NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Energy Systems Integration

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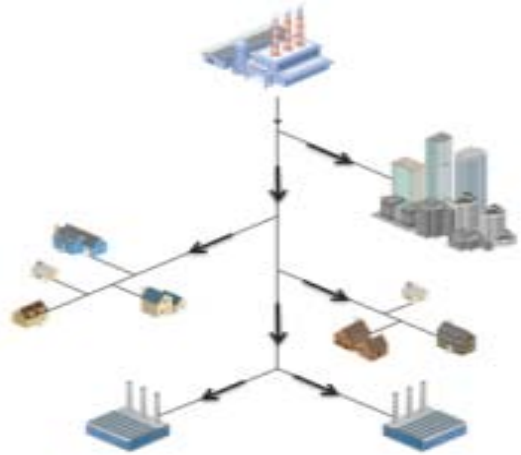
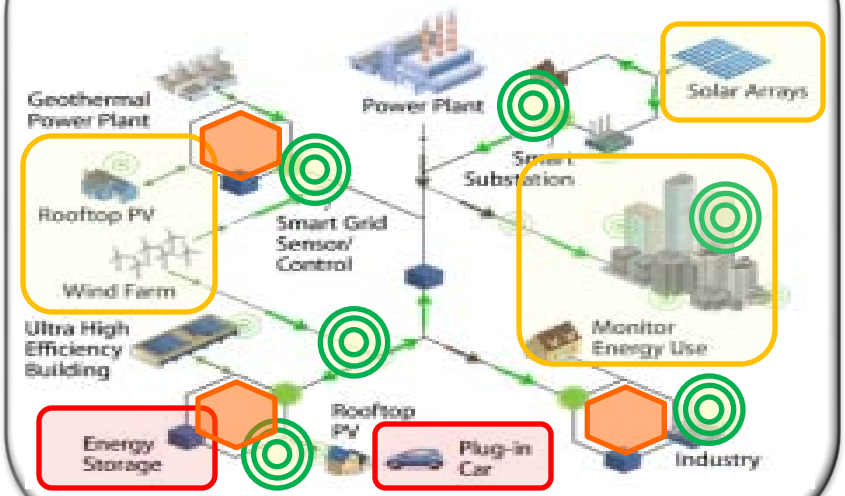
Why Energy Systems Integration?

Current Energy Systems



Future Energy Systems



Reducing investment risk and optimizing systems in a rapidly changing energy world

- Increasing penetration of variable RE in grid
- Increasing ultra high energy efficiency buildings and controllable loads
- New data, information, communications and controls
- Electrification of transportation and alternative fuels
- Integrating energy storage (stationary and mobile) and thermal storage
- Interactions between electricity/thermal/fuels/data pathways
- Increasing system flexibility and intelligence

Energy Systems Integration Continuum

Energy Systems Integration optimizes the design and performance of electrical, thermal, and fuel pathways at all scales.

Scale

Appliance (Plug)

Building DistGen Vehicle (meter)

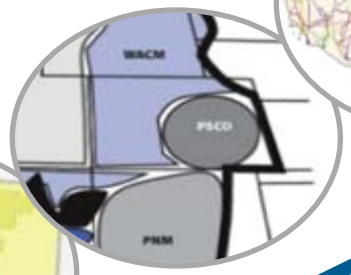
Campus Subdivision (feeder)

Community (substation)

Area (Service Territory)

Region (Balancing Area)

Nation



Energy Informatics: Linking Data to Knowledge to Control

Complexity

Electricity

Thermal

Fuel

Data

ESIF System Integration Capabilities

Energy System Research and Development Across Technologies

Solar and Wind

- RE integration
- Power electronics
- Building integration
- Thermal and PV system optimization

Grid Planning and Operations

- Transmission and Distribution Systems
- Smart Grid Technologies
- Microgrids
- Standards

Energy Storage

- CSP Thermal Storage
- Utility scale batteries
- Distributed storage

Buildings

- Sensors and controls
- Design and integration
- Modeling and simulation
- Big Data warehousing and mining
- System integration

Fuel Cells and Hydrogen

- H_2/electric interfaces
- RE electrolyzers
- Storage systems
- Standards
- Fuel cell integration
- Fueling systems

Advanced Vehicles

- Plug-in-hybrids and vehicle-to-grid
- Battery thermal management
- Power electronics

Full systems interface evaluation for integration of electricity, fuels, thermal, storage, and end-use technologies

NREL's Energy Systems Integration Facility (ESIF)

- NREL's largest R&D facility (182,500 ft^2)
- Space for 200 NREL staff and research partners
- Focus of the ESIF is to conduct R&D of integrated energy systems (Electricity, Fuels, Transportation, and Buildings & Campus systems)

