NREL
NATIONAL RENEWABLE ENERGY LABORATORY

NREL Research Energizes American Innovation

Electrifying Fleets and Demonstrating Zero Emissions Technology

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Ports/Airports – Lab Lead
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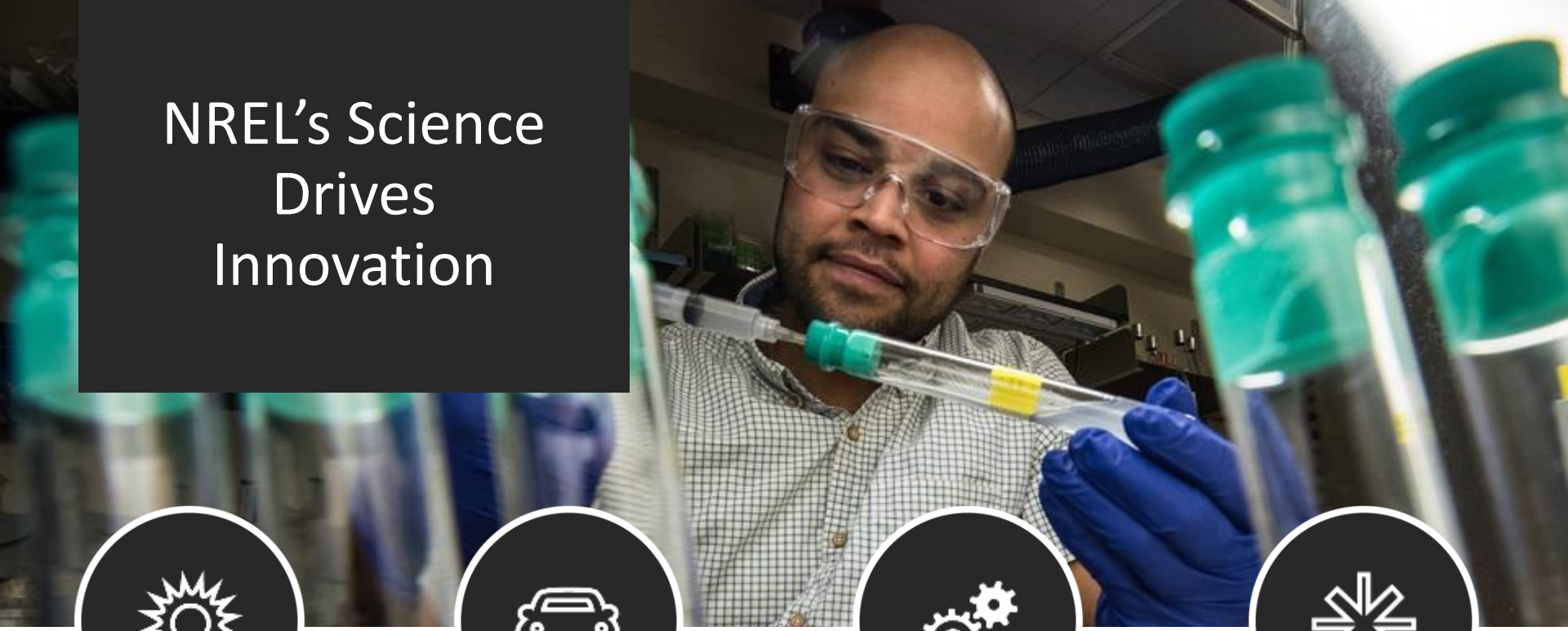
NREL's Science Drives Innovation



