U.S. DEPARTMENT OF
ENERGY
Office of Electricity

DOE-OE Advanced Modeling Grid Research Program

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U.S. Department of Energy Electricity Advisory Committee Meeting

July, 2018

U.S. DEPARTMENT OF ENERGY
Office of Electricity

Division of Advance Grid R&D Advanced Modeling Grid Research/ Advanced Grid Modeling (AGM)

The AGM program supports the nation's foundational capacity to analyze the electric power system using Big Data, advanced mathematical theory, and high performance computing to assess the current state of the grid and understand future needs.

Successful research in this area would enable grid operators to optimize their decision-making in real-time giving the industry a sophisticated tool to dramatically improve reliability, resiliency, and grid security.

Advanced Grid R&D Programs At-A-Glance

Grid Controls and Communications	*1. Resilient Distribution Systems*	Advanced Distribution Systems	Advanced Microgrids	Dynamic Controls and Communications	Advanced Low-Cost Sensors
Grid Controls and Communications	*2. Transmission Reliability and Resilience*	Synchrophasors		Advanced Grid Modeling	
Grid Systems and Components	*3. Transformer Resilience and Advanced Components*	Advanced Power Grid Components			
Grid Systems and Components	*4. Energy Storage Systems*	Energy Storage			

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The Need for Advanced Grid Modeling

Grid operation decision making has not utilized new analytical tools or big data modeling power.

Third party vendors and distributed energy resources are capturing and producing valuable grid data.

Grid operators do not have detailed visibility of the rapid technology deployment on the system.

Utilities and regulators need standardized data and advanced models to support their operational, planning, and decision making processes.

Advanced Grid Modeling (AGM) Objectives

To address these challenges, OE's AGM Program objectives are:

- **Support** the transformation of data to enable **preventative actions rather than reactive responses** to changes in grid conditions;
- **Direct the research and development of advanced computational and control technologies to improve the reliability, resiliency, security**, and flexibility of the nation's electricity system;
- **Help** system operators and utilities **prevent blackouts and improve reliability** by expanding wide-area real-time visibility into the conditions of the grid;
- **Help** system operators and utilities **minimize the effect of the extreme events and improve resilience** through pre-impact operations and the recovery/restoration process;
- **Support** improvement of the performance of **modeling tools and computations** that are basis of the grid operations and planning; and
- **Support** the tracking and expansion of the use of quantitative risk and uncertainty methods by federal and state level energy system **decision makers regarding energy infrastructure investments**.

Advanced Grid Modeling Program Areas

Research Areas	Goal
Data Management & Analytics	• Focus on the way data is collected, used, stored, and archived to improve applicability of large, multi-source datasets for real-time operations and off-line planning studies
Mathematical Methods & Computation	• Address emerging mathematical and computational challenges arising in power systems • Reduce barriers to data employment by utilities, research community and policy makers
Models & Simulation	• Research on a new class of fast, high fidelity capabilities that underpin better grid operations and planning in a large-scale, dynamic, and stochastic environment

Government Role to Spur Advanced Grid Modeling

Convening:

- Create new relationships with grid operators, academia, and advanced computing to understand how to turn complex data analytics into actionable business value

Catalyzing:

- Assess and disseminate successful and innovative modeling solutions throughout the highly fractured electricity industry

Capacity Building:

- Support partnerships with, and between, academic institutions and utilities to create opportunities to build out mathematical capabilities within the field of grid operations

Key Partnerships Going Forward

- Expand partnerships with and between academia and industry stakeholders
- Explore how data analytics, mathematics, and models can be integrated to fully address the complexity of the electric grid
- Identify ways to accelerate the adoption of these new methods
- Continue to break down the barriers to the high-quality data

