U.S. DEPARTMENT OF ENERGY

Report on the First

Quadrennial Technology Review

Report DOE/S-0001

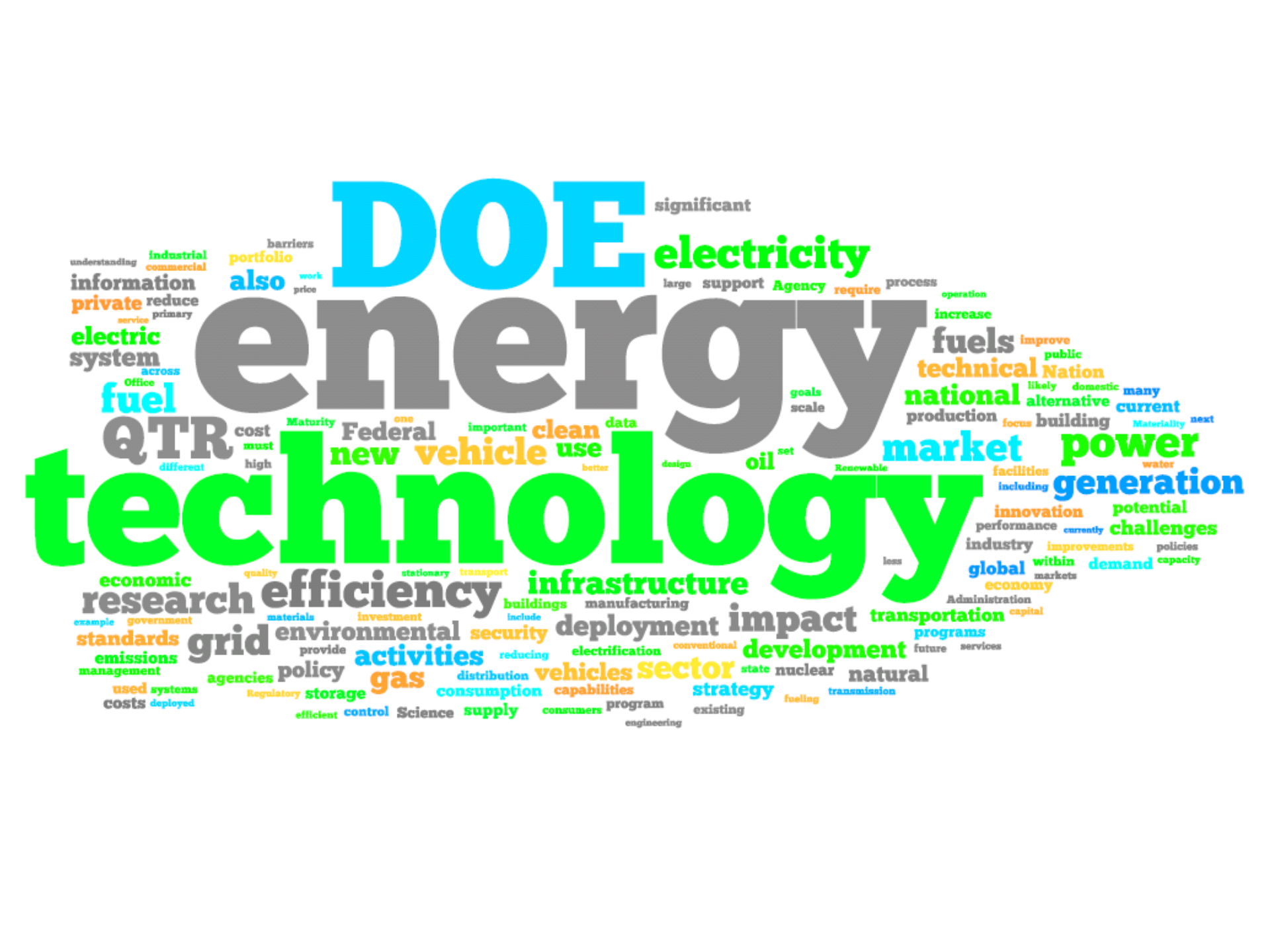
Steven Koonin

Under Secretary for Science

US Department of Energy

www.energy.gov/QTR

October 10, 2011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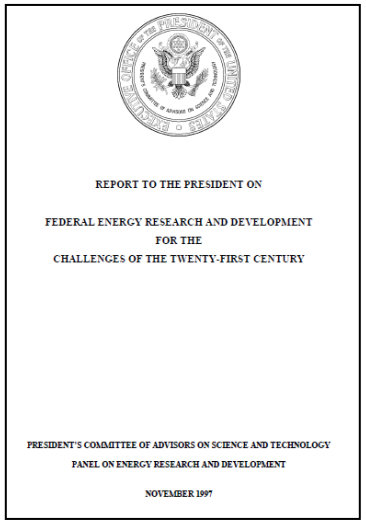
QTR's Origins and Goals


REPORT TO THE PRESIDENT ON

FEDERAL ENERGY RESEARCH AND DEVELOPMENT
FOR THE
CHALLENGES OF THE TWENTY-FIRST CENTURY

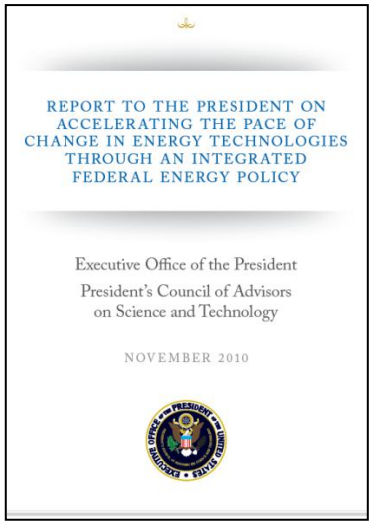
PRESIDENT'S COMMITTEE OF ADVISORS ON SCIENCE AND TECHNOLOGY
PANEL ON ENERGY RESEARCH AND DEVELOPMENT

NOVEMBER 1997

November, 1997: "Federal Energy R&D for the Challenges of the 21st Century"

(J. Holdren, Panel Chair; J. H. Gibbons, Dir OSTP and PCAST Co-Chair)

Recommended "much more systematic effort in R&D portfolio analysis"


REPORT TO THE PRESIDENT ON
ACCELERATING THE PACE OF
CHANGE IN ENERGY TECHNOLOGIES
THROUGH AN INTEGRATED
FEDERAL ENERGY POLICY

Executive Office of the President
President's Council of Advisors
on Science and Technology

NOVEMBER 2010

November, 2010: "Accelerating the Pace of Change in Energy Technologies through an Integrated Federal Energy Policy"

(E. Moniz & M. Savitz, Panel Co-Chairs; J. Holdren, Dir OSTP and PCAST Co-Chair)

"Quadrennial Energy Review (QER) could establish government-wide goals"

"DOE component of the full interagency QER focused on energy technology innovation, promptly."