Renewable Power

- Solar
- Wind
- Water
- Geothermal

Sustainable Transportation

- Bioenergy
- Vehicle Technologies
- Hydrogen

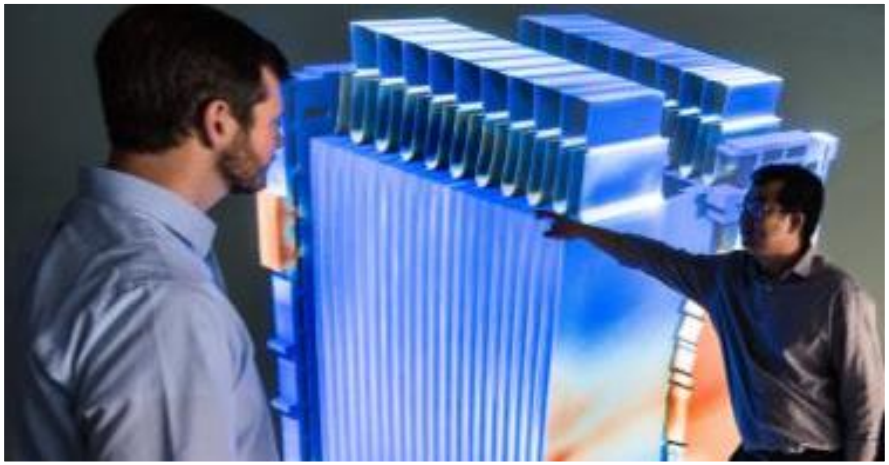
Energy Efficiency

- Buildings
- Advanced Manufacturing
- Government Energy Management

Energy Systems Integration

- High-Performance Computing
- Data and Visualizations

Path to Sustainable Transportation Technologies



Key Research Areas

- **Co-optimizing fuels and engines** – R&D to maximize performance, efficiency, and compatibility with existing infrastructure
- **Increasing sustainable mobility** – connected and autonomous transportation innovations for intelligent, efficient, integrated network
- **Reducing expense of battery development** – Computer-Aided Engineering for Electric-Drive Vehicle Batteries (CAEBAT) tool
- **Improving efficiency of heavy-duty vehicles** – commercial truck fuel, engine, thermal management, and powertrain innovation
- **Demonstrating electrification of vehicles** – energy storage for plug-in electric and fuel cell electric vehicles; power electronics; and infrastructure R&D to boost performance and market viability

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Advanced Fueling Infrastructure

Connected & Automated Vehicles

Urban Science

SMART MOBILITY LAB

CONSORTIUM

7 labs, 30+ projects, 65 researchers, $34M* over 3 years.

