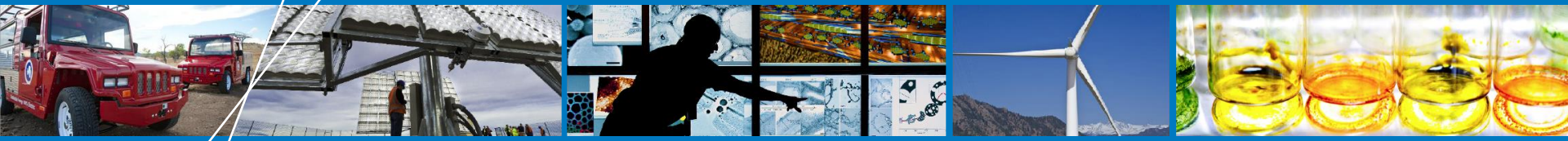
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

U.S. Perspectives on Energy Systems Integration



iiESI European Workshop (DTU) 2014

May 27, 2014

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Science & Technology
National Renewable Energy Laboratory

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Energy Market Dynamics

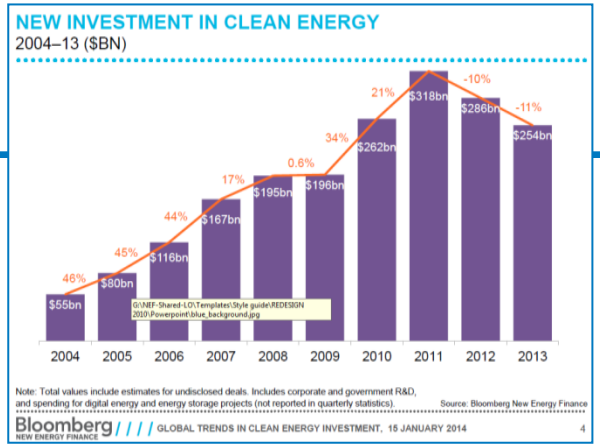
Global renewable industry growing, but facing challenges

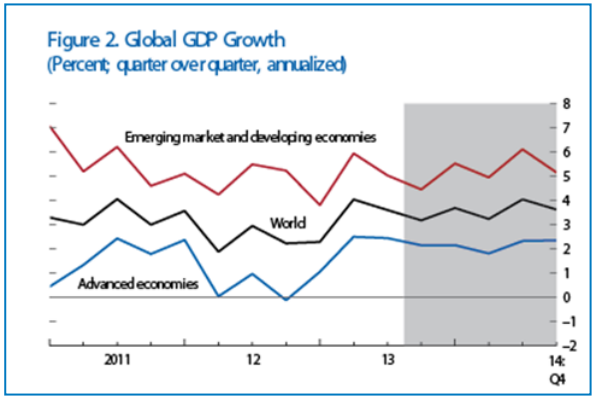
Public policy evolving

Effects of Great Recession still evident

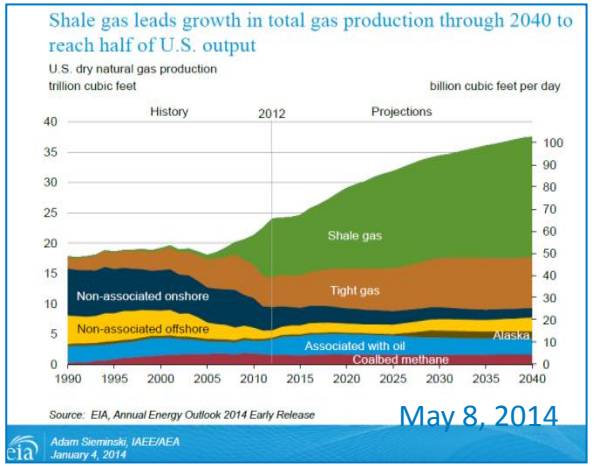
Shale gas a growing focus in U.S. and elsewhere

Infrastructure investments will be made, focus on flexibility





http://www.imf.org/external/pubs/ft/weo/2014/update/01/index.htm



May 8, 2014

Why Grid Modernization?

