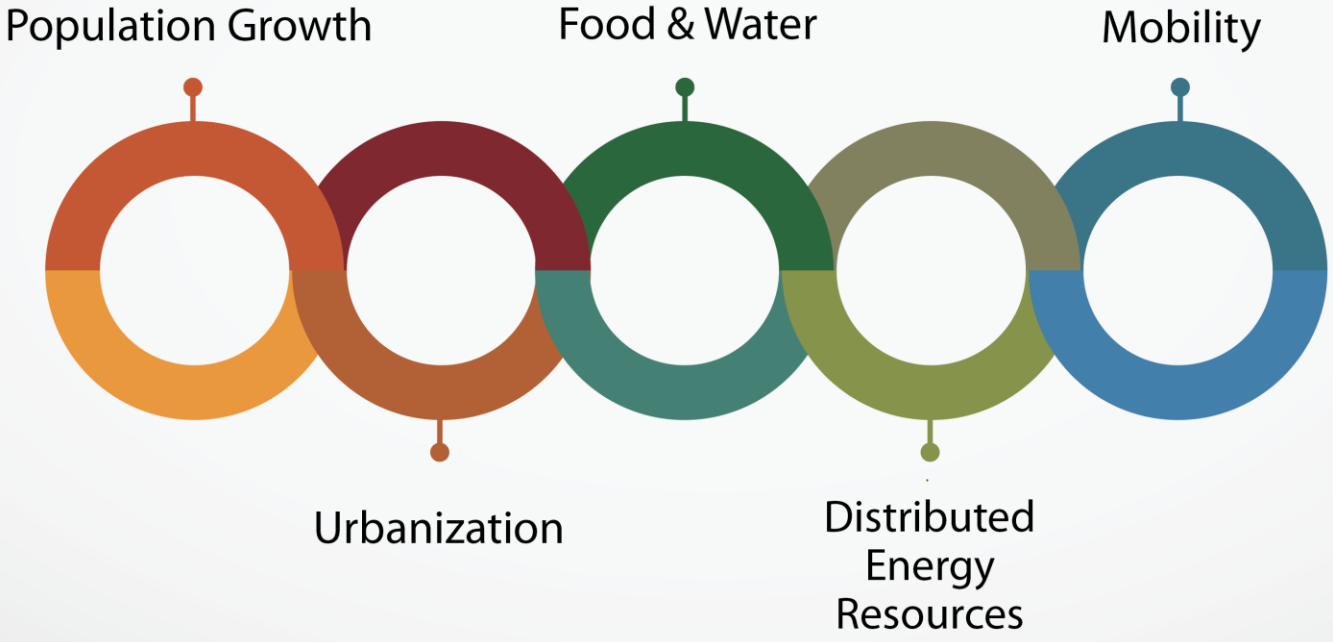
NREL: *Transforming Energy through Innovation*

