

Microgrid/Smartgrid Research Facility

US Department of Energy, Energy Systems Integration Facility Case Study



2015 IDEA Conference
Clean Campus Energy
for the Next Generation
Denver, Colorado

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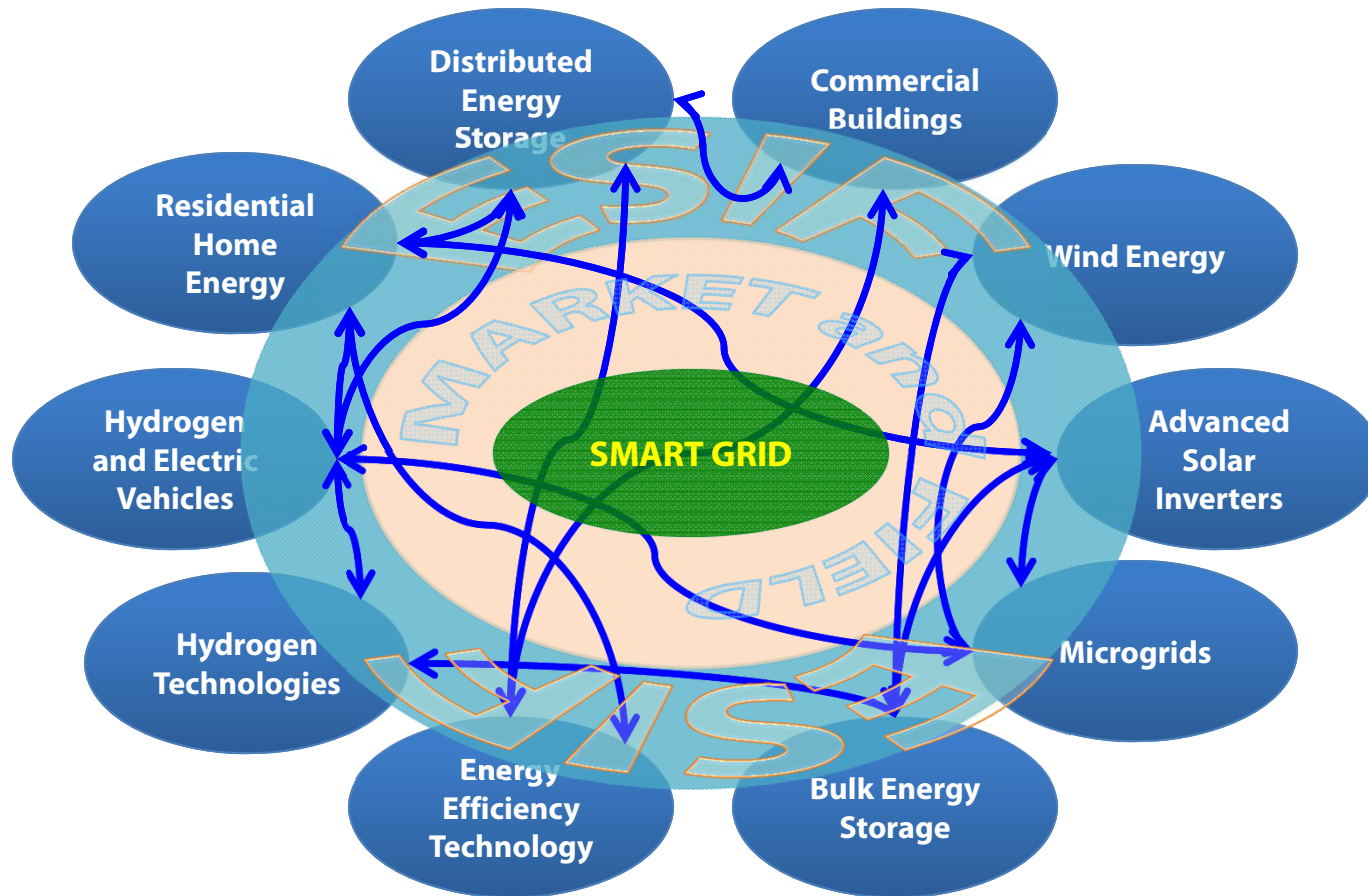
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Learning Objectives

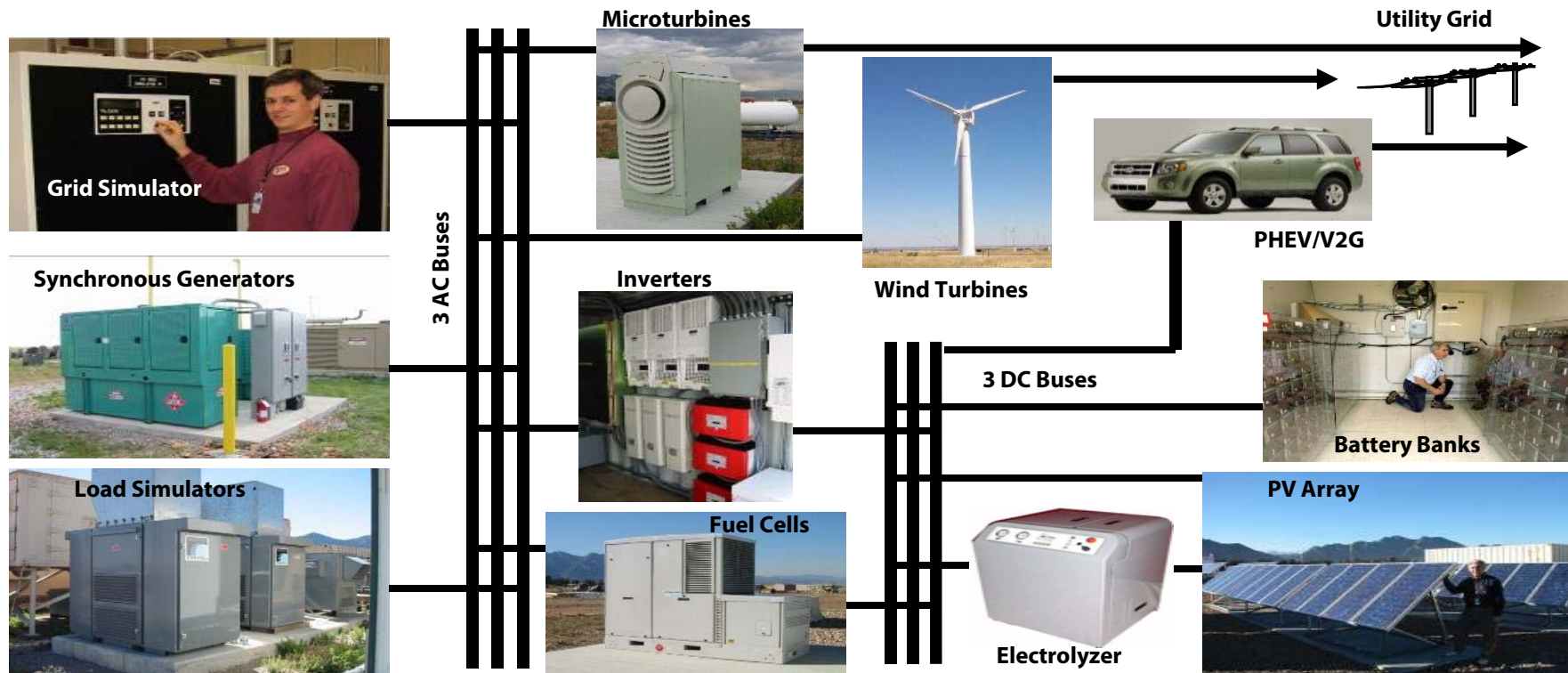


- Understand research and associated infrastructure requirements to advance smartgrids and microgrids.
- Understand extents of DC components and power converters and their associated challenges and hazards.
- Understand key component challenges in the optimization of safe, reliable and sustainable smartgrids and microgrids.

