Quadrennial Technology Review-2015
Chapter 1: Energy Challenges

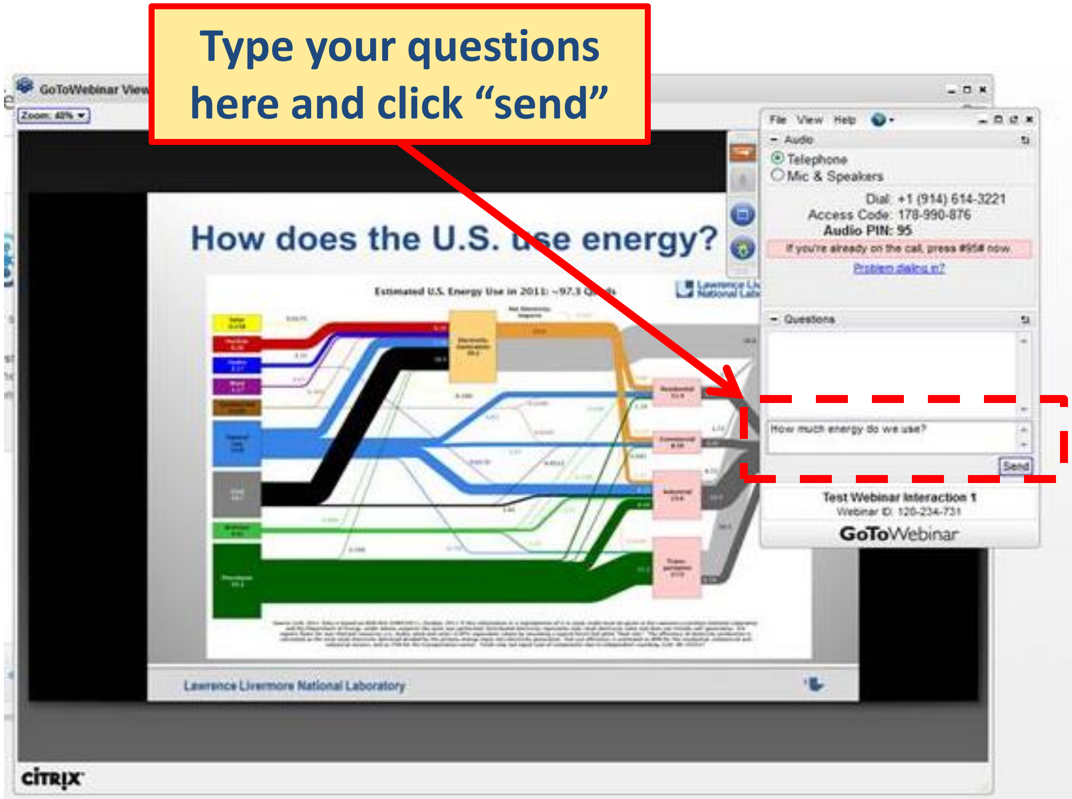
Public Webinar

Draft Notional Content Under Discussion

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.

- 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.



Webinar Schedule (all times EST)

Begin	End	Chapter	Topic
10:00 AM	11:00 AM	1	Energy Challenges
11:00 AM	12:00 PM	2	What Has Changed?
12:00 PM	1:00 PM	3	Systems
1:00 PM	2:00 PM	10	Enabling Science
2:00 PM	3:00 PM	11	Competitiveness
3:00 PM	4:30 PM	12	Integrated Analysis
4:30 PM	5:30 PM	13	Accelerating RD3

QTR-2015 – Why Now?

- **Dramatic changes across the energy industry:**
  - Unconventional fossil fuel production
  - Renewables cost reduction and market penetration
  - Nuclear power opportunities
  - Electricity sector
  - Transportation electrification
  - Buildings efficiency
  - Industry efficiency
  - Manufacturing and competitiveness
  - Increasing use of digital technologies: Power, Vehicles, Buildings
- **The grand challenges, policies, and dramatic changes in industry and technology require new approaches that better configure our programs, capabilities, and infrastructure for success.**

Quadrennial Reviews Underway

- Quadrennial Energy Review: Called for by the President to analyze government-wide energy policy, particularly focused on energy infrastructure.

- Quadrennial Technology Review: Secretary Moniz requested the QTR-2015 building on QTR-2011, and that it should be published in parallel with the QER to provide analysis of the most promising RDD&D opportunities across energy technologies in working towards a clean energy economy.

The resulting analysis and recommendations of the QTR 2015 will inform the national energy enterprise and will help guide the Department of Energy's programs and capabilities, budgetary priorities, industry interactions, and national laboratory activities.

Expanded Scope of QTR 2015

- **The QTR-2015 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.**

- **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.**

Selection Criteria Under Consideration

Building on the work of the QTR-2011, the following selection criteria are being considered for the QTR-2015:

- **Maturity:** Technologies should have the potential for significant advances in cost, performance, or other key metrics with further RD3 over the next 10 years, leading to commercialization within 15 years.
- **Materiality (Impacts):** The system and associated technologies, in aggregate, should have the potential to save or supply at least 1% (1 Quad) of the primary energy of the U.S. or of a region, or similarly impact a key energy-linked challenge such as reducing carbon emissions.
- **Market potential:** The system or technology should have significant potential to succeed in competitive markets, recognizing that markets are driven by economics and shaped by public policy.
- **Public benefits:** The system or technology should have significant public benefits, such as: improvements in public safety and security; much lower emissions of CO_2 or other pollutants; reductions in environmental impacts to land, water, or biota; or others.
- **Public role:** The system or technology should be one that provides value to the public, that the private sector is unlikely to undertake the RD3 at sufficient scale alone, and for which the public contribution can make a significant impact in advancing the technology.

Selection Criteria, continued

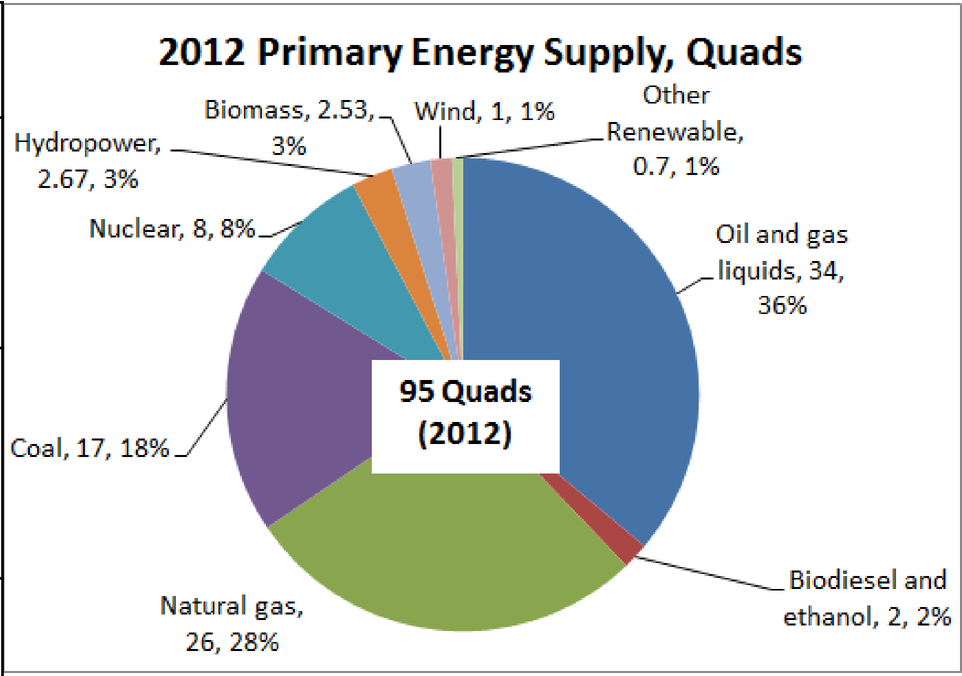
In addition, key elements of strategy for energy science and technology RD^3 that are being considered include the following:

- **Portfolio diversification**: The technology should not duplicate another, similar technology unless it offers significant differences in risk, return, time-of-impact, or other benefits.

