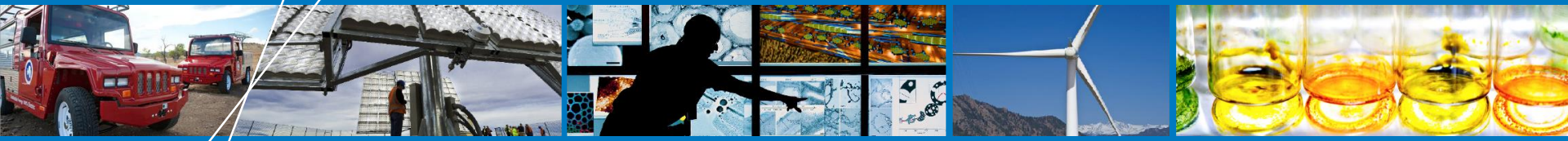
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

The Intelligent Grid: An Integrated Energy Systems Approach

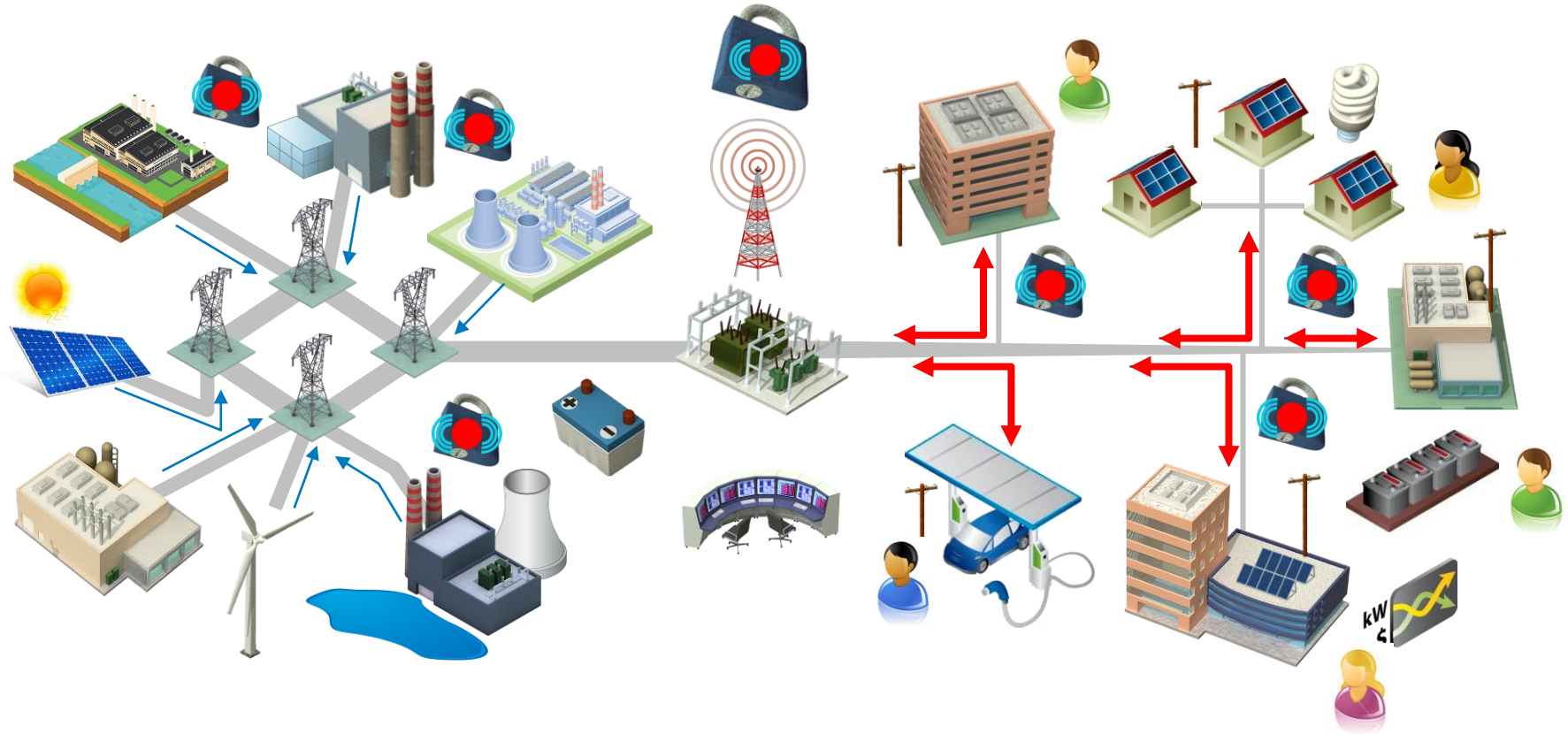


D. Arent

NCAC

April 2014

The Evolving Power System …



How Soon? How Fast? What Business Model(s)?