The existing electrical grid has served us well…

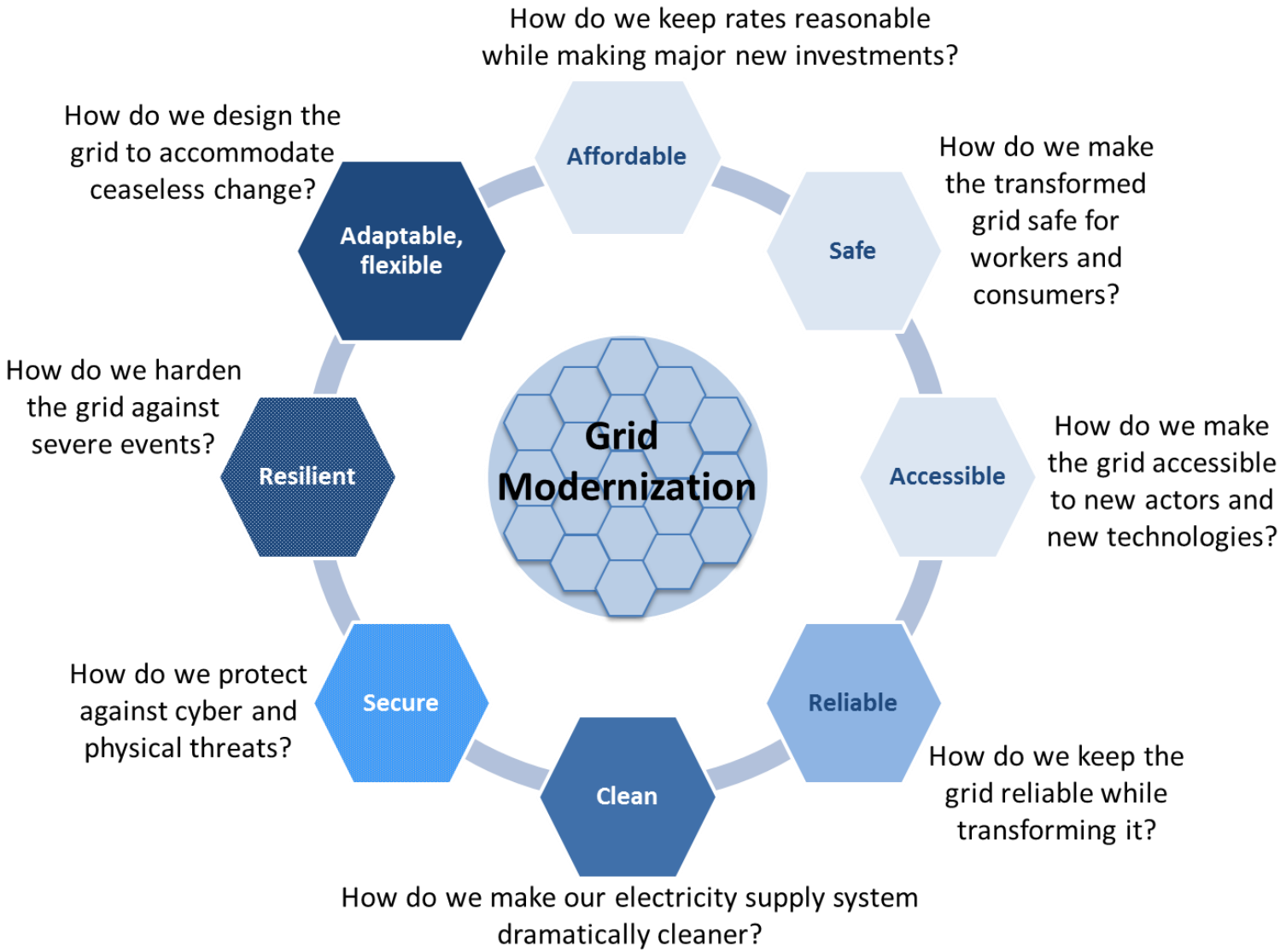
but a clean energy future needs a modernized grid.

