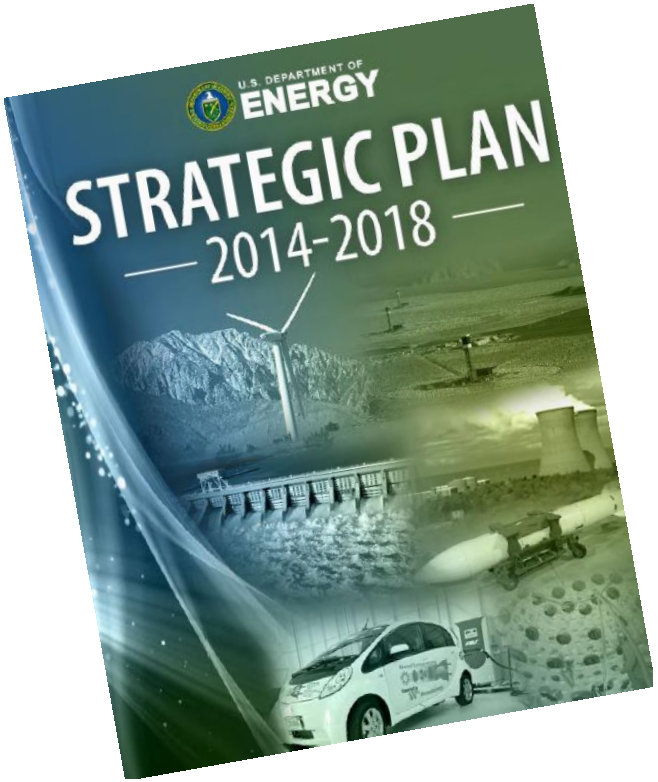
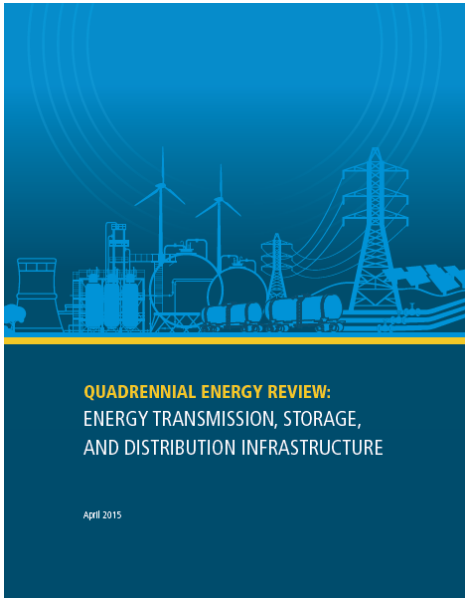
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

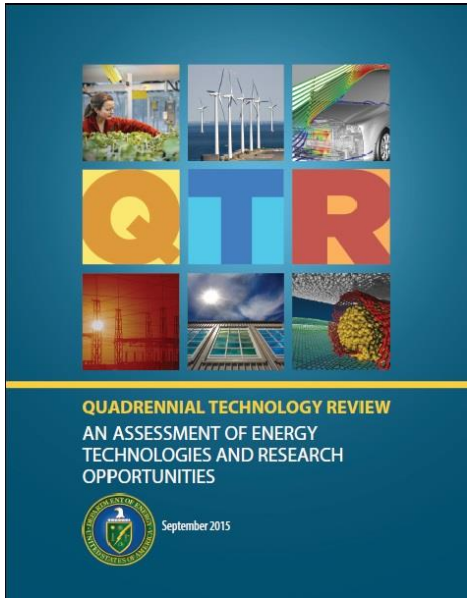
Biomass R&D TAC

EERE Planning Drivers

- President's Climate Action Plan (CAP)
- 2014–2018 DOE Strategic Plan
- Quadrennial Energy Review (QER)
- Quadrennial Technology Review (QTR)

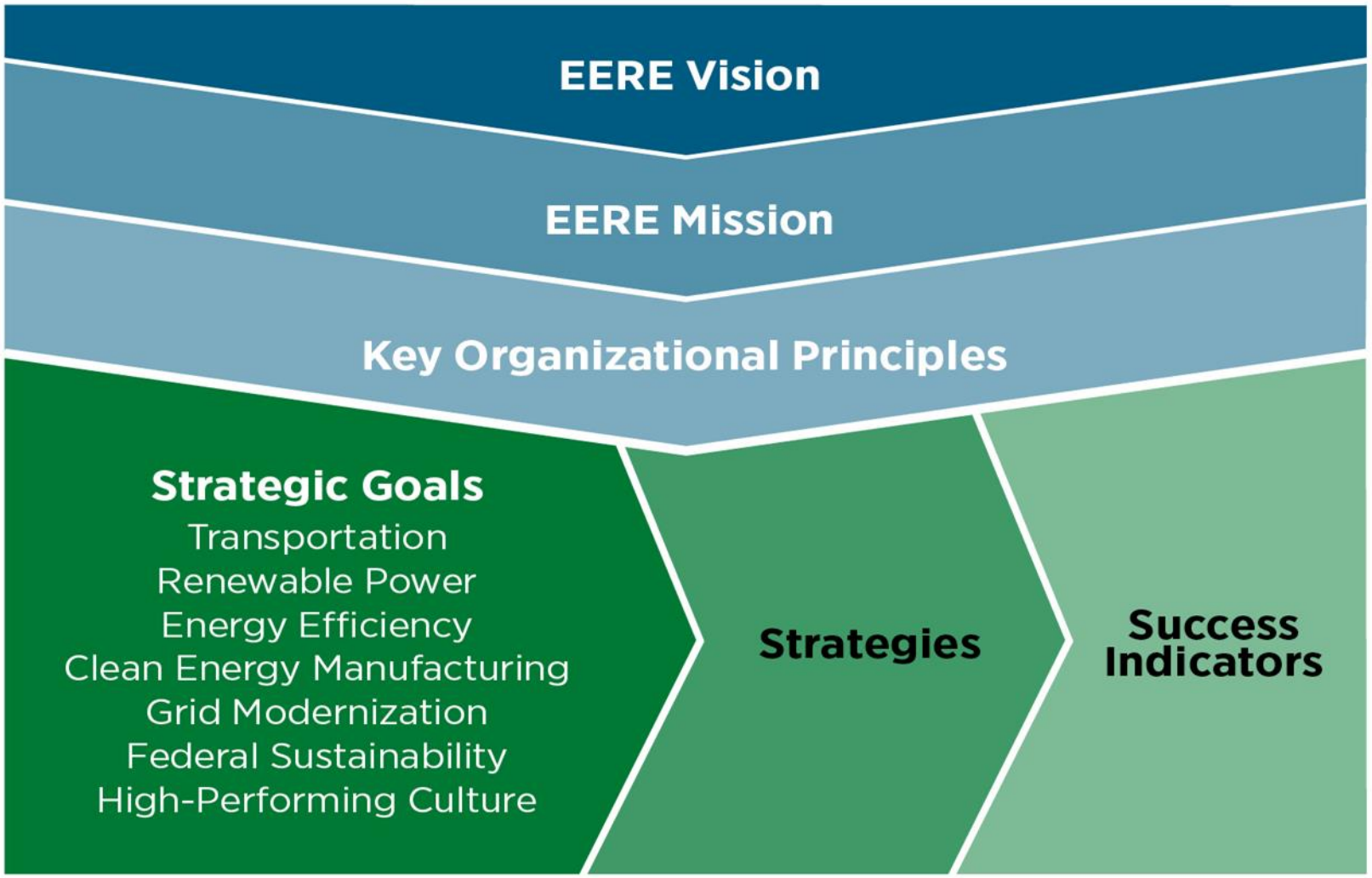






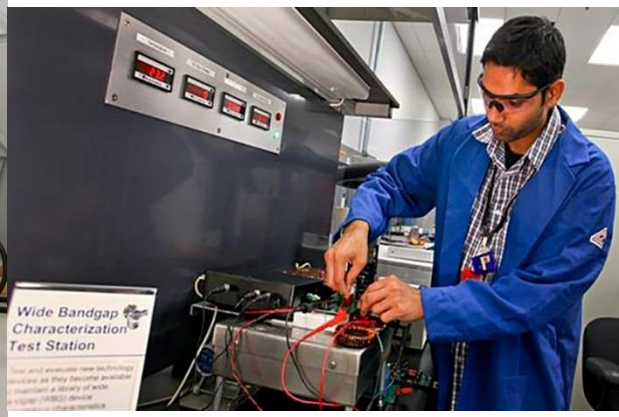
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EERE Strategic Plan Structure