- **Transition strategy**: As the private sector's capabilities in the technology mature and grow, they should shoulder an increasing role in the RD^3, and the federal role may shift to such factors as codes and standards, information, convening authority, policy, and others, or may end.

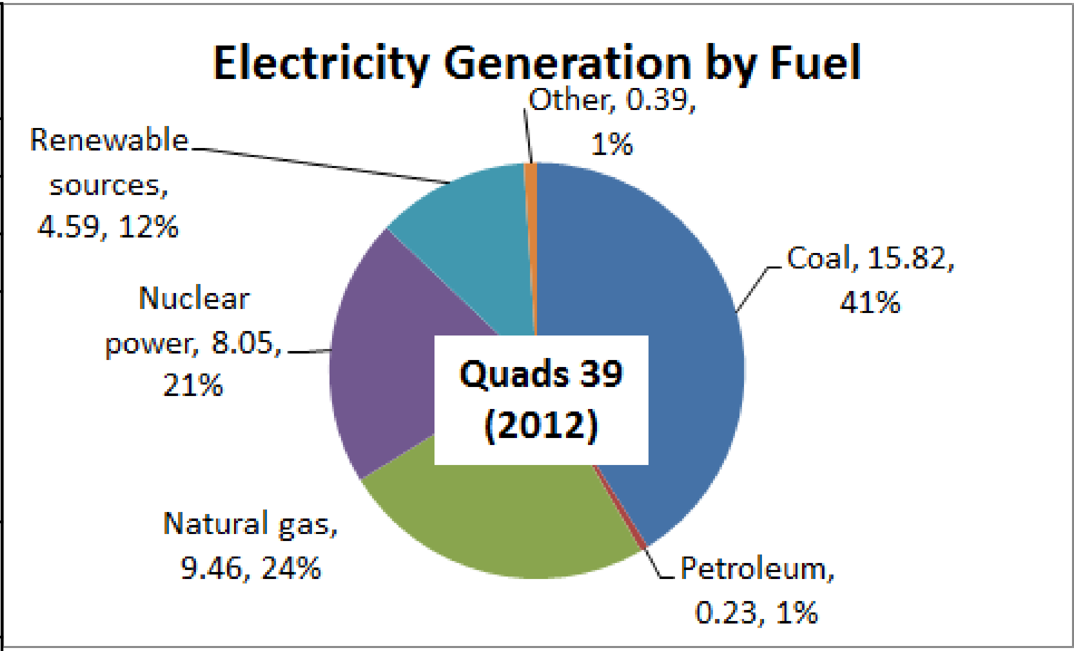
U.S. Energy Supply & QTR-2015 Systems/Technologies RD3
(Issue areas under consideration)

4. Advancing Systems/Technologies for Cleaner Fuels
--Oil & Gas: Shale Development; Drilling and Completion (Onshore & Offshore); Spill Prevention; Enhanced Oil Recovery; Methane Hydrates
--Subsurface Engineering R&D: Intelligent wellbores; Subsurface Stress & Induced Seismicity; Permeability Manipulation; New Subsurface Signals
--Biofuels: Feedstocks and Logistics; Conversion Pathways; Fuels and Fueling Infrastructure
--Hydrogen: Production and Delivery
--Other Alternative Fuels: LNG/CNG/Propane; Ammonia and Carbon-Free Carriers; Coal (and Biomass) to Liquids; Methanol and DME
CROSSCUTTING ISSUES
--Water-Energy: Produced Water; Biomass Water Requirements
--Enabling Science: Geoscience; Direct-Solar Fuels



U.S. Energy Supply & QTR-2015 Systems/Technologies RD3
(Issue areas under consideration)

5. Enabling Modernization of the Electricity Delivery System
--Grid Architectures and Concepts
--Transmission Control Systems
--Distribution Control Systems
--Integration of Demand-Side Resources and Grid Interfaces: Smart Loads; Distributed Generation; Electric Vehicles; Smart Buildings; Microgrids
--Planning Tools: Market Simulators; Decision Support
--Transmission & Distribution Components and Infrastructure: Transformers; FACTS; Protection Equipment; Cables and Conductors
--Electrical Energy Storage Systems: Batteries; Flywheels; Superconducting Magnetic Energy Storage; Electrochemical Capacitors
--Cyber and Physical Security



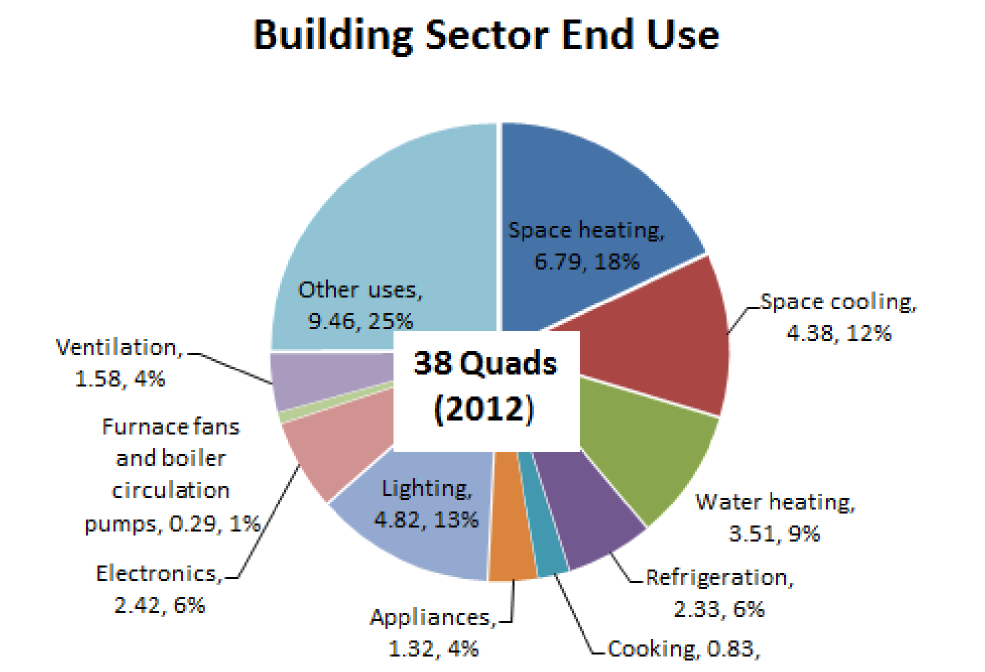
U.S. Energy Supply & QTR-2015 Systems/Technologies RD3
(Issue areas under consideration)

