ENERGY RESILIENCE FOR THE AMERICAS

FRAMEWORKS, TOOLS, AND APPLICATIONS, AND EXPERIENCES IN REINFORCING ENERGY SYSTEMS

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ARGONNE HAS BROAD ENERGY RESILIENCE CAPABILITIES

From Development of Advanced Algorithms and Models to Deployment to External Customers

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
- EZMT
- AMP
- onVCP/vBEOC

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.)

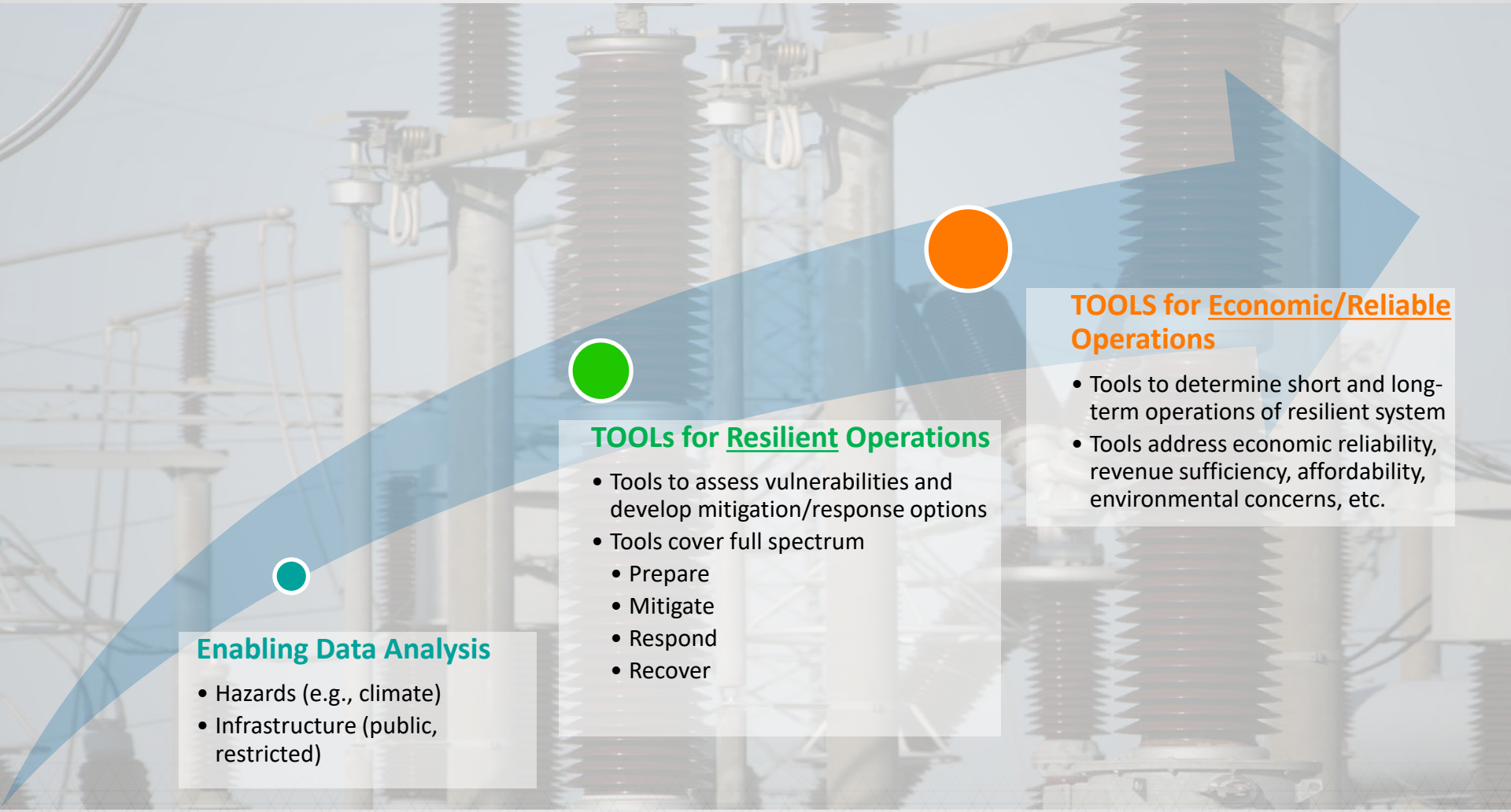
System Modeling

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

System Restoration and Response Modeling

- Physical restoration/repair time; crew scheduling/staging
- Electrical restoration at transmission-level
- Electrical restoration at distribution level
- Response logistics