Addressing the challenges of large-scale integration of clean energy technologies into the energy systems infrastructure

http://www.nrel.gov/eis/facilities_esif.html

Current Status and Construction Targets

- **October 2012 – substantial completion**
- **November 2012 – commissioning and move-in**
- **January 2013 – complete move**

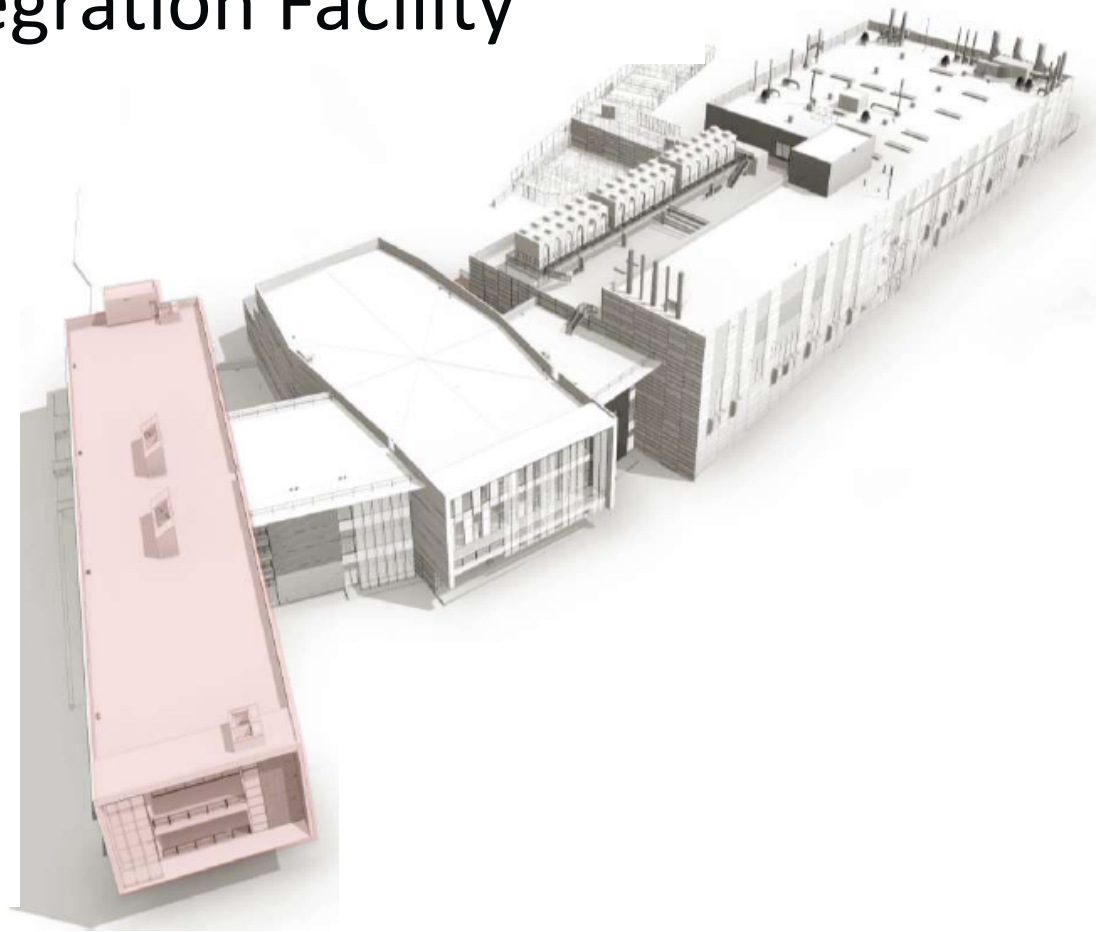
- **DOE Programs moving into ESIF**
  - Solar – Systems Integration, CSP
  - Wind - Systems Integration
  - Fuel Cell Technologies
  - Buildings
  - Vehicles (lab testing)
  - Office of Electricity
  - Scientific Computing

