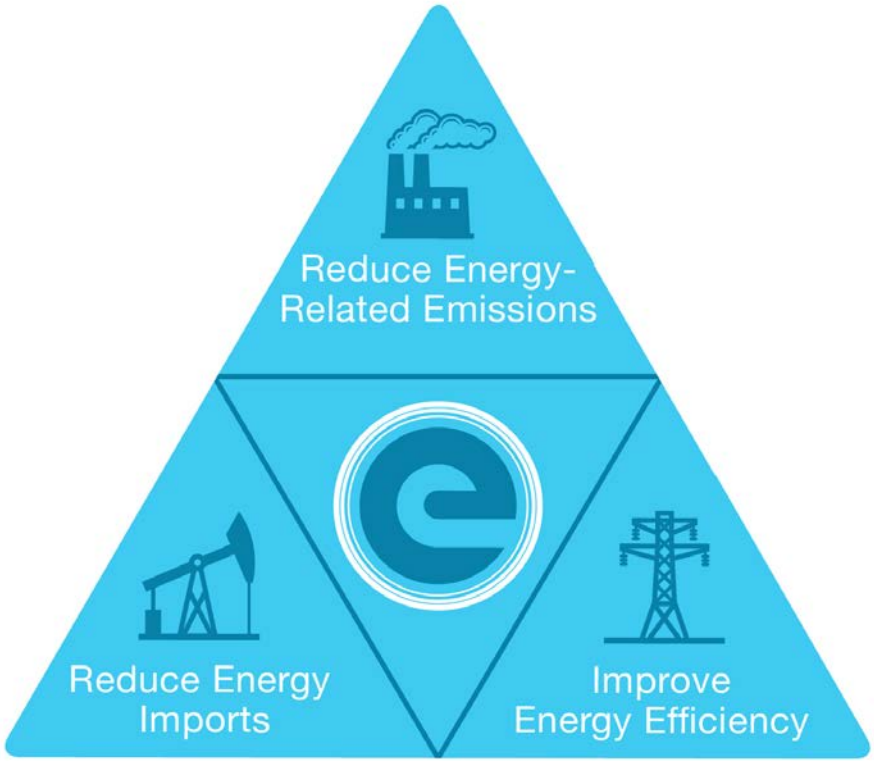
CHANGING WHAT'S POSSIBLE

Overview of ARPA-E Vehicular Energy Storage Programs

May 8, 2013

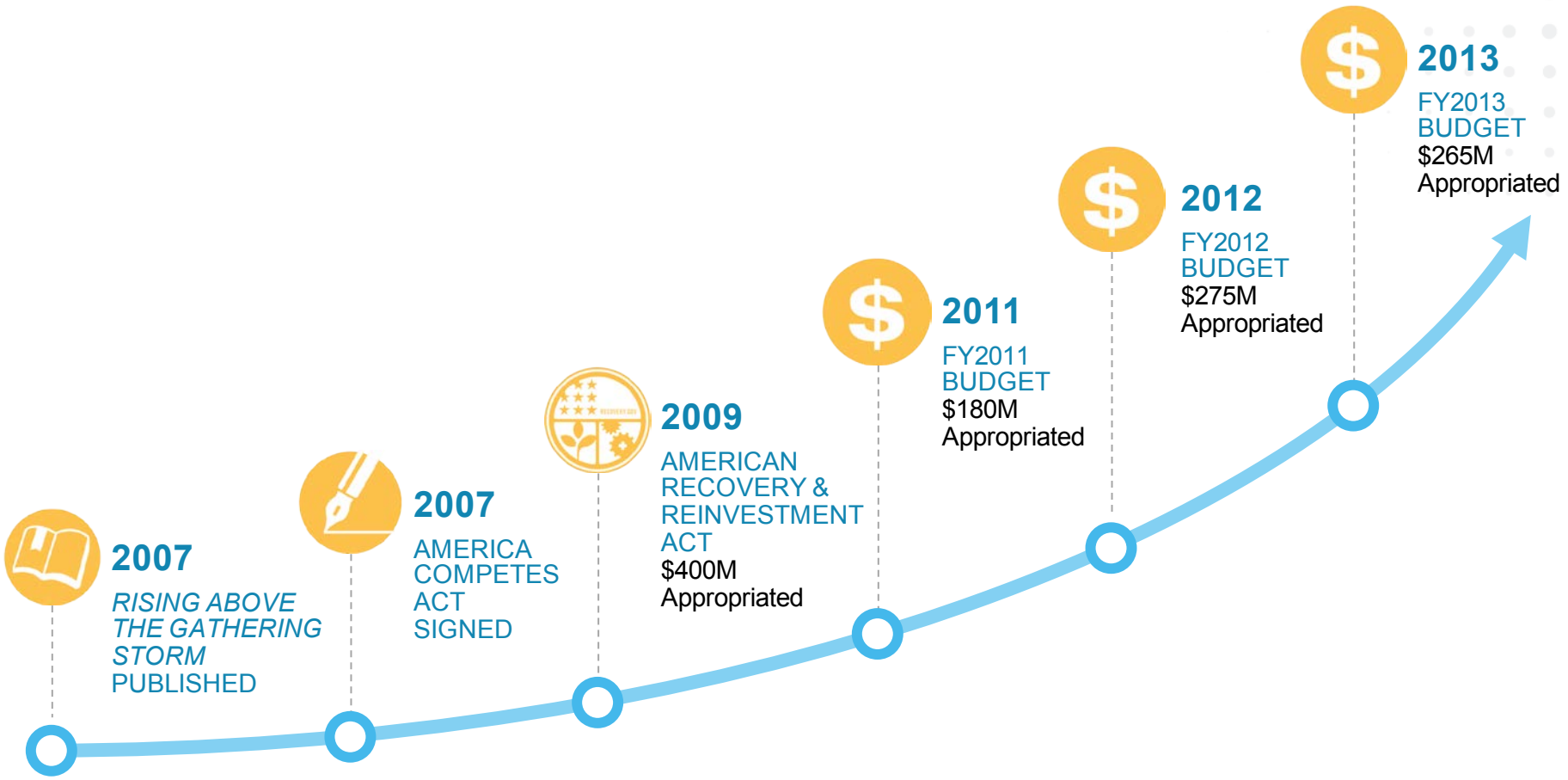
ARPA-E Mission

