The Potential and Importance of Biomass

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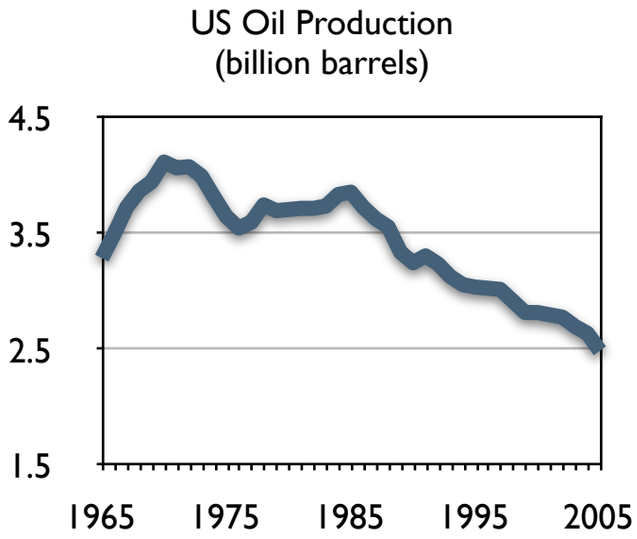
OIL ADDICTION
TREATMENT CENTER
KOREN

It Has Happened Before...

- 1972: US oil production peaks
- 1973: Yom Kippur war
  Oil embargo
- 1978-1981: Energy crisis
- 1979: Iranian revolution



What Was At Stake Then?

- National security
- Competitiveness
- Economic prosperity

The Moral Equivalent of War

- Tonight I want to have an unpleasant talk with you about a problem unprecedented in our history. With the exception of preventing war, this is the greatest challenge our country will face during our lifetimes. The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.

- Our decision about energy will test the character of the American people and the ability of the President and the Congress to govern. This difficult effort will be the "moral equivalent of war" -- except that we will be uniting our efforts to build and not destroy."

Jimmy Carter
Address to the Nation, April 18, 1977

Technology Was Our Weapon Then!

- Synfuels
  - coal gasification
  - coal liquefaction
  - “clean coal” technologies (IGCC)
  - Oil shale, tar sands
- Biofuels

"History Repeats Itself"

Thucydides

Back to the Future...

- Instability in the Middle East
- High(er) oil prices
- Concerns about our oil supply
- Concern about US competitiveness and economic prosperity
- ...and more...

From Malaise to Addiction...

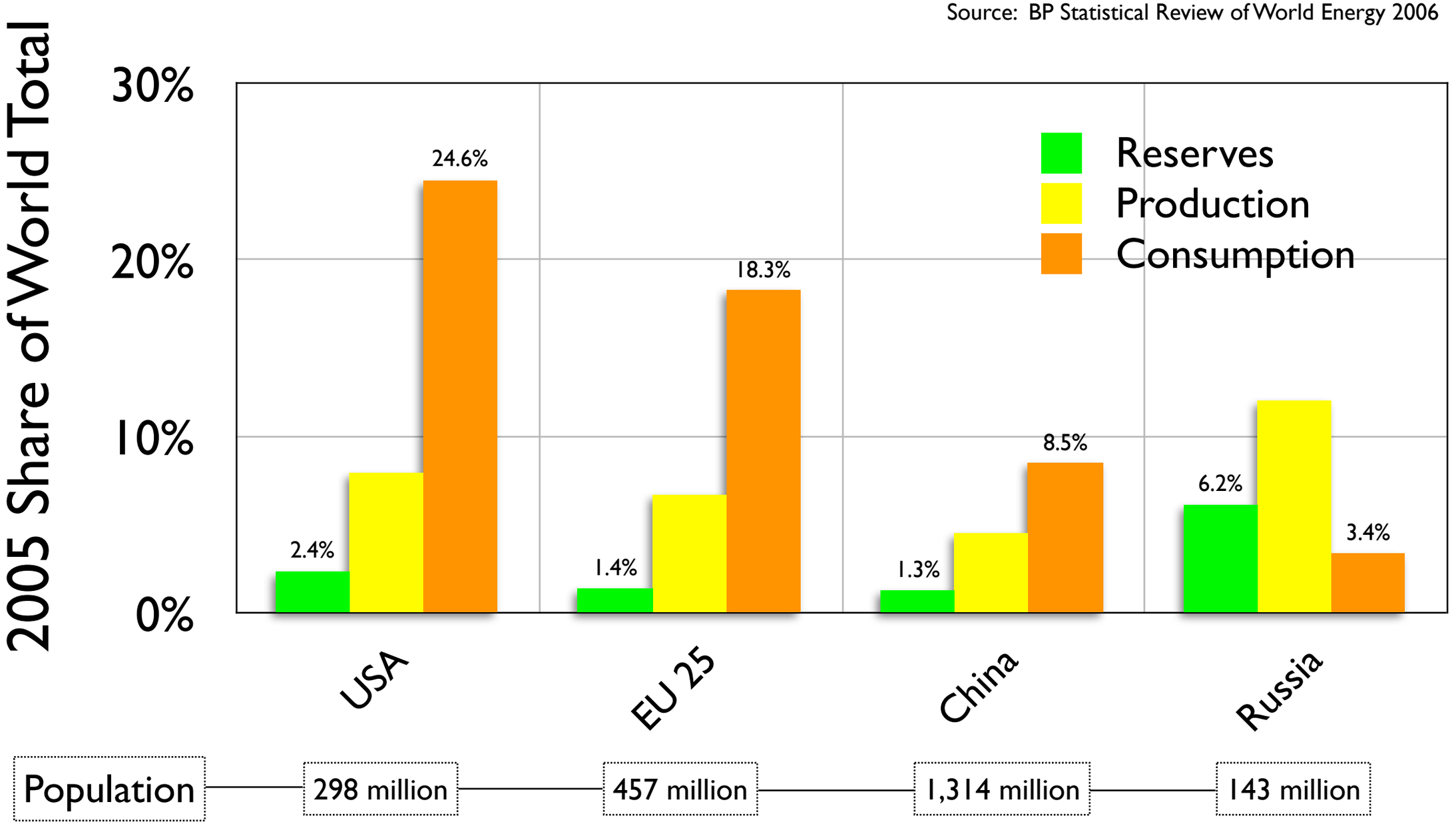
- "... Keeping America competitive requires affordable energy. And here we have a serious problem: America is ***addicted to oil***, which is often imported from unstable parts of the world. The best way to break this addiction is through technology. Since 2001, we have spent nearly $10 billion to develop cleaner, cheaper, and more reliable alternative energy sources -- and we are on the threshold of incredible advances..."

