

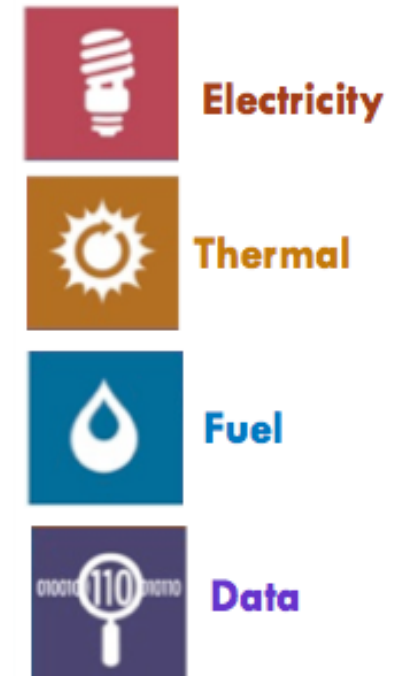
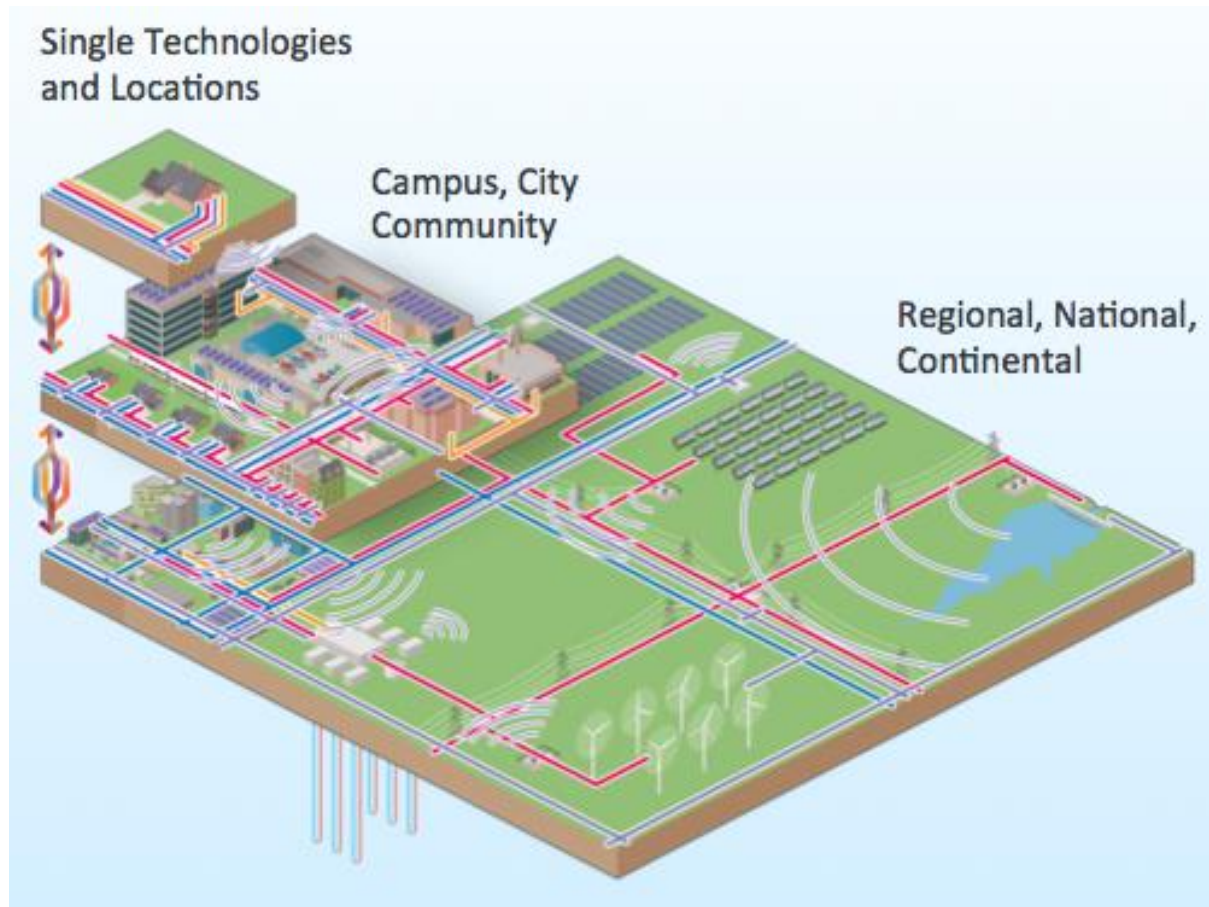
Smart and Renewable Power System Transformation Overview, Issues, and Projects