National Science Foundation

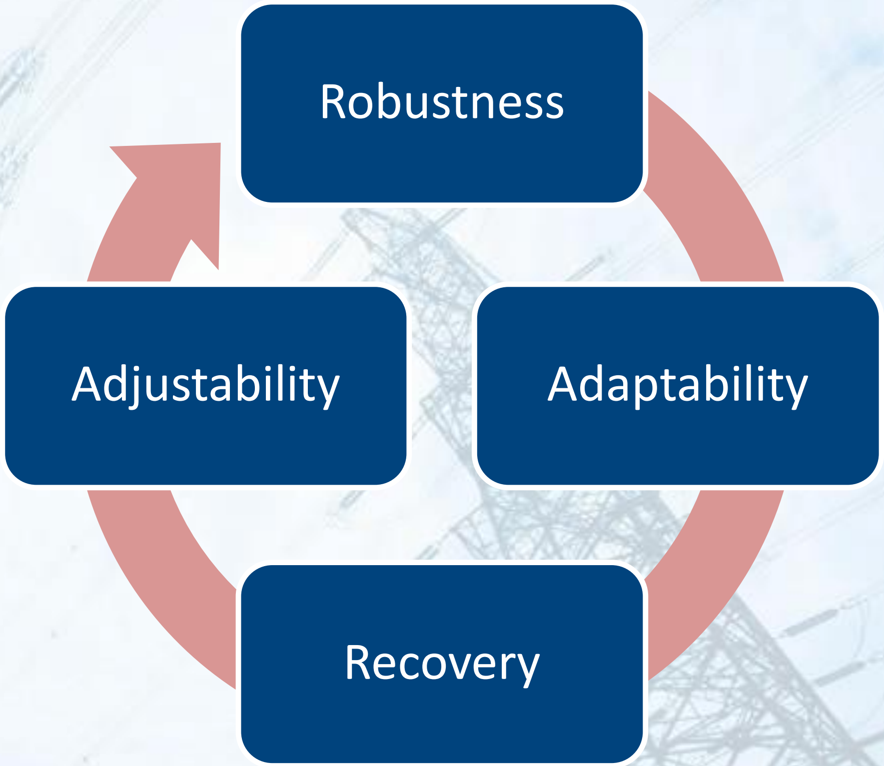
OE-AGM and NSF came together to form the "Algorithms for Modern Power Systems (AMPS)" partnership to develop the next generation of mathematical and statistical algorithms for improvement of the security, reliability, resiliency, and efficiency of the modern power grid.

Current Modeling Projects under AGM

- Advanced Mathematical Algorithms for Model Reduction and Stochastic Modeling for the Emerging Power Grid
- Data-Driven Modeling Preserving Controllable DER for Outage Management and Resiliency
- Dynamical Modeling and Optimal Control of Electrical Grid & natural Gas Transmission System
- Interconnection-level Load Modeling for Eastern Interconnection
- Modeling and Optimization of Electric Grid Resilience Recovery and Restoration
- Modeling of Dynamic Grid Partition and Operation Enhancing Grid Resilience
- Modeling tool for regulators
- Multi-Fidelity Modeling via Machine Learning for Real-time Prediction of Power System Behavior
- Open-Source High-Fidelity Aggregate Composite Load Models of Emerging Load Behaviors for large-Scale Analysis
- Resilient All Power Electronics Grid (APEG) Modeling and Operation
- Robust Real-Time Modeling of Distributed Systems with Data-Driven Grid-Wise Observability
- Stochastic Modeling of the Power Grid
- ***North American Resilience Model Initiative***

