



Quadrennial Technology Review-2015

Chapter 2: What Has Changed Since 2011?

Public Webinar

Chapter Leads:

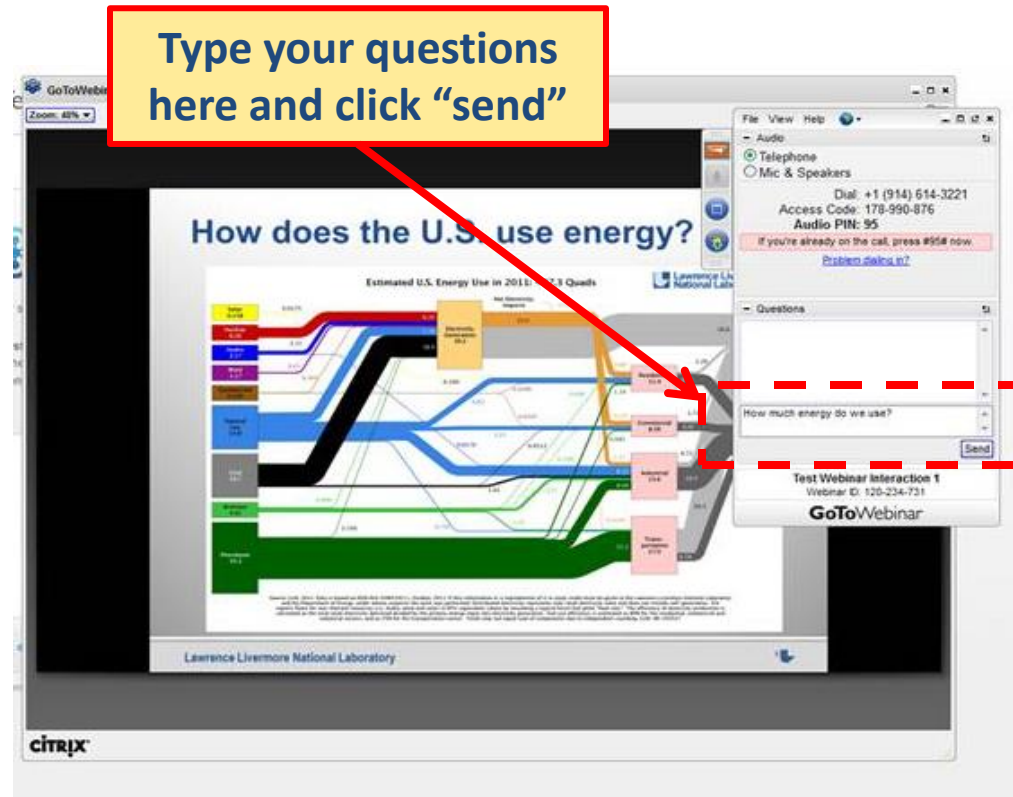
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2015-03-04



Webinar Logistics

- Due to the large number of expected participants, the audio and video portions of this webinar will be a “one way” broadcast. Only the organizers and QTR authors will be allowed to speak.
- Submit clarifying questions using the GoToWebinar control panel. Moderators will respond to as many questions as time allows. Substantial input regarding chapter content should be submitted by email to: DOE-QTR2015@hq.doe.gov





QTR 2015 Chapter Outline

Introduction

1. Energy Challenges
- 2. What has changed since QTR 2011**
3. Energy Systems and Strategies

Assessments

4. Advancing Systems and Technologies to Produce Cleaner Fuels
5. Enabling Modernization of Electric Power Systems
6. Advancing Clean Electric Power Technologies
7. Increasing Efficiency of Buildings Systems and Technologies
8. Increasing Efficiency and Effectiveness of Industry and Manufacturing
9. Advancing Clean Transportation and Vehicle Systems and Technologies
10. Enabling Capabilities for Science and Energy

Integrated Analysis

11. U.S. Competitiveness
12. Integrated Analysis
13. Accelerating Science and Energy RDD&D
14. Action Agenda and Conclusions; Web-Appendices
Web Appendices



Chapter Overview

- **Approach of the QTR: 2011 vs. 2015**
- **US and Global Energy Market Trends**
- **2011 Assessments: 17 updates**
 - **Vehicle Efficiency** (*Combustion Engines, Lightweighting and Aerodynamics, Electrification*)
 - **Alternative Hydrocarbon Fuels**
 - **Building and Industrial Efficiency** (*Buildings, Industrial*)
 - **Electrical Grid** (*Infrastructure, Storage, Measurement Modeling and Control*)
 - **Clean Electric Power** (*Carbon Capture and Storage, Concentrating Solar Power, Fuel Cells for Distributed Generation, Geothermal, Nuclear, Solar Photovoltaic, Water, Wind*)
- **Accomplishments and Lessons Learned**



