About ARPA-E

**Mission:** To overcome long-term and high-risk technological barriers in the development of energy technologies

**Goals:** Ensure America’s
- Economic Security
- Energy Security
- Technological Lead in Advanced Energy Technologies

**Means:**
- Identify and promote revolutionary advances in fundamental and applied sciences
- Translate scientific discoveries and cutting-edge inventions into technological innovations
- Accelerate transformational technological advances in areas that industry by itself is not likely to undertake because of technical and financial uncertainty

Reduce Energy Imports
Reduce Emissions
Improve Energy Efficiency
Energy Technology “Mountains of Opportunity”

- **Research**
  - ARPA-E now

- **Prototype**
  - ARPA-E Future?

- **Demonstration**
  - Commercialization

- **Commercialization**
  - Manufacturing/Market
  - $1M

- **Private Sector**
  - $10M
  - $100M

*“The new agency proposed herein [ARPA-E] is patterned after that model [of DARPA] and would sponsor creative, out-of-the-box, transformational, generic energy research in those areas where industry by itself cannot or will not undertake such sponsorship, where risks and potential payoffs are high, and where success could provide dramatic benefits for the nation.”…

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**ARPA-E’s History**

- **2008**: The COMPETES Act is signed.
- **2009**: The American Recovery & Reinvestment Act is signed.
- **2009-2016**: The Advanced Research Projects Agency for Energy (ARPA-E) is established.
- **2010-2016**: ARPA-E announces programs. The number of announced programs increases from 1 in 2009 to 500+ by 2016.
- **2009-2016**: ARPA-E awards money increasing from $400 Million (Recovery Act) to $291 Million (FY2016).
- **2010-2013**: ARPA-E hires T2M from Inception.
- **2011-2012**: ARPA-E hires 1st Deputy Director for Commercialization.

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**Timeline**

- **2007**: Rising Above the Gathering Storm is published.
- **2009**: American Recovery & Reinvestment Act is signed.
- **2010**: 1st Deputy Director for Commercialization
- **2011**: 1st Programs with T2M from Inception
- **2012**: 1st T2M Hires
- **2013**: Anticipated
- **2014**: Anticipated
- **2015**: Anticipated
- **2016**: Anticipated

**Funding**

- **2009-2016**: ARPA-E awards money increasing from $400 Million (Recovery Act) to $291 Million (FY2016).
## Program Portfolio

<table>
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<th>ELECTRICITY GENERATION</th>
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<th>EFFICIENCY &amp; EMISSIONS</th>
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### Timeline
- **2010 - 2012**
- **2013-2014**
- **2015**
- **2016**
ARPA-E supports multi-institutional teams with substantial involvement from the private sector:

- 72% of projects involve more than one institution
- 84% of projects include the private sector, as leads or partners
ARPA-E’s Success

- New Companies formed (Public, Acquired, or Private)
- Over $1.25 Billion in Private Sector Funding
- Follow-on Funding from Other Government Agencies
Motivation: Megatrends In America

Population Increase
2015: 310 million people
2045: 390 million people
In 30 years, our population is expected to grow by about 70 million—more than the current populations of NY, TX, and FL.

Older Americans — Redefining Longevity
By 2045, the number of Americans over age 65 will increase by 77%. About one-third of people over 65 have a disability that limits mobility. Their access to critical services will be more important than ever.

Millennials — Shaped by Technology
There are 73 million Millennials aged 18 to 34. They are the first to have access to the internet during their formative years and will be an important engine of our future economy. Millennials are driving less. By the end of the 2000s, they drove over 20% fewer miles than at the start of the decade.

Income Inequality
10% of the population takes home one-third of our national income. Transportation is the second-largest expense for U.S. households.

Bumper-to-Bumper
On average, we spend over 40 hours stuck in traffic each year. The annual financial cost of congestion is $121 billion.

Megaregions and Shifts in Population Centers
11 megaregions are linked by transportation, economics, and other factors. They represent over 75% of our population and employment. In 2014, 365,000 people moved to the South—up 25% from 2010—and moves to the West doubled.

Demographic and social change
Shift in global economic power
Rapid urbanisation
Climate change and resource scarcity
Technological breakthroughs

Increase in global energy demand by 2035
33%
By 2020, more than 50% of the workforce will be Generation Y and Z members—and they have grown up connected, collaborative and mobile.