ESIF - Office Area

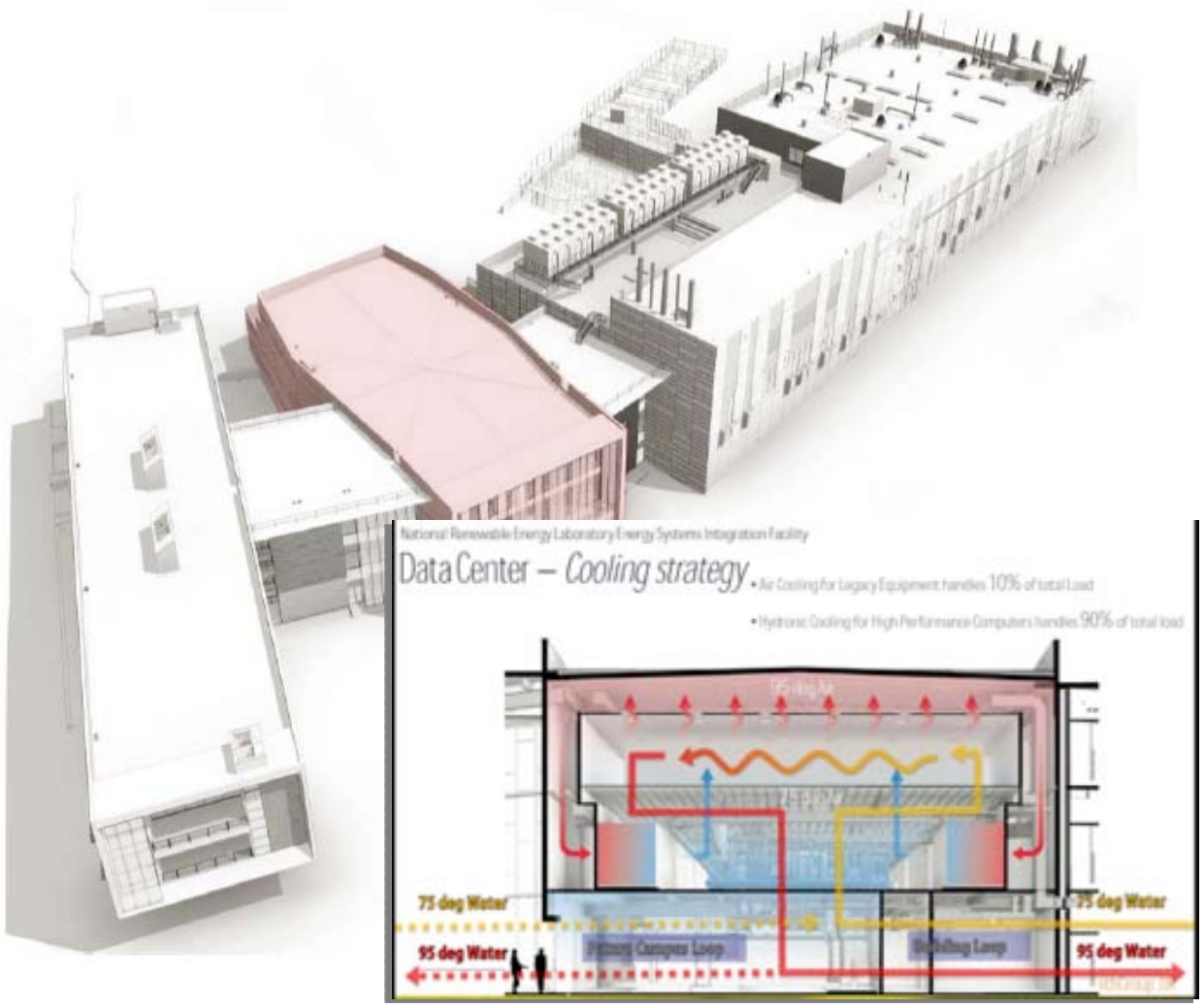
National Renewable Energy Laboratory
Energy Systems Integration Facility

Office Space

- Energy Target (Site EUI): 26.7 kBtu/sf/yr
- National Average Site EUI: 90 kBtu/sf/yr (CBECS)
- Energy Efficiency over National Average (w/server): 74%
- Energy Efficiency over National Average (w/out HPC): 87%



ESIF - High Performance Computing Data Center



Showcase Facility

- Use evaporative rather mechanical cooling.
- Waste heat captured and used to heat labs & offices.
- World's most energy efficient data center, PUE 1.06!

20 year planning horizon

- 5 to 6 HPC generations.

Energy Data Hub

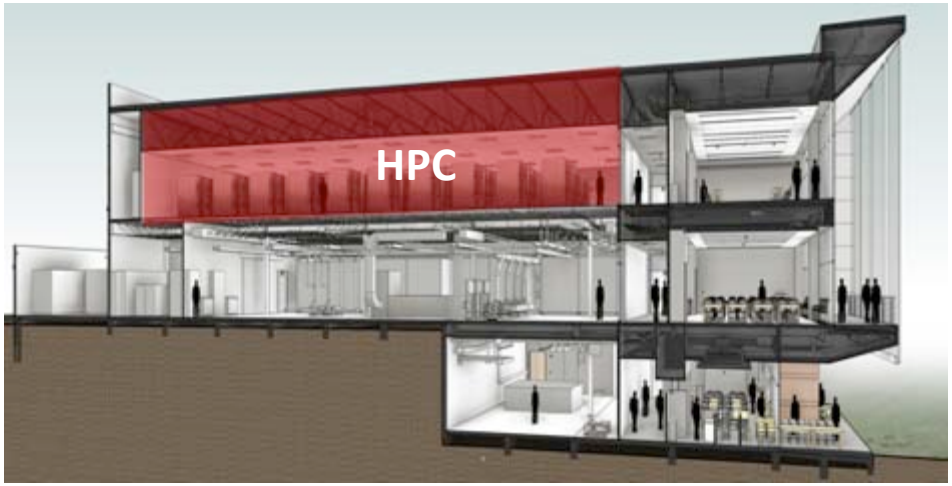
- Data mgmt, mining, analytics
- Smartgrid.gov
- High frequency data from technology deployment

Insight Center

- Scientific data visualization
- Collaboration and interaction.

