RTDS and HIL Testing

The INL Energy Systems Complex and the DOE "SuperLab" Concept for Solving Grid Integration of Renewable Energy

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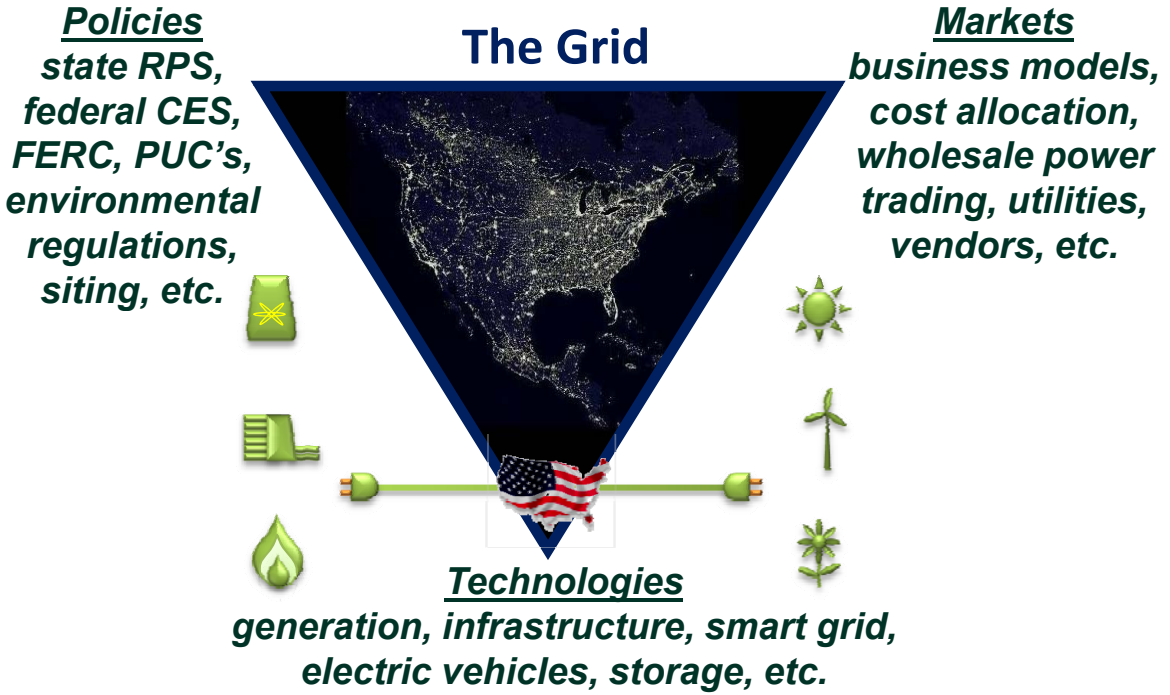
Idaho National Laboratory

DOE's Research Goals

- Enhance the penetration of renewable energy while maintaining grid reliability, security and resiliency
  - Dr. Danielson's goal is 80% renewable penetration by 2050
- Integrate energy storage systems, balancing power and energy
- Optimize integration of diverse energy resources
  - Dr. Danielson's goal is to increase clean energy sources
- Improve utilization of delivery existing infrastructure
- Advance electric vehicle penetration

DOE EERE/OE Approach: The Grid Tech Team

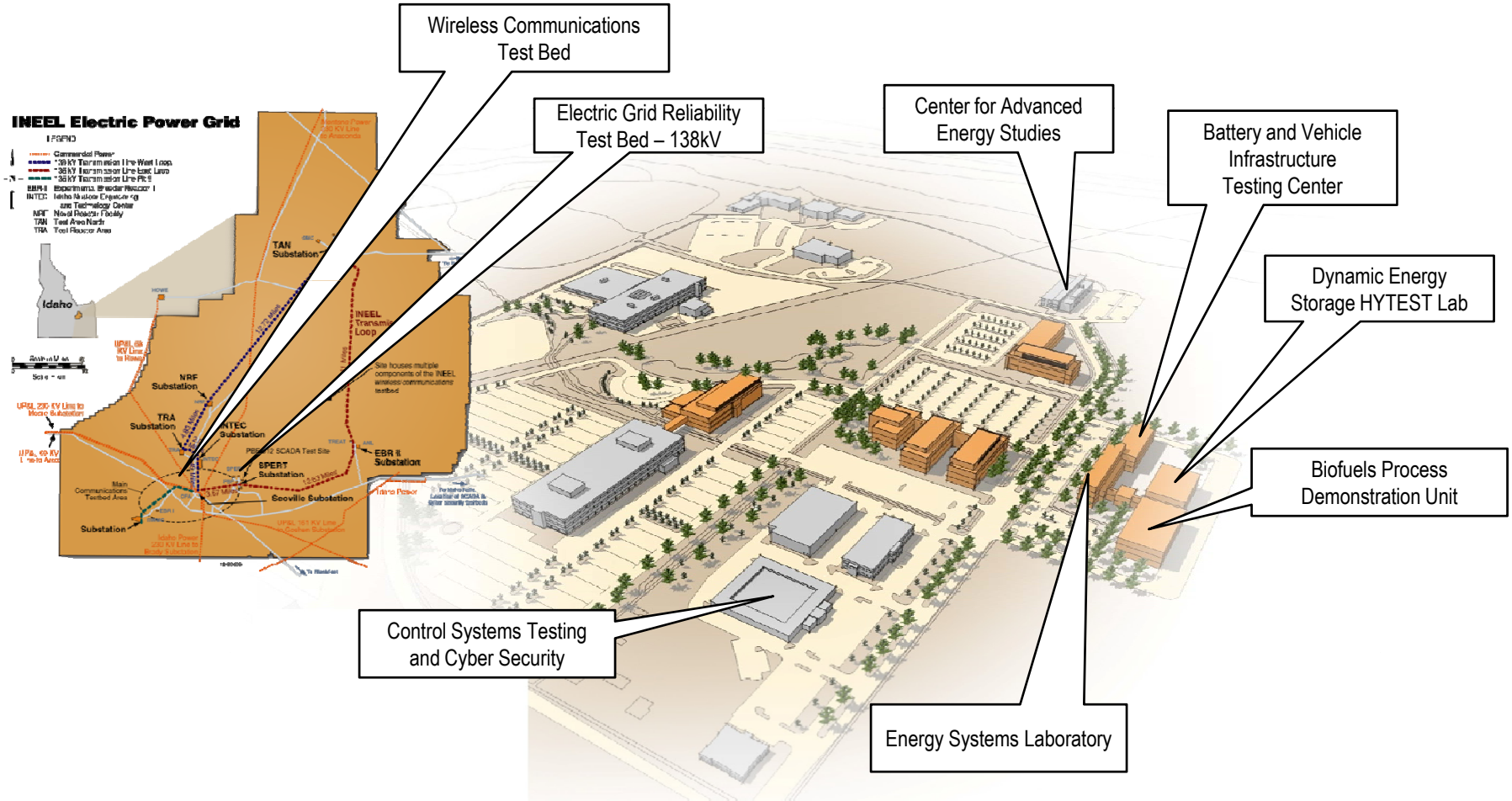


Vision 2020: *INL will have established nationally recognized Energy Systems Testing Complex and Provided Leadership in Developing new Business Model for DOE with the Energy and Power Systems Super Lab*