6. Advancing Clean Electric Power Technologies
--Fossil Power with Carbon Capture and Storage: Capture; Storage; Demonstrations; Capture on Gas Plants; Capture from Industry
--Nuclear Power: LWRs; SMRs; HTR; Fast Spectrum Reactors; Fuel Cycles; Waste Management; Hybrid Systems
--BioPower
--Stationary Fuel Cells
--Geothermal:
--Solar Power: Photovoltaics; Concentrating Solar Power
--Hydropower
--Marine and Hydrokinetic Power
--Wind Power: Plant Optimization; Components and Materials; Offshore; Grid Integration
CROSSCUTTING ISSUES
--Supercritical Carbon Dioxide Power Cycles
--Subsurface Science and Technology: Carbon Sequestration; Geothermal Energy; Nuclear Waste Isolation
--Water-Energy: Advanced Cooling; Water Treatment; Waste Heat Utilization

U.S. Energy End-Use & QTR-2015 Systems/Technologies RD3

(Issue areas under consideration)

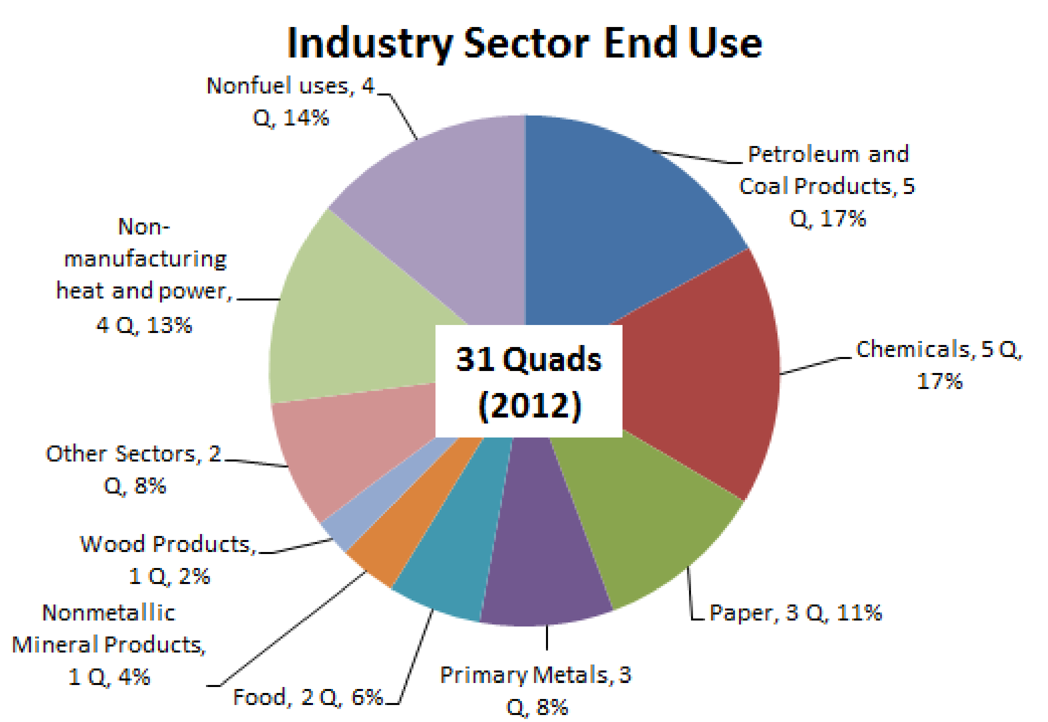
7. Increasing Efficiency of Buildings Systems and Technologies
--Thermal Comfort and Air Quality: Building Envelope; Ventilation; HVAC Equipment including Heat Pumps; Moisture Removal; Heat Exchangers; Thermal Storage
--Lighting: Windows, Daylighting and Lighting Controls; Lighting Devices
--Appliances: Hot Water; Clothes Dryers; Refrigerators
--Electronics and Miscellaneous Loads: Information Processing and Data Centers; Displays
--Building Systems: Sensors, Controls and Networks; Building Design and Design Tools; Building Operations and Operation Models; Social and Behavioral Research; Embodied Energy; DC Systems



U.S. Energy End-Use & QTR-2015 Systems/Technologies RD3

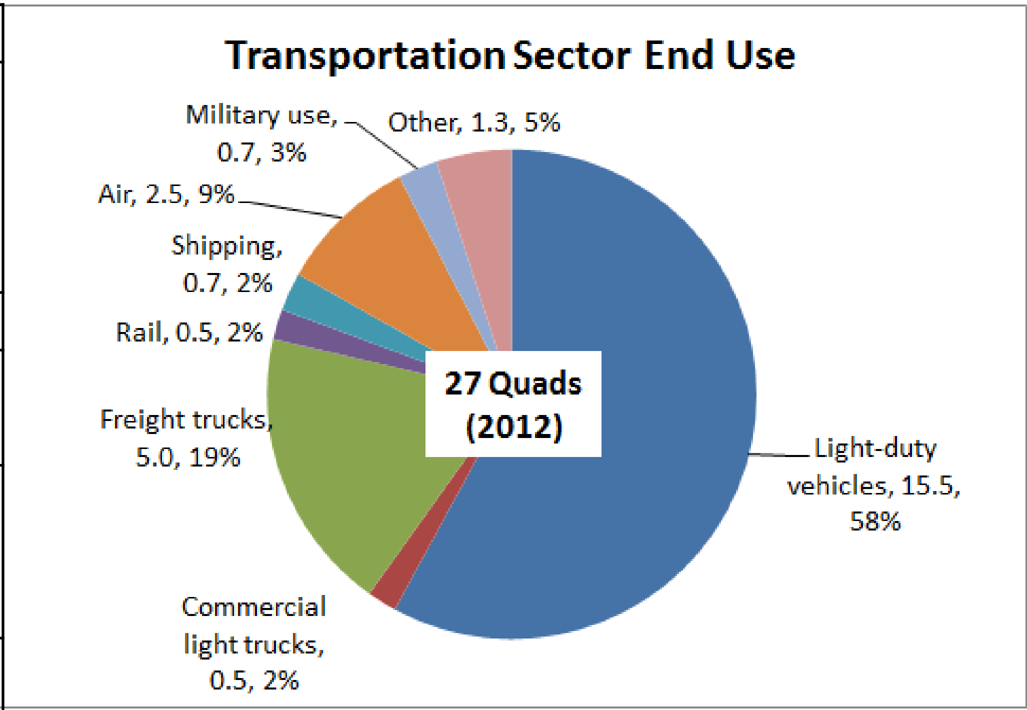
(Issue areas under consideration)

8. Energy Technologies in Advanced Manufacturing
--Existing Unit Operations: Process Heating Systems; Motor Driven Systems
--New Manufacturing Approaches: Process Intensification; Roll-to-Roll Processing; Additive Manufacturing
--Facility-level Energy Management: Combined Heat and Power (CHP); Waste Heat Recovery
--Data and Automation: Smart Manufacturing; Demand-side Management (DSM)
--Managing Material Demand: Critical Materials and their Alternatives; Sustainable Manufacturing; Manufacture of Novel Materials
--Manufacturing of Clean Energy Products: Thermoelectrics; Materials for Harsh Service; Wide Bandgap; Composites