Catalyze the development of transformational, high-impact energy technologies

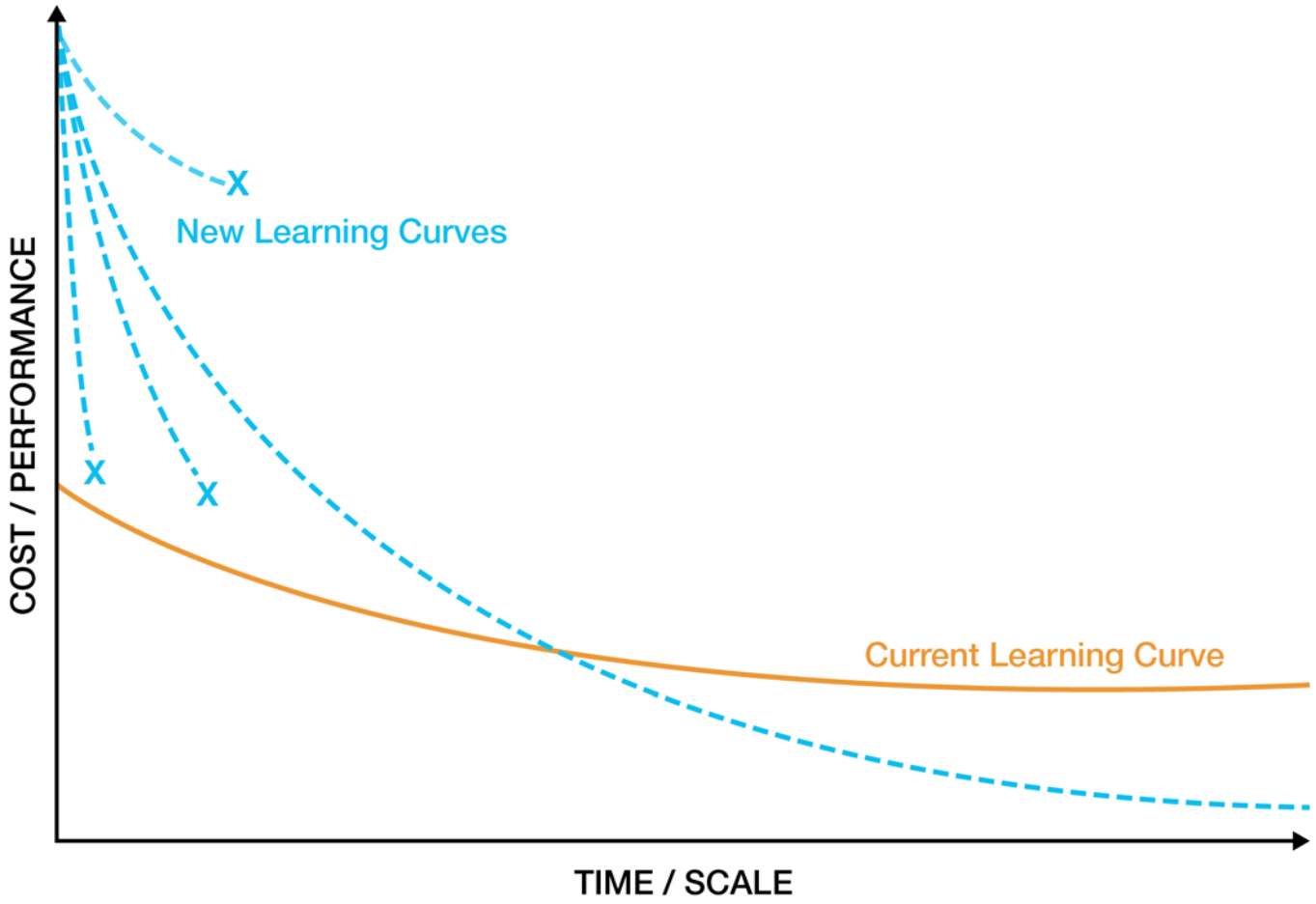


Ensure the U.S. maintains a lead in the development and deployment of advanced technologies

