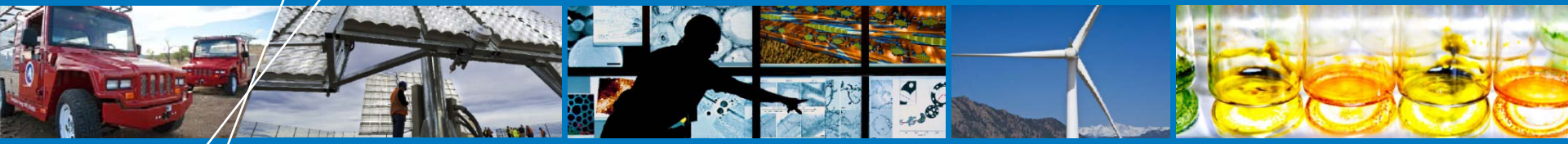
NREL
NATIONAL RENEWABLE ENERGY LABORATORY



Energy Systems Integration Overview and Vision

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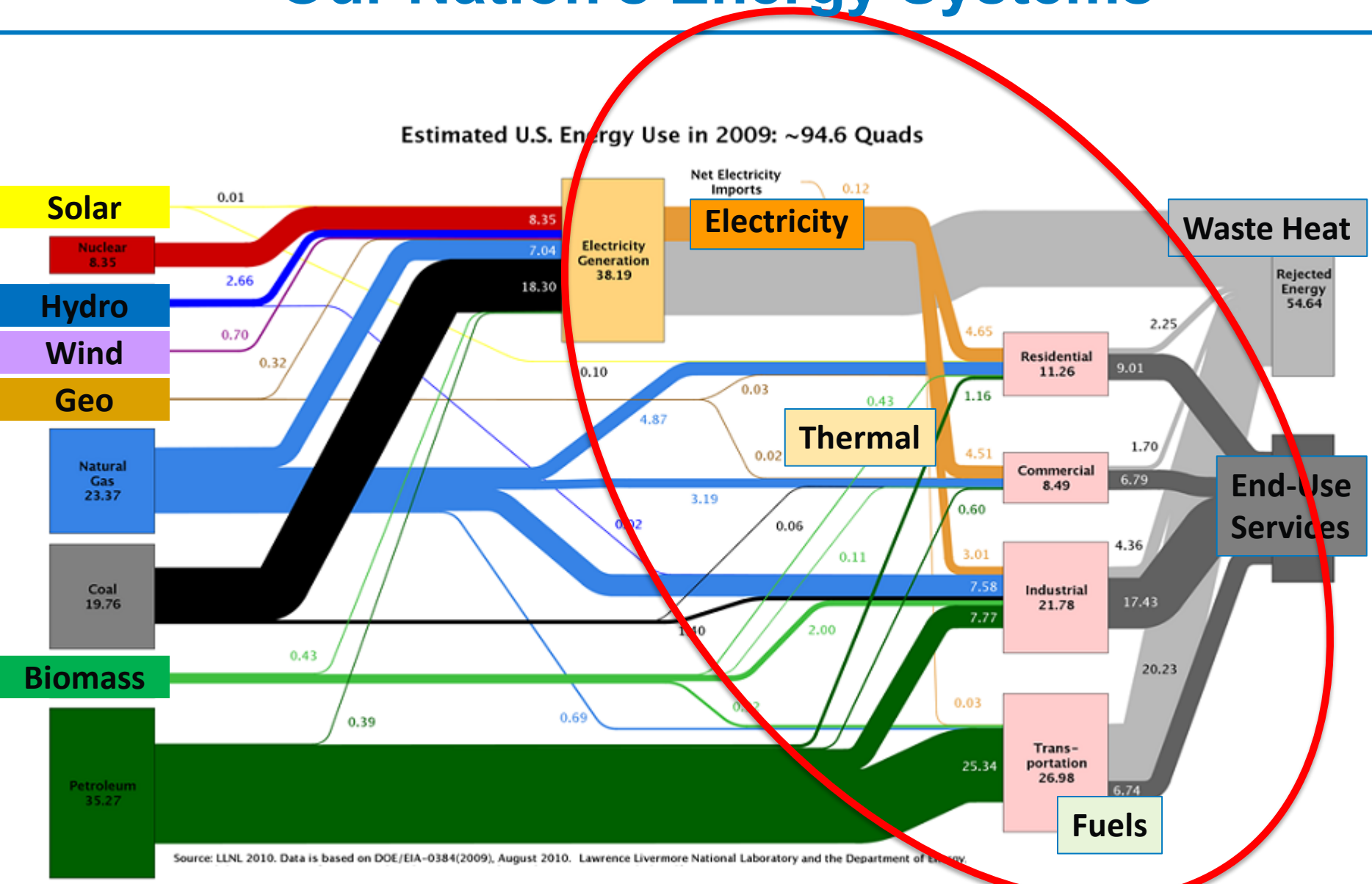
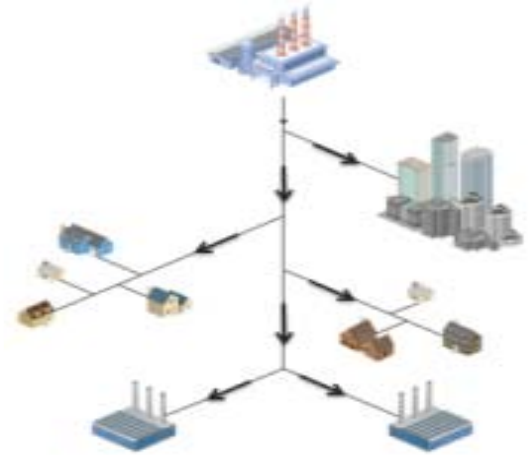
Our Nation's Energy Systems