Figure: courtesy of B. Hannegan, EPRI

Grid Modernization Components

Emerging Technologies

Renewable Energy

Sustainable Transportation

Energy Efficiency

Scales and Challenges

Consumer

City

Regional

More Variable Supply and Demand

Limited Grid Flexibility

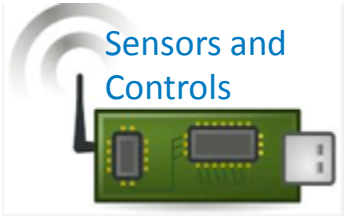
Aging Infrastructure

Vulnerability to Extreme Events

Challenges to Reliability

Increasing Costs

Solutions



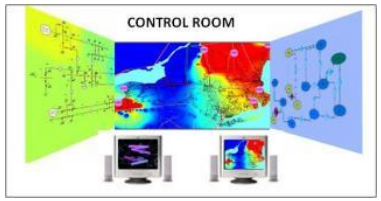
Sensors and Controls

Energy Storage

Interconnection

Interoperability

Analysis, Modeling and Simulation

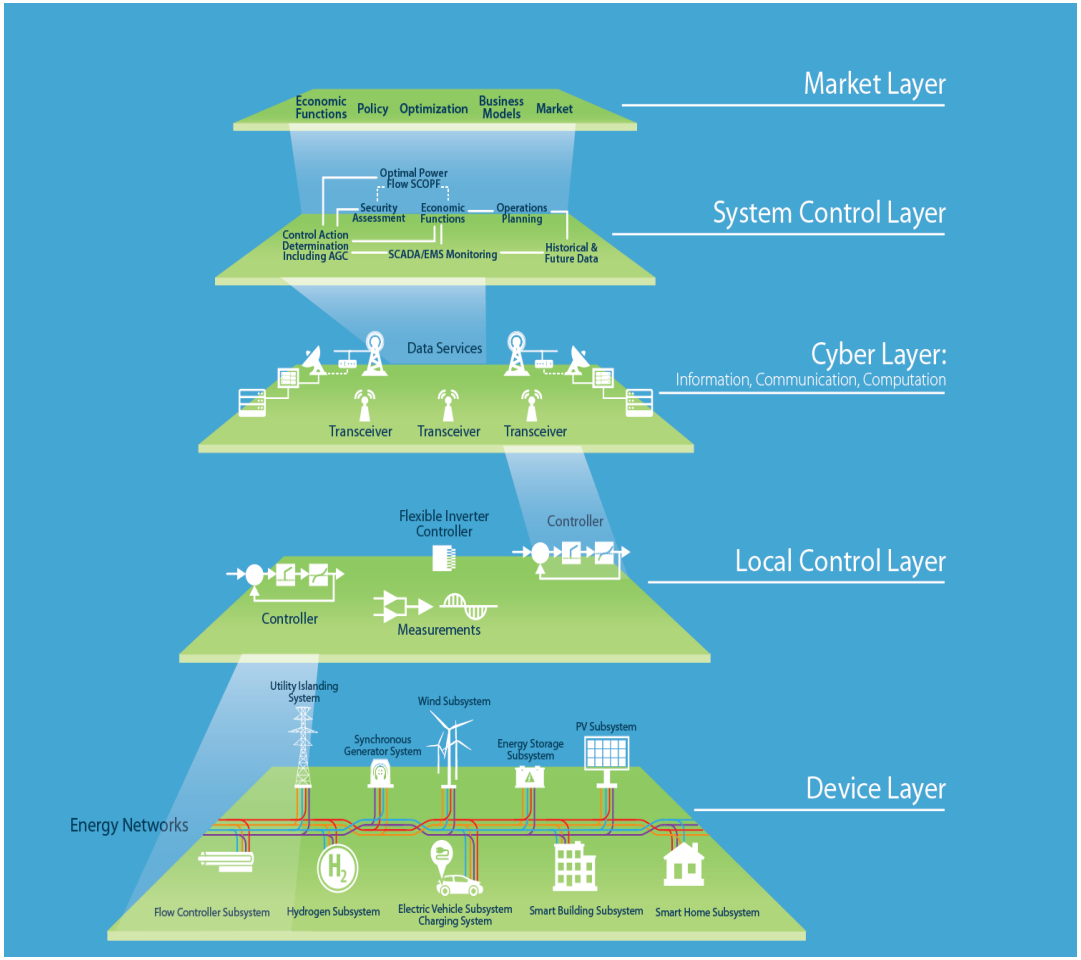


Markets and Business Models

Policy and Regulation

Energy Systems Integration: *New Concepts*

Layered Energy System Integration Capability (LESIC)



- **Market Layer**, responsible for addressing economic, optimization, regulatory, financial, and policy aspects of the system and its environment.
- **System Control Layer**, responsible for the system level concerns of security and reliability of a collection of connected devices interconnected to hosting infrastructures. This layer includes monitoring, system estimation, energy network security assessment, etc.
- **Cyber Layer**, including communications, information and computation platforms, necessary to support control applications at the system level.
- **Local Control Layer**, consisting of the electromechanical, electronic or software based modules necessary to control a single device (in the Device Layer) in a stand-alone manner.
- **Device Layer**, consisting of the physical energy devices that produce, consume, store or transport energy (e.g. high voltage wires, a wind turbine and generator, a battery, a pipe, the power elements of a transformer, a refrigerator motor, or a dishwasher).

Energy Systems Integration – The Facility

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

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

"This new facility will allow for an even stronger partnership with manufacturers, utilities and researchers to help integrate more clean, renewable energy into a smarter, more reliable and more resilient power grid." - Energy Secretary Ernest Moniz