George W. Bush

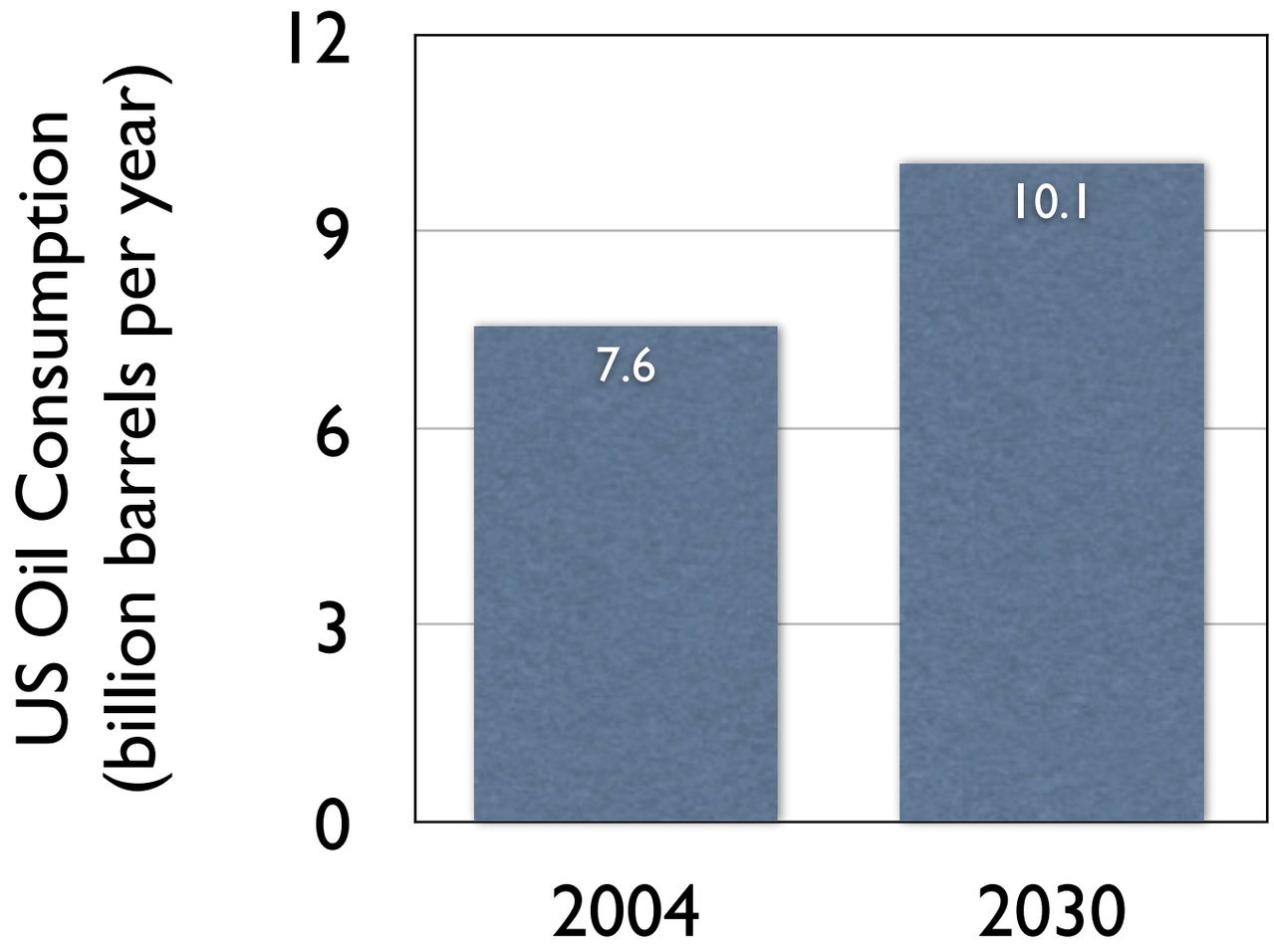
2006 State of the Union Address

Today's Concerns

Source: BP Statistical Review of World Energy 2006



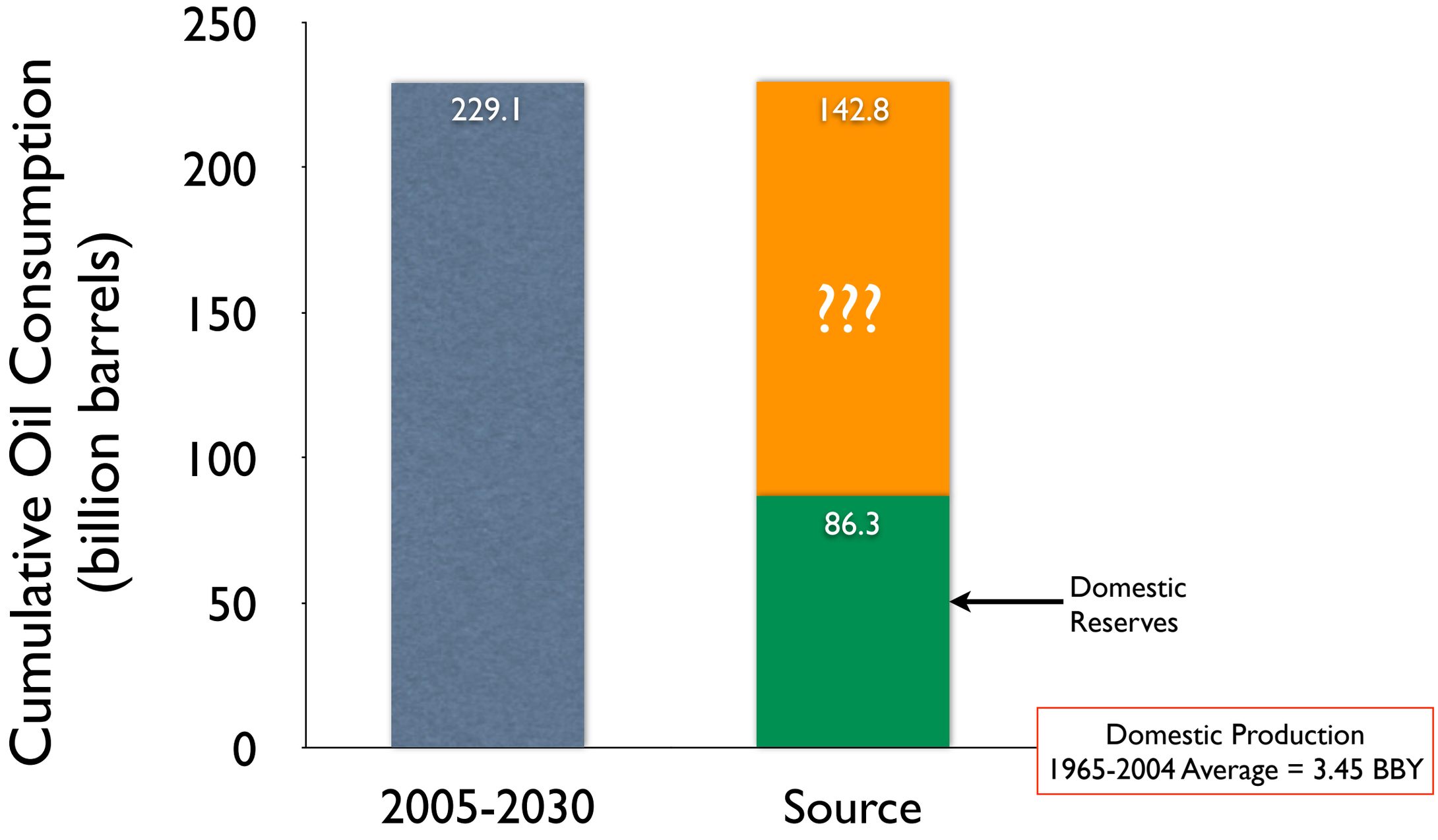
Projections to 2030



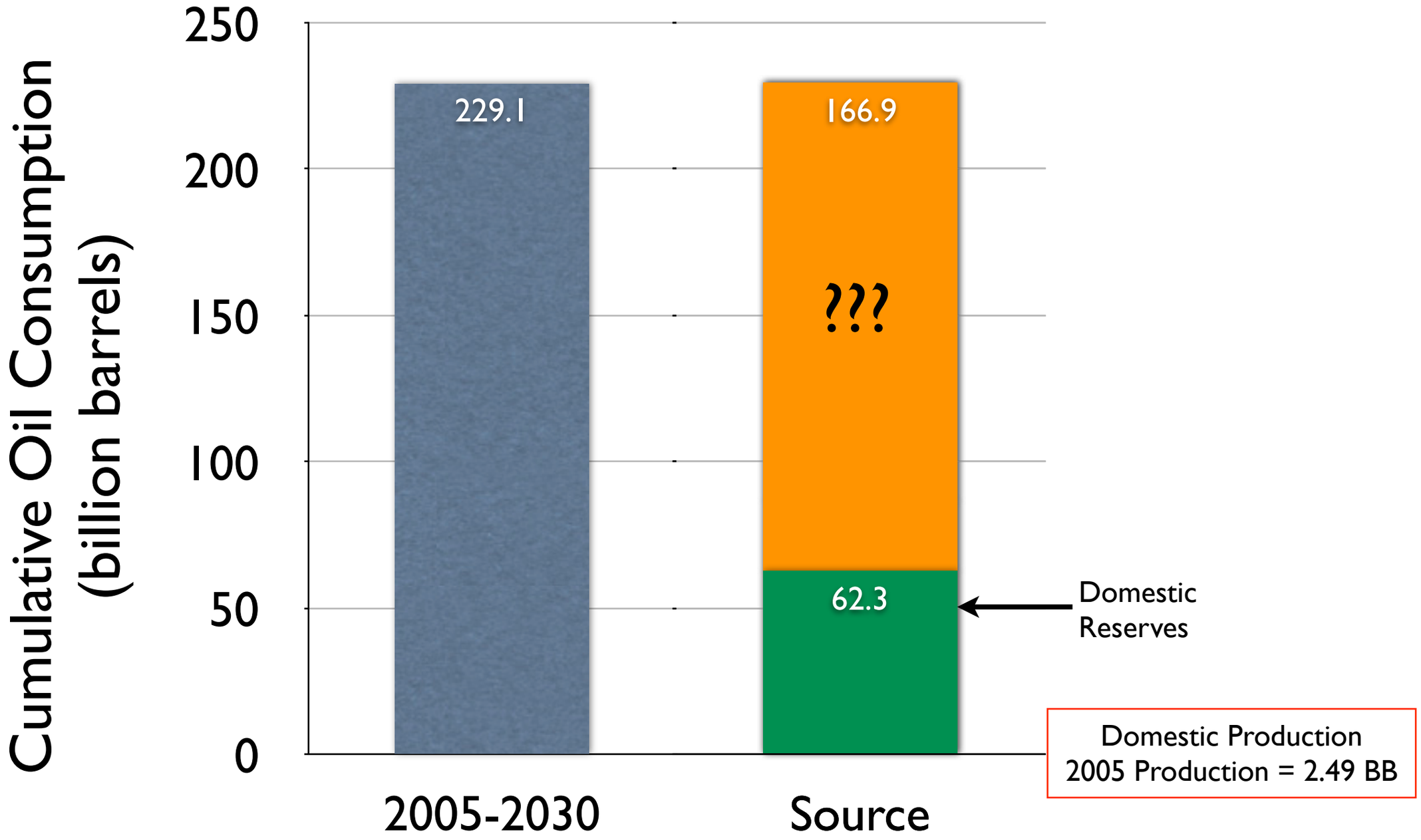
Average annual rate of increase = 1.1%

Source: Energy Information Administration (EIA), 2006

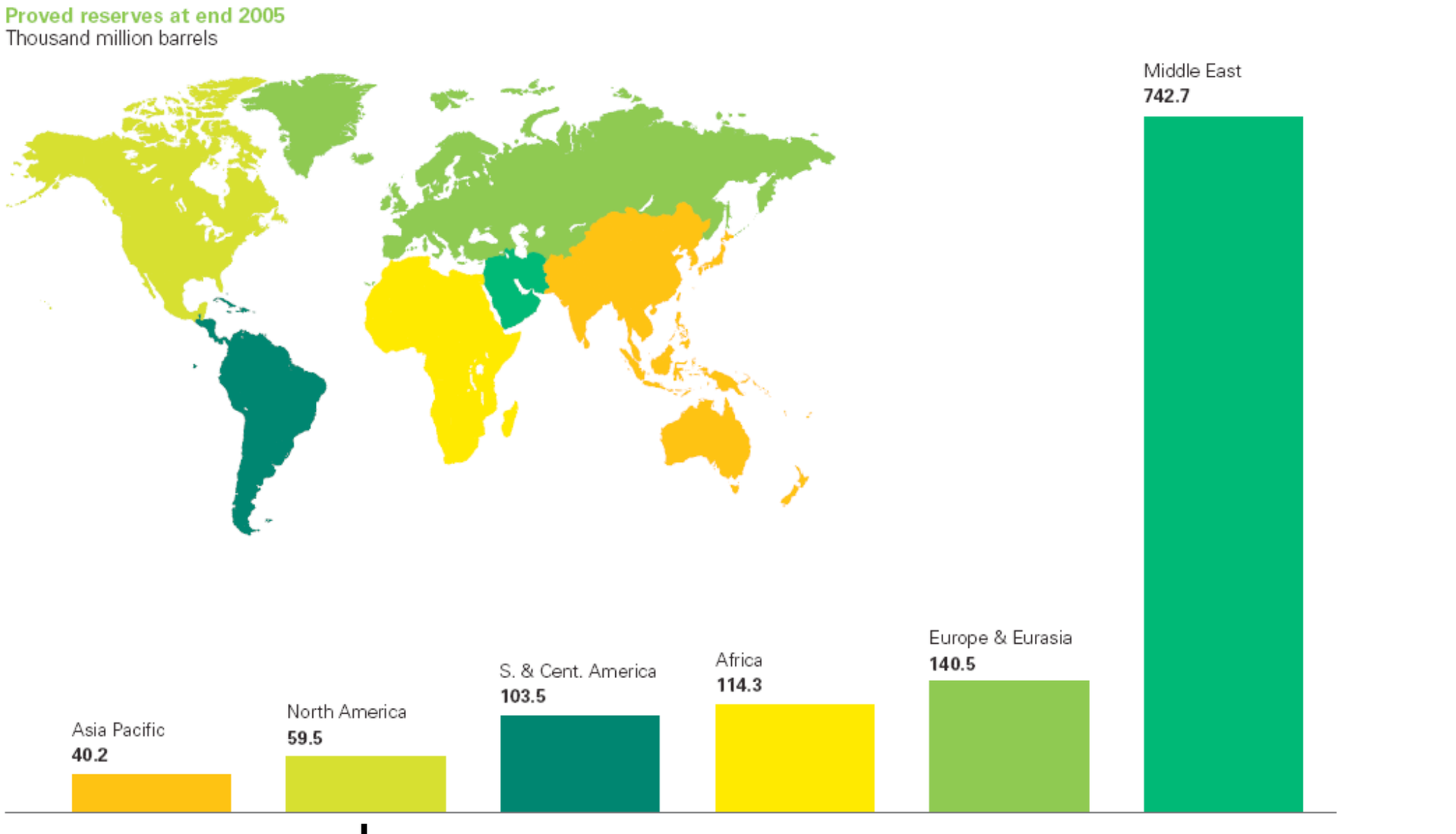
Cumulative US Oil Consumption from 2005 to 2030



