

# DOE's Research to Improve Transportation Energy Security and Affordability

Briefing to National Academies to Support NAS Study of Technologies for Light-Duty Vehicle Fuel Economy, 2025-2035 Timeframe

**Steven G. Chalk, Deputy Assistant Secretary for Transportation** 07/16/2018



## Strategies to Achieve Transportation Energy Security and Affordability

### **EERE Transportation Portfolio**



**Fuel Diversification | Low Emissions**Reduces Price Volatility, Domestic
Resources



**Vehicle Efficiency** | Energy-Efficient Vehicle Technologies



**Mobility Systems** | Energy Efficient Transport Systems (People & Goods)

### 6 key research areas:

- Combustion Engines/Fuels
- Lightweight Materials
- Batteries and Electrification
- Fuel Cell Vehicles
- Biofuels
- **Energy Efficient Mobility Systems**

Energy storage research is a key enabler to variable renewables, greater grid resiliency

## **Transportation Uses 28% of Nation's Energy**





70% of petroleum used for transportation.

85% of it used for on-road vehicles,



Transportation is the 2<sup>nd</sup> largest expense for U.S. households.



In 2016, transportation accounted for the largest portion (28%) of total U.S. greenhouse gas emissions.

## **EERE Transportation R&D Portfolio (FY 18 = \$670M)**



## **EERE Transportation Program Goals**

(Cost goals are budget driven, not market-clearing)

#### Batteries, Fuel Cells, Biofuels

- Batteries: \$100/kWh pack, increase range to 300 miles decrease recharge time <15 mins by 2028; ultimate goal \$80/kWh
- Fuel cell system: \$40/kW by 2025
- Hydrogen: \$7/GGE by 2025
- Biofuel: \$3/GGE by 2025

#### **Next Gen Engines**

Improve fuel economy by 25% from advanced engine research by 2030 compared to 2015 baseline

#### Fuels and Co-Optima

Improve fuel economy by additional 10% (from co-optimization with fuels by 2030 compared to 2015 baseline

