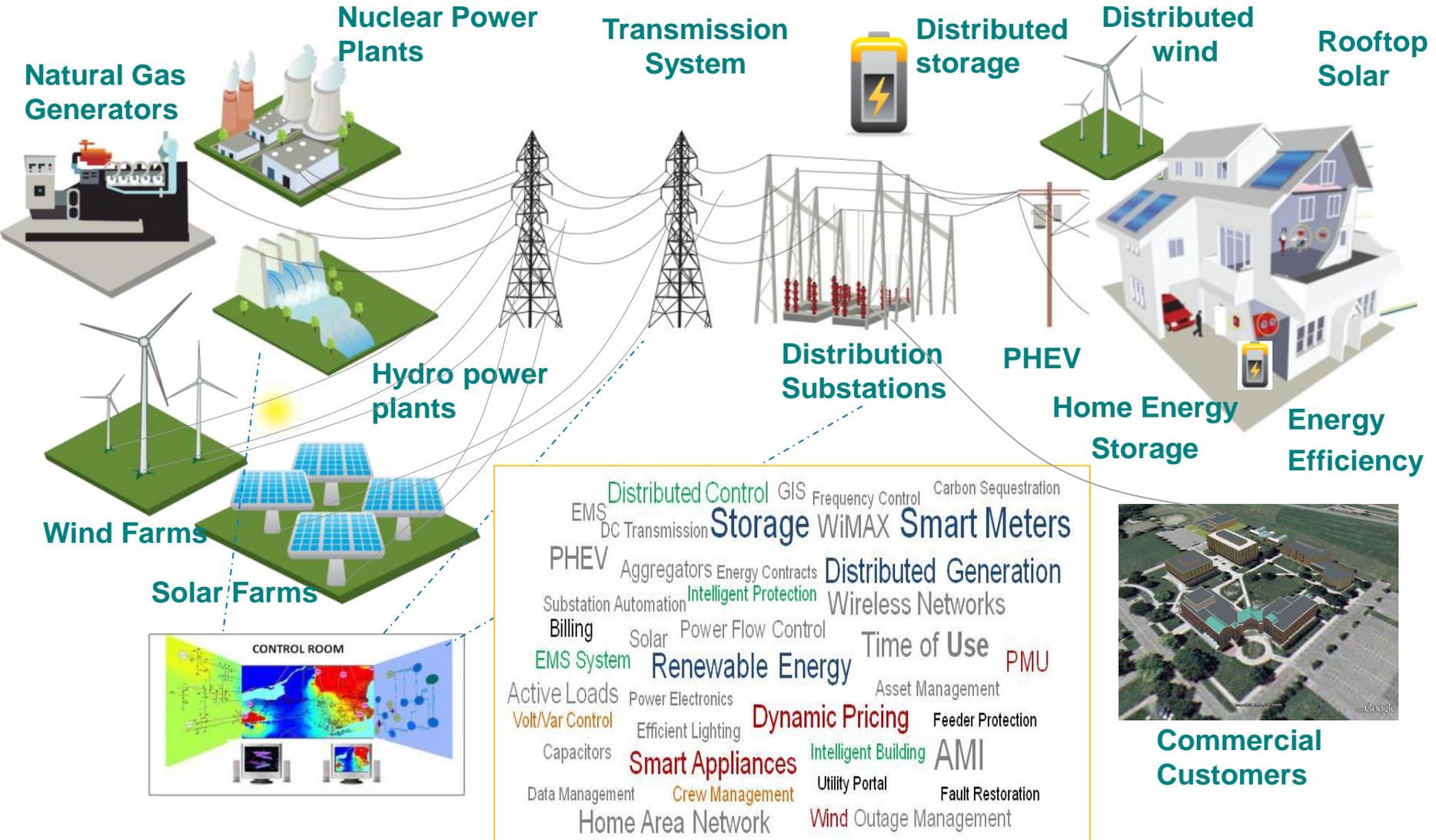


# Energy Systems Integration Research and Facility at NREL

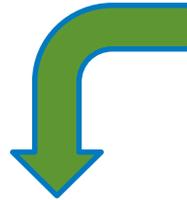


James Cale, Ph.D., Group Manager  
Distributed Energy Systems Integration (DESI)  
Power Systems Engineering Center  
National Renewable Energy Laboratory