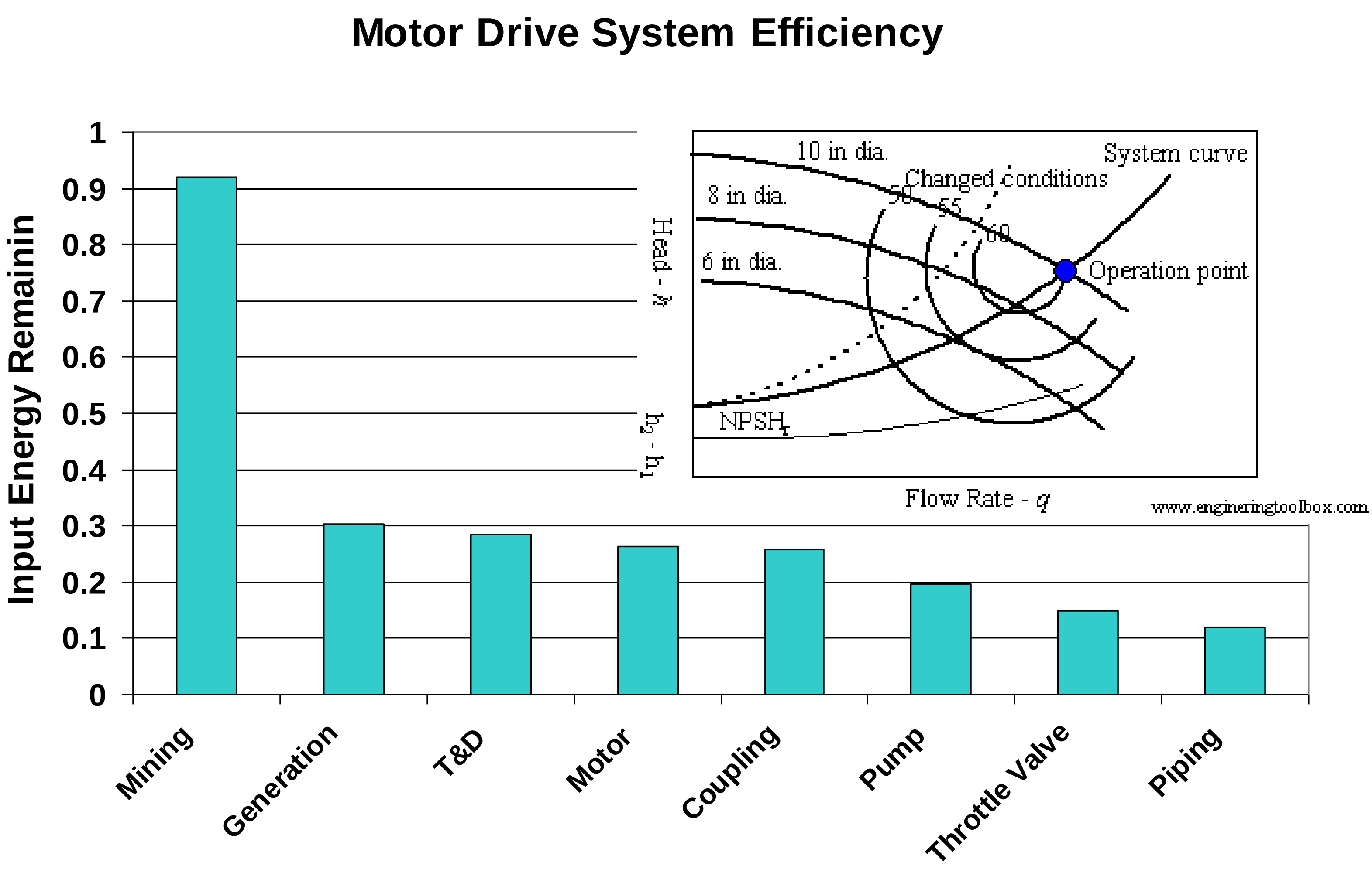


U.S. Energy End-Use & QTR-2015 Systems/Technologies RD3
(Issue areas under consideration)

9. Clean Transportation & Vehicles Systems
--Combustion Vehicles: Combustion Research; Emissions Controls; Fuel/Vehicle Co-optimization; Heavy Duty Vehicle Systems
--Lightweighting
--Vehicle Electrification: Batteries; Electric Drive Technologies; Charging Systems
--Hydrogen and Fuel Cell Vehicles: Storage; Fuel Cell Technologies; Safety, Codes and Standards
--Other Modes: Aviation; Marine (domestic and international); Pipeline; Rail, Off-Road
--Vehicle Automation

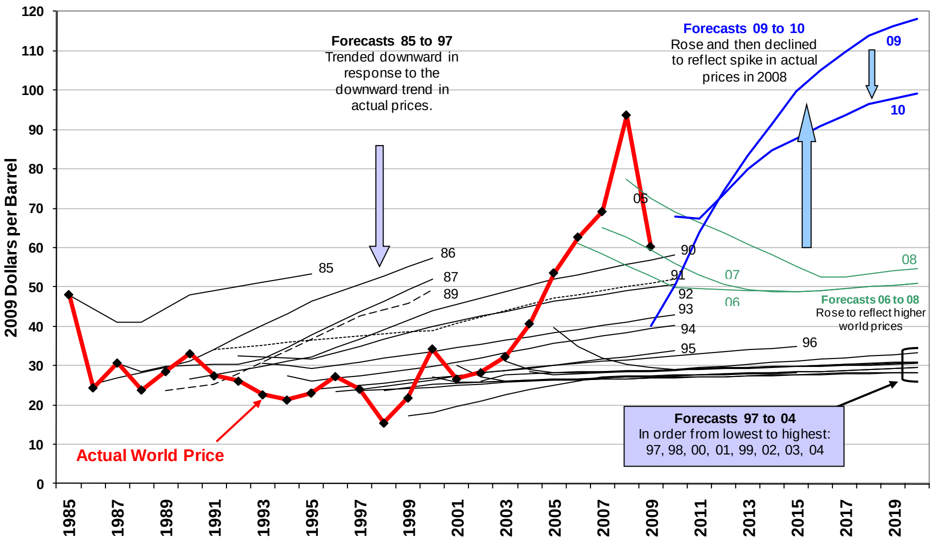


System Efficiencies: A Notional Example



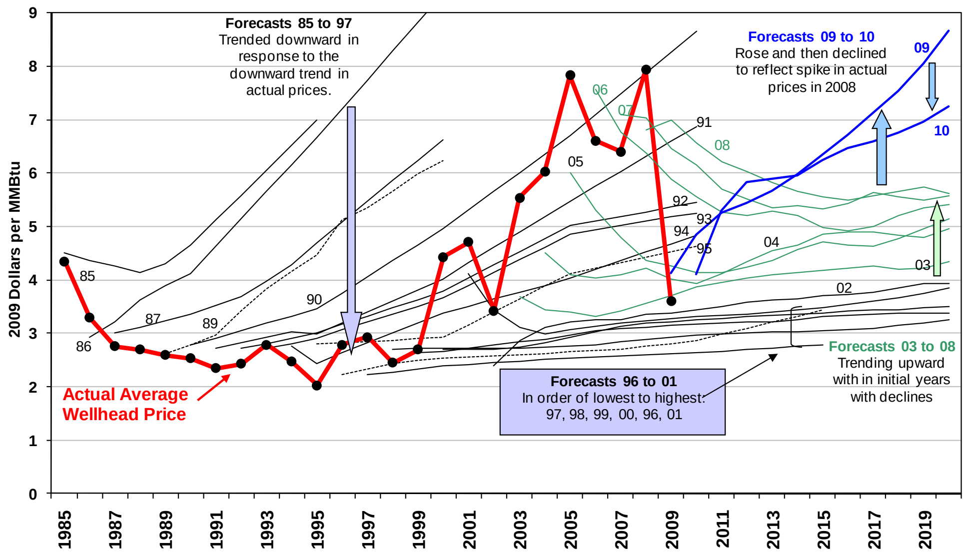
Uncertainties

Historic AEO World Oil Price Forecasts vs. Actual World Oil Prices
(Landed Cost of Imports)