Dr. Martin Keller, Director

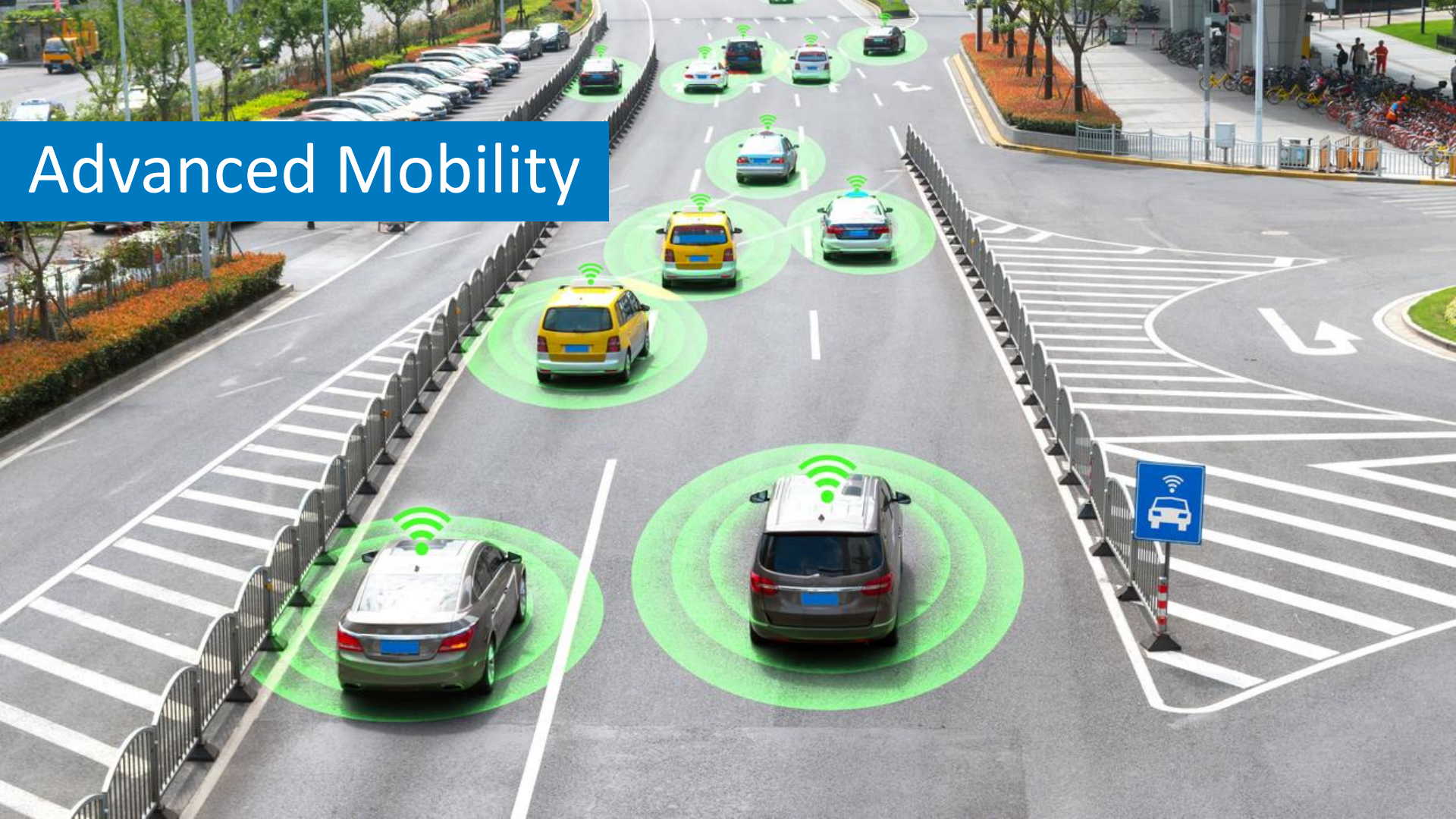
May 30, 2019

Mega Trends


Population Growth
Food & Water
Mobility
Urbanization
Distributed
Energy
Resources

Population Growth

Urbanization


Advanced Mobility

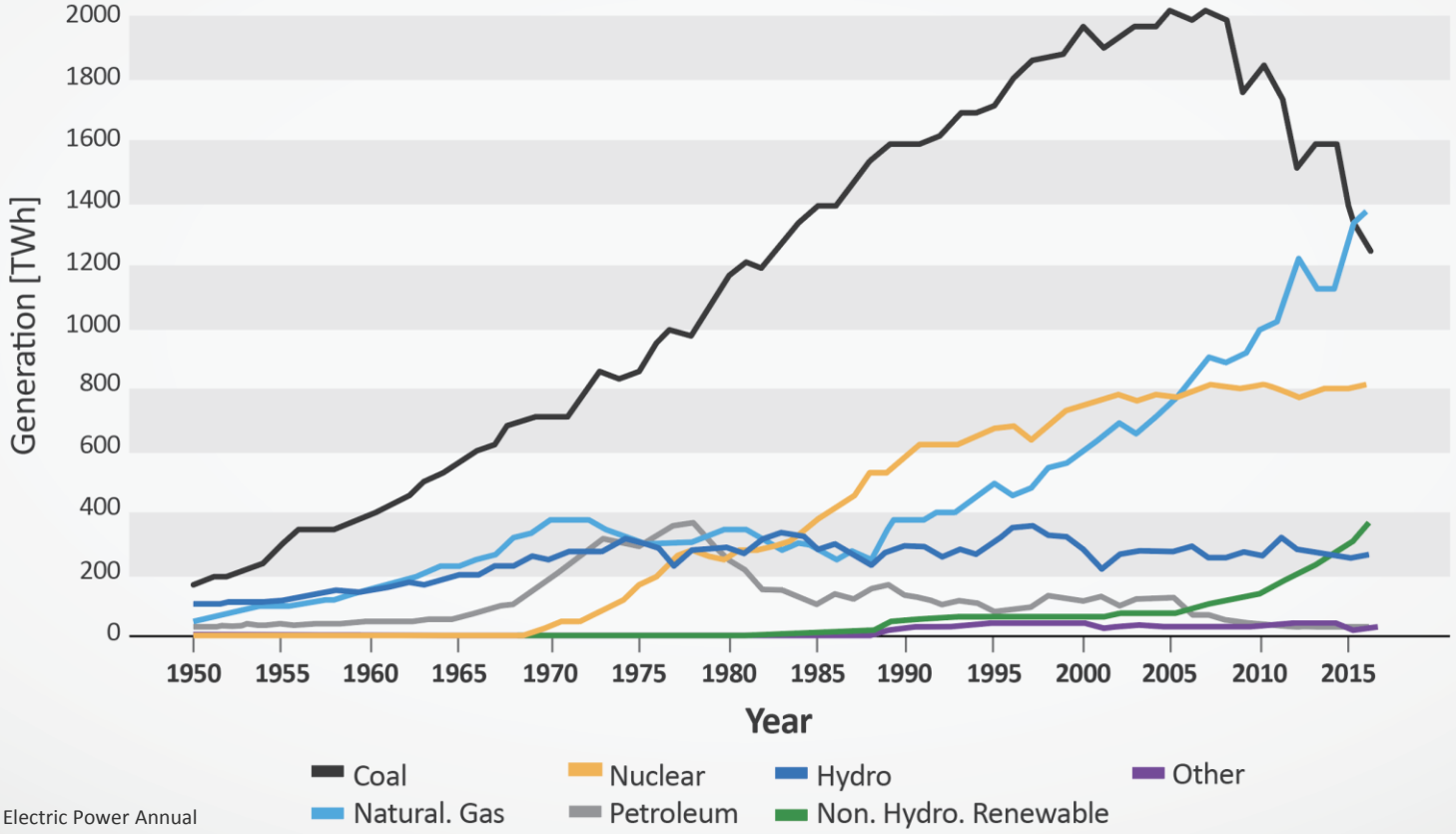
Environmental Scan: Observations Toward 2040

Assumptions that Guided NREL's Strategy Formulation:

- Growth of energy use in the developing world will far outpace growth elsewhere.
- Global renewable power demand will grow.
- Urbanization trends will dominate new infrastructure growth.
- Electrification and electric vehicle adoption will grow strongly.
- Demand for high-density liquid fuels will grow.
- Digitization, data, decentralization will be strong drivers of energy transition.