The majority of demand will come from China, India and the Middle East.

Motivation: Technology is Changing

More and more, the transportation sector is relying on data to drive decisions, and on technology to reimagine how we move people and goods.

Connected Vehicles
Vehicles that communicate are the latest innovation in a long line of successful safety advances.
The motor vehicle fatality rate has dropped by 80% over the past 50 years.
Connected vehicles and new crash avoidance technology could potentially address 81% of crashes involving unimpaired drivers.

Robotics
Advances in robotics are changing transportation operations and will impact the future transportation workforce.
Robots will perform vital transportation functions, such as critical infrastructure inspection.

NextGen
GPS and new technologies are leading to a safer, more efficient U.S. airspace.
By 2020, one-second updates will pinpoint the aircraft location and speed of 30,000 commercial flights daily.

Real-time Travelers
Mobile access to everything from traffic data to transit schedules informs our travel choices.
90% of American adults own a mobile phone.
20% use their phones for up-to-the-minute traffic or transit information.
Smartphones are regularly used for turn-by-turn navigation.

Big data is all around us. Global data generated is projected to grow by 40% annually.
Data enables innovative transportation options, such as car-sharing, ride-sharing, and pop-up bus services, and more rapid delivery of goods.

Motivation: Energy Used Per Traveler

Quads Used

MPGe (per traveler)

0.058 0.053 0.011 0.0074

0 3 6 9 12

0 60 90 120

44 32 23 11

4.4 47 48 108
Future Mobility: Vehicle Ownership vs. Control

Autonomous Control

Private Autonomy
Sub-Optimal

Shared Autonomy
Optimal

Private Ownership

Shared Ownership

Private Drivers
Baseline

Shared Drivers
Current Trend

Human Control
What are the Energy Implications of Future Mobility?

2050 Baseline Energy Consumption

Potential Increase in Energy Consumption: +200%

Potential Decrease in Energy Consumption: -90%
What are the Energy Implications of Technology?

% Change in Energy Consumption Due to Vehicle Automation

- Platooning
- Eco-Driving
- Congestion Mitigation
- De-Emphasized Performance
- Improved Crash Avoidance
- Vehicle Right-Sizing
- Higher Highway Speeds
- Increased Features
- Travel Cost Reduction
- New User Groups
- Changed Mobility Services
- Infrastructure Footprint

Does increased Connectivity, Automation, and MaaS lead to increased or reduced transportation energy use and GHG emissions?

Data from: http://www.qualenergia.it/sites/default/files/articolo-doc/Automation%20manuscript-accepted.pdf
Can CAVs Reduce Energy Consumption?

**Goal:** Develop new and emerging vehicle dynamic and powertrain (VD&PT) control technologies to reduce the energy consumption of future vehicles through the use of connectivity and vehicle automation.

**Vision:** Reduce the energy consumption of a 2016 baseline light-, medium- or heavy-duty vehicle by at least 20% through connectivity and automation (of up to L3 capability), without extensive powertrain architecture or vehicle hardware modifications.
Can Commuter’s be Optimized for Energy Efficiency?

**TRANSNET Program**
Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation
TRANSNET Overview

- Optimize the **energy efficiency** of urban, multi-modal transportation, while maintaining expected quality-of-service
  - Embed system-level energy optimization into the daily commute and emerging urban mobility services
  - Provide high accuracy mobility and energy simulations for planning and evaluation purposes
The Solution Elements of TRANSNET

- **Decentralized Predictive Models**
  - Interpret Data (Prediction)

- **Data Aggregation**
  - Measure Energy Use (Model)

- **Mode**

- **Route**

- **Traveler Incentives**
  - Improve Efficiency (Control)

- **Traveler**
TRANSNET:

- **System Model (SM):** A parameterized model of a multi-modal urban transportation network with accurate energy estimation per traveler
- **Control Architecture (CA):** Network control that enables system-level energy reductions via personalized information and incentives to individual travelers

Approach (initial phase):

Build SM and use it to benchmark the energy effects of the CA *in silico*, for various scenarios

Some challenging problems:

- **Quality-of-Service** Combining unconstrained & constrained modes (e.g., car ➔ transit)
- **Integration across scales** Macro-, meso-, and micro-scale, computed concurrently & dynamically
- **Influencing traveler behavior** What can really motivate significant behavioral shifts?
<table>
<thead>
<tr>
<th></th>
<th>“Traditional”</th>
<th>TRANSNET</th>
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<tbody>
<tr>
<td>Simulation</td>
<td>Long-term planning</td>
<td>Real-time predictive</td>
</tr>
<tr>
<td>Focus</td>
<td>Vehicle</td>
<td>Traveler</td>
</tr>
<tr>
<td>Controls</td>
<td>Tolls/Laws</td>
<td>Information &amp; Incentives</td>
</tr>
<tr>
<td>Optimization</td>
<td>Time</td>
<td>Energy (+Time)</td>
</tr>
</tbody>
</table>
TRANSNET: 5 Projects; $14.5M

- **Modes:** Walk, Bicycle, Car, Bus, Rail, Rideshare
- **Variables:** Departure Time & Location, Route, Arrival Time & Location, Travel Mode, Number of Travelers, Traffic Incidents, Congestion, Events, Parking, Weather, etc.
- **Data:** INRIX, RITIS, Metro Services, DOT, Vehicles, Smartphones, & other Intelligent Transportation Systems
- **Controls:** Departure Times, Alternative Routes, Travel Modes
- **Traveler Incentives:** Personalized Info, Rewards, Points
PARC: Collaborative Optimization and Planning

Problem: Lack of knowledge about energy impacts and mobility options exacerbates independent travel behavior and sub-optimal energy use.

Solution: Develop planning and incentive algorithms to promote energy efficient collaborative travel behavior and adoption of efficient modes.

Project Description

• Developing a SOA multi-modal travel and energy use microsimulation for Los Angeles to analyze system energy effects of personalized incentive strategies.
• New multi-trip/multi-agent planning and optimization algorithms for collaborative mobility and new forms of dynamic ridesharing.
• Phone app and algorithms will pair transportation options and predict energy use to offer a personalized energy saving portfolio of paths through the network.
• Personality analysis will enable the optimization of messaging strategies to maximize the likelihood of adoption.

Project Outcomes

• Improved QOS and happier travelers.
• Real time energy reduction responses to changing network conditions.
• Quantified energy impacts of transportation decisions for citizens and cities.
• Access to new transportation service providers and collaborative travel options.

Supporting Partners

• LA Metro
• LA DoT
• LA Mayor
• SCAG
• INRIX

Greater information about available options and associated energy use will allow travelers to optimize commute and energy.
Georgia Institute of Technology: Network Performance Monitoring & Distributed Simulation

Problem: Centralized simulations are not sufficiently cost/compute scalable for population level personalized transportation prediction and energy advising.

Solution: Develop a distributed simulation system deployed on network and mobile devices to scalably predict conditions and influence efficient traveler behavior.

Project Description
- Link big data analysis and pattern recognition with simulation (traditional and distributed) to scalably connect traveler behavior to future network states and energy use.
- Estimate energy, time, and cost tradeoffs for alternative departure times, modes, driving styles, and routes.
- Use the phone app to deliver personalized messages to influence travel decisions and monitor outcomes and the associated energy costs.

Project Outcomes
- More accurate and efficient prediction of real time energy use and on road conditions.
- Cost and compute scalable real-time transportation energy and cost advising using monitored traveler responses and benefits assessment.

Supporting Partners
- Morehead State
- Wyle Consulting

Existing Commute Warrior app will be used as the platform for monitoring and advising.

Conceptual overview of a system linking data, simulations, and models via an efficient precomputed summary of network states.
NREL: The Connected Traveler

Problem: Energy effects are not yet directly connected to the daily commute or the emerging “Mobility As a Service” economy.

Solution: Pair NREL energy estimation methods with adaptations of Metropia congestion reduction techniques to promote energy smart travel behavior.

Project Description
- Will estimate energy savings resulting from incentivized traveler behavior for an existing real world user base rather than from modeling and simulations.
- Available phone app allows for A/B type testing of new personalized incentive strategies, potential for widespread adoption, and revealed traveler behavior.
- NREL data and engineering tools capture individual energy consumption in response to incentives and estimate system energy effects.
- Will use similar principles and incentive based techniques already shown to be effective in reducing congestion to promote energy reductions.