ESIF Mission to Enable “Smart Grid”



ESIF Genesis: DERTF Precursor Facility

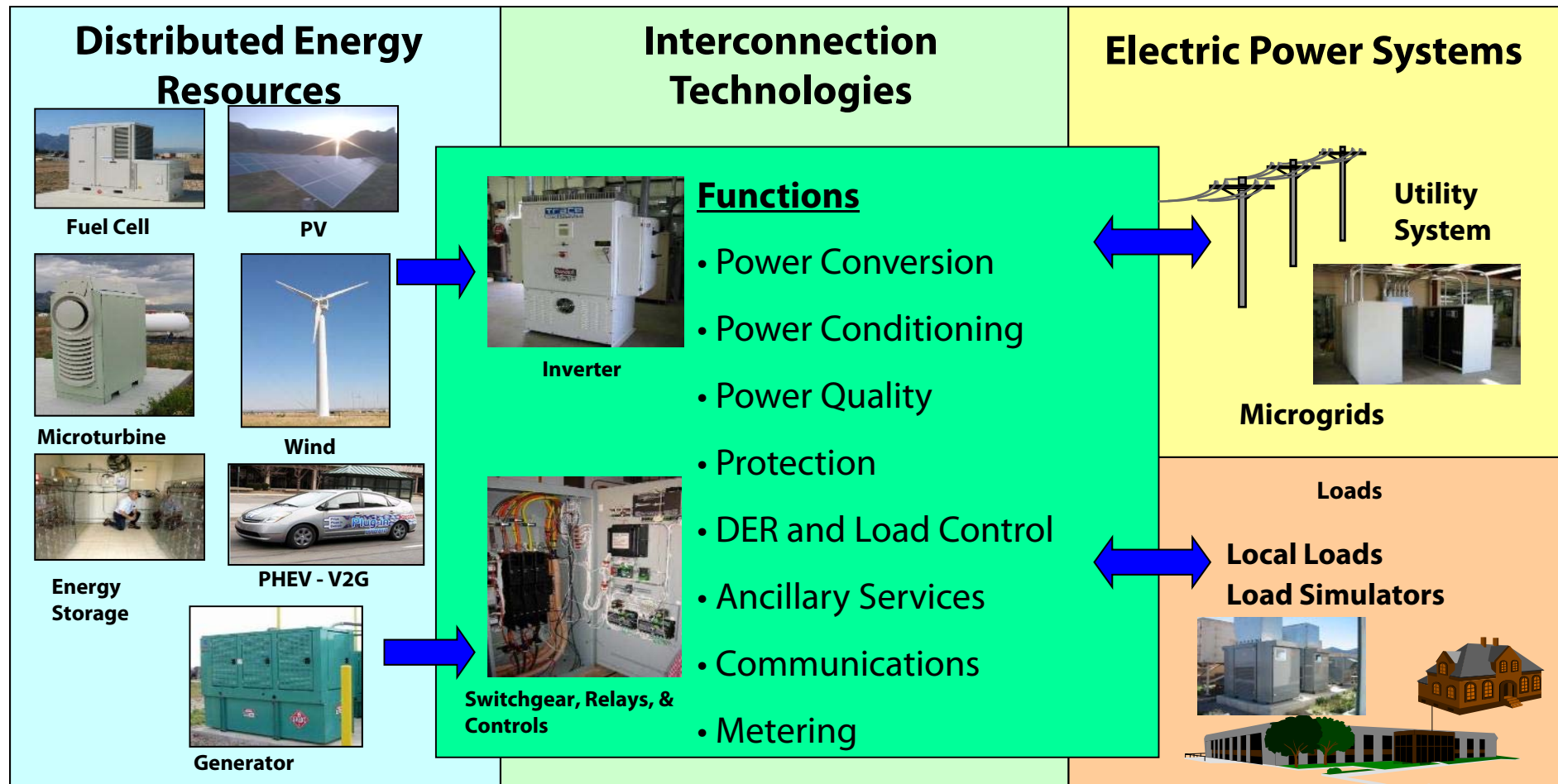


Test and Evaluation of all types of distributed generation, storage and interconnection systems

ESIF Genesis: DERTF Precursor Facility

Distributed Energy Research Test Facility (DERTF)

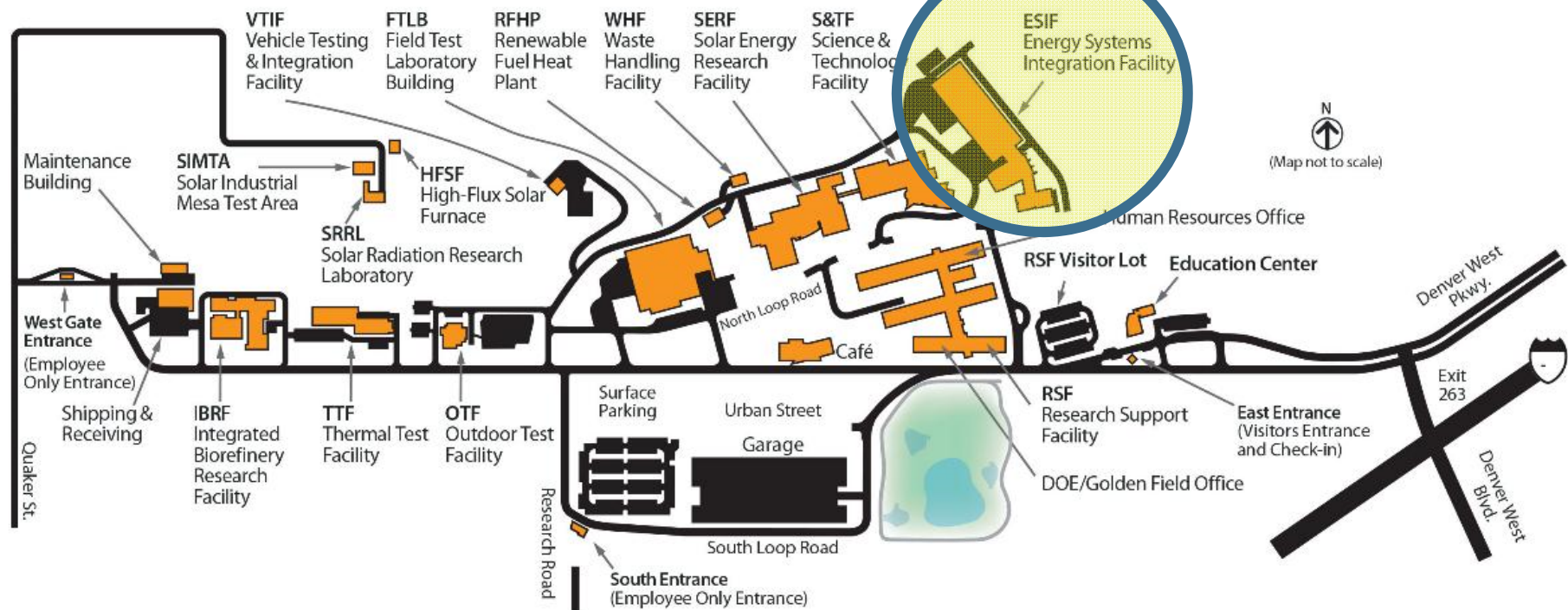
Example Projects – Interconnection System Testing



