DOE Quadrennial Technology Review

Steven E. Koonin
Under Secretary for Science
US Department of Energy
May 2011

http://www.energy.gov/QTR

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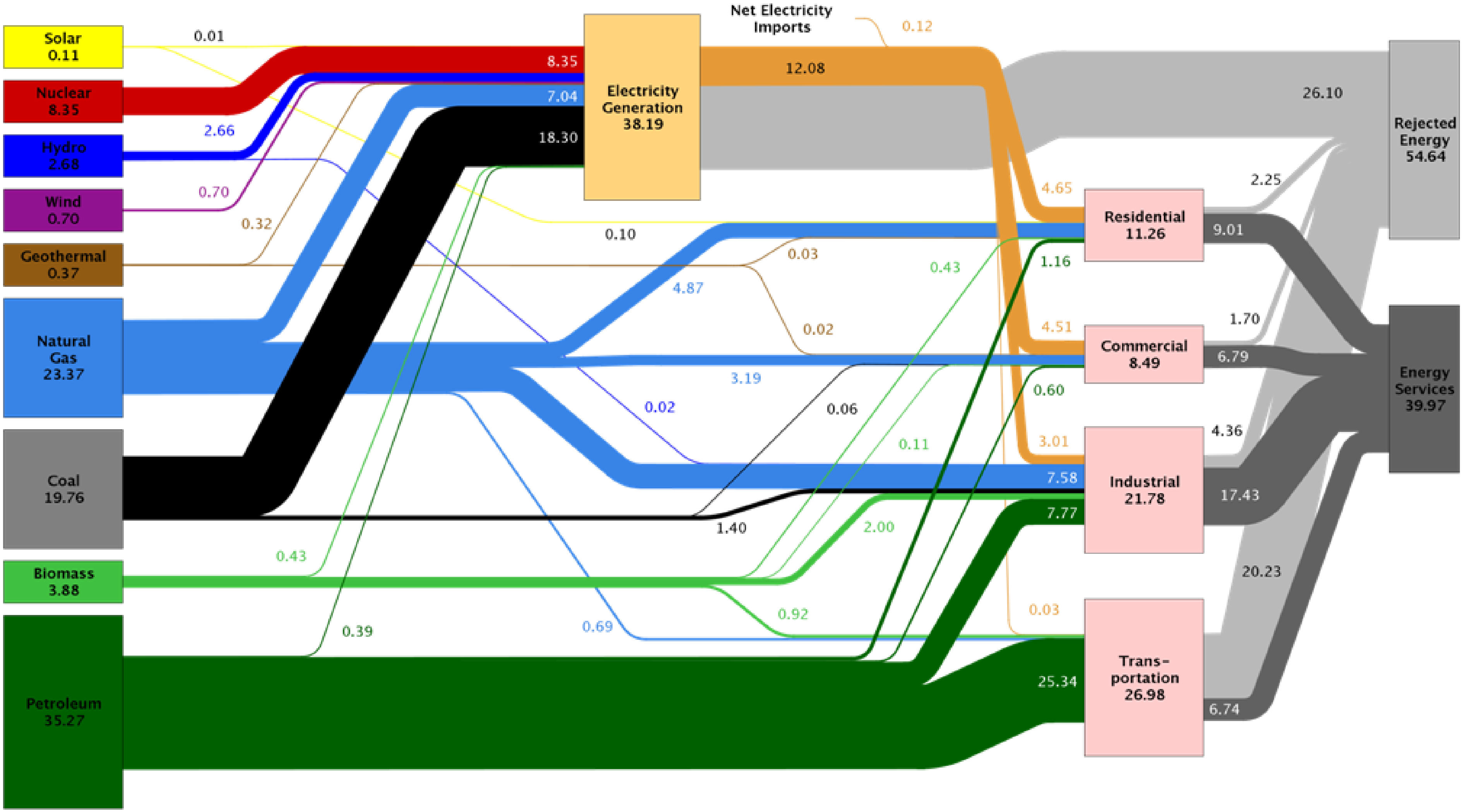
Estimated U.S. Energy Use in 2009: ~94.6 Quads



https://flowcharts.llnl.gov/

Lawrence Livermore National Laboratory

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Energy Essentials

As a whole, energy is

- A big and expensive system
- In private hands
- Governed by economics, modulated by government policies

Demand

- Many distributed players, shorter-lived assets
- User benefit (economics, convenience, personal preference)
- Determined by price, standards, behavior
- Little attention to system optimization for stationary use

Supply

- Fewer, long-lived centralized facilities with distribution networks
- Change has required decades
- Power and fuels are commodities with thin margins
- Markets with government regulation and distortion
- Technology alone does not a transformation make
- Transport and Stationary are disjoint
- Transport is powered by oil
- Power
    - Requires boiling large amounts of water
    - Sized for extremes (storage is difficult)
    - Numerous sources with differing...
        - CapEx and OpEx
        - Emissions
        - Base/Peak/Intermittency

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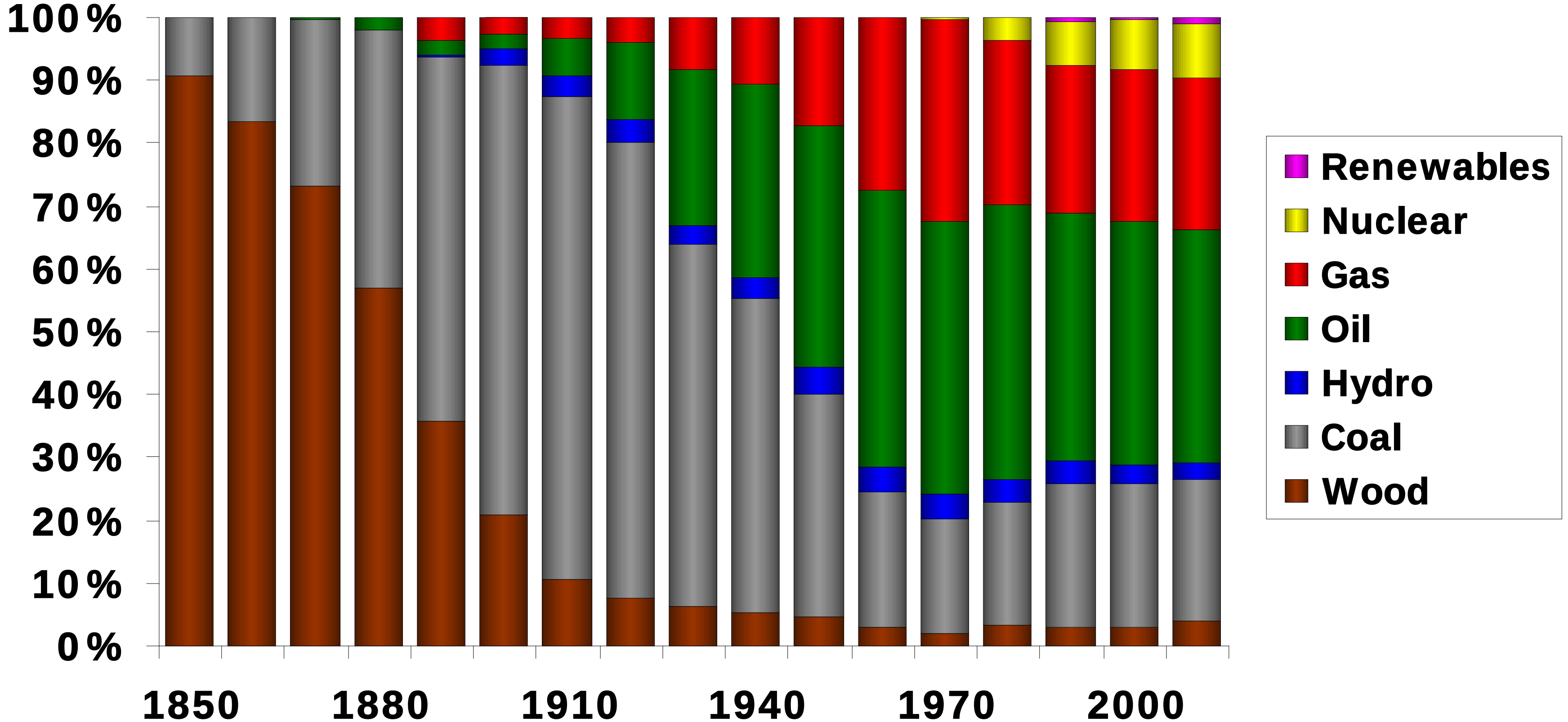
Energy supply has changed on decadal scales

US energy supply since 1850



Source: EIA

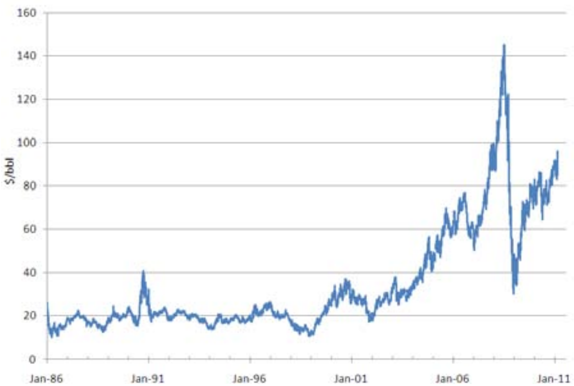
U.S. Energy Challenges

Energy Security

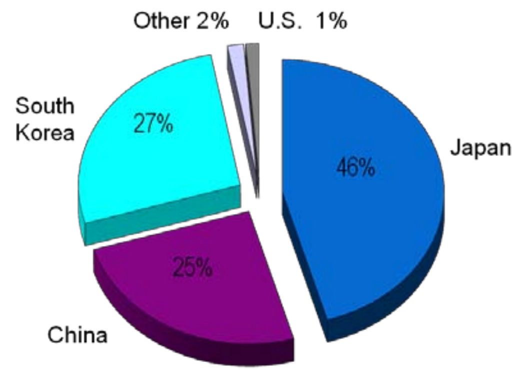
Competitiveness

Environment

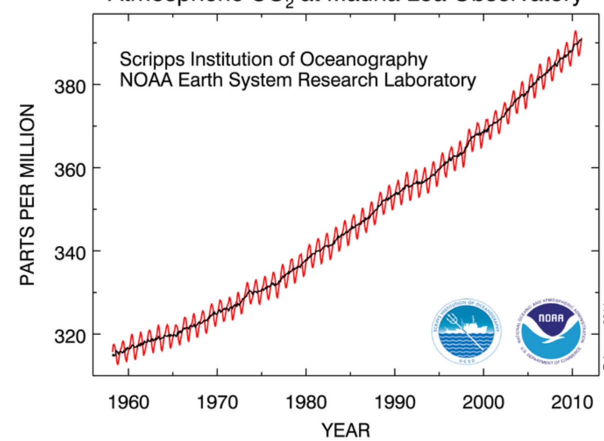
Daily Spot Price OK WTI



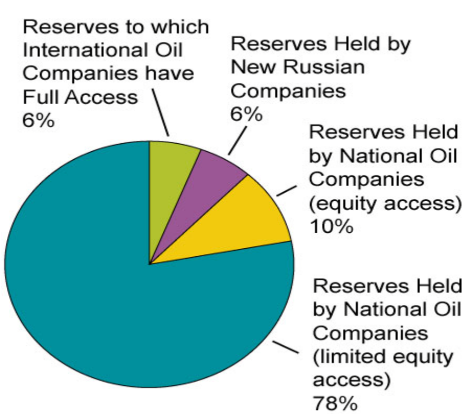
Global Lithium-ion Battery Manufacturing (2009)