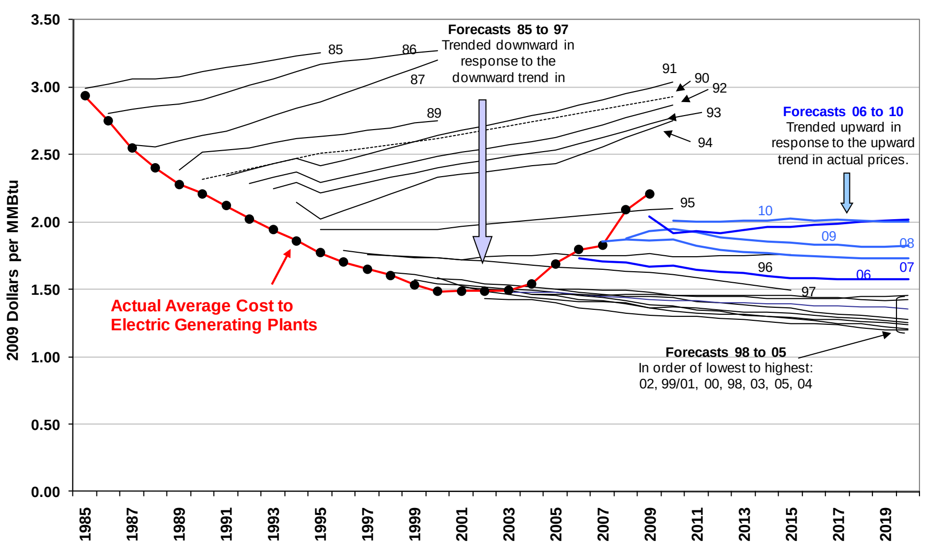
Sources: EIA *Annual Energy Outlooks*

Historical AEO Natural Gas Price Forecasts vs. Actual NG Prices
(Average Lower 48 Wellhead Prices)



Sources: EIA *Annual Energy Outlooks*

Historical AEO Coal Price Forecasts vs. Actual Coal Prices
(Costs to Electric Generating Plants)



Sources: EIA *Annual Energy Outlooks* (2008 is Early Release)

QTR-2015 Chapter Outline--Draft

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

- **Overview.** An extensive set of web appendices will be linked through the .pdf of the main report. This will allow additional material to be presented, extending the discussion in the main volume. The content to be included or linked to in these appendices potentially includes:
  - QTR Technology Assessments
  - Technology Roadmaps and their updates, and other key RD3 information.
  - Workshops
  - Webinars
  - Program In-Progress Peer Reviews and other Reviews

- **Updates.** A significant advantage of supplying these materials on the web is that they can be updated over the next several years so that this can be an ongoing central source of information for the DOE science and energy programs.

- **Additional Information.** Another potential advantage of this web-based approach is that more complex materials, such as visualizations, analytical tools, and other materials can potentially be developed over time and linked.

QTR-2015 Notional Goals

- **Frame the energy-linked challenges** that the United States faces and identify key energy science and technology RD^3 that could help meet these challenges.
- **Assess technology opportunities**, and identify approaches for evaluating the strengths, weaknesses, and tradeoffs among them, and the development of a portfolio for RD^3 balanced across key dimensions of investment, return, timeframe, risk, and others.
- **Identify cross-cutting activities** that link the energy science and technology programs on strategically important RD^3, and strengthen the analytic underpinnings for these in DOE work.
- **Examine roles** that the DOE, national labs, private sector, and academia can fill on energy RD^3 and how they can better leverage the best strengths of each to meet our energy challenges.

What the QTR-2015 Will Not Do

- **The QTR is not a budget document** and does not itself systematically prioritize specific activities; instead it intends to frame a broad range of important RD^3 opportunities and provides key data and analysis about them.

- **The QTR is not a strategic plan**; instead it intends to build on the DOE strategic plan and focus in more depth on key energy science and technology RD^3 opportunities going forward.

- **The QTR is not a programmatic roadmap**; instead it intends to provide detail and analysis of the overall RD^3 options space and provide links to the QTR Technology Assessments, roadmaps, and other documents to provide detailed inputs to specific programmatic work.

- **The QTR does not develop scenarios or projections** of how energy systems will evolve; instead it intends to map energy RD^3 options and broadly frame their potential returns and other important metrics.

- **The QTR is not a policy document**; instead it intends to focus on RD^3. Energy policy issues are primarily addressed by the QER.

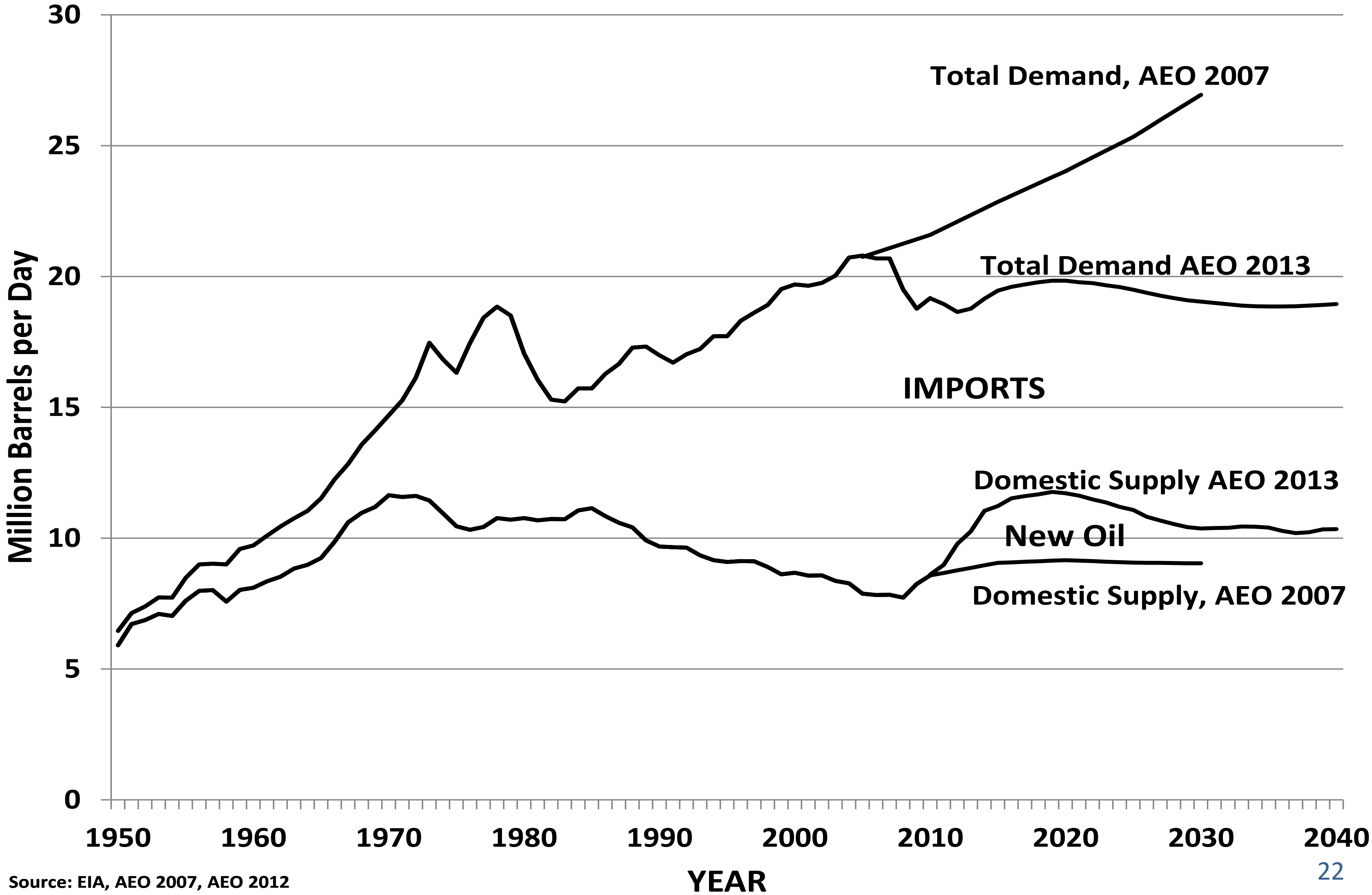
QTR-2015 -- Challenges

- **The United States faces serious energy-linked challenges:**
  - **Economic**
  - **Environmental**
  - **Security**