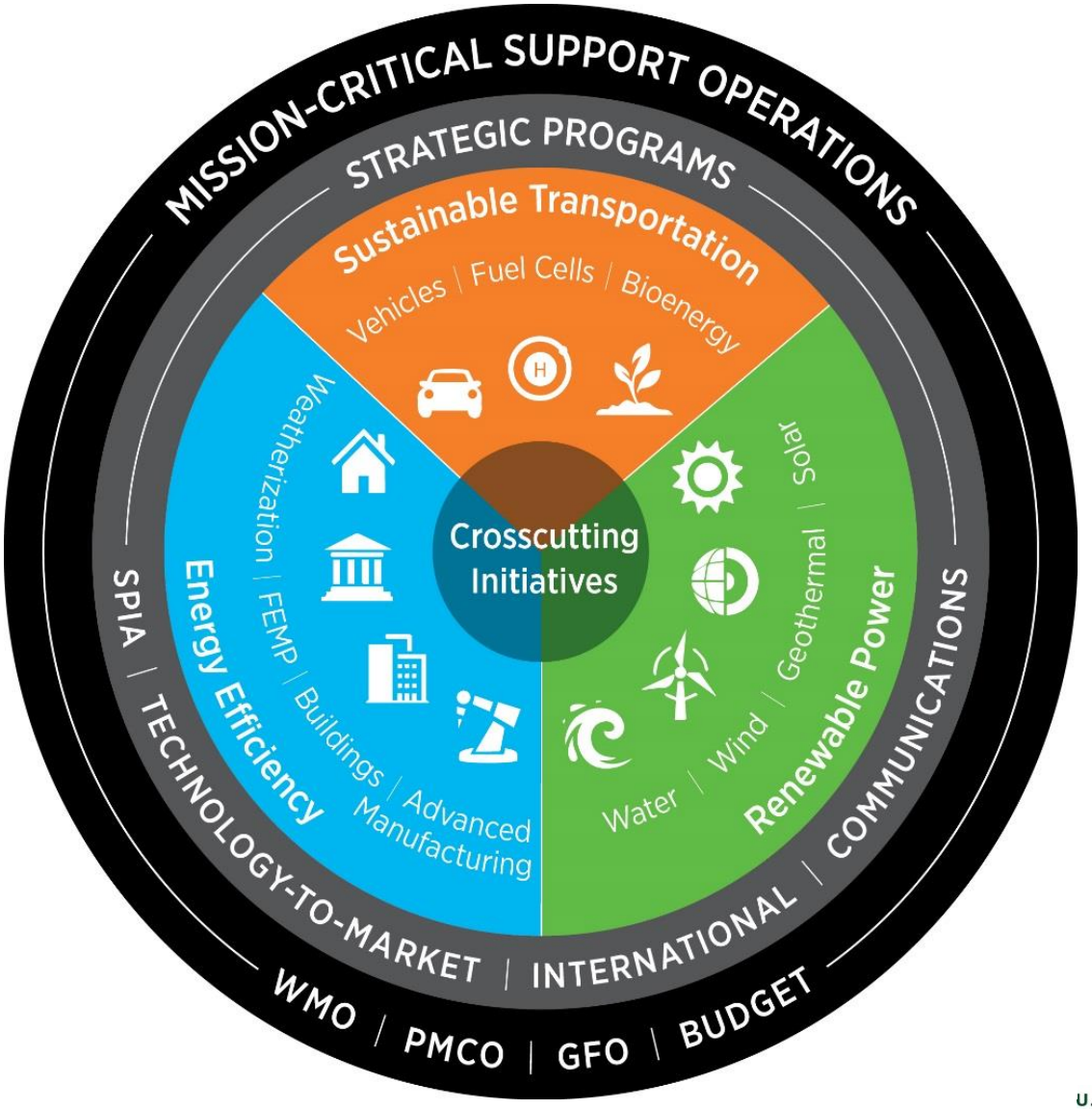
EERE Vision

A strong and prosperous America, powered by clean, affordable, and secure energy



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

EERE Mission



To create and sustain American leadership in the transition to a global clean energy economy

EERE Organizational Principles

- Economic Prosperity
- Affordability
- Reduced Environmental Impact
- Energy Security
- Consumer Choice

EERE Five Core Questions

- **Impact**
  Is this a high-impact problem?
- **Additionality**
  Will EERE funding make a large difference relative to existing funding from other sources, including the private sector?
- **Openness**
  Are we focusing on the broad problem we are trying to solve and open to new ideas, approaches, and performers?
- **Enduring Economic Impact**
  How will EERE funding result in enduring economic impact for the United States?
- **Proper Role of Government**
  Why is this investment a necessary, proper, and unique role of government rather than something best left to the private sector?

EERE Strategic Plan Goals

Goal 1: Sustainable Transportation

Accelerate the development and adoption of sustainable transportation technologies

EV Everywhere
U.S. DEPARTMENT OF ENERGY

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Example Strategies: Sustainable Transportation

Cost Reduction and Performance Improvement

- Develop Technologies That Enable the Cost-Effective Production of Electric-Drive Vehicles

Technology Validation and Risk Reduction

- Support Pilot and Demonstration Facilities for Alternative Fuel Production

Reducing Market Barriers

- Support Pioneering Deployments of Market-Ready Vehicles and Alternative Fuels in Key Early Markets

Goal 1: Sustainable Transportation

Success Indicators

1. By 2020, through improvements in engine efficiency, increase the fuel economy of gasoline and diesel light-duty vehicles by 35% and 50%, respectively
2. By 2022, develop materials that enable a cost-effective 30% weight reduction for light-duty vehicles
3. By 2022, develop a battery pack demonstrating a modeled cost of $125/kWh and an electric drive system demonstrating a modeled cost of $8/kW and efficiency greater than 94%
4. By 2017, demonstrate a 50% improvement in long-haul truck freight efficiency
5. By 2017, validate at pilot scale at least one technology pathway for hydrocarbon biofuel production demonstrating a mature modeled cost of $3/gge with GHG emissions reduction of 50% or more
6. By 2022, validate at pilot or demonstration scale two additional pathways for hydrocarbon biofuel production at a modeled cost of $3/gge with GHG emissions reduction of 50% or more
7. By 2020, develop and demonstrate a fuel cell system for light-duty vehicles achieving 150,000-mile durability and a modeled cost of $40/kW
8. By 2020, reduce the modeled cost of hydrogen production from renewable resources to less than $4/gge

Strategic Goal: Accelerate the development and adoption of sustainable transportation technologies