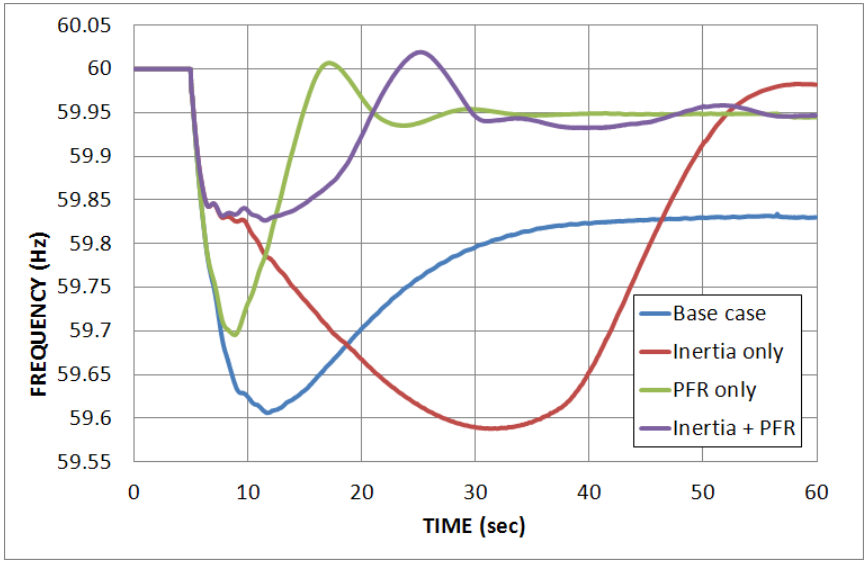
NREL NATIONAL RENEWABLE ENERGY LABORATORY | ENERGY SYSTEMS INTEGRATION FACILITY

U.S. DEPARTMENT OF ENERGY

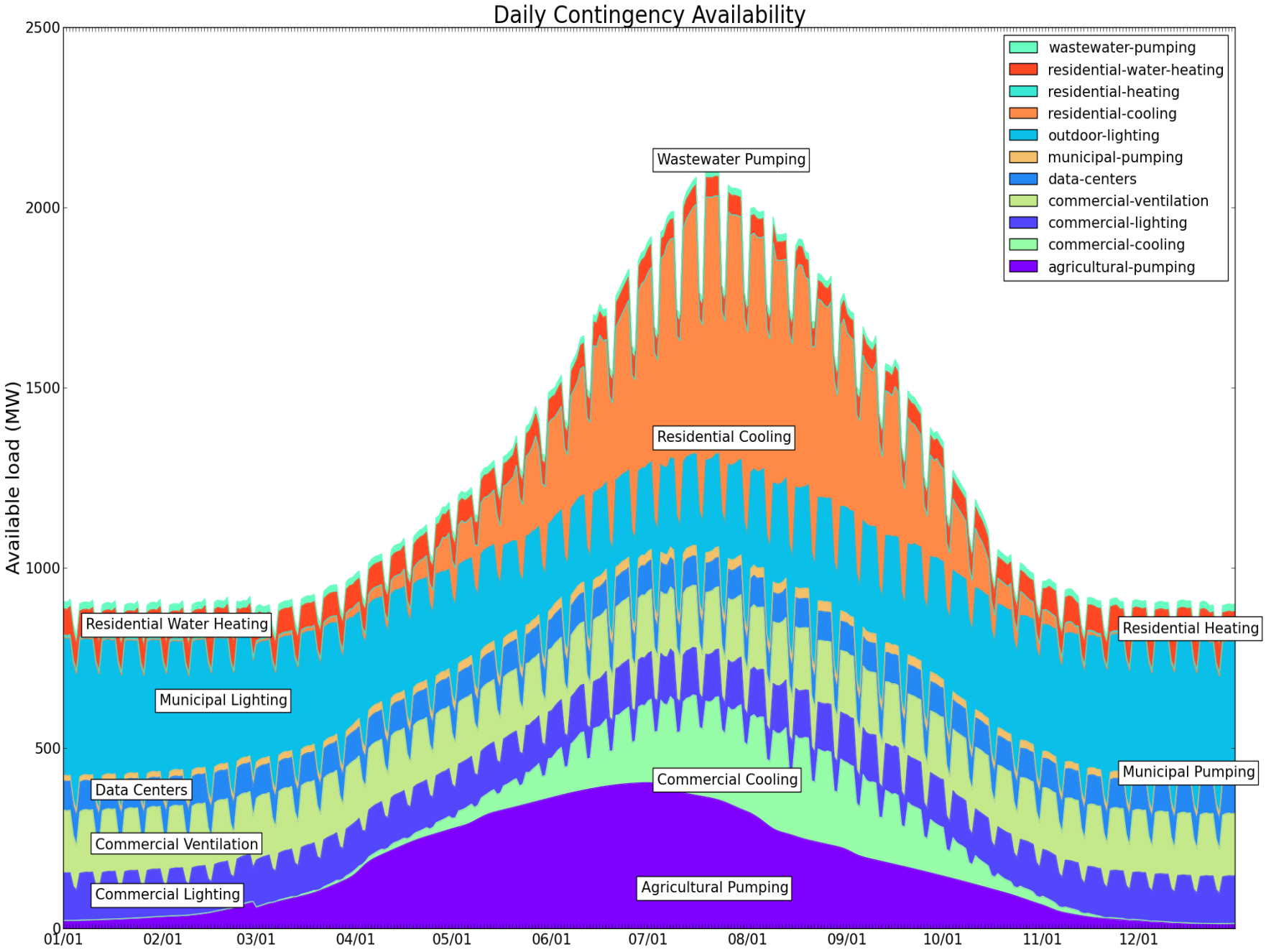
- NREL's largest R&D facility (182,500 ft^2/20,000 m^2)
- Space for ~200 NREL staff and research partners
- Petascale HPC and Data Center supports all research at NREL
- Labs focus on R&D of integrated energy systems
  - Electricity
  - Fuels
  - Transportation
  - Buildings & Campus
- Integrated electrical, thermal, fuel, and data infrastructure