PUE = Power Usage Effectiveness

ESIF's Unique Advanced Capabilities

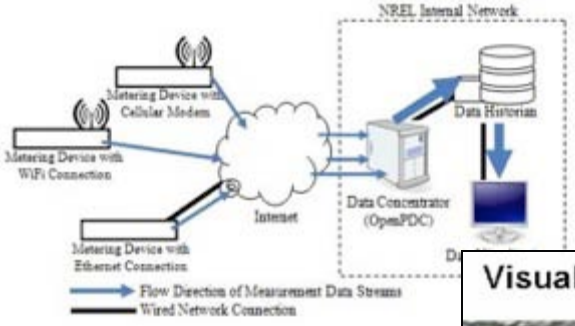


- Petascale HPC and data management system in showcase energy efficient data center.

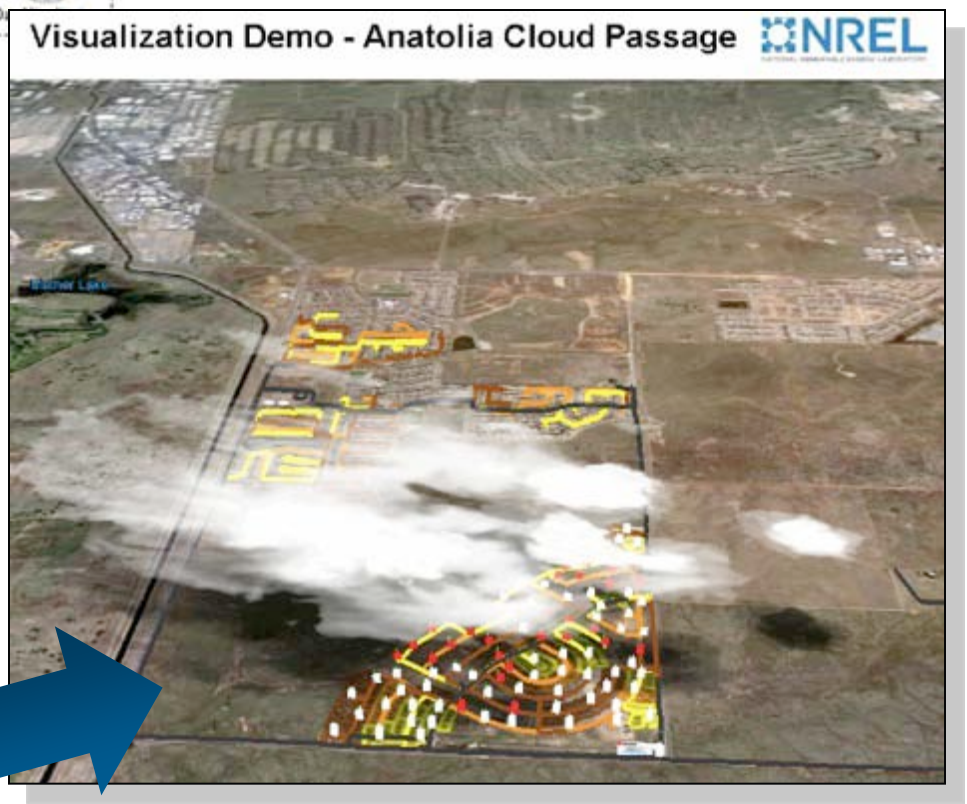
- Virtual utility operations center and visualization rooms to understand impact of high penetration variable renewables, electric vehicle, and energy efficiency deployments.

- Interconnectivity to external field sites for data feeds and model validation.