Sustainable TRANSPORTATION

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

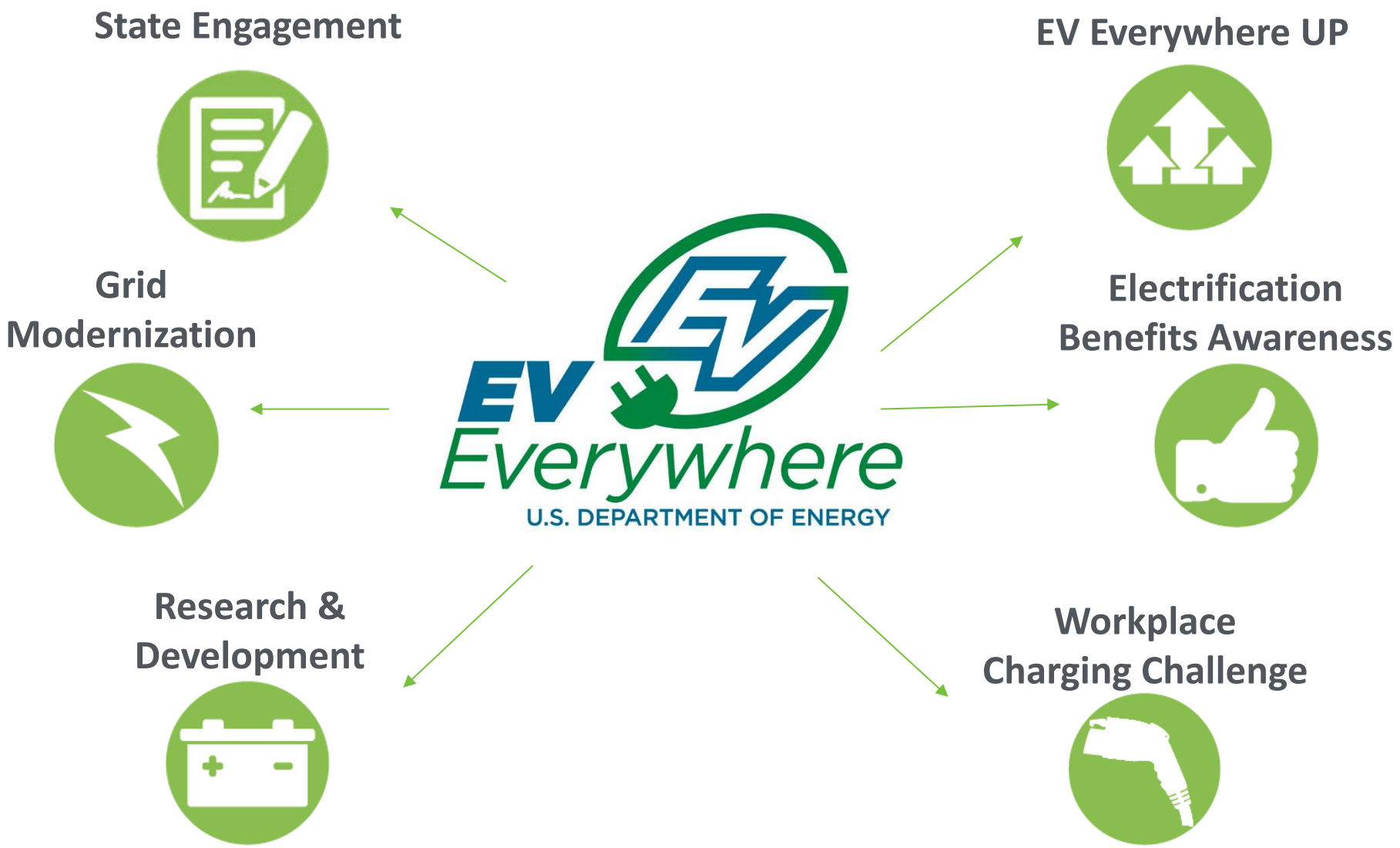
Sector Priorities:

1. Strategic Whitespace for Crosscutting RD3
2. New, Emerging Areas (Off-Roadmap Ideas, Mega-Trends)
3. Innovative Platforms to Compress RD3 Cycle

Transportation Sector Dashboard

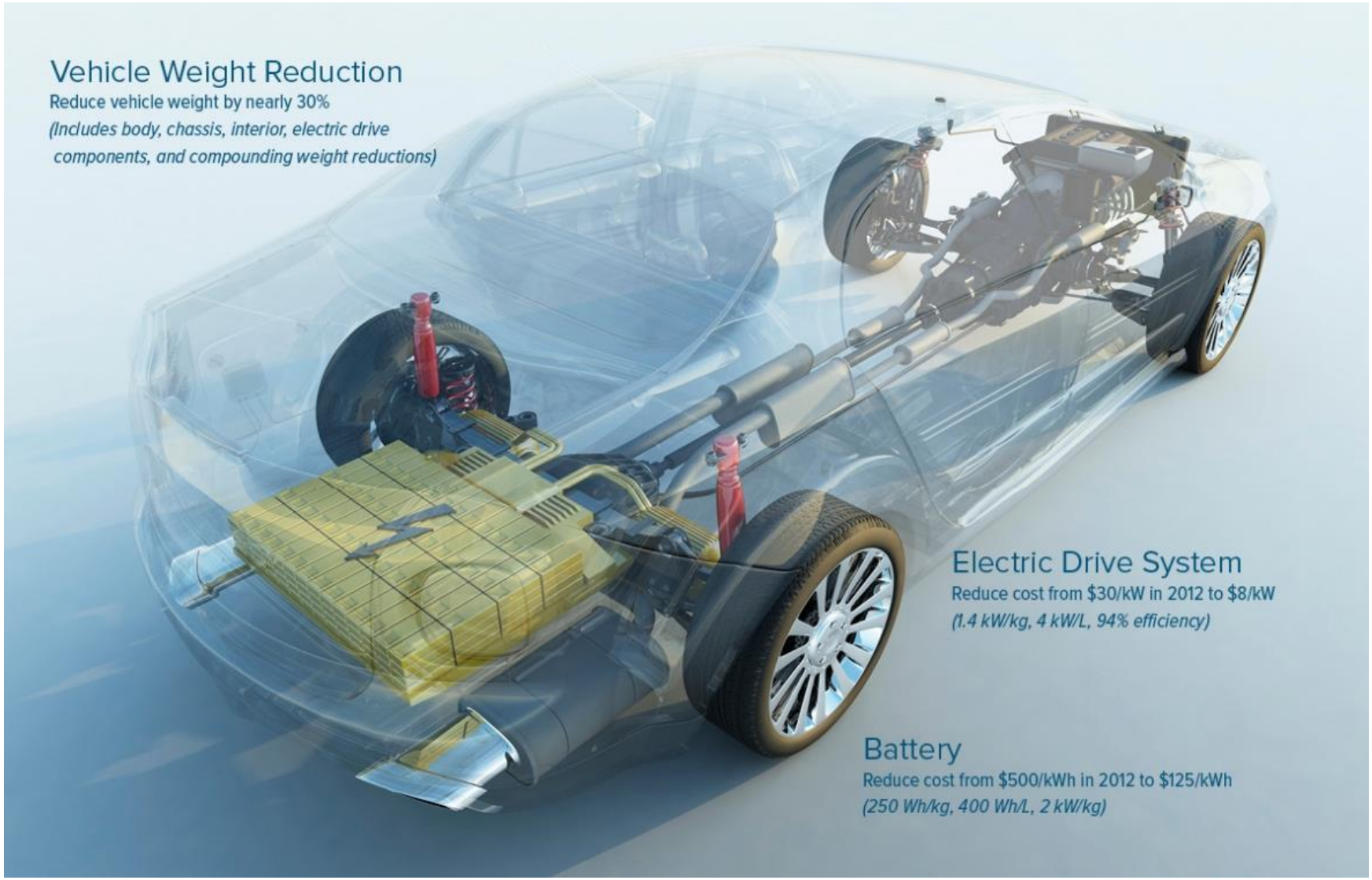
- Key sector priorities
  - EV Everywhere
  - SuperTruck II
  - Optima
  - H2USA
  - Transportation as a System
  - Energy Materials Network
  - Synthetic Biology
  - Integrated Biorefineries (Pilot, Demo)
  - Bioeconomy
  - Clean Cities