# The Emerging Grid

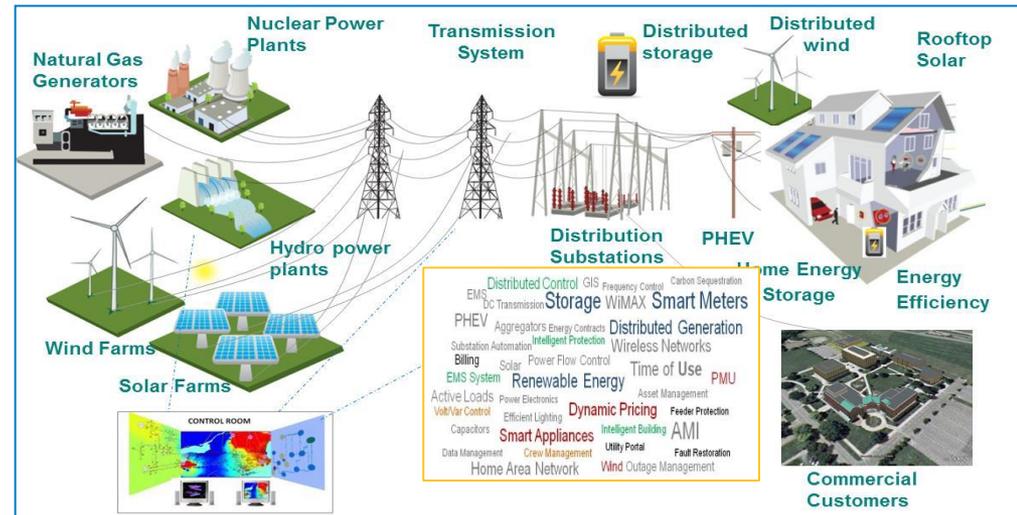


## Research Drivers



### 1. Information Age

- Can't avoid it ("IOE")
- Natural progress of industry
- *Theoretically*, can enable better asset control and management
- But, requires advancement in highly-distributed controls, solutions for Big Data, cyber-security



### 2. Sustainability as a Political and Social Value

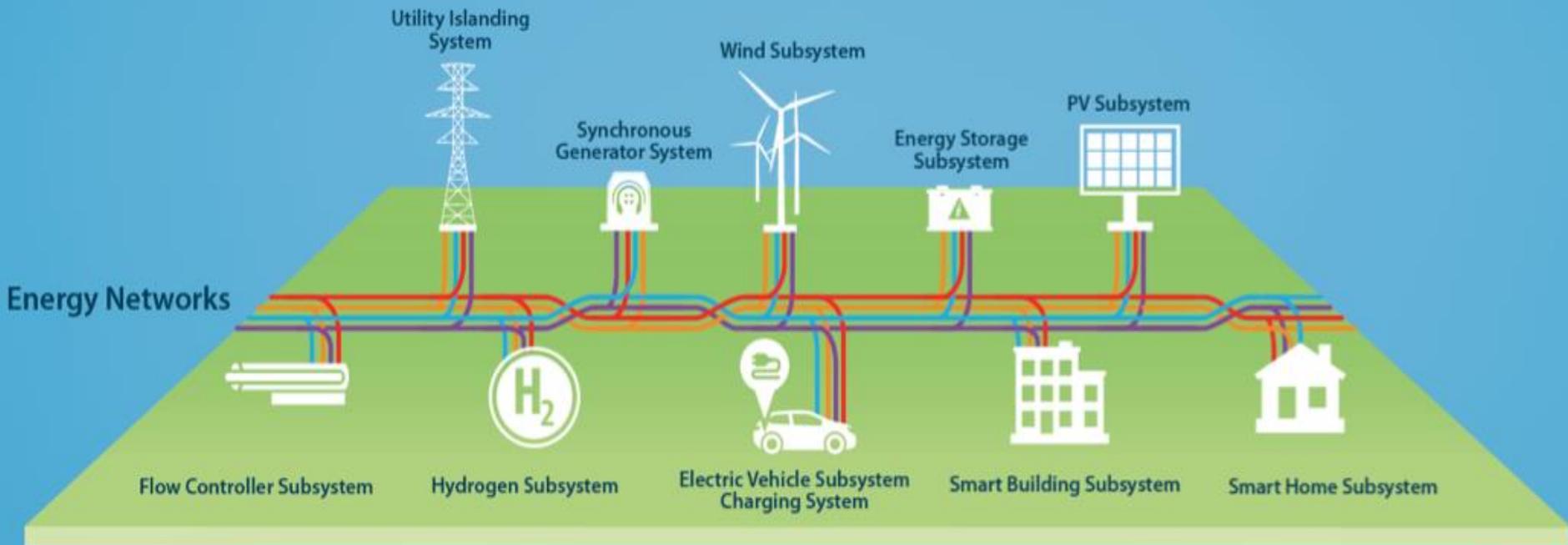
- Climate change is a very important issue – especially the younger generation
- Evaluating the total cost of electricity