National Renewable Energy Laboratory Snapshot

Dedicated Solely to Advancing Energy Efficiency and Renewable Energy Research toward Enabling Deployment onto a Modernized Grid

- Physical Assets Owned by the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
- Operated by the Alliance for Sustainable Energy under Contract to DOE
- 2400 staff and world-class facilities
- More than 350 active partnerships annually
- Campus is a living model of sustainable energy

Key Aspects of Grid Modernization

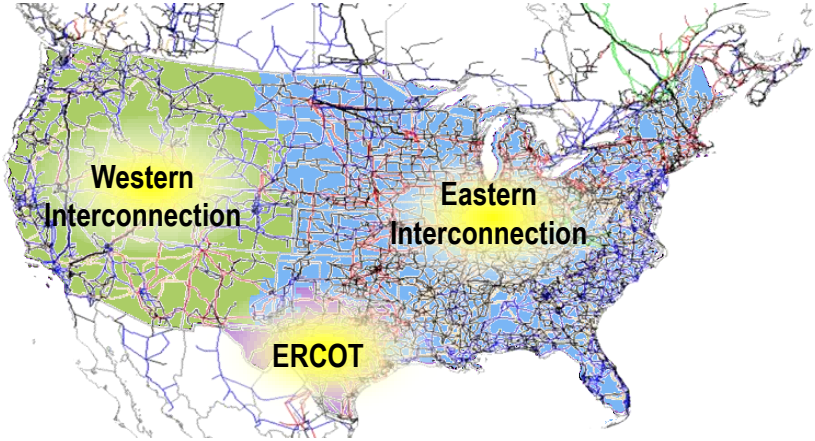


U.S. DOE Grid Modernization Initiative

Grid Modernization

- **Architecture and System Control**
- **Design and Planning Tools**
- **Sensing and Measurements**
- **Devices and Integrated System Testing**

Institutional Support and Regional Partnerships



Challenges

- Aging infrastructure
- Increased asset stress
- Fuel mix changes
- Increase variability and uncertainty
- More information and potential control points

Goals

- Maintain reliability, safety, affordability
- Increase security and resilience
- Double installed renewables by 2020
- 80% clean electricity by 2035

NREL's Energy Systems Integration Facility (ESIF)

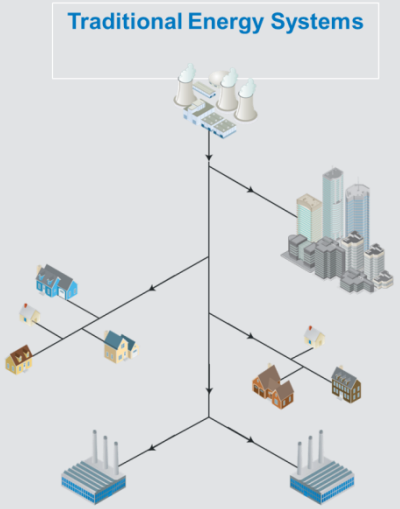
- Focus is to conduct R&D of integrated energy systems (electricity, fuels, transportation, and buildings and campus systems)
  - Grid integration / battery lifetime impacts
  - Hydrogen production and fueling; fuel cell R&D
  - Integration of vehicles (electric drive, fuel cells) with renewable electricity generation

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

www.nrel.gov/eis/facilities_esif.html

innovation

Electricity System Innovations

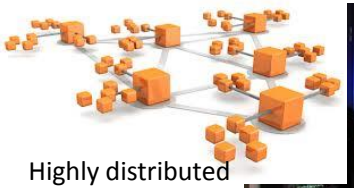


"Plug and Play Components"