Ongoing Transformation of the Energy Supply in the United States

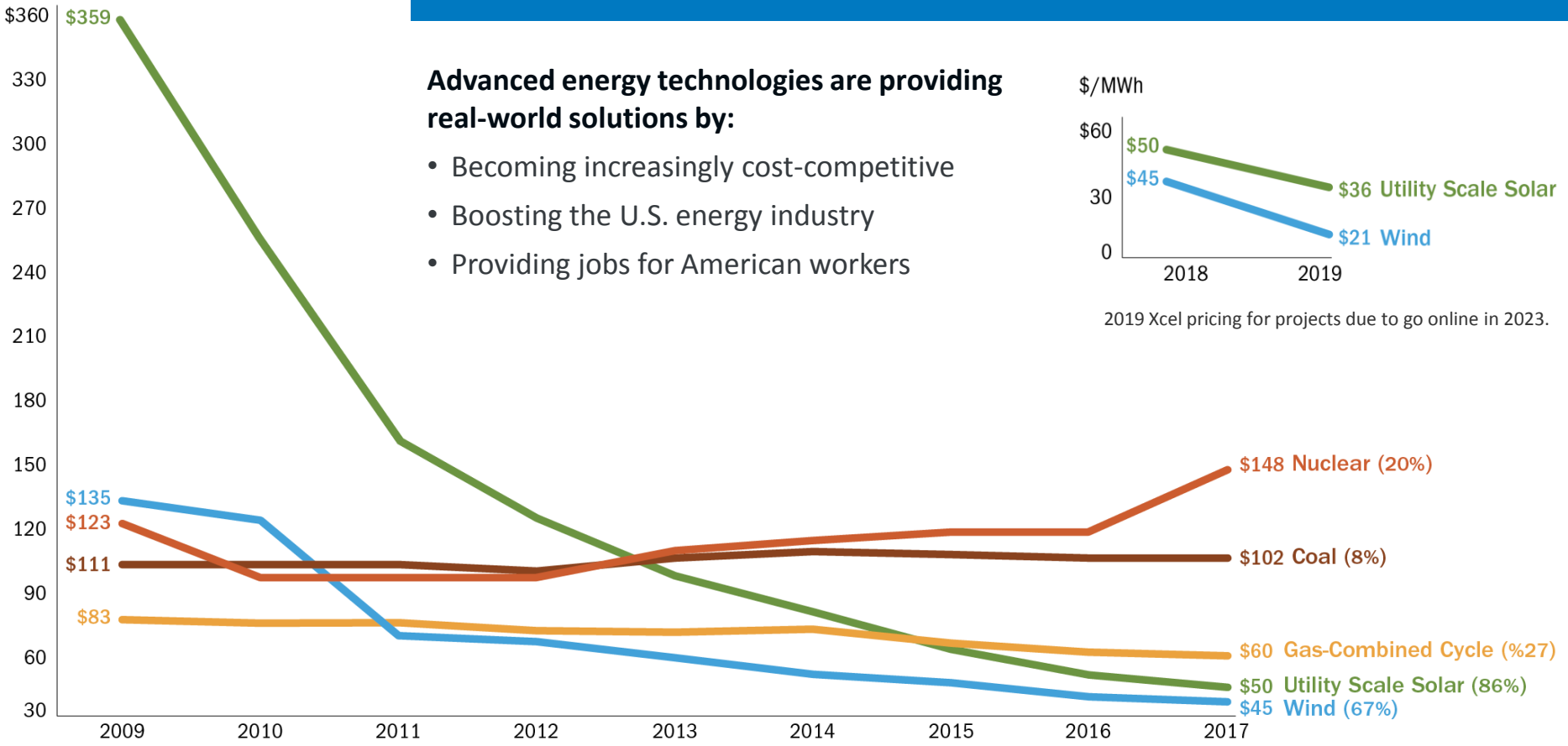
U.S. Power System Massive Transition



Source: EIA – Electric Power Annual

Costs for Renewables are Falling

Mean LCOE
$/MWh



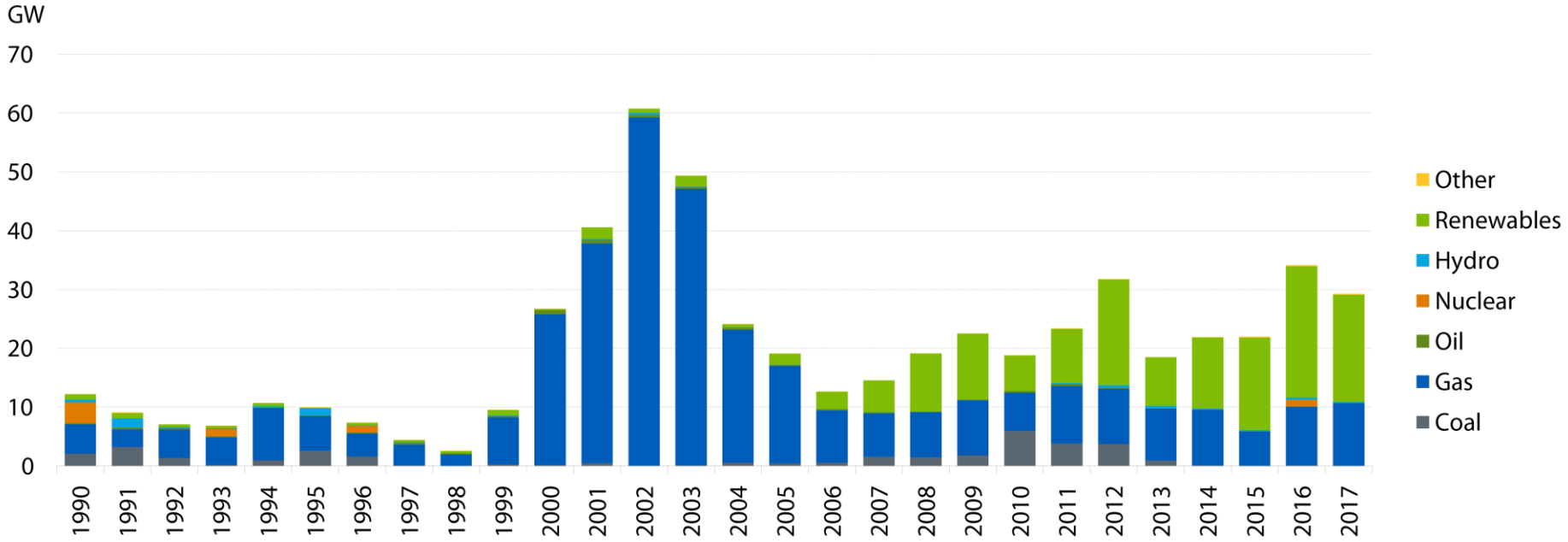
Advanced energy technologies are providing real-world solutions by:

- Becoming increasingly cost-competitive
- Boosting the U.S. energy industry
- Providing jobs for American workers

2019 Xcel pricing for projects due to go online in 2023.

Source: *Lazard's 2017 Levelized Cost of Energy Analysis,* Version 11, 2 November 2017

U.S. Energy Capacity by Fuel Type



Source: *2017 Sustainable Energy in America Factbook*, Bloomberg New Energy Finance and the Business Council for Sustainable Energy, February 2018

NREL at a Glance

2,050

Employees,
Plus more than
400
early-career researchers and visiting scientists

World-Class
facilities, renowned technology experts

817

Partnerships
with industry, academia, and government

Campus
operates as a living laboratory

$1.1 billion annually

National Economic Impact

NREL Science Drives Innovation

Renewable Power

Solar

Wind

Water

Geothermal

Sustainable Transportation

Bioenergy

Vehicle Technologies

Hydrogen

Energy Efficiency

Buildings

Advanced Manufacturing

Government Energy Management

Energy Systems Integration

High-Performance Computing

Data and Visualizations

Solar Research

From 2008 - 2018, solar experienced an average annual growth rate of 59%. Solar is growing extraordinarily fast. In the United States, records show that there were 1 million installations in 2016 and 2 million by 2018.

Research Achievements

- Demonstrated that perovskite solar cells can be made stable for thousands of hours and were able to demonstrate cells at a 23% conversion efficiency.
- Reached a 25.3% efficiency single-junction gallium arsenide cell using a new process that is substantially cheaper and may reduce costs from $300 a watt to 20 – 80 cents a watt.
- Both of these research achievements are potential gamechangers for the solar cell industry.

Wind

U.S. wind power rose to 275 million MWh in 2018. Wind now accounts for 6.5% of total U.S. electricity generation, making it the third largest source of generation. Plus, average costs for wind turbines have decreased from $1600/kW in 2008 to $750/kW.

Research Achievements

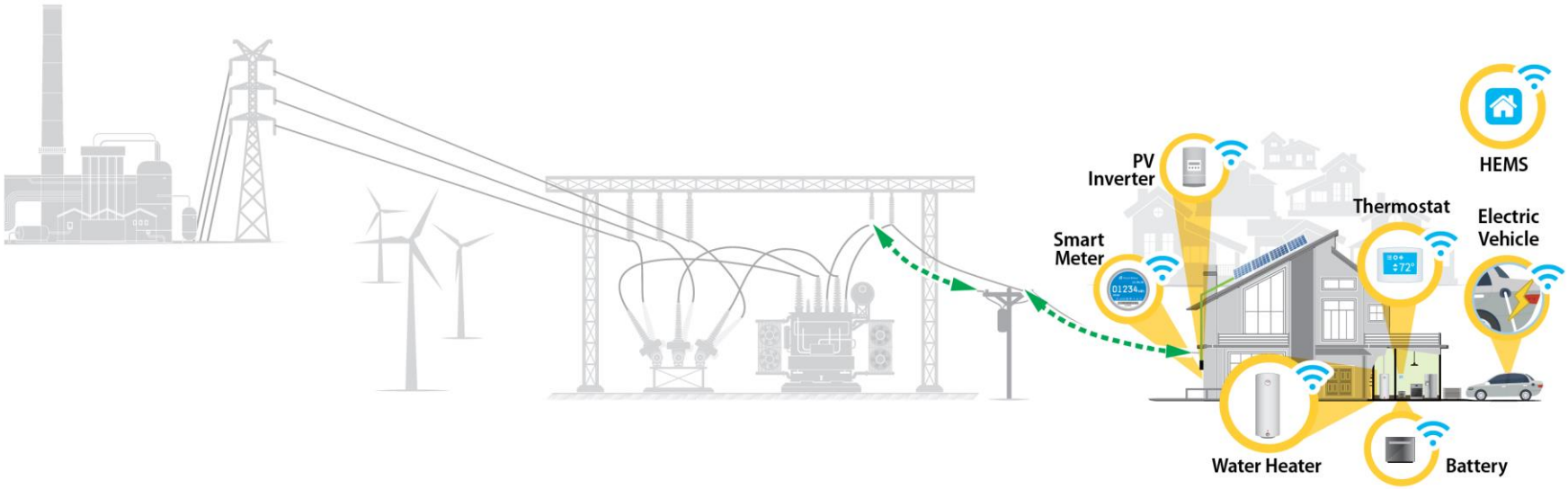
- Wind Plant Integrated System Design and Engineering Model (WISDEM), a software for the design and optimization of wind energy systems, is demonstrating that steering a turbine rotor to redirect its wake optimization at the plant level may increase U.S. wind power capacity by 2.5 GW.
- Gearbox Condition Monitoring Improvements have the potential to reduce costs for wind plant owners and operators by improving gearbox reliability.
- Partnership with the U.S. Geological Survey will help mitigate the impact of wind energy on wildlife.