EV Everywhere Grand Challenge



Affordable plug-in electric vehicles by 2022

EV Everywhere Technology Targets

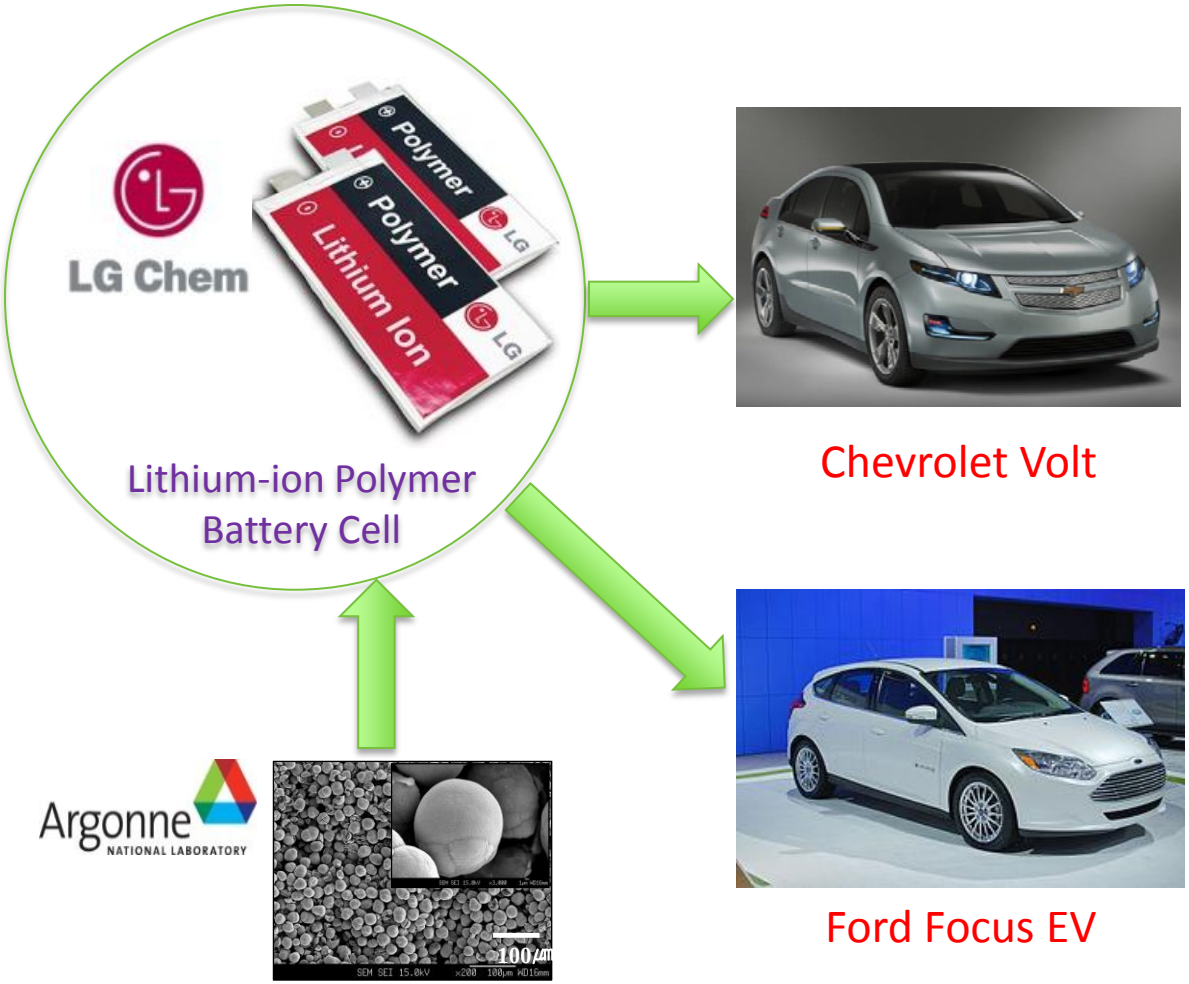


DOE has invested more than $300M in RD&D; more than 400,000 PEVs sold

Battery Technology Highlights

Lithium-ion Battery Technology for Plug-in Electric Vehicles

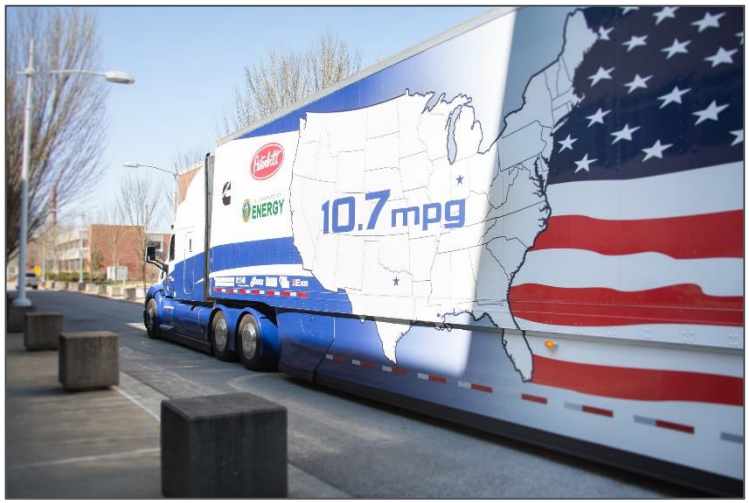
- EERE VTO supported the development of the core cell technology that is currently used in the Chevrolet Volt PEV battery and the Ford Focus EV battery.
- The cell, which contains a graphitic anode and a mixture of Nickel-Manganese-Cobalt and Manganese spinel oxides, was developed in collaboration with LG Chem Michigan from early 2004 through 2012.
- The Nickel-Manganese-Cobalt cathode in the LG Chem cell was developed at Argonne National Laboratory with support from EERE VTO from 2002-2010.



SuperTruck I

Cummins and Daimler

Achieved 50% engine efficiency; exceeded freight efficiency goal.