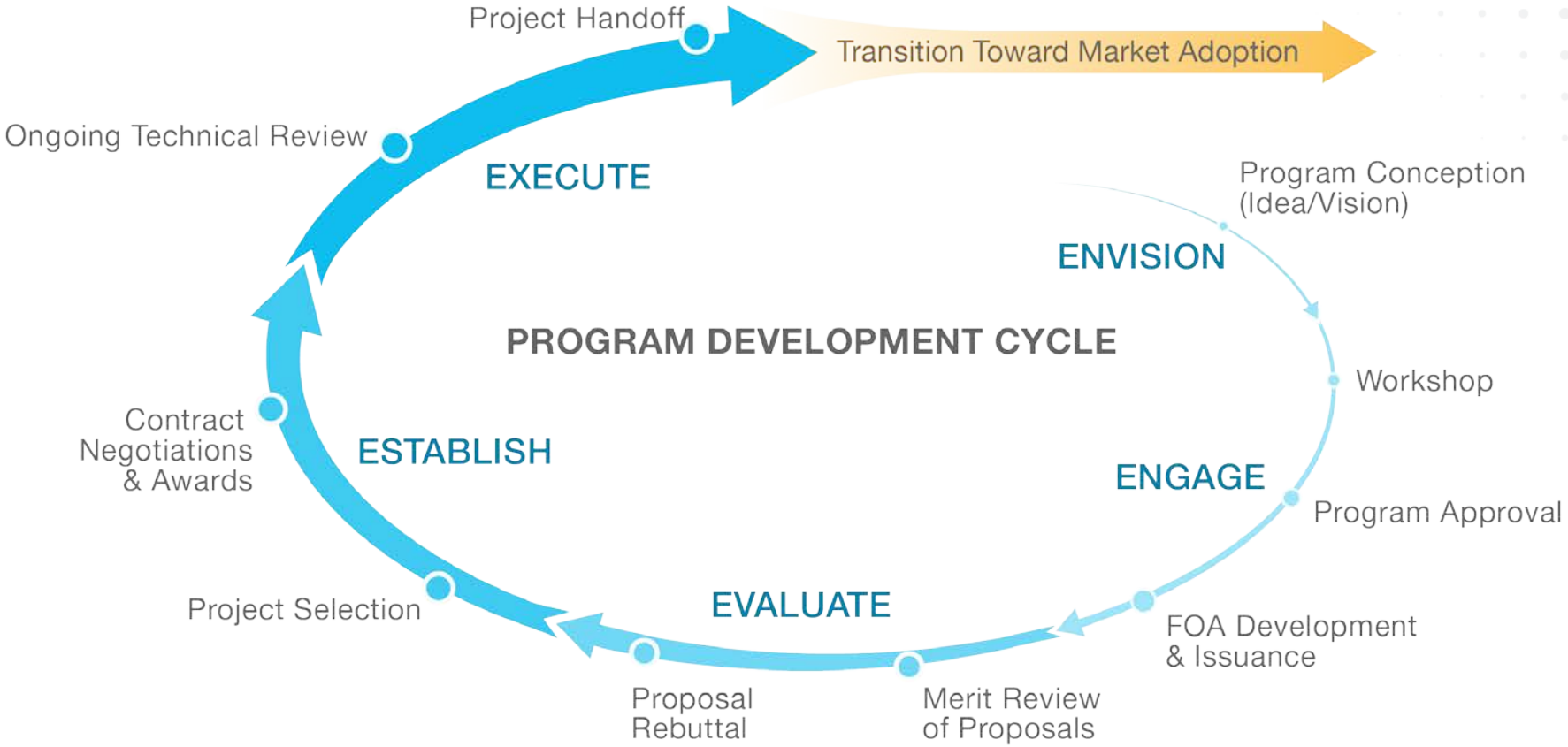
Evolution of ARPA-E



Creating New Learning Curves

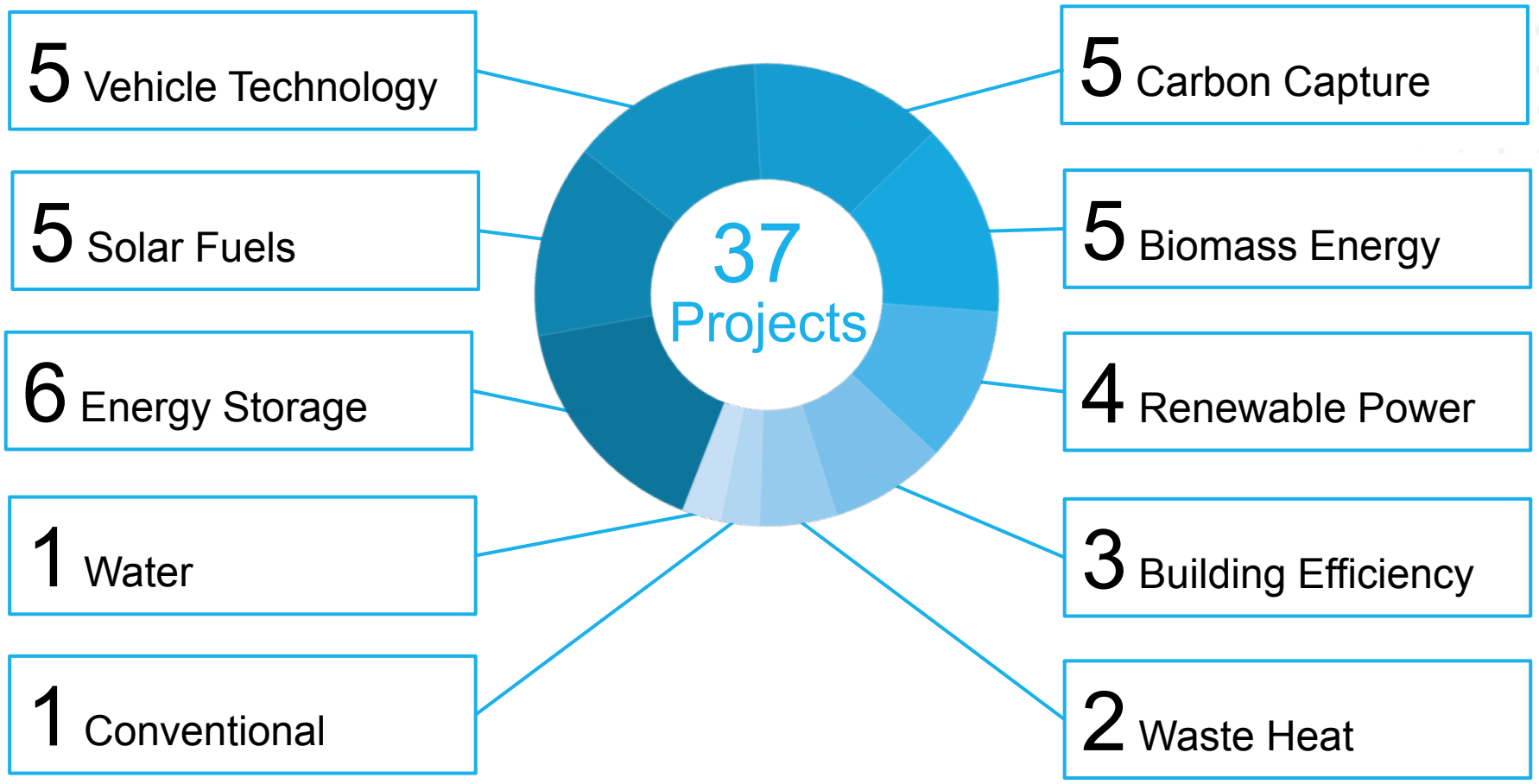


Technology Acceleration Model

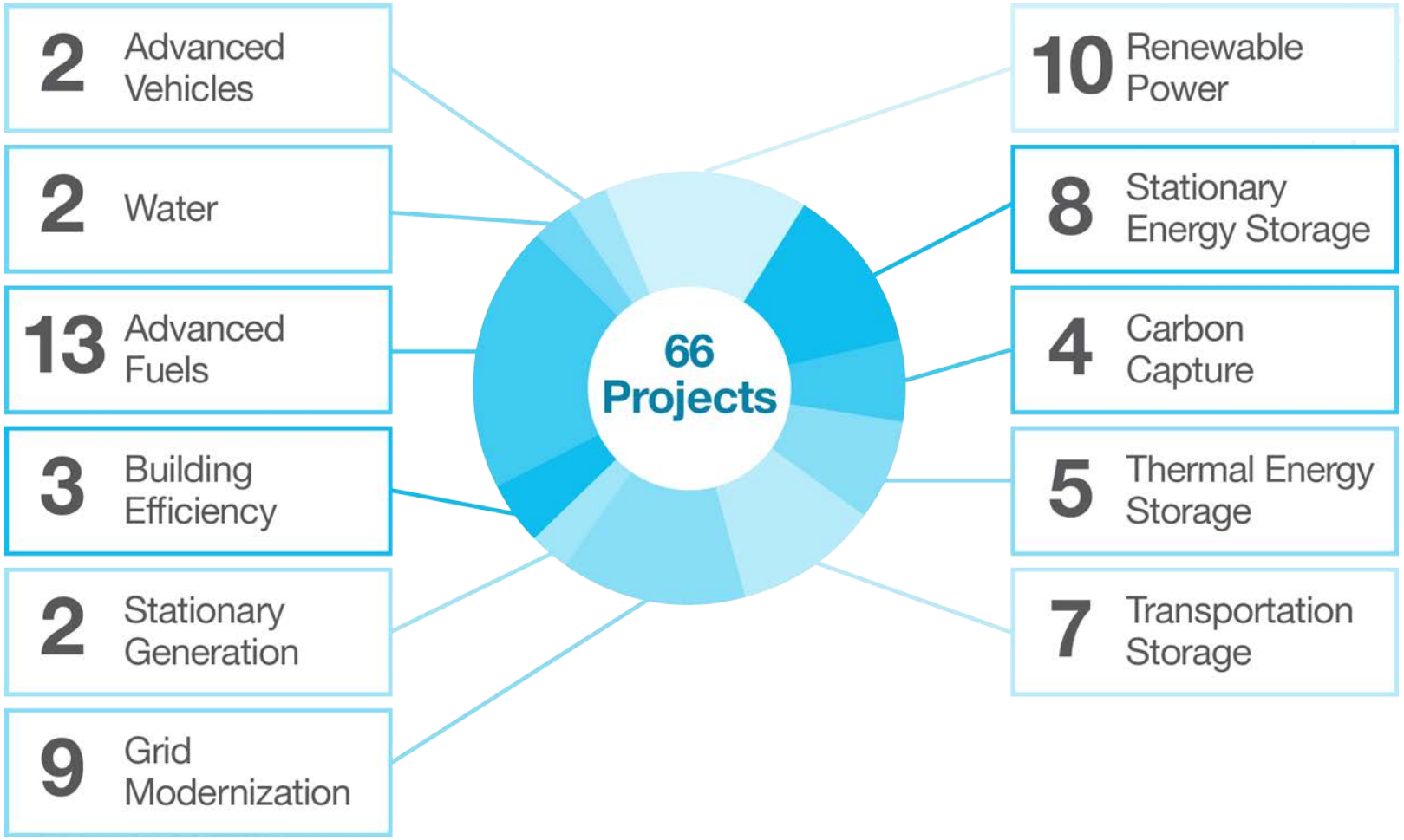


Open FOA

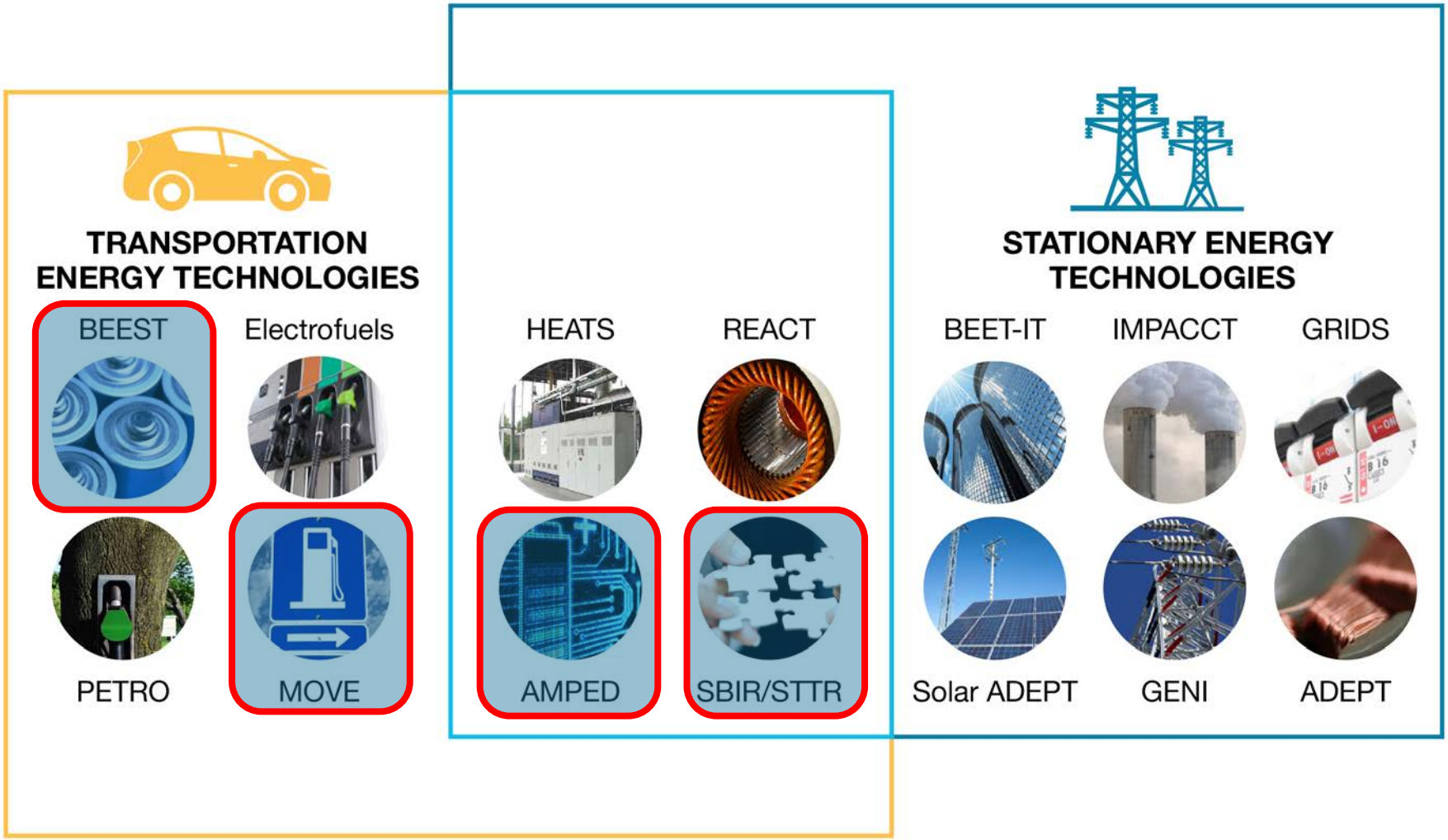
2009: $151M, 37 Projects, 10 Areas



OPEN 2012: 66 Projects, 24 States, 11 Areas



Focused Programs



What Makes an ARPA-E Project?

IMPACT

- High impact on ARPA-E mission areas
- Credible path to market
- Large commercial application

TRANSFORM

- Challenges what is possible
- Disrupts existing learning curves
- Leaps beyond today's technologies

BRIDGE

- Translates science into breakthrough technology
- Not researched or funded elsewhere
- Catalyzes new interest and investment

TEAM

- Comprised of best-in-class people
- Cross-disciplinary skill sets
- Translation oriented

Focused Programs (2010-2012)