Energy Systems Integration Facility

Research Focus Areas

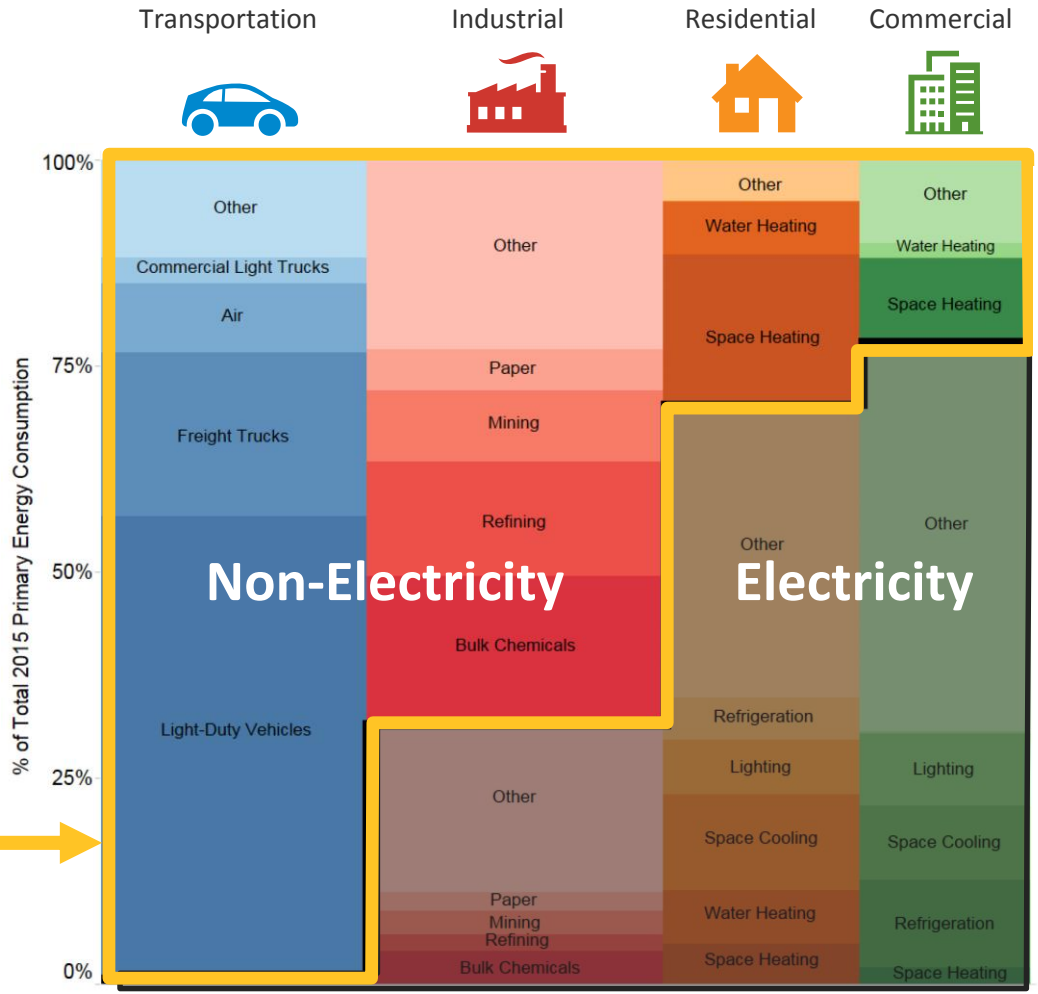
- Renewable electricity to grid integration
- Vehicle-to-grid integration
- Renewable fuels-to-grid integration
- Battery and thermal energy storage
- Microgrids
- Large-scale numerical simulation
- Cybersecurity and resilience
- Smart home and building systems
- Energy-water nexus
- High-performance computing, analytics, and visualization