Cummins/Peterbilt
70% improvement

Daimler Trucks North America
115% improvement

Navistar and Volvo: on track to achieve 50% freight efficiency goal

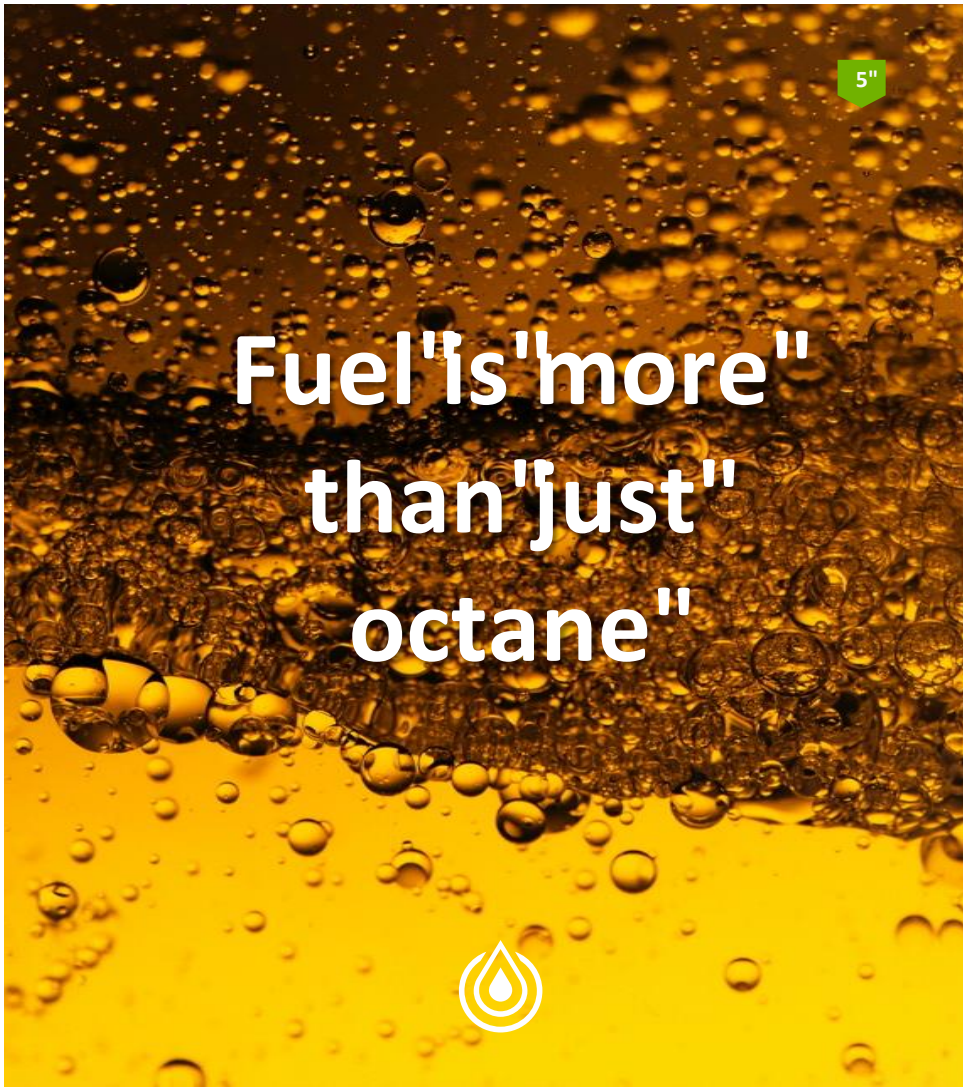
SuperTruck technologies are already influencing vehicle design

Announcing SuperTruck II

- DOE EERE Funding Opportunity Announcement
- **$80M** for up to four cost-shared projects (subject to appropriations)
- Research, develop, and demonstrate class 8 long-haul truck with **greater than 100%** improvement in vehicle **freight efficiency** relative to a 2009 baseline.
- **Engine brake thermal efficiency** greater than or equal to **55%**.
- Cost effective technologies that meet performance demands

Current Fuels Constrain Engine Design

RON viscosity MON volatility cloud point bulk modulus of compressibility Wobbe index heating value sensitivity heat of vaporization soot precursor formation PMI flammability limits smoke point cetane number T50 heat of combustion flame stretch ignition limits C/H ratio strain sensitivity density specific heat ratio naphthene level Markstein length T10 surface tension flash point T90 exergy destruction olefin level energy density sulfur level laminar burning velocity diffusivity drivability index flame speed aromatics level oxygenate level



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Engines Will Dominate Fleet for Decades

New fuels open up engine design options

6

boost level
ignition energy
valve lift
downsizing
tumble ratio
powertrain design
ignition timing
fuel stratification
compression ratio
air/fuel ratio
hybridization
swirl ratio
heat exchanger design
valve timing
injector design
cylinder deactivation
injection timing
direct injection
real time controls
EGR ratio
number of injections
injection pressure
charge temperature
on-board reforming
injection duration
on-board separation
valve overlap
turbulence
downspeeding

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Tandem Design of Fuels & Engines

Fuel and Engine Co-Optimization

- What fuel properties maximize ICE engine operations?
- How do engine parameters affect ICE efficiency?
- What fuel and engine combinations are sustainable, affordable, and scalable?

2

Biofuel blend stocks are promising candidates for improved fuels with reduced GHG emissions

***Additional* 15-20% fuel economy improvement possible (50% total vs. 2009)**

Fuels & Engines Co-Optimization Effort

- FY16 - **$22M** ($12M VTO, $10M BETO) **$30M** FY17 Request
- Coordinated RD&D across **9 National Laboratories**
- Go beyond what we know about octane and ethanol today

Thrust 1

spark ignition (SI)

2025 commercial entry

Low Reactivity Fuel
(gasoline)
high RON

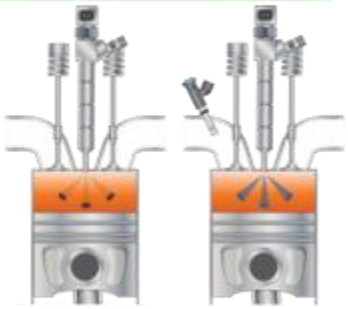
- Octane & beyond
- Downsized, boosted engines, higher CR
- FY16 Q1 -Select 20 fuels
- **FY17 Q2- Go/No Go vs. existing high octane alternatives**

Thrust 2

Advanced compression ignition (ACI)
including low temperature, kinetic regimes

2030 commercial entry

High Reactivity Fuel
(diesel)
high cetane



Range of Fuel Properties TBD
(new fuel)
undetermined fuel needs

- Kinetically controlled
- Low temperature combustion
- Maximize fuel efficiency with very low emissions
- Less known needs
- **Parallel to Thrust 1**

Backward / Forward Compatibility Legacy fleets, Thrust 1, Thrust 2

High performance, low carbon fuels for high efficiency engines

H_2USA: Public-Private Partnership

H_2USA

Partners

~ 45 Partners in 2015

Mission

To address hurdles to **establishing hydrogen fueling infrastructure**, enabling the **large scale adoption of fuel cell electric vehicles**