Cumulative US Oil Consumption from 2005 to 2030



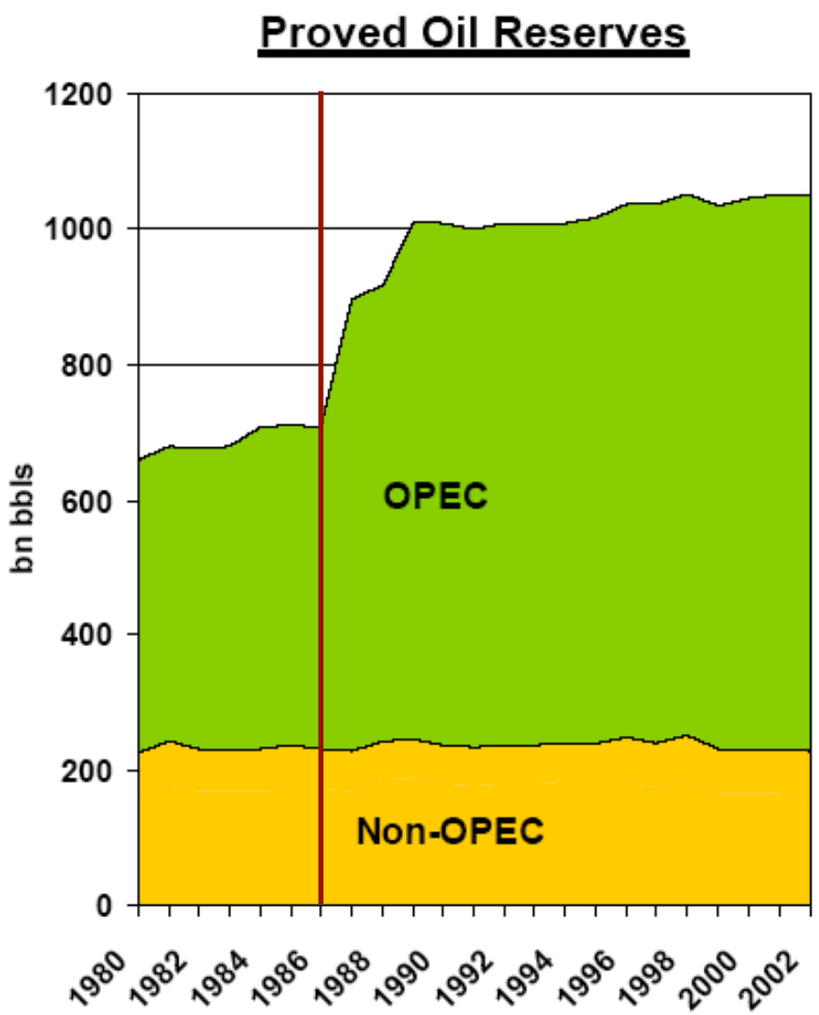
Oil Reserves

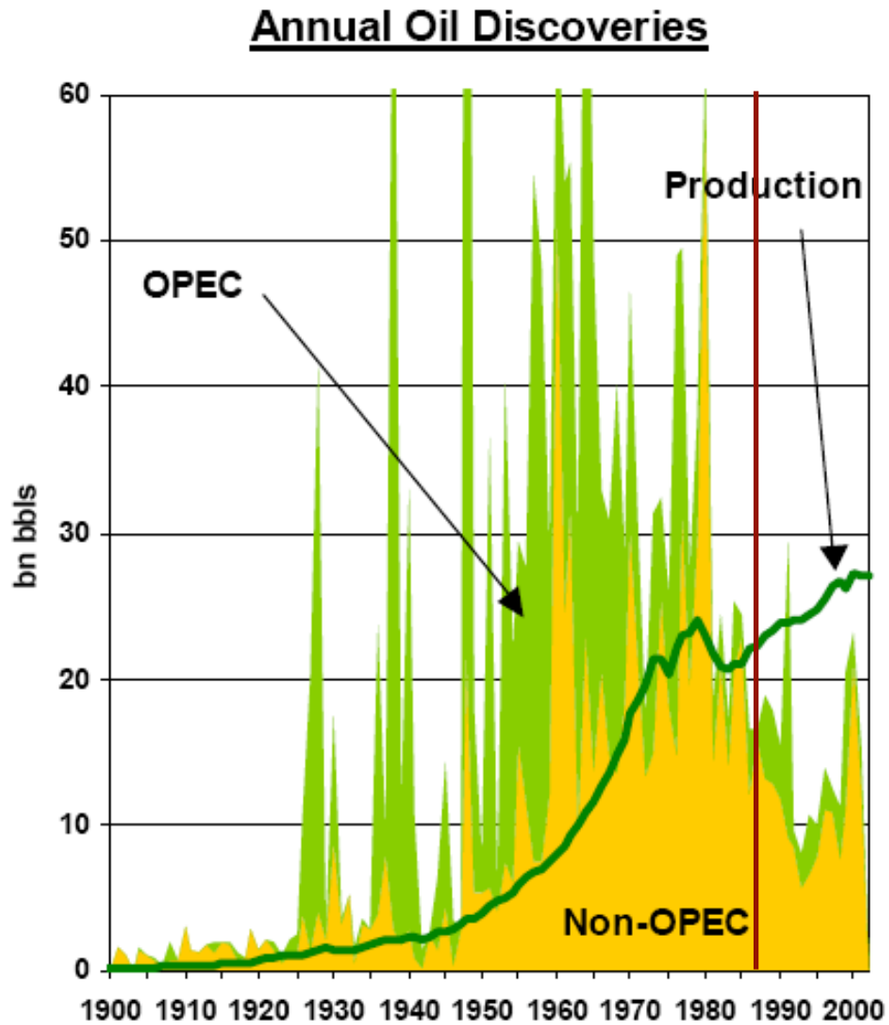


US share: 2.4%

Source: BP Statistical Review of World Energy 2006

Reserves and Discovery

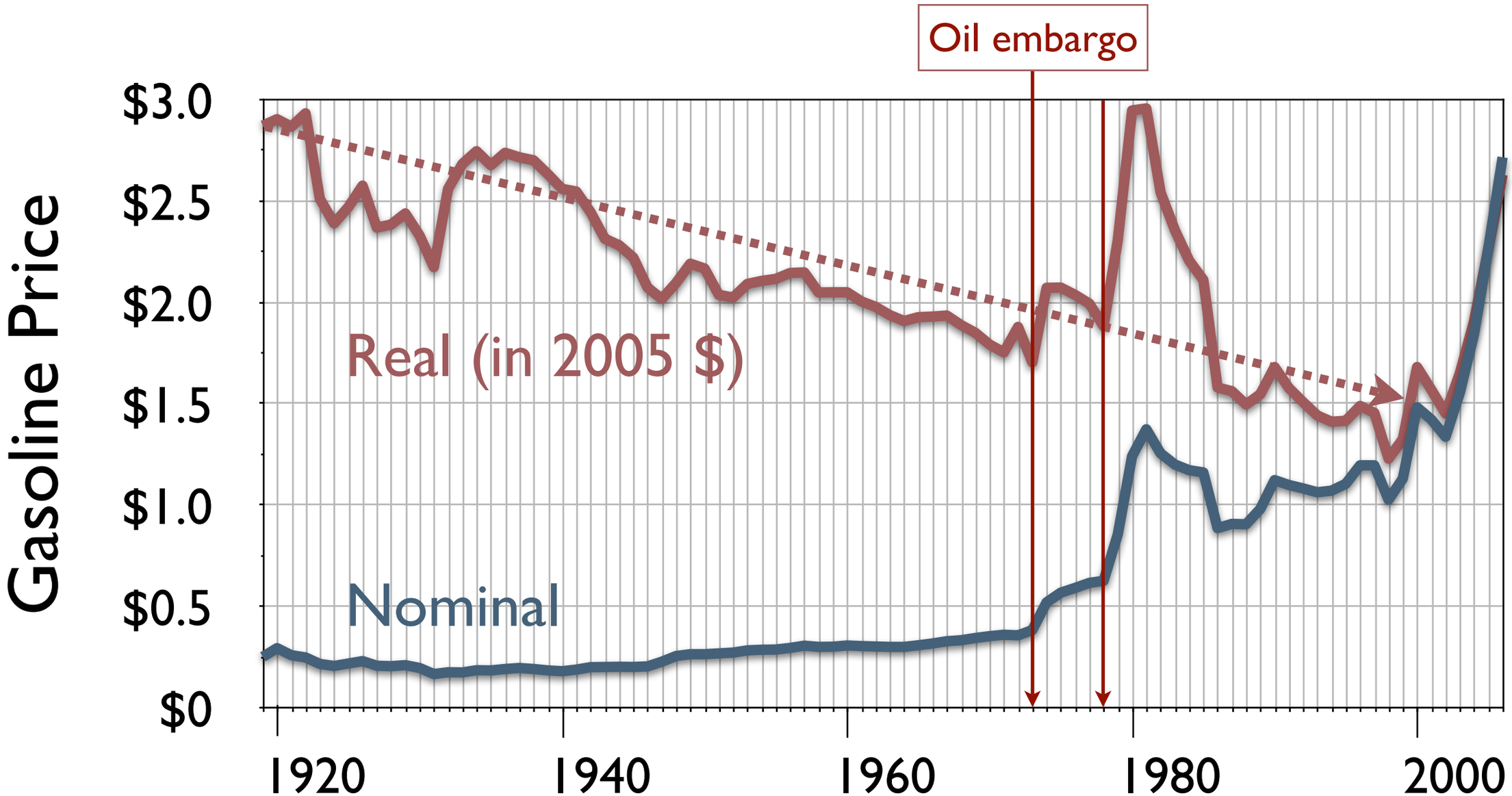




Source: BP Statistical Review of World Energy 2003

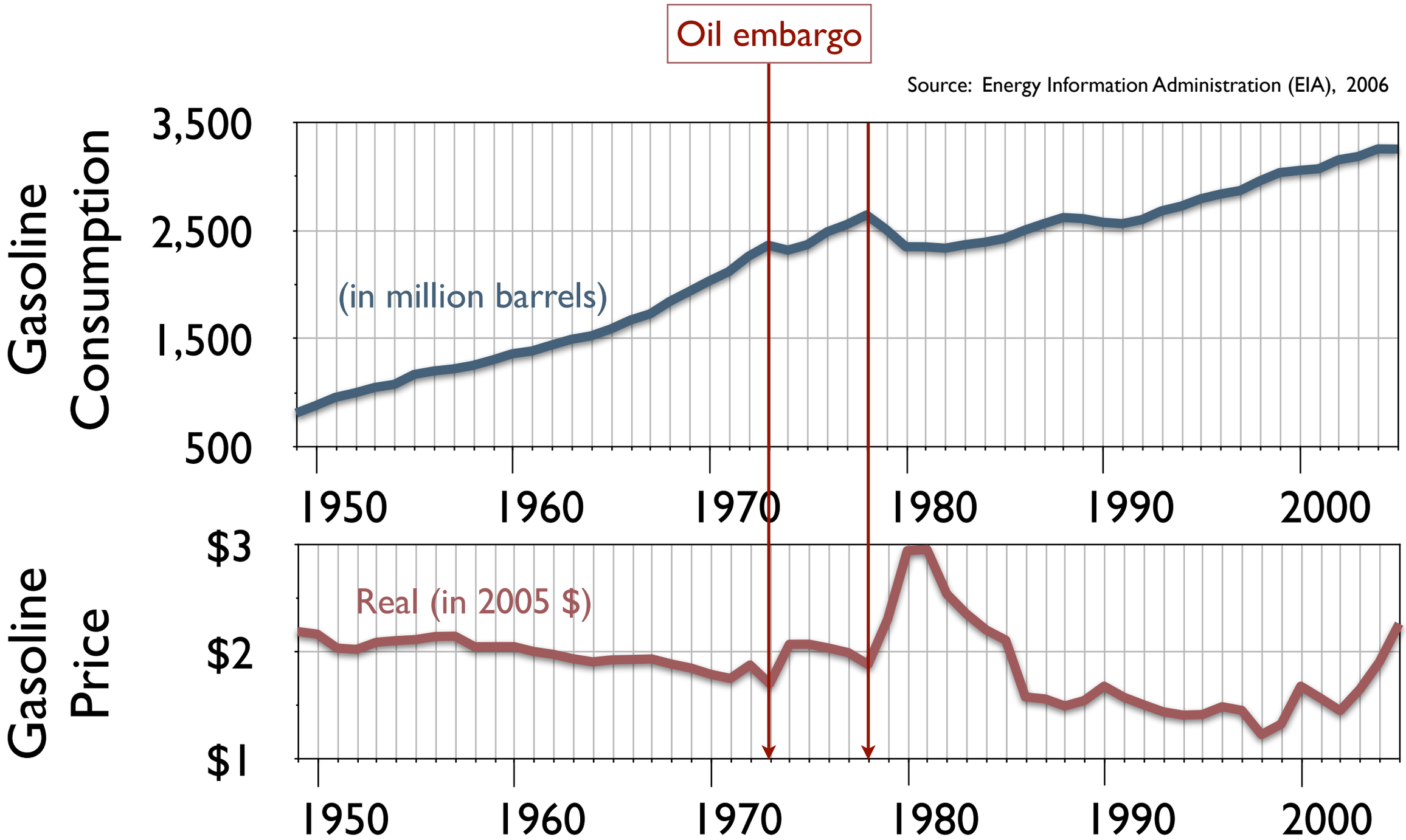
bp

Why Are We Addicted to Oil?