- **Research, development, demonstration and deployment (RD3) of innovative energy technologies will be critical to achieving these objectives.**

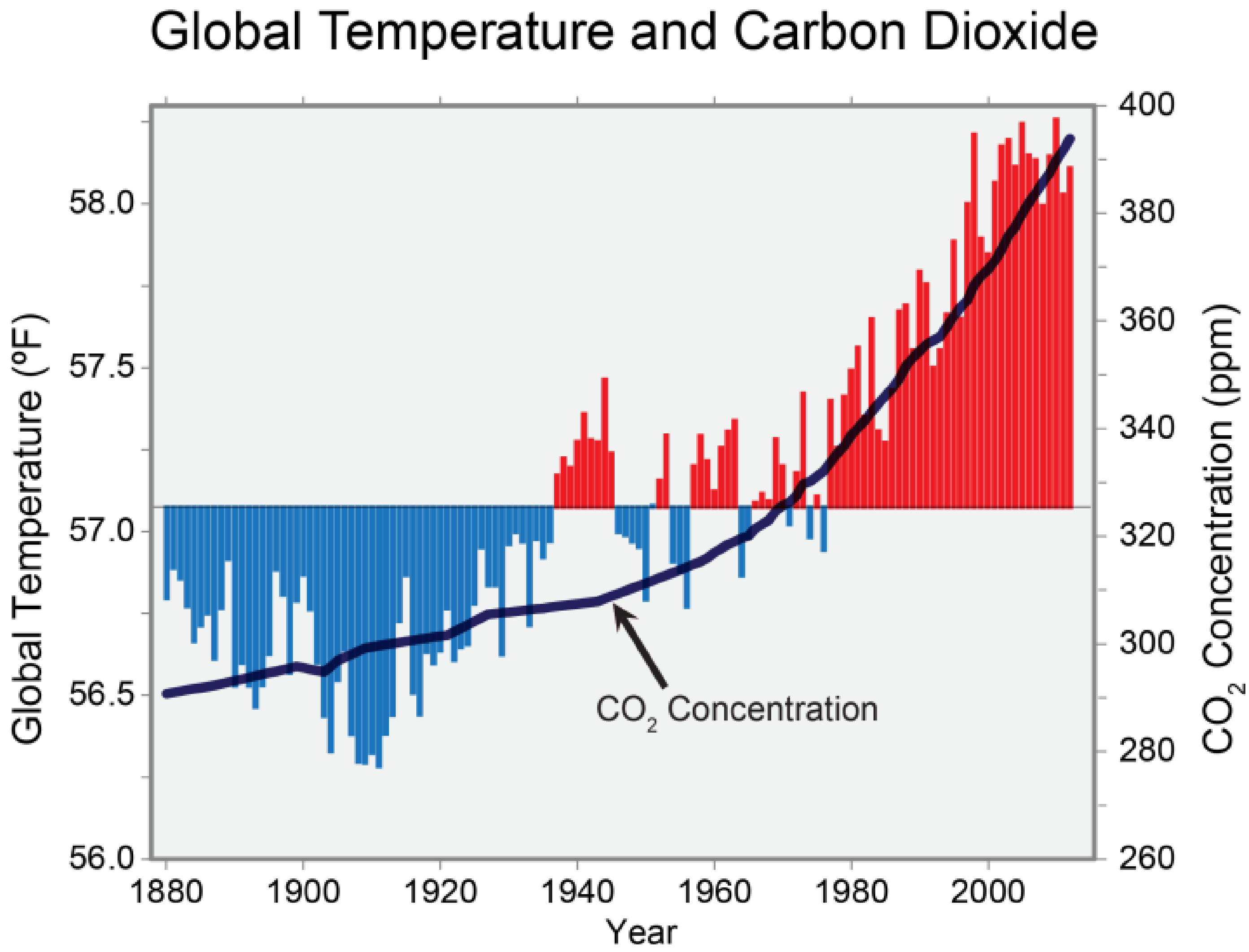
- **The QTR-2015 will examine a broad range of energy science and technology RD3 opportunities to provide information useful for decision-makers.**

Economic Challenges: Oil Supply and Demand?



Source: EIA, AEO 2007, AEO 2012

Environmental Challenges



Source: National Climate Assessment, 2014. http://nca2014.globalchange.gov/ "Figure 2.2: Global annual average temperature (as measured over both land and oceans) has increased by more than 1.5°F (0.8°C) since 1880 (through 2012). Red bars show temperatures above the long-term average, and blue bars indicate temperatures below the long-term average. The black line shows atmospheric carbon dioxide (CO_2) concentration in parts per million (ppm). While there is a clear long-term global warming trend, some years do not show a temperature increase relative to the previous year, and some years show greater changes than others. These year-to-year fluctuations in temperature are due to natural processes, such as the effects of El Niños, La Niñas, and volcanic eruptions. (Figure source: updated from Karl et al. 2009"

