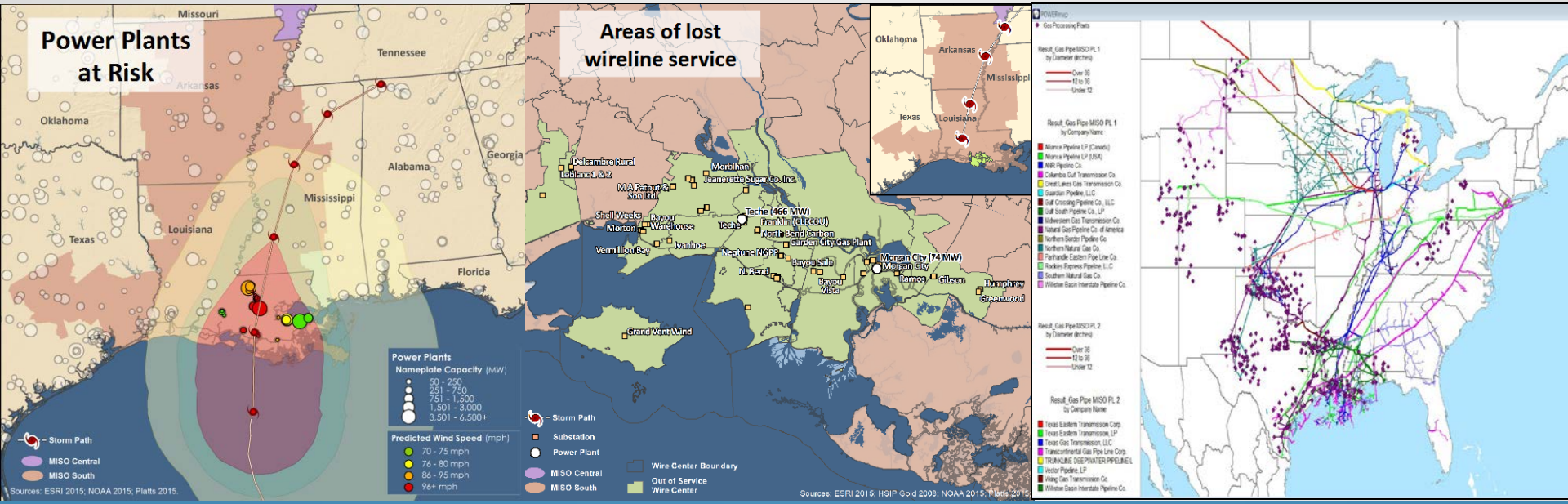






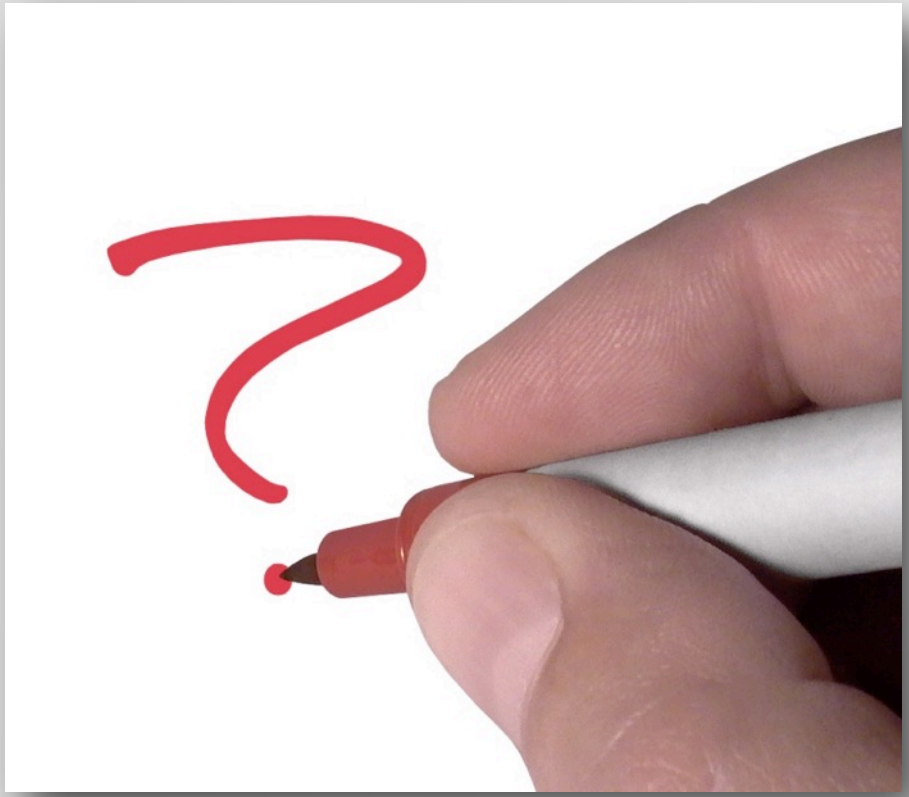


TOOL APPLICATION: PREPARE GRID OPERATORS FOR STORMS



- Support for Midcontinent Independent System Operator (MISO) working group for Emergency Preparedness and Power System Restoration
- Recent 2016 spring drill and upcoming fall drill include hurricane scenario and impact estimation and interdependencies with telecommunications and natural gas

FOR MORE INFORMATION PLEASE CONTACT:



Guenter Conzelmann
Center for Energy, Environmental, and Economic Systems Analysis
Argonne National Laboratory
630-252-7173
guenter@anl.gov

Steve Folga
Risk and Infrastructure Science Center
Argonne National Laboratory
630-252-3728
sfolga@anl.gov