DOE NREL South Table Mountain Campus Golden, Colorado

South Table Mountain Campus

15013 Denver West Parkway
Golden, CO 80401



Q: Why NREL ESIF as a case study?

A: It has it all



2014 LABORATORY
OF THE YEAR **R&D**

Photo by Dennis Schroeder, NREL

Three Building Components: East Elevation

Office

Data Center

**High Bay
Laboratories**

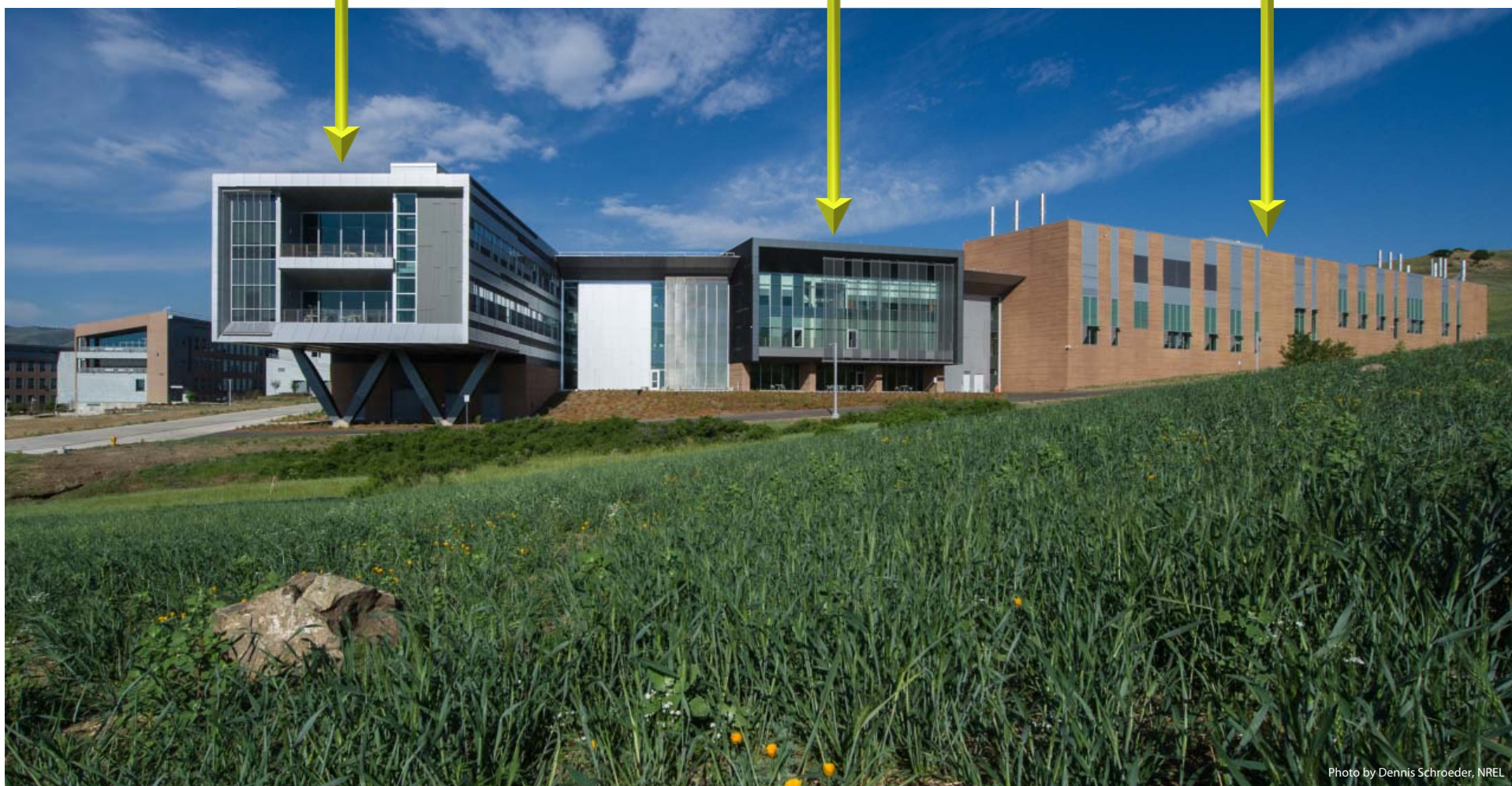
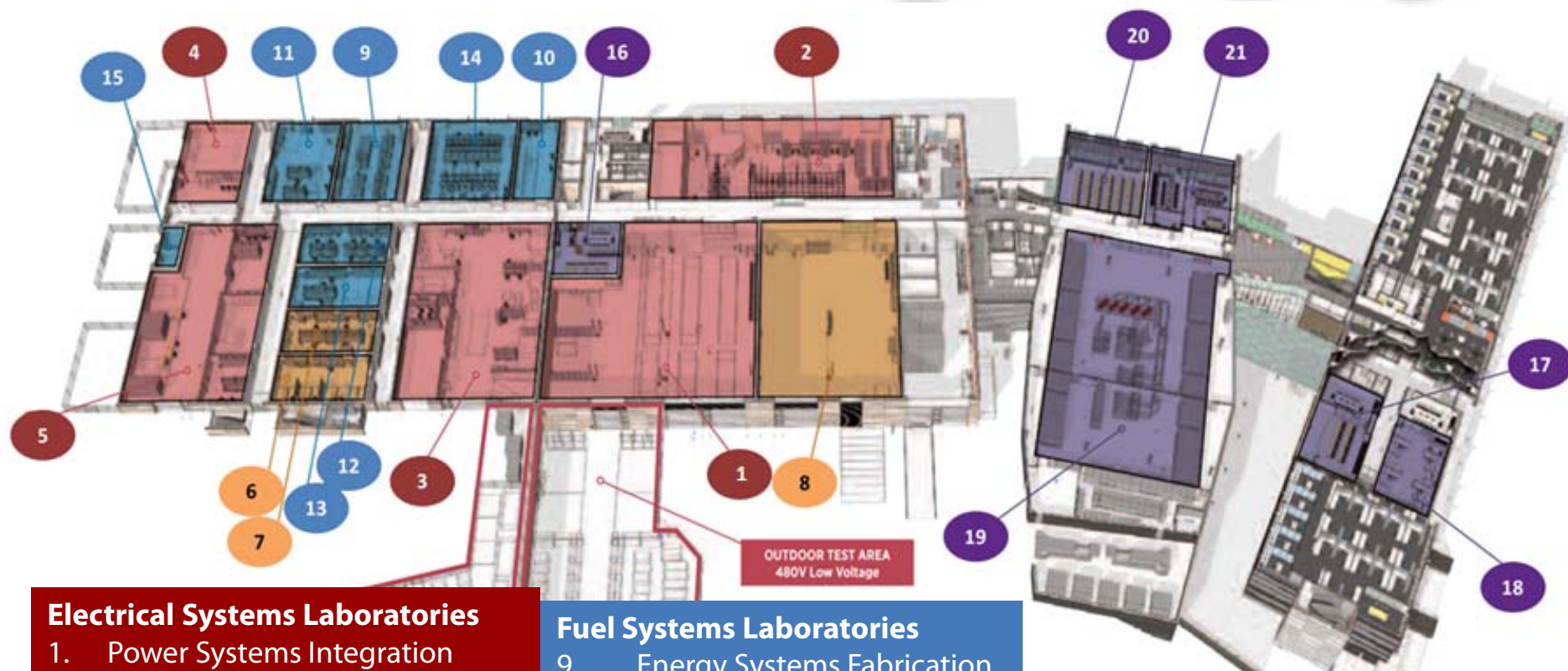