FROM DATA ANALYSIS TO MODELING RESILIENT AND ECONOMIC/RELIABLE OPERATIONS



Enabling Data Analysis

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

TOOLs for Resilient Operations

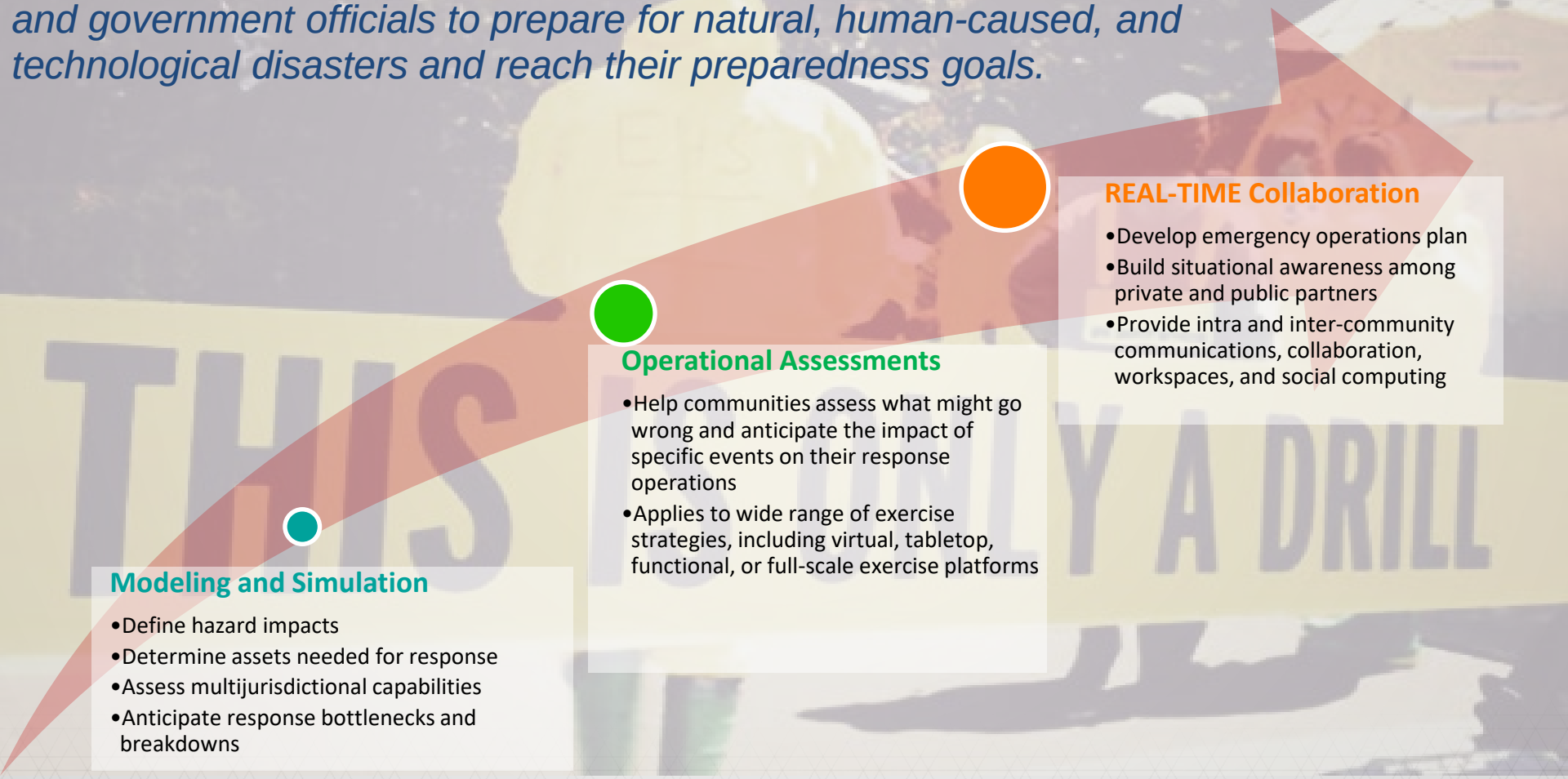
- Tools to assess vulnerabilities and develop mitigation/response options
- Tools cover full spectrum
  - Prepare
  - Mitigate
  - Respond
  - Recover

TOOLS for Economic/Reliable Operations

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

FROM MODELING AND ANALYSIS TO LARGE-SCALE DRILLS AND EXERCISES

For more than 30 years, we have supported the emergency management community and government officials to prepare for natural, human-caused, and technological disasters and reach their preparedness goals.



Modeling and Simulation

- Define hazard impacts
- Determine assets needed for response
- Assess multijurisdictional capabilities
- Anticipate response bottlenecks and breakdowns

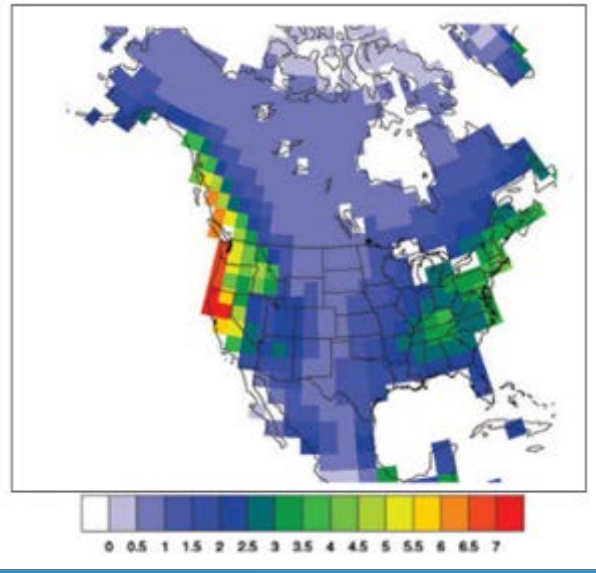
Operational Assessments

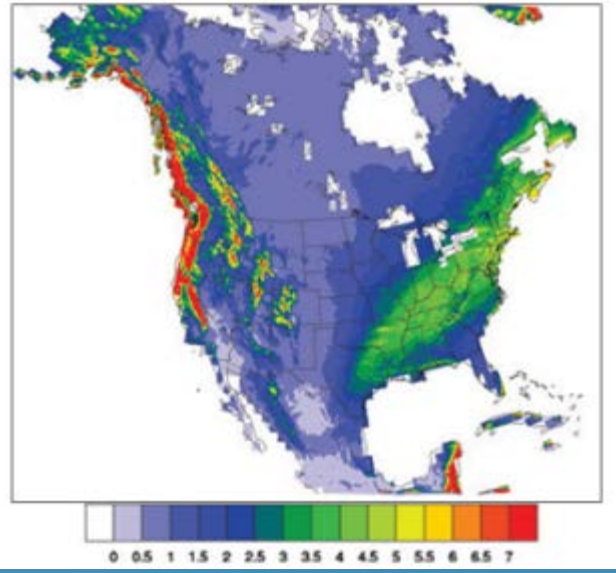
- Help communities assess what might go wrong and anticipate the impact of specific events on their response operations
- Applies to wide range of exercise strategies, including virtual, tabletop, functional, or full-scale exercise platforms

REAL-TIME Collaboration

- Develop emergency operations plan
- Build situational awareness among private and public partners
- Provide intra and inter-community communications, collaboration, workspaces, and social computing