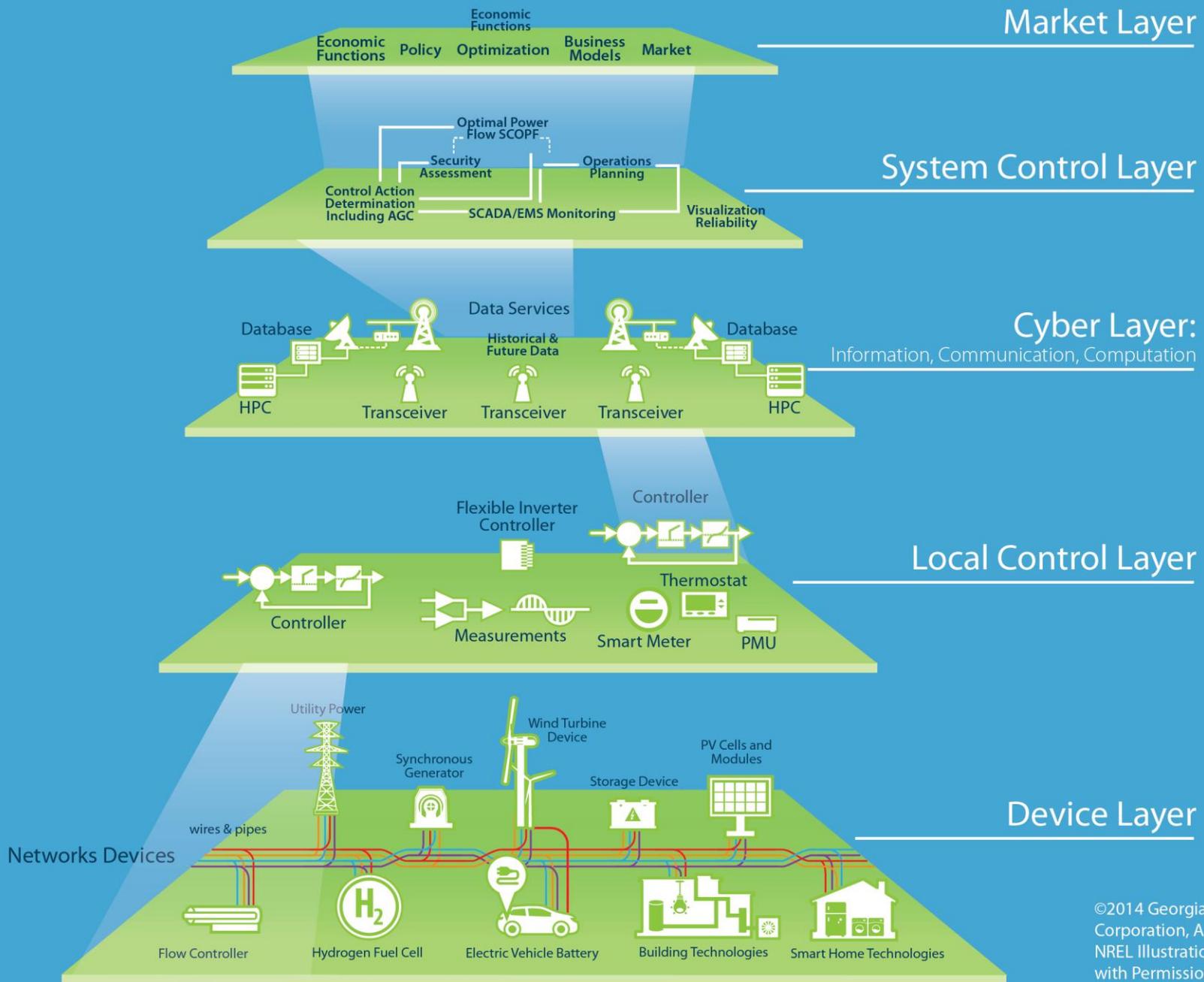
# ESI Strategy at NREL

Energy  
System  
Integration

of Renewable Energy Sources  
of Energy Efficiency

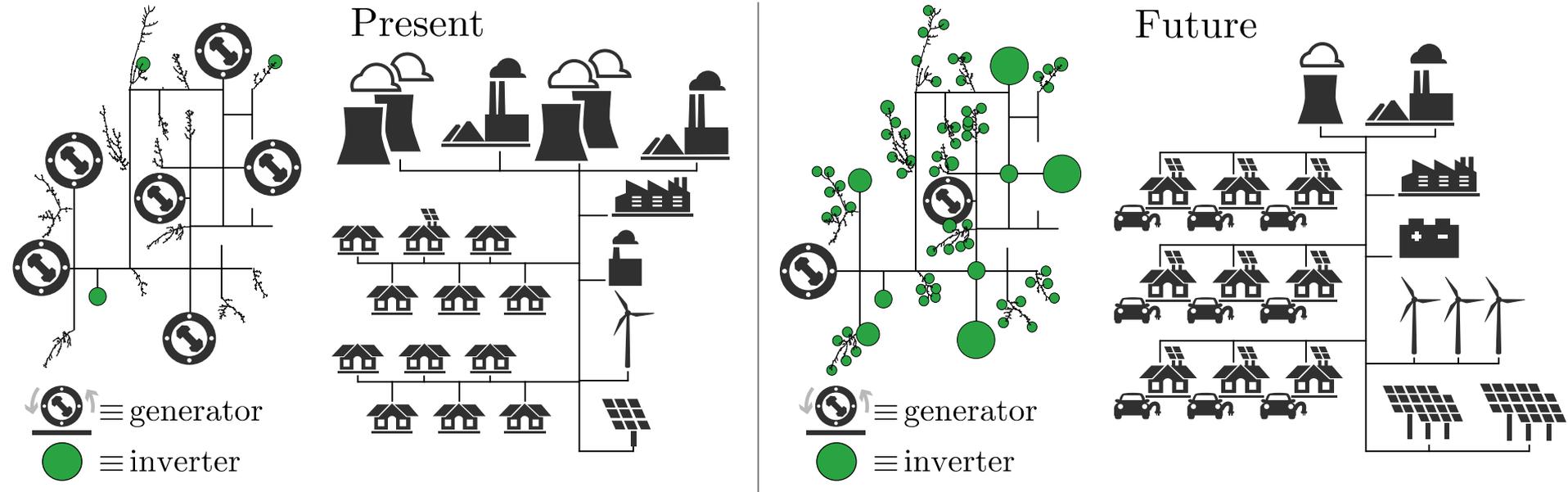
across all energy carriers  
across spatial scales  
across functional layers





“In times of change learners will inherit the earth, while the ‘learned’ find themselves beautifully equipped to deal with a world that no longer exists.’