Sam Booth
Asia Clean Energy Forum
June 18th 2015

Energy Systems Integration – The Concept

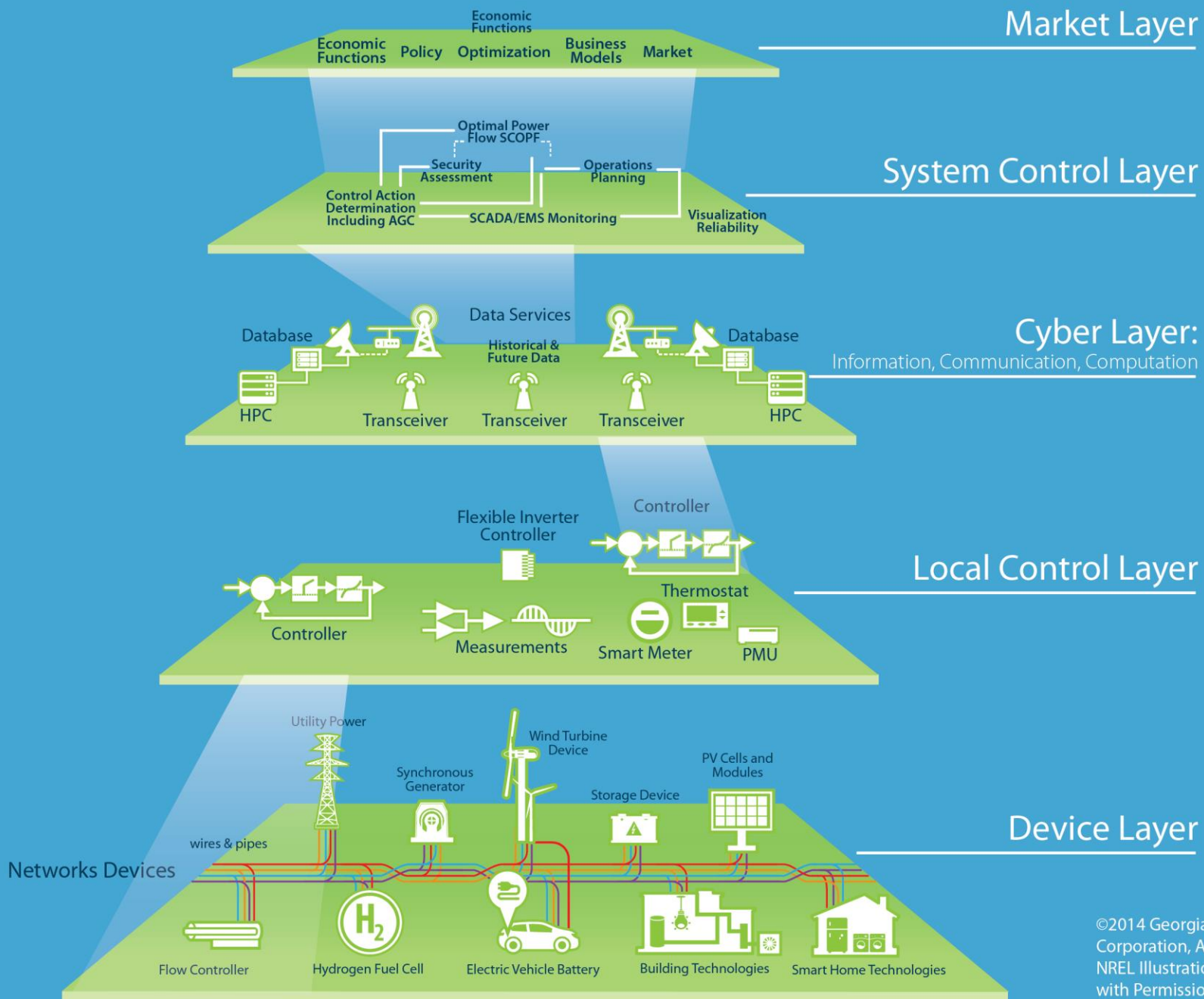
ESI Vision: Highly integrated, flexible, and efficient systems that enable utilization of clean energy sources while maintaining reliability at an affordable cost