Structure

4 Working Groups coordinated by the **Operations** Steering Committee

H_2FIRST Coordination panel

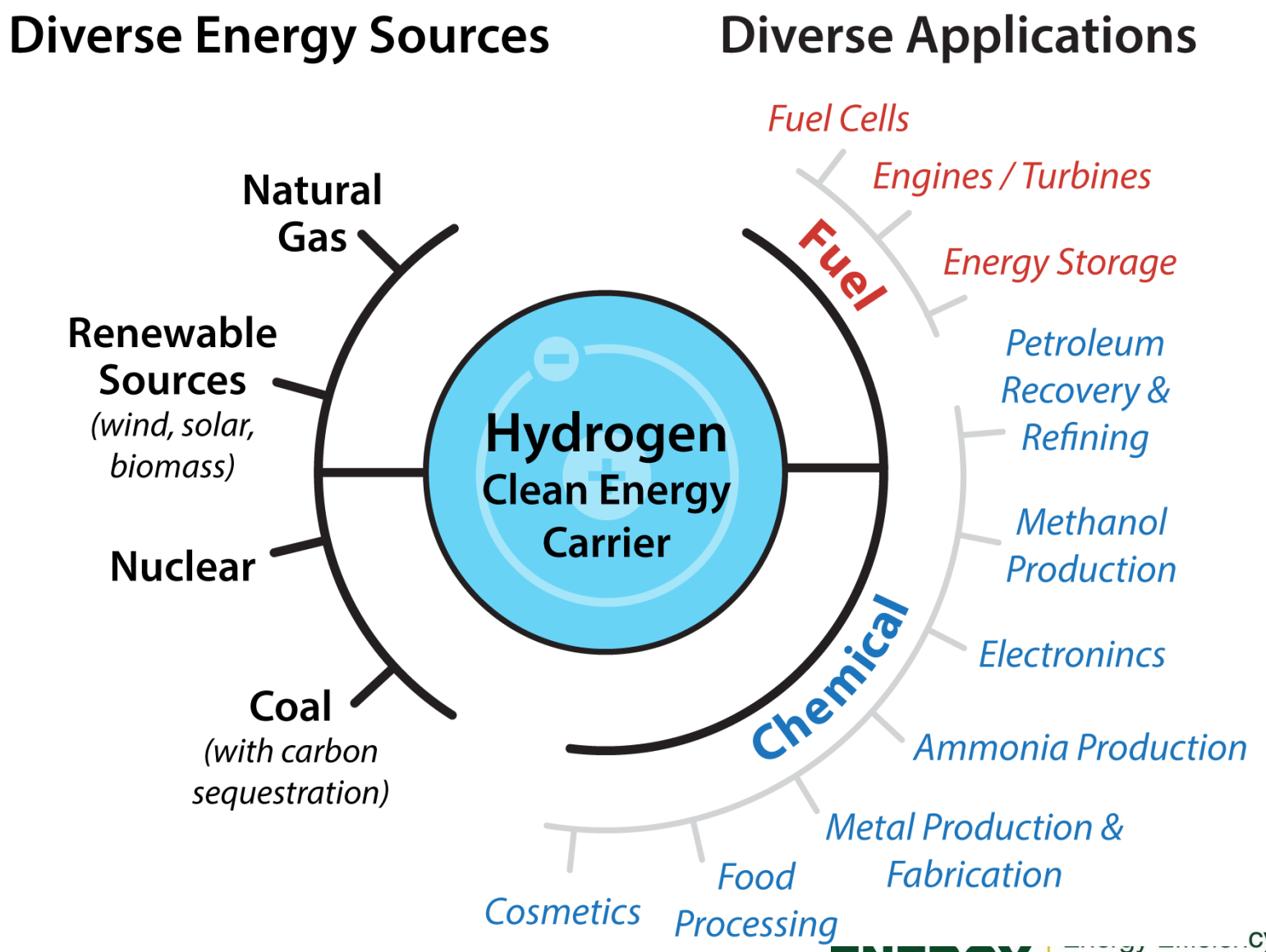
H_2FIRST

H_2USA's Working Groups

- **Hydrogen Fueling Station**
- **Locations Roadmap**
- **Financing Infrastructure**
- **Market Support & Acceleration**

More than 45 partners working towards adoption of FCEVs and H_2

Hydrogen – An Energy Carrier and Feedstock



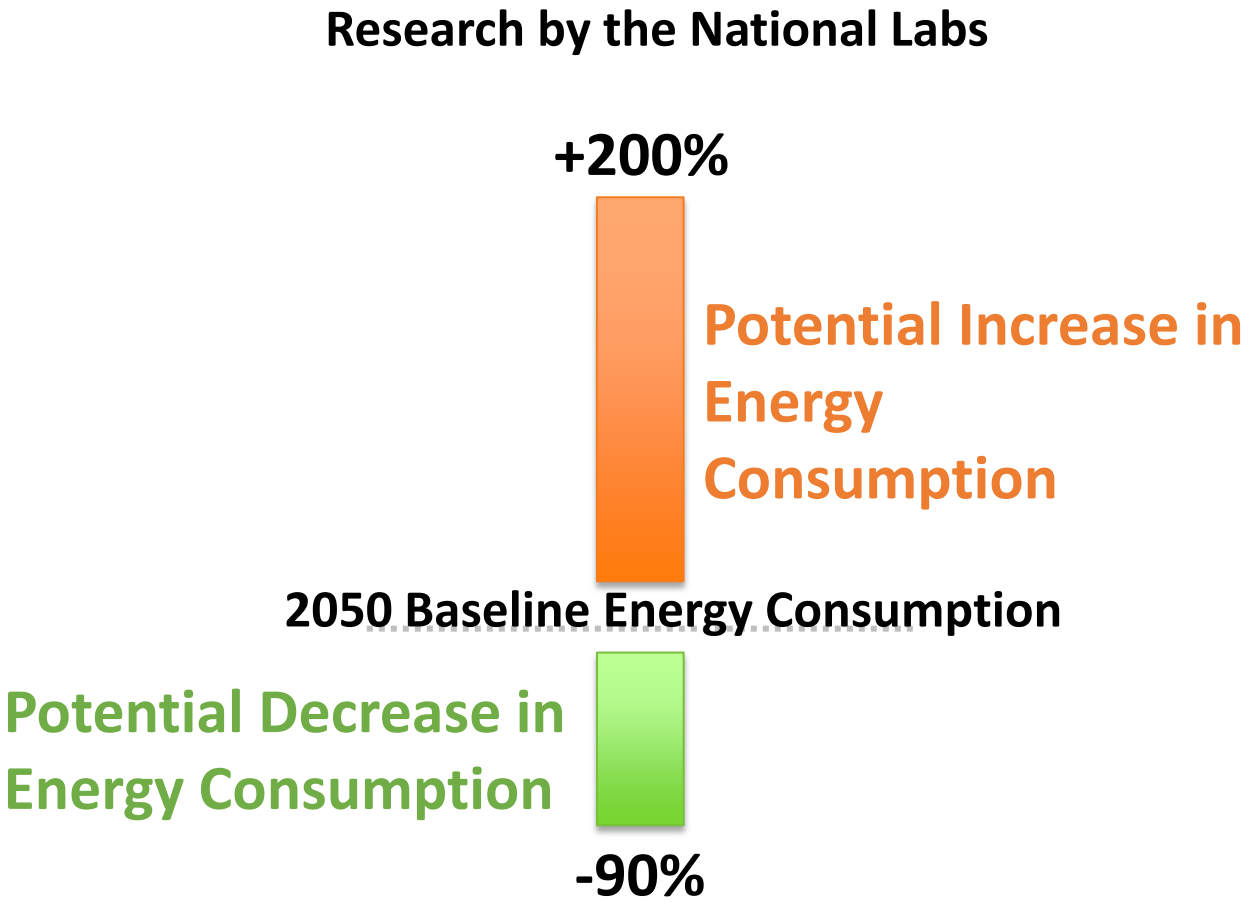
Transportation as a System (SMART Mobility)

Today:
- Vehicle level focus
- Independent
- Unconnected
- Subject to behaviors & decisions

Tomorrow:
- System level focus
- Connected
- Automated
- In concert
- Across modes
- Managed behaviors & decisions