Expanded Scope of QTR 2015

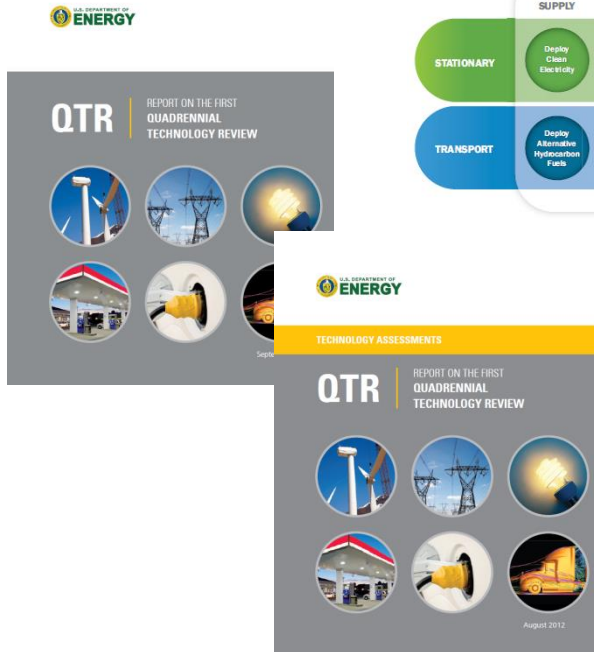
- The QTR will evaluate major changes since the first volume of the QTR was published in 2011 and provide forward leaning analysis to inform DOE's strategic planning and decision making.
- In doing so, the QTR 2015 will provide three levels of analyses:
 - Systems Analyses – Uses systems frameworks to evaluate the power, buildings, industry, and transportation sectors, enabling a set of options going forward.
 - Technology Assessments – Examines in detail, the technical potential and enabling science of key technologies out to 2030.
 - Road Maps – Uses these analyses and assessments to extend R&D Roadmaps and frame the R&D path forward.
- The QTR is a comprehensive assessment of science and energy technology research, development, demonstration, and deployment (RD3) opportunities to address our nation's energy-linked economic, environmental, and security challenges.



QTR 2011 vs. 2015

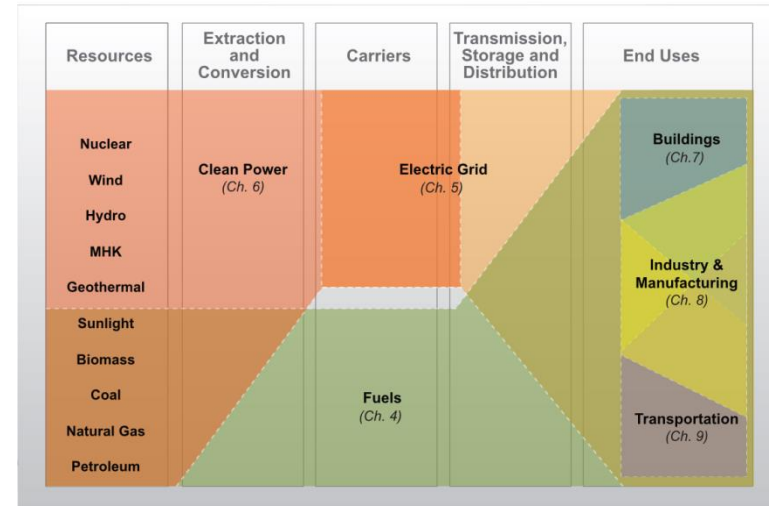
2011

- 6 Strategies + 3 Supporting Chapters
- 17 Technology Assessments
- Snapshot of Technology and DOE Operations



2015

- 6 Technical Chapters + 7 Supporting Chapters
- 50+ Technology Assessments
- Systems-oriented
- Surveys Opportunity Space





Systems Analyses & Technology Assessments

- A new level of systems analyses and technology assessments will be completed.
- Increased science, energy, and cross-technology integration involving a large community – Over 300+ national laboratory participants working with DOE Staff.

- Designs, Architectures, Concepts
- Measurement, Comm., Control
- Flexible & Distributed Resources
- Cyber Security
- T&D Components
- Electric Energy Storage

- Carbon Capture
- Carbon Storage
- CCS for Industry
- Fossil Advanced Energy Systems
- CCS Cross-cutting Technologies
- BioPower – CCS
- Stationary Fuel Cells
- Geothermal Power
- Hydropower
- Nuclear Fast-Spectrum Reactors
- Nuclear Fuel Cycle
- Nuclear Light Water Reactors...

- Additive Manufacturing
- Combined Heat and Power
- Composite Materials & Manufact
- Critical Materials
- Materials Flow Through Industry
- Process Heating
- Process Intensification
- Roll-to-roll Processing
- Smart Manufacturing
-

Sectors/Systems Analyses	Technology Assessments
Clean Fuels	8
Grid Modernization	6
Clean Electric Power	17
Buildings	7 (Roadmaps)
Industry & Manufacturing	14
Clean Transportation & Vehicles	5
Enabling Science	0



U.S. and Global Energy Market Trends

- Overall U.S. Energy Demand
- Carbon Dioxide Emissions
- Shale Revolution
- Rapid Deployment and Falling Cost of Wind and Photovoltaics
- Nuclear Energy Market Changes
- Ethanol Market Changes
- Electrical Grid Data Availability
- Increasing Building Energy Efficiency
- Increasing Opportunities for U.S. Manufacturing
- Decreasing Growth in U.S. Gasoline Consumption
- Growing Market for Electric Vehicles