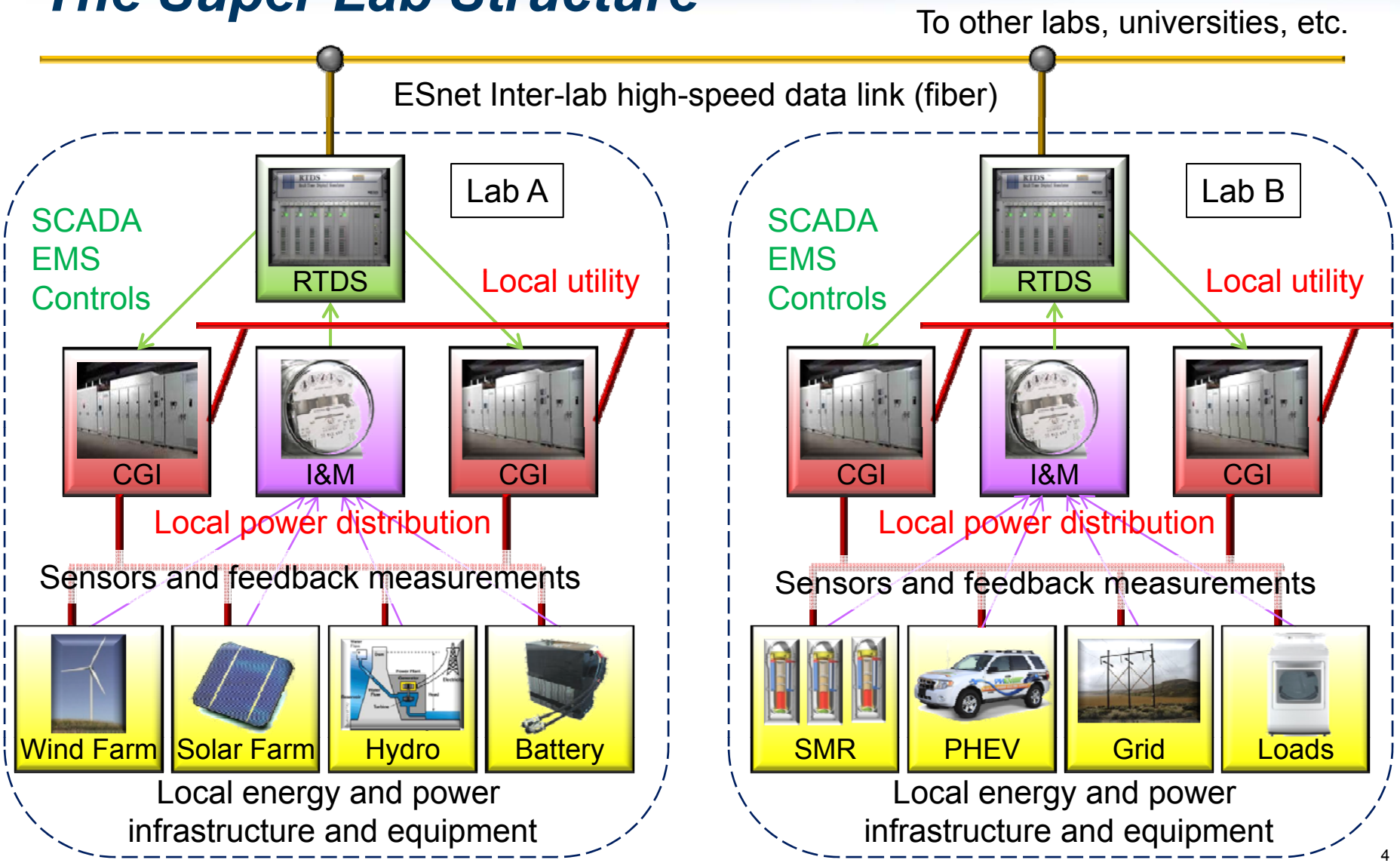
Phase I: Develop integrated & differentiating INL Campus/Site Energy Systems Complex

Phase II: Establish resilient energy and power "systems super lab" with other DOE Labs

Phase III: Integrate nuclear and fossil energy research needs



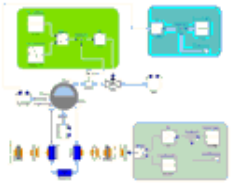
The Super Lab Structure



Analysis, Testing & Optimization of Dynamic Energy Systems

- Innovation
- Collaboration
- HiL demonstration

"Runtime integration and cooperation of simulation tools & hardware assets"



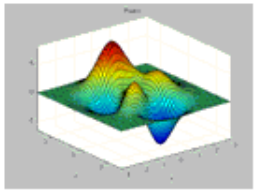
HES Dynamic Co-Simulation Test Bed

Dynamic Physical Systems Simulations
- Acausal dynamic simulations
- Causal dynamic simulations
- Multi-domain hybrid models

Monitoring, Controls & Intelligent Systems

- Resilient Control Systems
- Diagnostics & Prognostics
- Predictive Monitoring & Controls

Data Analysis & Optimization

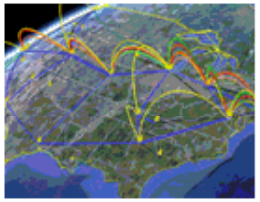


- Dynamic Performance Analysis
- Dynamic Cost/Economic Analysis
- Multidimentional Optimization

Hardware-in-the-Loop (HiL)

- INL Powergrid Test bed
- INL Telecommunication Test Bed
- Power / Thermal Converters
- Realistic Electrical / Thermal Components (e.g., SCADA, transformers, heat exchangers)

Collaborator links w/ Real-time data



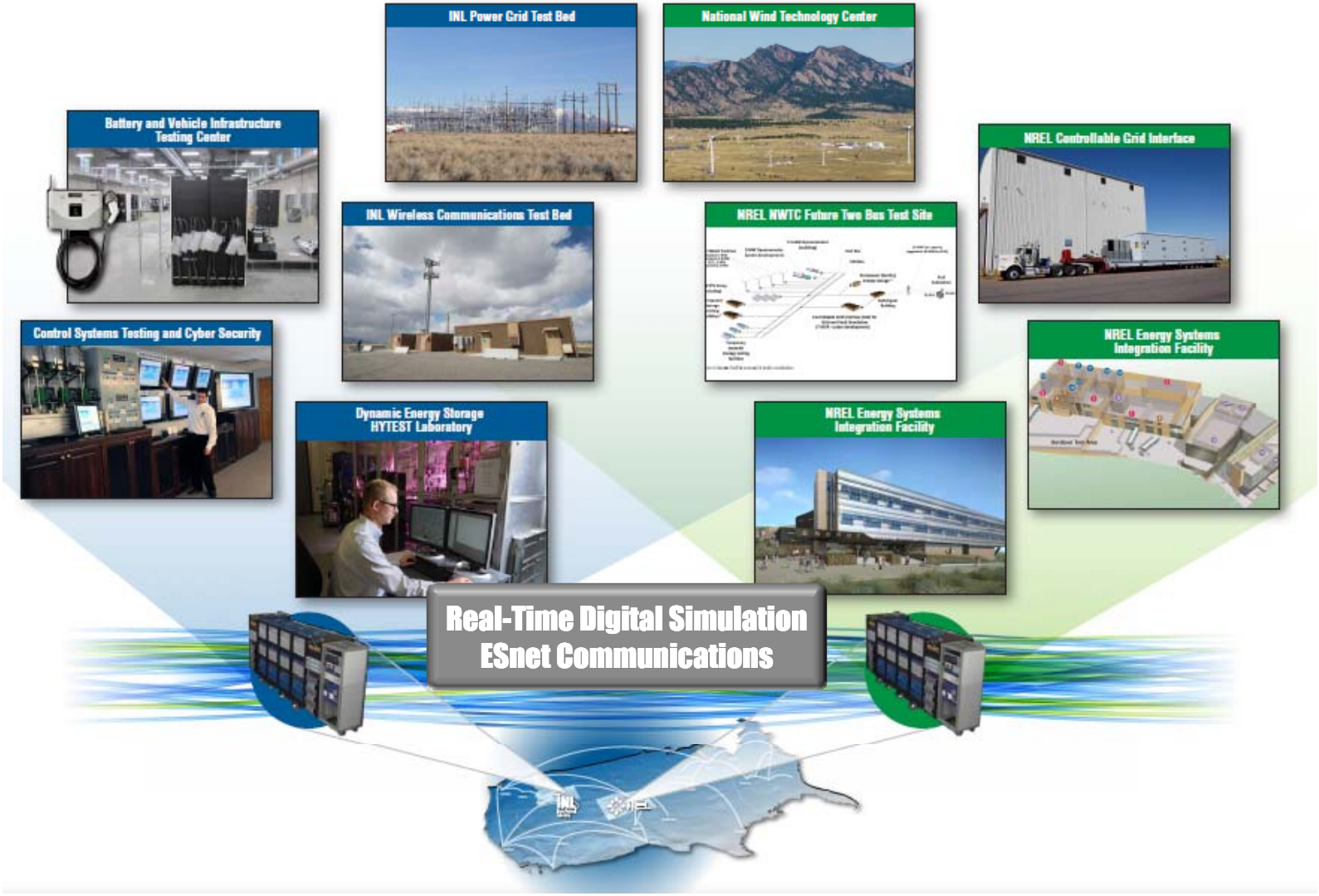
- Energy Sciences Network (ESnet)
- INL RTDS & communication links
- Collaborators' assets