ESIF - Energy System Visualization



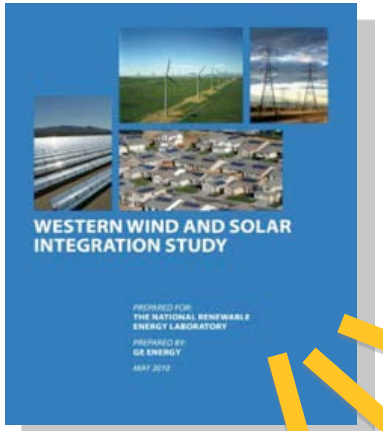
NREL is working with SMUD on visualizing impact of DG deployments



ESIF - Energy System Simulated Operations

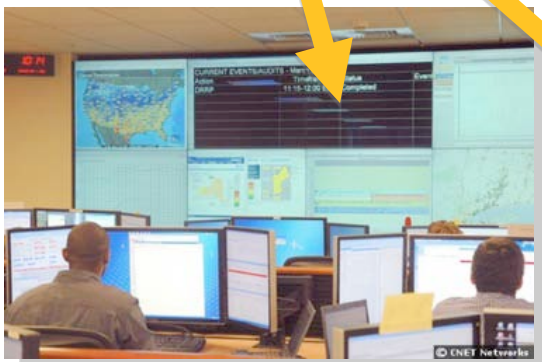
A Flight Simulator for Energy System Operators

"connecting integration studies to operations"

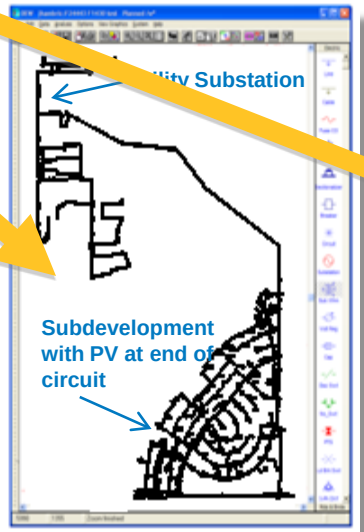


Operations techniques development for:

- High renewables and energy efficiency penetrations
- New systems configurations and contingency response
- High storage / DR penetrations
- Resource forecast integration



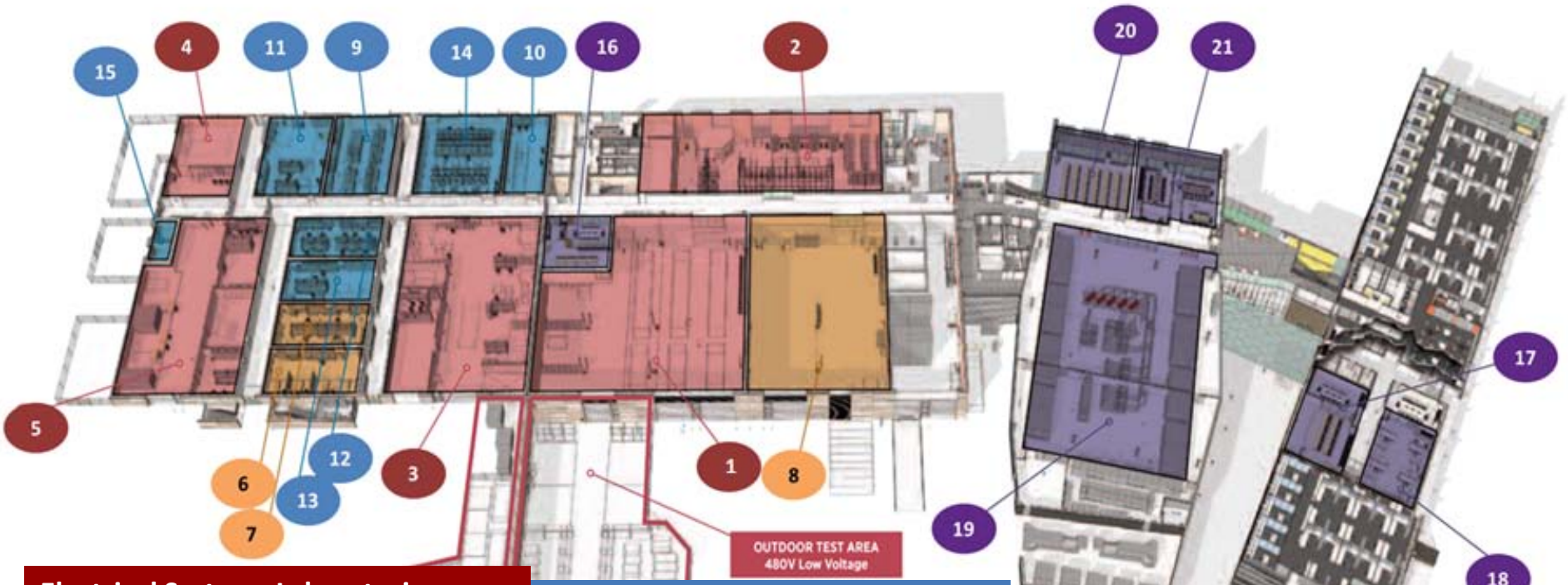
Transmission



Distribution

Campus Energy Dashboard

ESIF Laboratories



Electrical Systems Laboratories

1. Power Systems Integration
2. Smart Power
3. Energy Storage
4. Electrical Characterization
5. Energy Systems Integration