14 Programs, $430M

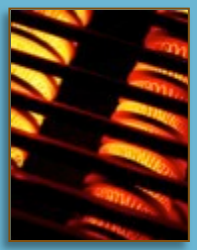
Stationary

Transportation

Electrofuels

BEEST

HEATS



REACT

IMPACCT

BEETIT

GRIDS

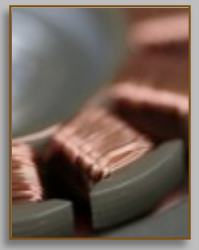
PETRO

MOVE

AMPED

SBIR/STTR

ADEPT



GENI

Solar ADEPT

BEEST:
Ultrahigh Energy Density Batteries

BEEST Program – Dane Boysen PD

Batteries for Electrical Energy Storage for Transportation

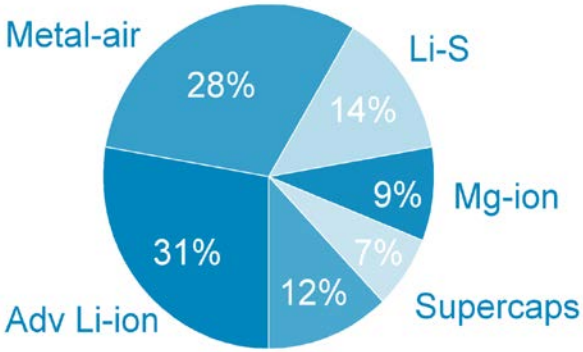
Objectives

- Cost-competitive with conventional vehicles
- 30% of today's cost at 2-5x energy storage
- 300-500% longer battery life + range

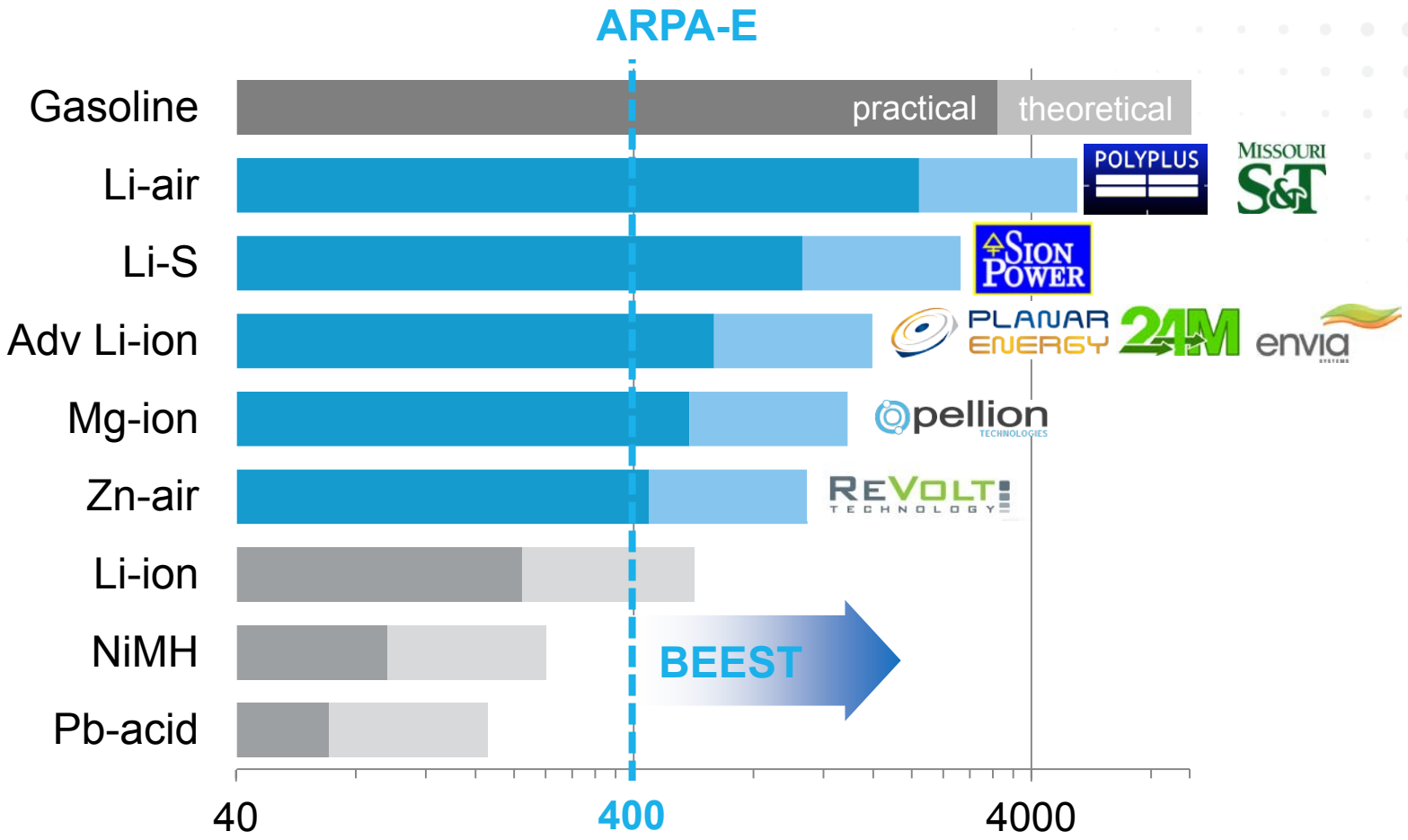
2-5x performance
+
1/3 price

1. 24M-MIT
2. Applied Materials, Inc
3. Missouri University of Science & Technology
4. Pellion Technologies, Inc.
5. PolyPlus Battery Company
6. Recapping, Inc.
7. ~~ReVolt Technology LLC~~
8. Sion Power Corporation
9. Stanford University
10. ~~Planar Energy~~ active program management

Term:	2010-2013
Projects:	10
Investment:	$33.6M



What is new about our approach?



New batteries chemistries with potential for higher energy density and lower cost

AMPED:
Make Better Use of Today's Batteries

Opportunity: Can't we do better with today's chemistries?