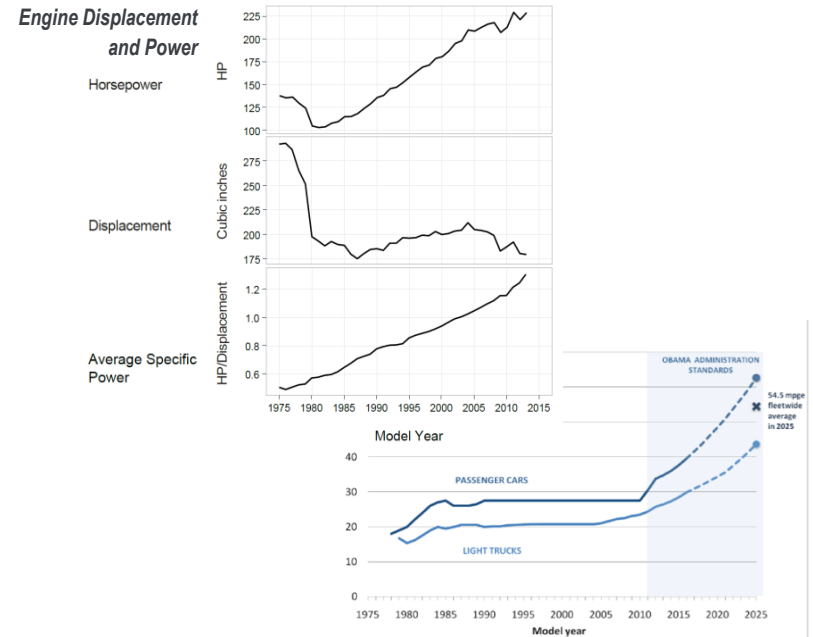
Vehicle Efficiency: Internal Combustion Engines

Market Changes

- Multi-valves, Variable Valve Timing, Gasoline Direct Injection, Small Displacement Turbocharged Engines.
- CAFE Standards

DOE's Role

- 2+ decades of research on advanced ICE technologies, including those listed above supported by EERE/VTO
- Collaboration among National Laboratories, University, Industry, Suppliers.
- >90% projects have industry partners, many with cost-share.



2010 - 2014 DOE Highlights

- Combustion Research: Optical Access
- Simulation: Fast Chemical Kinetics Solvers
- Demonstrations: Supertruck



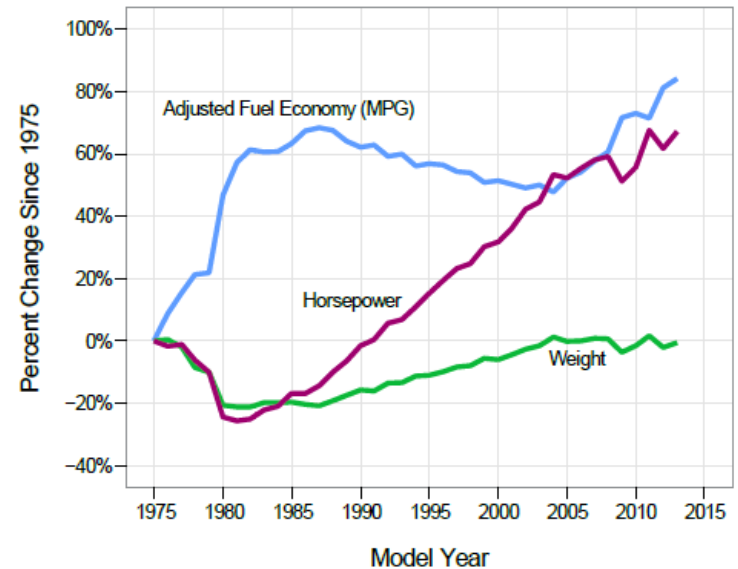
Vehicle Efficiency: Lightweighting and Aerodynamics

Market Changes

- Advanced High-Strength Steel, Aluminum, Magnesium, Carbon Fiber
- Premium (eg. Chevrolet Corvette) AND Mass Market (eg. Ford F-150)

DOE's Role

- 2+ decades of research on lightweight materials
- Collaboration among National Laboratories, University, Industry, Suppliers.
- >90% projects have industry partners, many with cost-share.



2010 - 2014 DOE Highlights

- Magnesium Vehicle Front-End (multi-material vehicle)
- Aluminum Tailor Welded Blanks (joining dissimilar thickness parts)



Vehicle Efficiency: Electrification

Market Changes

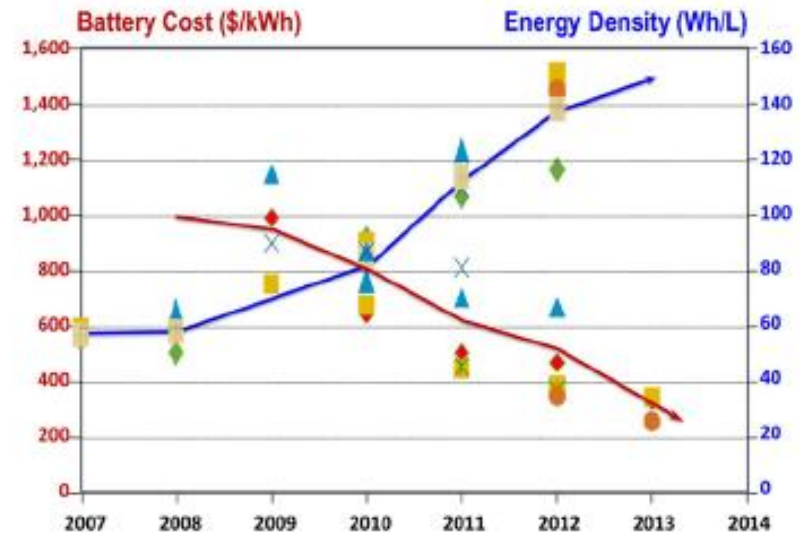
- 150,000 Plug-In vehicles sold
- Premium (eg. Tesla) AND Compact (eg. Chevrolet Volt, Nissan Leaf)

DOE's Role

- 3+ decades of research on batteries
- Li-Ion technologies developed under DOE-funded USABC are used in vehicles on sale today.