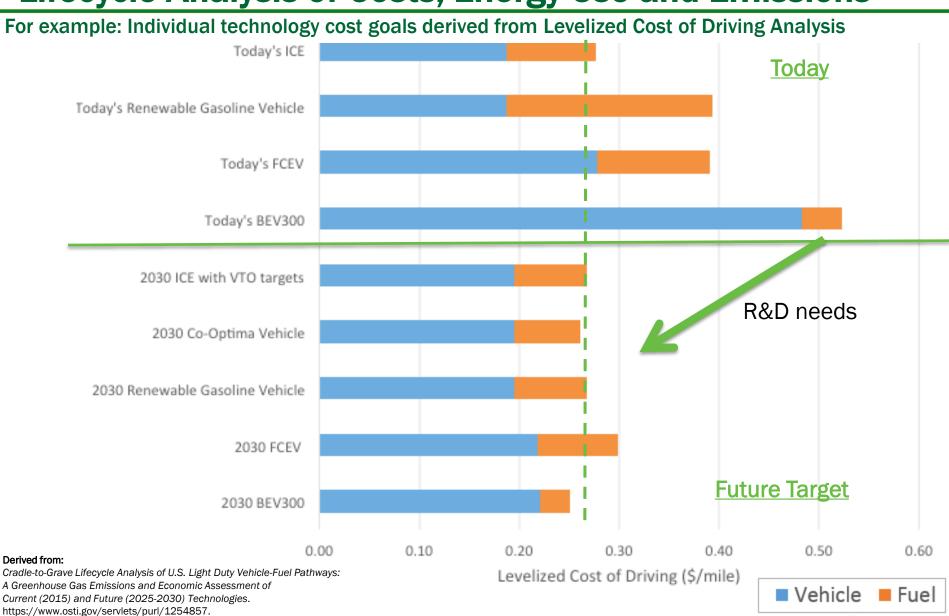
#### **Light Weight Materials**

25% glider weight reduction compared to 2012 baseline at <\$5/lb.-saved by 2030

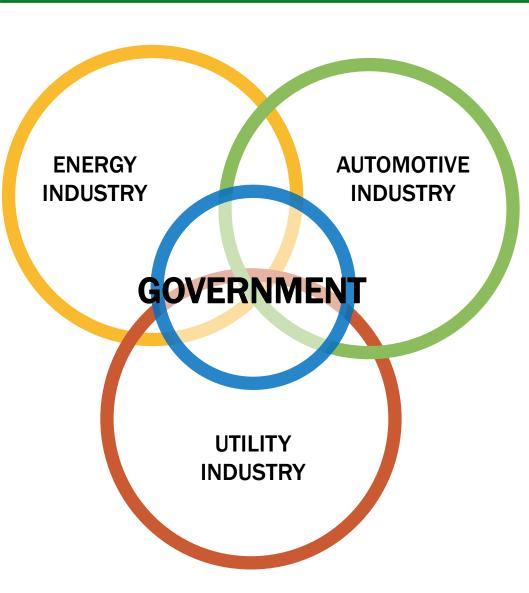
#### **Energy Efficient Mobility Systems**

Identify pathways and develop innovative tools and technologies that can dramatically improve mobility. Metric: mobility energy productivity/affordability

# **EERE develops research metrics from Cradle-to-Grave Lifecycle Analysis of Costs, Energy Use and Emissions**



## **Government-Industry Partnerships LDV Focus**

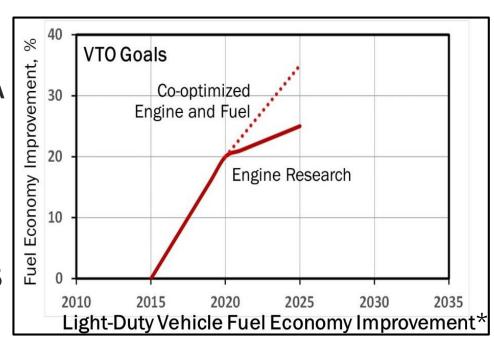




- Prevents duplication, ensures
   Federally-funded research remains
   focused on critical barriers to
   technology commercialization
- 13 Technical Teams convene monthly, set joint targets, develop joint roadmaps, evaluate R&D progress
- Executive Steering Group provides overall strategic direction
- energy.gov/eere/vehicles/us-drive

## **Advanced Engine and Fuel Technologies**

- By 2025, 25% improvement from engine efficiency relative to a 2015 baseline vehicle\*, while meeting EPA Tier 3 emissions standards.
- An additional 10% improvement in fuel economy by 2025 through engine and fuel Co-Optimization
- Success case is equivalent to a 2025 unadjusted, combined fuel economy of 48.6 MPG (without credits or multipliers, not including other improvements in light-weighting, aerodynamics, hybridization, etc.)



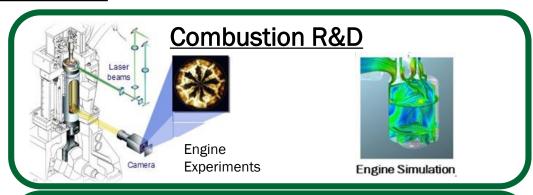
## **Next Generation Engines and Fuels**

#### Research is focused on 3 key areas:

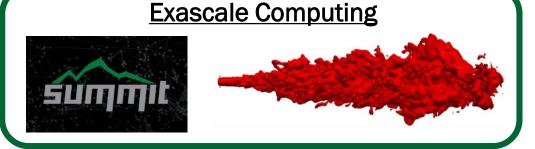
 New combustion regimes, multi-mode SI/ACI, and lean dilute combustion

2. "Low Temperature" emissions control systems

3. Can we fully model/simulate/optimize combustion using exascale computing?







## **Co-Optimization of Fuels and Engines**

#### **Co-Optima Goal:**

Develop fuel and engine technologies that will work in tandem to achieve significant efficiency gains.

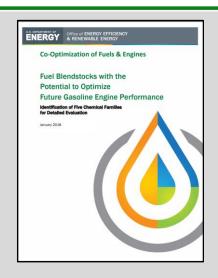
- What fuel / engine combinations are sustainable, affordable, and scalable?
- What fuel properties maximize engine performance?
- How do engine parameters affect efficiency?