Advanced Inverter

Hybrid Systems

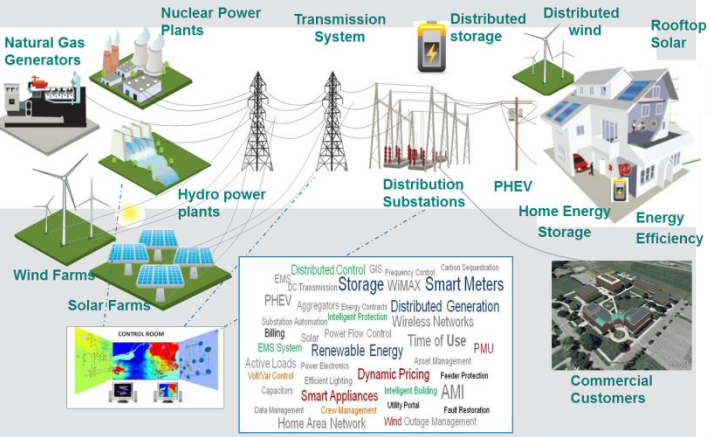
Dynamic Simulation Models



Highly distributed generation & distribution models

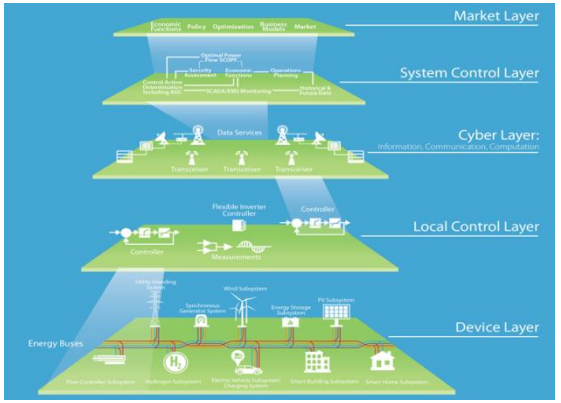
Resource Forecasting

Improvements in design tools and operational tools

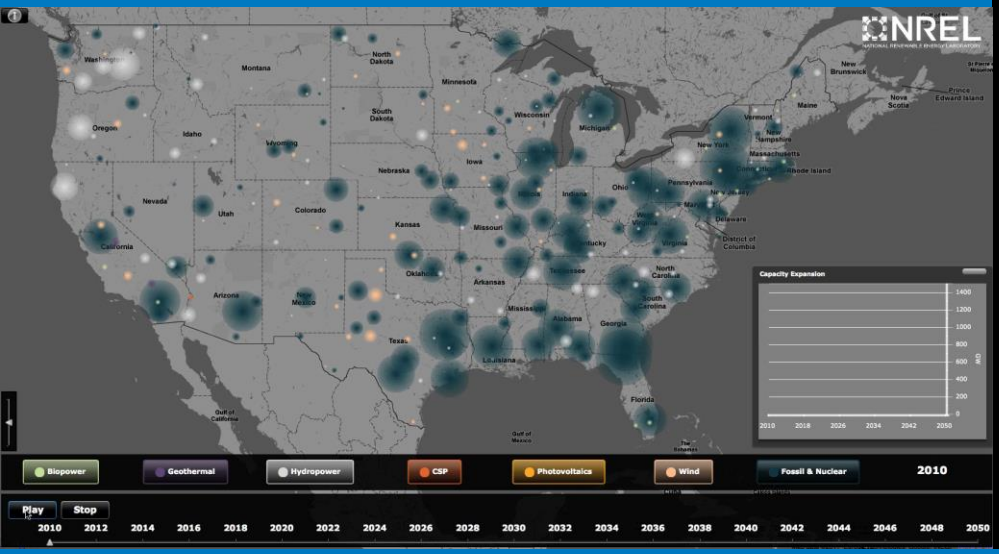


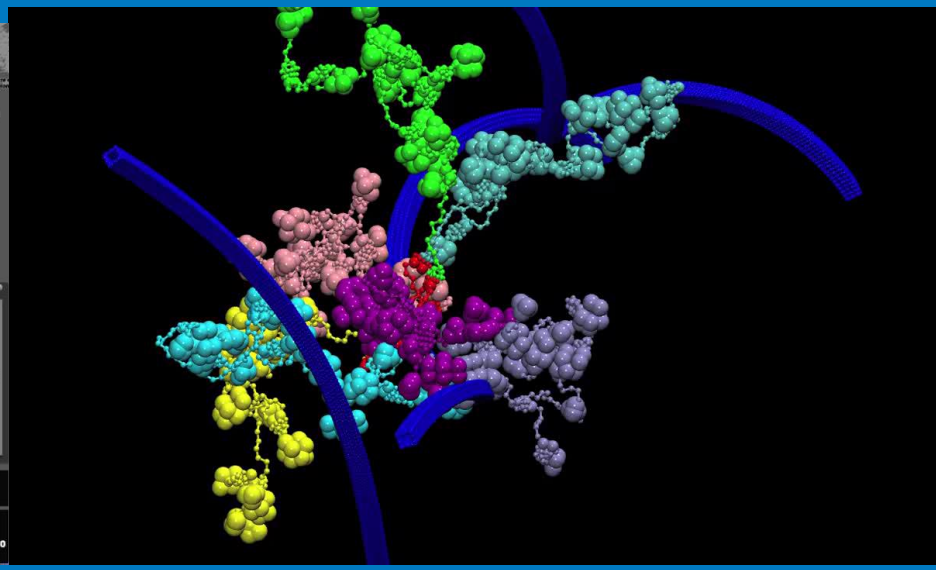
" Big Data" Integration and Visualization