Other Simulations & Legacy Models

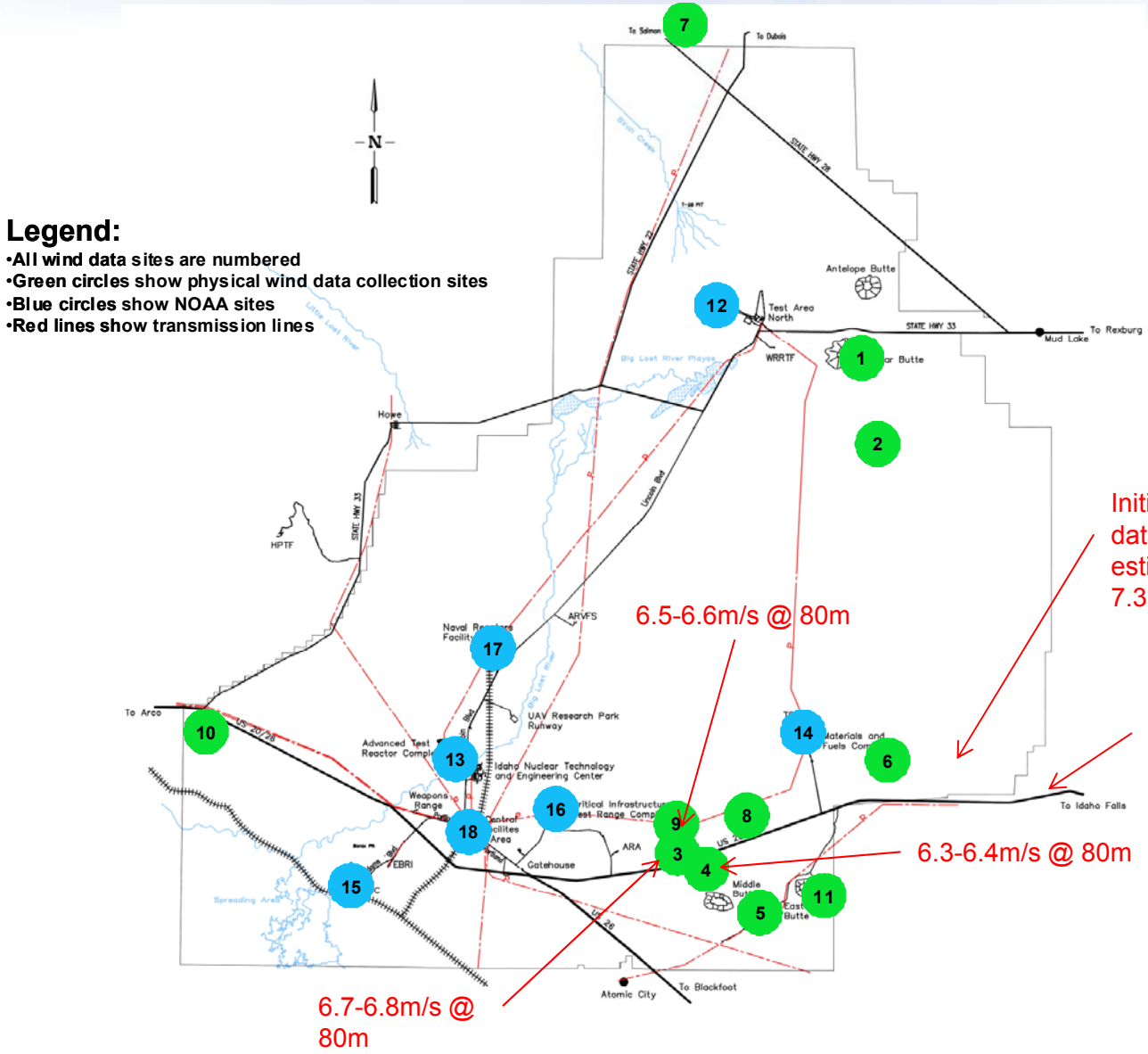
RELAP5 3D

- Fortran, C/C++, Java, Python programs
- MATLAB/Simulink, LabView, Scilab
- RELAP, ASPEN, HYSYS, FAST/AeroDyn

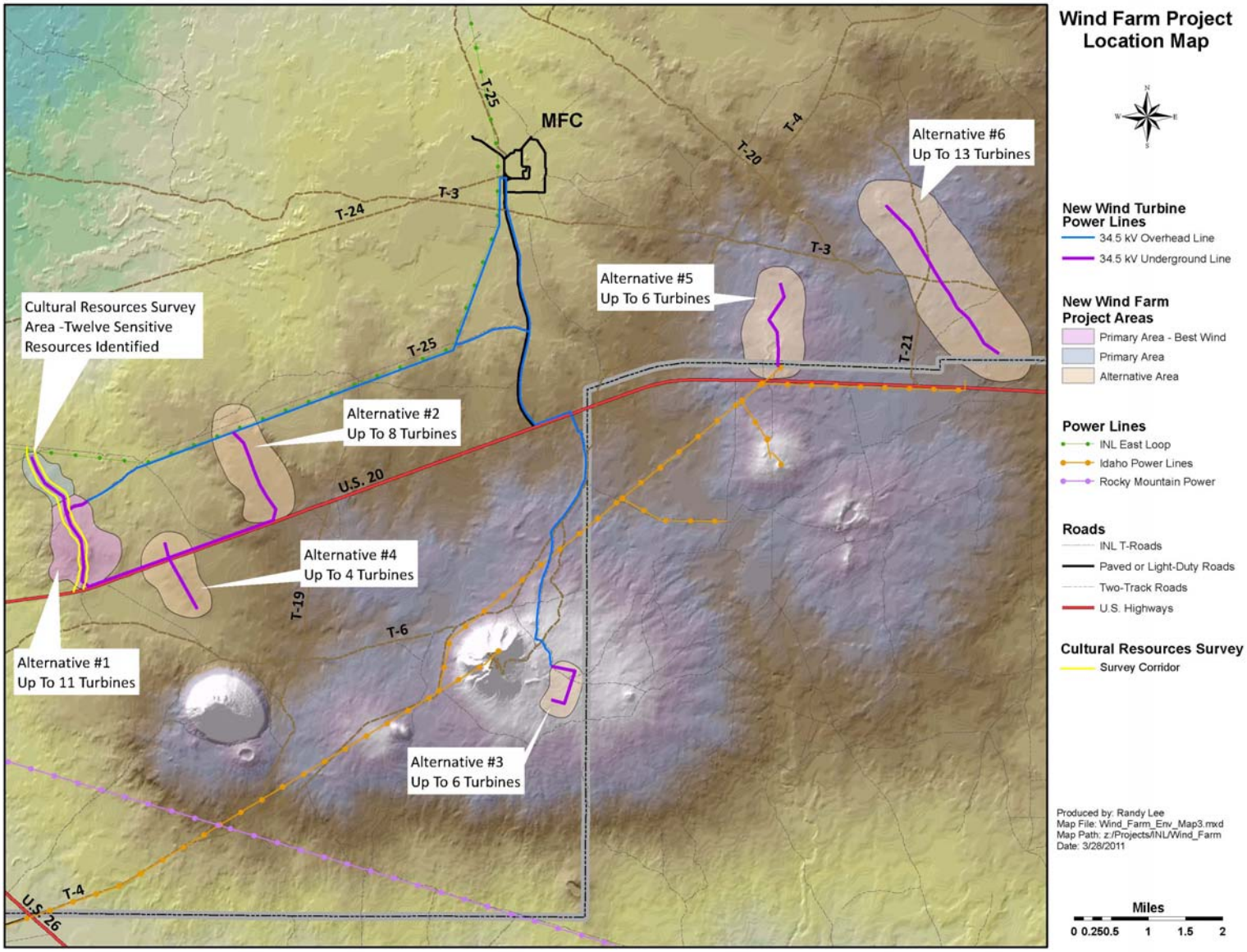
The Super Lab Core Partnership: Leveraging INL and NREL Assets to Form Initial Core of SuperLab Team