2010 - 2014 DOE Highlights

- Projected 50% battery pack cost reductions with DOE-developed technologies.
- Met/exceeded \$5/kWh, 12 kWh/kg targets for electric drive.
- 18,000 EV charging stations installed under ARRA





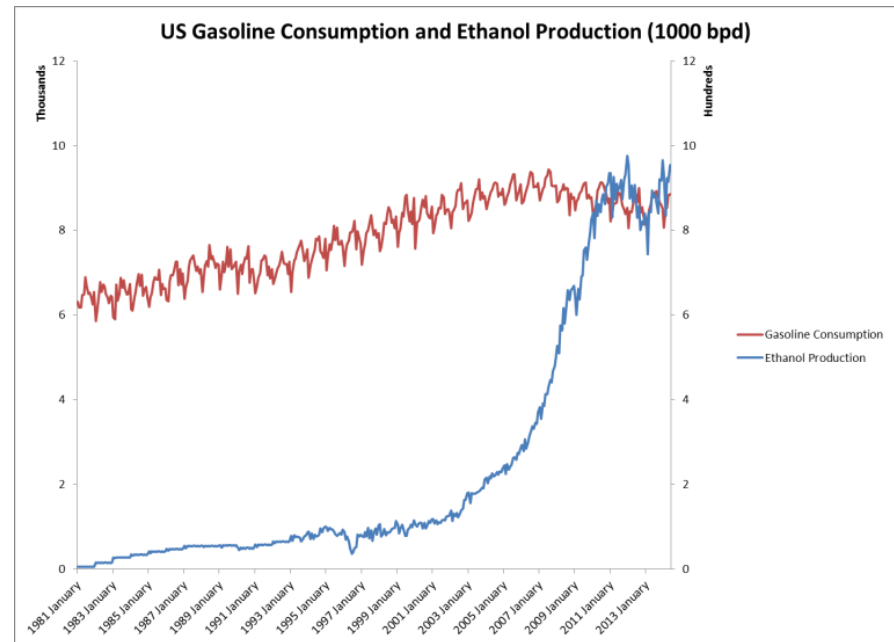
Alternative Hydrocarbon Fuels

Market Changes

- Ethanol “Blend Wall”
- Flattening U.S. Gasoline Demand
- 3 Commercial Scale Cellulosic Ethanol Plants online

DOE’s Role

- Supported development of feedstock and pre-treatment technologies used at Poet and Abengoa
- Loan Guarantee Program supported commercial plant financing



2010 - 2014 DOE Highlights

- Estimated costs of cellulosic ethanol decreased from \$9 to \$2.15/gallon
- Increasing research on drop-in fuels with DoD.



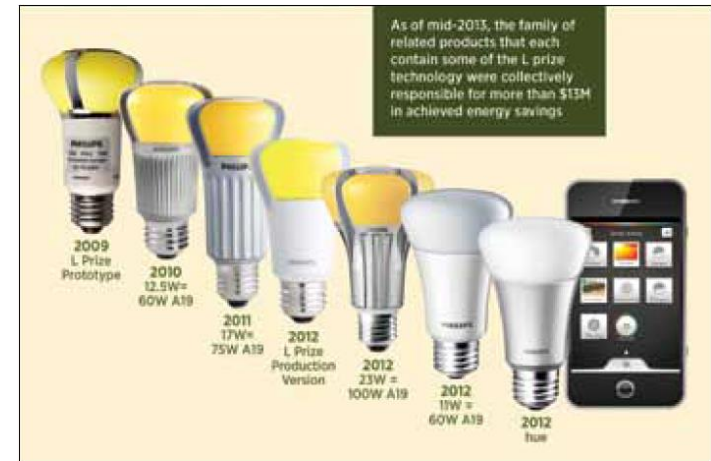
Buildings and Industry: Residential and Commercial Buildings

Market Changes

- Residential
 - Solid State Lighting (LED)
 - Smart Sensors & Controls (niche)
- Commercial
 - Networked Sensors and Controls (Building Energy Management)
 - Regional/Municipal Benchmarking

DOE's Role

- Multi-pane windows, Low-e glass
- Heat Pump Water Heaters
- Solid State Lighting



The family of Philips products that contain technology developed for the 60W L-Prize winner (top)

2010 - 2014 DOE Highlights

- L-Prize
- Better Buildings Alliance
 - 200 members
 - 10 billion sq. ft. of commercial space



Buildings and Industry: Industrial Efficiency

Market Changes

- Low and stable natural gas prices
- Federal investments
- Lower labor costs
- Additive Manufacturing

2010 - 2014 DOE Highlights

- Printed Car
- Superior Energy Performance
 - 29 Demonstrations
 - 12 Sectors
 - 10% improvement
 - \$500k/yr in 9 facilities
- Centers (*MDF, CMI, America Makes, WBG*)



DOE's Role

- Industrial efficiency
 - Combined Heat and Power
 - Waste heat reduction & utilization
 - Variable Speed Drives