Photo by Dennis Schroeder, NREL

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

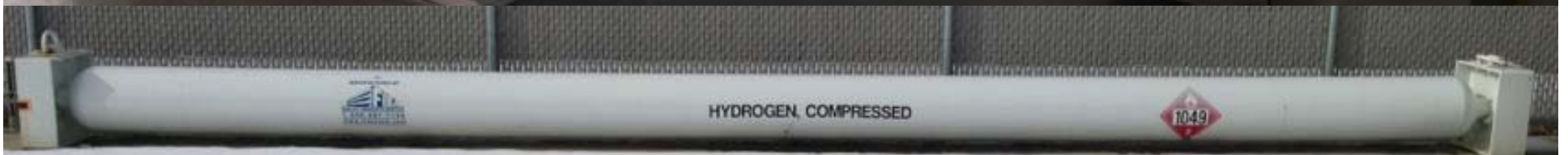
Fuel Systems Laboratories

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

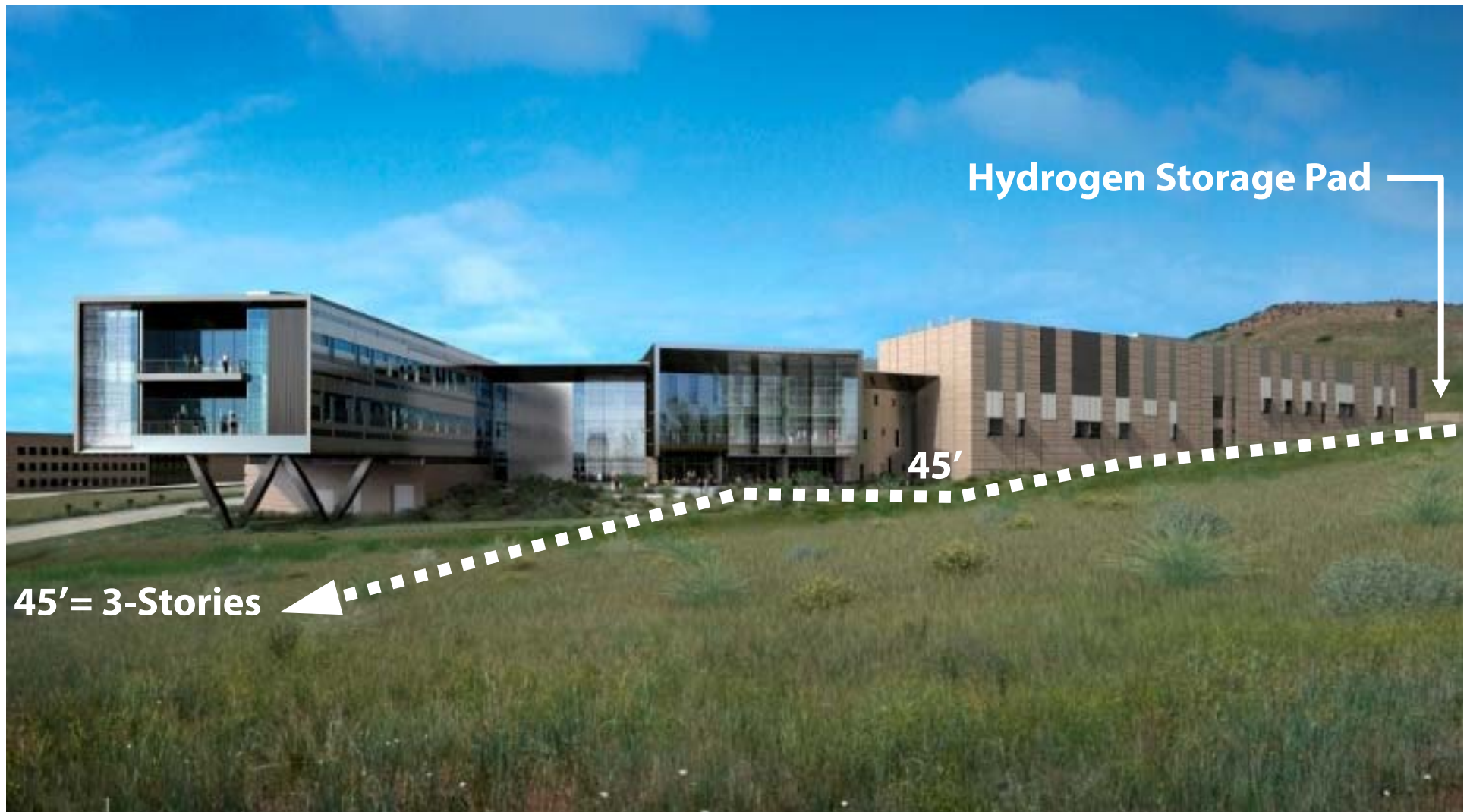
High Performance Computing, Data Analysis, and Visualization