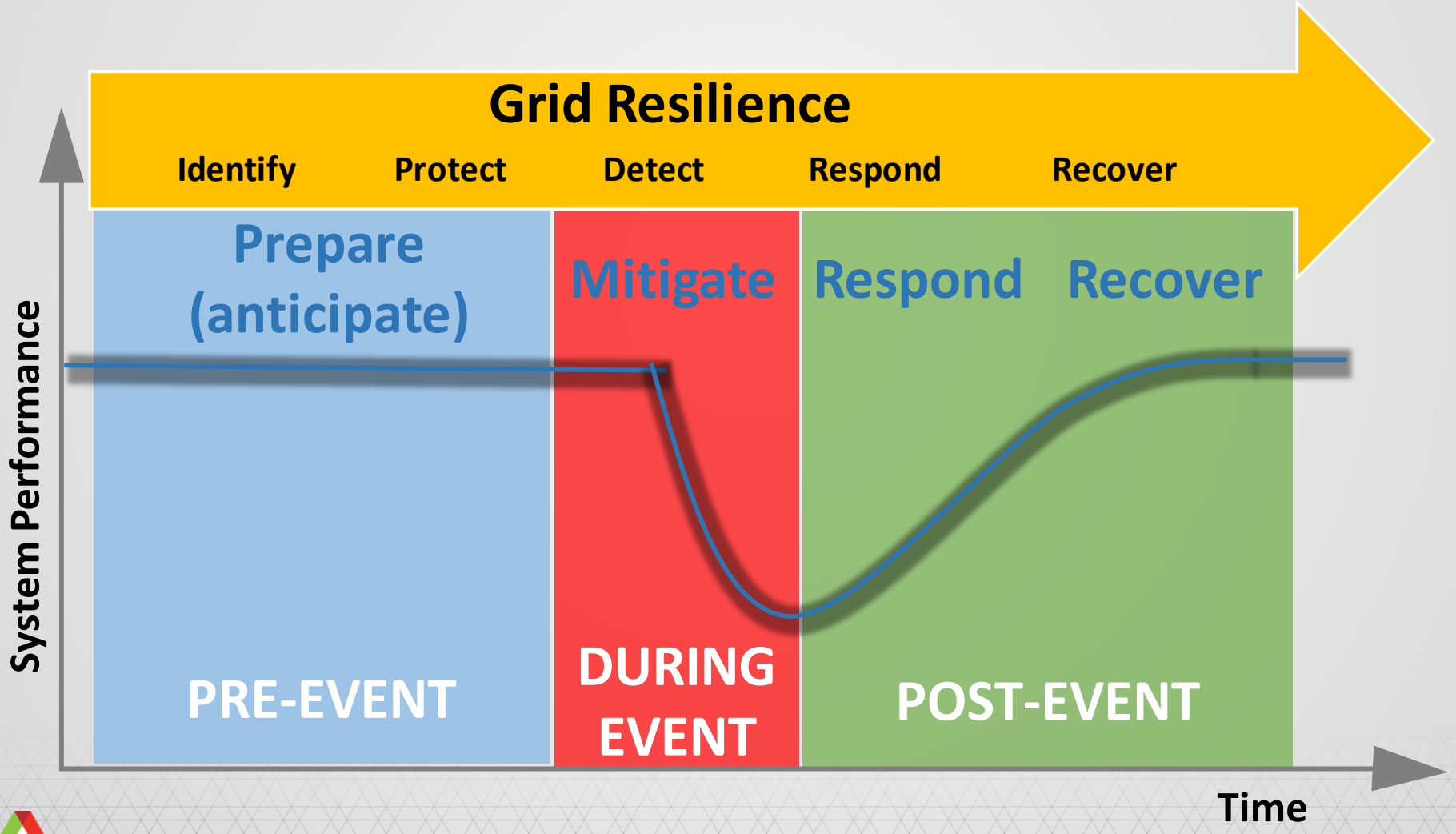
DOWN-SCALED CLIMATE DATA FOR REGIONAL ASSESSMENTS





- Generated high-resolution (12-km) climate projections/probability distributions of downscaled climate variables for all of North America, including Caribbean; 3-hour time steps, over 600 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
- Publically available; used in regional U.S. resiliency assessments
- Currently developing next-generation data (4x4km resolution) available next year
- Also working on downscaled climate data for Brazil

ARGONNE RESILIENCE AND RESTORATION TOOLS COVER ENTIRE RESILIENCE SPACE



ARGONNE RESILIENCE AND RESTORATION TOOLS

Prepare

- Emergency planning (**onVCP/ SyncMatrix, SpecialPop, AMP**)
- EP/PSR exercise/ drill (**Scenarios, Threat-Damage, Impact Models**)
- Gas-electric coordination (**Ngfast/ NGrealtime**)
- Dynamic stability, cascading failures (**DSAT, EGRIP**)

Mitigate

- Mitigation assessment (**EPfast, NGfast, POLfast, others**)
- Resource mitigation measures, dependencies (**IST-RMI**)
- Power system restoration, blackstart resource planning (**EGRIP**)
- Gas-electric coordination (**Ngfast/ NGrealtime**)