How We Use Electricity is Changing



Scenarios of Electrification of the U.S. Economy

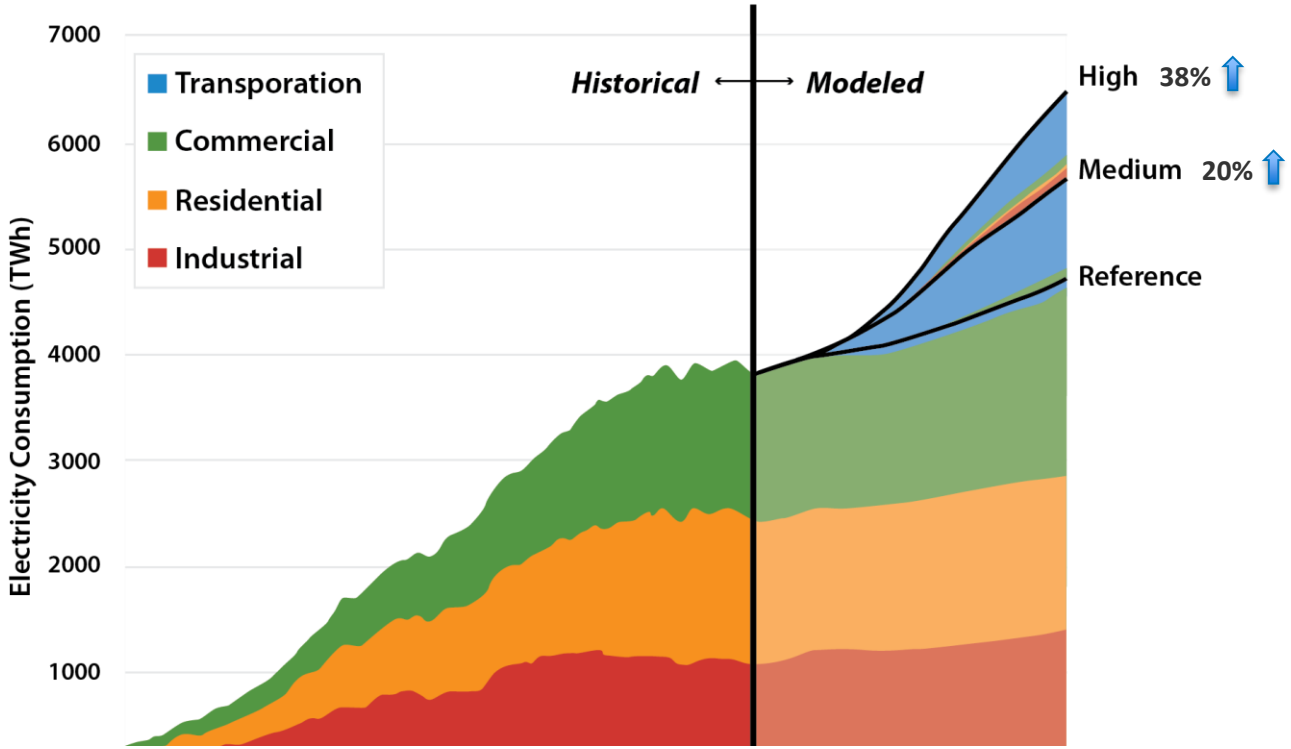
Several energy system transformation scenarios assume a great degree of future electrification, especially for transportation.



Source: https://www.nrel.gov/analysis/electrification-futures.html

Electricity Consumption 1950–2050

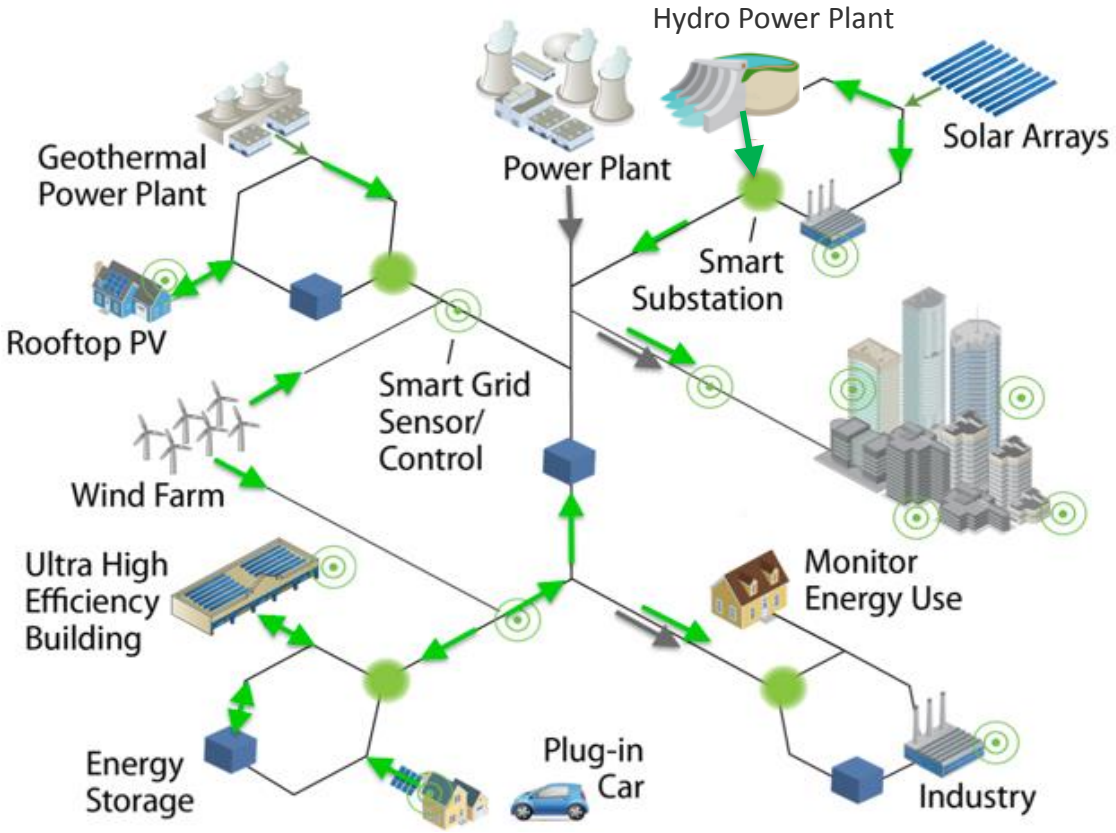
Historical and Projected Annual Electricity Consumption



Moderate technology advancements are shown. Slight adjustments were made to the modeled industry consumption estimates for 2017 – 2020 to align them with available historical data.