Mobility Decision Science

Multi-Modal Transport

*Based on anticipated funding

Expected EV Growth

37%

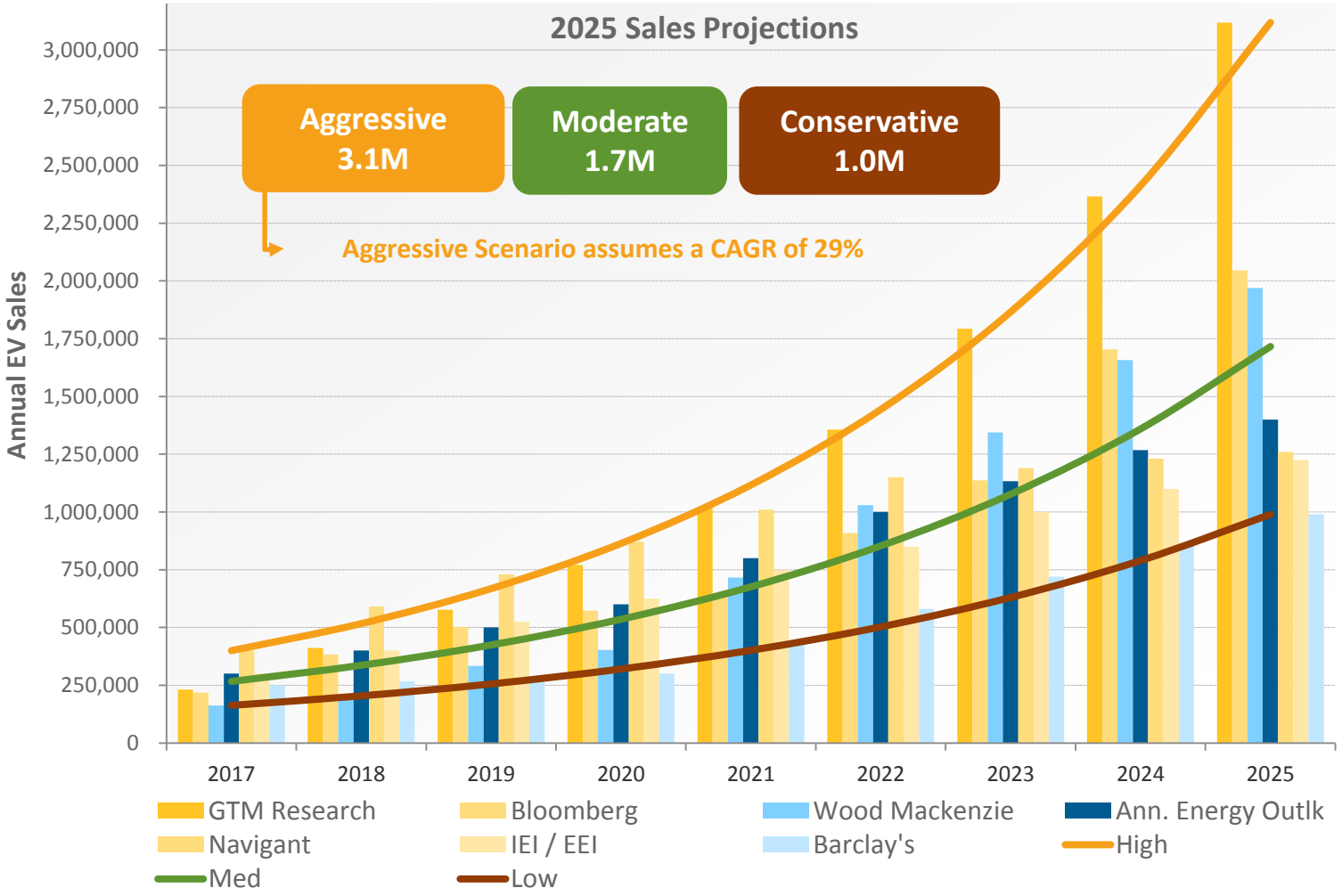
Year-over-year national sales growth of EVs in 2016

Source: Insideevs.com

62%

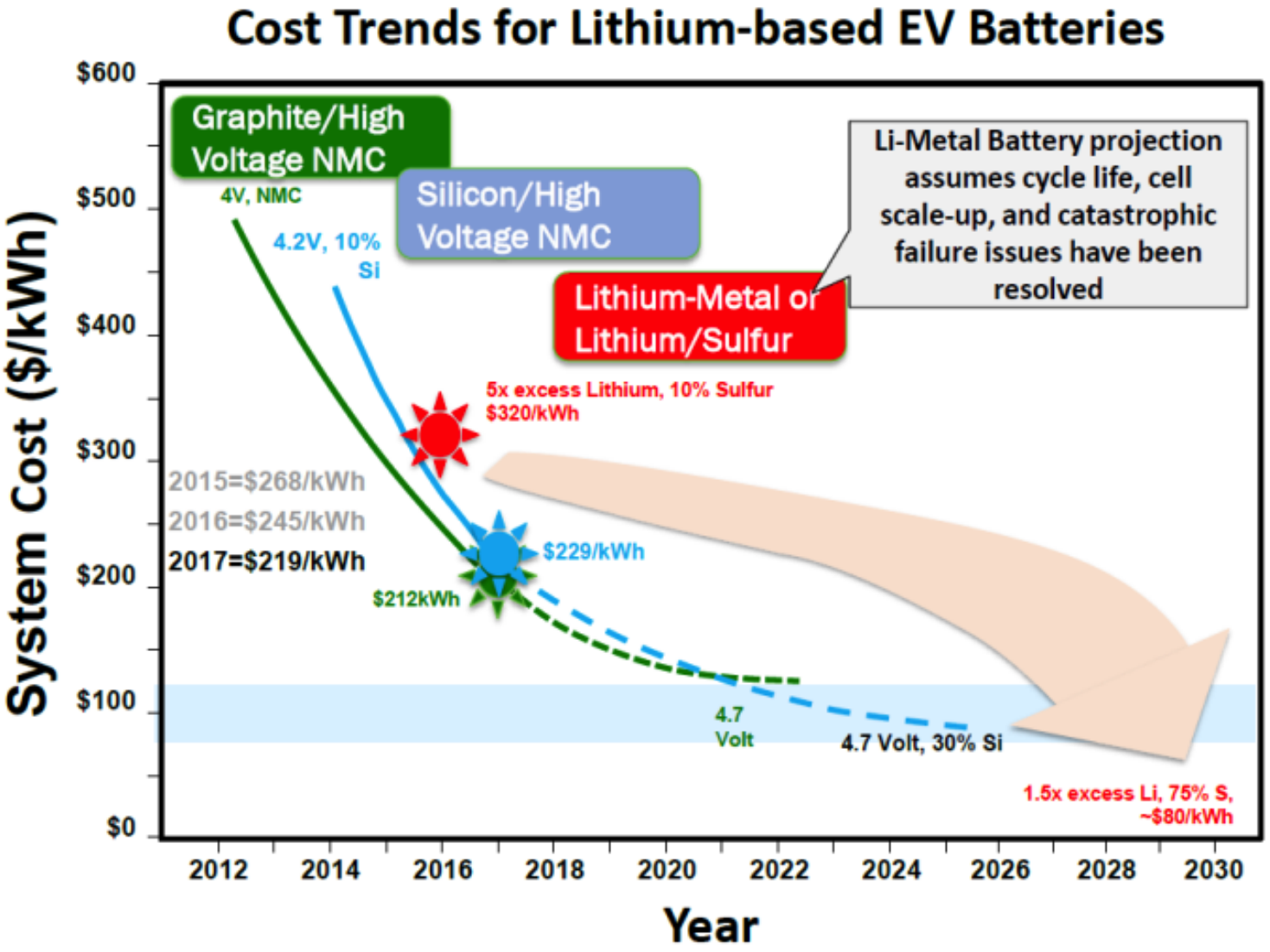
Year-over-year national EV sales growth in 2017