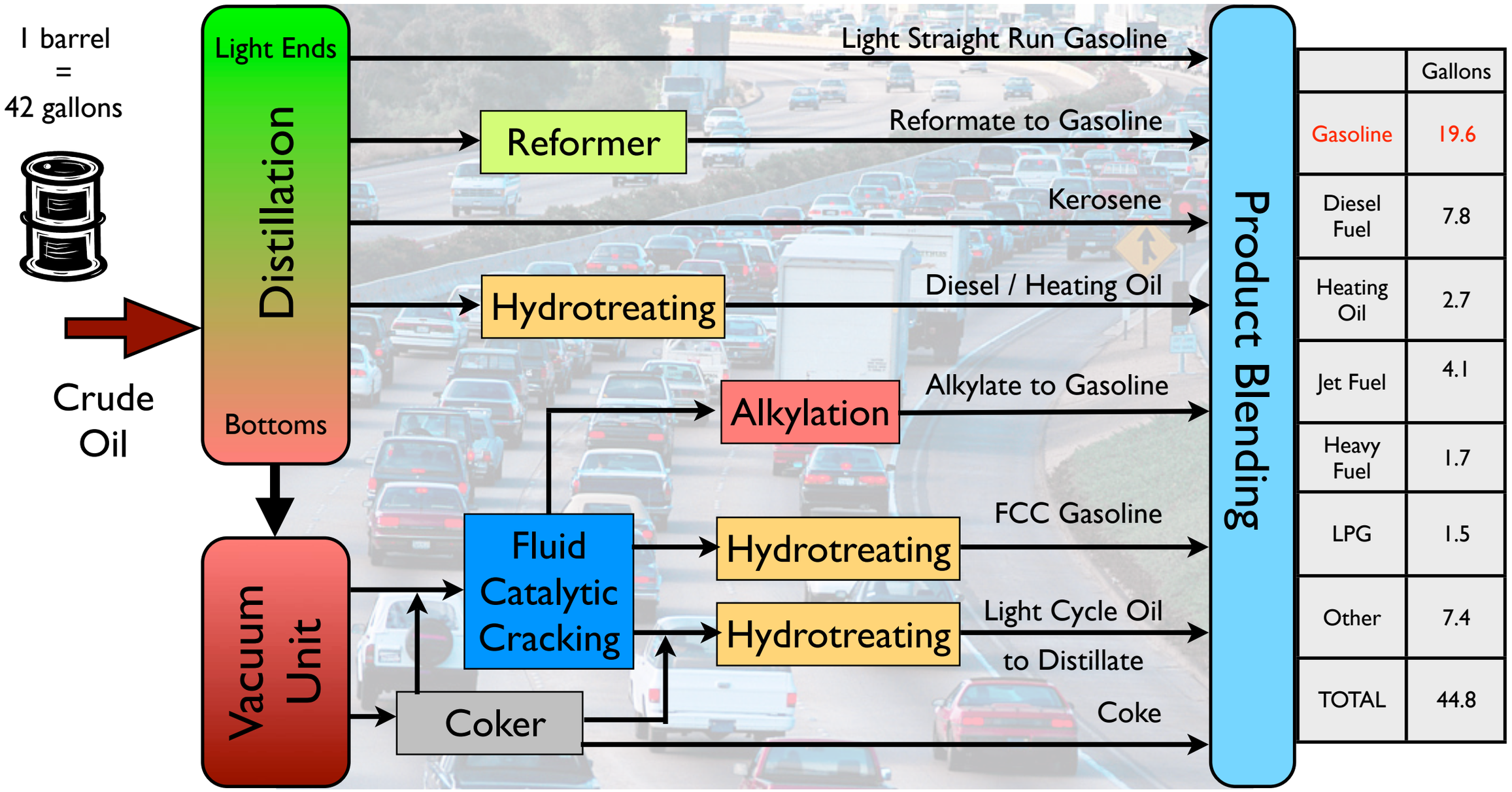


Source: Energy Information Administration (EIA), 2006

Oil for Transportation

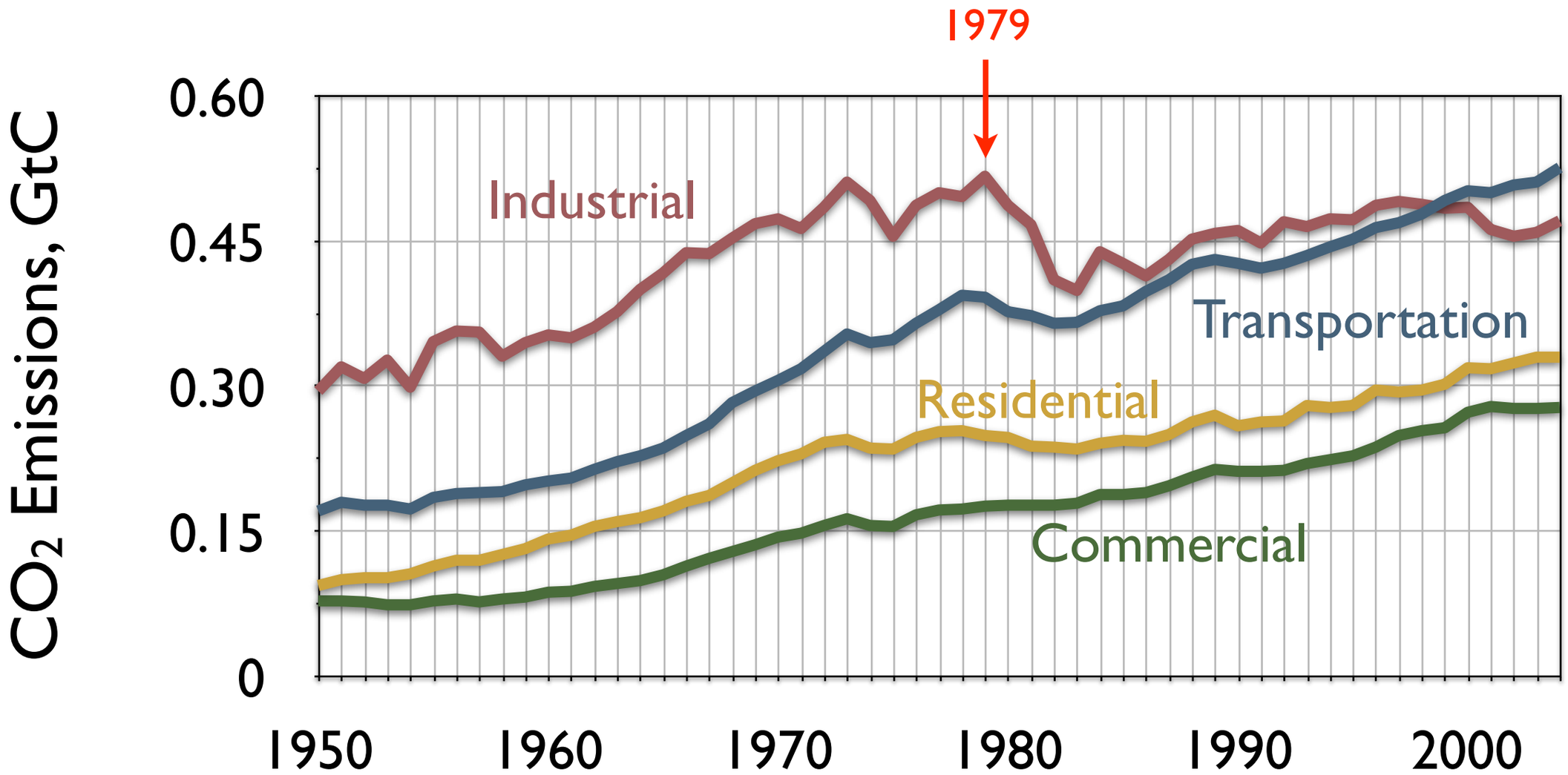


Integrated and Optimized Processing



	Gallons
Gasoline	19.6
Diesel Fuel	7.8
Heating Oil	2.7
Jet Fuel	4.1
Heavy Fuel	1.7
LPG	1.5
Other	7.4
TOTAL	44.8

CO_2 Emissions by Sector



Source: DOE / EIA, December 2005

"I suppose I could live with two slices at a time."

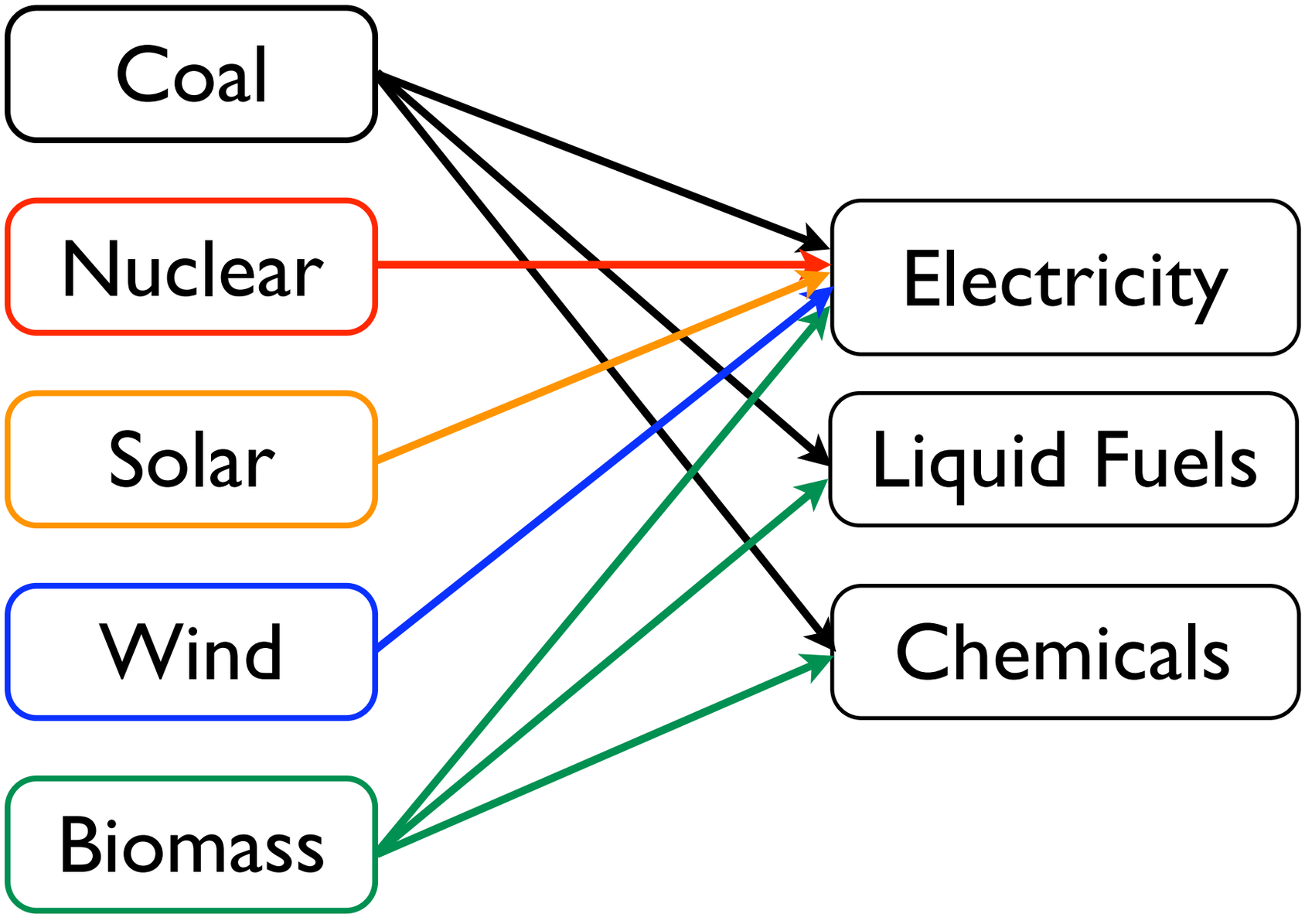
Energy Vision

Mission: Build the bridge to a sustainable, affordable and secure energy future.