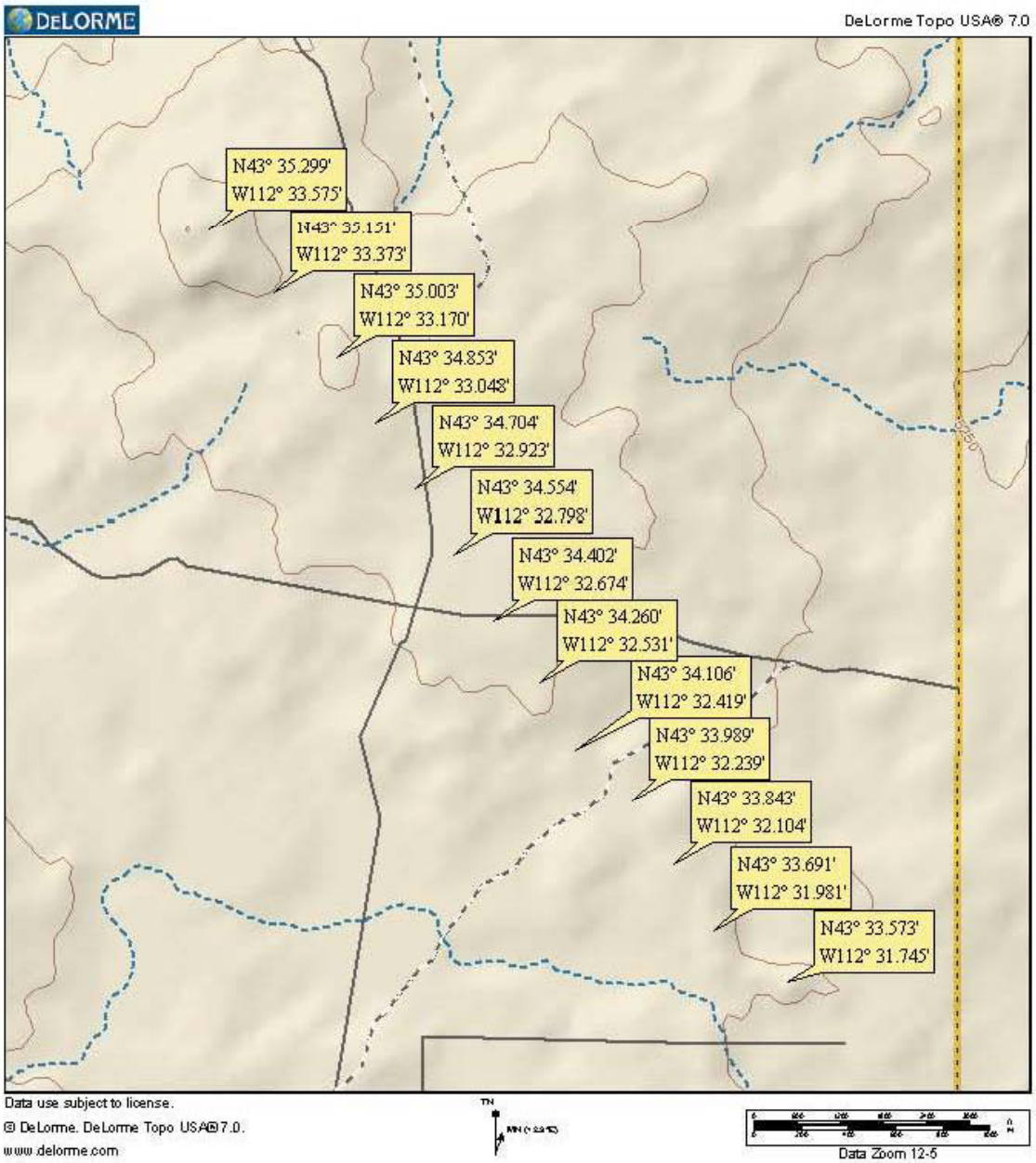
INL Wind Site Areas



INL Project Location Map



Area #6 Potential Turb Layout



Overview/Status

- Class 3 wind site identified: commercially viable
- At area #6, with low wind turbine model, gross capacity factor estimated between 38-40%.
- Many locations around INL have been assessed to characterize the wind resources, and best wind sites identified.
- Possible alternatives identified for electrical interconnection
- No anticipated fatal flaws
  - Biological survey—mitigation looks promising
  - Cultural survey—mitigation looks promising
- Power line connection design will not impact safety system

Project Description

- Total wind farm nameplate capacity is planned at 20MW
  - Potential for larger project size
  - This will be driven by project economics and turbine availability at time of contract award
- Total number of turbines combined from all areas will range between 8-13 turbines
  - Depending on the nameplate size of the wind turbine chosen for the project
  - Wind turbine nameplate size will range between 1.5-3.0MW.
  - Wind turbine hub height will be between 80-100 meters depending on turbine chosen
  - Wind turbine rotor diameters will likely be between 82-117 meters depending on turbine chosen

Super Lab Capabilities

- Super Lab concept will pave the way for research testing of models such as the Renewable Energy and SuperGrid Integration project

Issue

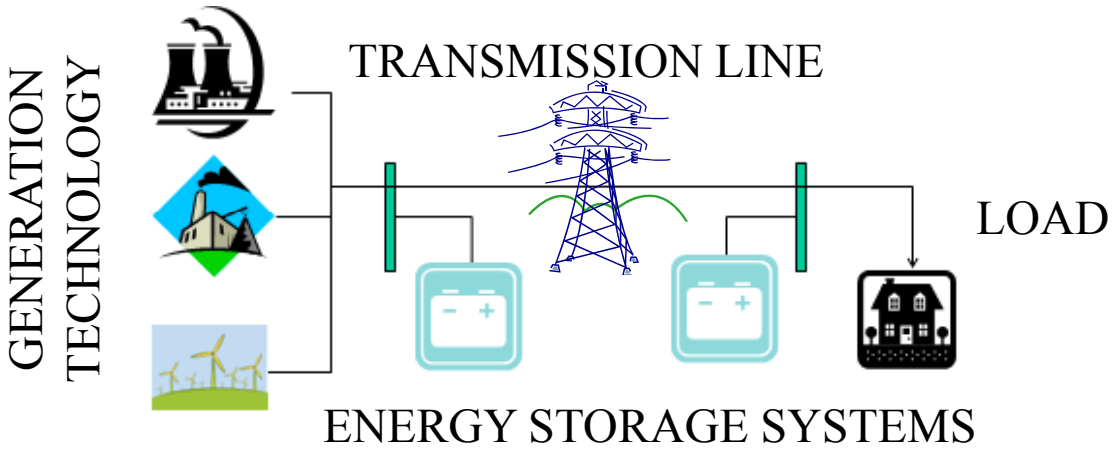
Unable to meet demand if largely dependent upon variable generation

$$Pdemand = Pbase + Pdispatchable + Pvariable$$

Transmission system capacity built to handle peak demand, but is rarely met

Goal

Use ESS to control variable generation
Maximize transmission system capacities at all times