Source: Insideevs.com



Sources embedded in chart above

EV – Battery costs



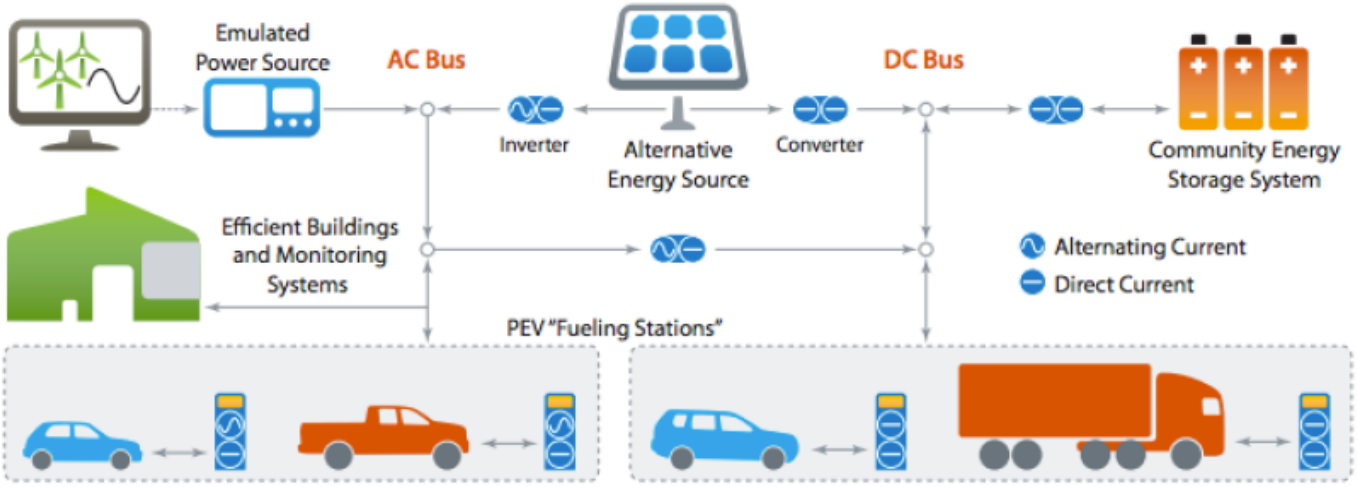
EV Charging Infrastructure

Combination of fast charge batteries and a network of high capacity chargers can minimize range anxiety, promote the market penetration of BEVs, and increase total electric miles driven.