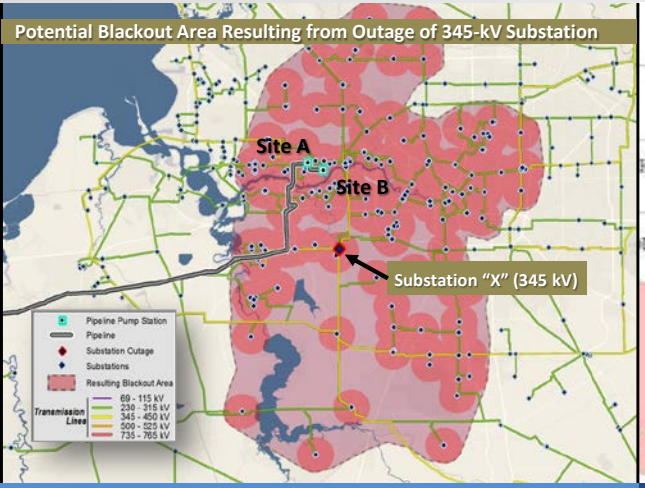
Respond

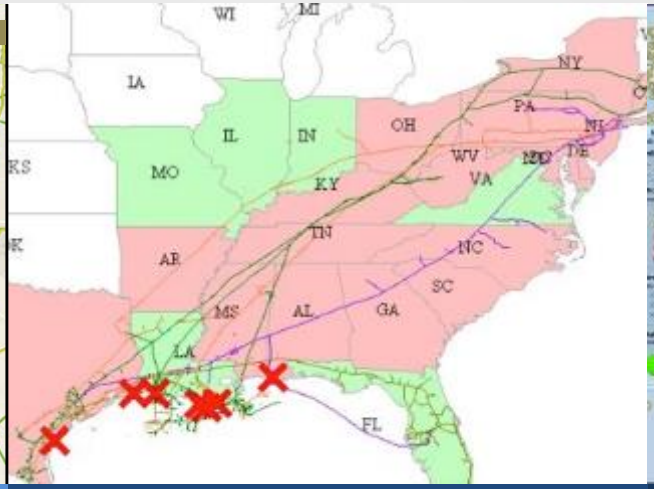
- Impact assessment (**Threat-Damage, Impact Models**)
- Hurricane assessment (**HEADOUT**)
- Emergency management/response (**onVCP, vBEOC**)
- Response logistics (**AMP**)

Recover

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

ARGONNE'S ENERGY SECTOR RESILIENCE MODELING TOOLS



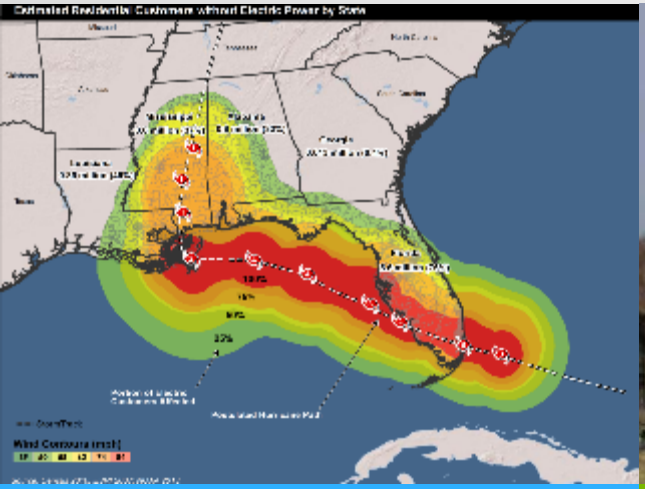


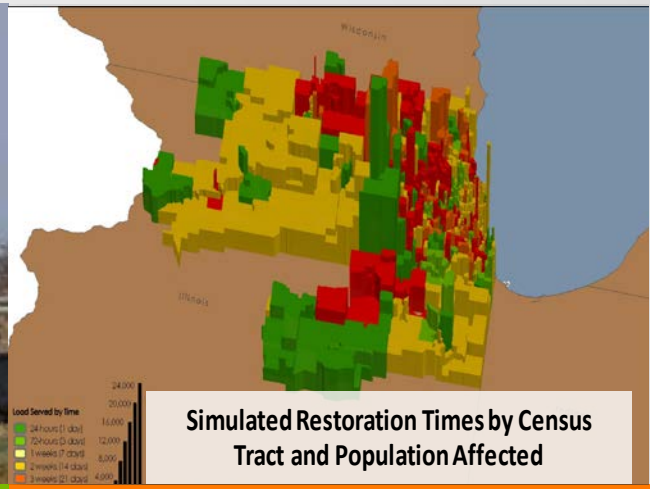
- **EPFAST** examines the impacts of power outages on large electric grid systems
- Models the tendency of power systems to "island" after either man-made or natural disturbances, which can lead to regional power disruptions

- **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





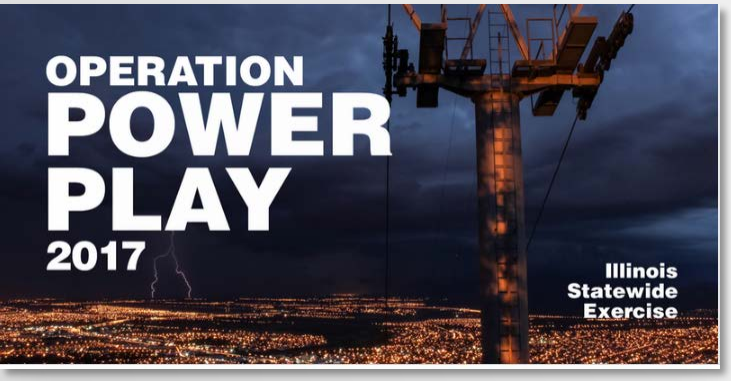
- **HEADOUT** produces an estimation of the potential number of electric customers that will experience a loss of commercial electrical power as a tropical cyclone makes landfall

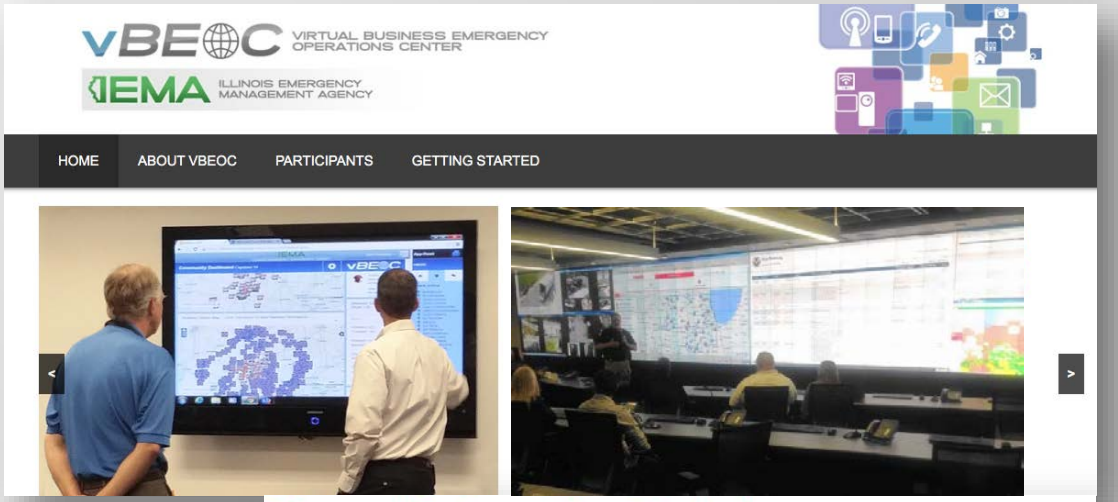
- **RESTORE** offers insights into *physical* outage repair times at critical infrastructure facilities
- Identifies the dependencies of the affected infrastructure and its impact on the restoration process