Balance of System	Physical protection Thermal management Charge balancing State monitoring Etc.
Overhead Capacity	Additional capacity buffer: safety/lifetime assurance
Base Capacity	Capacity needed to meet load requirement

State-of-the-Art XEV or Grid Storage Unit

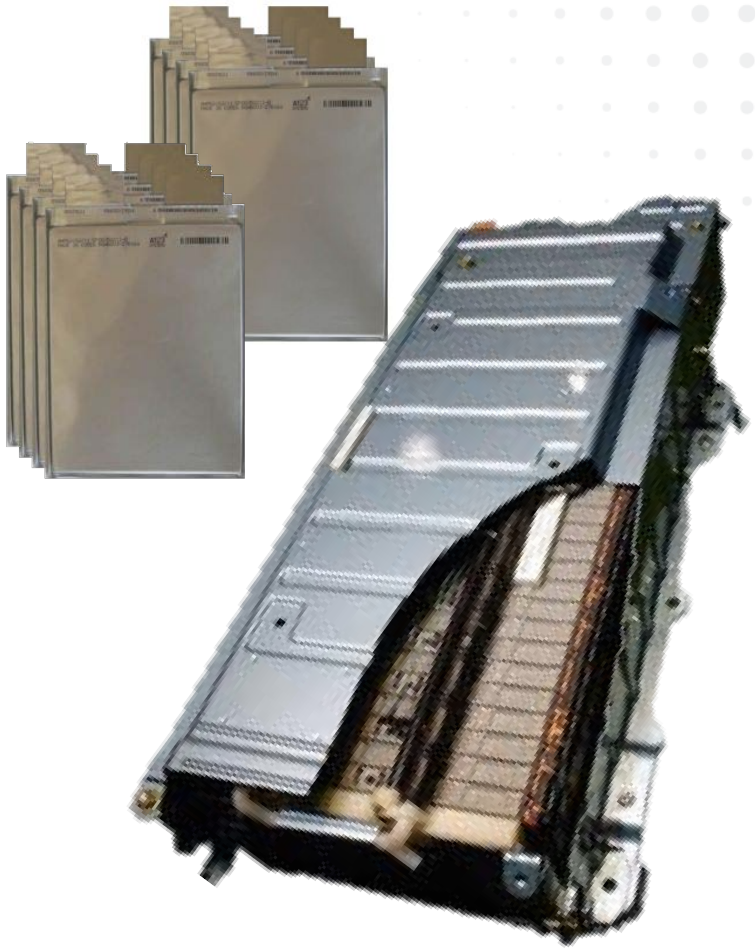


Image Source: http://http://jcwinnie.biz/wordpress/

Need: Full Situational Awareness and Response

State of the cells
- Thermal
- Chemical
- Physical

Operational state
- Weather
- Terrain
- Drive profile

Degradation
- Extent
- Modes
- Impact

Operational flex
- Level of control
- Hybridization
- Behavior / economics

AMPED: Advanced Management and Protection of Energy storage Devices

Program Director: Dr. Ilan Gur

1. Sensing

- Monitor **internal cell temperature** in real time?
- Monitor **intercalation strain** for SOC/SOH estimation?
- Track physical/chemical states with **optical sensing**?
- Track **gas signatures** of various degradation modes?

2. Modeling & controls

- Employ **real-time physical state and degradation models** to optimize utilization and balancing control?

3. Systems

- Implement **cost effective cell-level power management?**
- Utilize **flexible power architectures** for diff'l diagnostics?
- **Wireless communications** and control
- Design **intra-cell thermal management** systems?

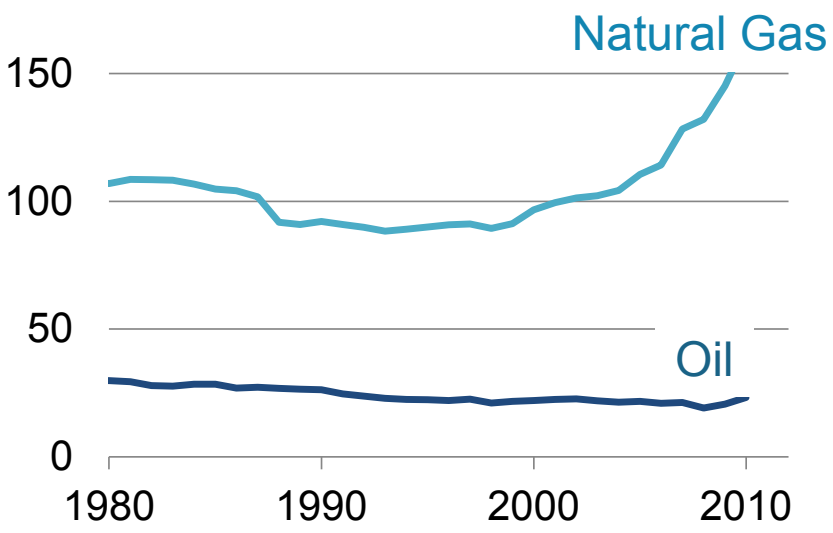
ALSO: Diagnostics & prognostics

- Identify degradation/failure modes quickly with non-destructive **acoustic inspection?**
- Measure **high-precision columbic efficiency** on production cells and practical drive cycles?