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

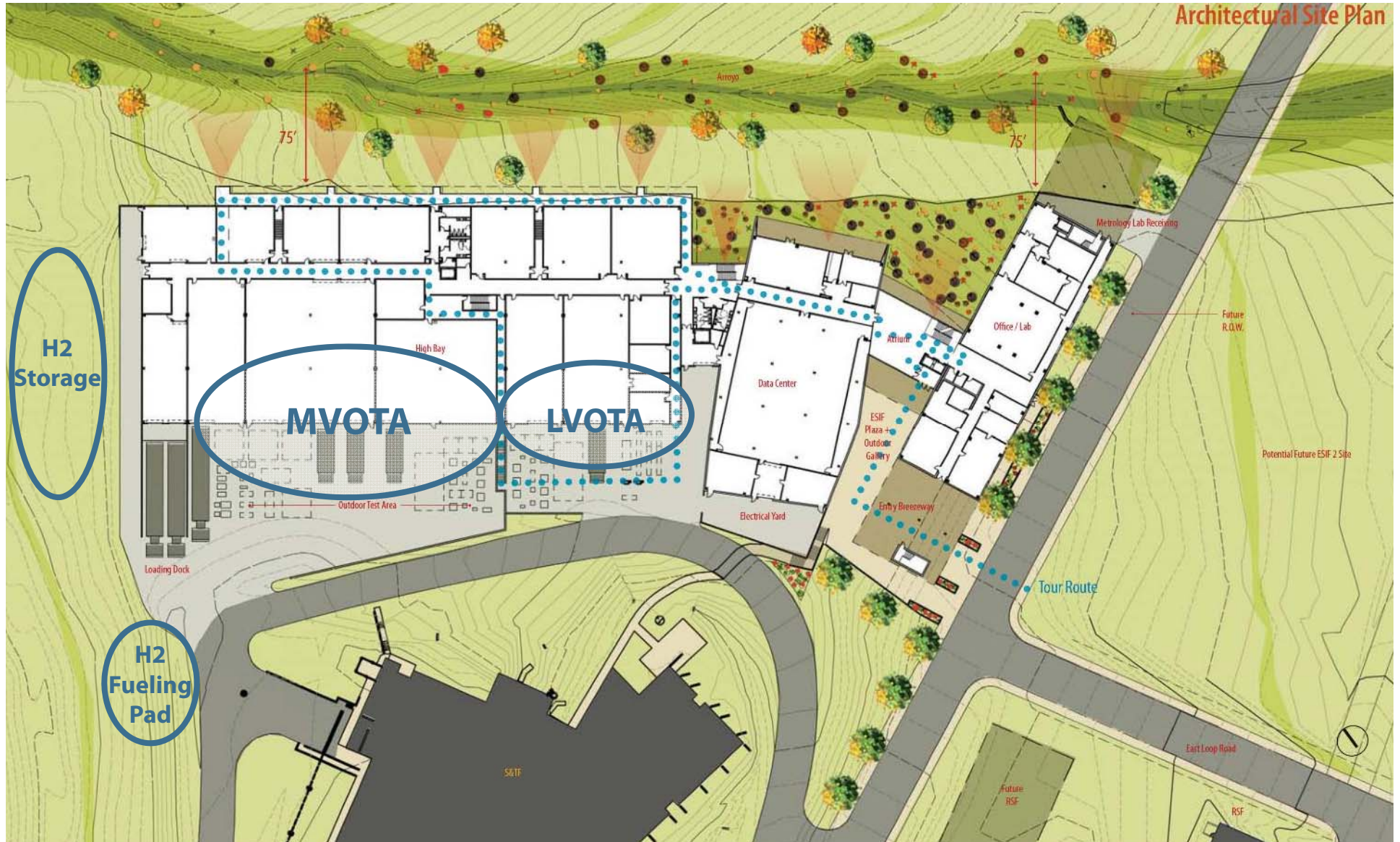
Hydrogen Systems



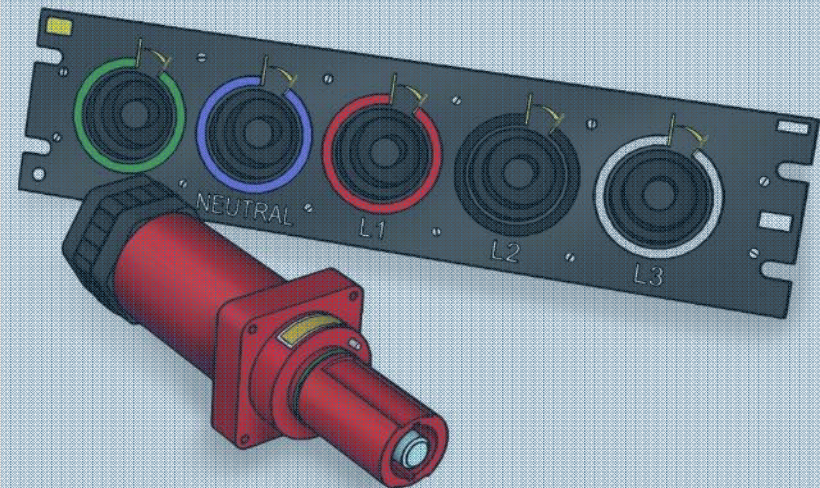
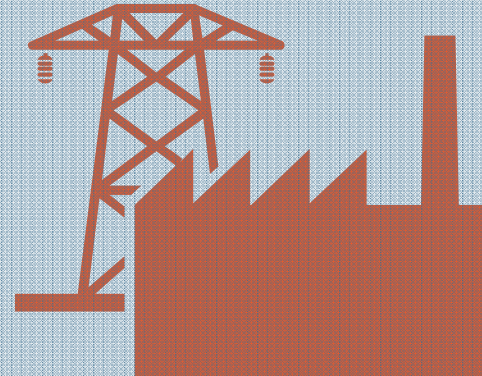
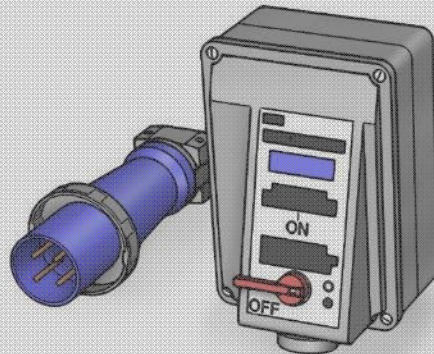
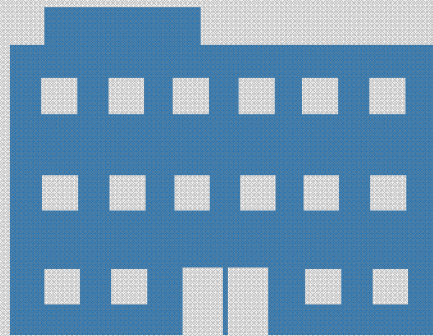
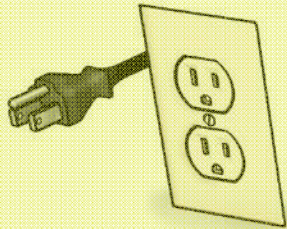
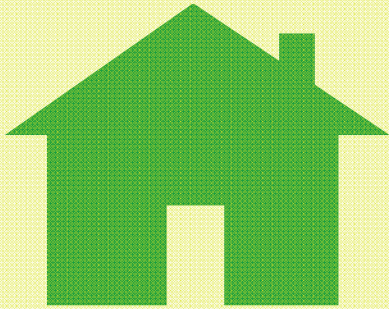
Safety Programming: Proactive and Reactive