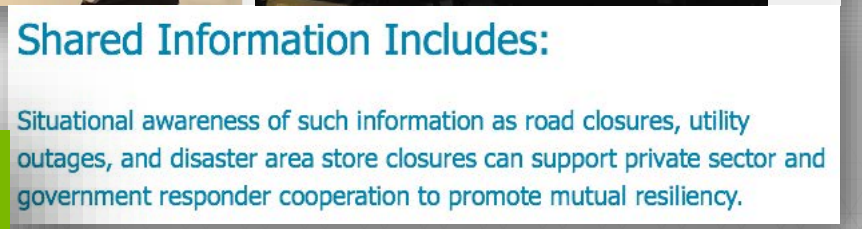
- **EGRIP** is an AC power flow based cascading failure/outage and integrated power system restoration optimization tool
- Restoration module supports restoration planning and operational decision-making for bulk-level and distribution-level restoration

ARGONNE'S ENERGY SECTOR RESILIENCE MODELING TOOLS

- **online Virtual Community Platform (onVCP) and Virtual Business Emergency Operations Center (vBEOC) provide situational awareness and Common Operating Picture for drills/exercises and during actual events**

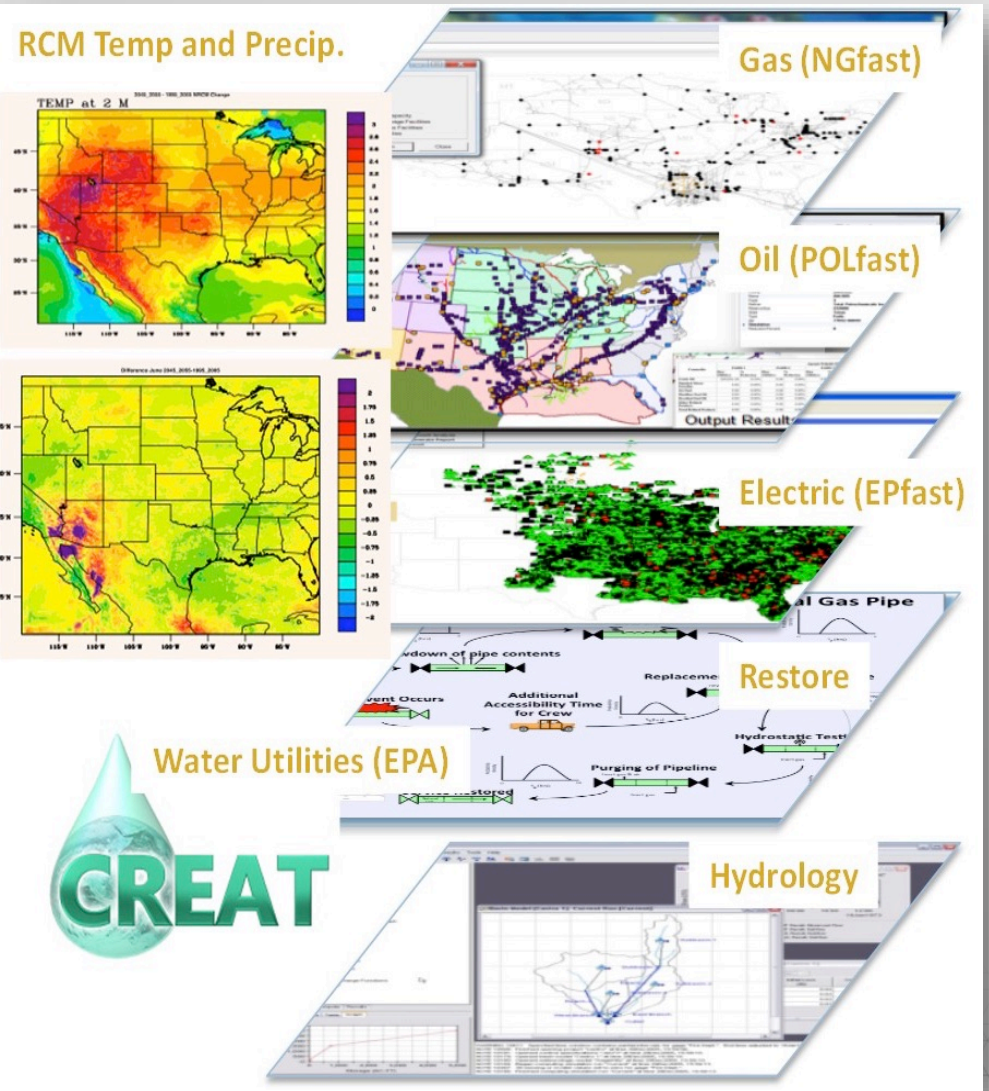






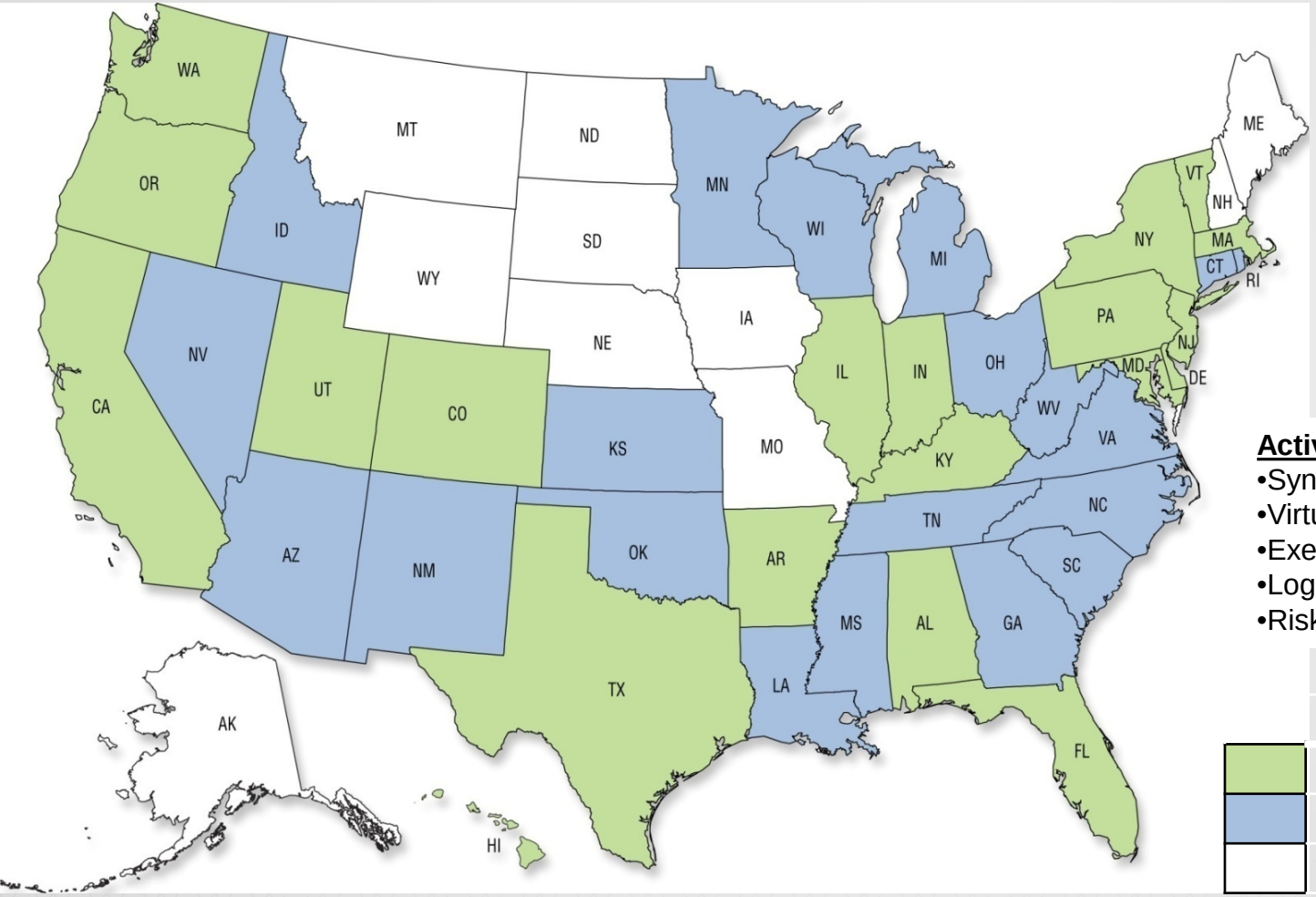
onVCP/vBEOC 4000+ users;
700 unique organizations

TOOL APPLICATIONS: SUPPORT DHS REGIONAL ENERGY RESILIENCE STUDIES