QTR Goals

- **To define and promulgate a simple framework for energy**
- **To explain to DOE and its stakeholders the various roles in energy transformation**
- **To establish a common sense of priorities among the suite of DOE's energy activities**

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QTR Timeline

Volume I

Nov 2010
PCAST recommended DOE do QTR to prep for future govt-wide QER

2011: Mid-March through mid-April
Public comment period for DOE's QTR Framing Document

April 20
First batch of 60 public comments released on project website

Mid-May through Mid-July

Held workshops and discussions

8/5/11
Submitted QTR Draft Report to EOP

Mid-Sept
DOE receives all comments from EOP on QTR Draft Report

Sept 27
DOE releases *Report on the QTR* with Rollout Events on East and West Coasts

Volume 2

March
Coordinated DOE Technology Teams to write reports

July-Aug
QTR team reviewed and normalized TA drafts

Mid-Late Aug
Sent QTR Technology Assessments for peer review

Mid-Late Sept
Receive and process peer reviewed comments

Late Oct
Release Peer-Reviewed QTR Technology Assessments

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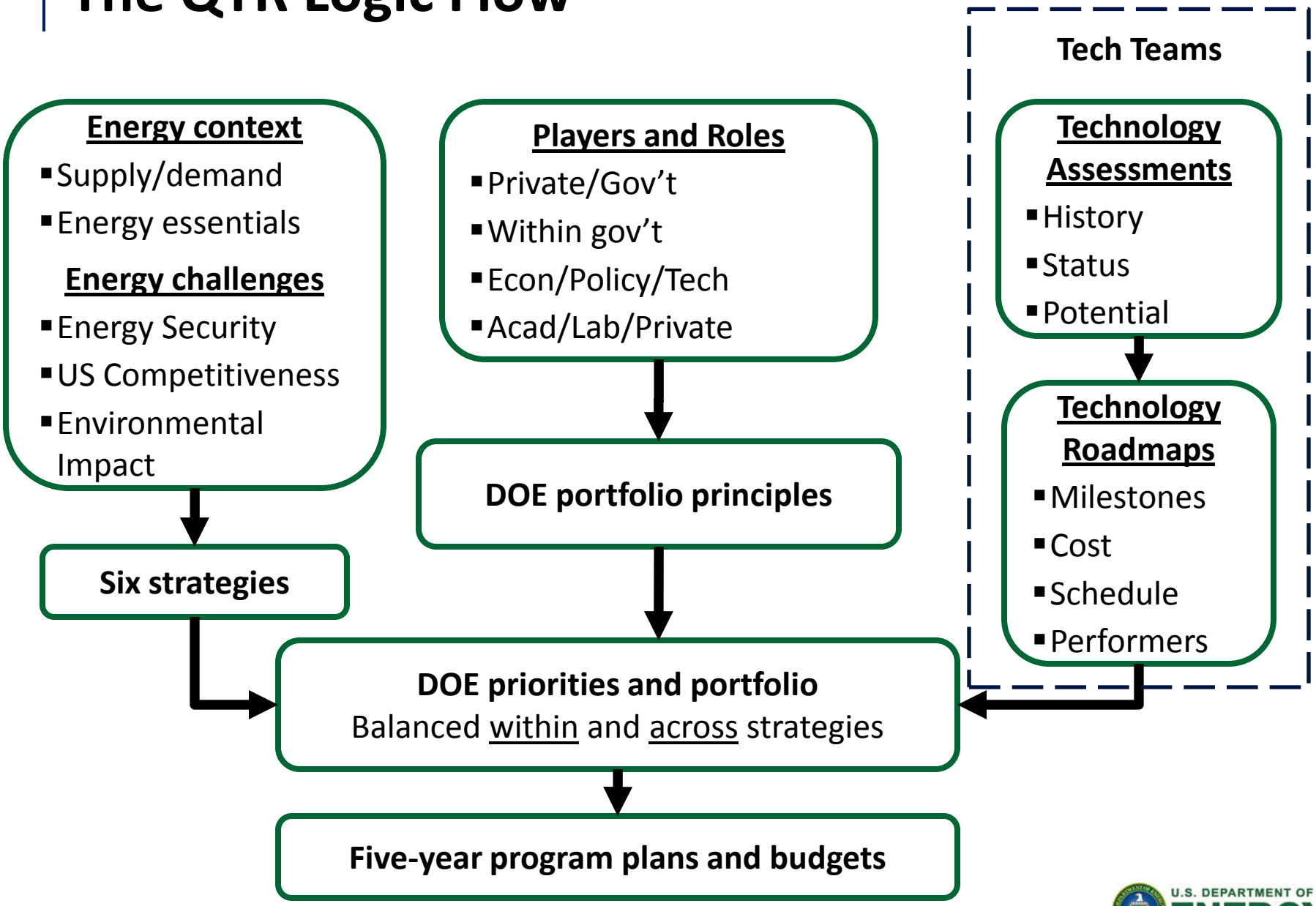
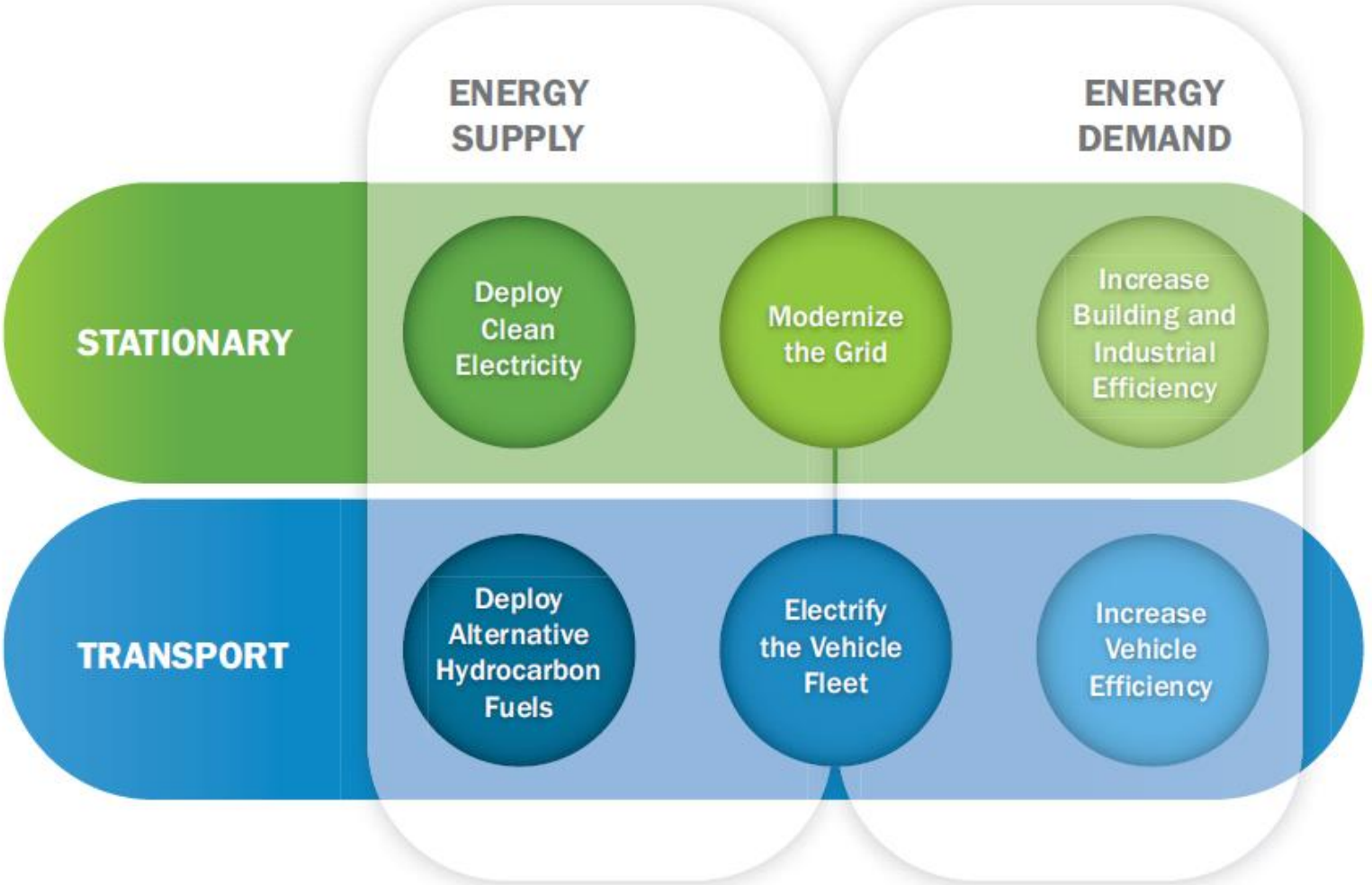
The QTR Logic Flow