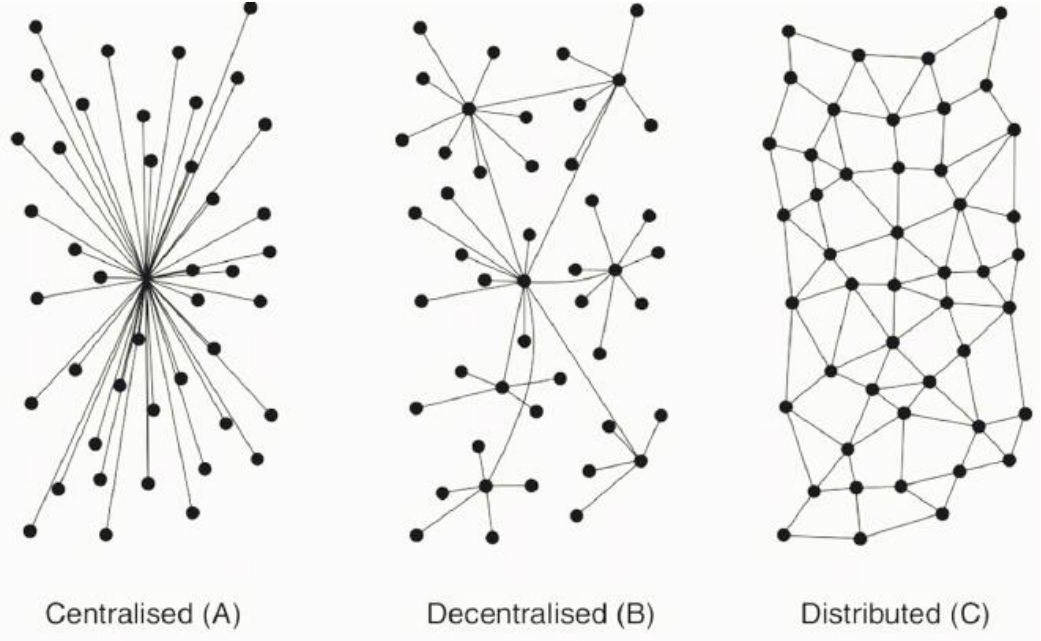
Source: Electrification Futures Study, *NREL*, 2018

Future Energy System



- The future energy system will integrate all types of energy systems and be more complex, distributed, and interdependent.
- If designed properly, it will also be more efficient, resilient, and affordable.

New Controls that are Distributed, Scalable, and Operate in Real-Time are Needed



Not only are the technologies changing, but the device system controls will also need to change.

Power electronics devices allow more controllability.

We are moving from a system that centrally controls 10^4 devices at the largest scale to a system that will have 10^8 controllable devices.

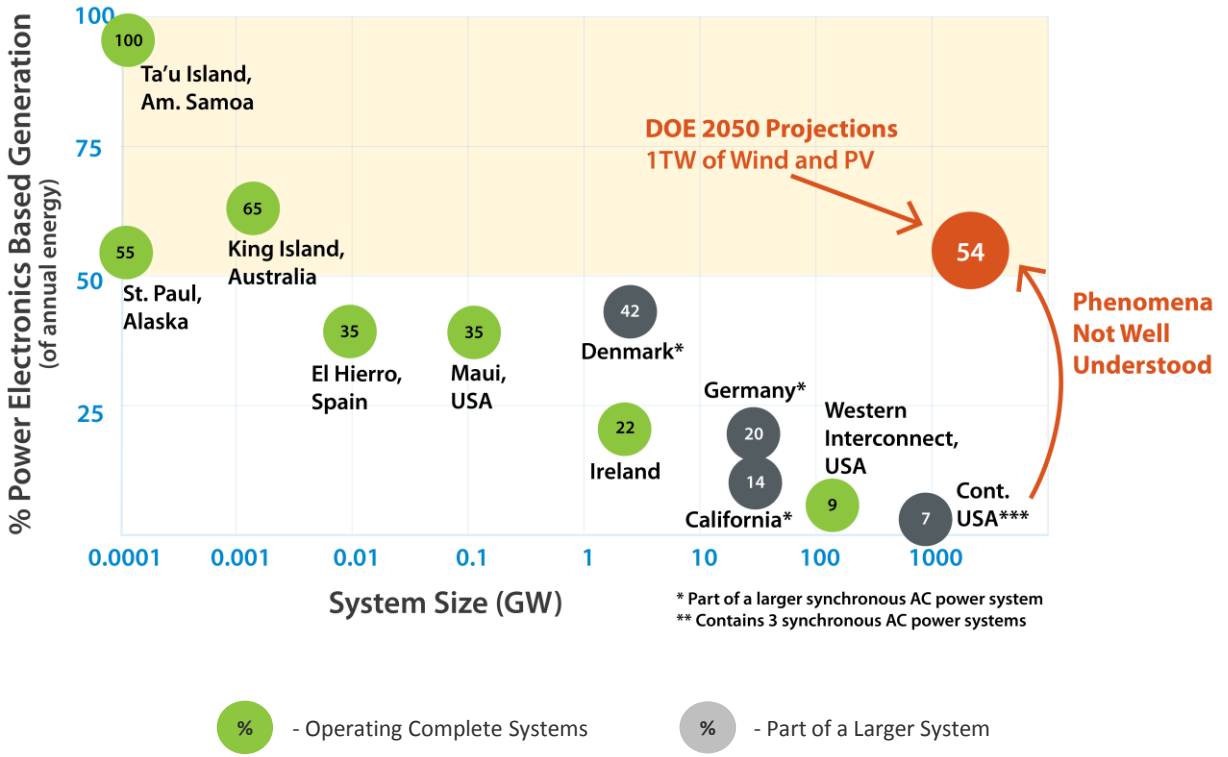
Power Electronics-Based Energy System

Generation
- Solar PV, wind, microturbines, fuel cells use power electronics (PE) interfaces to connect to the grid
- Over 50% PE generation by 2050
- Other bulk source work synergistically

Storage
- Batteries use PE interfaces to connect to the grid
- Pumped hydro can add PE to increase controllability and provide grid services

Building Loads
- Over 60% of major home appliances expected to be PE-based by 2021
- Lighting switching to LEDs
- Variable speed drives for motors

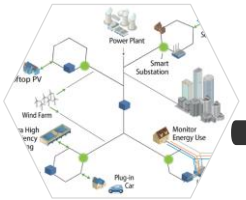
Mobility
- EVs – 7 million by 2025
- MD/HD – Electrifying