Energy Systems Integration: *New Outcomes*

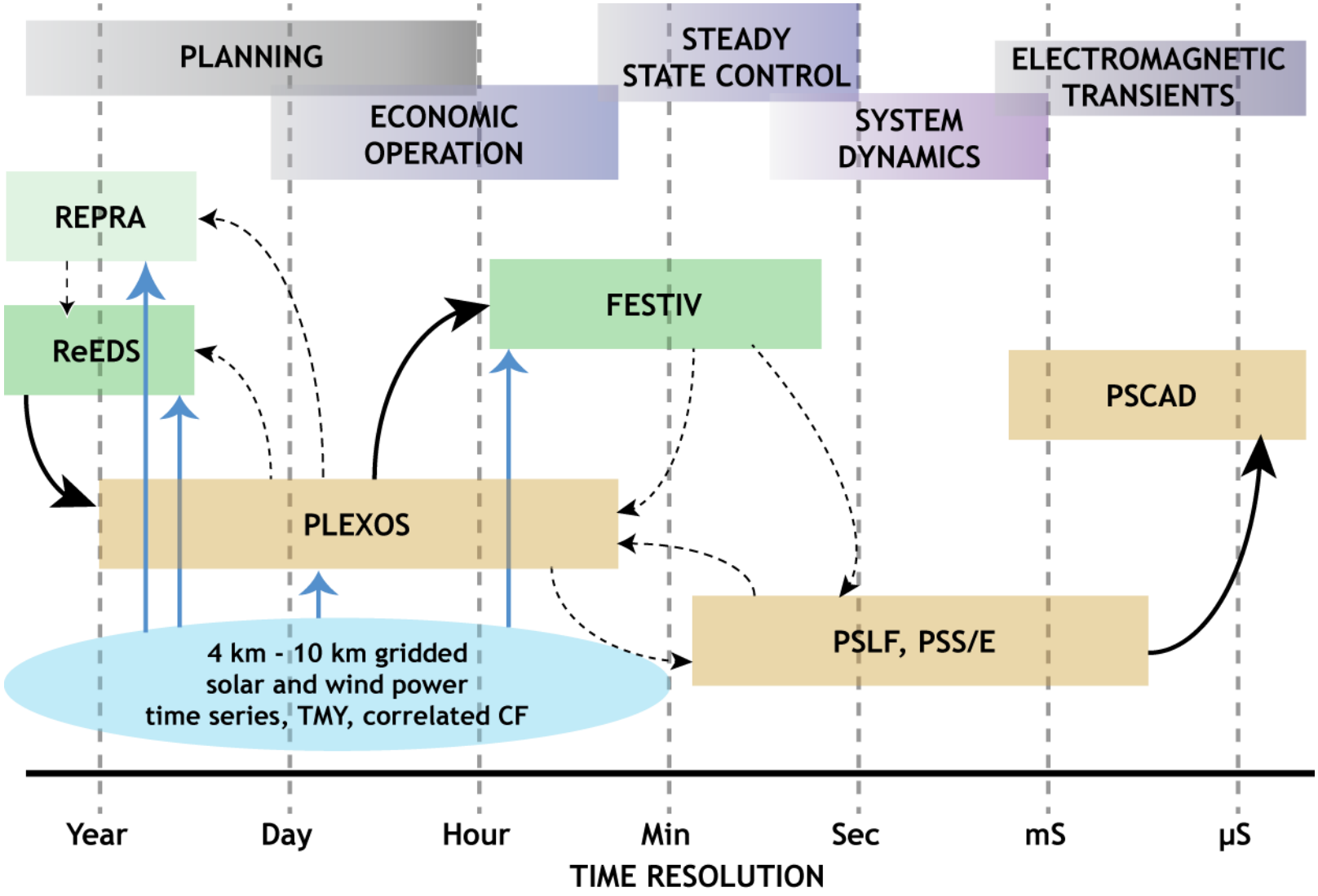
- **Active Power Controls for Wind**
  - Joint w/EPRI, Univ. of Colorado
  - Identified "tremendous promise" for dispatch of wind energy w/APC
  - Example: Primary Frequency Response (PFR) + Inertial Response for 50% Wind