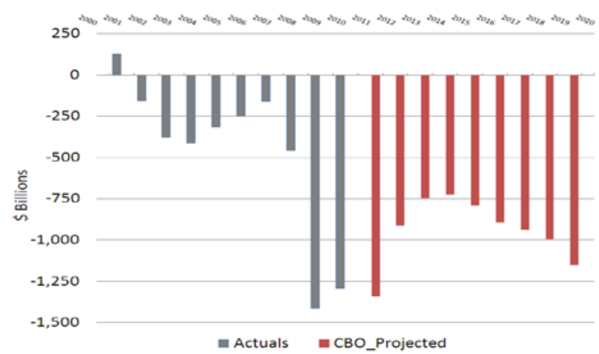
Atmospheric CO_2 at Mauna Loa Observatory



Share of Reserves Held by NOC/IOC



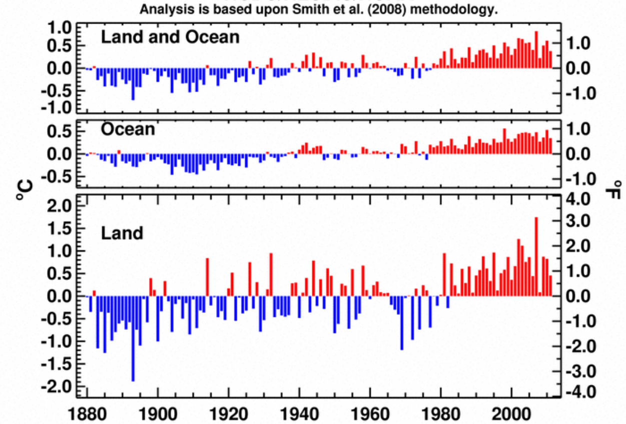
Federal Deficit



January Global Surface Mean Temp Anomalies

NCDC/NESDIS/NOAA

Analysis is based upon Smith et al. (2008) methodology.



Administration Goals

Transport

- Reduce oil imports by 1/3 by 2025 (~3.7 M bbl/day)
- Put 1 million electric vehicles on the road by 2015

Stationary

- By 2035, generate 80% of electricity from a diverse set of clean energy sources
- Make non-residential buildings 20% more energy efficient by 2020

Environmental

- Cut greenhouse gas emissions in the range of 17% below 2005 levels by 2020, and 83% by 2050

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Six Strategies

	Supply		Demand
Stationary	Deploy Clean Electricity	Modernize the Grid	Increase Building and Industrial Efficiency
Transport	Deploy Alternative Fuels	Progressively Electrify the Fleet	Increase Vehicle Efficiency

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DOE-QTR Scope

The DOE-QTR will provide a **context and robust framework** for the Department's energy programs, as well as principles by which to establish multiyear programs plans and budgets. It will also offer **high-level views of the technical status and potential** of various energy technologies.

The primary focus of the DOE-QTR process and document will be on the following:

- Framing the energy challenges
- A discussion of the roles of government, industry, national laboratories, and universities in energy system transformation
- Summary roadmaps for advancing key energy technologies, systems, and sectors
- Principles by which the Department can judge the priority of various technology efforts
- A discussion of support for demonstration projects
- The connections of energy technology innovation to energy policy

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DOE-QTR Timeline

Nov 2010

PCAST made recommendations for DOE to do QER

3/14 – 4/15

Public comment period for DOE-QTR Framing Document

4/20

First batch of public comments released on project website

Through mid-June

Hold workshops and discussions of each of the Six Strategies

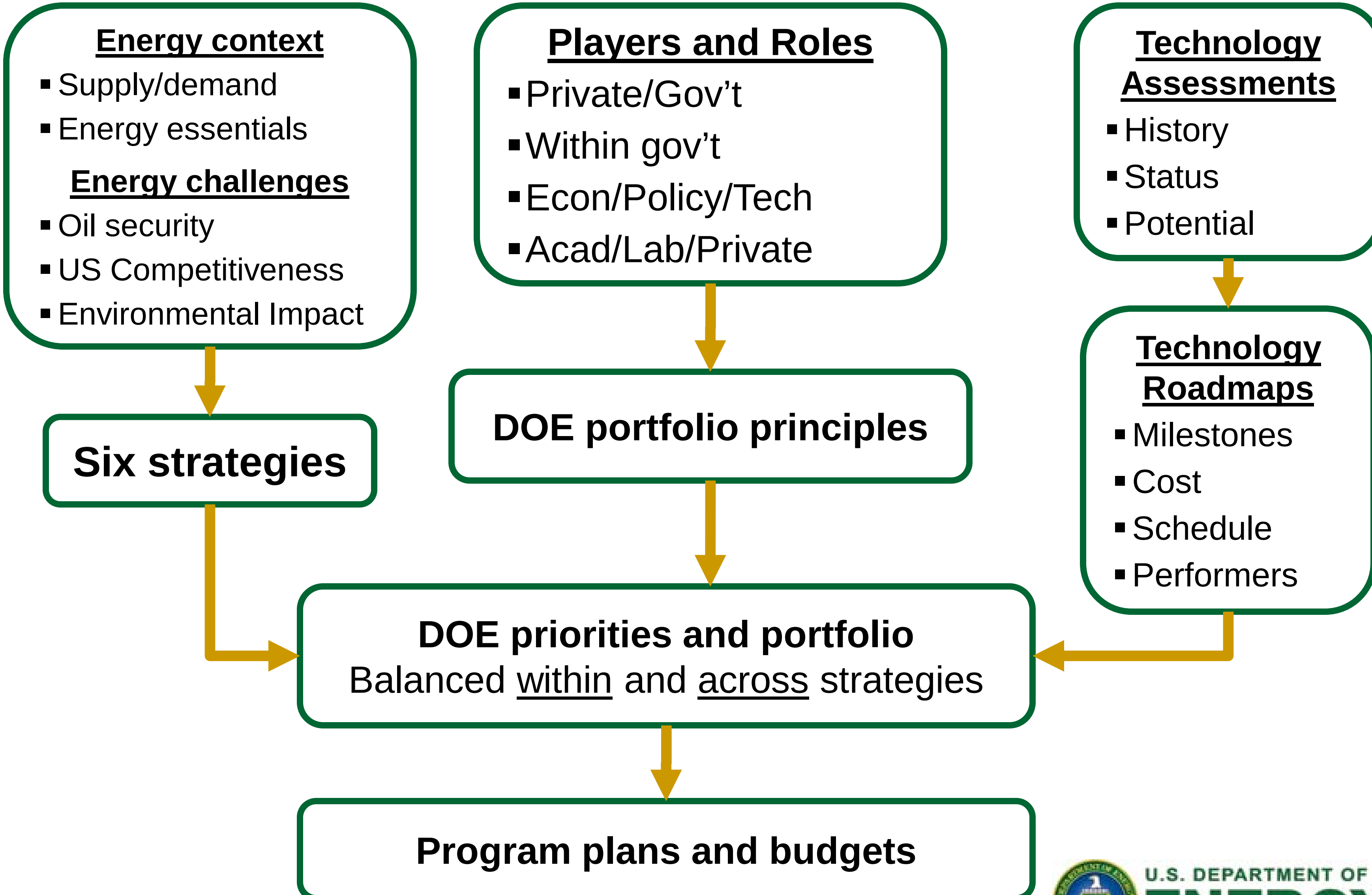
End July/Aug

Submit DOE-QTR to White House for approval

Before Dec 2011

Release DOE-QTR

DOE-QTR Logic Flow



THE TECHNOLOGY STRATEGIES

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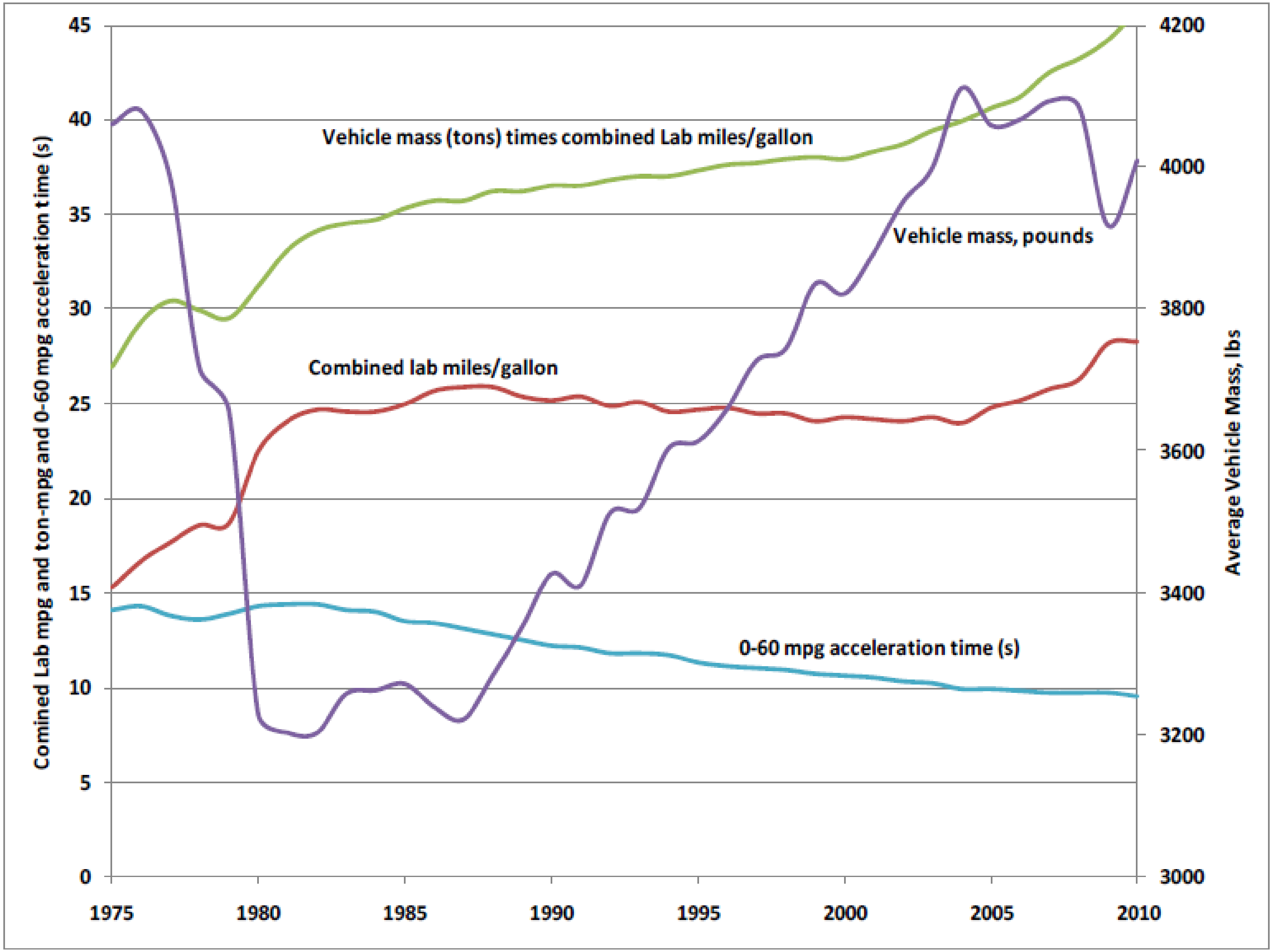