How can we achieve this?

- Broad Portfolio of Technologies
- Lower CO_2 Emissions - Renewable Sources
- Optimized Processes
- Fuel Choices
- Expanded Domestic Fuel Supply

Alternatives to Oil and Gas?



What Is the Proper Mix?

Oil Biomass Coal

$$\text{Liquid Fuels} : LF(t) = P(t) + B(t) + C(t)$$

$$\text{Electricity} : E(t) = C(t) + G(t) + S(t) + N(t) + W(t) + B(t) + O(t)$$

Coal Natural Gas Solar Nuclear Wind Biomass Other

How Do We Find the Proper Mix?

Understand !

- Potential
- Advantages and disadvantages
- Environmental consequences
- Economics (But, technology is rapidly evolving !)

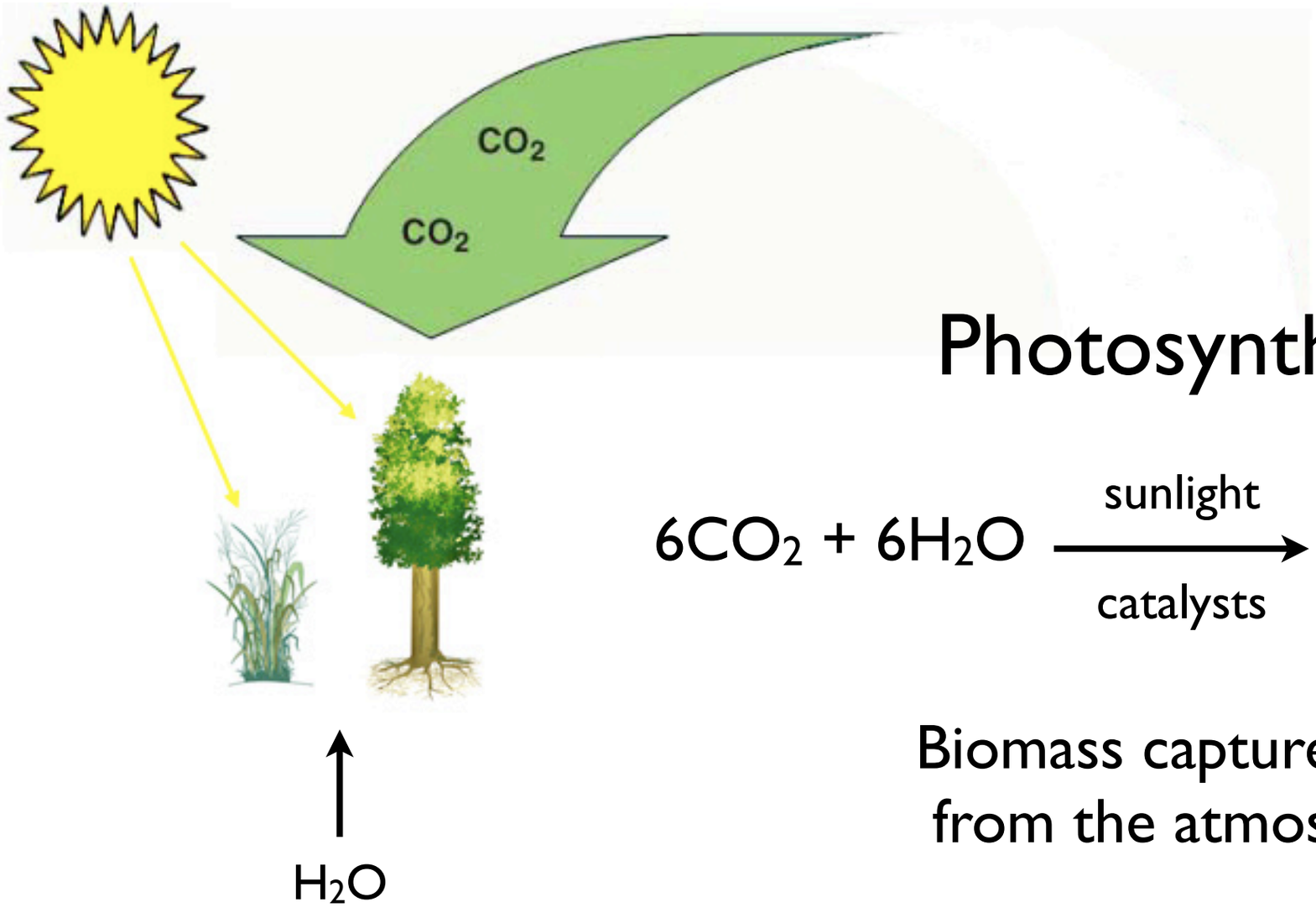
Then, Act !

- Establish policies

Biomass

- Can it reduce CO_2 emissions?
- How much energy can it really provide?
- Will it impact the environment adversely?
- What about the economics?

Biofuels Recycle CO_2

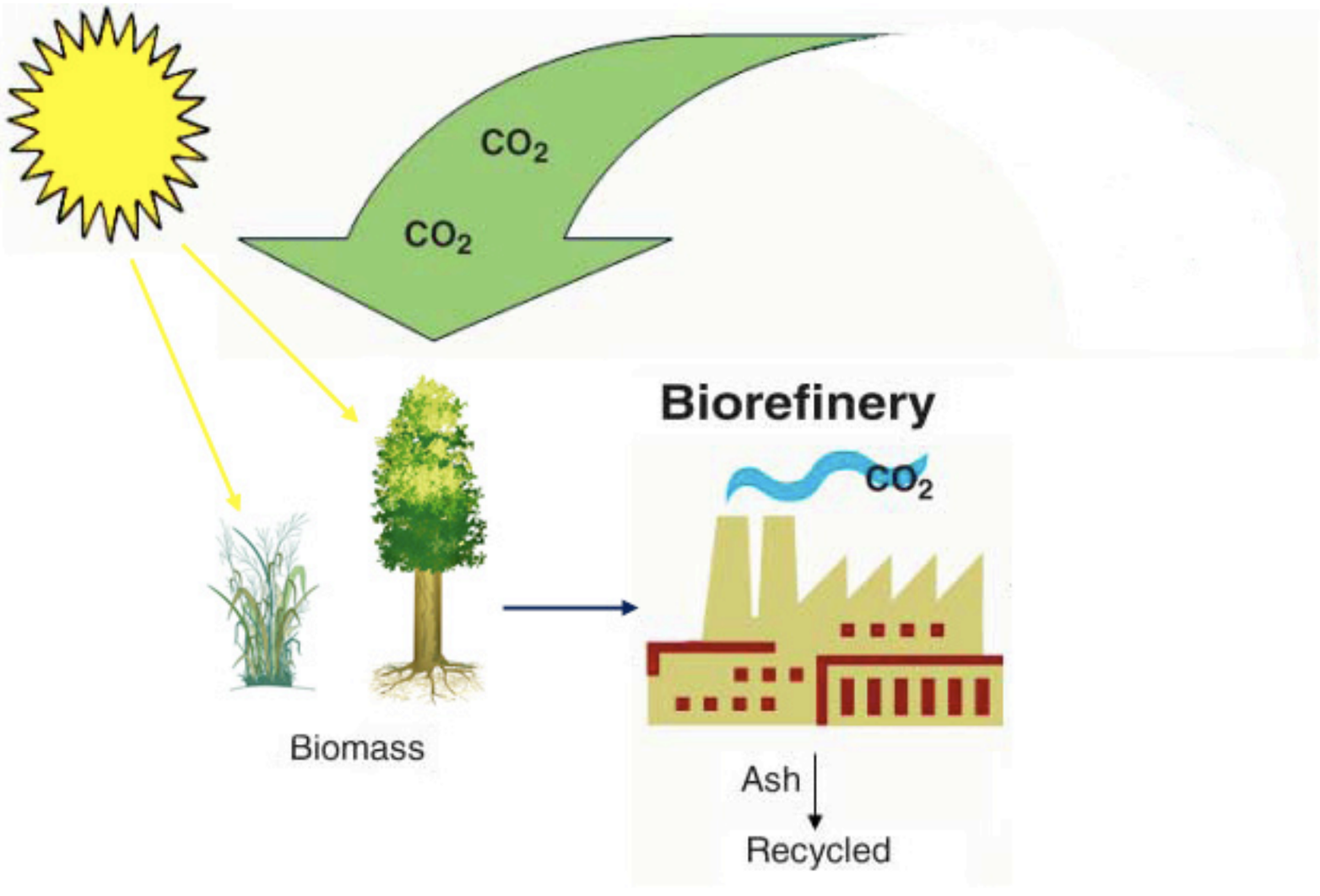


Photosynthesis

$$6CO_2 + 6H_2O \xrightarrow[\text{catalysts}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Biomass captures CO_2 from the atmosphere