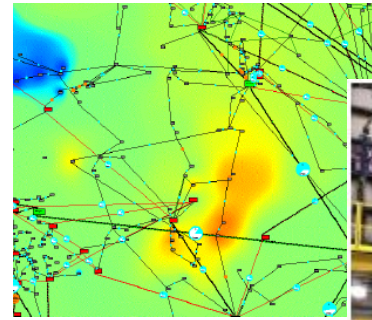
Grid Modernization: Infrastructure

Market Changes

- Aging Components
- Variable Generation
- Increasing availability of data
- Distribution voltage support

2010 - 2014 DOE Highlights

- ARPA-E GENI:
 - Power Flow Control (*Smart Wires, Magnetic Amplifier Transformer*)
 - Topology Control
 - HVDC Hardware
 - Power System Optimization



DOE's Role

- Capital Stock Assessment
- Initiatives:
 - DOE Grid Tech Team
 - Grid Modernization Laboratory Consortium



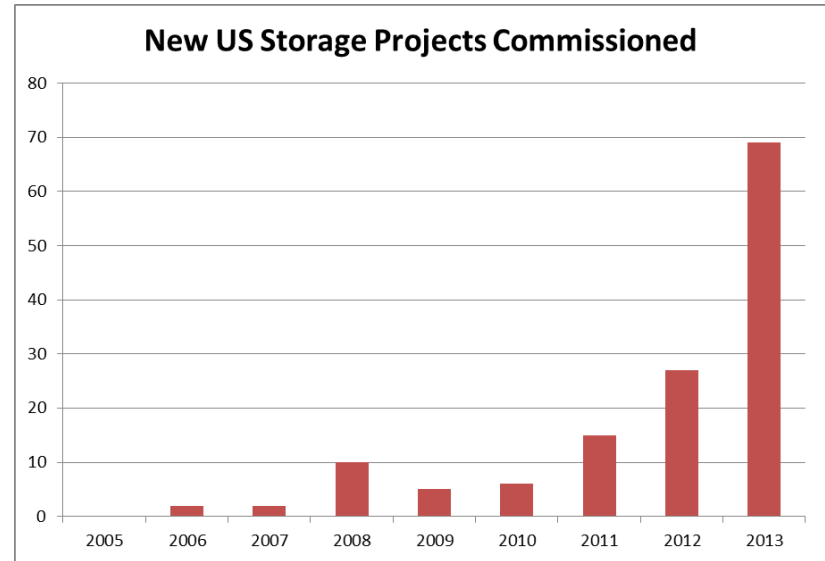
Grid Modernization: Storage

Market Changes

- Variable Generation
- Increasing availability of data
- Storage Mandates (CA)
- FERC 755 (Frequency Regulation)

2010 - 2014 DOE Highlights

- Tehachapi Wind (8MW, 32MWh)
- Beacon/NYISO Flywheel
 - Not commercially viable, but informed pay-for-performance
- Vermont Resilient Community (4 MW, 3.4 MWh)



DOE's Role

- 12+ years
- Flywheels, Pb-Acid, Li-Ion, Na-S, Hydrogen, CAES
- \$180 MM in ARRA funds leveraged >\$500MM in cost share
- 10x scale-up from previous efforts



Grid Modernization: Measurement, Modeling and Control

Market Changes

- 65 million smart meters
- 1000 Phasor measurement units
- Variable Generation

2010 - 2014 DOE Highlights

- Feeder sensors and switches reduce frequency (11 – 49%) and duration (<56%) of outages
- 1% - 2.5% consumption reduction using advanced conservation voltage technologies
- Operational efficiencies realized from smart meter deployment



DOE's Role

- Primary responsibility for ARRA Smart Grid Investments
 - \$9 Billion (~50% cost share)
 - Metering Infrastructure



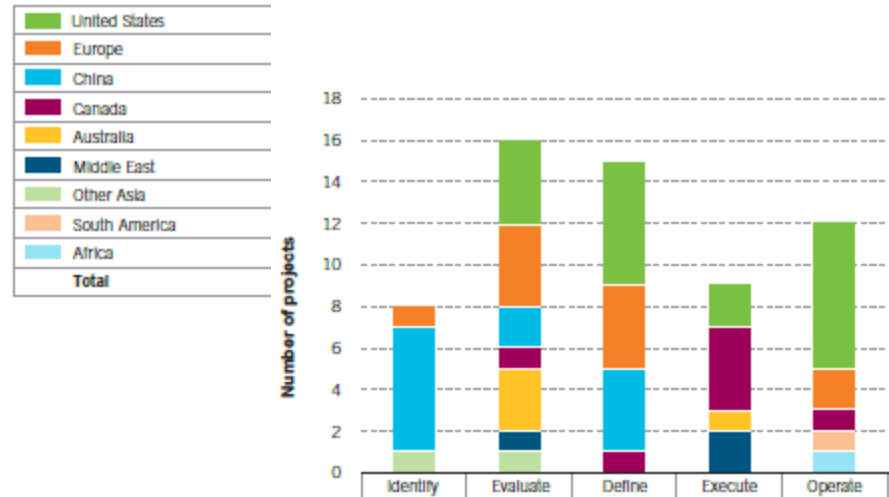
Clean Power: Carbon Capture and Storage

Market Changes

- Shift from Coal to Gas
- EPA Draft Rules (111d)
- Nascent Emissions Trading Markets and Platforms
- 4 major demonstration projects online

2010 - 2014 DOE Highlights

- 6 Advanced Technology Projects moved from bench to pilot (*solvents, sorbents, membranes*)
- Cumulative Injection of 6.4 Million Tons of CO₂ (up from 1.3 in 2011)