Trends in Car and Light-Duty Truck Average Attributes showing changes in customer preferences, data from (EPA2010)

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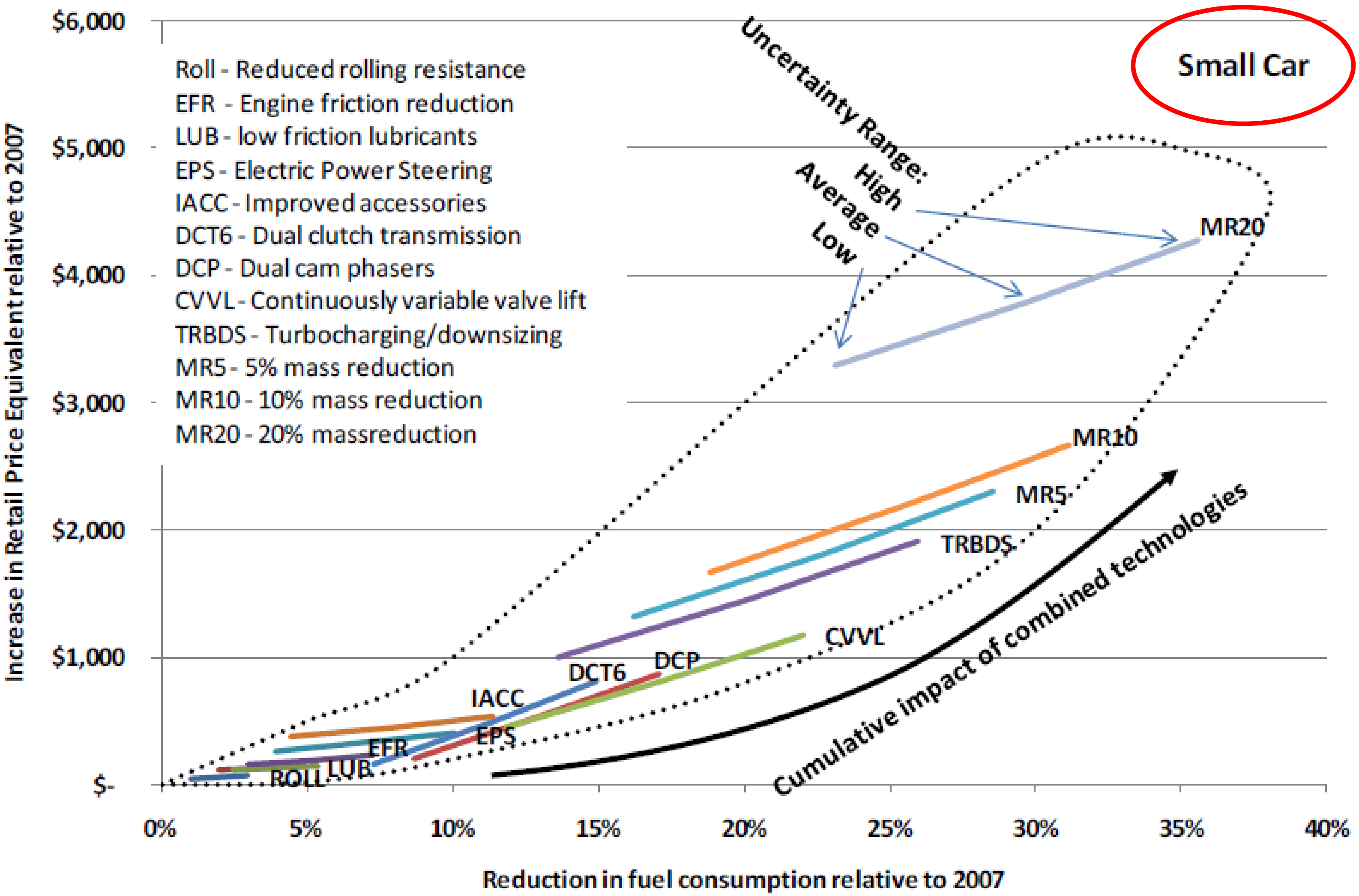

Cumulative retail price equivalent and fuel consumption reduction relative to 2007 for spark ignition powertrain without hybridization (NRC2010)

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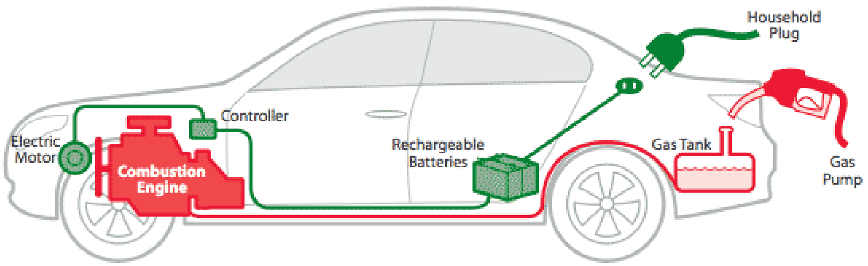
Progressively Electrify the Fleet

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

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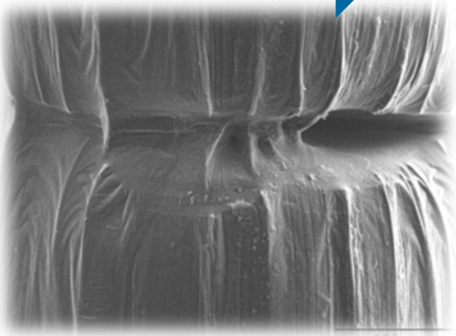
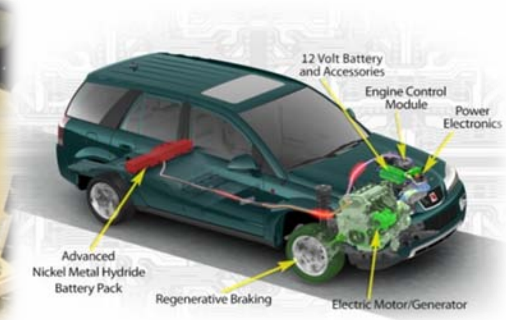
Battery Evolution: R&D to Commercialization

The energy storage effort is engaged in a wide range of topics,
from fundamental materials work through battery development and testing

Advanced Materials Research → **High Energy & High Power Cell R&D** → **Full System Development And Testing** → **Commercialization**





- High energy cathodes
- Alloy, Lithium anodes
- High voltage electrolytes
- Lithium air couples

- High rate electrodes
- High energy couples
- Fabrication of high E cells
- Ultracapacitor carbons

- Hybrid Electric Vehicle (HEV) systems
- 10 and 40 mile Plug-in HEV systems
- Advanced lead acid
- Ultracapacitors

Lab and University Focus

Industry Focus

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Hybrid Electric Systems

Petroleum Displacement via Fuel Substitution and Improved Efficiency

Administration Goal:1 Million EVs by 2015

Types of Vehicles and Benefits

HEV →

Toyota Prius
50 MPG

PHEV →

Chevy Volt
>100 MPGe

EV →

Nissan Leaf
All Electric

System Cost

Year	PHEV Battery Cost per kW·h	Power Electronics Cost per kW
2008	$1,000 - $1,200	$22
2010	$700 - $950	$19
2012	Goal = $500	Goal = $17
2014	Goal = $300	
2015		Goal = $12