Creating Autonomous Energy Systems

Applications

Power Grids



Transportation

Buildings

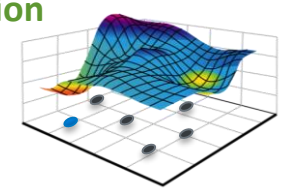
Wind Plants

Common Problems:

- Real-time controls and optimization
- Hundreds to millions of control points
- Asynchronous data and communications
- Multi-domain systems (complex) and stochastic systems (variable renewables, consumer/occupant behavior)

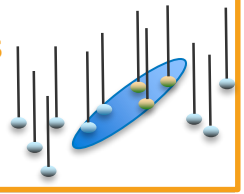
Nonlinear Control

Optimization



Complex Systems

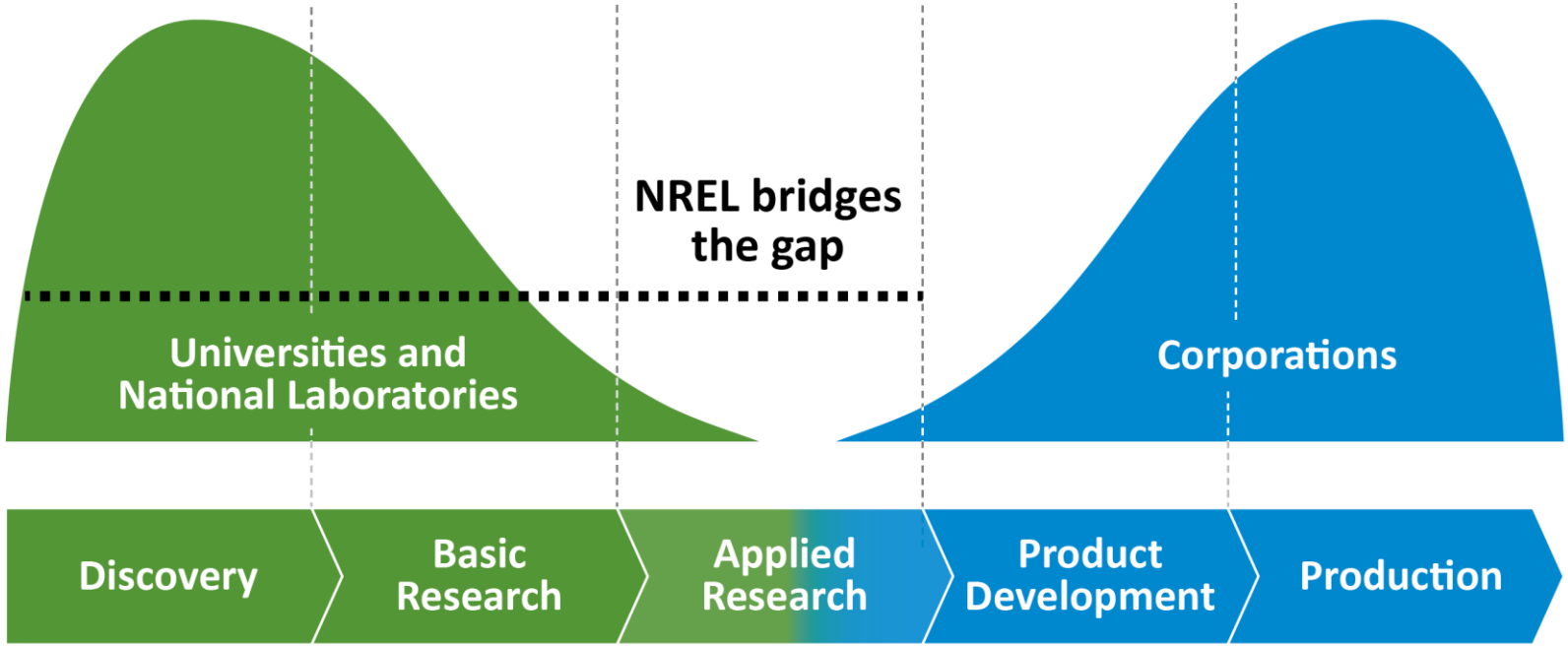
Big Data Analytics



Partnering for Impact

NREL Reduces Risks in Bringing Innovations to Market

- Bridging the gap from basic science to commercial application.
- Forward-thinking innovation yields disruptive and impactful results to benefit the U.S. economy.
- Accelerating time to market delivers advantages to American businesses and consumers.



WELLS FARGO + NREL Transforming ENERGY

Partnering with Wells Fargo

Innovation Incubator (IN_2)

- Expanding this scalable model to other partners and technologies
- Growing to a multiyear, $30 million program
- Providing funding to 20 early-stage startups
- Coaching and mentoring
- Conducting research and validation support

EATON Powering Business Worldwide + NREL Transforming ENERGY

Partnering with Eaton Corporation

Eaton and NREL Researchers Working Side-by-Side at the ESIF

- Distributed Energy Resource Management
- Grid Intelligence
- Advanced Energy Storage Systems
- Electrical Load Identification
- Techno-Economic Analysis
- Virtual Modeling and Analysis
- High-Performance Computing

ExxonMobil + NREL Transforming ENERGY

Partnering with ExxonMobile

- NREL scientists and engineers are collaborating to conceive and create solutions for today's energy challenges.
- This new partnership will stimulate collaborative projects between ExxonMobil, NREL, and the National Energy Technology Laboratory. It will also facilitate work with other national laboratories, such as the Idaho National Laboratory.
- This is a 10-year $100 million partnership that is intended to fill gaps in traditional energy approaches.

Thank you

www.nrel.gov

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