Trends in Power System Transformation

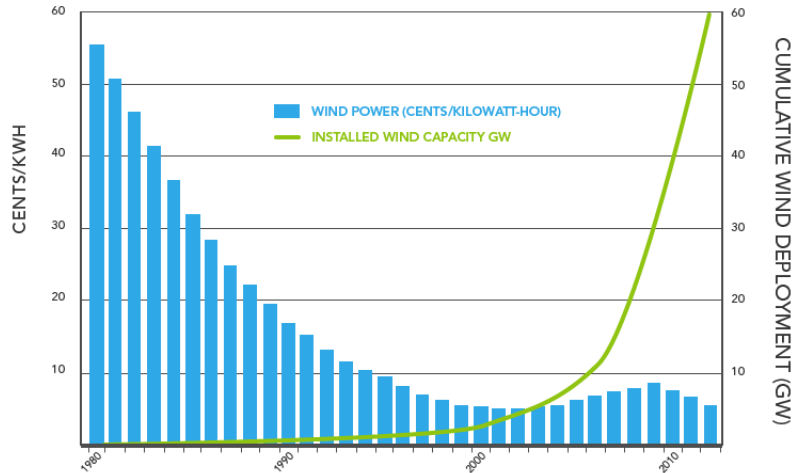
- Energy and IT convergence for more: data, sensors, intelligence and control
 - Need for more flexible power systems
 - Increased renewable energy with lower costs
- Evolving customer engagement
 - Increased interactions with other sectors
 - Global concerns about emissions
 - Energy access initiatives
 - Market and investment challenges
 - Changes to utility business models



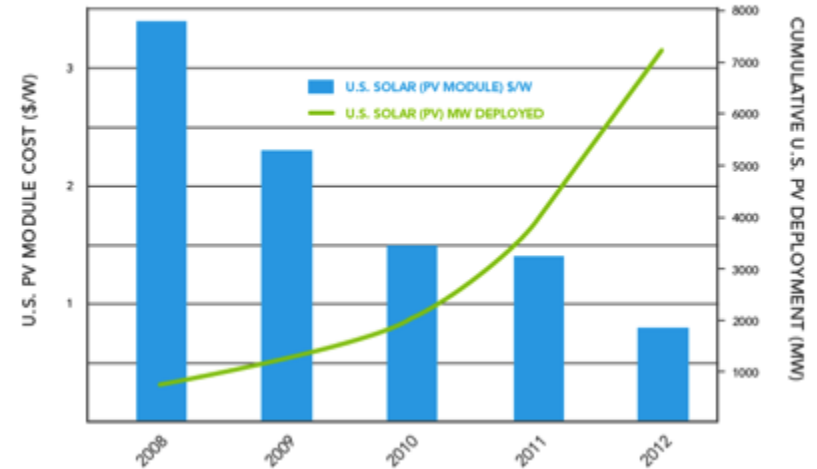


Costs are Declining and Deployments are Increasing

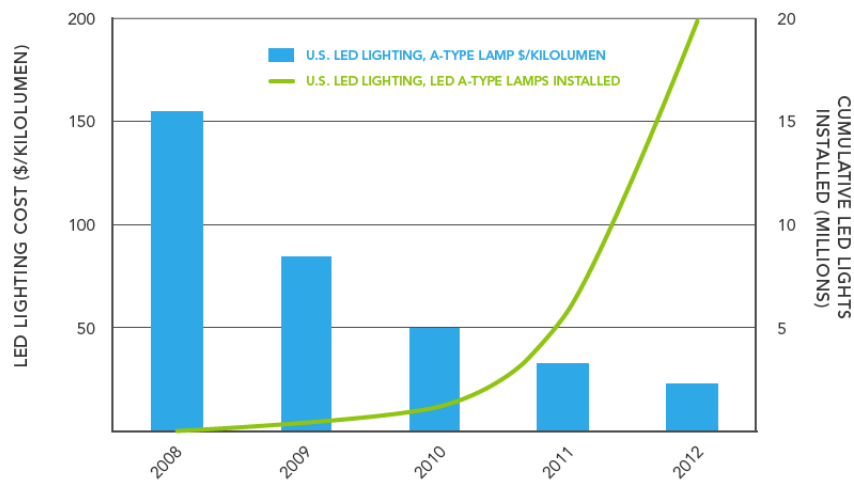
Deployment and Cost for U.S. Land-Based Wind
1980-2012