Targets and Status

2014 PHEV: Battery that has 40-mile all-electric range and costs $3,400

2015 Power Electronics: Cost for electric traction system no greater than $12/kW peak by 2015

Status: $8,000-$11,000 for PHEV 40-mile range battery

Status: Current cost of electric traction system is $40/kW

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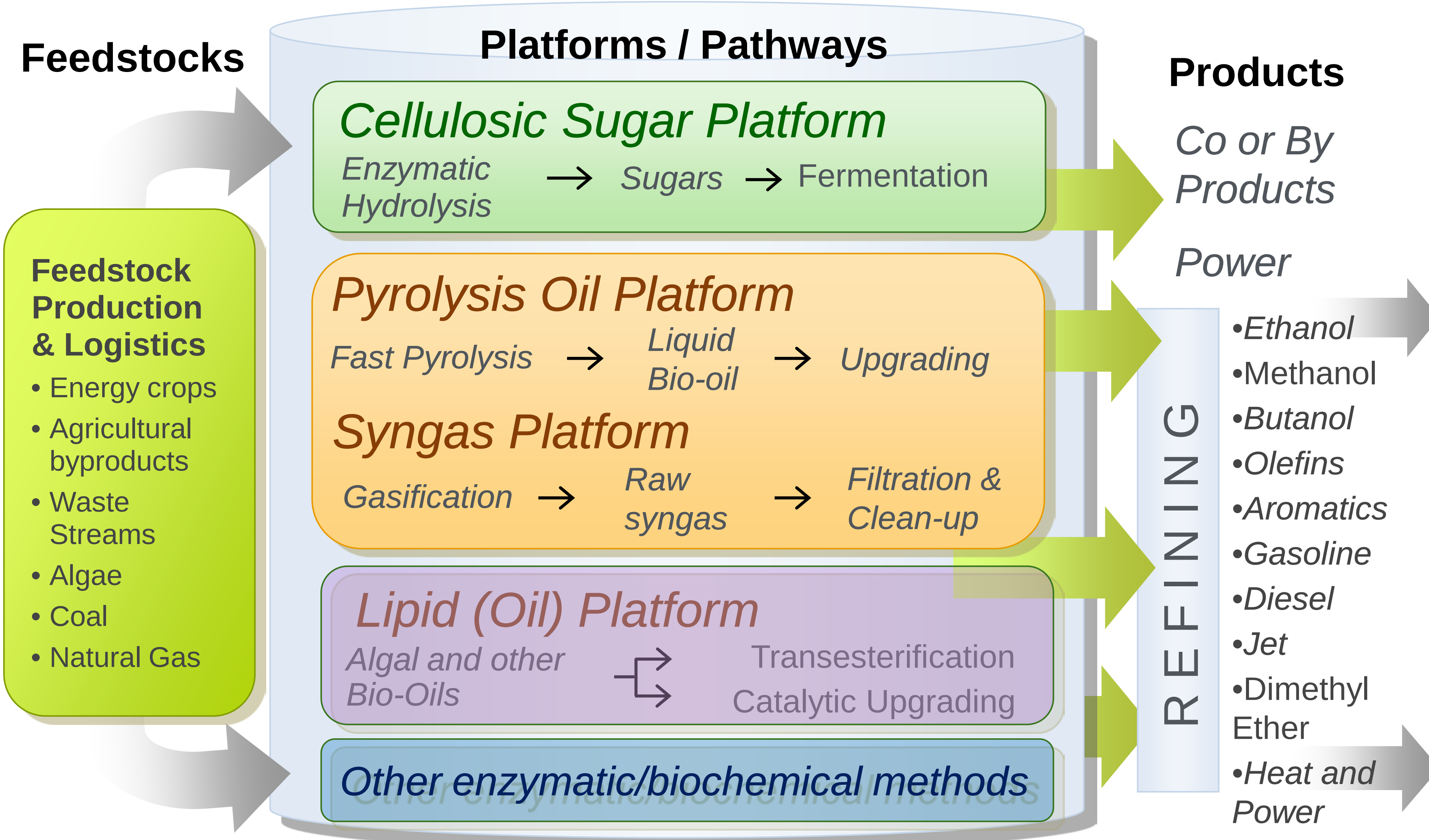
Deploy Advanced/Alternative Fuels



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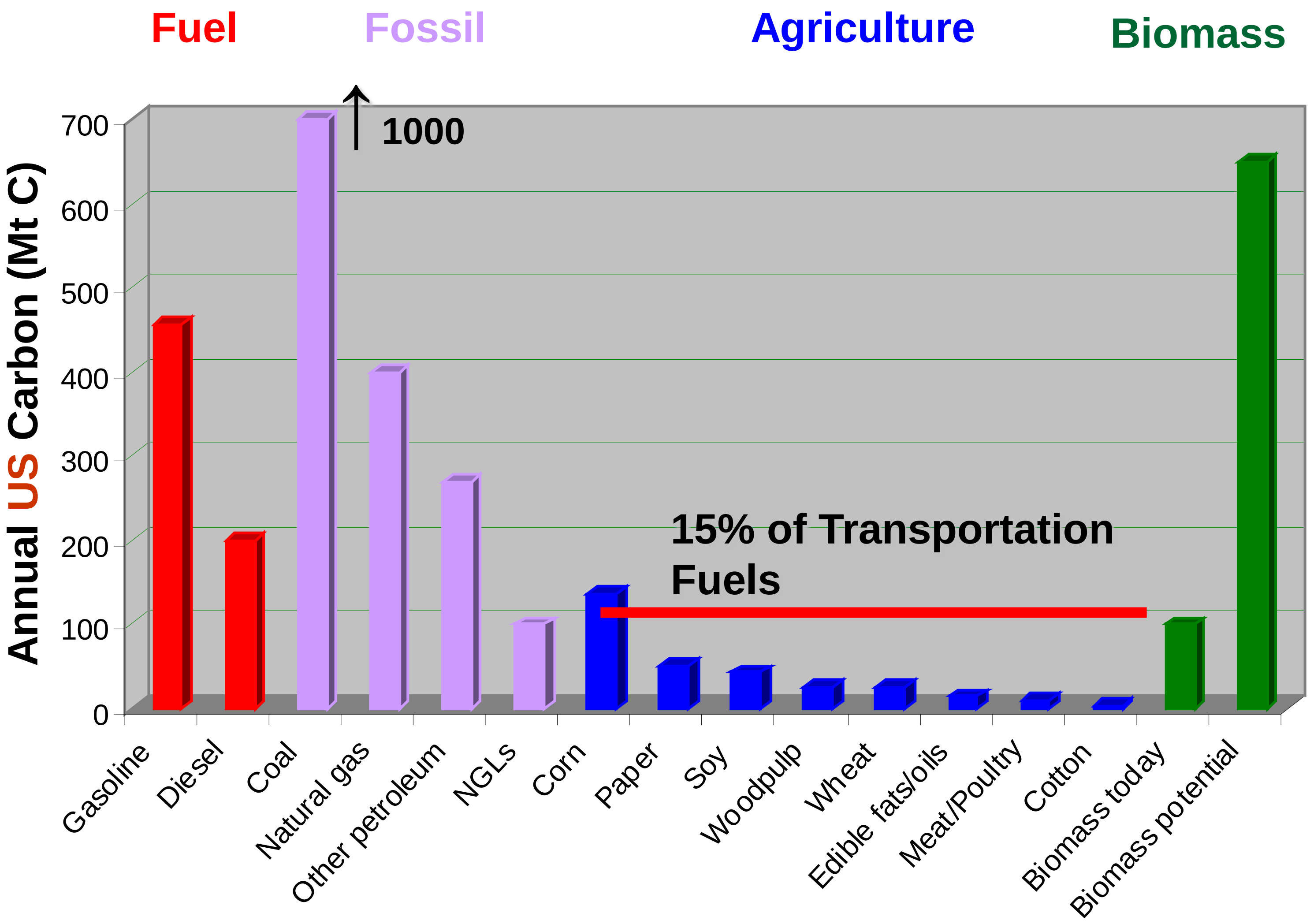
Biomass can provide significant carbon



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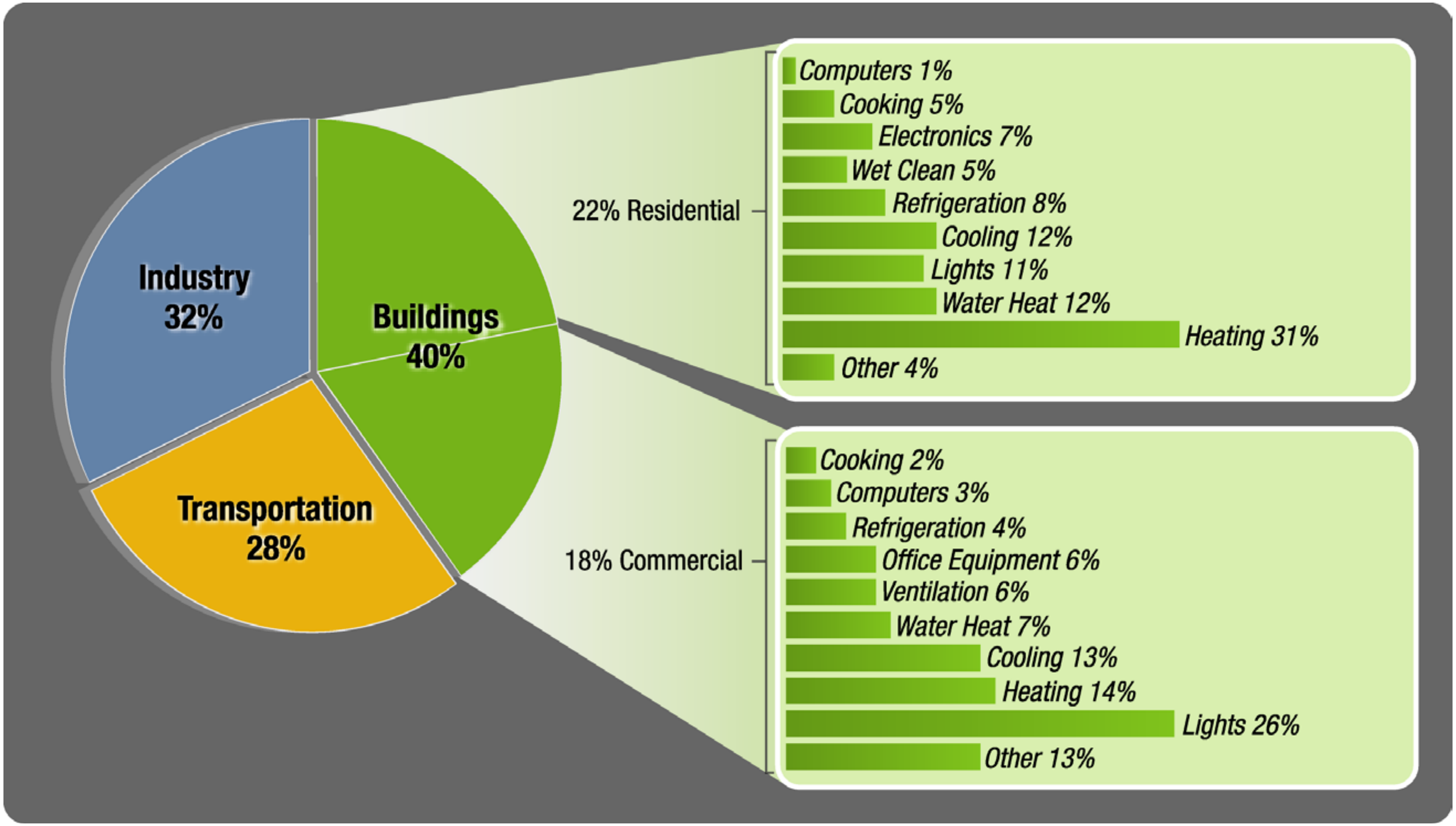
Categories of US Energy Consumption