Six Strategies



www.energy.gov/QTR

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The Transport Logic

We are coupled to a global oil market

- Balance of payments, high and volatile prices, insecurity, GHGs
- Demand is growing, easy resource is concentrating

Increased domestic production fixes jobs, balance of payments, security; not price

- We cannot produce enough fast enough to affect the global market; OPEC distorts
- Conventional and unconventional crude, biofuels, CTL/CTL/CBTL/… sold at oil price
- Go beyond "energy independence" to "price independence" (*cf* UK fuel riots of 2000)

Must decouple from the global oil market

- Reduce oil demand materially through efficiency
- Shift LDVs to a non-fungible fuel (Grid? Hydrogen? Natural Gas?)
- Advanced biofuels for the remaining HDV demand

Strategies (ordered by cost-effectiveness and time-to-impact)

- **Increasing vehicle efficiency -** nearest-term impact with existing technology.
- **Electrifying the light duty fleet -** a graceful transition: HEVs to PHEVs to BEVs
- **Deploying alternative hydrocarbon fuels -** biased toward fuels for HDVs

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Transport: Technology Headroom for DOE

<u>Vehicle Efficiency</u>

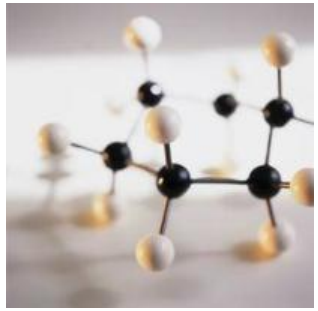
- Increase internal combustion engine efficiency
- Lightweighting and aerodynamics