## Co-Optima Team:

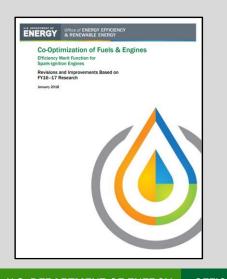
- Bioenergy Technologies Office
- Vehicle Technologies Office
- 9 National Labs
- 13 Universities
- External Advisory Board:
- USCAR, American Petroleum Institute, Fuels Institute, Truck & Engine Manufacturers Association, Advanced Biofuels Association, Flint Hills Resources EPA, CA Air Resources Board, UL, University Experts, Industry Experts



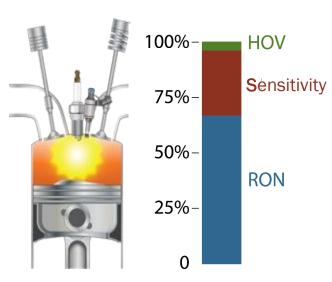
#### **Co-Optima Research Identifies Key Properties**



## energy.gov/eere/bioenergy/co-optima-publications

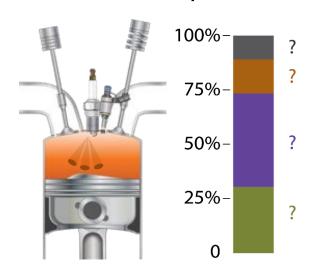


#### **Boosted SI**

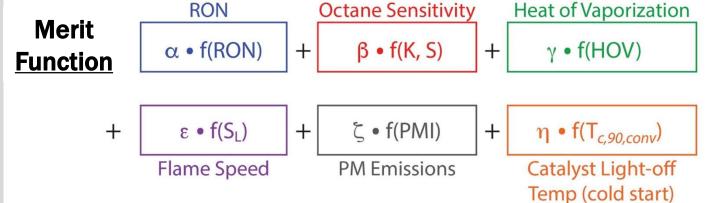


Relative ranking of key fuel properties for efficiency benefit

#### Multi-mode SI/ACI



Current research is identifying relative importance of key fuel properties



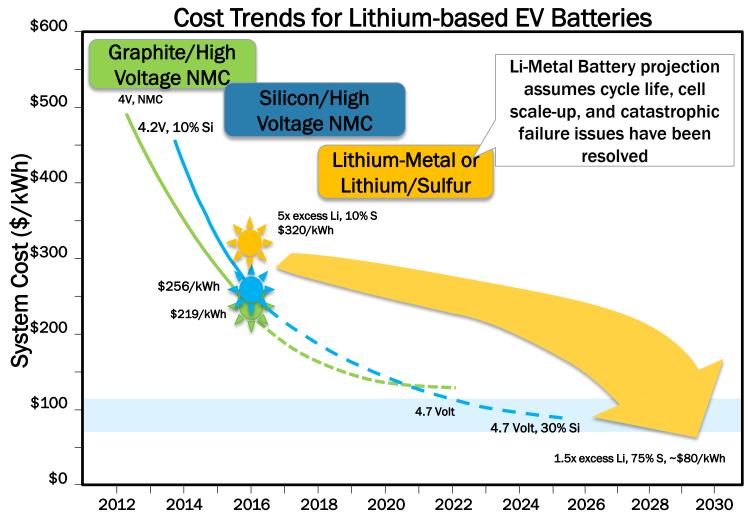
## **Potential for Future Battery Technology Cost Reductions**

#### **Status**

DOE R&D has lowered the cost of EV battery packs to \$219/kWh; ~80% reduction since 2008

#### **GOAL**

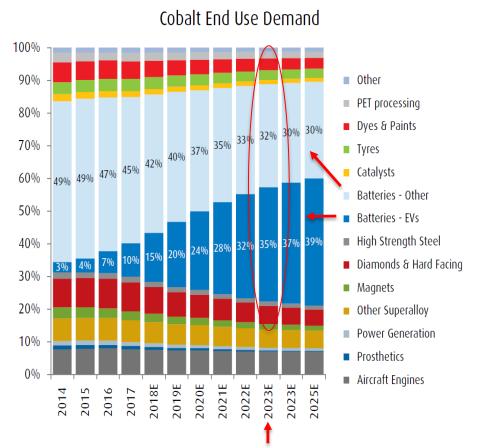
Reduce the cost of EV battery packs to less than \$100/kWh, increase range to 300 miles and decrease charge time to 15 minutes or less.