Biofuels Recycle CO_2



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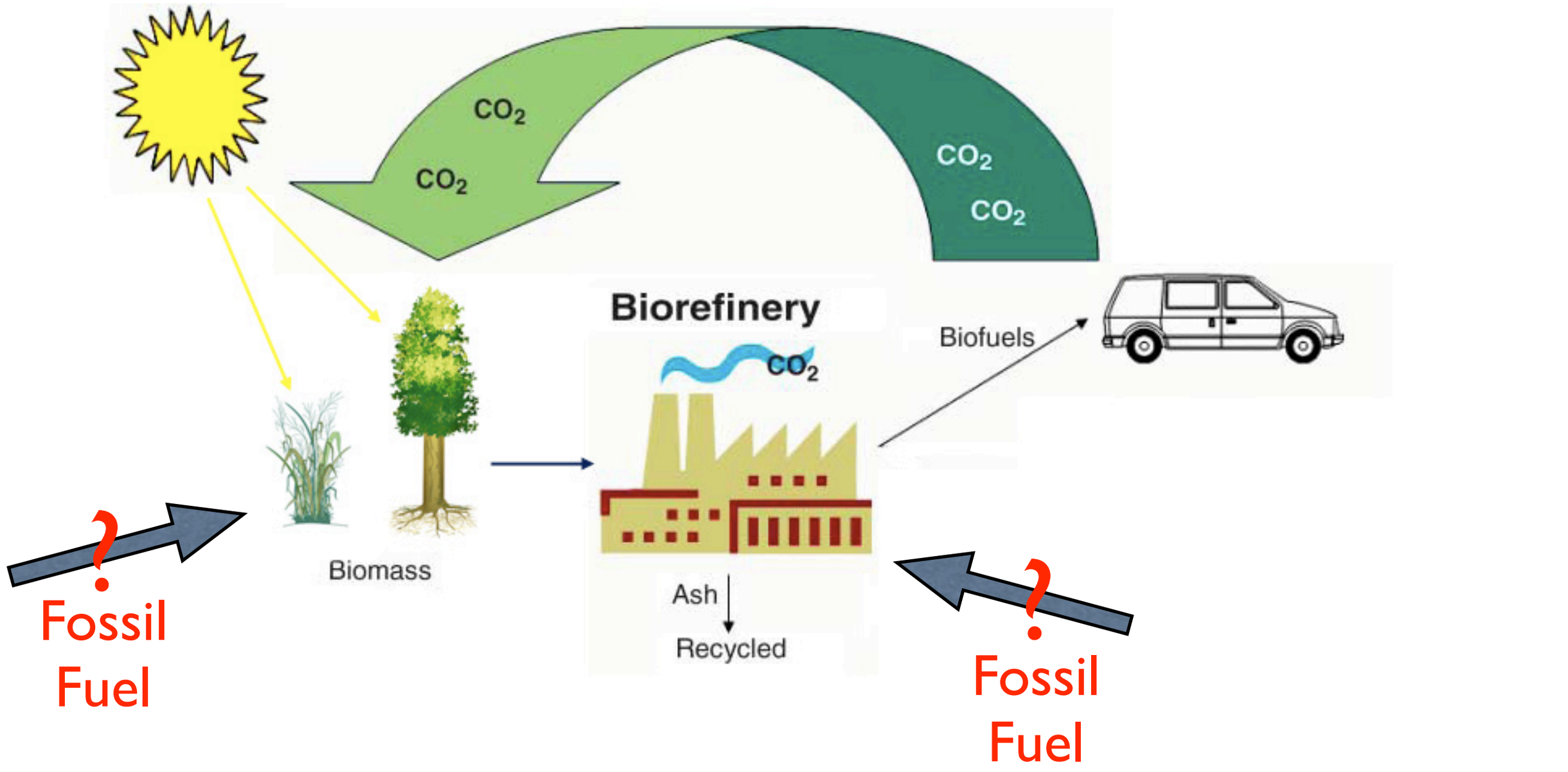
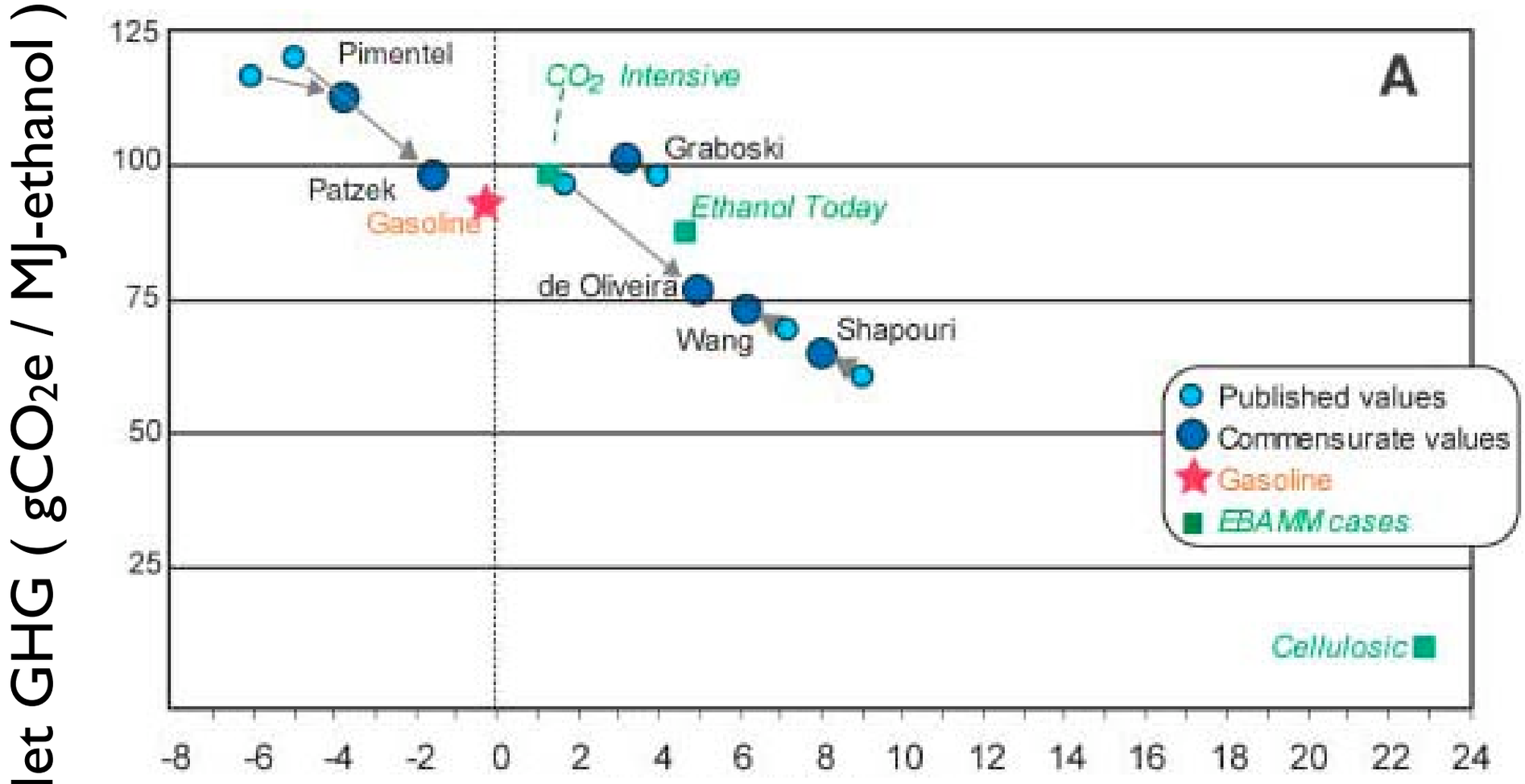
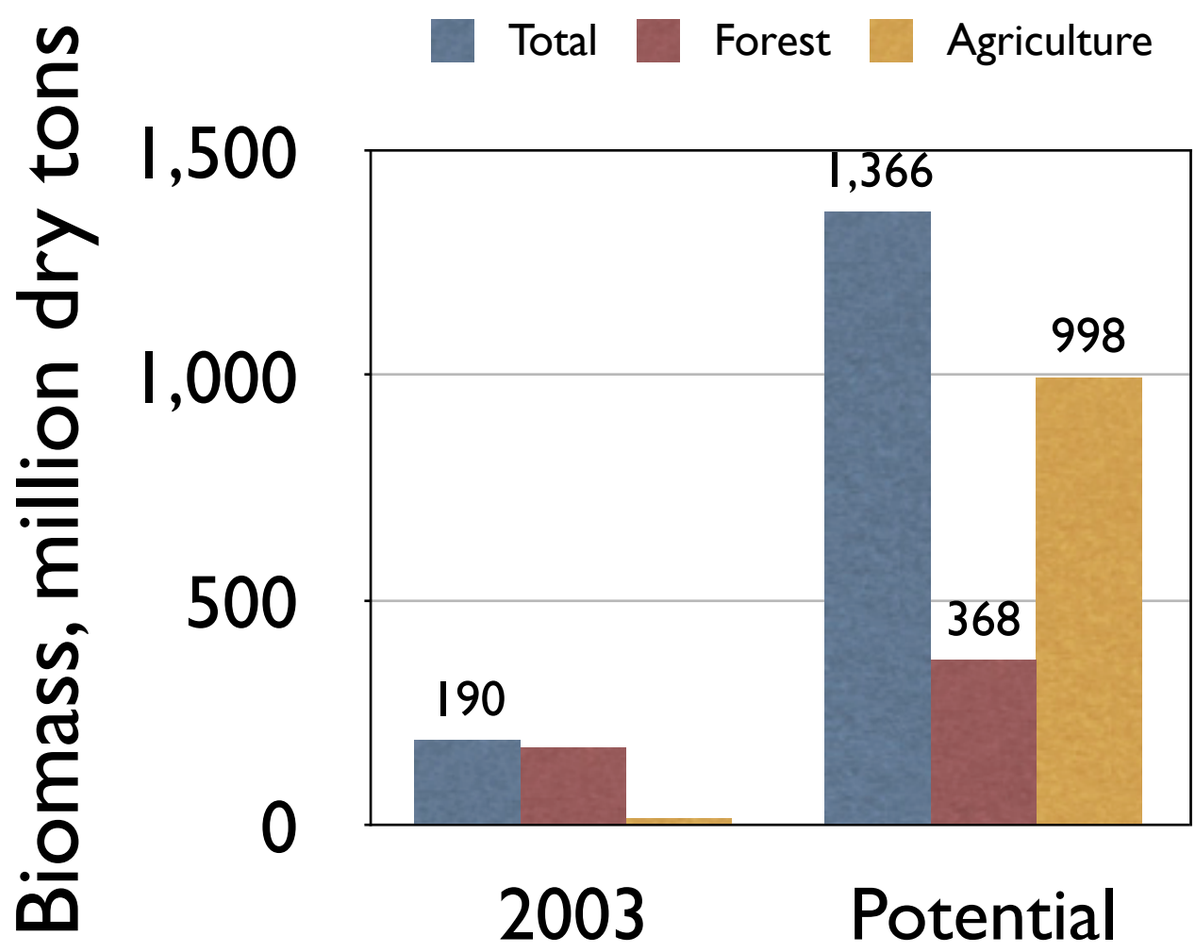


Net GHG Emissions



Farrell et al., *Science*, **181**, 506-508 (2006)

1.3 Billion Ton Scenario



Source: DOE Report, 2005

2003:

- 190 million dry tons of biomass contributed about 3% of the US energy needs.

Potential

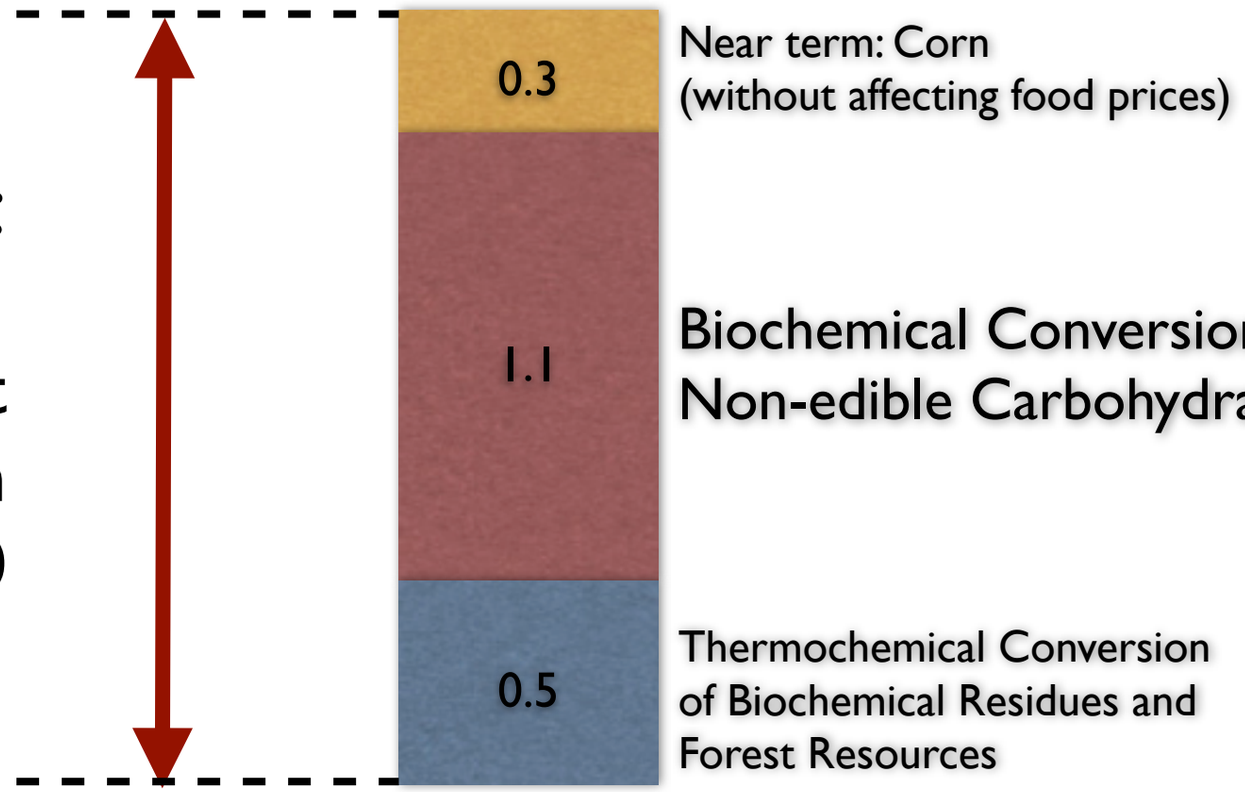
- More than 1.3 billion tons of dry biomass from forest and agricultural resources through:
  - Increased yields
  - No-till cultivation
  - Perennial crops on 55 million acres (switchgrass, poplar trees)