DOE's Role

- Support for all U.S.-based Large Scale Integrated Projects
- Support for over half of global LSIPs
- Decades of CO₂-EOR research



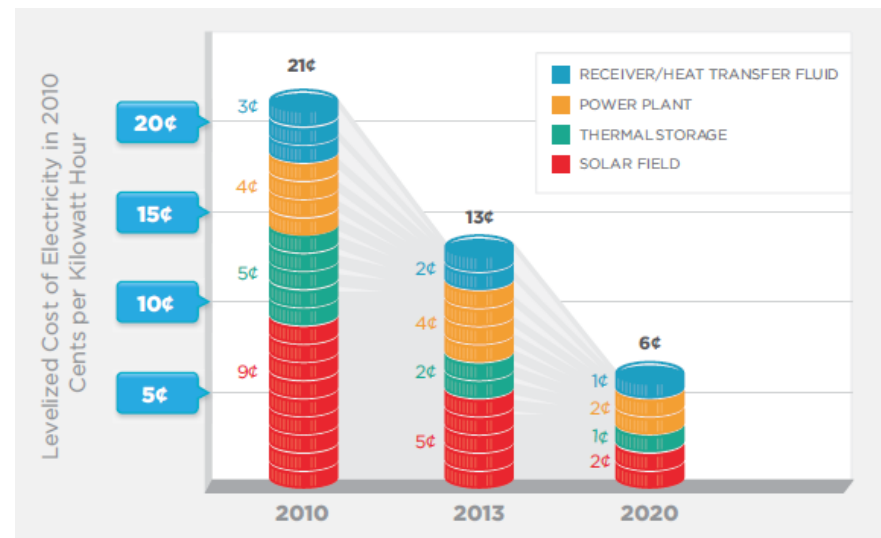
Clean Power: Concentrating Solar Power

Market Changes

- ~300% increase in capacity (430 MW to 1380 MW) spread over 5 projects (*Solanal, Ivanpah, Crescent Dunes, Mojave, Genesis*)
- Renewable Portfolio Standards

2010 - 2014 DOE Highlights

- Enabling Technology Development (*hydrophobic mirror coatings, supercritical CO2 working fluid*)
- Manufacturing/Installation Technologies (*Abengoa*)



DOE's Role

- Major investments from 1970s through 1990s developed trough technology
- Demonstrated Power Tower technology at Solar One in 1980s
- Loan Programs supported all 5 recent major projects



Clean Power: Fuel Cells for Distributed Generation

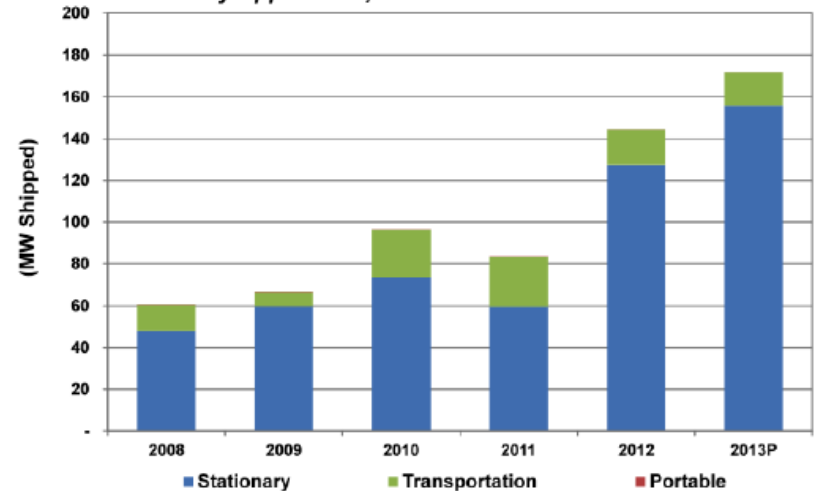
Market Changes

- ~2x growth in shipments of fuel cells (by kW) globally, most in the large stationary sector)
- Material Handling (Forklift) market for small fuel cells

2010 - 2014 DOE Highlights

- 13% decrease in precious metal loading for PEM
- 30% increase in carrying capacity of hydrogen tank trucks
- Focus on durability and costs (via manufacturing)

Megawatts of Fuel Cells Shipped
by Application, World Markets: 2008-2013



DOE's Role

- Large program since 1999, involving every commercial manufacturer
- Since 2006, 50% cost reduction and 150% increase in durability



Clean Power: Geothermal

Market Changes

- Modest capacity growth
- Large diversity of projects
 - Flash and Binary
 - Greenfield and Expansion
 - Hydrothermal and EGS

2010 - 2014 DOE Highlights

- 10 MW EGS demonstration at The Geysers
- Demonstrated operational and economic feasibility of low temperature recovery at Beoweave
- Engineering prototype of laser drilling



DOE's Role

- Loan Program Office supported 6 of 14 new projects between 2009 and 2014
- Polycrystalline Coated Diamond (PDC) drill bits enable EGS, and have helped transform O&G industry