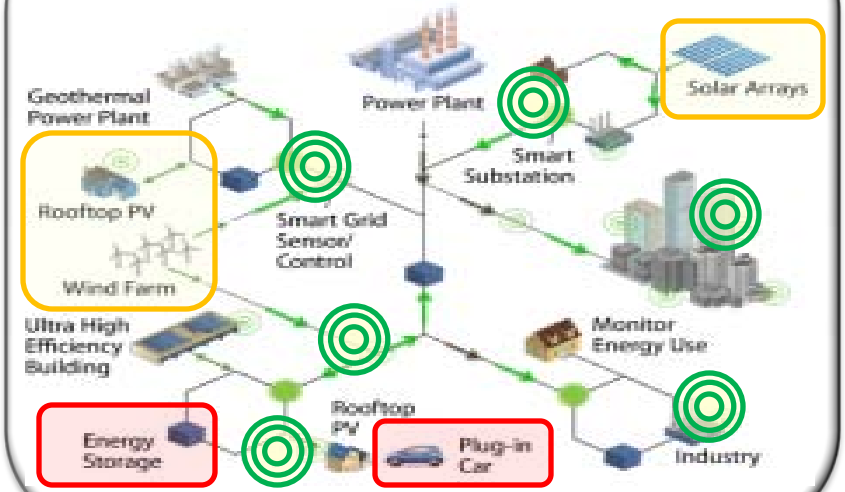


Why Energy Systems Integration?

Current Energy Systems



Future Energy Systems



New Challenges – Need to tackle hard problems

- New energy technologies and services
- Increasing penetration of variable RE in grid
- New communications and control models
- Electrification of transportation
- Integrating energy storage
- Increasing system flexibility
- Understanding interactions between electricity/thermal/fuels

Addressing National Clean Energy Challenges

Addressing the impacts of large-scale deployments of renewable energy (RE) and energy efficiency (EE) technologies on the nation's energy infrastructure.

Optimize the integration and operation of RE and demand side systems configurations under various load and storage configurations.

Reduce uncertainties for utilities and integrators by conducting research and analysis of RE and EEE technologies under different operating and geographic conditions.

What is NREL's Role in Energy Systems Integration?