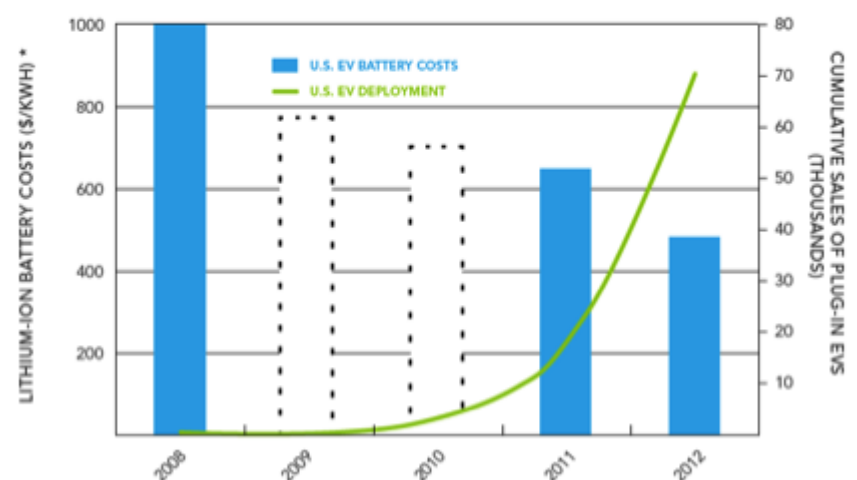
U.S. Deployment and Cost for Solar PV Modules
2008-2012