Thermal Systems Laboratories

6. Thermal Storage Process and Components
7. Thermal Storage Materials
8. Optical Characterization

Fuel Systems Laboratories

9. Energy Systems Fabrication
10. Manufacturing
11. Materials Characterization
12. Electrochemical Characterization
13. Energy Systems Sensor
14. Fuel Cell Development & Test
15. Energy Systems High Pressure Test

High Performance Computing, Data Analysis, and Visualization

16. ESIF Control Room
17. Energy Integration Visualization
18. Secure Data Center
19. High Performance Computing Data Center
20. Insight Center Visualization
21. Insight Center Collaboration

ESIF Labs - Interior

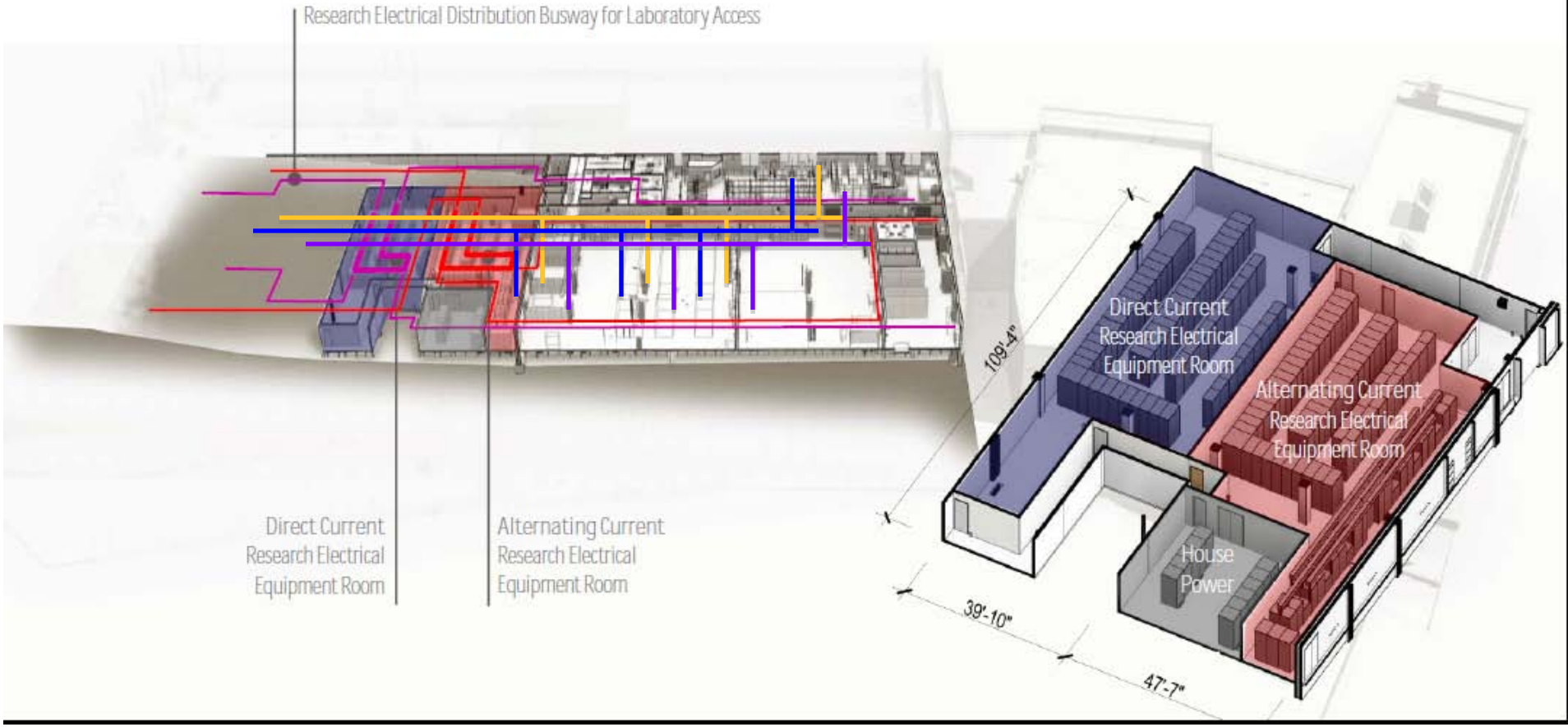