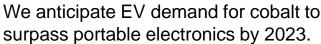


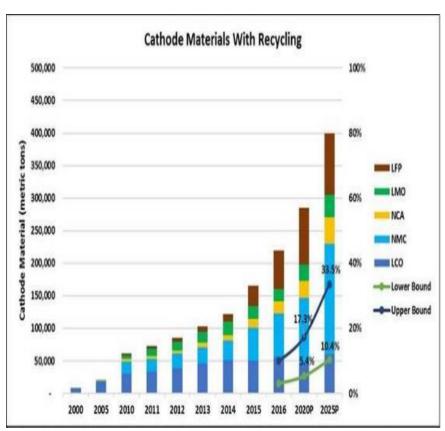
SOURCE: BatPaC: A Lithium-Ion Battery Performance and Cost Model for Electric-Drive Vehicles http://www.cse.anl.gov/batpac/ and US Advanced Battery Consortium

## Launching significant battery critical materials research

Cobalt is considered the highest material supply risk for EVs in the short and medium term







#### Potential for materials demand filled by recycled materials

- Lower Bound: 10.4% cathode materials supply with 50% collection and 50% material recovery
- Upper Bound: 33.5% cathode materials supply with 90% collection and 90% materials recovery

Source: National Energy Renewable Laboratory CEMAC

## **Pursuit of Extreme Fast Charging (XFC)**

## Charging at less than 15 min for 200 miles

Some key findings of recent EERE Report include:

- Potential negative impacts to the life, safety, and cost of the battery
- Potential negative impacts to the grid

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			TESLA	(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;

## **Lightweight Research Strategy and Goal**

#### **Lighweighting Focus**

Joining Dissimilar Materials, Carbon Fiber, and Propulsion

To get 25% glider weight reduction compared to 2012 baseline at <\$5/lb. saved by 2030

#### **Manufacturing Innovation**

- Reducing price of Carbon Fiber
- Use additive manufacturing to reduce costs (collaboration with Advanced Manufacturing Office)

## **Hydrogen Fuel Cell Electric Vehicles**



- Fuel efficiency: Over 60 mpgge\*
- Range: More than 360 mi.
- Refueling Time: 3-5 mins.
- Nearly 5,000 cars on U.S. roads<sup>†</sup>

\*miles per gallon of gasoline equivalent +As of Jun 2018

## Cost of driving a fuel cell car

Today

(current tech. manufactured at high volume)

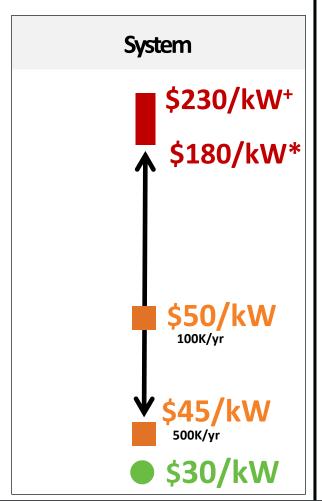
**Ultimate Target** 

\$0.39 per mile

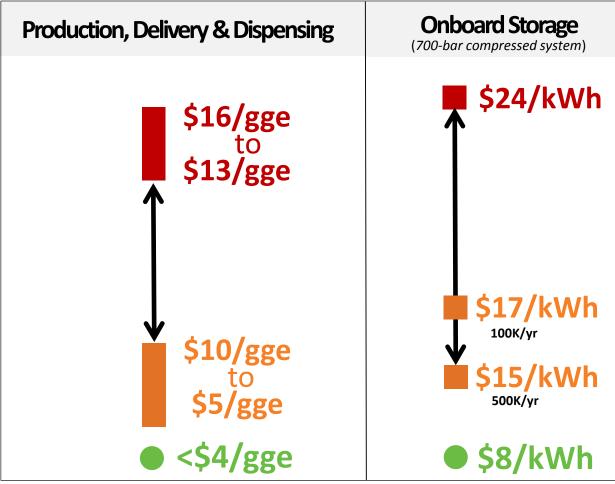
\$0.27 per mile

## **DOE Cost Status & Targets for Fuel Cell/Hydrogen**





#### Hydrogen R&D









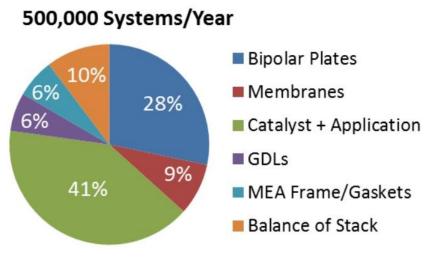
Note: Graphs not drawn to scale and are for illustration purposes only.