<u>Electrification</u>

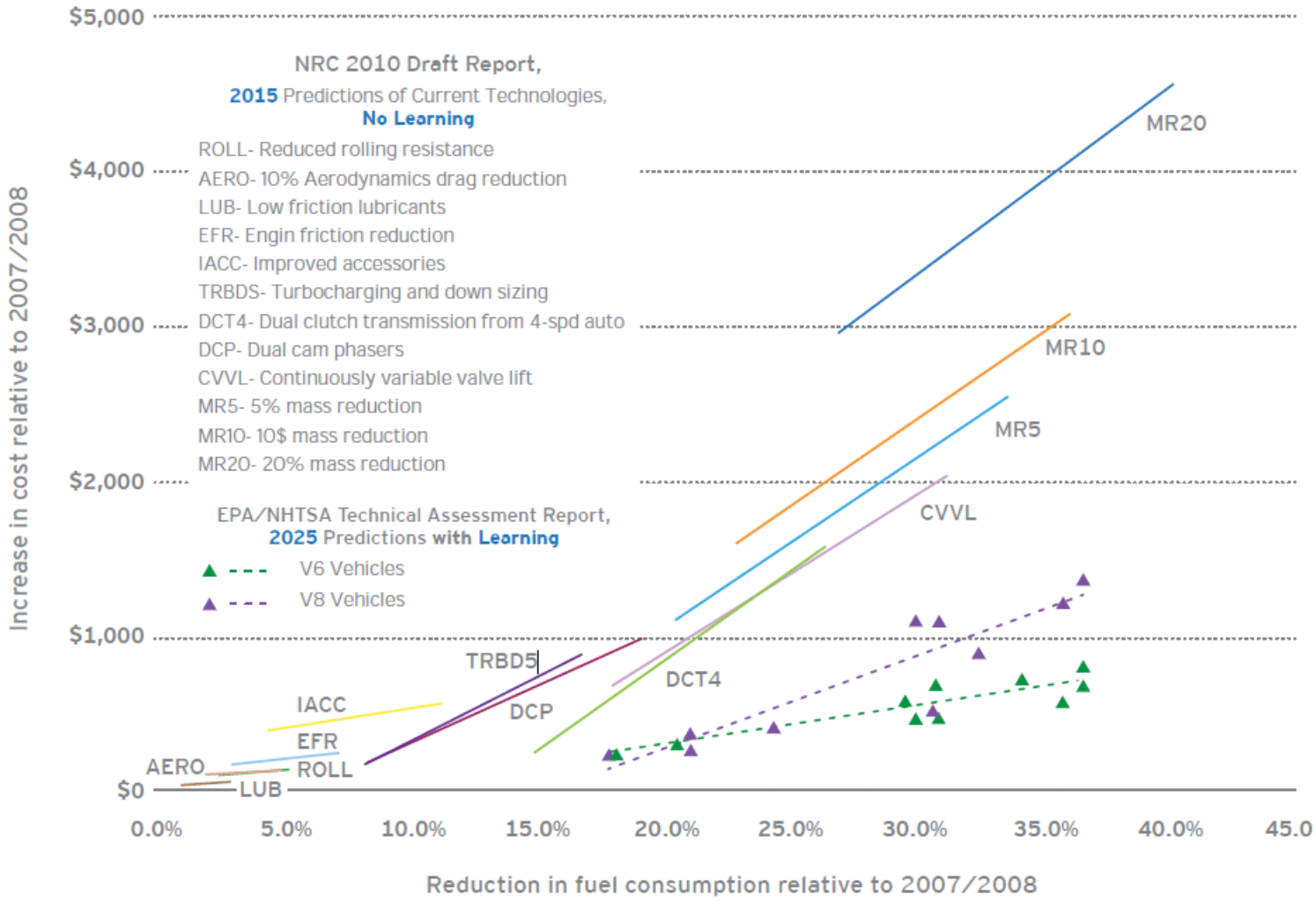
- Batteries
- Electric motors and power electronics

<u>Alternative Hydrocarbon Fuels (for HDVs)</u>

- Biofuels
- Alternative fossil fuels (only if less carbon than gasoline/diesel)



Projected Reductions in the Fuel Consumption of Large Cars and Small Trucks through Technology



Source: National Research Council with data adapted by a National Petroleum Council study committee; joint study by the Environmental Protection Agency and National Highway Traffic Safety Administration (EPA/NHTSA).

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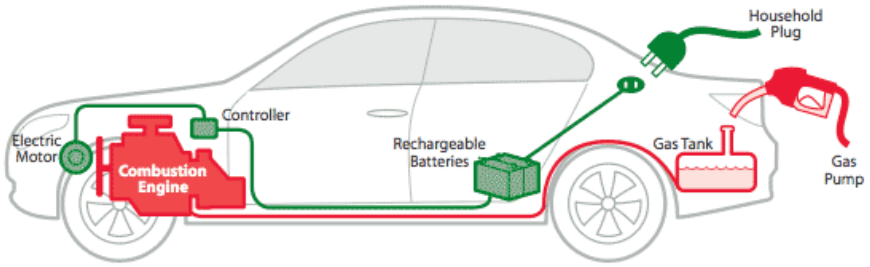
Progressive Electrification of the Light-Duty Fleet

Internal Combustion Engine (ICE) → Hybrid Electric Vehicle (HEV) → Plug-in Electric Hybrid Vehicle (PHEV) → Battery Electric Vehicle (BEV)



Challenges with Batteries and Motors

Batteries
- Cost
- Performance
- Physical Characteristics

Adequate supply chain
- Rare-earth elements in permanent magnet motors
- Lithium in batteries
- OEM & component manufacturing capacity

Charging
- Infrastructure
- Standardization of chargers and grid interface
- Charging times
- Consumer behavior

The Stationary Logic

Generation, transmission, and demand are interdependent

- More complicated than transport

The U.S. is energy independent here

- Competitiveness and environmental impacts come to the fore.
- Strengthening domestic innovation and manufacturing capabilities
- Keep energy affordable while keeping it clean

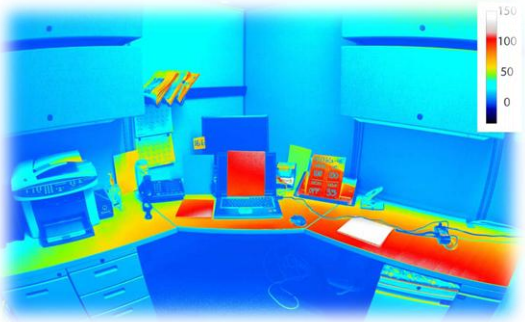
Strategies (ordered by cost-effectiveness and time-to-impact)

- **Increasing energy efficiency in buildings and industry -** most immediate route to increasing energy productivity.
- **Modernizing the grid** will not only increase reliability and security, but also give greater control to meet clean energy aspirations in other strategies.
- **Deploying clean electricity -** accommodates retirement of existing generators and reduces environmental impacts (greenhouse gas emissions, water, …).