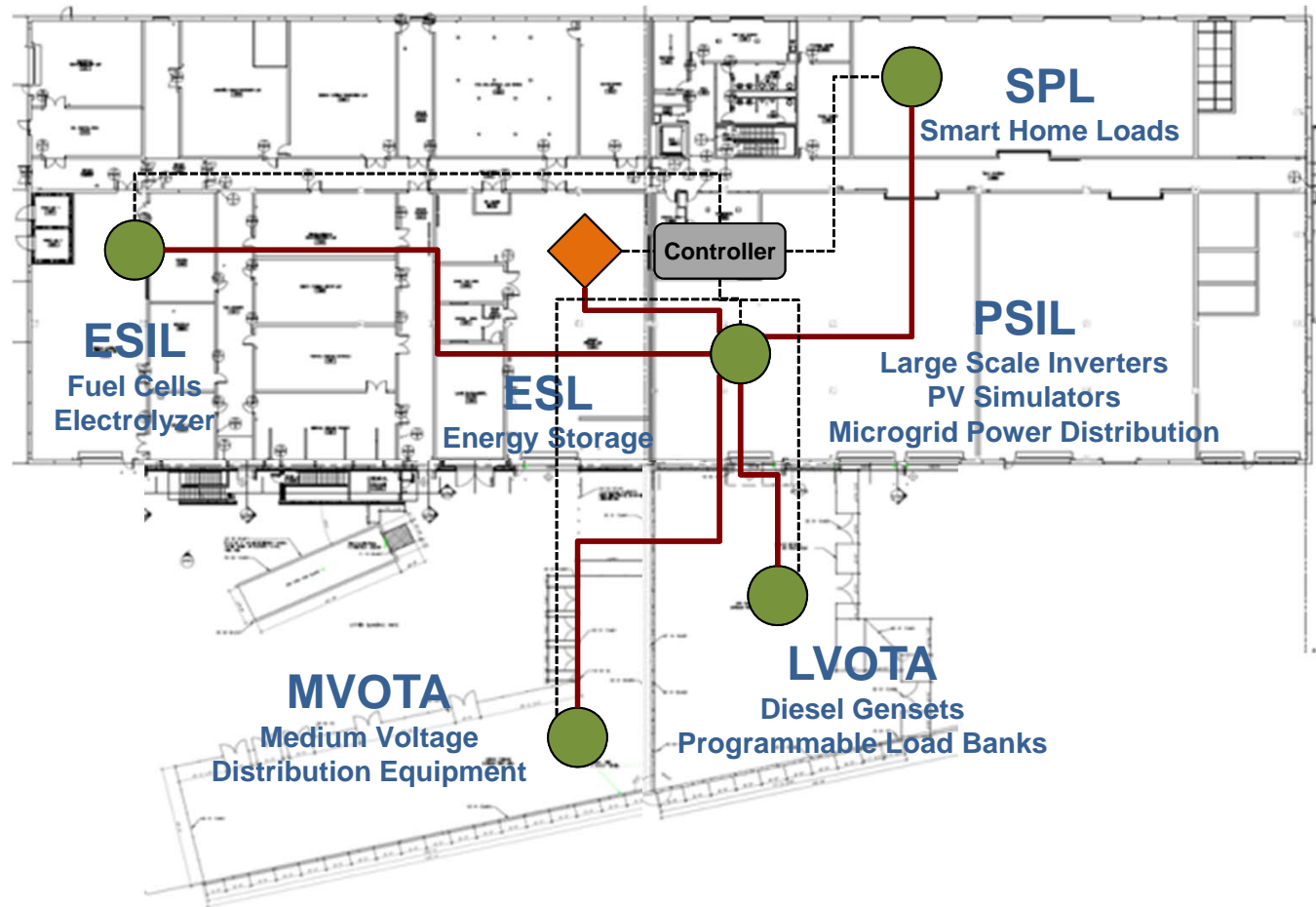
Conceptual Site Plan



Three Scales: Residential, Commercial & Industrial/Grid

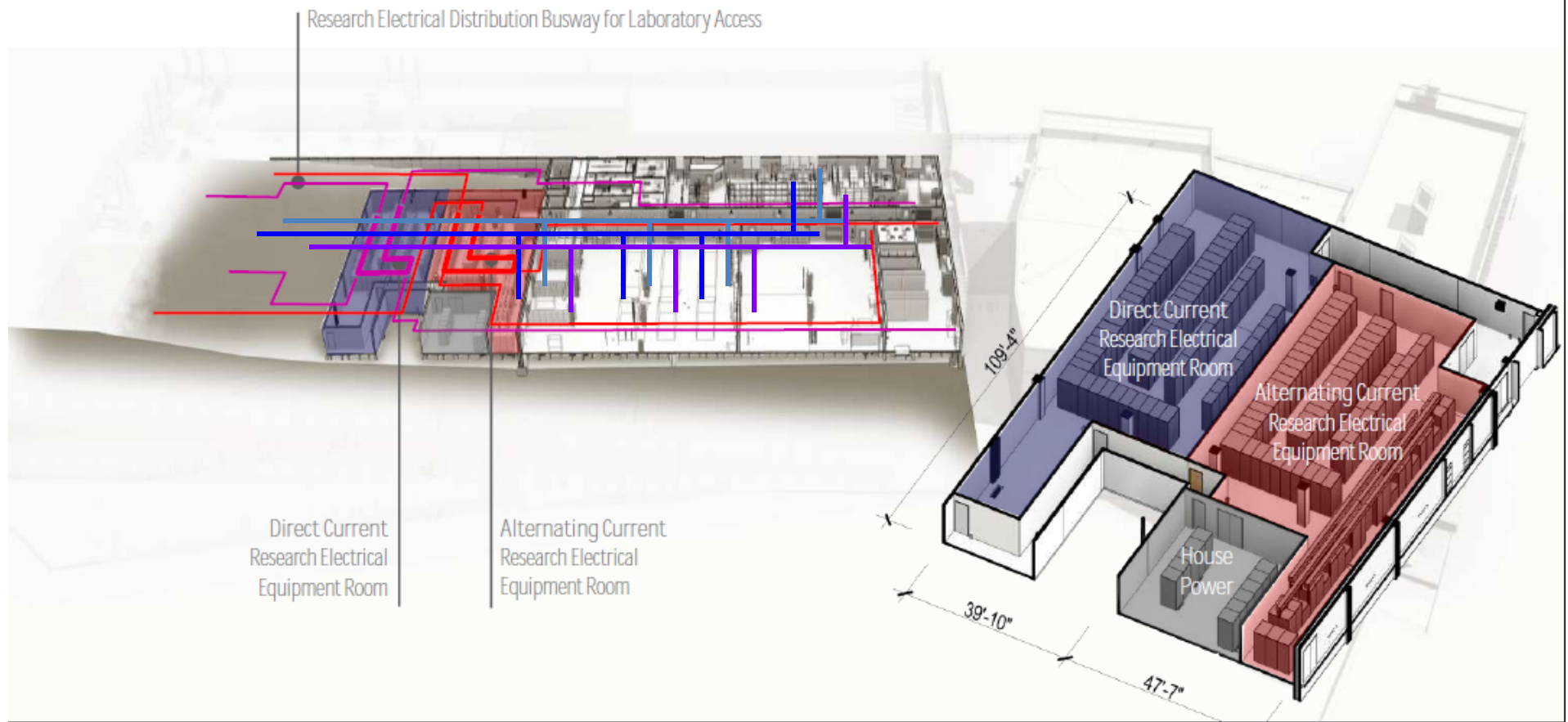


Conceptual Connectivity



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)