Super Lab Provides Full Scale Testing

ESnet Inter-lab high-speed data link (fiber)

Variable Generation

NREL

Transmission System

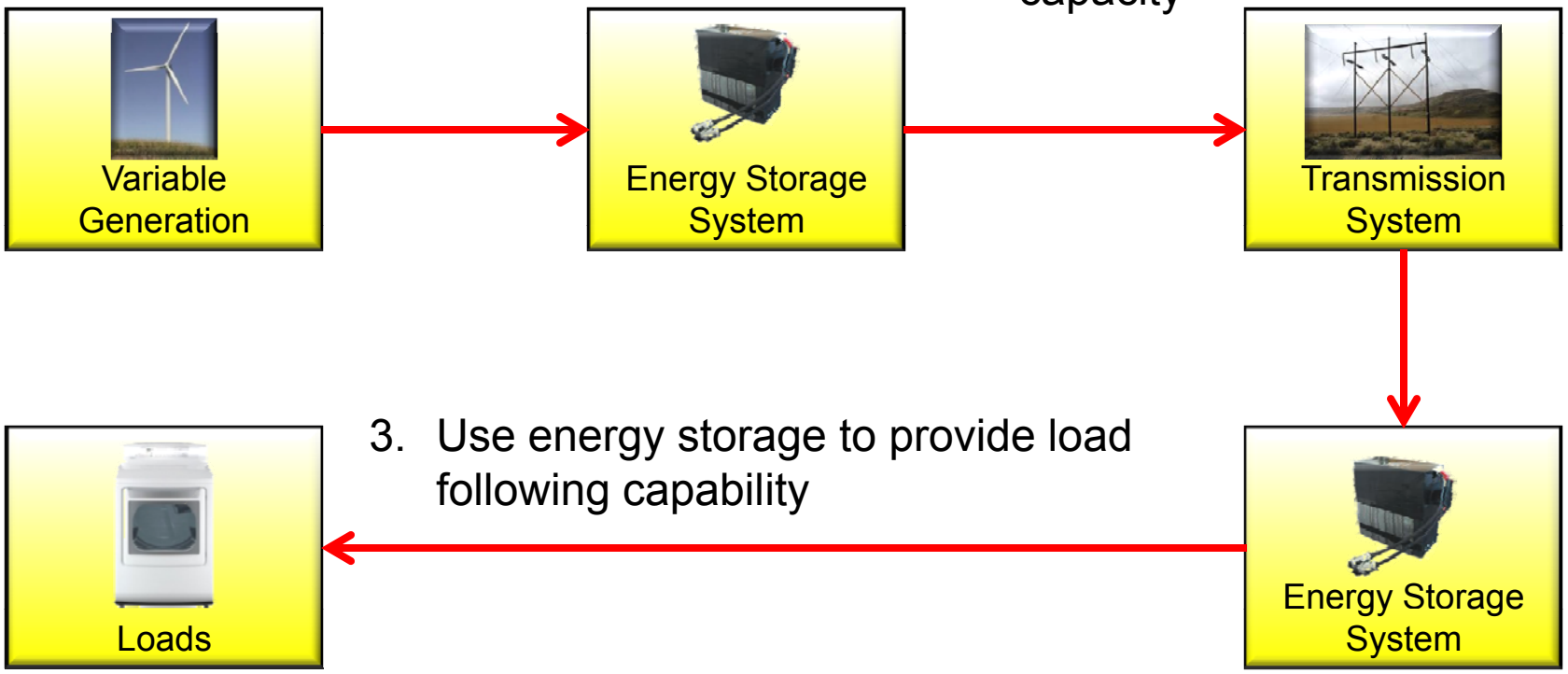
INL

Pumped Hydro Energy Storage

ARGONNE

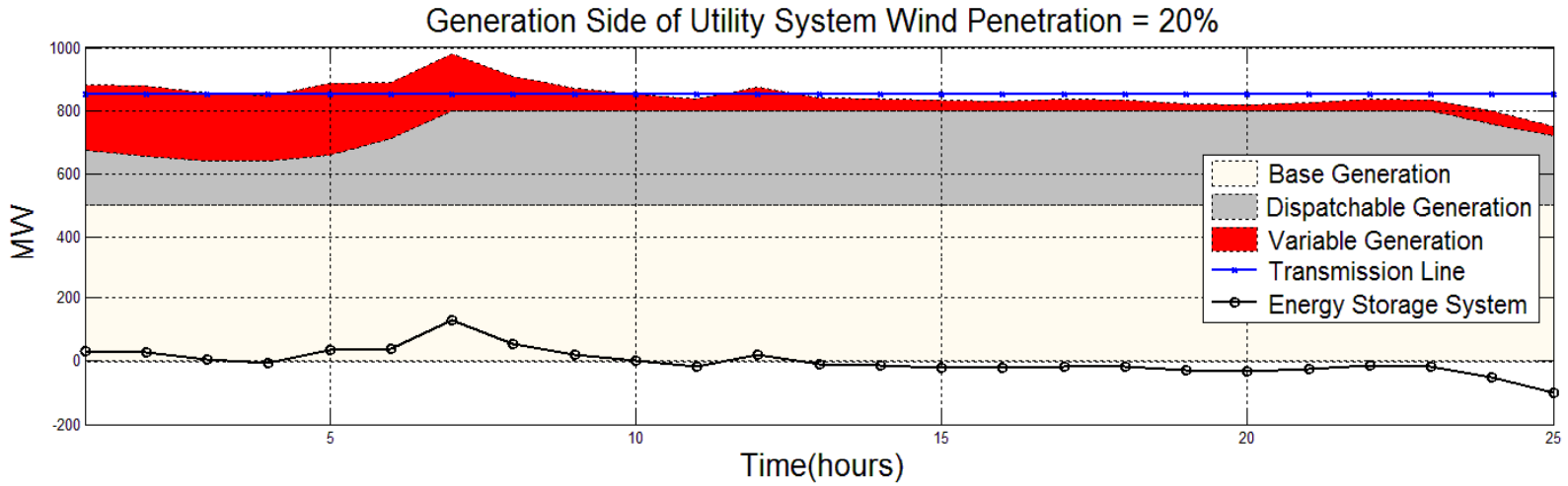
Using Energy Storage to Control Variable Generation

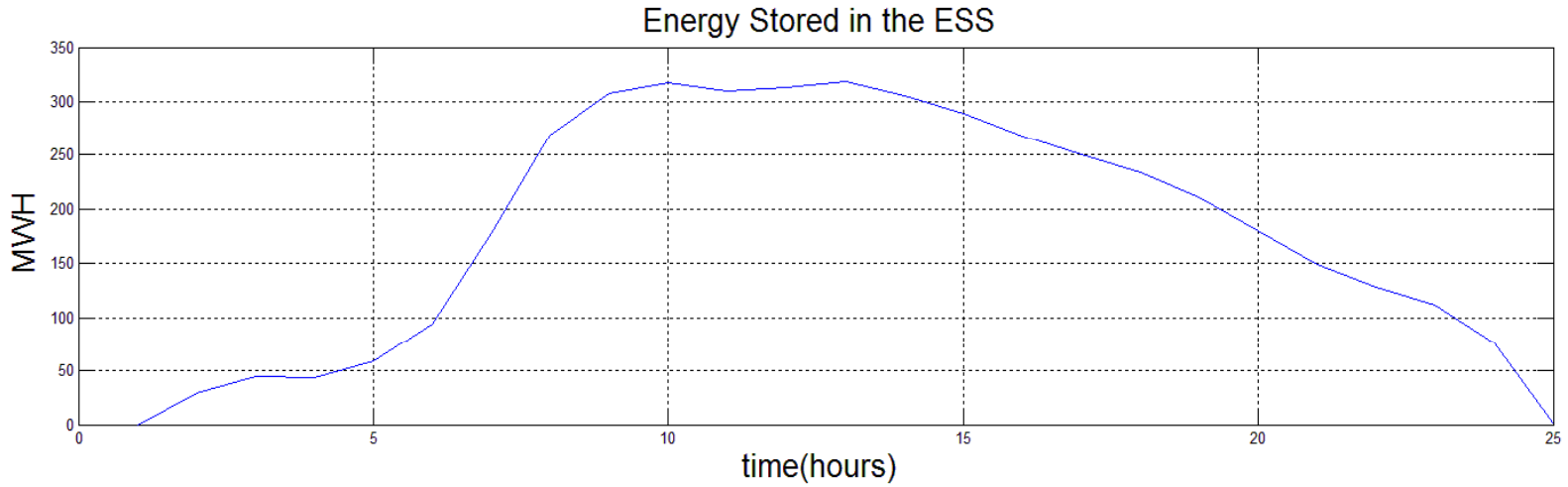
1. Control variable generation through use of energy storage
2. Constant energy flow at nominal rating for optimized transmission capacity