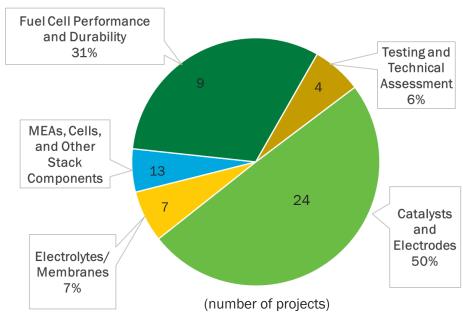
<sup>&</sup>lt;sup>†</sup>Based on commercially available FCEVs \*Based on state of the art technology gge: gallon of gasoline equivalent

## **Fuel Cell R&D Priorities and Strategy**

#### PEMFC Stack Cost Breakdown

#### **R&D Portfolio Funding Distribution**





<u>Catalyst cost</u> is projected to be the largest single component of the PEMFC stack cost



### <u>Strategy</u>

- Reduce or eliminate PGM levels in catalysts \*
- Improve MEA performance

\* PGM elimination mitigates US dependence on precious metal imports

## **Production and Delivery R&D Priorities and Strategy**

#### Challenge

#### **Strategies**

#### **R&D Focus**

#### **Key Areas**

#### Sustainable Low-Cost Hydrogen

- Materials efficiency and durability
- Feedstock use
- Capital costs
- Station Footprint

## Foundational and Applied Research

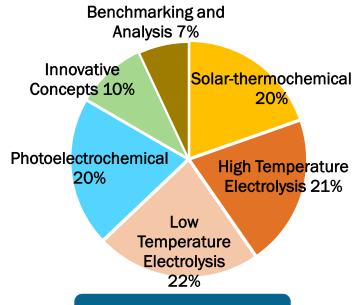
- Foundational R&D to enable broad H<sub>2</sub> production options
- Novel integration strategies for delivery

## Research Guided by Techno-economics

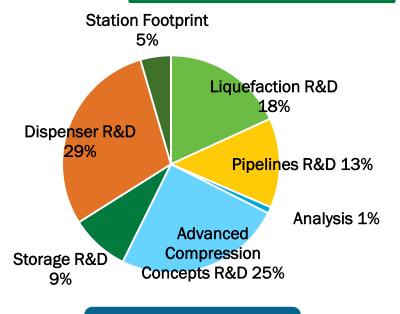
 Early-stage materials R&D addressing key challenges in energy conversion, catalysis, separations, compression, hydrogen compatibility, etc.

## Enable H<sub>2</sub> production from diverse domestic resources

- Advanced water-splitting
- Waste & bio-conversion
- Nuclear/hybrid approaches
- High strength steels
- Non-mechanical compression and liquefaction



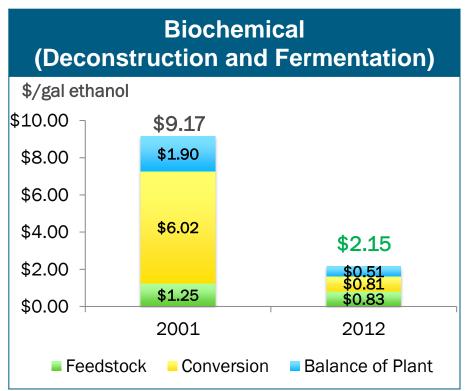
R&D
Portfolio
Funding
Distribution

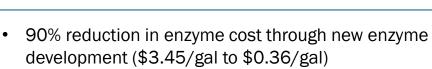


H<sub>2</sub> Delivery

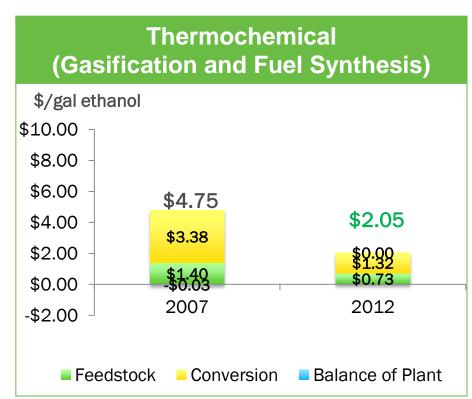
## Status: Cellulosic Ethanol Research, Scale-up challenges remain

DOE's National Laboratories successfully showed feedstock and conversion processes that reduced the modeled mature cost of production of cellulosic ethanol