Buildings use about 40% of total US energy



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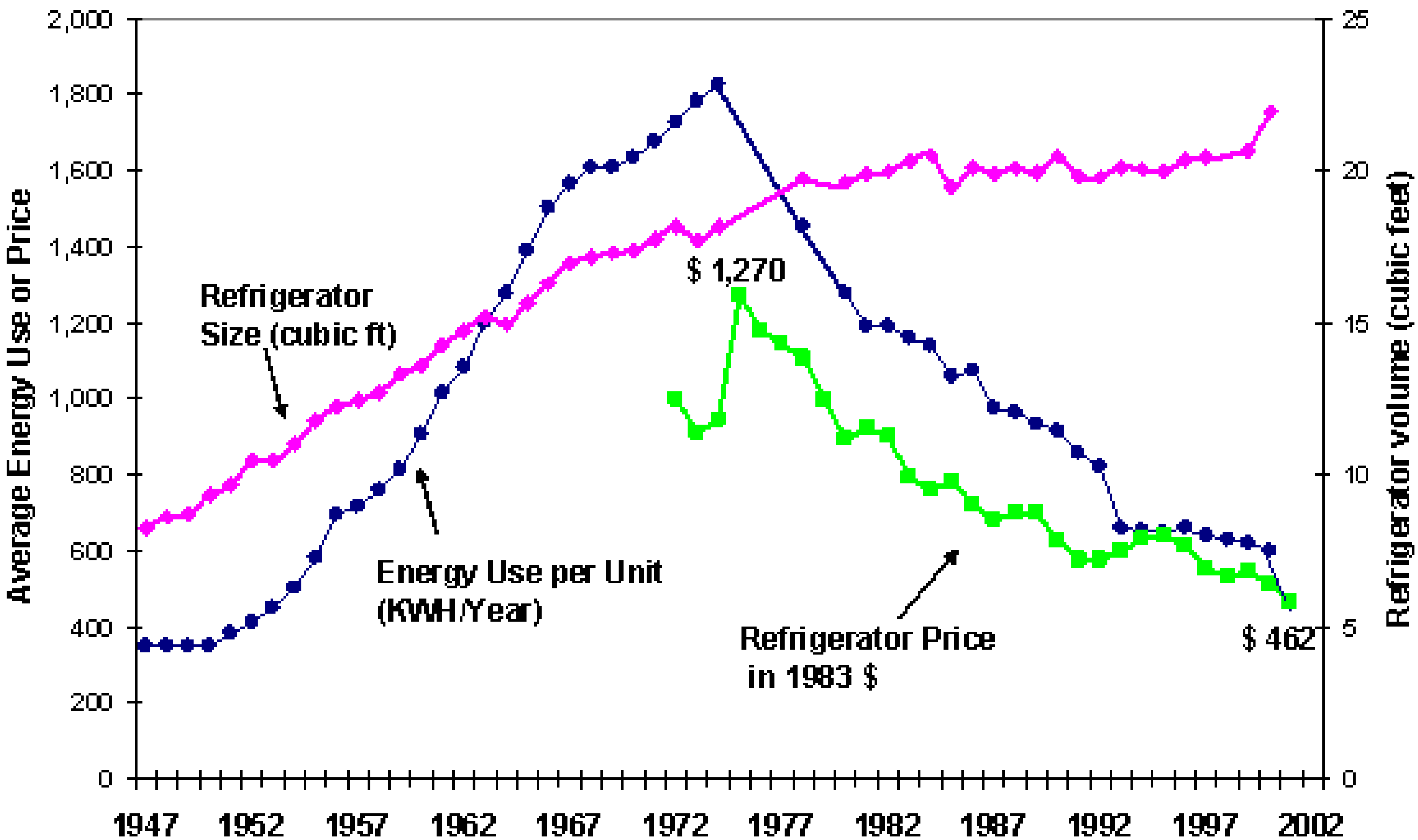
U.S. Refrigerator Properties



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The U.S. Grid

- **The numbers**
  - > 200,000 miles of transmission lines distribute approx. 1 TW of power
  - Over 3,500 utility organizations
- **Desiderata**
  - Reliability
  - Efficiency
  - Security
  - Flexibility to integrate intermittent renewables
  - Two-way flow of information and power
  - Growth to handle growing demand
- **Challenges**
  - Active management is required to balance generation, transmission, and demand at all times
  - Excursion from ideal operation can be catastrophic

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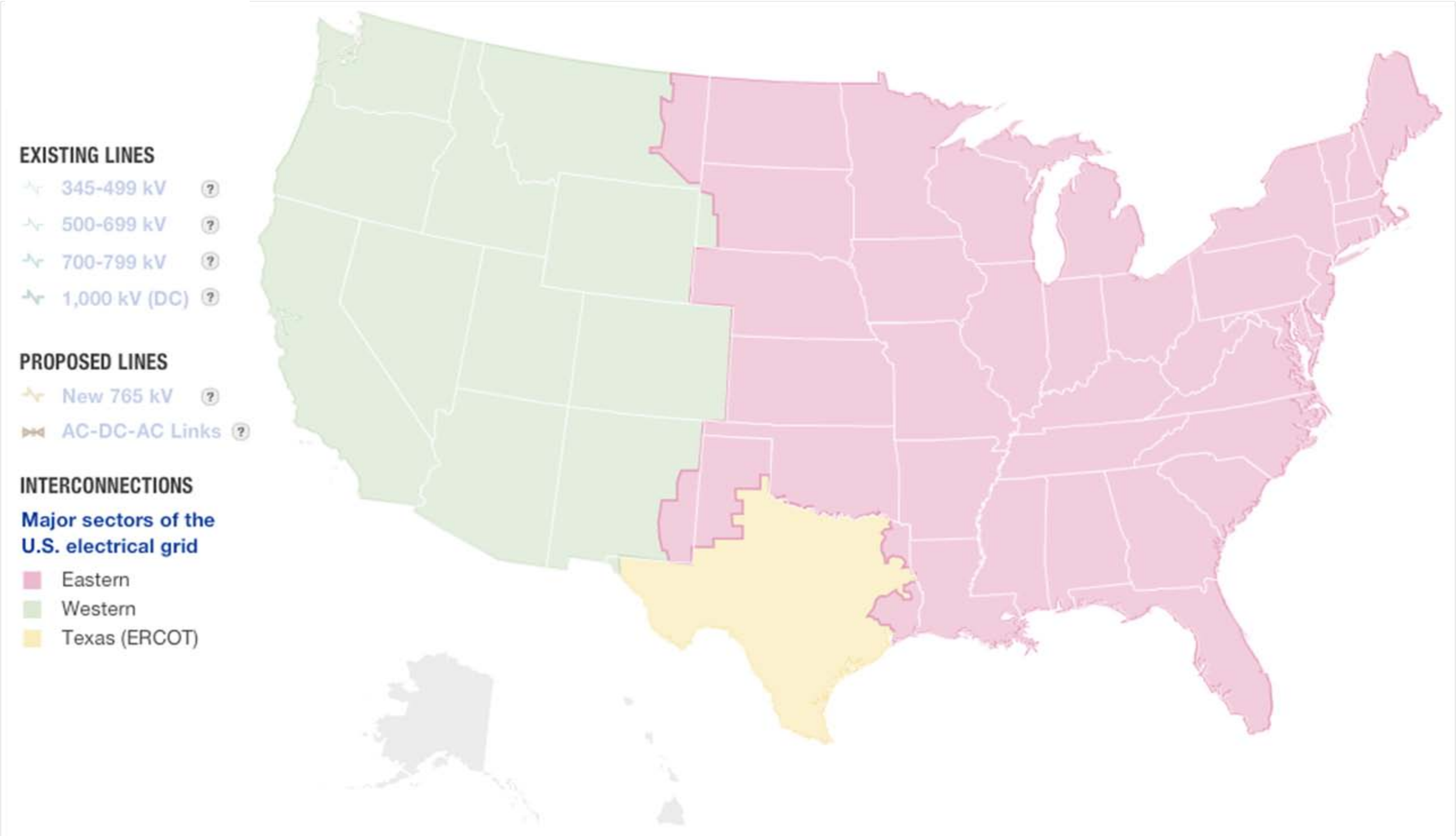
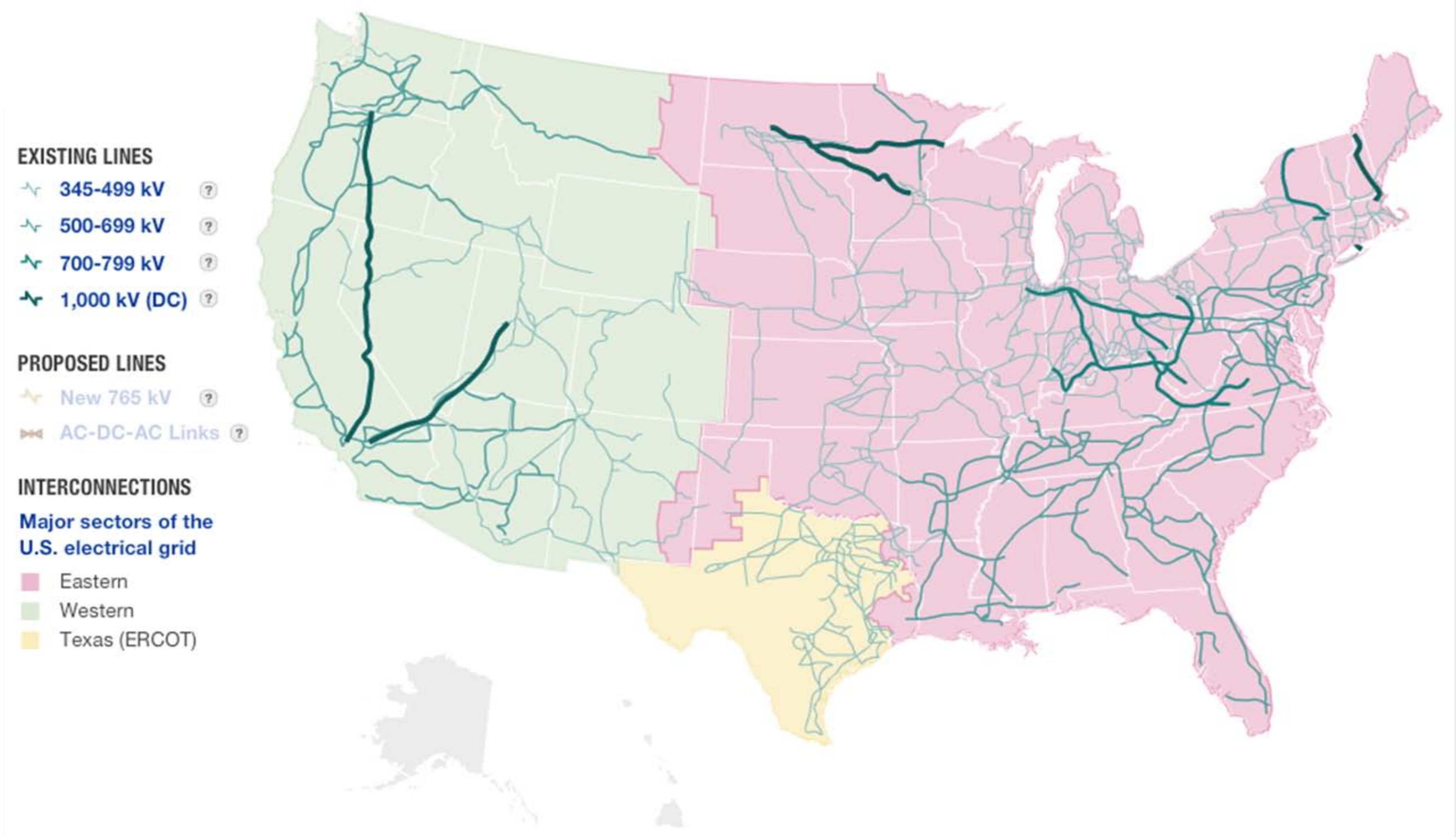