Elements of Resiliency

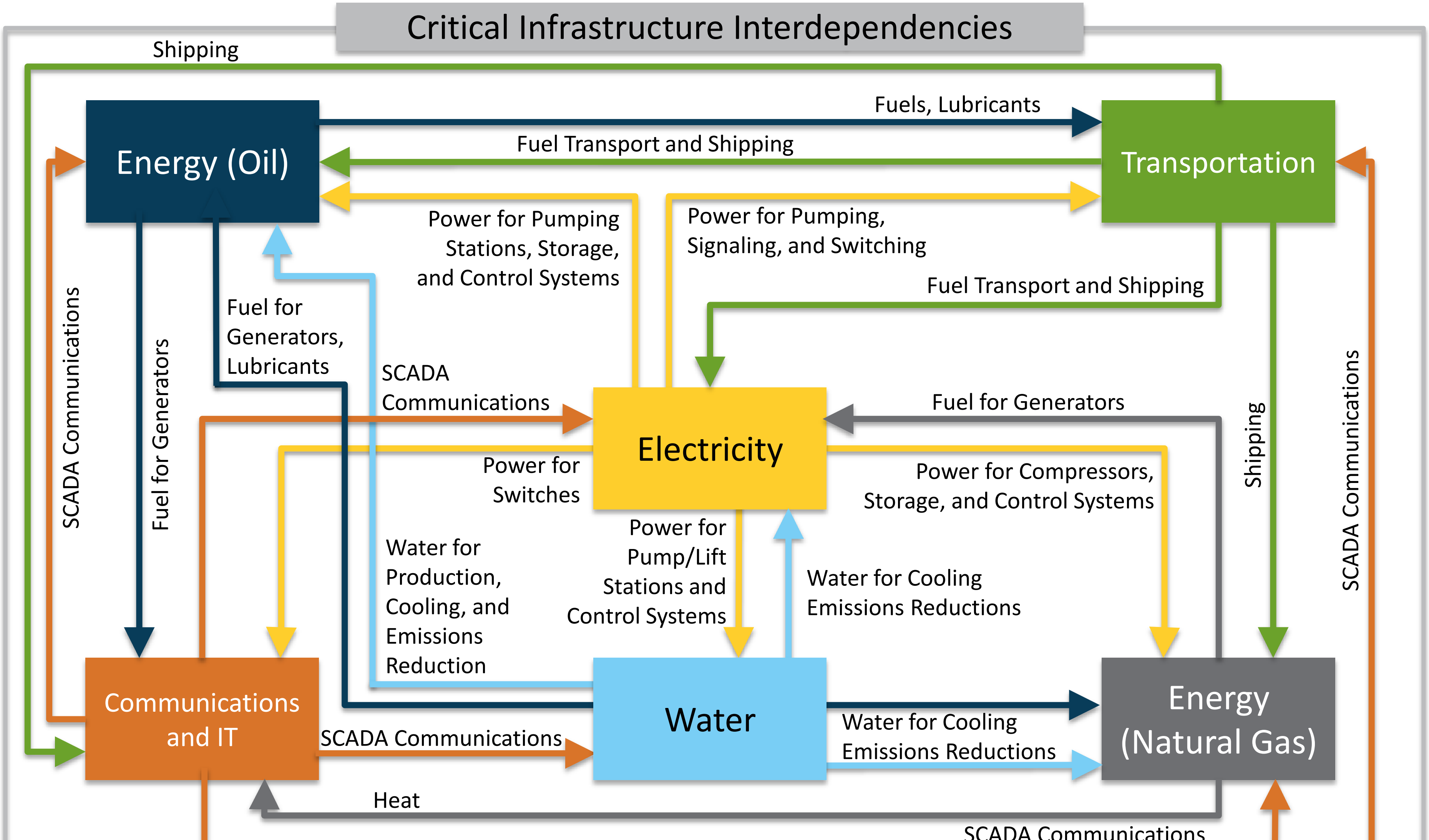
- **Robustness—the ability to absorb shocks and continue operating;**
- **Adaptability—the ability to quickly and effectively modify the system to manage and overcome the crisis as it unfolds;**
- **Recovery—the ability to restore the system as quickly as possible;**
- **Adjustability—the ability to make adjustment based on lessons learned from past events.**