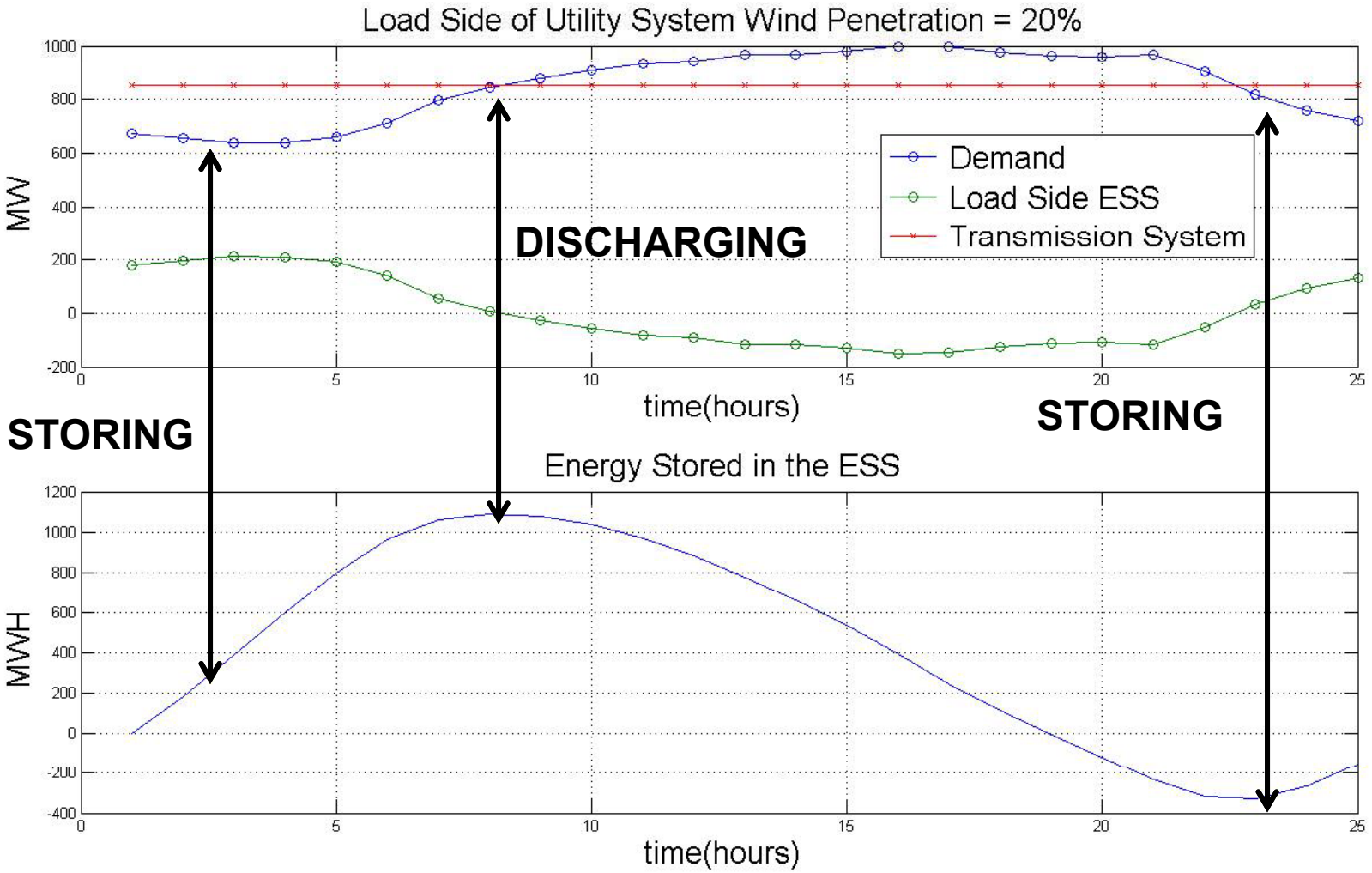
3. Use energy storage to provide load following capability

Generation Side Energy Storage





Load Side Energy Storage



Capability Summary

- Energy storage is required on both generation and load side of a system
  - Controls variable generation
  - Optimizes transmission system capacities
  - Satisfies demands during both peak and off-peak time periods
- Energy storage size/stability depends upon location:

	Generation Side	Load Side
Size	% variable generation dependence	Demand profile
Stability	Transmission line capacity	Transmission line capacity

- Super grid enables full scale testing of energy storage and grid integration

General Benefits

For DOE

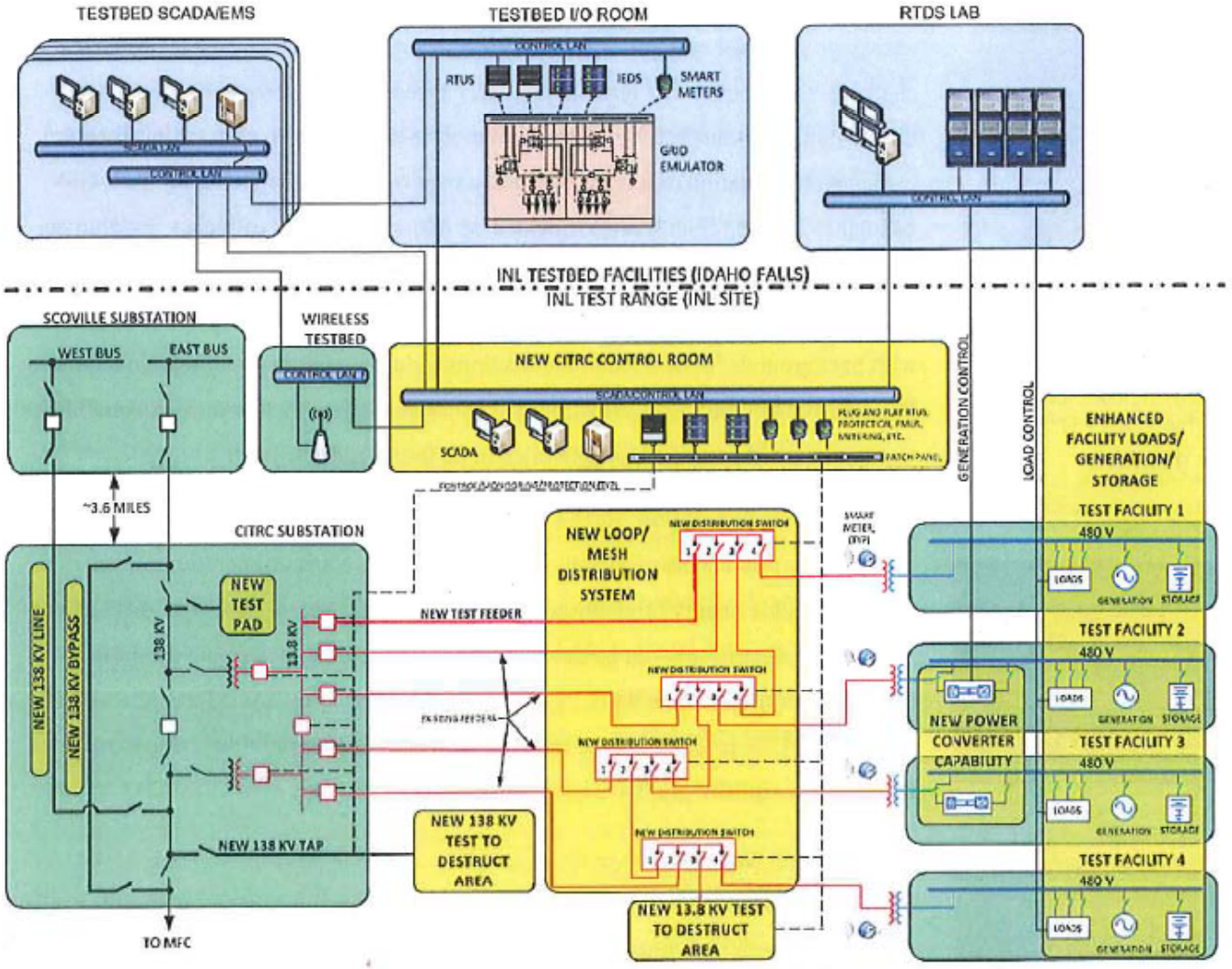
- Provides a new and needed business model to help achieve greater national impact.
- Leverage investments across the DOE
- DOE-EERE: Addresses enhancing penetration of renewable energy and EVs
- For DOE-OE: Helps address grid integration and cyber security challenges
- Provides new business model between two of the three DOE “energy labs”