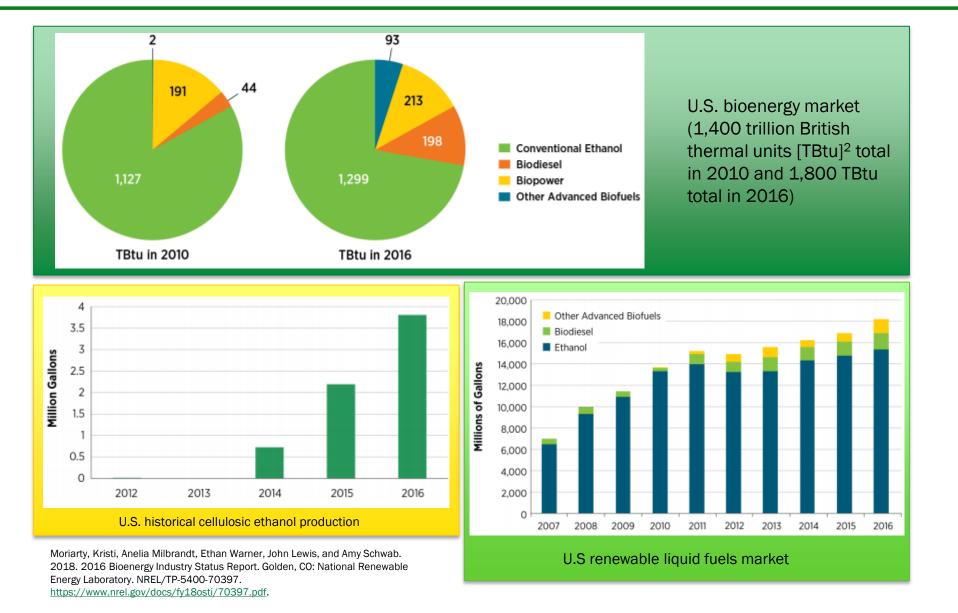
New microbes which improve sugar use from 50% to >95% (glucose, xylose, arabinose)



- Improved methane conversion from 20% to 80% in thermochemical processes
- Ethanol yields increased from 62 gallons/ton of dry biomass to > 84 gallons/ton of dry biomass

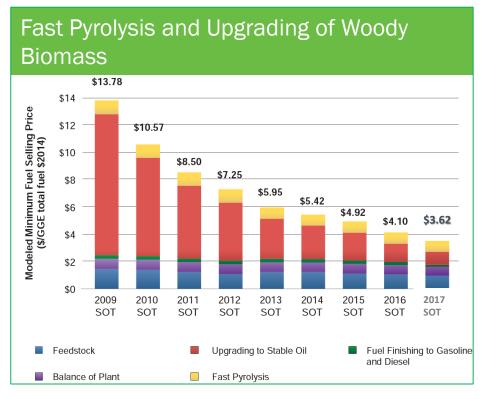
Bioenergy Technologies Office Multi Year Program Plan, July 2014, Appendix D

## **Current State of the Bioenergy**



# **2017 Key Accomplishment: Direct Liquefaction Verification**

DOE's National Laboratories showed feedstock and conversion processes that reduced the modeled mature cost of production of renewable gasoline and diesel



> 70% price reduction in 8 years

- The pathway presented here (the conversion of biomass into infrastructure-compatible hydrocarbon fuels via fast pyrolysis) represents a goal case targeting performance
- **Terrestrial Feedstock Supply:** By 2017, verified FSL systems to supply produce woody feedstocks at \$84/dry ton (in 2009 \$113/dry ton).
- **Conversion R&D:** In 2017 conversion costs reduced to \$2.62/gasoline gallons equivalent (in 2009 \$12.33/gge) technical breakthroughs: eliminated the need for a hydrocracker

## **Bioenergy Technologies Office's Research Areas**



#### **Production & Harvesting**

#### Feedstock Supply & Logistics

Works to reduce the cost, improve the quality, and increase the volume of sustainable feedstocks available for delivery to a conversion process.

#### **Advanced Algal Systems**

Focuses on improving the productivity of algal biomass and enhancing the efficiency of cultivation and harvesting.



#### Conversion & Refining

#### Conversion

Develops technologies to convert nonfood feedstocks into biofuels, bioproducts, and biopower.

Conducts feedstock blend testing, separations, materials compatibility evaluations, and techno-economic analyses to focus research on highest impacts.



#### **Systems Integration**

## Advanced Development and Optimization

Aims to reduce technology uncertainty in bioenergy by integrating individual technologies into a system/process and provides vital knowledge fed back to research programs.

#### Crosscutting

#### Sustainability and Strategic Analysis

Supports program decision-making and develops science-based strategies to understand and enhance the economic and environmental benefits of advanced bioenergy.