Source: http://www.npr.org/series/103281114/power-hungry-reinventing-the-u-s-electric-grid?ps=rs



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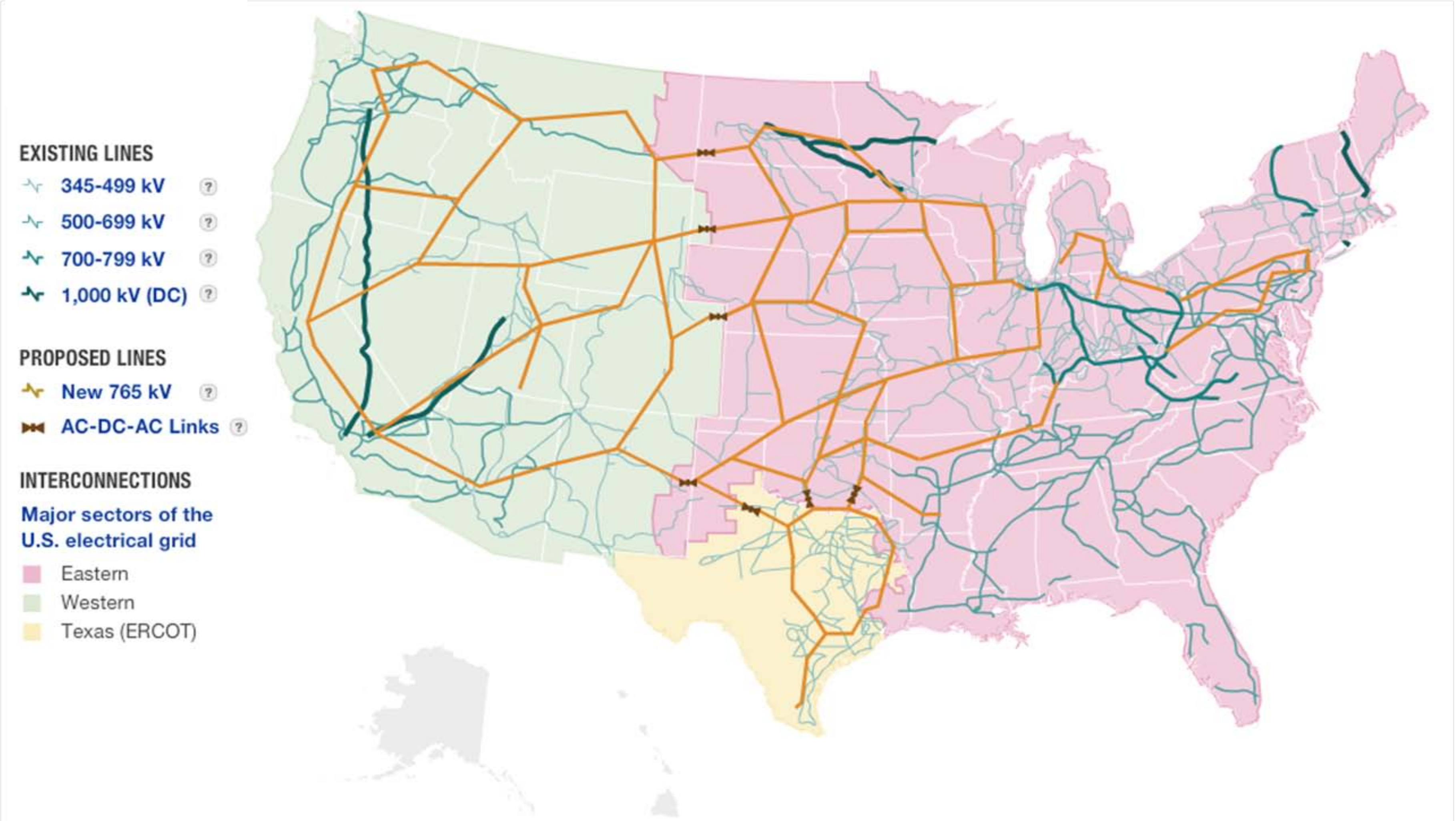

npr

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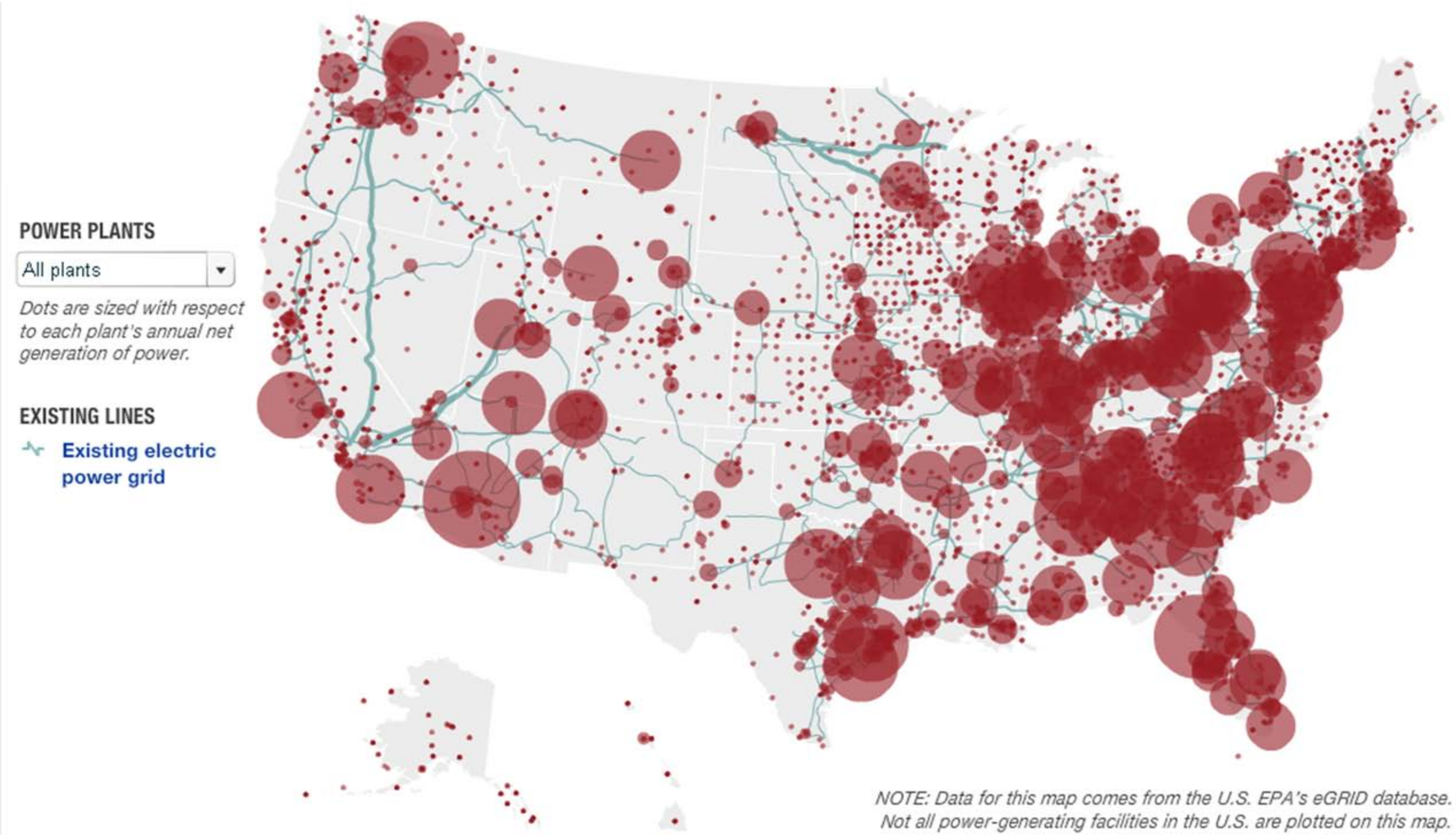

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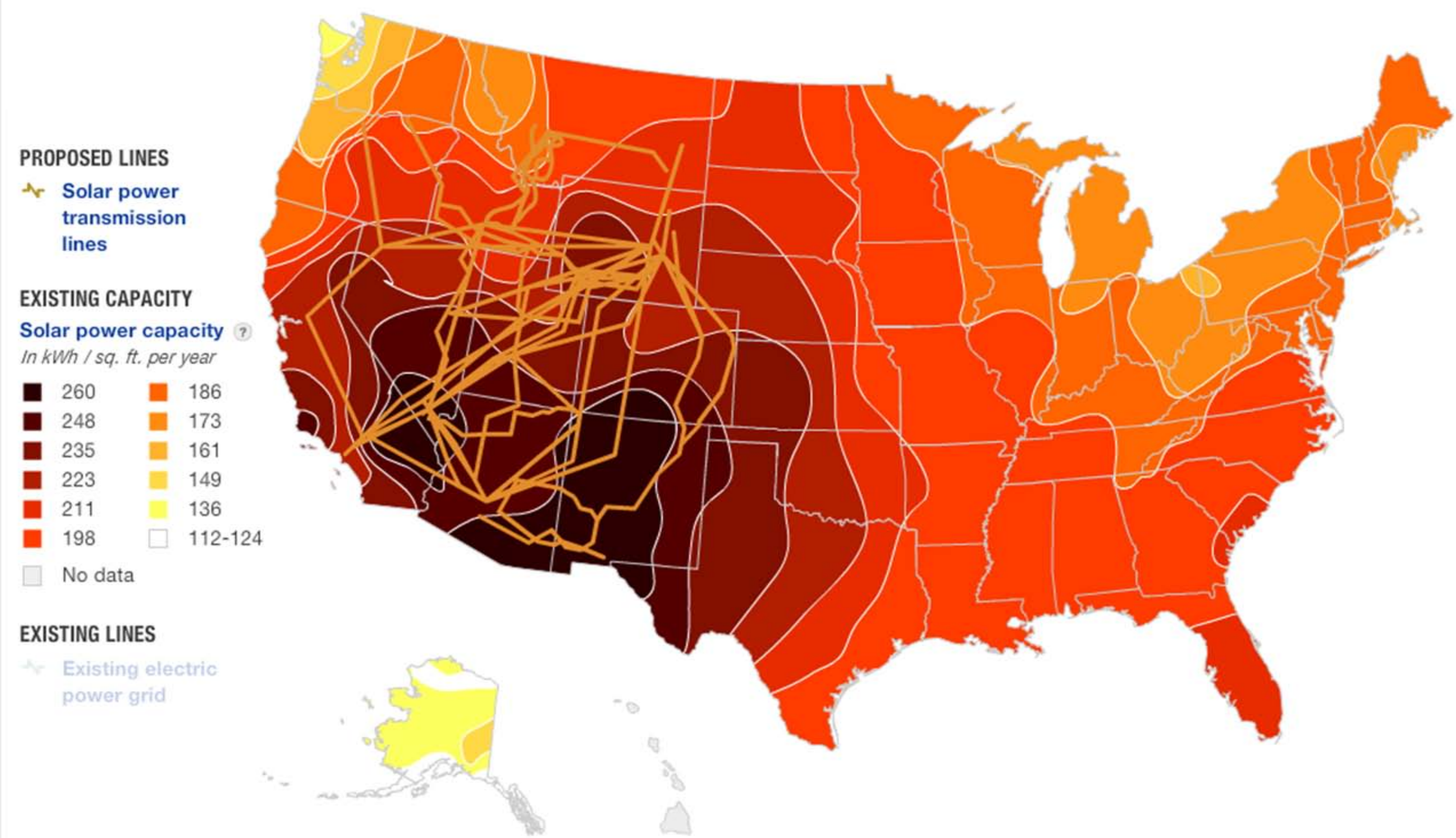