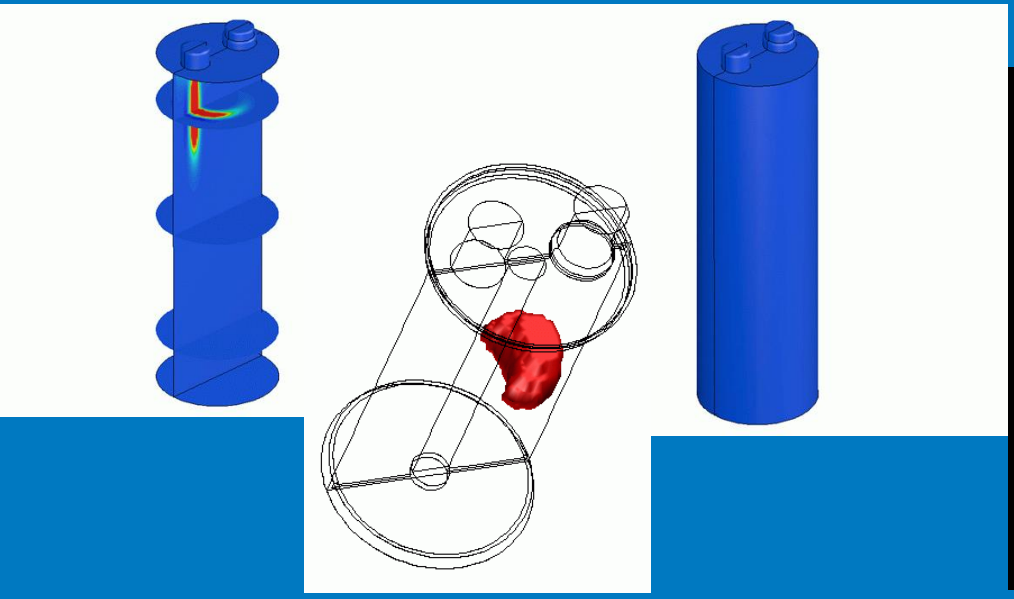
Communication and Control Architectures



Applying High Performance Computing to Solve Vexing Challenges







Computational Modeling of Turbine Wake Effects

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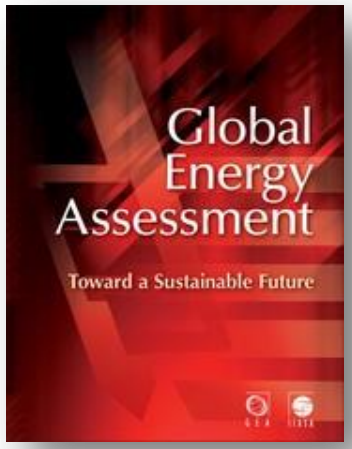
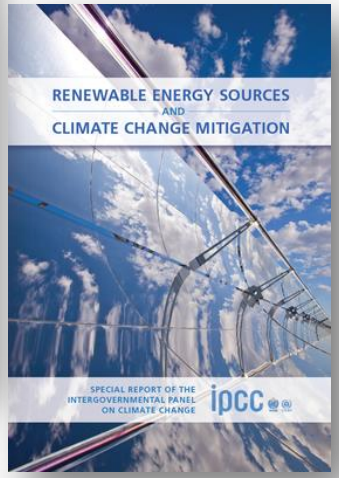
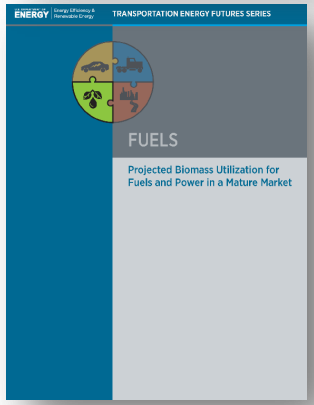
High Performance Computing

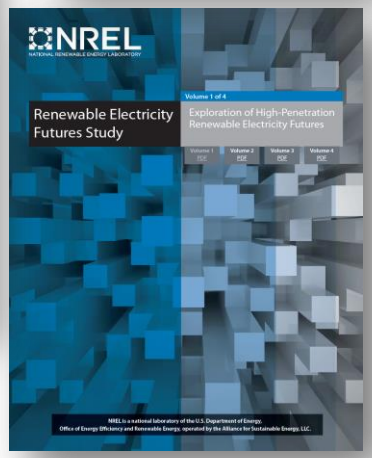
- "Peregrine" HPC - 1.2 Petaflops