North American Resilience Modeling

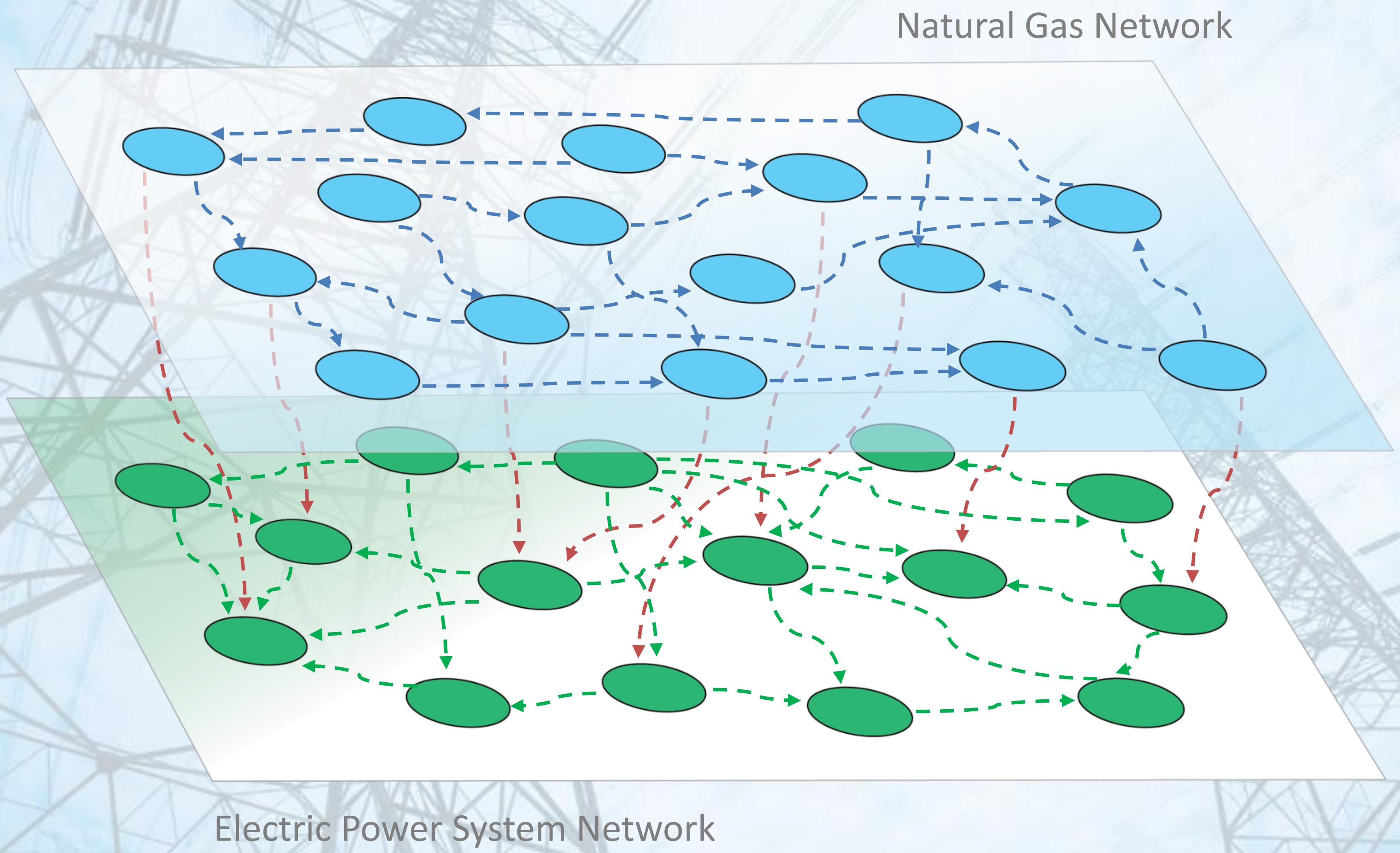
- **Study robustness and adaptability**
- **Provide insight into recovery strategies**
- **Improve the attributes of resilience**
- **Identify future investment to improve the resiliency of the system**