## **Select Bioenergy Technologies Office Consortia**



#### Feedstock-Conversion Interface Consortium (FCIC)

<u>Guiding Principle</u>: Feedstock chemical, physical and mechanical characteristics are primary considerations for process development, scale-up, and integration.

Focus: Science of scaling and integration of feedstock handling and conversion technologies.

<u>Ultimate Goal</u>: Develop and verify integrated feedstock supply-preprocessing-conversion processes that achieve >90% operational reliability (i.e., time-on-stream).



#### **Chemical Catalysis for Bioenergy** (ChemCatBio)

ChemCatBio is leveraging unique DOE capabilities for accelerating development of catalysts and related technologies to enhance conversion efficiency for the bioeconomy

ChemCatBio improves the Catalyst Value Factor for catalytic biomass conversion processes by improving productivity, increasing lifetime, and reducing catalyst cost.



#### Agile BioFoundry (ABF)

The Agile BioFoundry is a virtual, public infrastructure investment to increase U.S. industrial competitiveness, by providing a set of Design-Build-Test-Learn resources accessible to synthetic biology companies for enabling industry to reduce time-to-market of new bioproducts while driving conversion efficiency breakthroughs.

## **Potentially Untapped Carbon Resources**

Leveraging DOE's National Laboratories expertise in polymer deconstruction in biomass and applying it to distributed sources of waste carbon to make molecular building blocks for fuels, products, and energy.