- Regional Resilience Assessment Program (RRAP)
- RRAP process identifies critical infrastructure security and resilience gaps; dependencies; interdependencies; cascading effects; State, local, tribal, and territorial government capability gaps; and resilience measures
- Argonne completed **over 60 RRAPs** (2009-2017)
- RRAPs include multiple infrastructure assessment tools (oil, gas, electric, water, service restoration)

TOOL APPLICATIONS: SUPPORT EMERGENCY PREPAREDNESS IN 40 STATES



Activities

- Sync Matrix planning
- Virtual Joint Planning Office
- Exercises
- Logistics Process Analysis model
- Risk communication training

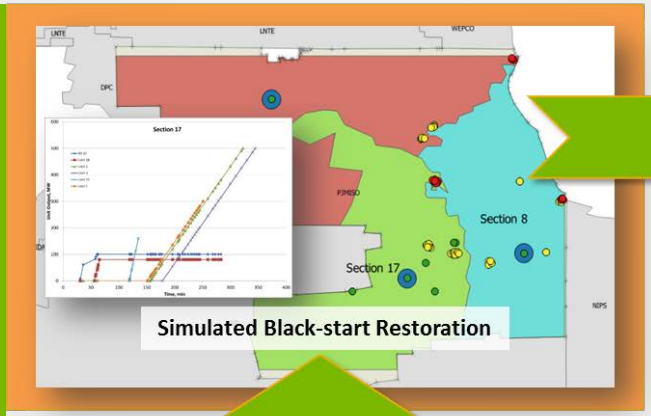
Legend
4 or more activities
1-3 activities
0 activities