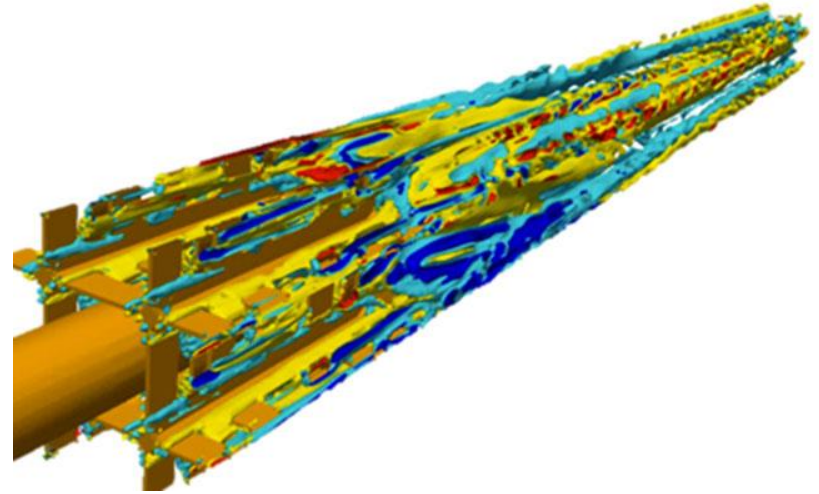
Clean Power: Nuclear

Market Changes

- 4 new reactors (first since 1977)
- 5 reactors slated for closure (economics)
- 2011: Fukushima (*Japan, Germany, China*)

2010 - 2014 DOE Highlights

- Small Modular Reactor Licensing Technical Support (2 competing designs)
- Modeling and Simulation at CASL addressing commercial problems such as grid-to-rod fretting



DOE's Role

- Advanced Light Water Reactor program supported design of AP1000 and ESBWR
- Fuel Cycle Operations program has supported uprates and higher fuel burnup



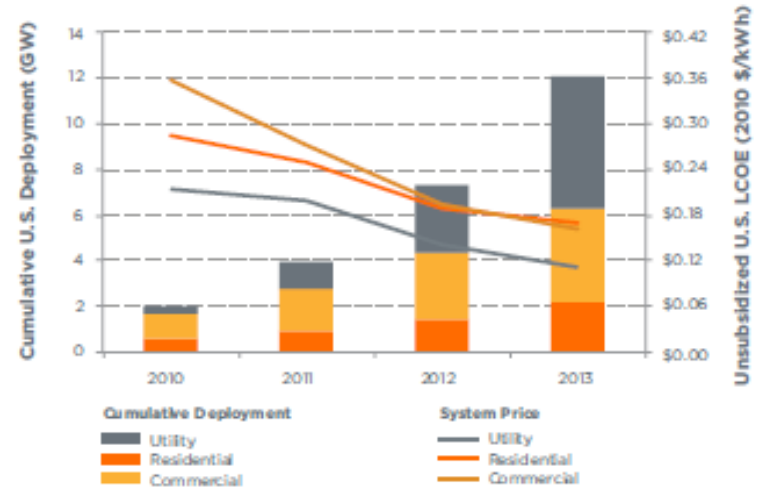
Clean Power: Solar Photovoltaics

Market Changes

- Largest growth rate of any energy resource
- Over 1% of US generating capacity is PV
- Steep cost declines (\$/kWh LCOE)
 - 0.21 to 0.11 (commercial)
 - 0.28 to 0.17 (residential)

DOE's Role

- Sunshot's deployment programs assist regional, state and local governments and utilities
 - Decades of historical RD3 in crystalline silicon
- Reduced permitting time by 40% and costs by 12%
 - 48% efficient 4-junction cell demonstrated
 - Demonstrated 10% efficient earth-abundant thin-film cell



2010 - 2014 DOE Highlights



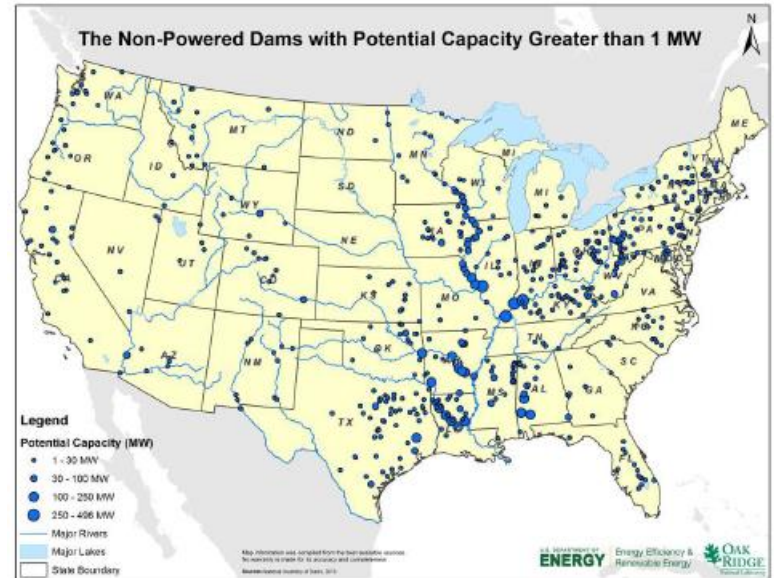
Clean Power: Water Power

Market Changes

- Mature Technology
- Increased need for dispatch flexibility (increasing variable generation)
- Reduce biological impacts

DOE's Role

- Resource Characterization
- Testing Infrastructure, Instrumentation
- System/Component Demonstrations



2010 - 2014 DOE Highlights

- Expansion Potential Analysis:
 - 84 GW (new stream reach)
 - 12 GW (unpowered dams)
- Pumped Hydro Storage Analysis
- Marine and Hydrokinetic concepts in pilot tests