Energy Production

Electricity generation

Fuels

Interfaces

Energy Systems Integration

Pathways from production to use are becoming much more complex

Provide the knowledge base and technology to enable design, integration, and reliable operation of systems of all scales

Systems Integration is an essential distinctive competency of an applied energy research laboratory

Interfaces

Energy Use

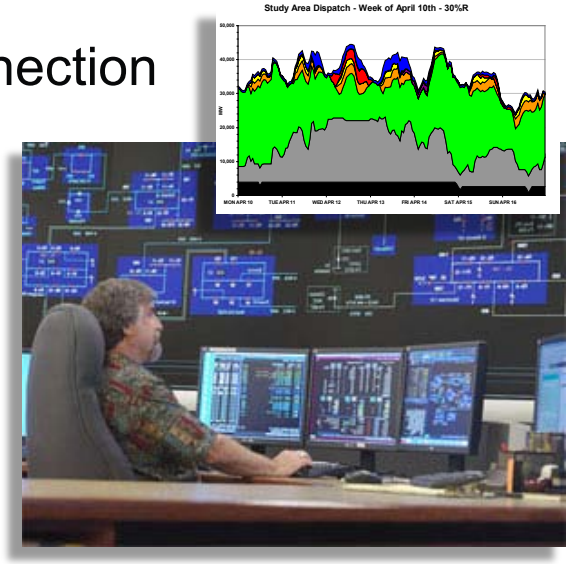
End-use loads

Building Systems
Lighting
Heating
Motors

Transportation

Imperatives for RE Integration and Grid Operations

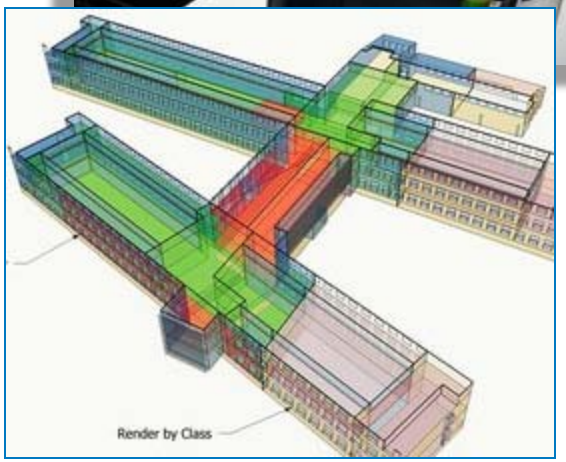
- **Solar**
  - Solar resource forecasting techniques
  - Advanced power electronics for grid interconnection
  - High penetration PV deployments
- **Wind**
  - Models and methods for wind-grid integration
  - Advanced wind forecasting techniques
  - Transmission and Operations modeling



- **Electricity System**
  - Smart grid architecture, standards, and interoperability
  - Smart grid modeling and testing
  - Storage optimization, control, and operation
  - Virtual utility operations for large-scale RE integration
  - Micro grid control and operations
  - Power electronics and controls

Imperatives for End-Use and Storage Integration

- **Buildings**
  - Whole building simulation and optimization
  - Sensors and controls development and integration
  - Building Integrated Photovoltaics (BIPV) design and utilization
  - Dynamic load integration and control
  - Electric and thermal storage
  - New material modeling and design
  - Code evaluation
- **Energy Storage**
  - Battery Technologies
  - Thermal Energy Storage



Imperatives for Fuel and Vehicle Integration

- **Advanced Fuels**
  - H2/electric interfaces/RE electrolyzers
  - Storage systems
  - Fuel cell integration
  - Fueling systems

- **Advanced Vehicles**
  - Plug-in-hybrids
  - Vehicle-to-grid and grid-to-vehicle
  - Battery thermal management
  - Power electronics