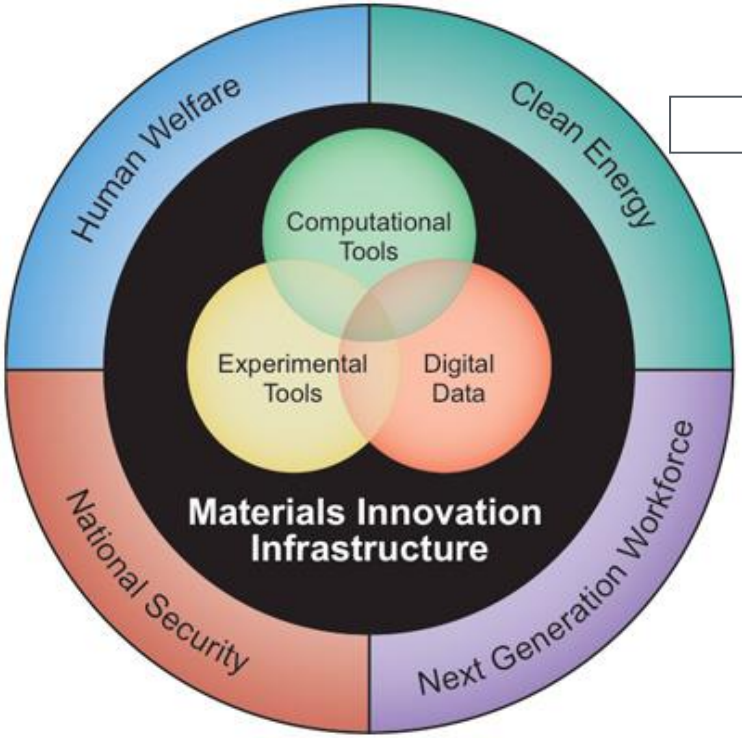
Exploring the untapped transportation system level efficiencies

Connectivity, Automation and Energy



Vast range of energy implications … more research required

In Support of the Materials Genome Initiative (MGI)



MGI - Framework

Energy Materials Network
U.S. Department of Energy

Coordinated resource network with a suite of capabilities for advanced materials R&D

Predictive Simulation Across Scales	Synthesis & Characterization	Rapid Screening	End Use Performance
Process Scalability	Process Control	Real-time Characterization	Reliability Validation

Data Management & Informatics

Materials Design & Synthesis → **Functional Design** → **Process Scale-Up & Qualification**

New Material Innovations for Clean Energy 2X Faster and 2X Cheaper

Network Requirements

1. ***WORLD CLASS MATERIALS CAPABILITY NETWORK:*** Create and manage a **unique, accessible set of capabilities** within the DOE National Laboratory system
2. ***CLEAR POINT OF ENGAGEMENT:*** Provide a **single point-of-contact** and concierge to direct interested users (e.g. industry research teams) to the appropriate laboratory capabilities, and to **facilitate efficient access**.
3. ***DATA AND TOOL COLLABORATION FRAMEWORK:*** **Capture data, tools, and expertise** developed at each node such that they can be **shared and leveraged** throughout the EMN and **in future programs**. Establish data repositories and, where appropriate, distribute data to the scientific community and public. Accelerate learning and development through data analysis using advanced informatics tools.
4. ***STREAMLINED ACCESS:*** Facilitate **rapid completion of agreements** for external partners, and aggressively pursue approaches to reduce non-technical burden on organizations seeking to leverage the EMN for accelerated materials development and deployment.

Key Guidance & Principles

1. ***NATIONAL LABORATORY LED CONSORTIA***
2. ***COMMON YET FLEXIBLE CONSORTIUM MODEL***
3. ***CONSISTENCY AND TRANSPARENCY ACROSS EFFORTS***
4. ***ENDURING CAPABILITIES WITHIN THE NETWORK***

The Energy Materials Network (Fiscal Year 2016)

Energy Materials Network
U.S. Department of Energy

Lightweight Materials	Chemical Reactions & Catalysis	Energy Conversion Materials	Coatings & Thin Films
LightMAT Lightweight Materials CONSORTIUM	ElectroCat Electrocatalysis Consortium	CaloriCool	DuraMAT Durable Module Materials Consortium
Lost Cost Mg Sheet for Auto	PGM-Free Catalysts and MEAs for Fuel Cells	Caloric Materials	Durable Materials for Solar Modules

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Planned Consortium

Consortia	FY16	FY17
LightMAT Lightweight Materials CONSORTIUM	Low Cost Mg Sheet for Auto	Low Cost Precursors for Carbon Fiber; Mg Corrosion
ElectroCat Electrocatalysis Consortium	PGM-Free Catalysts and MEAs for Fuel Cells	Continue
CaloriCool	Caloric Materials for Efficient Cooling	Continue
DuraMAT Durable Module Materials Consortium	Durable, PV Form Factors	Continue
Fuel Cell - Consortium #5		Materials Based, Low Pressure H2 Storage
Fuel Cell - Consortium #6		Advanced Water Splitting for Renewable Hydrogen
Bioenergy -Consortium #7		Advanced Catalysts for Biofuels

Budget Snapshot

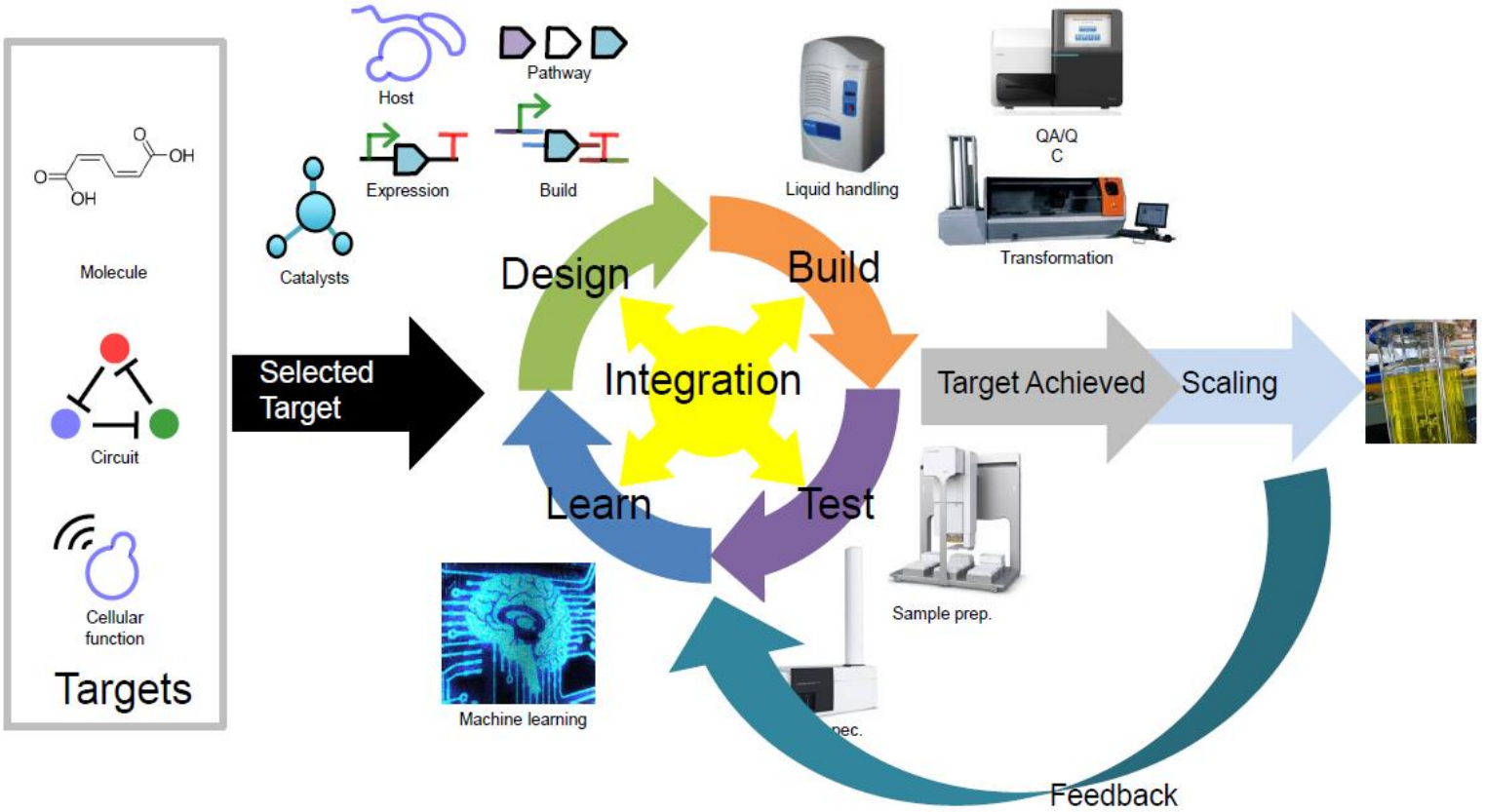
Consortia	FY16 (Enacted)	FY17 (Requested)
LightMAT Lightweight Materials CONSORTIUM	$12M	$39.3M
ElectroCat Electrocatalysis Consortium	$10M	$10M
CaloriCool	$8M	$8M
DuraMAT Durable Module Materials Consortium	$10M	$10M
Fuel Cell - Consortium #5	-	$10M
Fuel Cell - Consortium #6	-	$14.5M
Bioenergy -Consortium #7	-	$30M
Total	**$40M**	**$121.8M**