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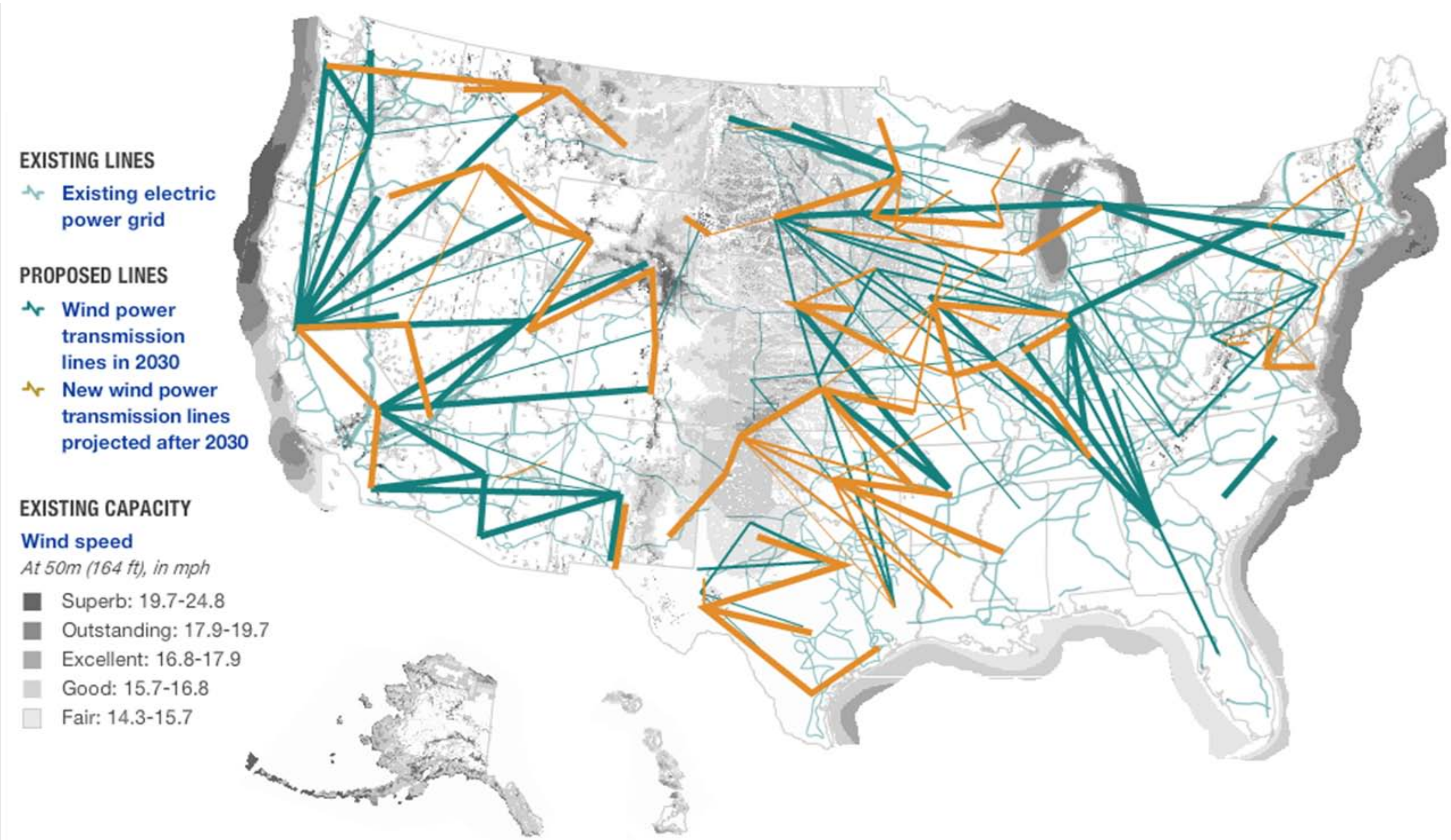

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Deploy Clean Electricity

Solar Photovoltaic (PV)

Wind

Nuclear Energy

Concentrating Solar Power

Carbon Capture and Storage

Other technologies

- Natural gas
- Hydro
- Solar thermal (parabolic troughs)
- Geothermal

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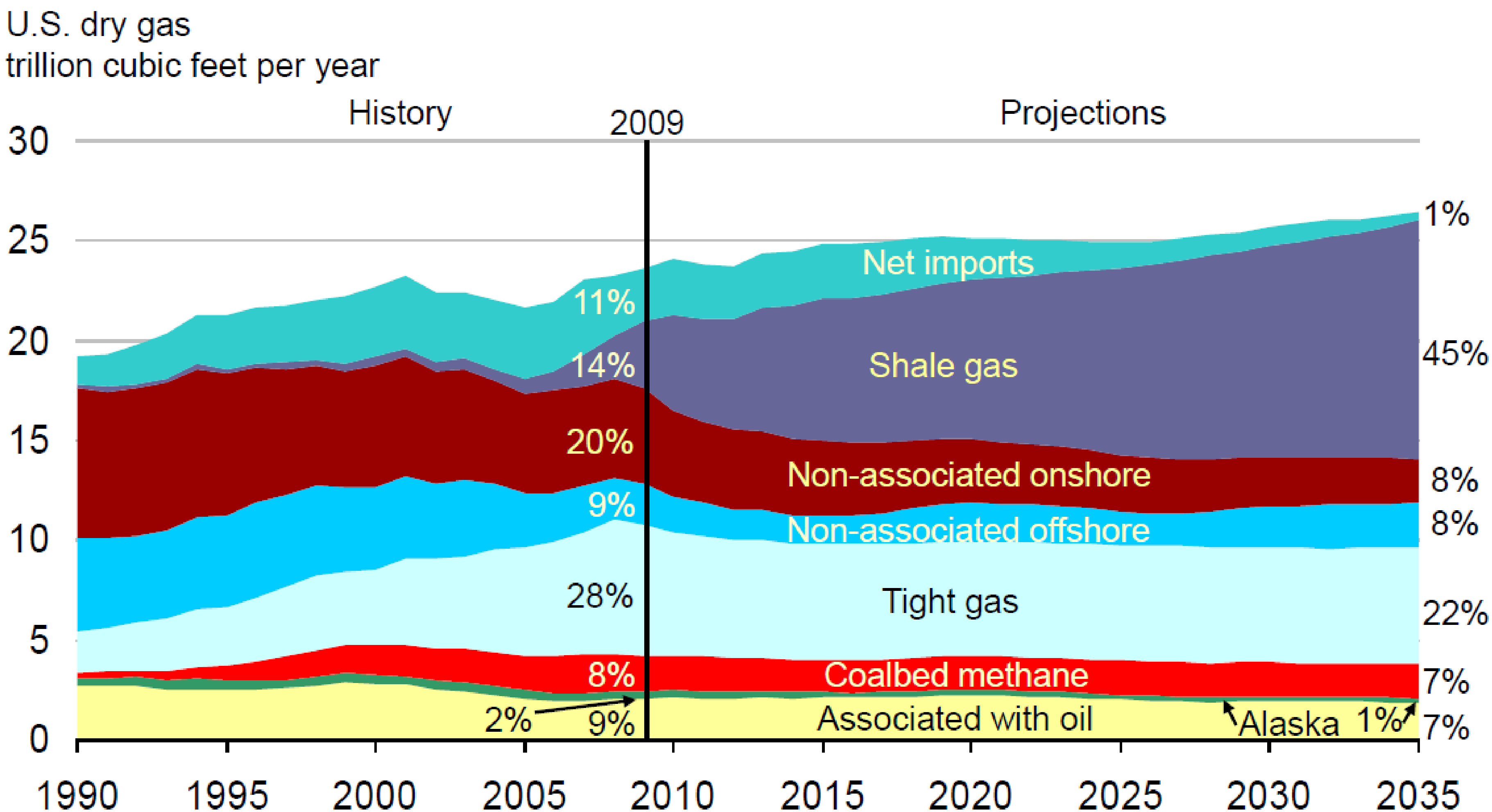
US Gas Supply by Source