Stationary: Technology Headroom for DOE

Building and Industrial Efficiency

- Data collection and usage
- Integrated systems analyses
- Next-gen processes and products



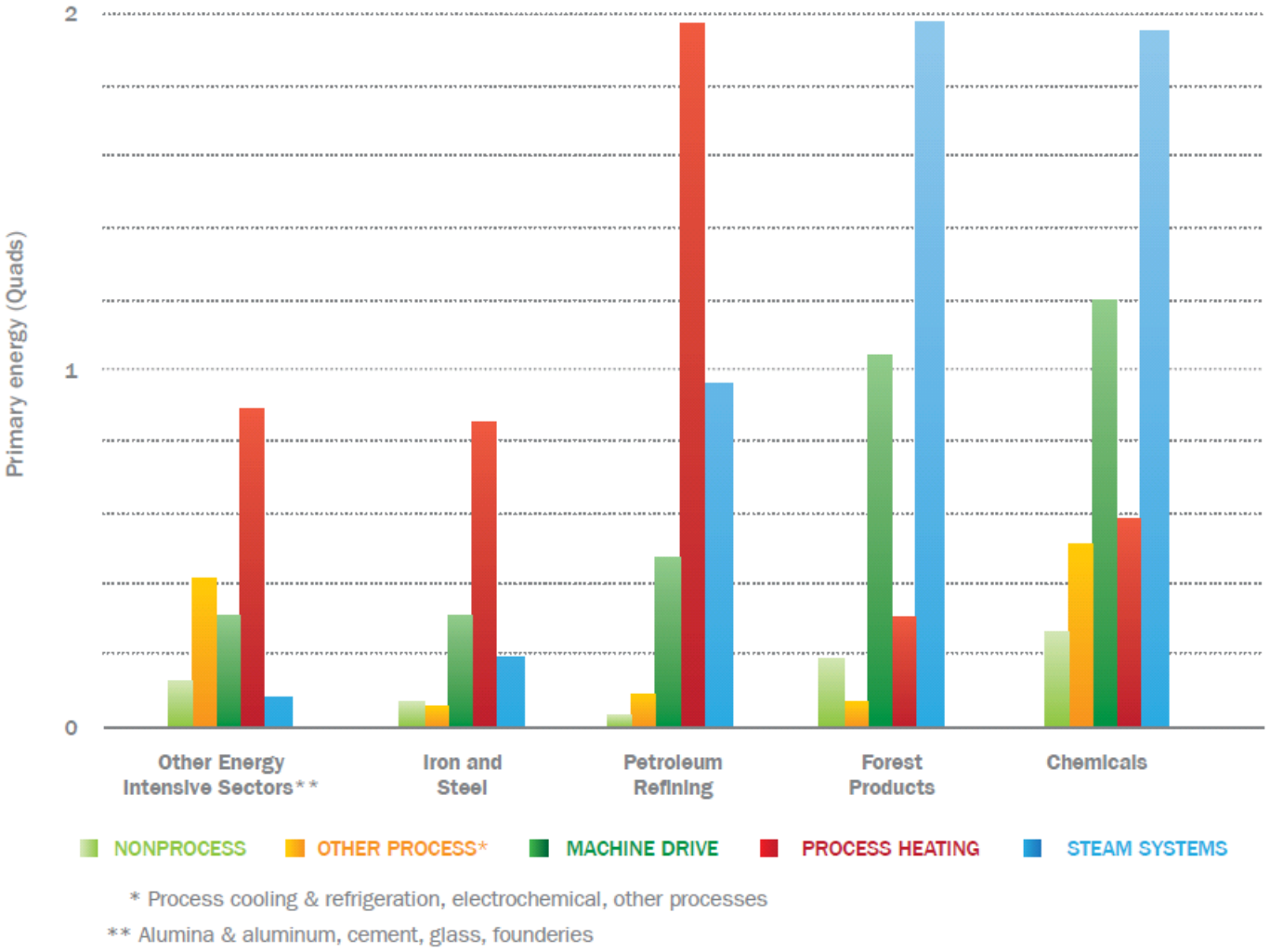
Grid Modernization

- Communication and data
- Management and control
- Energy storage

Clean Power

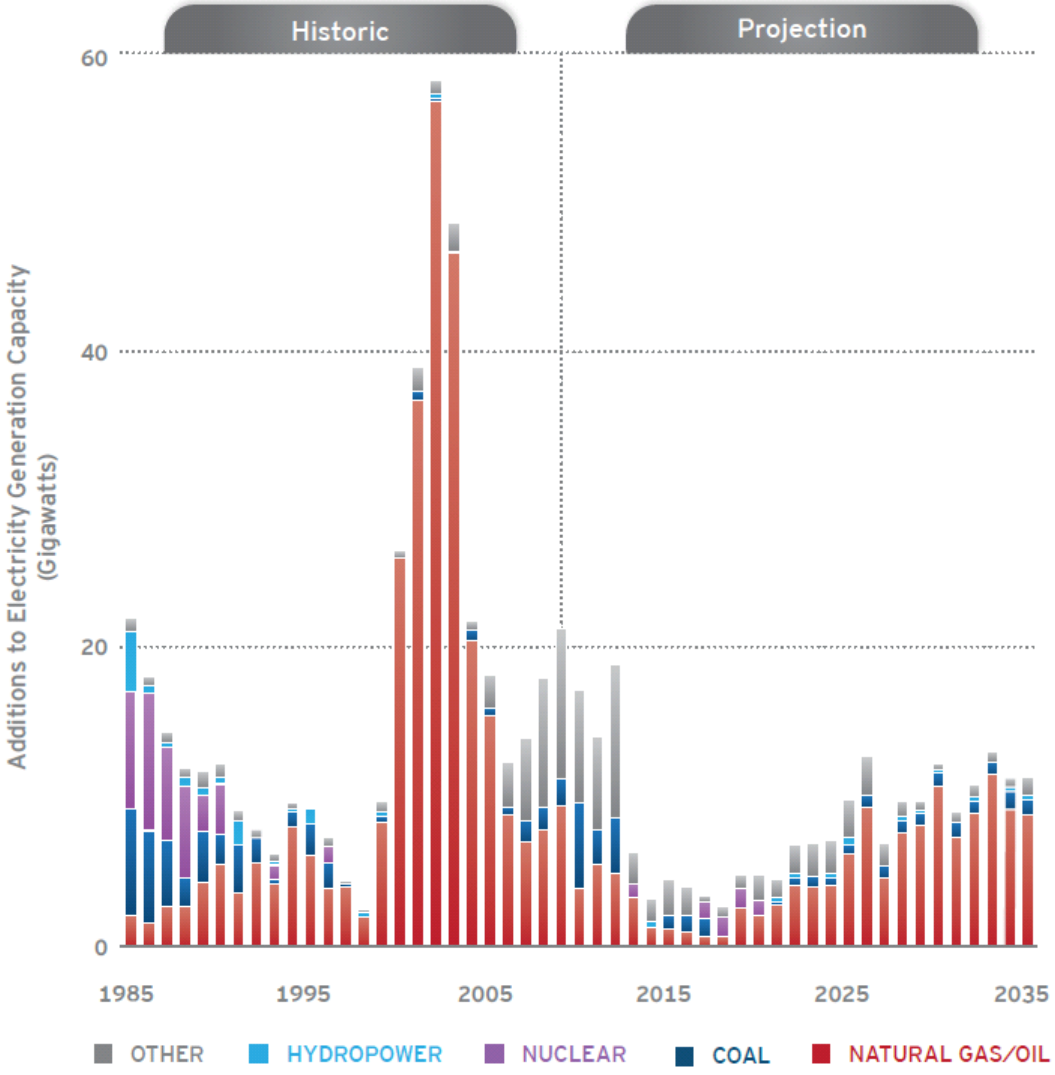
- Drive down costs
- Coupling between energy and water use
- Increase modularity and scalability
- Infrastructure compatibility

Annual Industrial Energy Use in Energy-Intensive Manufacturing by Technology and Subsector