ThermoCat

- **Goal:** Improved catalyst materials to lower the overall cost of biofuels production with lower development costs and lead-times
  - Identifying, synthesizing, and screening new catalysts is a cumbersome and time-intensive process.
  - High through-put screening capabilities, computational modeling, and high-energy particle beam lines

- Catalysis Working Group: a group of five National Labs that are working together to address common catalysis barriers in the thermochemical conversion of biomass to biofuels.
    - ANL, ORNL, NREL, LANL, PNNL
- $9 M in FY17

Synthetic Biology (SynBio) Foundry



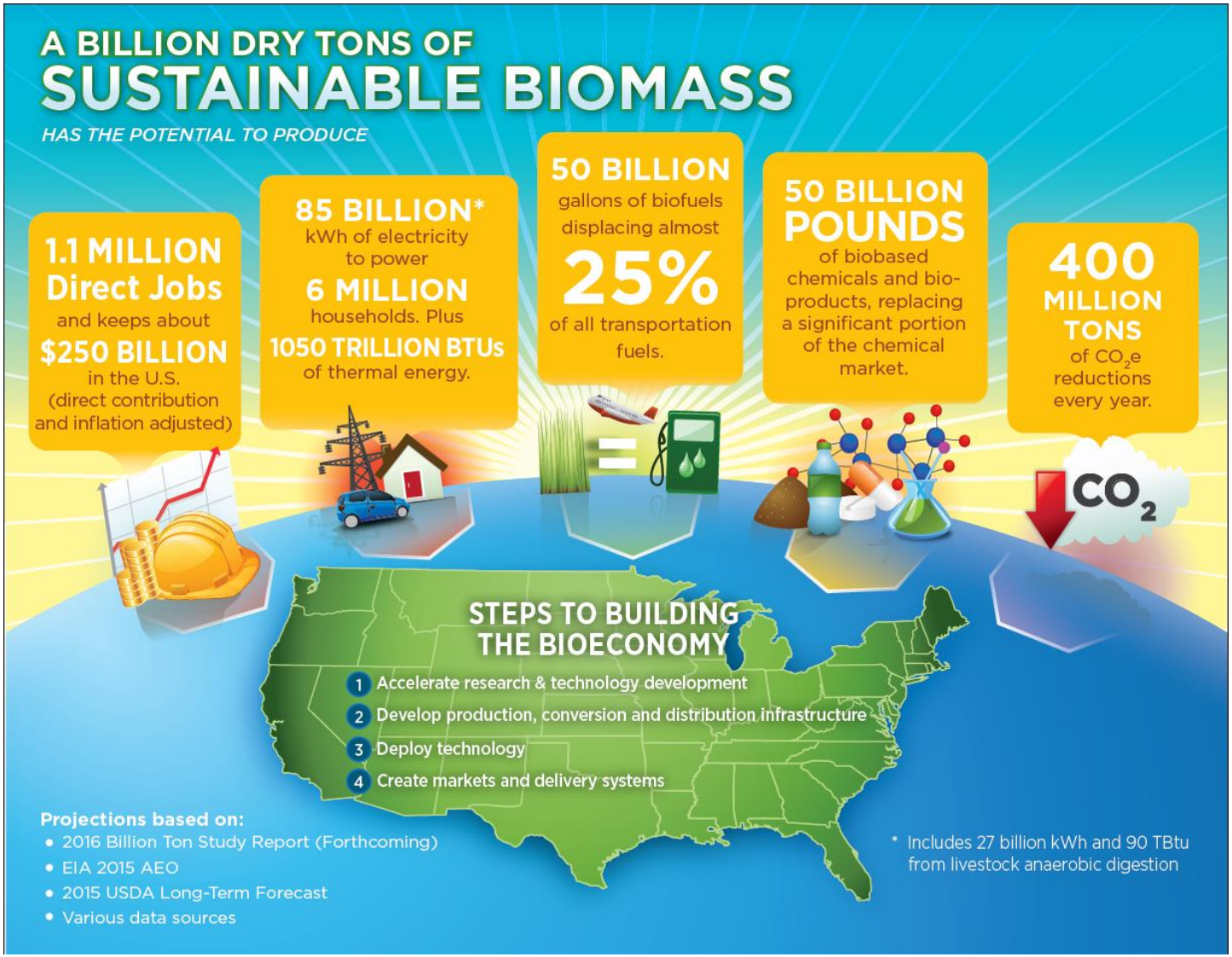
High-throughput R&D for renewable fuels and products from industrially relevant organisms

Publically available tools, host strains, and scale-up methods

Host strains that move beyond E. Coli and yeast

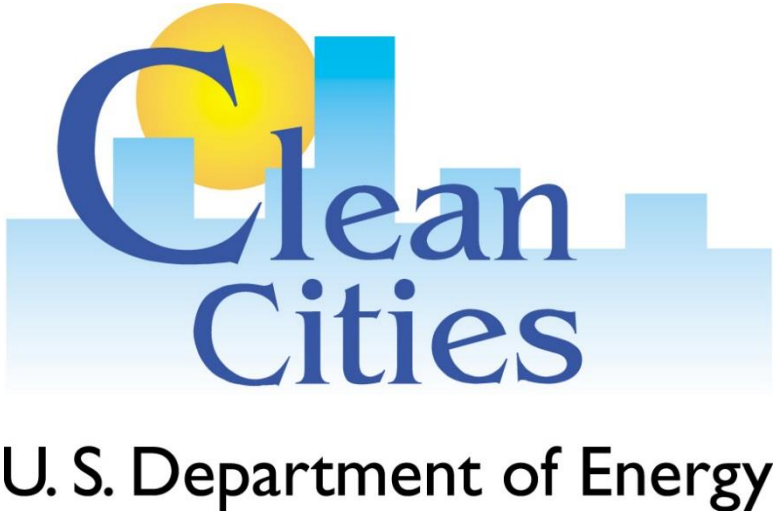
Suite of capabilities for accelerated R&D + Scale Up of biofuels & bioproducts

Potential Impacts of a Billion-Ton Bioeconomy



1 billion tons of biomass could be sustainably produced in the U.S.

Re-envisioning Clean Cities



Questions?