Source: EIA, Annual Energy Outlook 2011 Early Release

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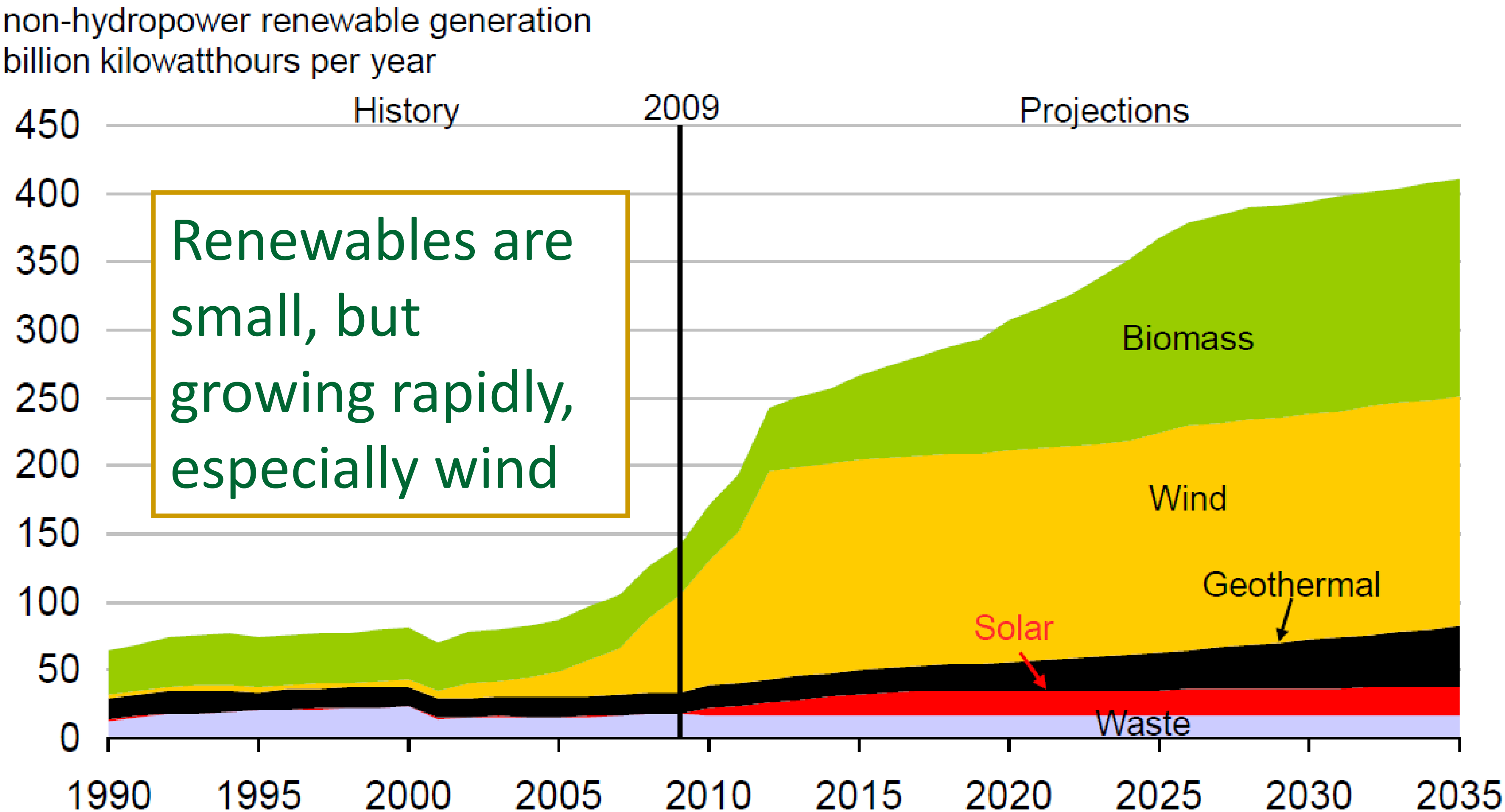
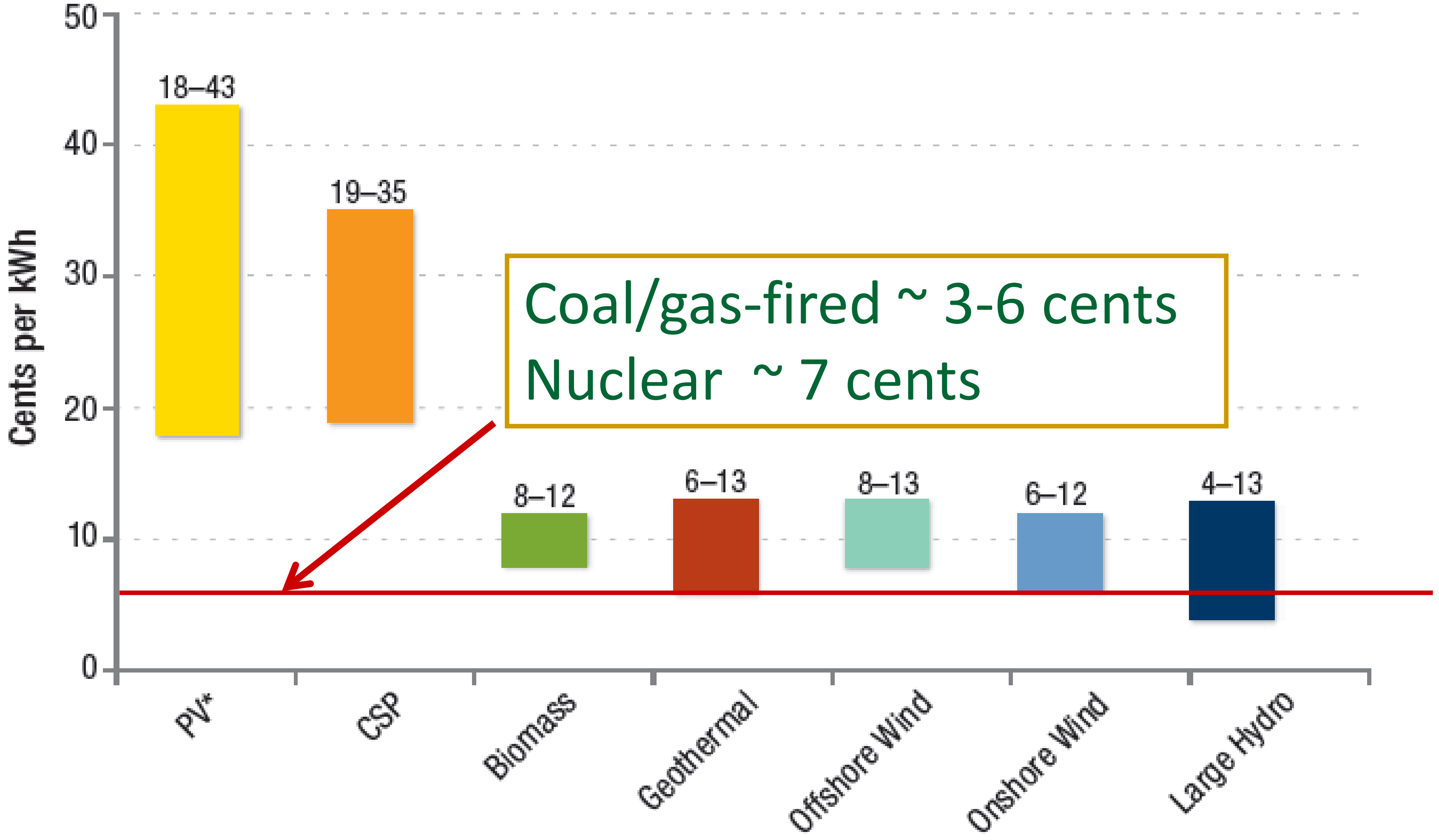
US Renewable Generation (GWh)



Source: EIA, Annual Energy Outlook 2011 Early Release

Renewable Electricity Costs (2009)



Coal/gas-fired ~ 3-6 cents
Nuclear ~ 7 cents

Source: 2009 Renewable Energy Data Book (EERE)

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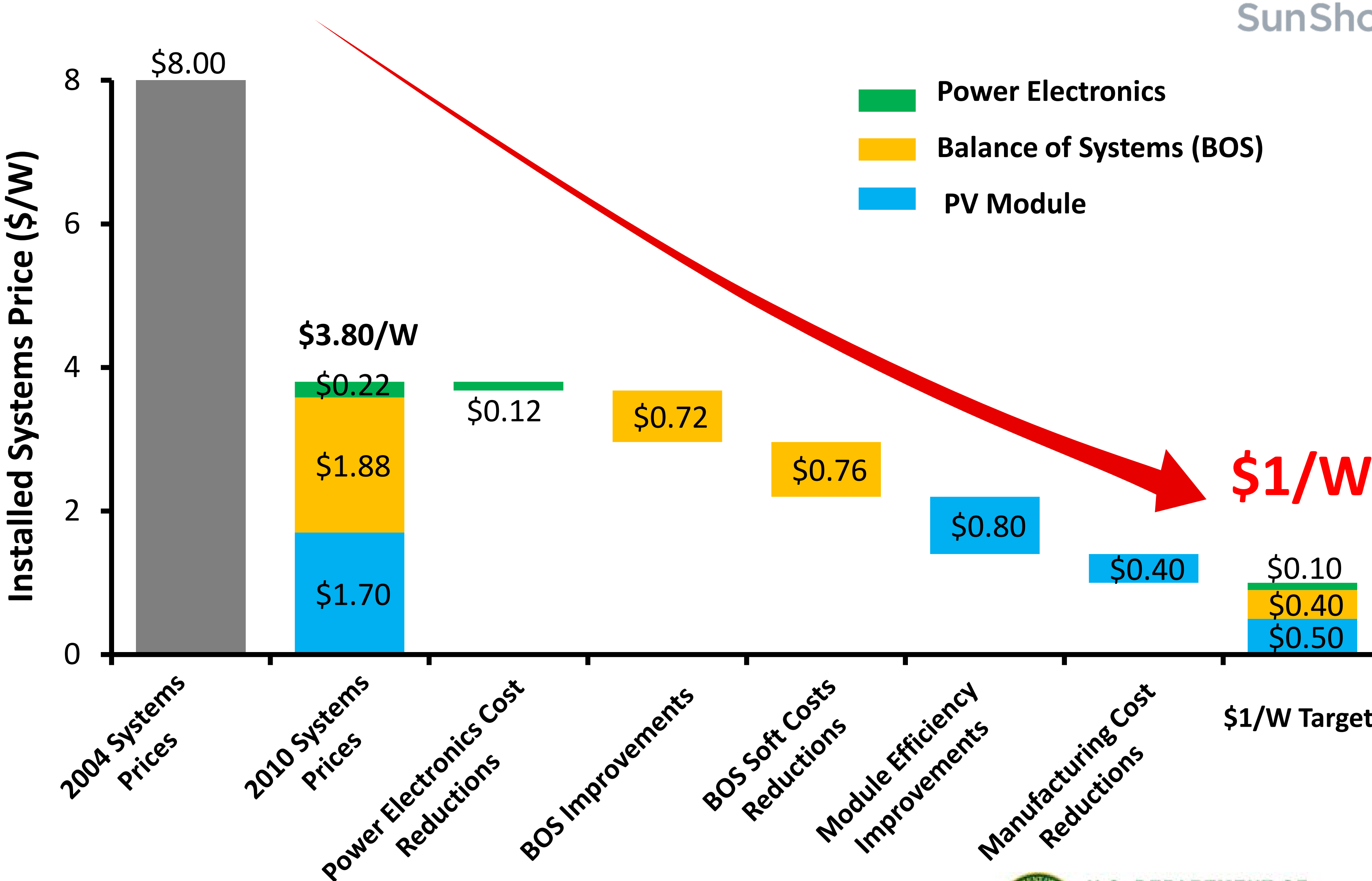
DOE SunShot Program



Framing Energy in the Social Science/Behavioral Context

- Incentives
- Rebound effect
- Discount rates
- Energy awareness
- Leveraging social norms and networks
- Technology perception, acceptance and adoption
- Energy economic modeling to incorporate behavior patterns
- Value on intangibles (ex: human life)

- Must include business in these discussions!

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QUESTIONS?/COMMENTS?

http://science.energy.gov/s-4
http://www.energy.gov/QTR

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