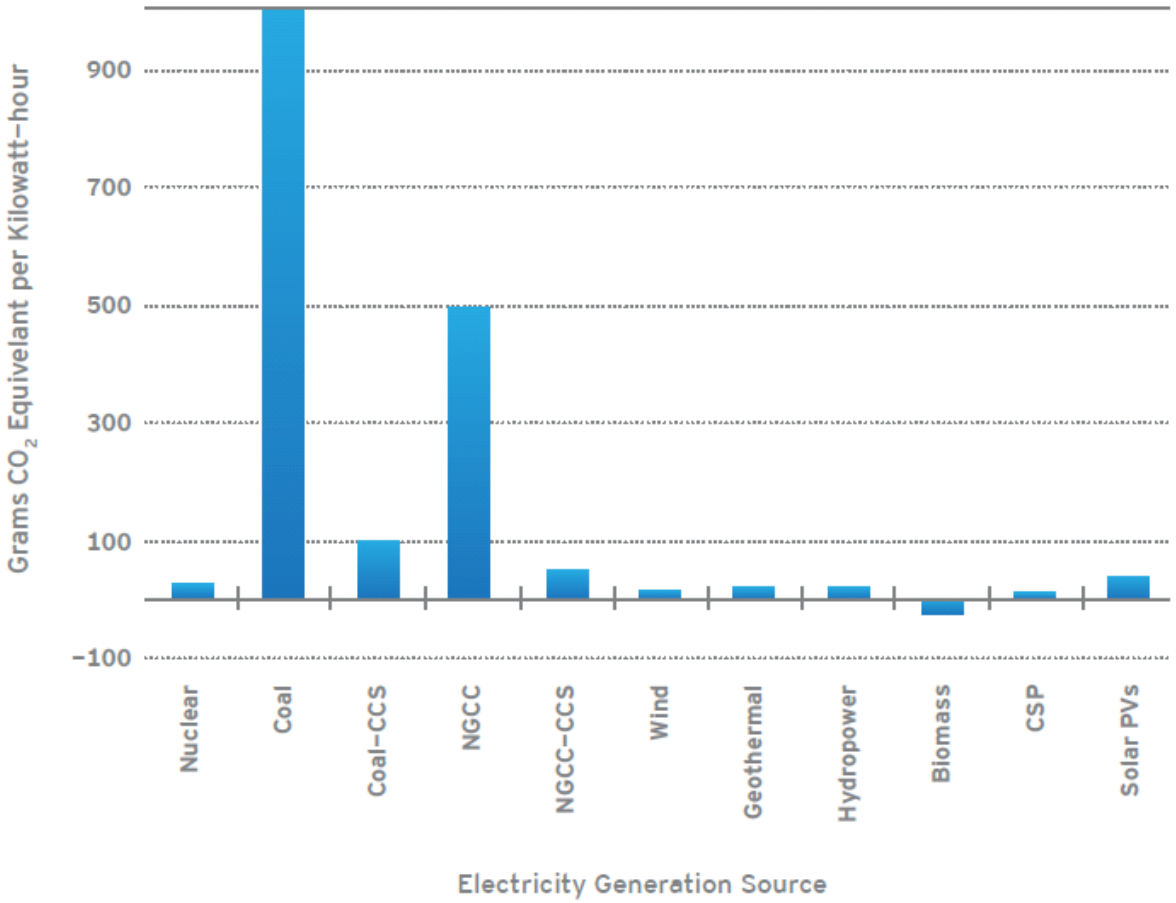
Source: EIA

Additions to U.S. Electricity Generation Capacity, 1985–2035



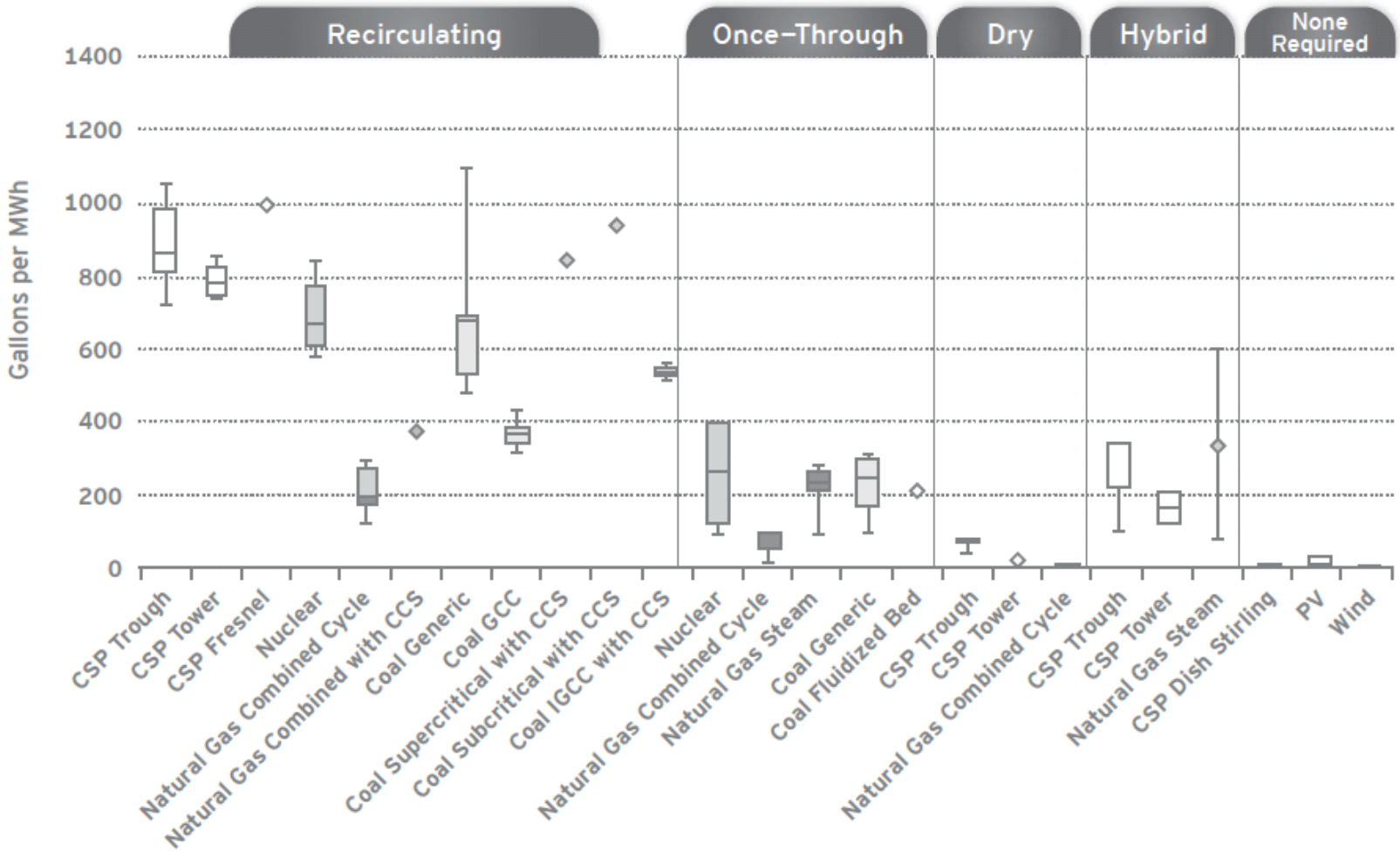
Source: EIA

Estimated Greenhouse Gas Emissions From Generation



CCS = Carbon Capture and Storage; CSP = Concentrating Solar Power;
NGCC = Natural Gas Combined Cycle; PV = Photovoltaic

Water Consumption for Various Power Generation Technologies



TECHNOLOGY POLICY

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Modes of DOE Operation

Capability

- Pre-competitive R&D and engineering science creates a knowledge about new and incumbent energy technologies
- Harnesses capability of national laboratories and universities and strengthens capabilities in private sector partners
- Expertise explores full spectrum of energy technologies for potential breakthroughs and develops a technical workforce capable of addressing energy emergencies (ex: responses to Deepwater Horizon, Fukushima)

Informational

- Information collected, analyzed, and disseminated by DOE shapes policies and decisions made by other governmental and private sector actors

Targeted Initiatives

- Coordination across RD&D process to help prove technologies for private sector adoption
- Highly visible activities that should be infrequent, carefully planned, and with clear technical off-ramps

Prioritization Criteria

DOE will maintain a mix of analytic, assessment, and engineering science capabilities in a broad set of energy technology areas without any expectation of additional DOE investment in demonstration or deployment activities. Status and significance of technology mix will be judged by:

- **Maturity:** Technologies that have significant technical headroom yet could be demonstrated at commercial scale within a decade.
- **Materiality:** Technologies that could have a consequential impact on meeting national energy goals in two decades. Although not equally applicable across all activities in DOE's portfolio, we define "consequential" as roughly one Quad per year of primary energy.
- **Market Potential:** Technologies that could be expected to be adopted by the relevant markets, understanding that these markets are driven by economics but shaped by public policy.

DOE will consider targeted initiatives, including demonstration activities, for only technologies that meet all 3 Ms.