- Put into production use Jan 1, 2014
- Over 90% utilized to date
- Already 3x over-subscribed for FY14
- Supports numerous DOE program milestones in Wind, Solar, and Bioenergy
- Most Energy Efficient HPC in the World.

Comprehensive Studies Validate Opportunity







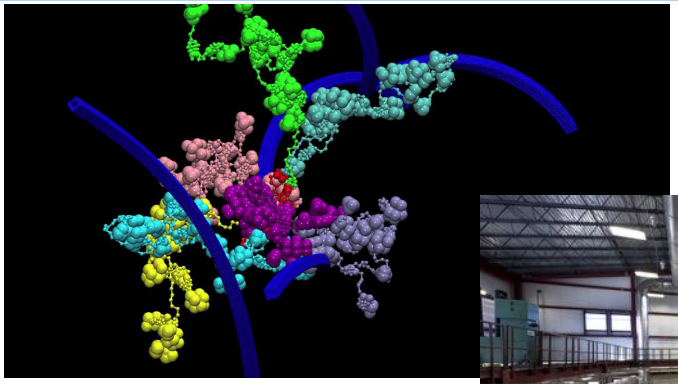


Dialogue Shifts from "Can it be done" to "How to do it"

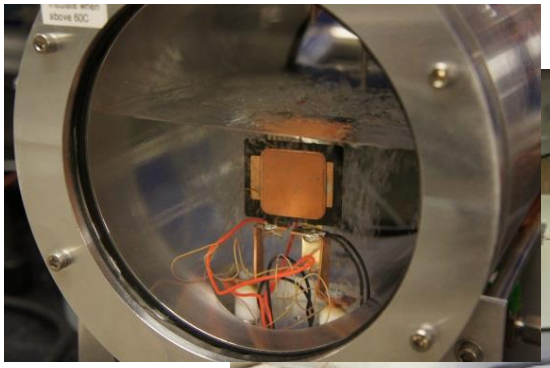
The New Frontiers: Integration and Scale