Published Drought Projections

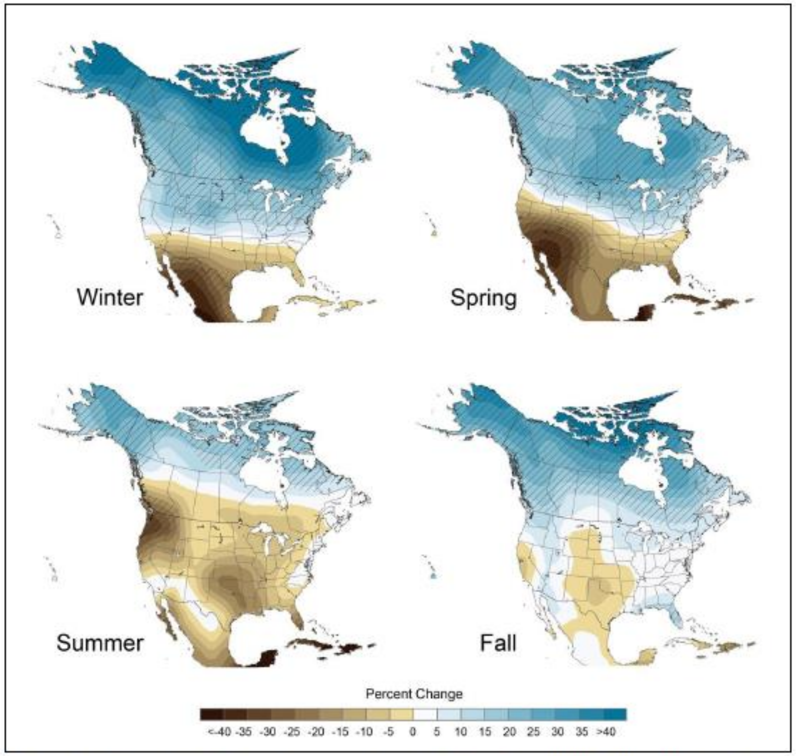
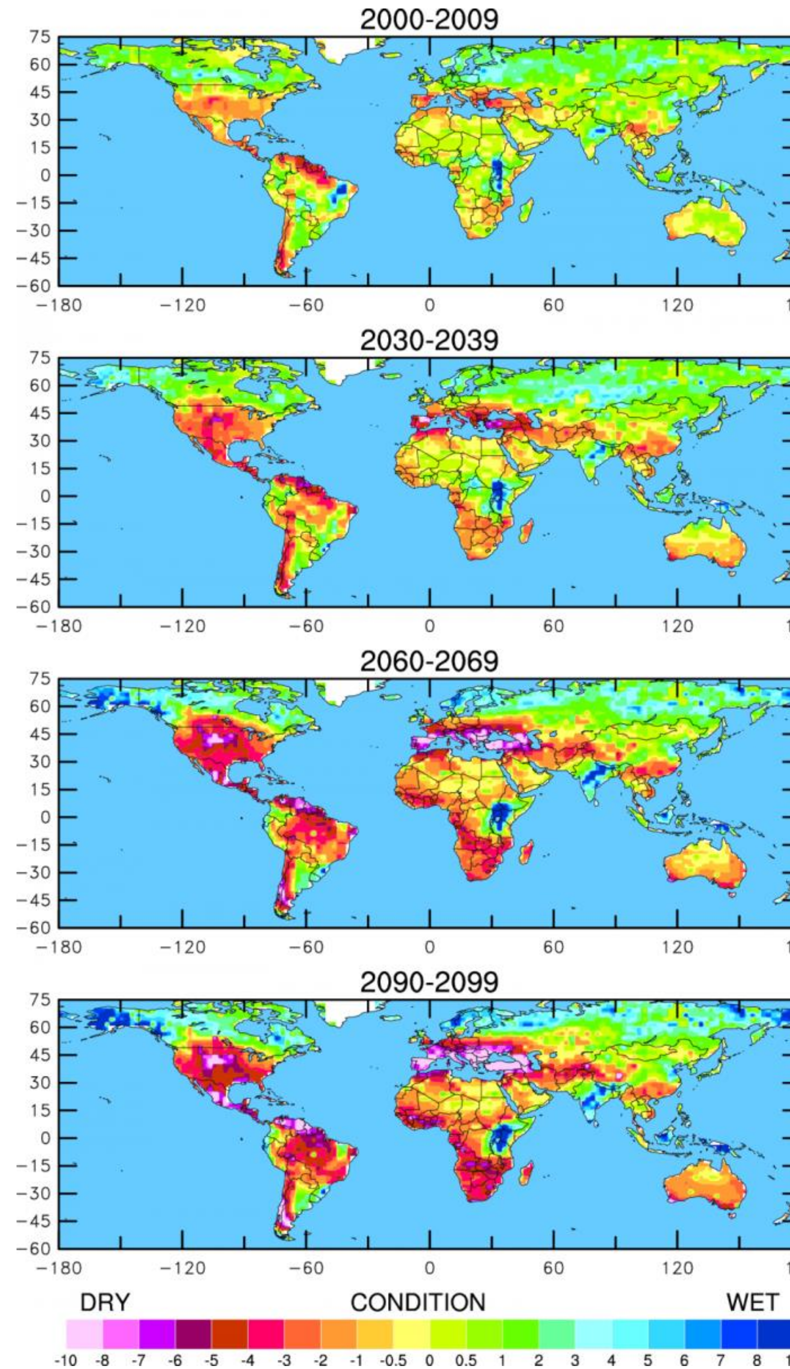


Figure 3.2 Projected future changes in precipitation by 2080-2099, relative to average seasonal precipitation in 1961-1979 under the A2 emission scenario and simulated by 15 climate models. Hatched areas show areas with highest confidence in the projected change. Source: USGCRP (2009)



Aiguo Dai, “Drought under global warming: a review”, Wiley InterDisciplinary Review: Climate Change, 2010, http://onlinelibrary.wiley.com/doi/10.1002/wcc.81/pdf For a correction, see: https://www2.ucar.edu/atmosnews/news/2904/climate-change-drought-may-threaten-much-globe-within-decades

Aiguo Dai, “Increased drought under global warming in observations and models”, Nature Climate Change V.3, Jan. 2013, pp.52-58.

Inter-Academy Panel
Statement On Ocean Acidification
1 June 2009

- **Signed by the National Academies of Science of 70 nations:**
  - Argentina, Australia, Bangladesh, Brazil, Canada, China, France, Denmark, Greece, India, Japan, Germany, Mexico, Pakistan, Spain, Taiwan, U.K., U.S.….

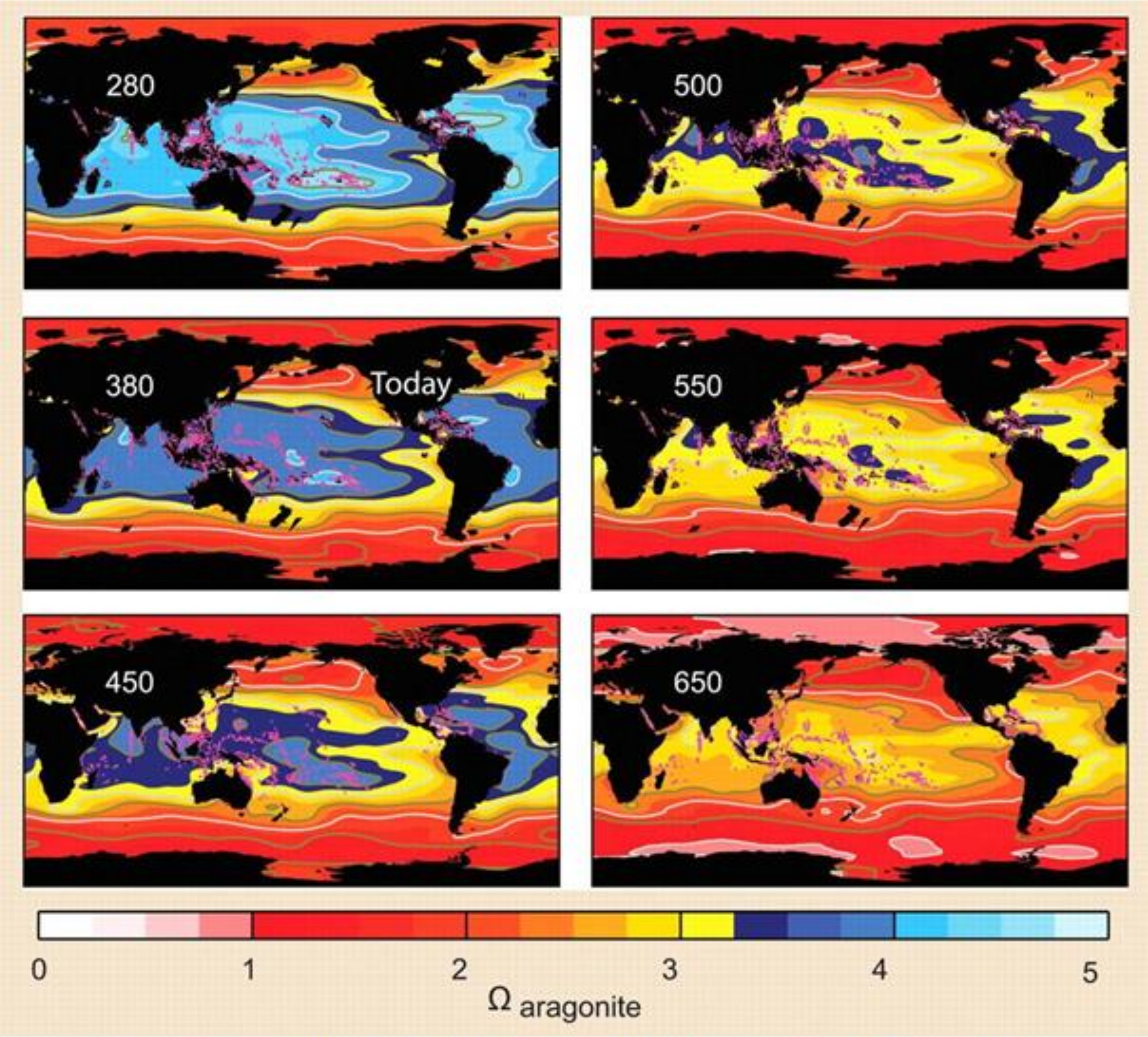
- **"The rapid increase in CO_2 emissions since the industrial revolution has increased the acidity of the world's oceans with potentially profound consequences for marine plants and animals, especially those that require calcium carbonate to grow and survive, and other species that rely on these for food."**
  - Change to date of pH decreasing by 0.1, a 30% increase in hydrogen ion activity.