Research Electrical Distribution Bus (REDB)



Research Electrical Distribution Bus (REDB)

AC

- Rated 600Vac 3 ϕ , 2 ϕ , or 1 ϕ
- 5-wire design: neutral with selectable ground bonding location
- 16 Hz to 400 Hz
- 250A and 1600A installed
- 250A and 2500A planned (future)
- Experiment connection via cart CB, bus plug CB or fuse, or direct (main lug only)
- Connects PSIL, SPL, ESL, GSE, LBE, LVOTA, MVOTA, ESIL

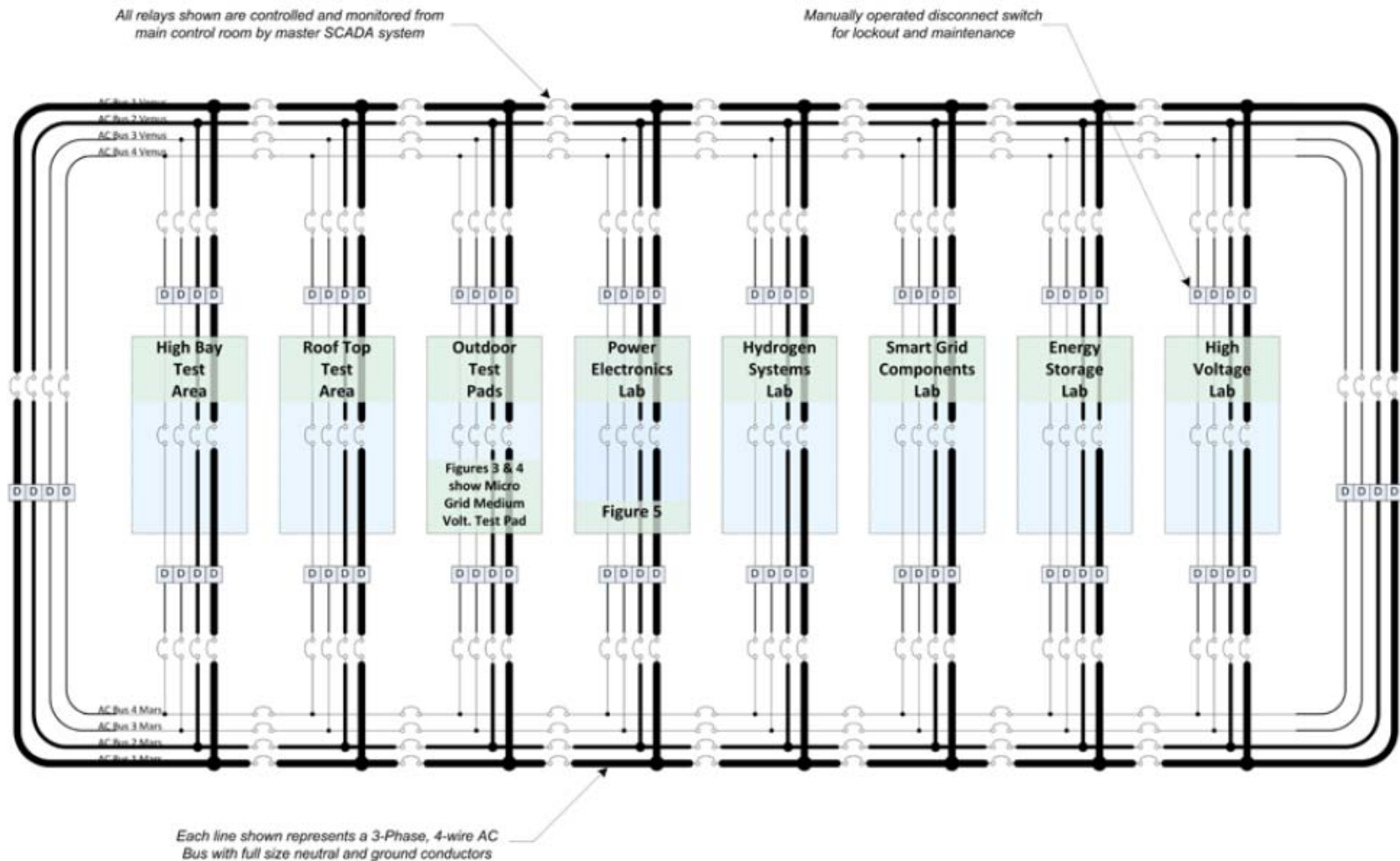
DC

- Rated ± 500 Vdc or 1000Vdc
- 4-wire design: positive, negative, common, and ground
- Any pole may be tied to ground at selectable location
- 250A and 1600A installed
- 250A and 2500A planned (future)
- Experiment connection via cart contactor/fuse or direct (main lug only)
- Connects PSIL, SPL, ESL, PVE, LVOTA, MVOTA, ESIL

Research Electrical Distribution Bus (REDB)

Figure 1: ESIF Research AC Bus One-Line Diagram

DOES NOT INCLUDE HOUSE POWER



REDB: 20,000 Circuit Permutations

- Unconstrained:
Total # Circuits (all Combinations)
1.33499E+95 !!!
- One Constraint:
Total # Circuits (all Combinations)
3.96141E+28!!
- Three Constraints:
Total # Circuits (all Combinations)
1.932E+4!
(19,320)