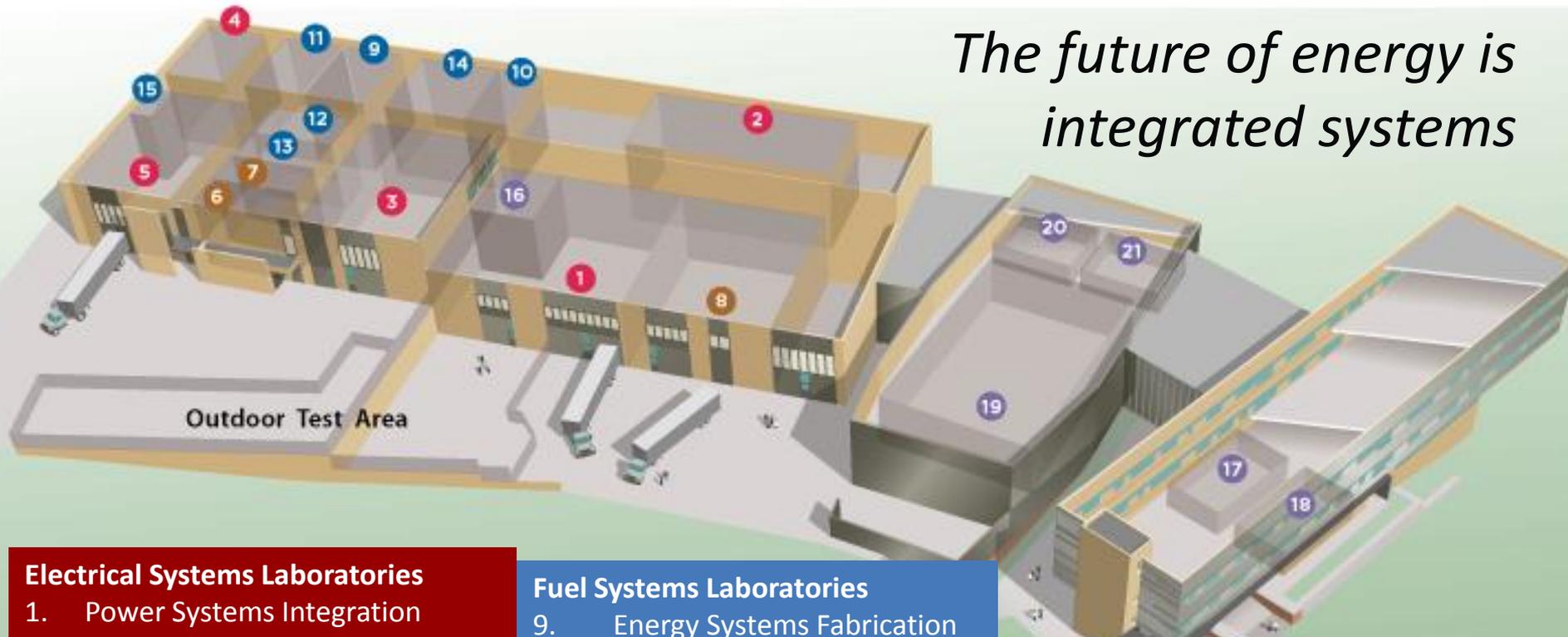
- Eric Hoffer



# ESIF Laboratories



*The future of energy is integrated systems*



## 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

🔴 Research Electrical Distribution Bus – REDB (AC  $3_{ph}$ , 600V, 1200A and DC  $\pm$ 500V, 1200A)

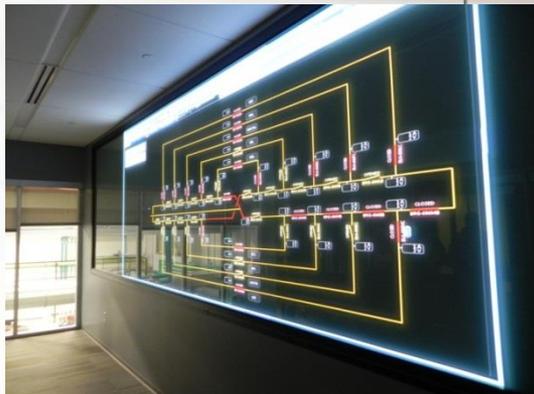
🟡 Thermal Distribution Bus

🔵 Fuel Distribution Bus

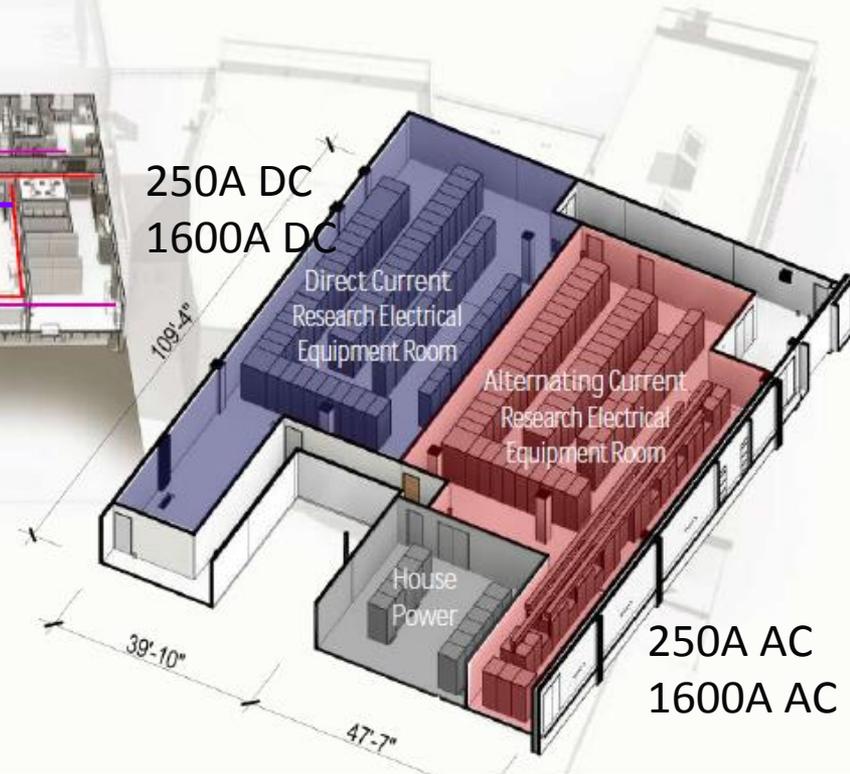
🟣 Supervisory Control and Data Acquisition (SCADA)