- **HPC Data Center Energy Efficiency**
  - Joint w/Asetek, Aspen Systems, HP
  - Hot water, direct-to-chip, data center liquid cooling technology
  - Cooling savings > 50%
  - HPCwire Editors' Choice Award


Daily Contingency Availability
Available load (MW)
2500
2000
1500
1000
500
0
01/01
02/01
03/01
04/01
05/01
06/01
07/01
08/01
09/01
10/01
11/01
12/01
wastewater-pumping
residential-water-heating
residential-heating
residential-cooling
outdoor-lighting
municipal-pumping
data-centers
commercial-ventilation
commercial-lighting
commercial-cooling
agricultural-pumping
Wastewater Pumping
Residential Cooling
Residential Water Heating
Residential Heating
Municipal Lighting
Municipal Pumping
Data Centers
Commercial Cooling
Commercial Ventilation
Commercial Lighting
Agricultural Pumping

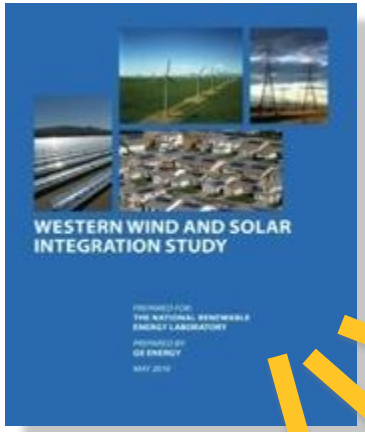
NREL models designed for different timescales



The Future - Energy System Planning and Operations

A Flight Simulator for Energy System Operators

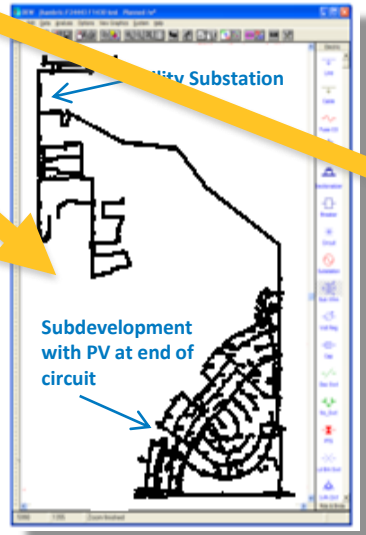
"connecting integration studies to operations"



Operations techniques development for:

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

Transmission



Distribution

Campus Energy Dashboard