U.S. Critical Infrastructures Depend on Electricity



Source: Finster, 2016

Example of Interdependency



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Threats

Hurricane	Drought	Winter Storms/Ice/Snow	Extreme Heat/Heat Wave
Flood	Wildfire	Sea-level rise	Earthquake
Geomagnetic Pulse	Wildlife/Vegetation	Physical Attack	Cyber Attack
Electromagnetic Pulse	Equipment Failure / Aging Infrastructure	Combined Threats	& others …

Modeling

- Models are intended to predict responses of the grid to disruption or predict outages due to a disruption.
- Generally Models primarily focused on natural hazards to inform utility risk analysis.
- Utilities are using modeling to prepare integrated resource plans that allow them to plan to balance the generation and load.
- System study needs to include the impact of interdependency between different infrastructure systems as well as the natural and man made threats.
- Based on the study done, plan(s) needs to be developed to improve resiliency of the system.

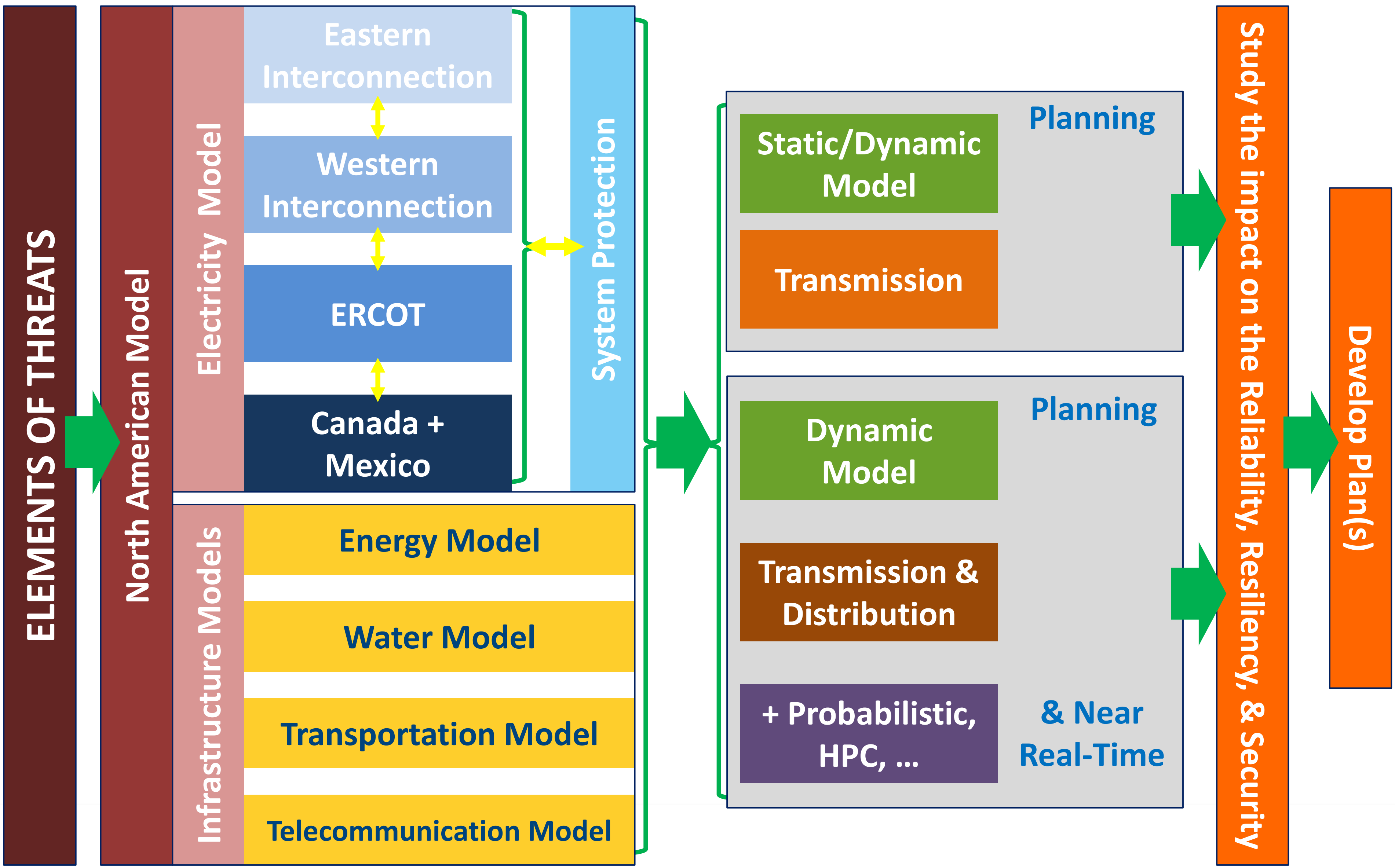
Examples of Scenarios for Modeling

- How a hurricane impacts the production of electricity
  - Elements of a Hurricane
    - High Wind
    - Rain & Flooding
    - Cloud
    - Debris
    - …

Examples of Scenarios for Modeling

- How a hurricane impacts the production of electricity
  1. Impact on Electricity equipment
     - Flooded substations
     - Down poles
  2. Impact on Energy
     - Interruption in power generated by solar, wind, gas, & …
  3. Impact on Transportation
     - Difficulty in getting to the impacted areas for repair
  4. Impact on natural gas
     - Outages in gas pipe lines

Conceptual Plan for the North American Resilience Modeling Initiative



Plans

- **Identify and protect critical asset(s) important for the National Security**
- Identify the potential impact of the interdependency between different infrastructure systems
- Minimize the impact of the threat and reduce risks
- Provide Corrective actions to get the system to the stable condition and continue the operation