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

Research Electrical Distribution Busway for Laboratory Access



Alternating Current  
Research Electrical  
Equipment Room



## AC



AC Grid Simulator

### AC Grid Simulator

- 1.5 MW, 600 V, 5 wire
- Bi-directional
- Independent Phase Control

### Utility Connection

- 600 V (250 or 1600 A bus)
- 13.2 kV (Medium Voltage Outdoor Test Area)

### Load Banks

- 1 MW, RLC, fine resolution steps

## DC



PV Array Simulator

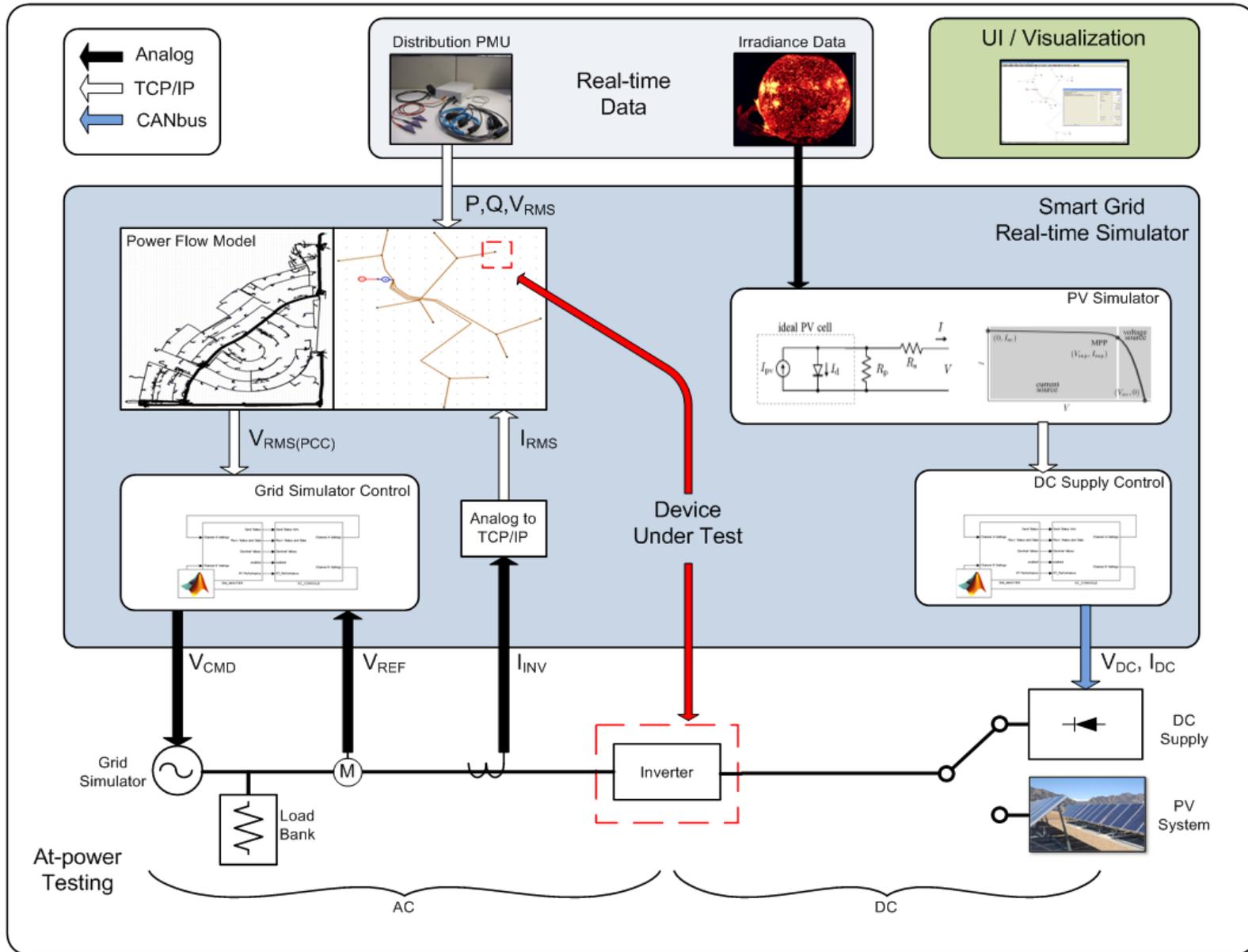
### Photovoltaic Array Simulator

- 1.5 MW, 1000 V
- Emulate a variety of PV modules under specific input conditions
- Evaluation using standards such as EN50530