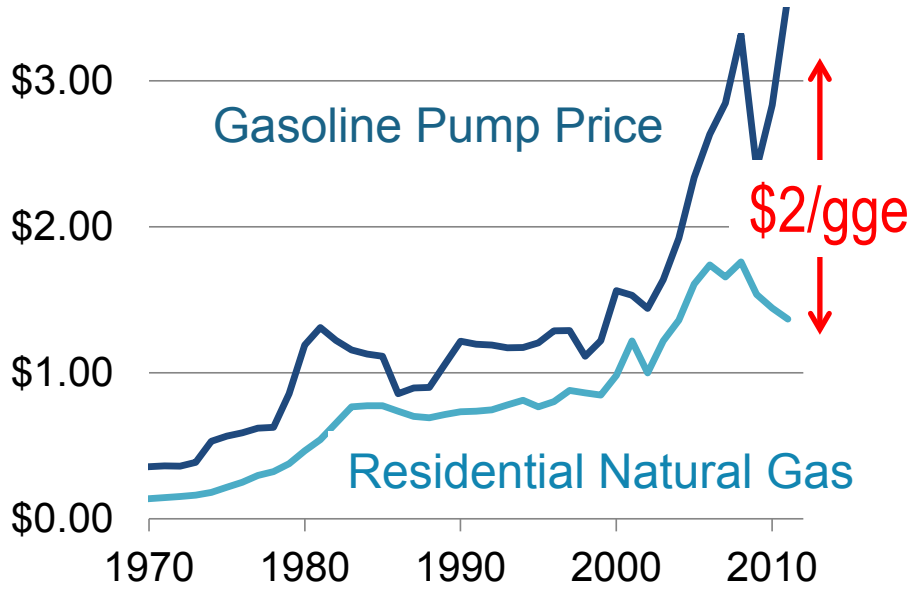
MOVE:
Enabling Natural Gas Vehicles

Historic Opportunity

U.S. Reserves
(billon barrels)



U.S. Consumer Prices
(dollars per gallon)



Challenges: No infrastructure, too costly, and too bulky

Component	Now	Need	How
At-home Refueling	$ 5500	**$ 500**	**ARPA-E**
On-board Storage	$ 3500	**$ 1500**	**ARPA-E**
Balance of System	$ 3500	$ 1000	volume
Total	$12500	$ 3000	

MOVE Methane Opportunities for Vehicular Energy

Mission

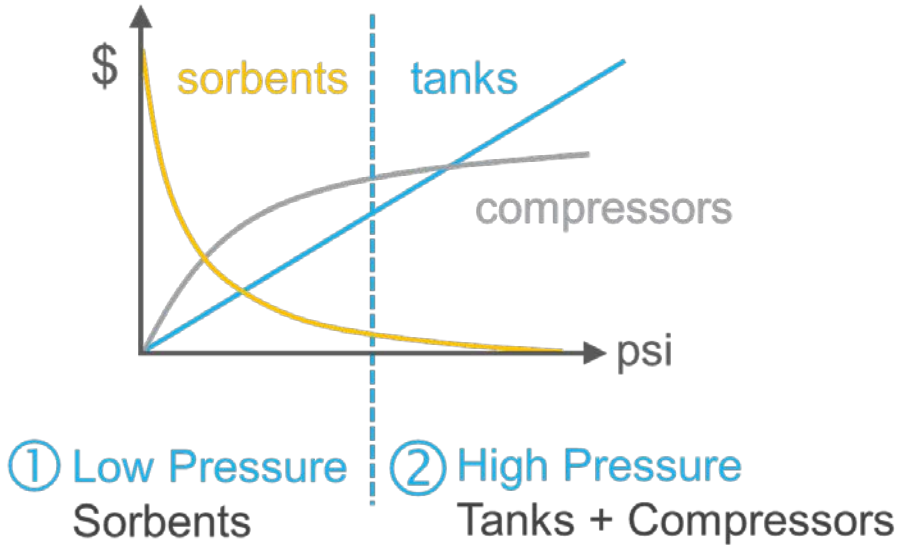
Reduce cost of natural gas light duty vehicles and home refueling

Program

- Funding: $30.0M
- Period: 2011-2014
- Projects: 13

Objectives

- 3x cheaper gas tanks ($1500)
- 90% conformable gas tanks
- 10x cheaper home refueler ($500)



ARPA-E Natural Gas Vehicle Projects

Program Goal

Payback less than 5 years for light duty vehicles with conformable tanks and at-home refueling

Compressors

- Liquid piston
- Multi-stage single piston
- Cryocool-sorbent
- On-board

Sorbents

- Metal organic frameworks
- Permeability modulated
- Mechanical-chemical tank

Tanks

- Internal struts
- Foam core
- Cellular module
- Small tube diameter

Current Solicitations

Funding Opportunity Announcement (FOA)

- Robust Affordable Next Generation EV-Storage (**RANGE**)
- Modern Electro/thermochemical Advances in Light-Metal Systems(**METALS**)
- Reduced Emissions Using Methonotropic Organisms For Transportation Energy (**REMOTE)**

Reduced Emission Vehicles - Summary of ARPA-E's Approach

Light weighting:
METALS: reduce cost and production energy

Alternative fuels:
MOVE: methane storage
REMOTE: methane conversion
Electrofuel: synthetic fuel
PETRO: alternative bio-fuel

Electrification:
BEEST: reduce battery weight and volume
AMPED: optimize the use of batteries
RANGE: robust storage to minimize vehicle system weight and cost
HEATS: thermal storage to reduce battery use
REACT: alternative magnetic materials

More to come…

U.S. DEPARTMENT OF
ENERGY

www.arpa-e.energy.gov