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Balancing the DOE Energy Technology Portfolio

Balancing Timescales

- Maximize impact of programs on achieving national energy goals
- Longer-term perspective vs urgency of impact at scale
  - Accelerate innovation relevant to today's energy technologies (now)
  - Information (near-term impact with high leverage)
  - Fundamental R&D and emerging technologies (longer-term or high-risk; high leverage)
- Reserve 20% of energy technology R&D portfolio for "out of the box" activities

Balancing Energy Challenges (Security, Competitiveness, Environment)

- No single challenge trumps the other two
- Address all challenges to increase portfolio robustness
- Transport contributes to all 3 challenges; stationary to 2 (but bigger impact on those 2)
- Be aware of domestic and global context and markets for energy technologies

Balancing Among Strategies

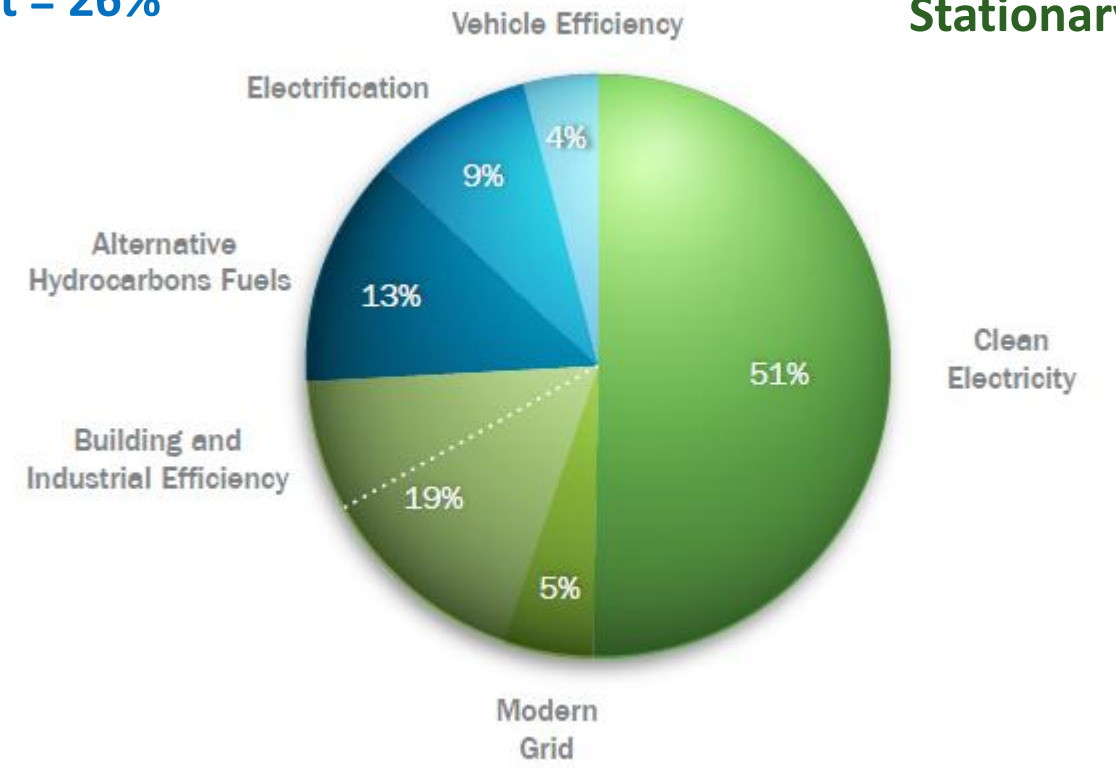
- Budget: federal agencies, international sources, and the private sector
- Give greater emphasis to transport sector, where innovation can impact all three energy challenges

The Department's Fiscal Year 2011 Energy Technology Budget, Categorized by Strategy

Total = $3.0B

Transport = 26%

Stationary = 74%



Additional Findings

Enduring Group within DOE w/Integrated Technical, Economic, and Policy Expertise

- Provides **integrated understanding of technology, markets, business, social science, and policy** for the planning and operation of technology programs.
- Major functions: energy and technology policy analysis; economic impact assessments of R&D, industry studies, and program evaluation; and technology assessment and cost analysis.

FACA: Under Secretary's Advisory Council

- Spans across DOE's four energy technology programs to **promote integrated view** of solving energy challenges and provide advice on QTR implementation

Social Science is Important

- Integrate applied social science into DOE's technology programs and planning processes

QTR Should Inform the Budget Process

- Integrate QTR decision criteria and priorities into continual development of program plans

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Continuation with Future QTRs and QERs

Future QTR

- 4-year process conducted by DOE
- Continuous evaluation and adjustments in programs plans
- Uses DOE's growing analytical capabilities to produce more detailed and comprehensive reports

Future QER??

- Develops more coordinated and robust Federal energy policy through engagement of agencies and departments across Executive Branch
- Provide effective tool for Administration-wide coherence on energy and for dialogue with Congress on a coordinated legislative agenda
- Provide multiyear roadmap with integrated view of technology-neutral energy objectives
- Put forward anticipated Executive actions coordinated across multiple agencies
- Establish government-wide goals, coordinate actions across agencies, and identify the resources needed for the invention, translation, adoption, and diffusion of energy technologies
- Led by the Executive Office of the President, with support from an Executive Secretariat provided by the Secretary of Energy

Key Takeaways

- There are “stories” for Transport and Stationary
  - Sensible futures, DOE’s role, technology programs
- DOE’s energy technology portfolio is not optimally balanced
  - Stationary much larger than Transport
  - Clean Power dominates Stationary (~50% of total)
- DOE needs integrated analytic capability (technology, business, market, policy, and social science)
- DOE’s informational and convening roles are highly valued by stakeholders, but under-valued within the Department (as compared to its technical capabilities)
- DOE needs to be more selective in its technology initiatives
- QTR establishes a framework for QER and future QTRs

Technology Assessments (Volume II of QTR Report)

Vehicle Efficiency:

- Internal Combustion Engine
- Lightweighting and Aerodynamics

Vehicle Electrification

- Vehicle Electrification

Alternative Hydrocarbon Fuels

- Alternative Hydrocarbon Fuels

Stationary Efficiency:

- Building Efficiency
- Industrial Efficiency

Grid Modernization:

- Measuring, Modeling, and Control
- Infrastructure
- Storage

Clean Power:

- Carbon Capture and Storage
- Concentrating Solar Power
- Fuel Cells for Distributed Power Generation
- Geothermal Power
- Nuclear Power
- Solar Photovoltaic Power
- Water Power
- Wind Power

Team @ QTR Capstone Workshop

www.energy.gov/QTR