Smart Power Lab

Energy Systems Integration Lab

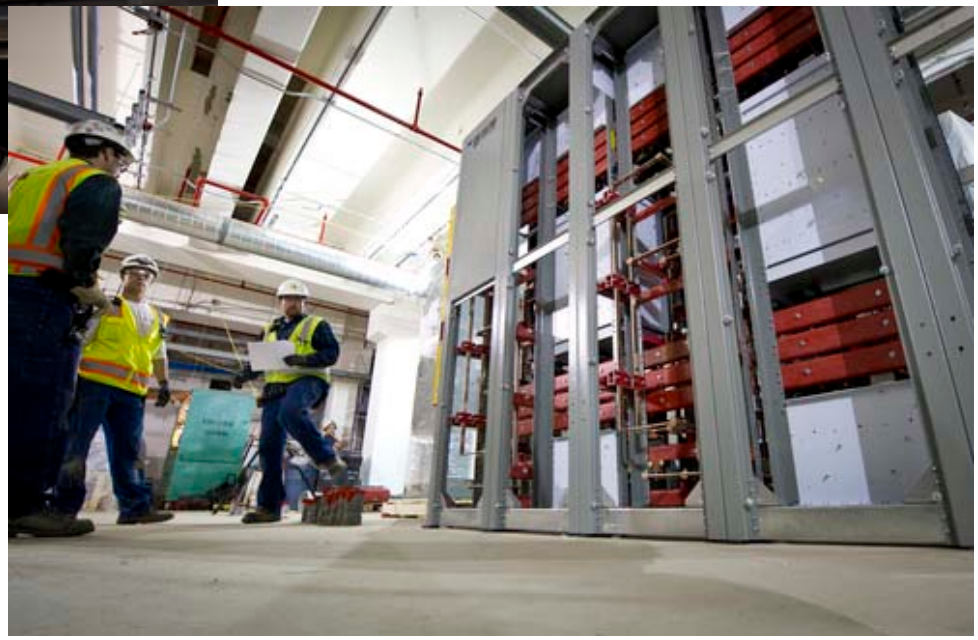
ESIF Research Infrastructure

- Research Electrical Distribution Bus – REDB (AC 3ph, 600V, 1200A and DC +/-500V, 1200A)
- Thermal Distribution Bus
- Fuel Distribution Bus
- Supervisory Control and Data Acquisition (SCADA)

- Utility Scale Research
- 1.5 MW – Single Source REDB
- 1 M – Micro Grid Simulation

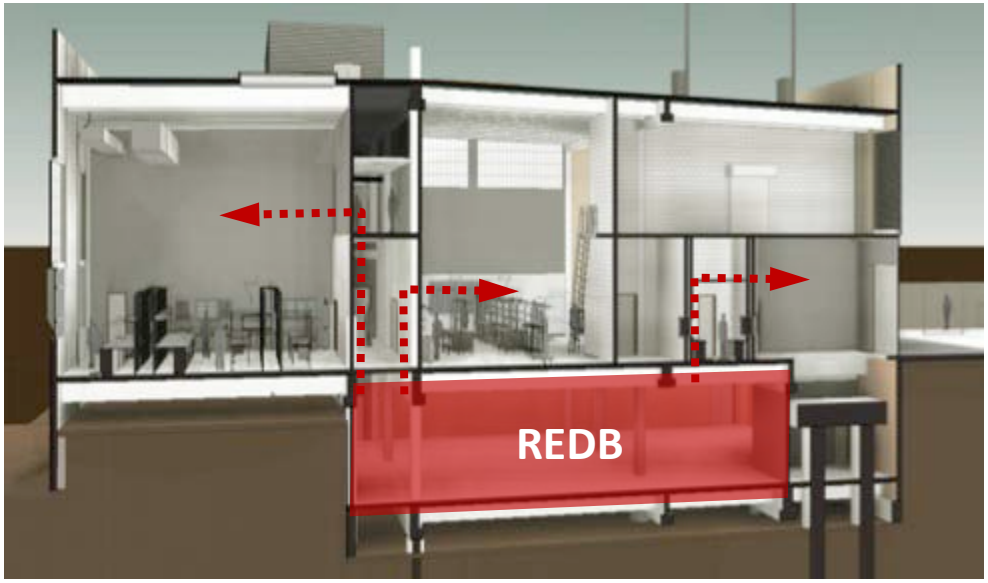


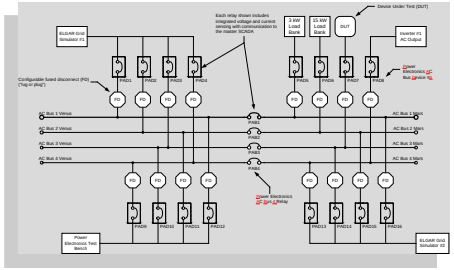
REDB Installation



ESIF's Advanced Capabilities

- Multiple parallel research electrical distribution busses (REDB) at MW power level with grid and load simulation.