REDB: One Permutation Example

National Renewable Energy Laboratory Energy Systems Integration Facility

ALLOWABLE SWITCHING CONFIGURATION

**Figure 1: ESIF Research AC Bus
One-Line Diagram**

DOES NOT INCLUDE HOUSE POWER



**Figure 2: ESIF Research DC Bus
One-Line Diagram**

DOES NOT INCLUDE HOUSE POWER

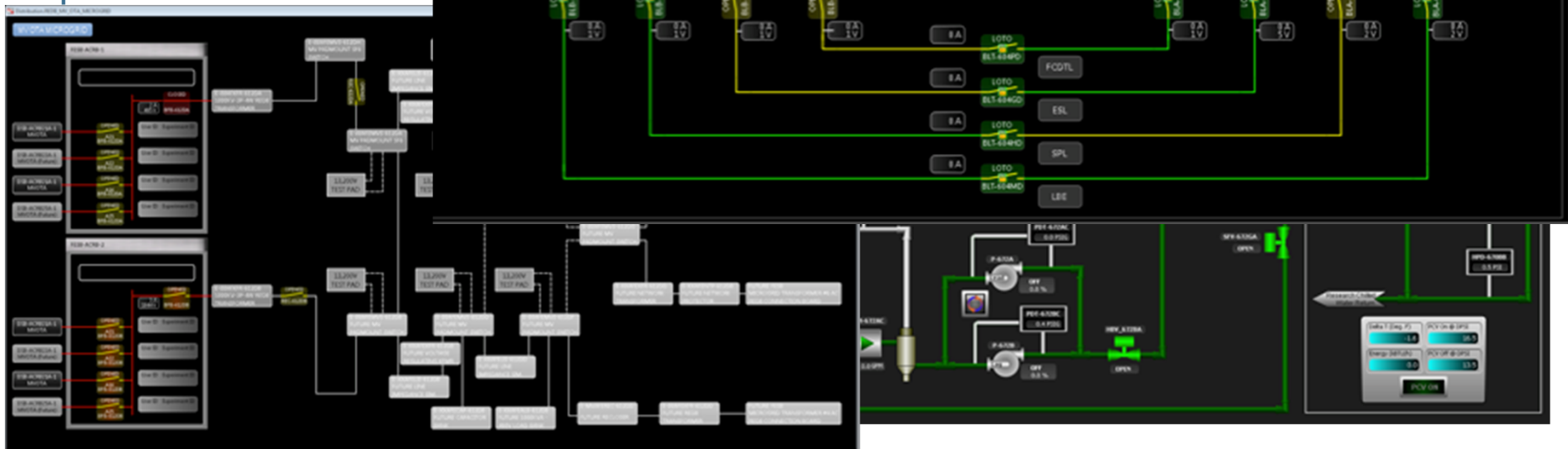
ESIF Laboratory Control Room



ESIF SCADA

Supervisory Control And Data Acquisition

- Electrical systems
- High speed data capture
- Thermal controls
- Gas valving and process controls



IEEE 1547.1 Testing

- ✓ Abnormal voltage (5.2)
- ✓ Abnormal frequency (5.3)
- ✓ Synchronization (5.4)
- ✓ DC injection (5.6)
- ✓ Unintentional islanding (5.7)
- ✓ Reverse power (5.8)
- ✓ Reconnect (5.10)
- ✓ Harmonics (5.11)

Planned Capabilities

- Temperature stability (5.1)
- Open phase (5.9)

Not Currently Planned

- Interconnection integrity (5.5)
- Flicker (5.12)

Inverter/Power Electronics Testing Capabilities

Basic

- Interconnection Standard Testing (e.g. IEEE 1547)
 - Over / Under Voltage and Frequency
 - Power Quality
 - Islanding, etc.
- Steady-state Performance
- PLL Response
- Maximum Power Point Tracking
- Efficiency
- Battery cycling

Advanced

- Advanced Functions
 - LVRT
 - FRT
 - Volt/VAR
 - Frequency/Watt
 - Volt/Watt
- 4-quadrant Operation
- Abnormal Grid Conditions
 - Loss of phase
 - Sags, Swells
 - Fault

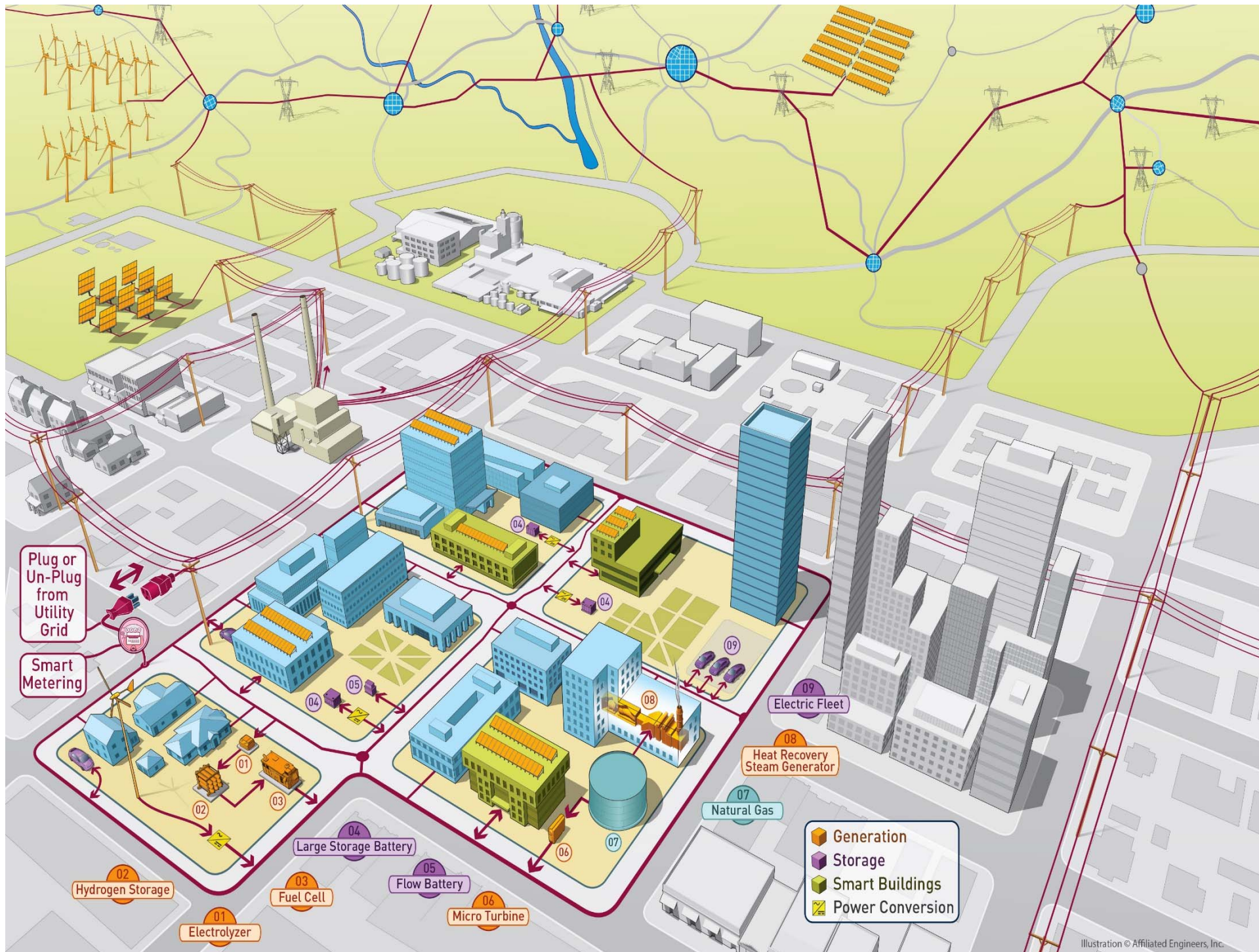
Additional Testing Efforts

A decorative graphic element consisting of three overlapping chevrons pointing to the right. The top chevron is grey, the middle one is blue, and the bottom one is green.

- Electric vehicles
- Battery energy storage
- Other energy storage
- Microgrids
- Home energy, appliances
- Fuel cell vehicles
- Hydrogen production and utilization systems

Large Advanced Inverter Development/Testing





Team Participants



Courtesy of SmithGroupJJR

DESIGN

SmithGroupJJR
Affiliated Engineers, Inc
Martin & Martin

CONSTRUCTION

JE Dunn Construction Company
MTech Mechanical
Encore Electric, Inc.

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QUESTIONS



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