Type of Charging Station	Level 2 220V (~7.2kW)	DC Fast Charger (50kW)	Tesla Super Charger (140 kW)	Extreme Fast-Charging (350kW)
Time to charge (for 200 miles)	8 hours	2 hours	25 mins	10-15 mins
Charging Device				(TBD)

Source: Alternative Fuels Data Center afdc.energy.gov; 2015 NACS Retail Fuels Report, http://www.nacsonline.com/YourBusiness/FuelsReports/2015/Documents/2015-NACS-Fuels-Report_full.pdf;

EV, Renewable Energy, Buildings, and Energy Storage - Working Together



Developing Systems Integrated Applications

Managed Charging

Evaluate functionality and value of load management to reduce charging costs and contribute to standards development

Local Power Quality

Leverage charge system power electronics to monitor and enhance local power quality and grid stability in scenarios with high penetration of renewables

Emergency Backup Power

Explore strategies for enabling the export of vehicle power to assist in grid outages and disaster-recovery efforts

Bi-Directional Power Flow

Develop and evaluate integrated V2G systems, which can reduce local peak-power demands and access grid service value potential

Vehicle-to-Grid Challenges

Life Impacts

Can functionality be added with little or no impact on battery and vehicle performance?

Information Flow and Control

How is information shared and protected within the systems architecture?

Holistic Markets and Opportunities

What role will vehicles play and what value can be created?

NREL's Electric Futures Study (Transportation)

Answering **crucial questions** about:

Technologies

What electric technologies are available now, and how might they **advance**?

Consumption

How might electrification impact electricity **demand** and **use patterns**?

System Change

How would the electricity system need to **transform** to meet changes in demand?

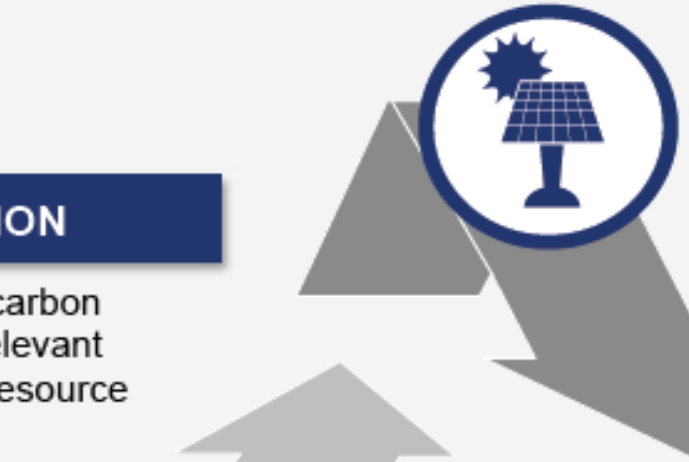
Flexibility

What role might **demand-side flexibility** play to support reliable operations?

Impacts

What are the potential **costs, benefits, and impacts** of widespread electrification?

Changing Electric Paradigm



DECENTRALIZATION

Makes customers active elements of the system, though requires significant coordination

Key technologies: energy efficiencies, decentralized storage, microgrids, demand response

ELECTRIFICATION

Critical to long-term carbon goals and will be a relevant decentralized energy resource

Key technologies: Electric vehicles, vehicle to grid/home, smart charging, heat pumps

Grid Edge Transformation

DIGITALIZATION

Allows for open, real-time, automated communication and operation of the system

Key technologies: Network technologies (smart metering, remote control and automation systems, smart sensors, optimization and aggregation platforms) and customer technologies (smart appliances and devices, Internet-of-Things)

Sources: World Economic Forum

Yard Tractor Usage Map – PANYNJ terminal

Current Announcements

- California CEC approval of 3 utilities $738M investment
- NYPA approval of $250M (throughout state, including airport)
- NJ's PSEG $300M investment
- VW Electrify America $2B investment

Thank You

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