Deployment and Cost for A-Type LED Lights
2008-2012

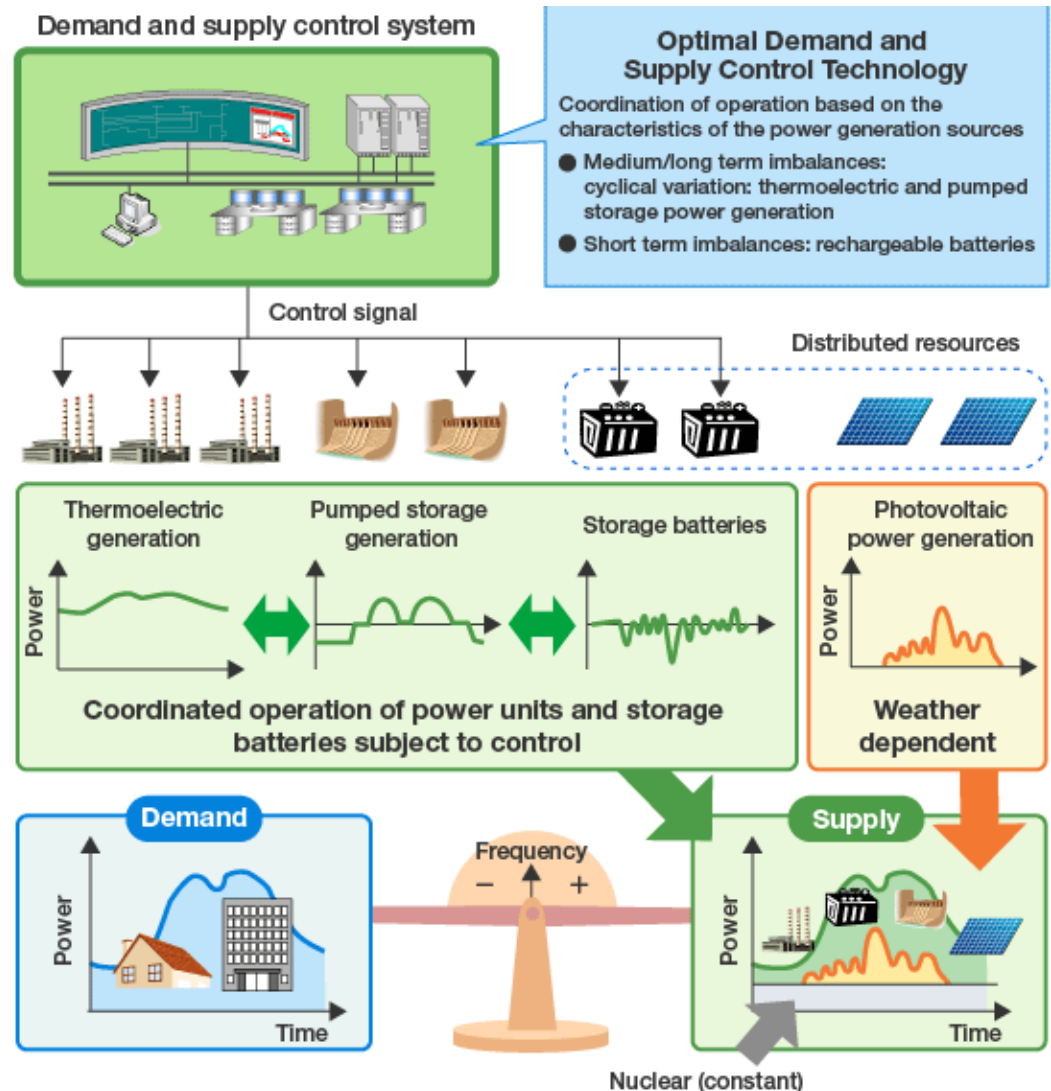


Deployment and Cost for Electric Vehicles and Batteries*
2008-2012

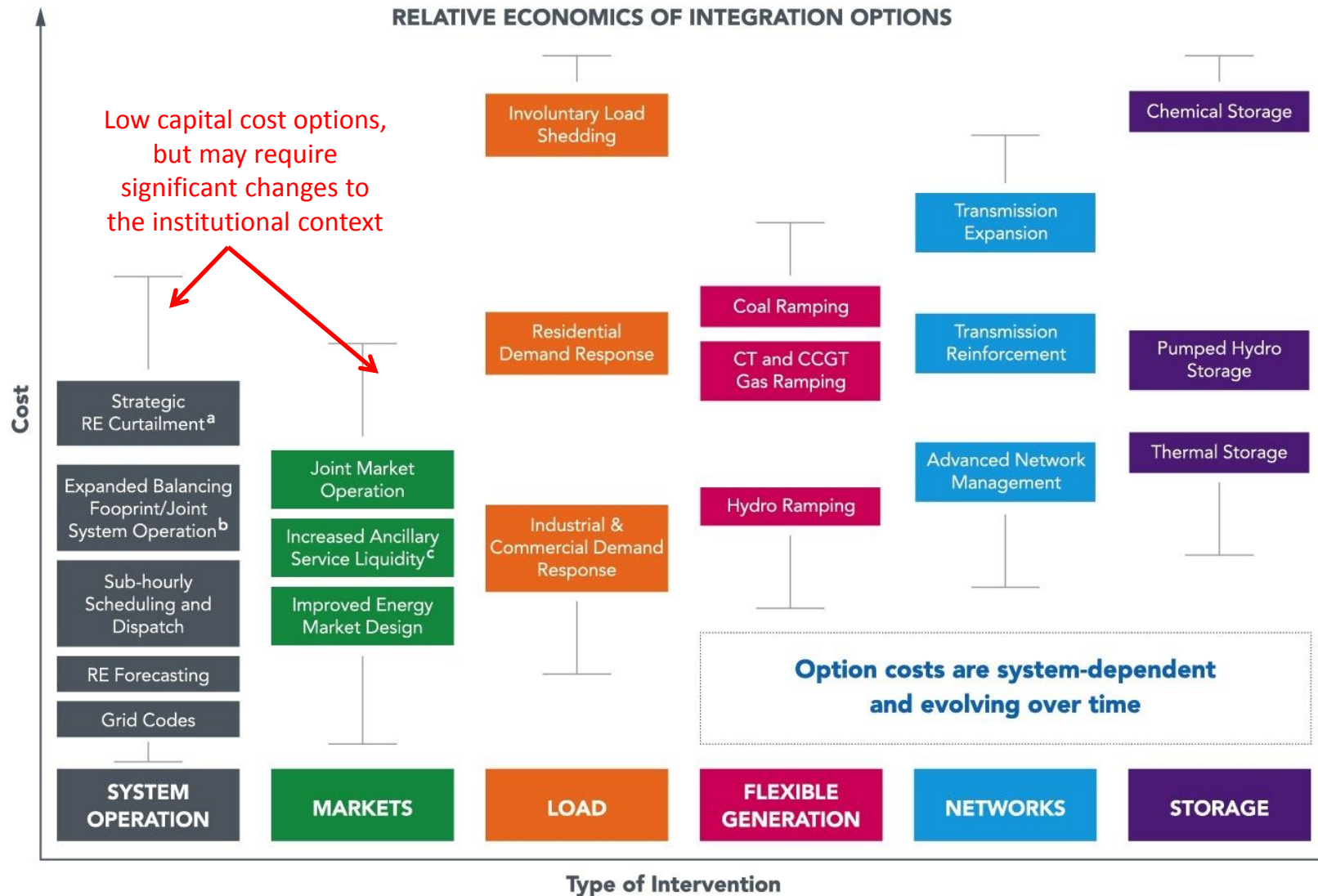


Grid Integration Issues

- High wind and solar means lesser but **more variable** use of other assets
- Issues with voltage and frequency regulation, can limit renewables