- **"At current emission rates, models suggest that all coral reefs and polar ecosystems will be severely affected by 2050 or potentially even earlier."**
  - At 450 ppm, only 8% of existing tropical and subtropical coral reefs in water favorable to growth; at 550 ppm, coral reefs may be dissolving globally.

- **"Marine food supplies are likely to be reduced with significant implications for food production and security in regions dependent on fish protein, and human health and well-being."**

- **"Ocean acidification is irreversible on timescales of at least tens of thousands of years."**

Published Projections of Ocean Acidification



Source: Hoegh-Guldberg, et al, Science, V.318, pp.1737, 14 Dec. 2007

Security Challenges to be Considered

- **Physical** security threats: potential damage to supply and delivery infrastructure. Such as by malicious actors (domestic or foreign, state- or non-state-sponsored). Additionally, climate change, weather, and natural hazards pose increasing risk to critical assets in the energy system. Storms such as Sandy, for example, have led to new attention to issues such as reliability and resiliency.

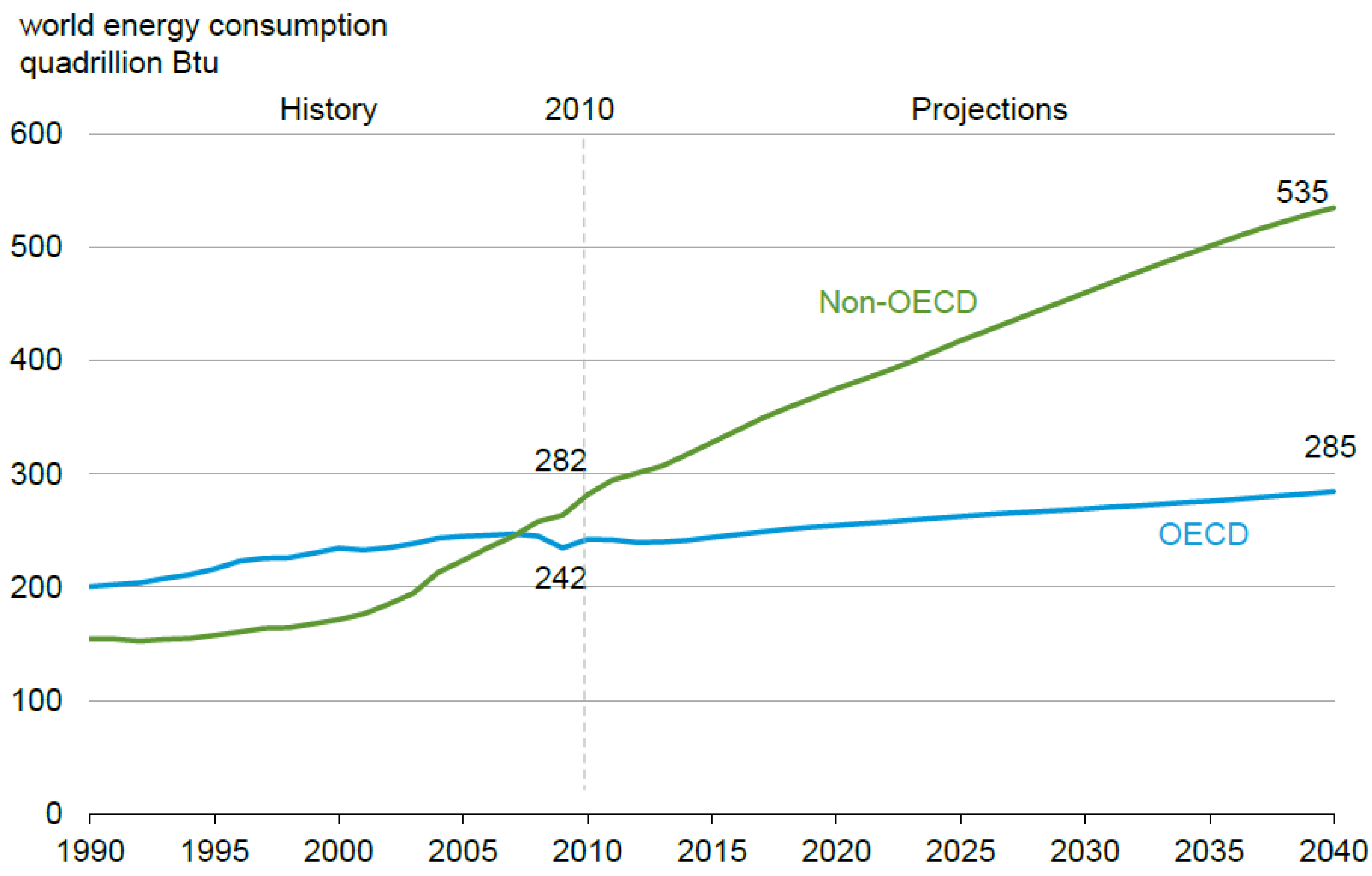
- **Cyber** security threats are related to the computer-based controls that operate and coordinate energy supply, delivery, and end-use systems. Malicious actors (domestic or foreign, state- or non-state-sponsored) could introduce malware.

- **Economic** security threats are related to price shocks, potential shortages of critical commodities and/or capital equipment, and long-term trade deficits (above). Commodity price shocks have led to significant economic disruptions in the past (e.g. oil shocks of 1970s). An emerging potential economic security threat is that critical energy system components (e.g., large transformers, large nuclear components) are made overseas where supply could be constricted unpredictably.

- **International** security threats include geopolitical stability, etc.

Energy Technology Opportunities?

Non-OECD nations drive the increase in energy demand



Source: EIA, International Energy Outlook 2013

The QTR-2015 Team Encourages Your Input

- More Information is at: http://www.energy.gov/qtr
- Email: DOE-QTR2015@hq.doe.gov

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