1.3 Billion Ton Scenario

1.9 billion barrels
of oil equivalent

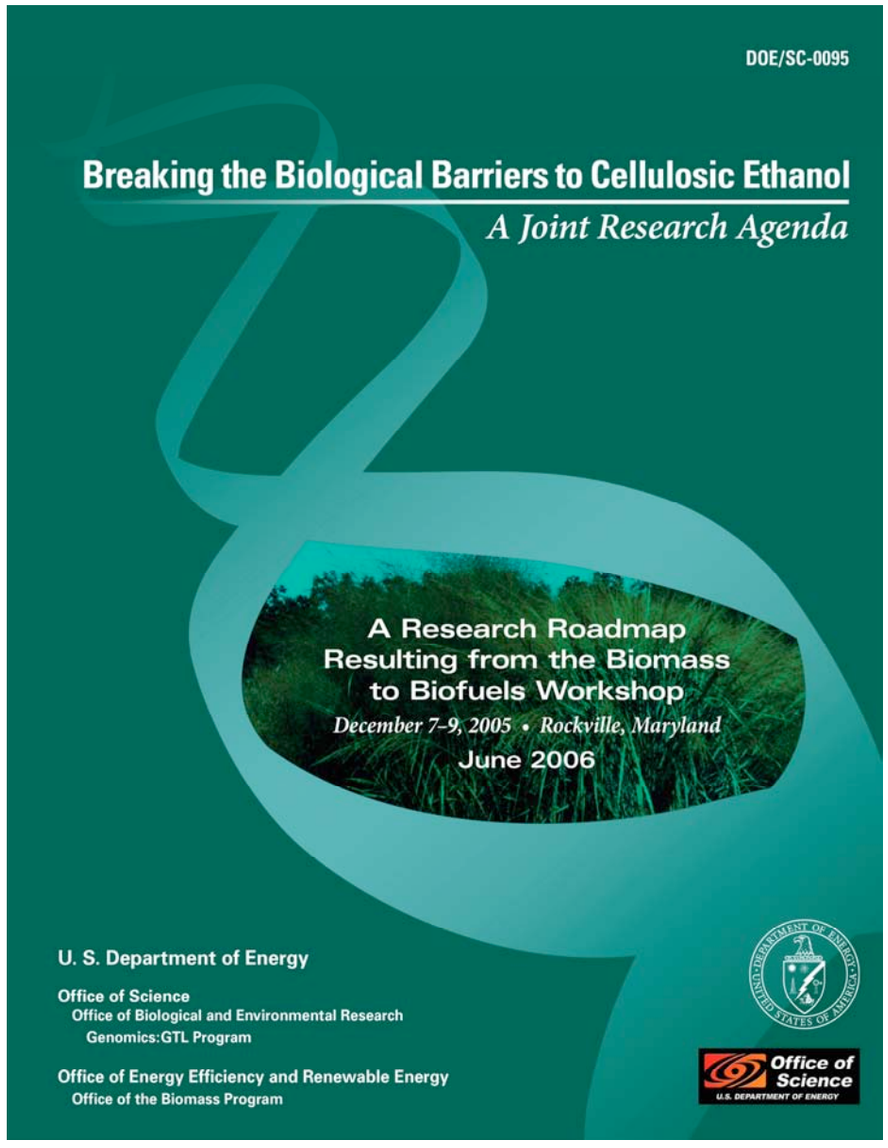
Target:

Replace 30% of current petroleum consumption by 2030



Source: DOE Report, 2005

AEI - DOE Roadmap



Cellulosic ethanol

- By 2030, replace 30% of 2004 gasoline consumption.
- Thus, 60 billion gallons of ethanol must be produced in 2030.
- At 80 gal/ton, we will need 750 Mton of dry biomass to produce this amount of ethanol.
- At 10 ton/acre, we will need 75 million acres to produce this amount of biomass.

Cellulosic Ethanol Roadmap

75 million acres

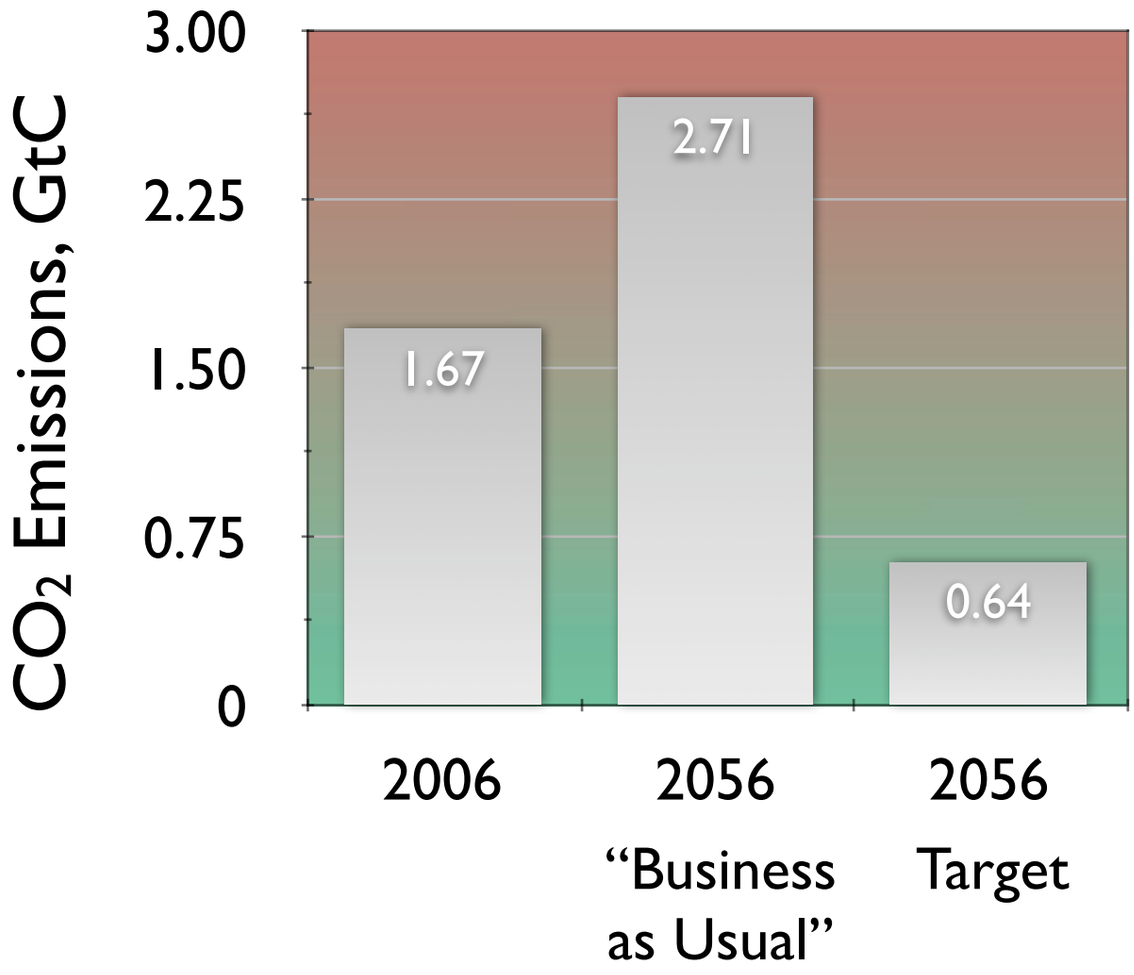
~57% of non-harvested cropland

US Statistics

Total Farmland = 938 million acres
Total Cropland = 434 million acres
Harvested Cropland = 303 million acres

Reduction of CO_2 Emissions

To keep temperature rise < 2 °C, we must stabilize atmospheric CO_2 concentration to 450 ppm.



S450Ce scenario:

- Must limit total CO_2 emissions in 21st century to 480 GtC.
- US emissions must total 84 GtC.
- To achieve this goal, US annual CO_2 emissions must decrease to 0.64 GtC in 2056 and 0.2 GtC in 2100.

Source: "Avoiding Dangerous Climate Change," Cambridge University Press, New York, 2006

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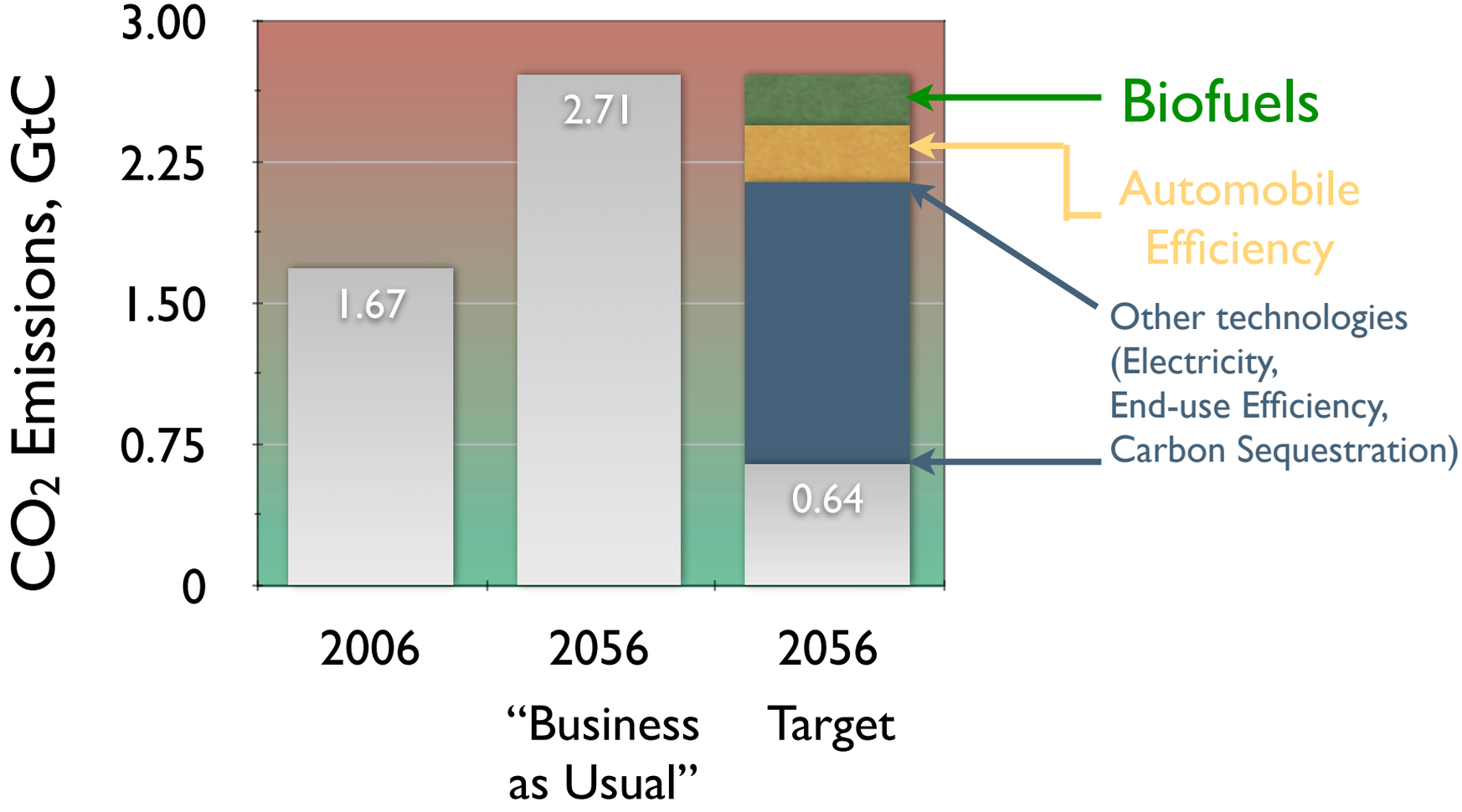


Oil Provides More Than Fuels!