- Identify viable plan(s) for outage management and system recovery
- Identify the future investment needs to prevent/minimize the impact of the event of the same nature as well as improve reliability, resiliency, and security. The future investment could be: building new generator(s); deploy Microgrid; utilize energy storage; diversify the fuel and generation mix; develop new operational procedure, and ….

Examples of Scenarios for Modeling - Continued

- Possible plans to deal with hurricane
  - Hardening substations to withstand high wind and flooding
  - Islanding the system
  - Utilizing energy storage and microgird
  - Utilizing diversification in fuel and generation mix to help with islanding
  - ...

February 2011 Southwest Cold Weather Event

- **Approximately 1.3 million electric customers did not have service at the peak of the event on February 2, and a total of 4.4 million were affected over the course of the event from February 2 through February 4.**

- **Natural gas customers experienced extensive curtailments of service during the event.**

- **Local distribution companies (LDCs) interrupted gas service to more than 50,000 customers in New Mexico, Arizona, and Texas.**

Lessons Learned - Southwest Cold Weather Event

- Capacity Awareness During an Energy Emergency Event
- **Gas and Electricity Interdependency**
- Transformer Oil Level Issues During Cold Weather
- Winter Storm Inlet Air Duct Icing
- Wind Farm Winter Storm Issues
- Rotational Load Shed
- Transmission Facilities and Winter Weather Operations
- Plant Onsite Material and Personnel Needed for a Winter Weather Event
- Plant Operator Training to Prepare for a Winter Weather Event
- Plant Instrument and Sensing Equipment Freezing due to Heat Trace and Insulation Failures
- Plant Fuel Switching and Cold Weather
- Adequate Maintenance and Inspection of Generator Freeze Protection
- Generating Unit Temperature Design Parameters and Extreme Weather Conditions

Key issues require EAC guidance

- Data Handling
- Industry Involvement
- Model Validation
- Information Sharing

Thank You!