- High efficiency, demand response, and new loads are changing demand and making it **more variable**
- Existing T&D grid increasingly strained by two-way power flow



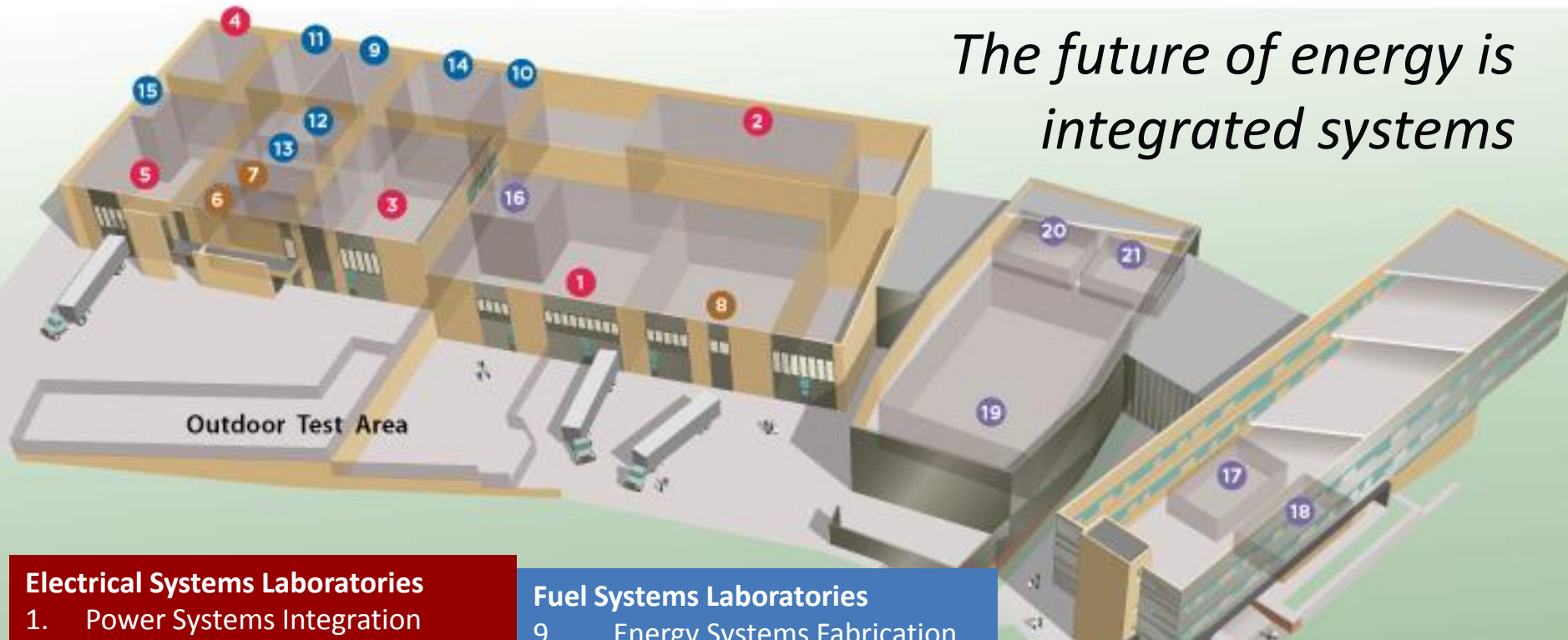
Frequently Used Options to Increase Flexibility



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

TECHNOLOGY ADDRESSED

Solar inverter controls validation for high penetration utility and commercial photovoltaics (PV).