- Integration of high-penetration renewables requires enhanced system-wide flexibility and new operating paradigm
  - Variable supply and variable load
  - Increased distributed resources
  - Enhanced energy imbalance market cooperation
  - Changing roles of consumers, utilities, investors, independent power providers, technology vendors, and regulators
- Regional considerations will continue to drive progress
- Production scale and supply chain critically important to lower manufacturing costs
- Investment in technology R&D is critical
  - Better monitoring and measurements
  - Advanced analytics processing and control
  - Demand-shifting and load profile shaping techniques
  - Two way power flow control electronics

Sustainable Mobility



Advanced Fuels – Biofuels and Hydrogen



Vehicle Electrification

Timing: Deployment of Connected and Automated Vehicles

Today

Image by NREL

Safety Benefits

Appealing consumer amenities commercially available now

- Collision aversion
- Park assist
- Limited drive-cycle smoothing
- GPS route mapping

Near-Term

Image courtesy of Ford

Fuel Economy Benefits

Additional amenities + savings Low barriers to deployment

- Efficient driving route selection
- Improved drive-cycle smoothing
- Traffic signal timing coordination
- Vehicle “platooning”
- Parking space location
- Stationary wireless power transfer
- Charging station location

Long-Term

Image Courtesy of GM

System-Wide Benefits

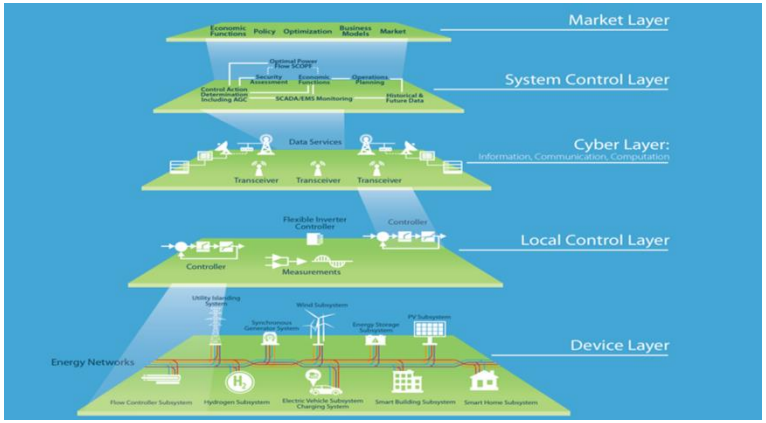
Dramatic innovations Deployment challenges

- Fully automated hands-free driving
- Automated vehicle “valet” parking and retrieval
- In-motion wireless power transfer

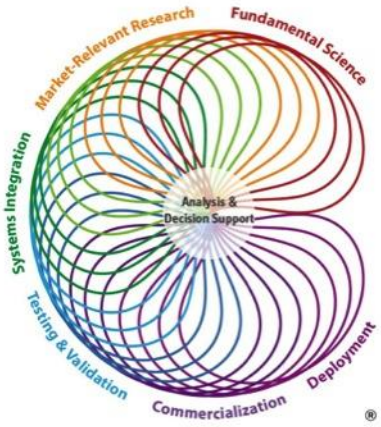
Moving Forward: Opportunities

Technologies

- Globally, more efficient transportation alone can realize projected savings of $70 trillion over the next 40 years[1].
- Next-generation technology solutions can reduce total energy consumption in all sectors and provide more choices to consumers. They can also have unintended consequences if not identified early on.
- Substantial RD&D is needed to meet the President's goal of reducing oil use by 1/3 by 2025.
- Analysis at all levels is needed.



Partnerships



The National Labs can serve as a resource to

- Leverage existing technology work portfolios and partnerships
- Provide access to world-class test facilities and capabilities
- Serve as a third-party for technology validation, market acceptance, analysis, and data dissemination
- Provide systems-level energy analysis

1. International Energy Agency: *A Tale of Renewed Cities*. July 2013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