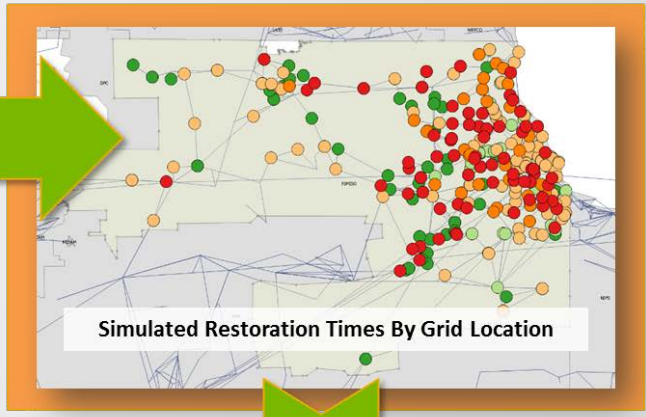
TOOL APPLICATIONS: SUPPORT REGIONAL AND NATIONAL-LEVEL EXERCISES

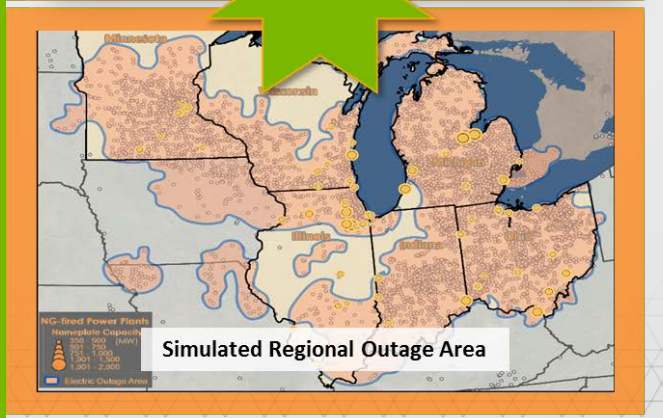
TOOL APPLICATIONS: SUPPORT FEMA REGIONAL POWER OUTAGE EXERCISES

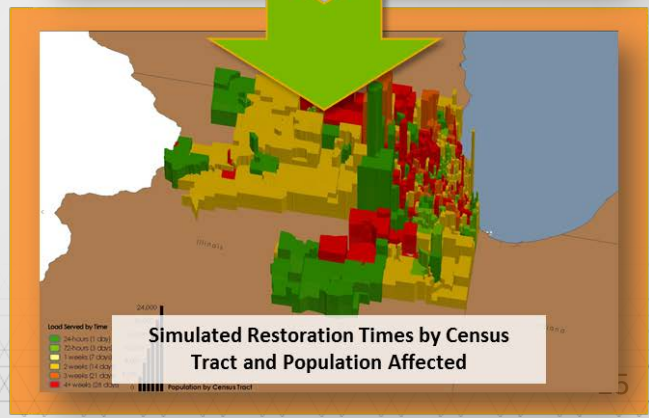
- Enable resilience stakeholders to consider restoration/recovery aspects for more effective emergency preparedness

- EPfast for impact/outage analysis, EGRIP to find optimal restoration plan that minimizes the overall power system restoration time
- DHS/FEMA Region 5: Grid impacts and response/recovery/ restoration from large-scale cyber attack
- DHS/FEMA Region 8: Impacts of major weather event