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
- System integration

Advanced Fuels

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

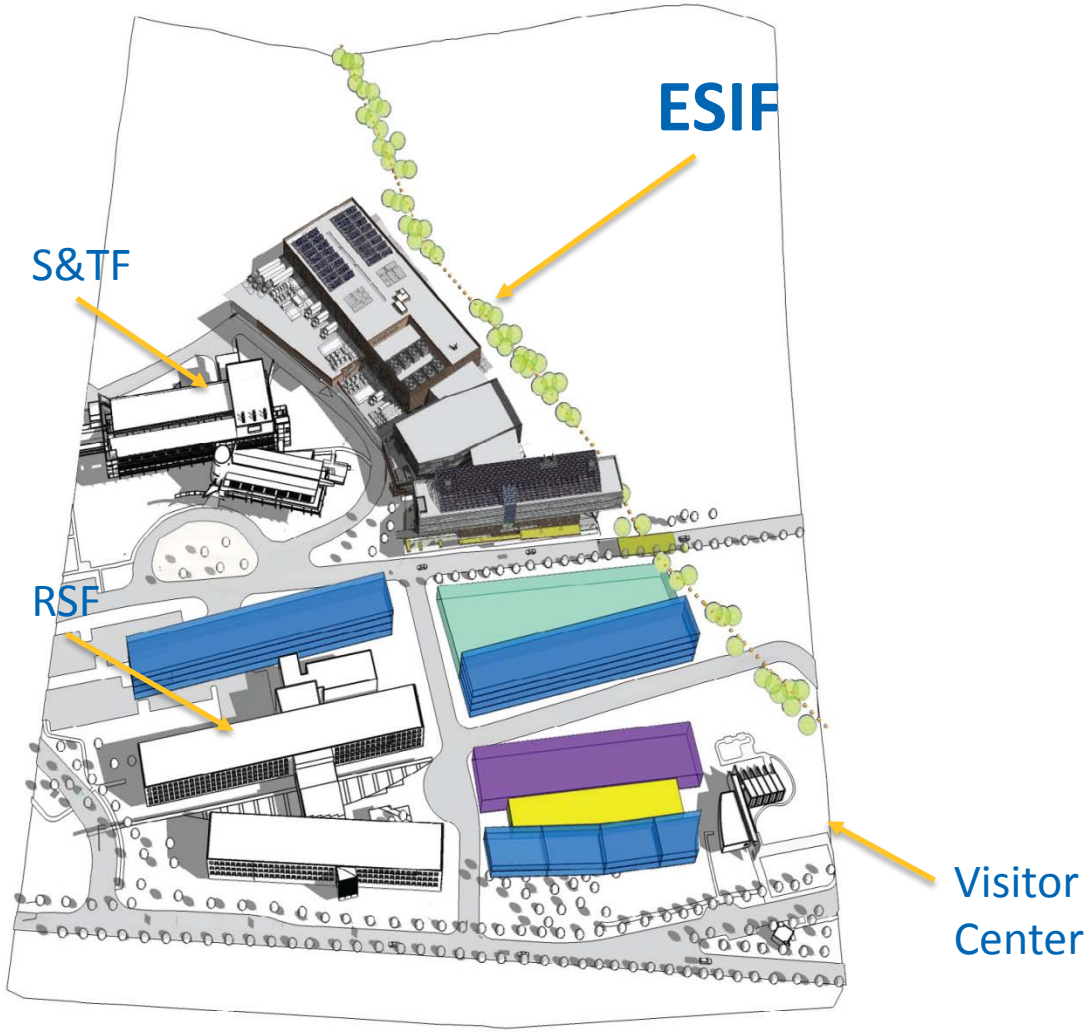
Advanced Vehicles

- 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

Energy Systems Integration Facility

The Energy Systems Integration Facility (ESIF) on the NREL campus will be able to conduct integrated megawatt-scale research and development of the components and strategies needed to safely move clean technologies into the energy infrastructure.



ESIF Snapshot

- Cost: $135M
- Square feet: 182,500
- Occupants: ~200
- High performance computer: one-half petaflop scale; planned to be expanded to petaflop
- State-of-the-art electric systems simulation and visualization

- Component and systems testing and at MW-scale power
- Integration of functioning systems with utility system simulations for real-time, real-power evaluation of high penetration scenarios
- Construction complete: Fall 2012