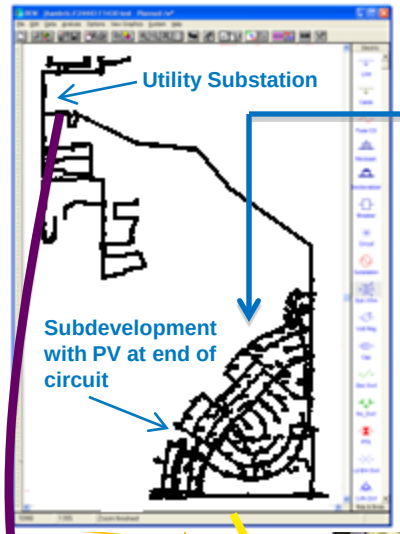




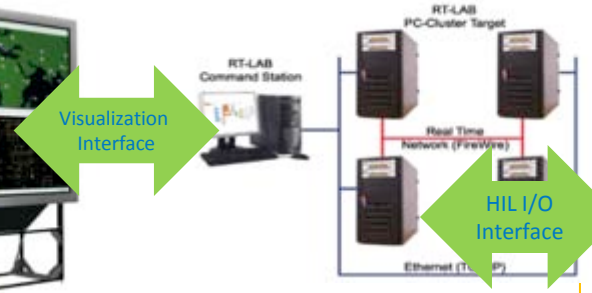
- Flexible interconnection points for electricity, thermal, and fuels to multiple labs.
- Medium voltage (15kV) microgrid test bed.
- Extensive selection of existing distributed energy systems and high power PV and wind simulation.

ESIF - Hardware-in-the-Loop (HIL)

Simulation validated
with real field data



Simulation and Visualization at ESIF



Actual hardware at ESIF

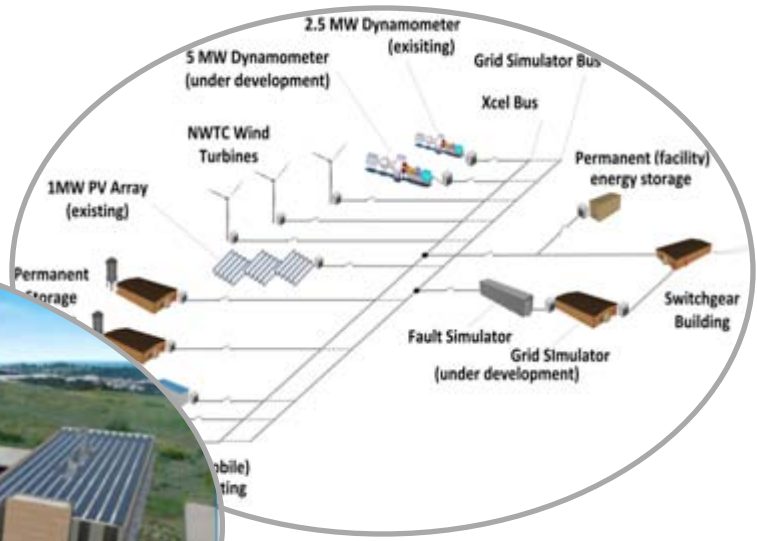
Replicated into
Larger Simulation

Simulation loop
closed with actual
hardware

NREL's Energy Systems Integration Facilities

NREL ESI - A unique national asset for energy systems integration R&D, testing, and analysis at various scales

NWTC – 2MW+



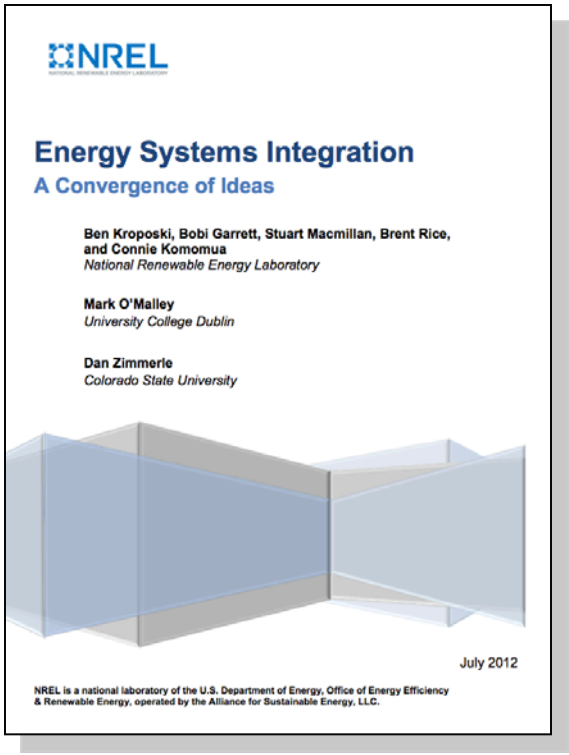
ESIF
1kW-2MW

DERTF
1kW-200kW

TTF

VTIF

Energy Systems Integration



For More information http://www.nrel.gov/esi

Thank you

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