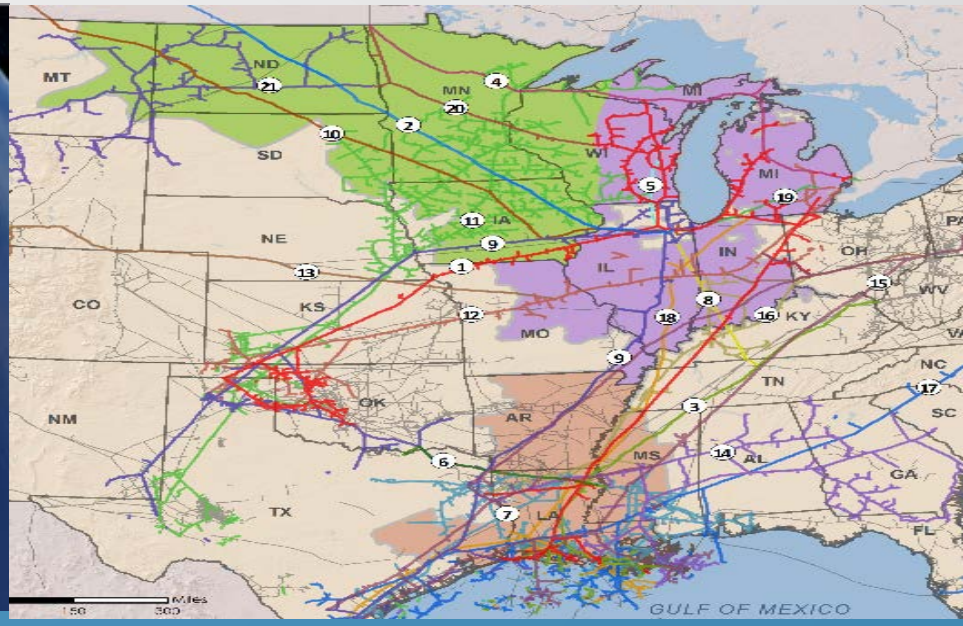








TOOL APPLICATIONS: MISO EP/PSR EXERCISES/DRILLS

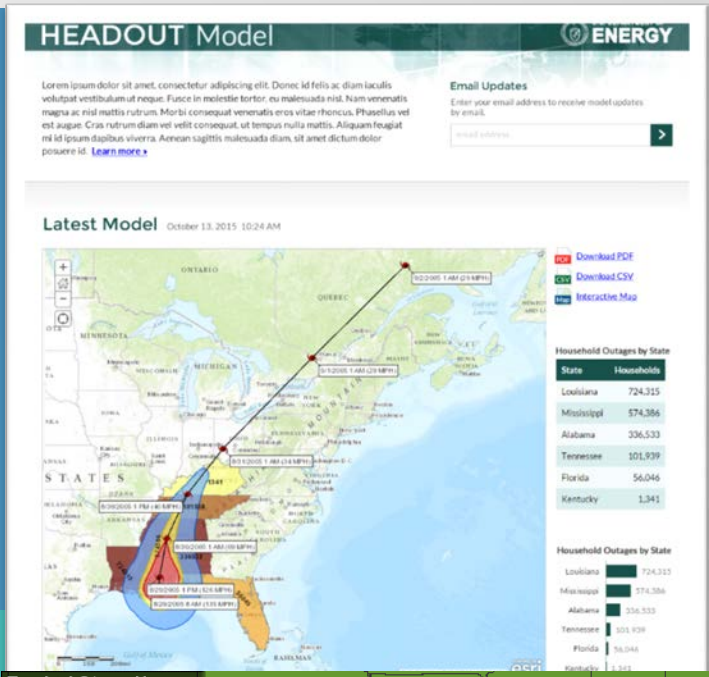


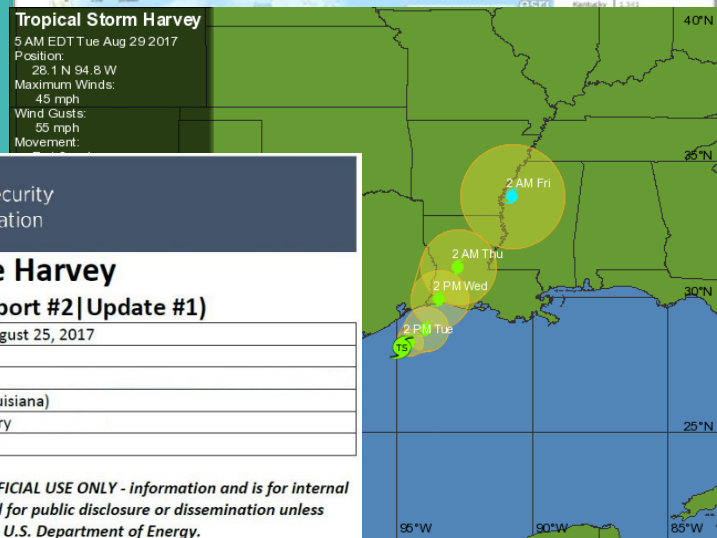
- Supported MISO working group for Emergency Preparedness and Power System Restoration (EP/PSR) since spring 2015
- Participated in 2016 spring drill on preparedness, October 2016 fall drill on response/recovery, April/May spring drill on preparedness
- Spring drills focus on hurricane scenario and impacts on various assets, including power plants, substations, transmission assets, and communications
- Fall drills focus on restoration while facing natural gas issues

TOOL APPLICATIONS: REAL-TIME IMPACT PROJECTIONS

- **Hurricane Electrical Assessment Damage Outage Tool (HEADOUT)**
- Quick turn around tool currently used by Federal Agencies
- HEADOUT tool typically used in support of DOE response activities; initially applied up to 5 days before hurricane landfall
- Currently applied to Hurricane Harvey providing critical information across U.S. Government

- Tool outputs: Customers at-risk of electric outage by county and State
- Results can be calculated by census tract and county
- Results updated when new NOAA Advisory information becomes available
- Maps and data files can be downloaded, and can be viewed on interactive map online





U.S. DEPARTMENT OF ENERGY | Infrastructure Security & Energy Restoration

Hurricane Harvey

Situation Report (Report #2|Update #1)

REPORT TIME & DATE:	4:00 PM EDT | Friday, August 25, 2017
INCIDENT START DATE:	Friday, August 25, 2017
PRIMARY LOCATION(S):	Gulf Coast (Texas and Louisiana)
THROUGH:	Deputy Assistant Secretary
REPORT DISTRIBUTION:	DOE, Federal, and State

The following report contains business sensitive - OFFICIAL USE ONLY - information and is for internal U.S. Government use only. This report is not intended for public disclosure or dissemination unless otherwise noted or approved by the U.S. Department of Energy.

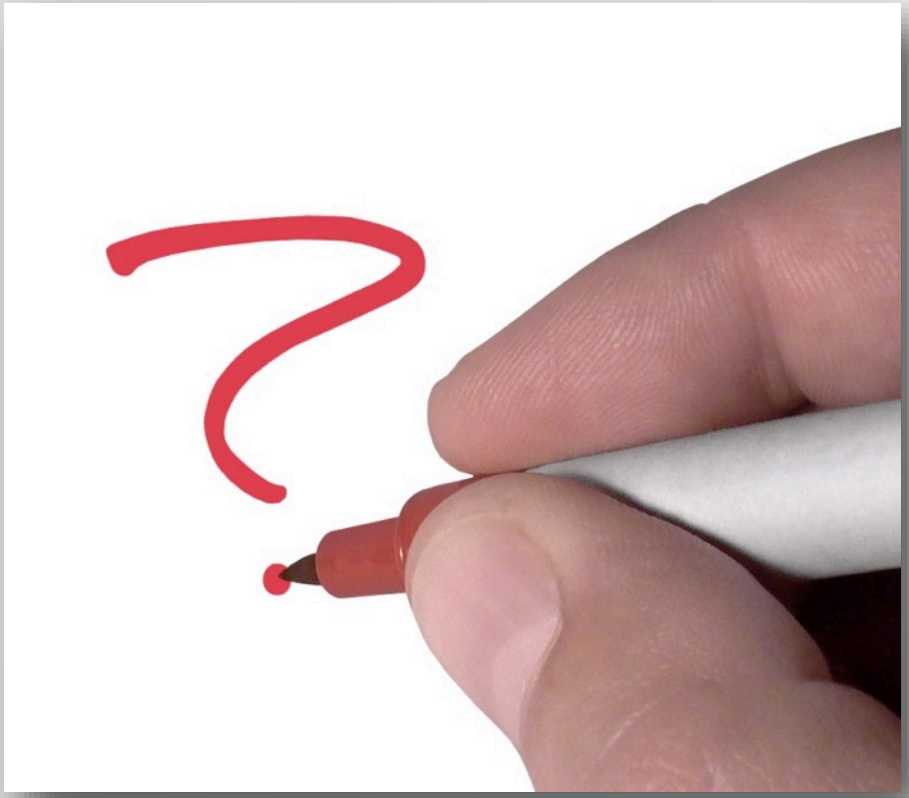
IN SUMMARY

- Argonne offers extensive experience and expertise and a range of tools to meet stakeholder needs for enhanced situational awareness, vulnerability and resilience analysis and evaluation, operational drill and exercise support, and faster and more efficient response and recovery

- Argonne works with diverse stakeholders, including electric, natural gas, and telecommunications industries, and emergency response agencies

- Argonne's tools are used extensively by industry and stakeholders and have already led to tangible steps to improve energy sector security and resilience

FOR MORE INFORMATION PLEASE CONTACT:



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