For INL

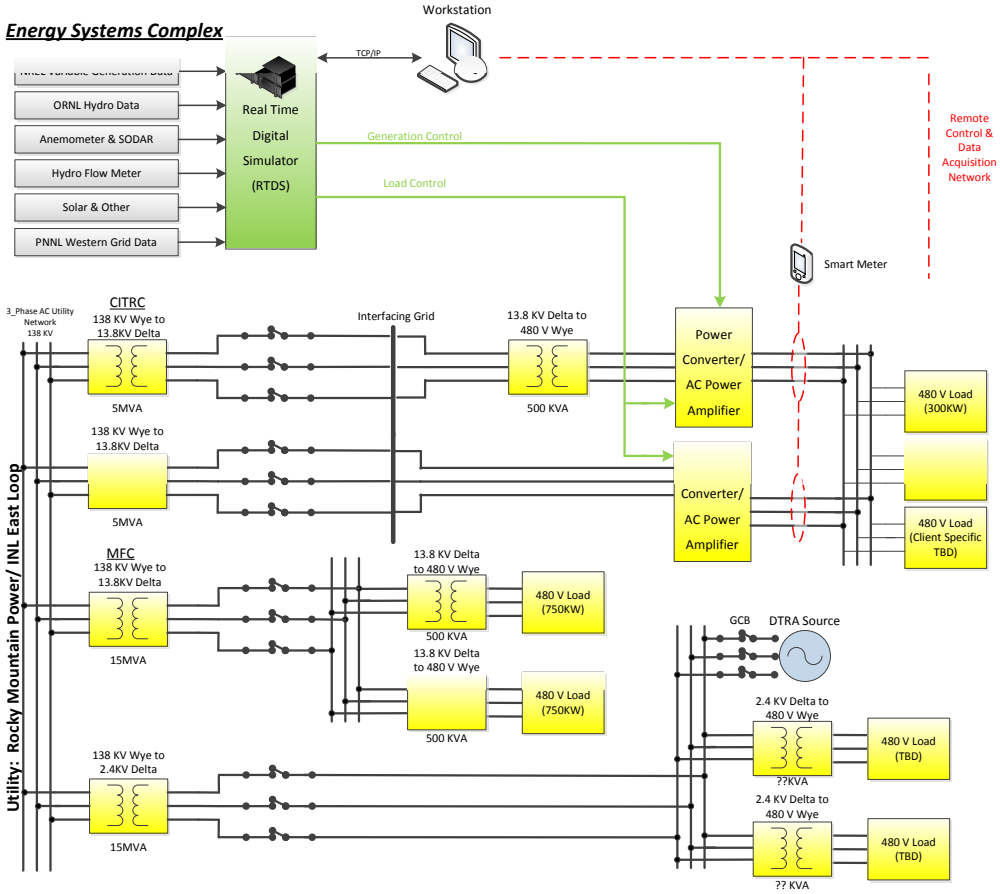
- Strengthens INL differentiator/offering
- Opens up new DOE and DoD market opportunities
- Becomes focal point for next level of integration and research
- Creates INL national branding opportunity
- Leverages INL / DOE complex assets - strengthening position with DOE
- Strengthens INL’s regional impact and HES position