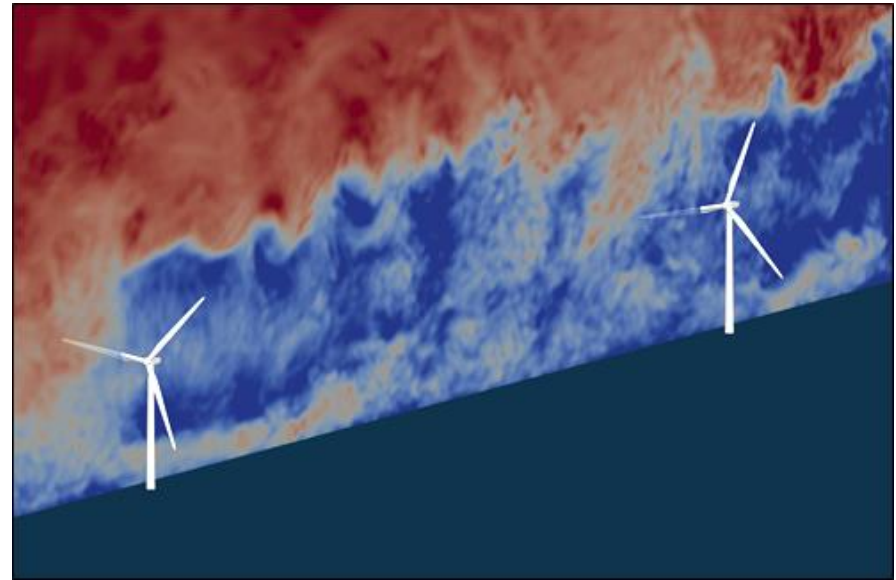
Clean Power: Wind

Market Changes

- 40 GW in 2010 vs 66 GW in 2014
- 4.3% of all electricity generated
- Larger turbines, lower costs
- Production Tax Credit

DOE's Role

- Decades of component development helped drive LCOE (\$/kWh) from 0.55 in 1980 to under 0.06 today
- Testing Centers for system and component validation
- Simulation code development (*FAST, Aerodyn, NuMaD*)



2010 - 2014 DOE Highlights

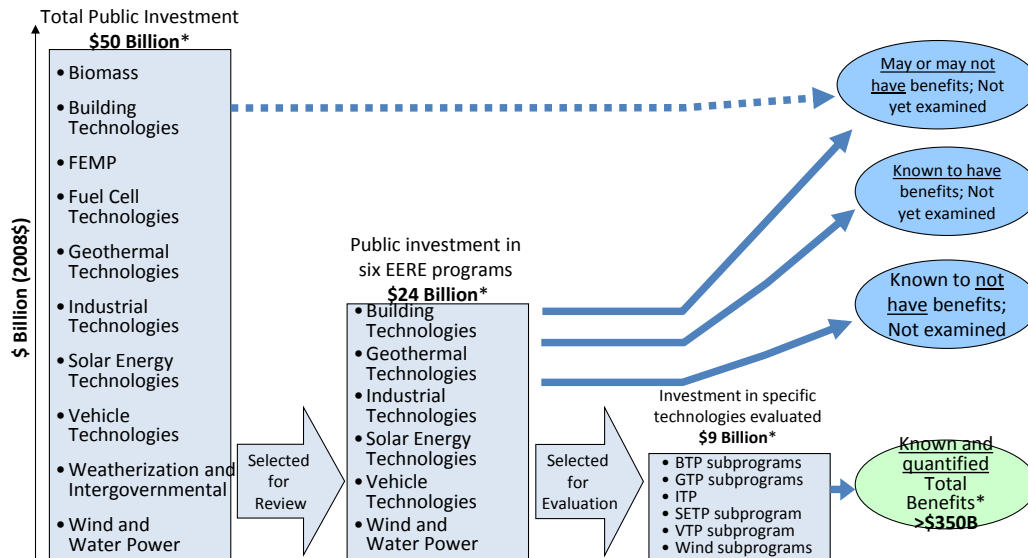
- NWTC and Clemson testing facilities (2.5, 5.8, 7.5 and 15 MW dynamometers)
- SWiFT test farm online
- Physics-based wind *plant* simulation



Accomplishments and Lessons Learned

- DOE Programs have played a role in the advancement of almost every energy technology.
- Much of the economic benefit of energy technology can be attributed to private industry.
- There are some “standout” economic returns on DOE RD3 programs... others have yet to show impact.

Economic returns analyzed to date



^a All dollars are expressed in 2008 inflation-adjusted dollars, not discounted.
^b \$326B net benefits = \$350B total benefits - \$24 investment in six programs.
^c Preliminary



Public Input

- You are encouraged to submit questions using GoToWebinar's "Questions" functionality. The moderators will respond, via audio broadcast, to as many appropriate questions as time allows.

A screenshot of a GoToWebinar interface. The main window displays a slide titled "How does the U.S. use energy?" with a Sankey diagram showing energy flow from various sources to different sectors. A red box highlights the text "Type your questions here and click 'send'". A red arrow points from this box to the "Questions" panel on the right. The "Questions" panel shows a text input field with the question "How much energy do we use?" and a "Send" button. Below the input field, it says "Test Webinar Interaction 1" and "Webinar ID: 120-234-731". The GoToWebinar logo is at the bottom of the panel. The background shows a Citrix logo in the bottom left corner of the webinar window.

- If you have questions or comments that cannot be addressed during the webinar, email them to DOE-QTR2015@hq.doe.gov



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