Project Outcomes
- Austin TX test bed will evaluate potential energy reductions matched to incentive strategies.
- A greater understanding of revealed commuter preferences w.r.t. tradeoffs of ease, energy, and cost.
- A fully developed energy saving commuter app that contributes to system wide congestion and energy benefits.

\[
\begin{array}{|c|}
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\text{Control Strategies} \\
\hline
\text{Change in Departure Time} \\
\text{Mode Choice} \\
\text{Carpooling} \\
\text{Alternate Routing} \\
\text{Alternate Destinations} \\
\text{Elimination of Need for Trips} \\
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\begin{array}{|c|}
\hline
\text{Incentive Spectrum} \\
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\text{Navigation Service} \\
\text{Travel Time Minimization} \\
\text{Predictive Analytics} \\
\text{Points, Points, Points} \\
\text{Products – ex., Starbucks coupon} \\
\text{Services – ex., transit pass or discount} \\
\text{Charity – ex., plant a tree} \\
\hline
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Personalized incentives will leverage demographics, personal preference, and available options to optimize energy use.
University of Maryland: Integrated and Personalized Traveler Information and Incentives

Problem: Energy reduction requires targeted personalized information integrated with centralized intelligent transportation systems.

Solution: Apply modern behavioral research to the design and presentation of incentives to guide travelers towards choices aligned with system optima.

Project Description
- Large-scale multimodal traveler and vehicle simulation for DC and Baltimore allows for the modeling and optimization of energy use and quality of service.
- Simulated individual energy profiles from multi-modal trajectories will indicate how route, driving style, and mode choices can be altered to optimize energy.
- An app will provide information and incentives, as well as information from social networks, to increase user adoption and incentive effectiveness.
- Cloud computing based prediction and optimization techniques will allow for eventual real world deployment of the incentive structure paired with an existing ITS infrastructure.

Project Outcomes
- Demonstrate a technology resulting in 10% overall energy savings with 20% market penetration.
- A greater understanding of stated and revealed commuter preferences w.r.t. tradeoffs of ease, energy, and cost.
- A fully developed regional model that will incorporate energy savings into day to day operations and planning.

Supporting Partners
- WMATA
- TomTom
- here
- RubryRide
- INRIX
- Virginia DOT
- Maryland SHA

The RITIS integration system allows the incorporation of public and private data types into transportation and energy management strategies.

Behavior research and optimization techniques will focus on personalized monetary/non-monetary rewards and information on travel conditions and options.
Massachusetts Institute of Technology: Mobility Electronic Market for Optimized Travel

Problem: Commercial and municipal stake holders lack a forum in which to advertise and leverage personalized incentives to change traveler behavior.

Solution: Create a market place of commercial, social, and independent incentives based on fungible units pegged to energy saving behaviors.

Project Description

- Developing an open-source agent-based simulator for multi-modal transportation networks, vehicle energy performance, and a wide set of traveler behaviors.
- A simulation-based system optimization framework that predicts traffic, energy consumption and the effect of different incentive strategies in real-time.
- Energy saving choices “pay out” at different token rates according to real-time system based optimization and personalized reward optimization.
- A personalized trip menu with real-time information and incentives integrated with a travel diary and an electronic mobility market in a smartphone app.

Project Outcomes

- System-wide energy optimization in response to real-time data.
- Quantification of the effect of personalized information and incentives on energy savings.
- Flexible platform for reward exchange using an app based tool.
- Energy performance assessment for Boston.

Supporting Partners
- Google
- City of Boston
- MPO
- MBTA

Conceptual framework showing the relationship between the energy and mobility simulations, system optimal states, and user needs linked by the token system.

Proposed mobility market place will offer a variety of commercial and civic incentives that are pegged to the network state and travel decisions facing a user.
Multi-Modal Commuter Dashboard

Policy Levers to Aid the Transportation Evolution

- Invest in alternative fuel research and infrastructure and the development of fuel efficient technologies
- Subsidize the purchase of electric and alternative-fuel vehicles
- Tax carbon emissions
- Support pricing and operational strategies that reduce congestion on roadways
- Increase and extend fuel efficiency standards across all modes
Policy Levers to Aid the Transportation Evolution

- Support zoning and development policies that discourage urban sprawl and private autonomy
- Encourage companies to adopt telework policies
- Invest in transit, rail and maritime infrastructure to support mode shifts
- Increase international government-to-government engagement to pursue joint commitments to control greenhouse gas emissions
Accelerate the Transportation Evolution

Questions?

“Hang on—I’ll Uber us a school bus.”

Thank You

www.arpa-e.energy.gov