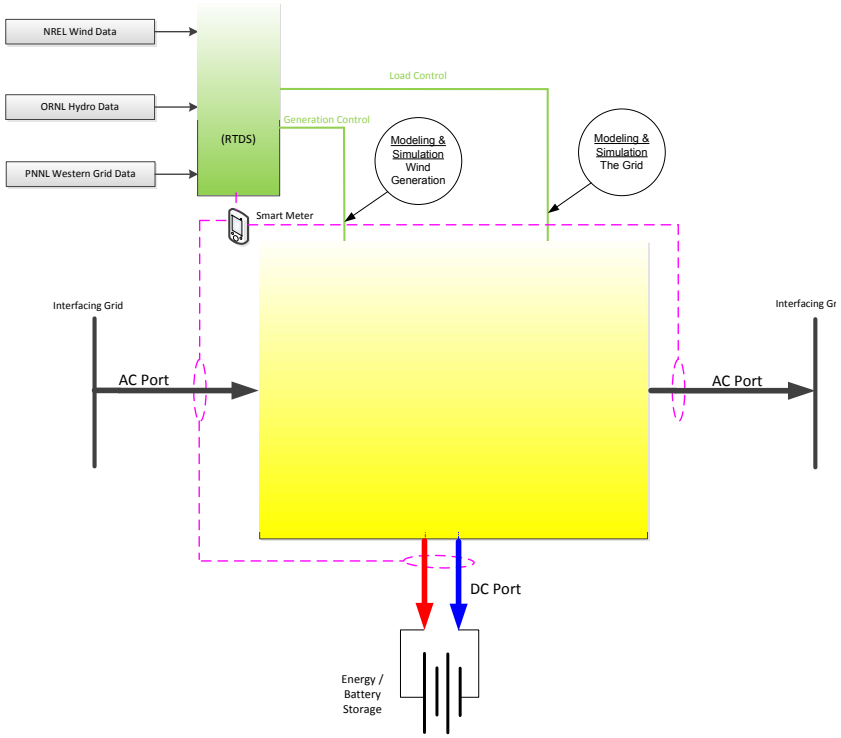
Backup Slides

NHS Proposed Electric Grid Reliability Test bed (EGRTB) Hardware



EEST Proposed Energy Systems Complex Hardware





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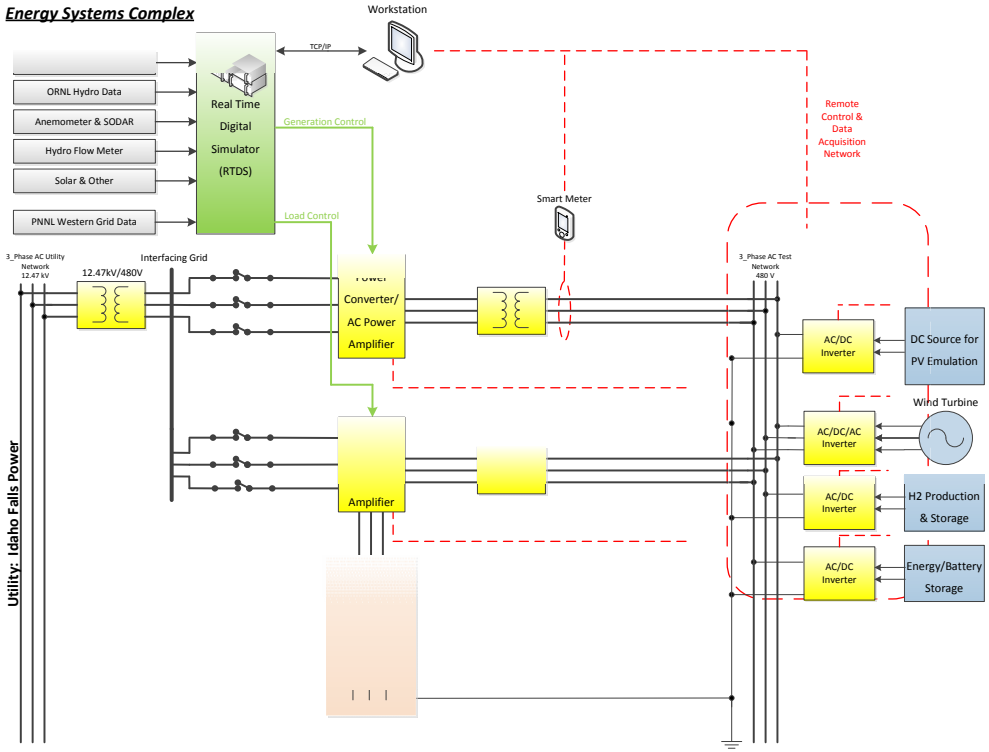
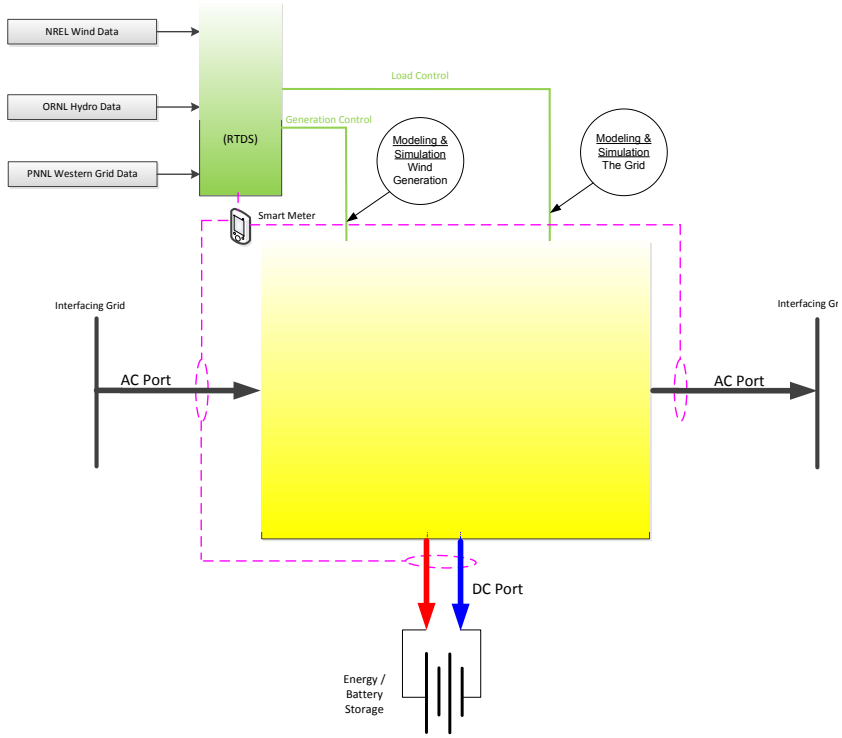
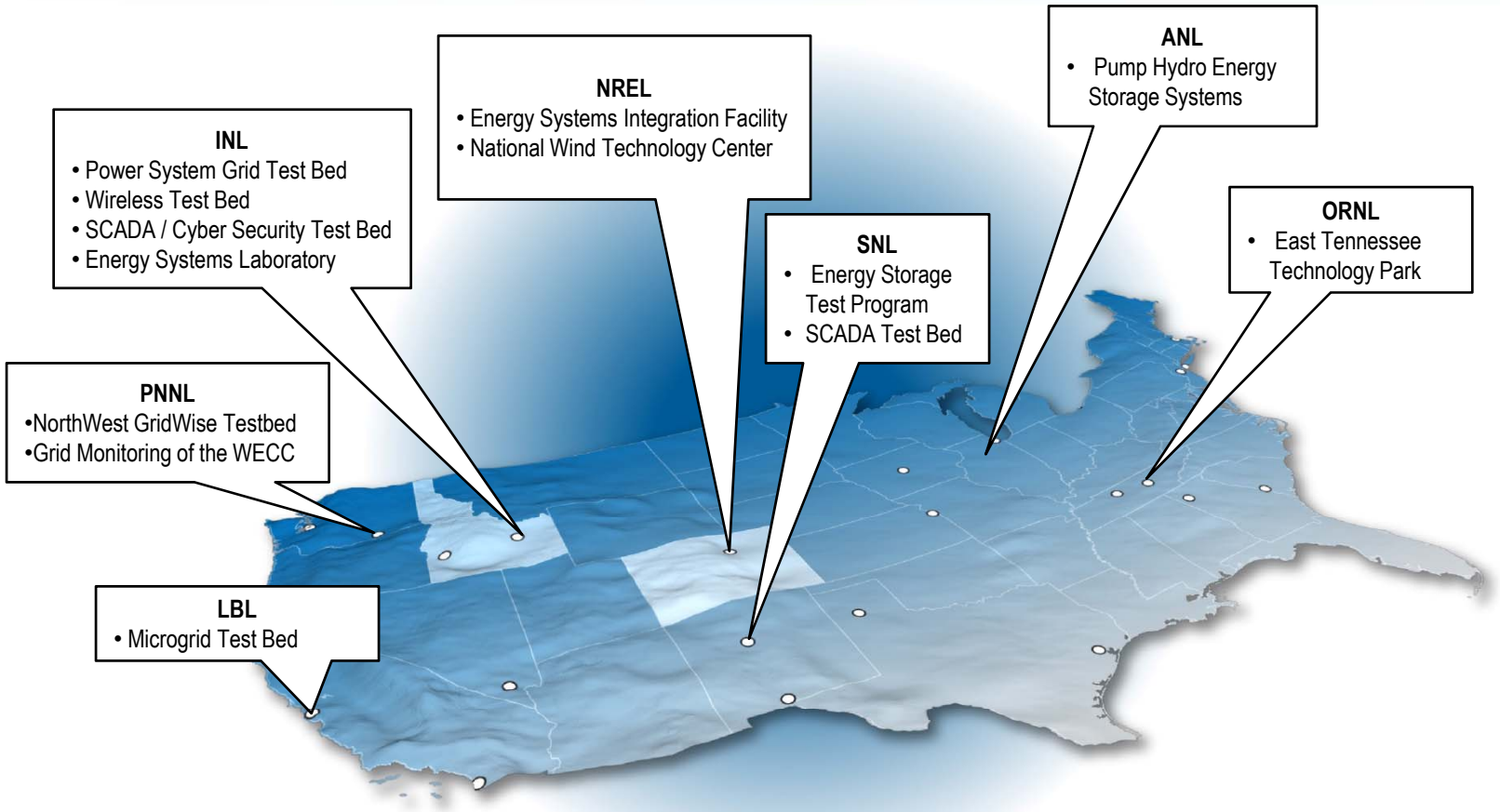




INL's Key Differentiator



Additional Partners

- **Clemson University Wind turbine drive train testing facilty**
- **GE Global Research Centers**
- **Industry**
- **Utilities**
- **DOD**
- **Universities**

Super Lab Capabilities
(Differentiating capabilities from just the testing on its own)

Idaho National Laboratory

- **Grid-in-the-loop**
  - Integrate and test new technologies
  - Use the NHS test grid and the RTDS lab
  - Simulation electric utility operations
  - Provide a “real world” modeling, testing, and validation environment

- **Large-scale renewable generation integration**
  - Test concepts, controls, and integration-supporting technologies
  - Integrate power farms and energy storage systems onto the test grid