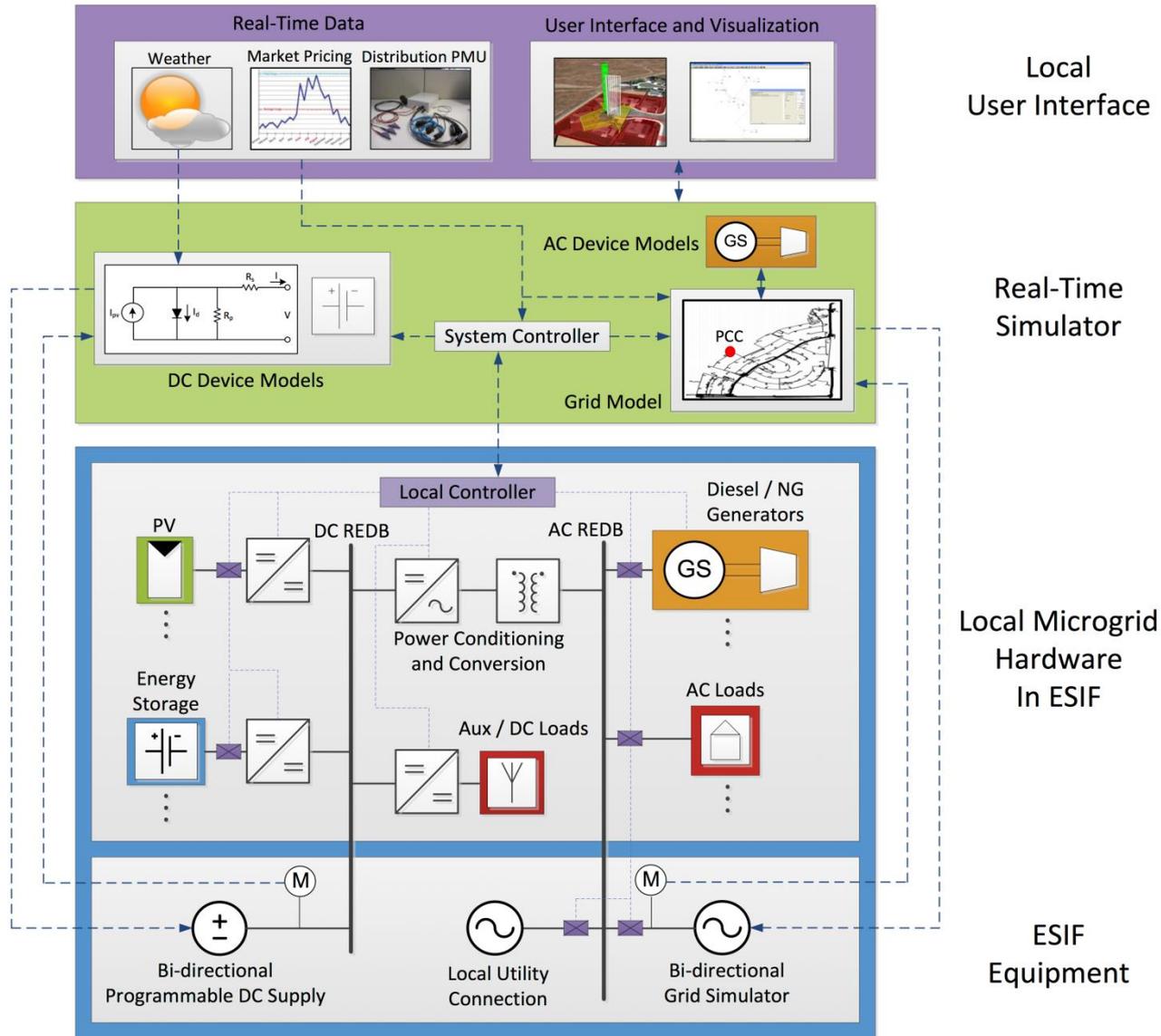
### DC Power Supply

- 500 kW, 900 V
- Bi-directional

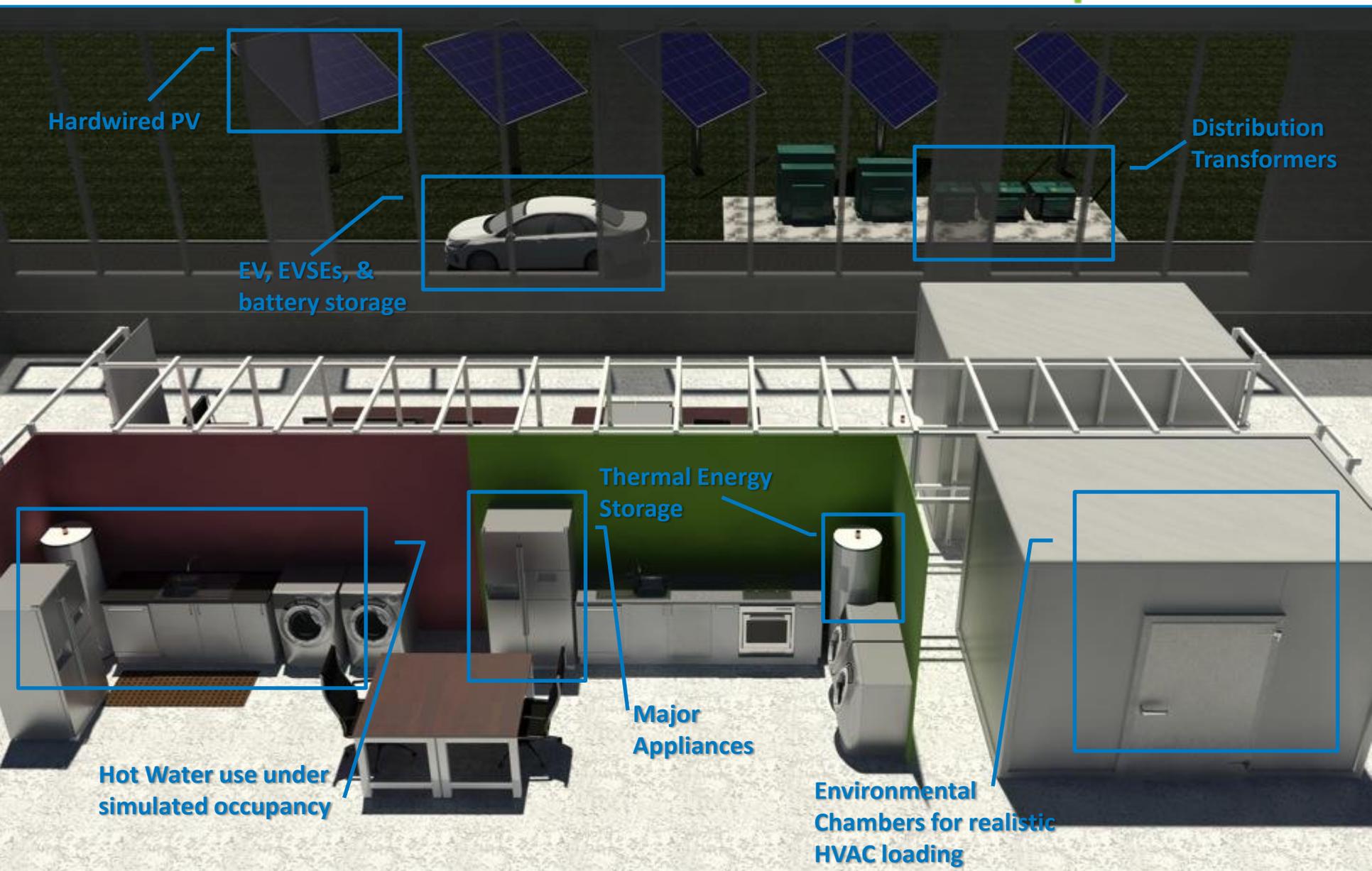
# Power Hardware-in-the-Loop