Wet Wastes:
Biosolids, Food
Wastes, Manures







Economically Advantageous Feedstocks



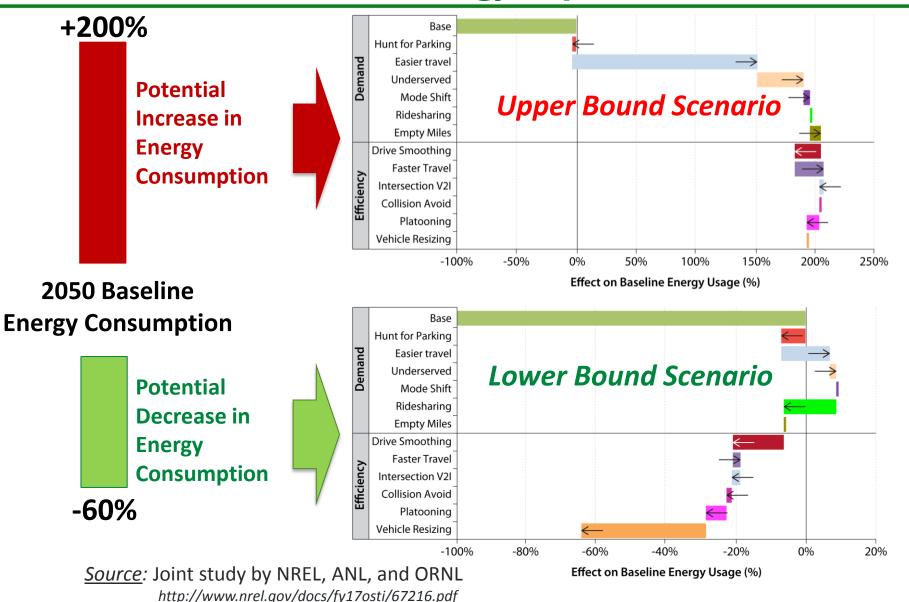


Solid Wastes: Sorted Municipal Solid Waste including Plastics





# Future Mobility: Autonomous, Connected, & Shared Potential for Dramatic Energy Impacts



# **Energy Efficient Mobility Systems (EEMS) Efforts Coordinated with U.S. DOT**

# SMART Mobility Lab Consortium Advanced Fueling Infrastructure

Connected & Automated Vehicles

7-Lab Consortium

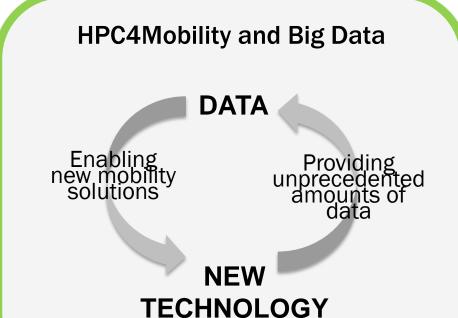
Urban Science

30+ Projects 65 Researchers

\$16M in FY2018

Mobility Decision Science

Multi-Modal Transport



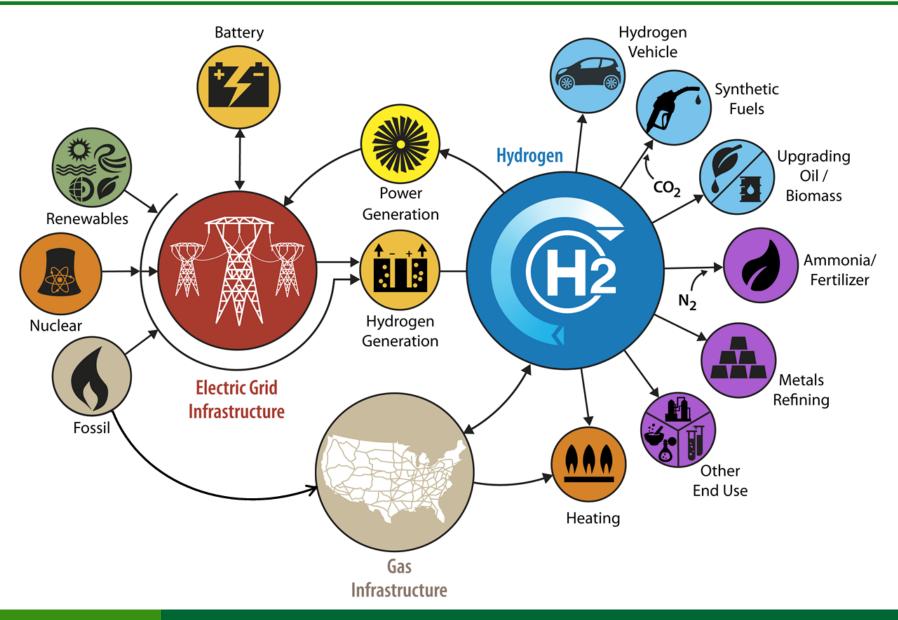
## Examples ongoing research:

- Platooning in the real world
- Innovative technologies addressing 1<sup>st</sup>/last mile
- Algorithms to allow drive cycle smoothing
- Refueling infrastructure for future transportation needs

### **Conclusions**

- DOE pursues portfolio of LDV options for consumer choice
- System efficiency opportunities, i.e., EEMS, exist beyond traditional vehicles and fuels technology research
- DOE support in other critical areas
  - Heavy duty vehicles, off-road vehicles, natural gas
  - Stationary fuel cells, other high-value applications
  - Bioenergy research for chemicals, products, power
- Synergies between transportation and other sectors
  - Reducing battery and hydrogen storage costs important to grid flexibility (with high variable RE) and resiliency in residential, commercial, industrial and grid scale applications.
  - Fossil Energy carbon capture technologies and other waste carbon sources combined with advanced biology, new catalysts technology, and low cost/curtailed electricity, creates opportunities for new molecular synthesis of chemicals, products, and fuels.
  - Example: H2@Scale

## H<sub>2</sub>@Scale: Enabling affordable, reliable, clean, and secure energy across multiple sectors



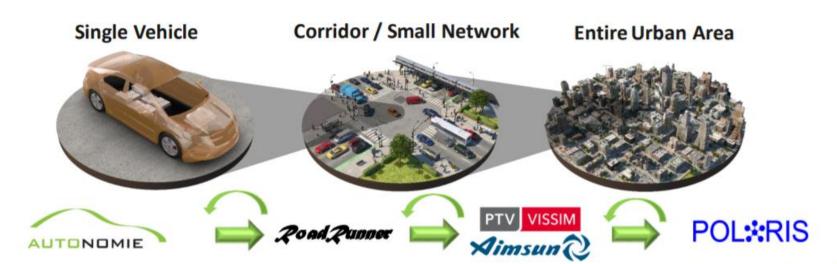


## Thank you!



## **BACK UP/ ALT SLIDES**

## **Backup: As Transportation Evolves, So Do Our Tools**



- Funded by US DOE
- Vehicle energy consumption
- VTO performance requirements, cost and benefits
- Only commercial tool with vehicle level control
- Licensed to >250 companies, cross-agencies

- Funded by US DOE
- Only system simulation of multivehicle and their environment focused on advanced control enabled by V2V, V2I...
- Uses Autonomie powertrain models

- Commercial Tools
- Microscopic traffic flow simulation
- Focus on detailed traffic flow, control

- Funded by US DOT/FHWA
- Agent-based mesoscopic traffic flow simulation
- Focus on traveler behavior, transport modes, technologies
- Use outputs from microsimulation, Autonomie, GREET & MA3T