R&D STRATEGY

Demonstrate 500 kW PV inverter performance by connecting the inverter to NREL's megawatt scale grid simulators, PV simulators, load banks and real-time electric distribution feeder models.

IMPACT

Increase PV saturation without negatively impacting the distribution grid through modifying the behaviors of inverters.



TECHNOLOGY ADDRESSED

Interconnection challenges when connecting distributed PV into the electrical distribution grid such as in Hawaii (HECO).

STRATEGY

Inverters from various manufacturers will be tested at ESIF using NREL's unique power hardware-in-the-loop capability to evaluate system-level issues such as anti-islanding and volt-VAR support.



Union Bridge, MD

IMPACT

HECO filed with the PUC to modify their interconnection policies to allow siting of PV systems with solar inverters on neighborhood distribution circuits up to 250% of minimum daytime load (MDL). Previously the full study requirements kicked in at 120% MDL

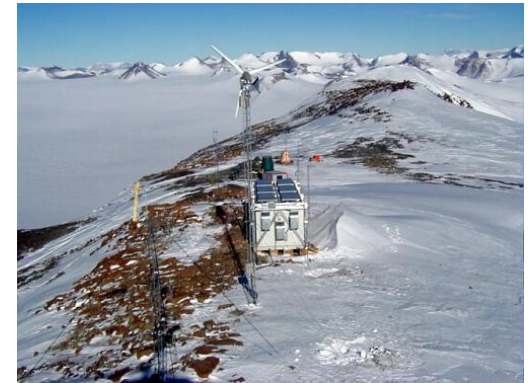
Consolidated Utility Base Energy (CUBE)

- **Integrated platform for 60 kW PV-Battery-Diesel hybrid power system**
- **Connections**
 - 60 kW load
 - Two 30 kW diesel generators
 - Four 5 kW PV Arrays
 - One 30 kW battery bank
 - One spare 30 kW battery connection
- **Components**
 - Modular power electronic building blocks
 - Power distribution components
 - Power protection components
 - Magnetics and other filter components
 - Liquid cooling system
 - Control platform based on FPGA and RT Controllers
- **Initial Partners**
 - NREL and U.S. Army Mobile Electric Power (MEP)
- **Current Partners**
 - NREL, Wyle, and U.S. Army Rapid Equipping Force (REF)



Deployment Project Summary

- **Energy strategies for islands**
 - Examples: USVI, Hawaii, and Brazil
- **Remote RE projects and mini grids**
 - Examples: Alaska, U.S. National parks, and Indonesia
- **Communications Infrastructure**
 - Example: Verizon cell towers
- **Microgrid Design and Analysis**
 - Examples: Lanai, MCAS Miramar, JB Soto Cano, Kwajalein



Indonesia MCC Overview

Supported \$600 M MCC Indonesia Compact with Green Prosperity Projects. Program development and pre-feasibility studies (hydro, biomass, cacao, peat lands, solar)

Example Project Overview

- **Off-grid hydropower**
 - Jambi -> Merangin -> Rantau Suli ~76 km from the grid
 - 2.5 MW hydro energy system
 - Supply power to 4,115 households and 19 villages
- **Integrated with NRM and SLU**
 - Catchment area protection
 - Agricultural intensification
- **Green Prosperity**
 - Expanded access to electricity
 - Increased lighting, TV, and appliances
 - Enough power for commodity processing
 - Hydropower replaces small diesel gensets
- **Grid Integration Issues**
 - Supply issues in dry season
 - Landslides and trees take out power lines
 - Power quality and operations and maintenance



Clean Energy Grid Integration Network

- **Partnership to support developing countries with grid integration challenges**
 - Information resources
 - Technical assistance
 - Trainings

<https://cleanenergysolutions.org/cegin>

Thank You and Questions?

samuel.booth@nrel.gov or 303-275-4625