# PHIL for Microgrid Experimentation



# The Future - Smart Homes



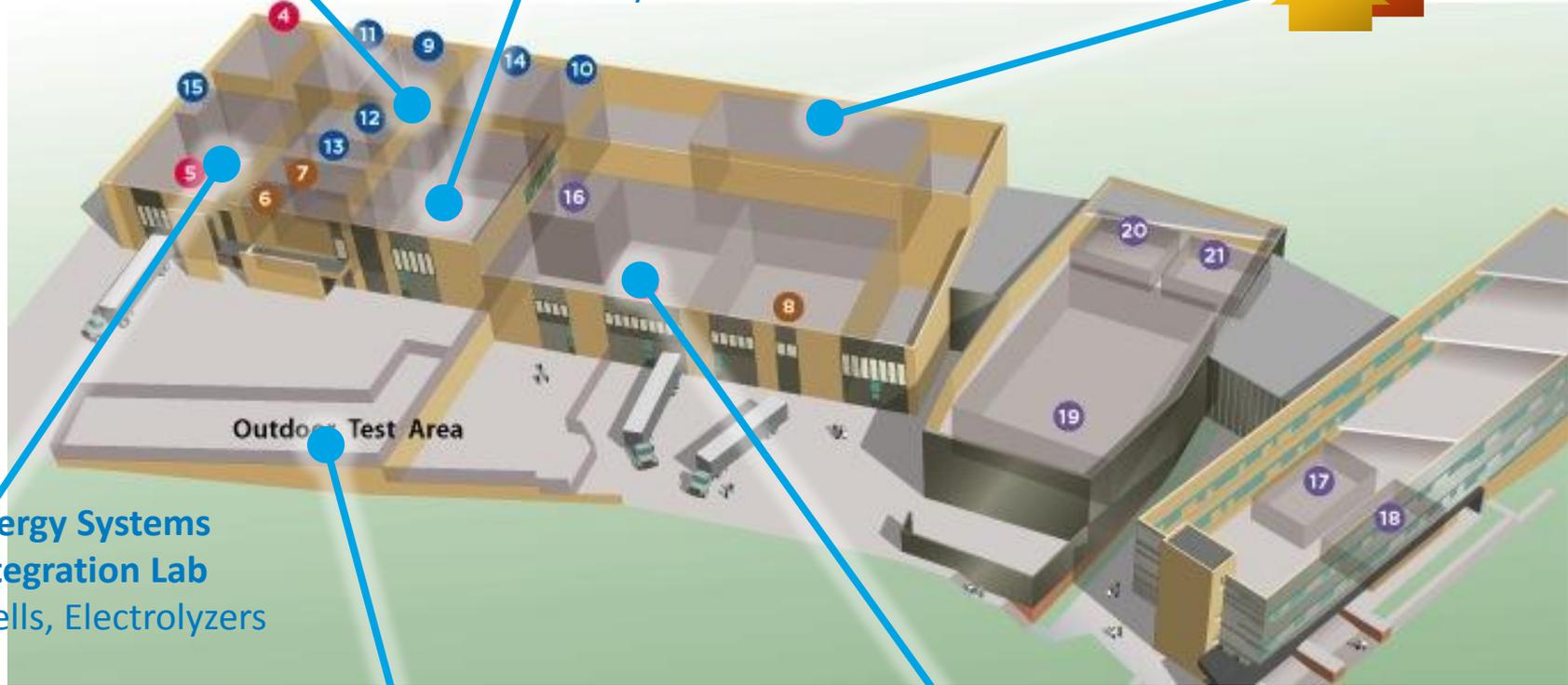
# Replication at Scale: Microgrid at ESIF

Rooftop PV & Wind



Energy Storage Lab  
Residential, Community  
& Grid Battery Storage,  
Flywheels & Thermal

Smart Power Lab  
Buildings & Loads



Energy Systems  
Integration Lab  
Fuel Cells, Electrolyzers

Outdoor Test Area  
EVs, Power Transformers

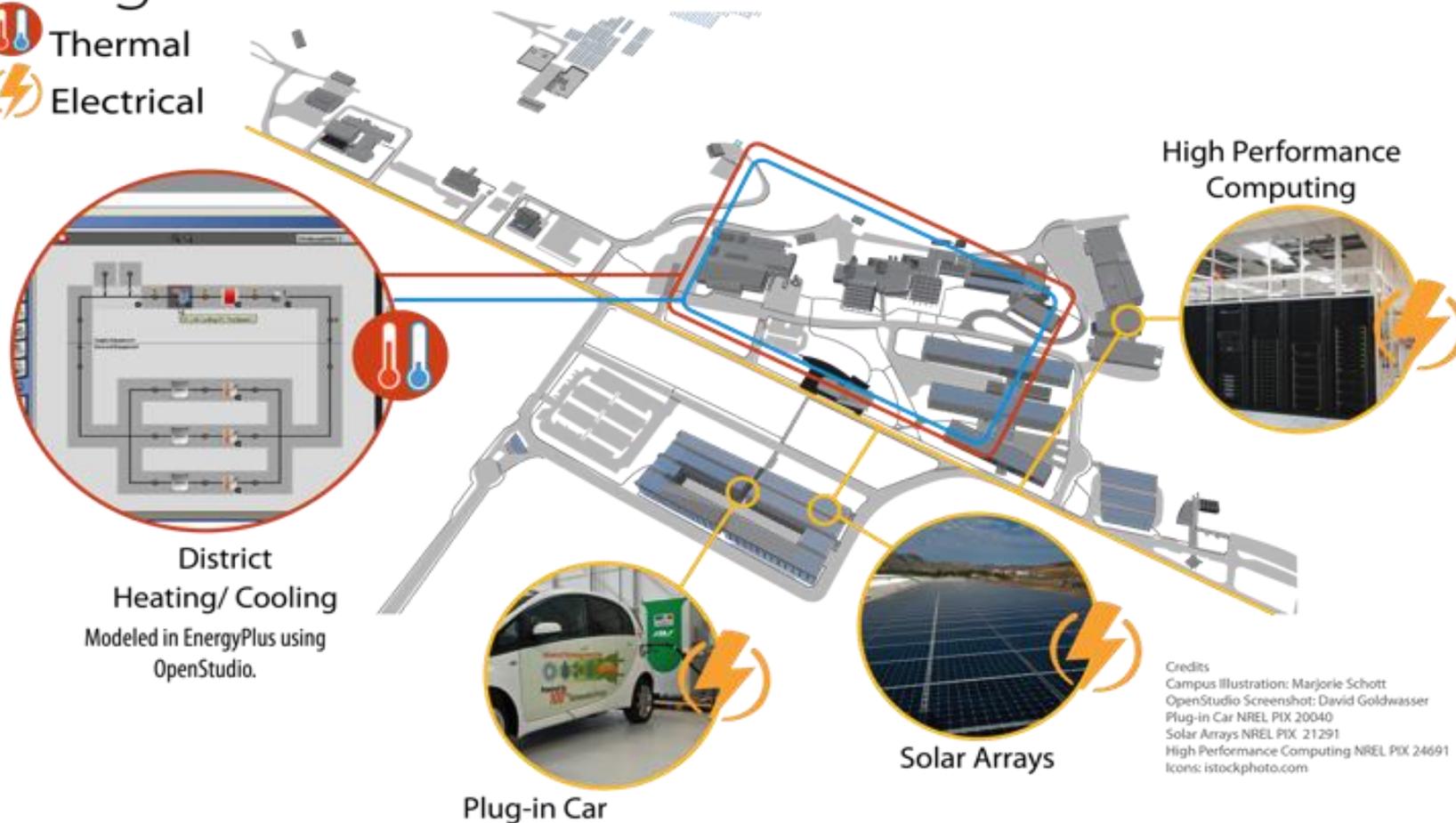


Power Systems  
Integration Lab  
PV Simulator



## Integrated Platform

-  Thermal
-  Electrical



District Heating/ Cooling  
Modeled in EnergyPlus using OpenStudio.

Credits  
Campus Illustration: Marjorie Schott  
OpenStudio Screenshot: David Goldwasser  
Plug-in Car NREL PIX 20040  
Solar Arrays NREL PIX 21291  
High Performance Computing NREL PIX 24691  
Icons: istockphoto.com

**Thank You!!**

James Cale, Ph.D.

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