Crude Oil and Natural Gas

Hydrocarbons

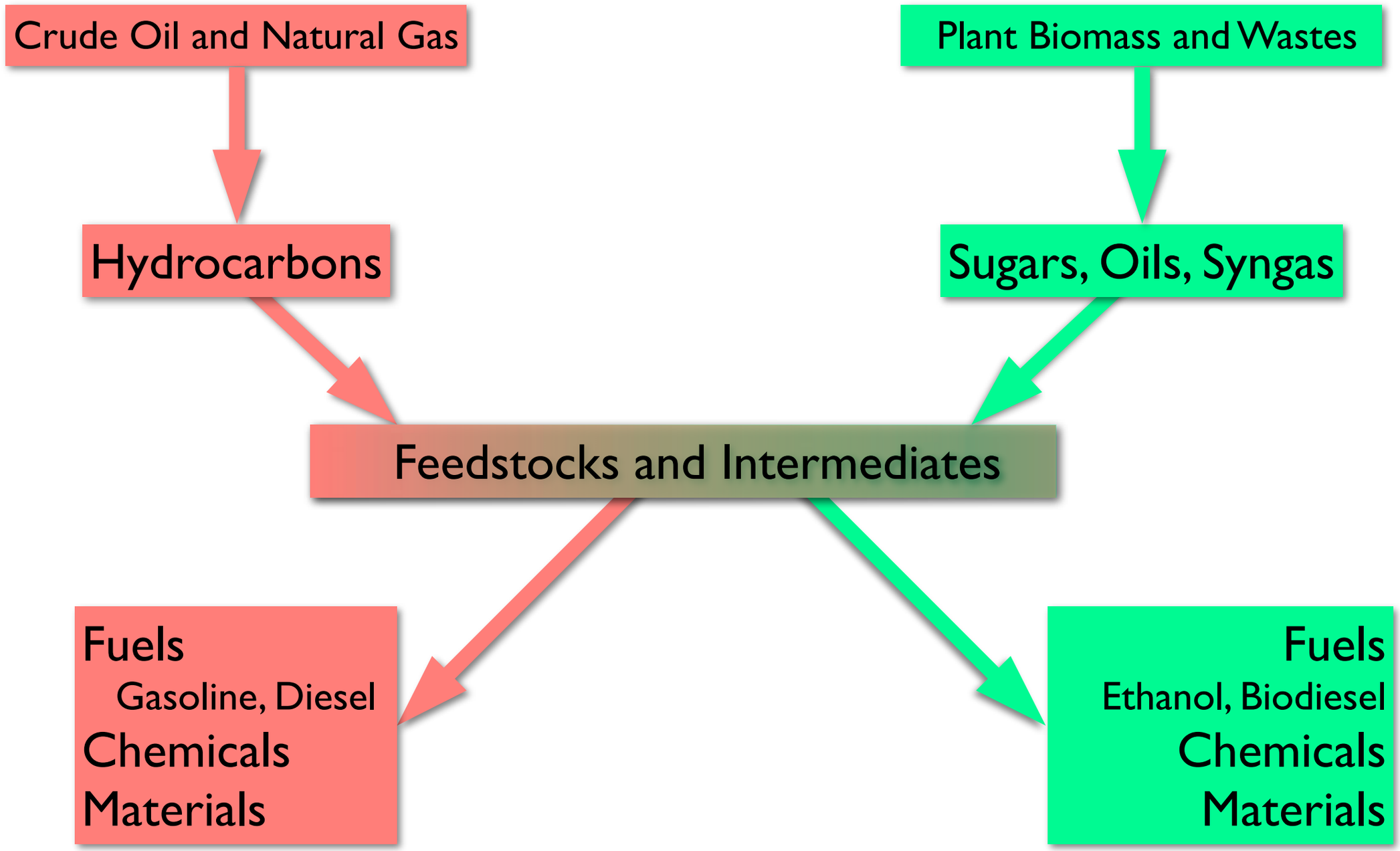
Feedstocks and Intermediates

Fuels
- Gasoline, Diesel

Chemicals

Materials

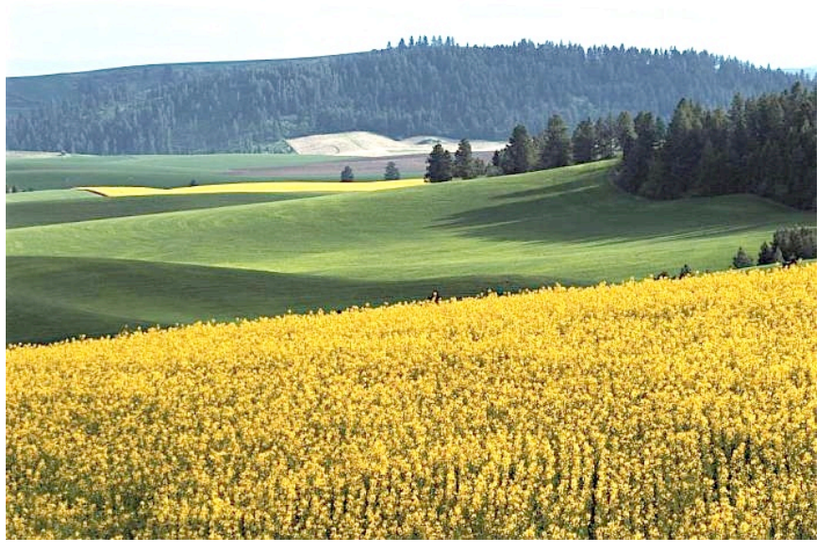
Bridge to the Future



Key Biomass Advantages

Biomass is

- Abundant
- Renewable
- Reduces CO_2 emissions
- Only sustainable source for materials!

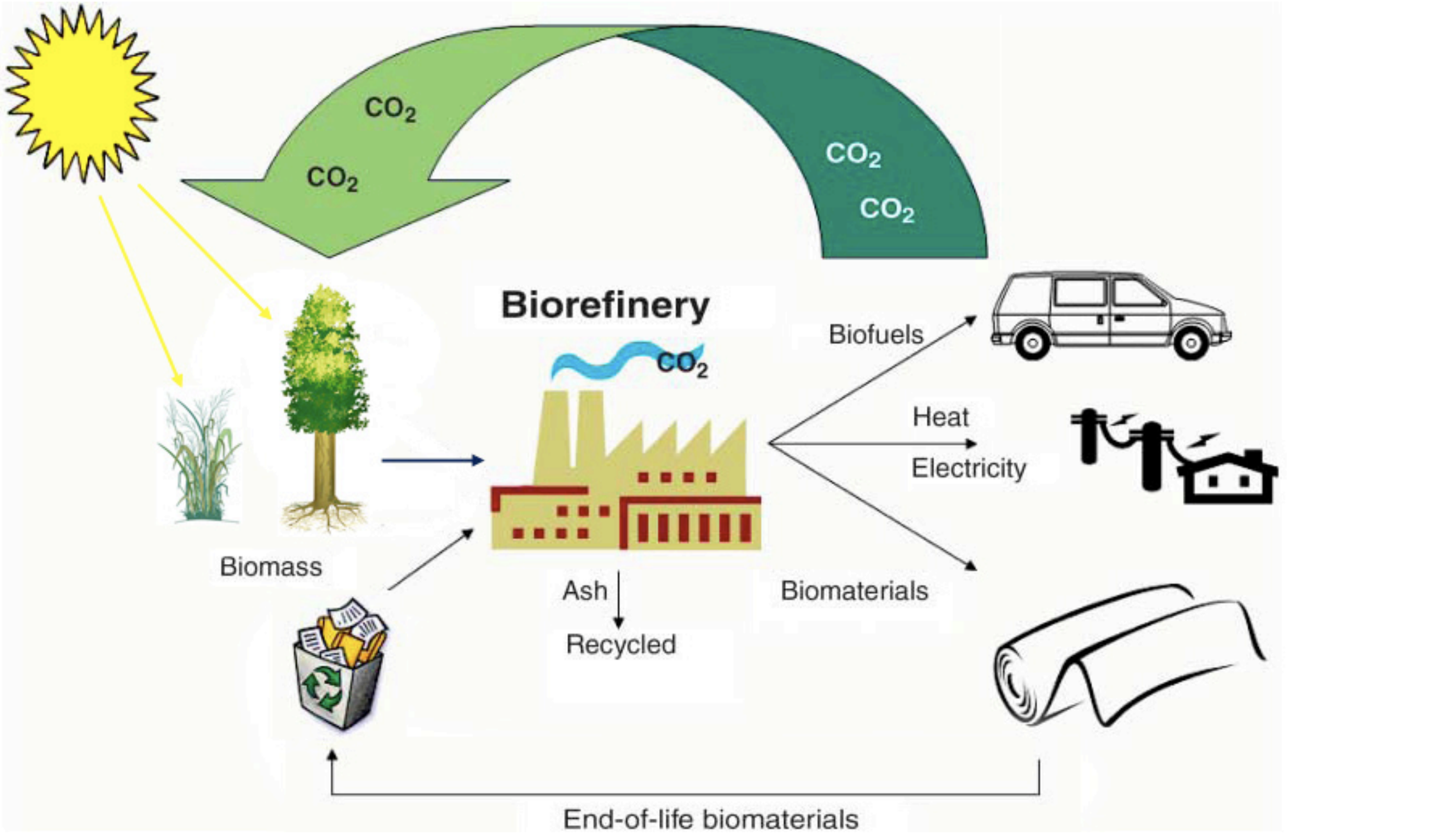


1999 NRC Report: "…the land and agricultural resources of the United States are sufficient to satisfy domestic and export demands for food, feed and fiber and still produce the raw materials for most bio-based industrial products..."

Other Advantages

- Biofuels can be used in current automobile engines with minor or no modifications
- Infrastructure exists for distribution and storage of liquid fuels
- Biomass can be used in existing power plants (co-firing with coal or re-powering)
- Biofuels may come from waste streams

Fully Integrated Cycle for Sustainable Technologies



Disadvantages and Challenges

Disadvantages

- Energy density is low.
- Heat content of biomass is low compared to petroleum or high rank coals.

Challenges

- Reduce use of water
- Minimize use of fertilizers and water pollution

Biomass to Chemicals and Fuels

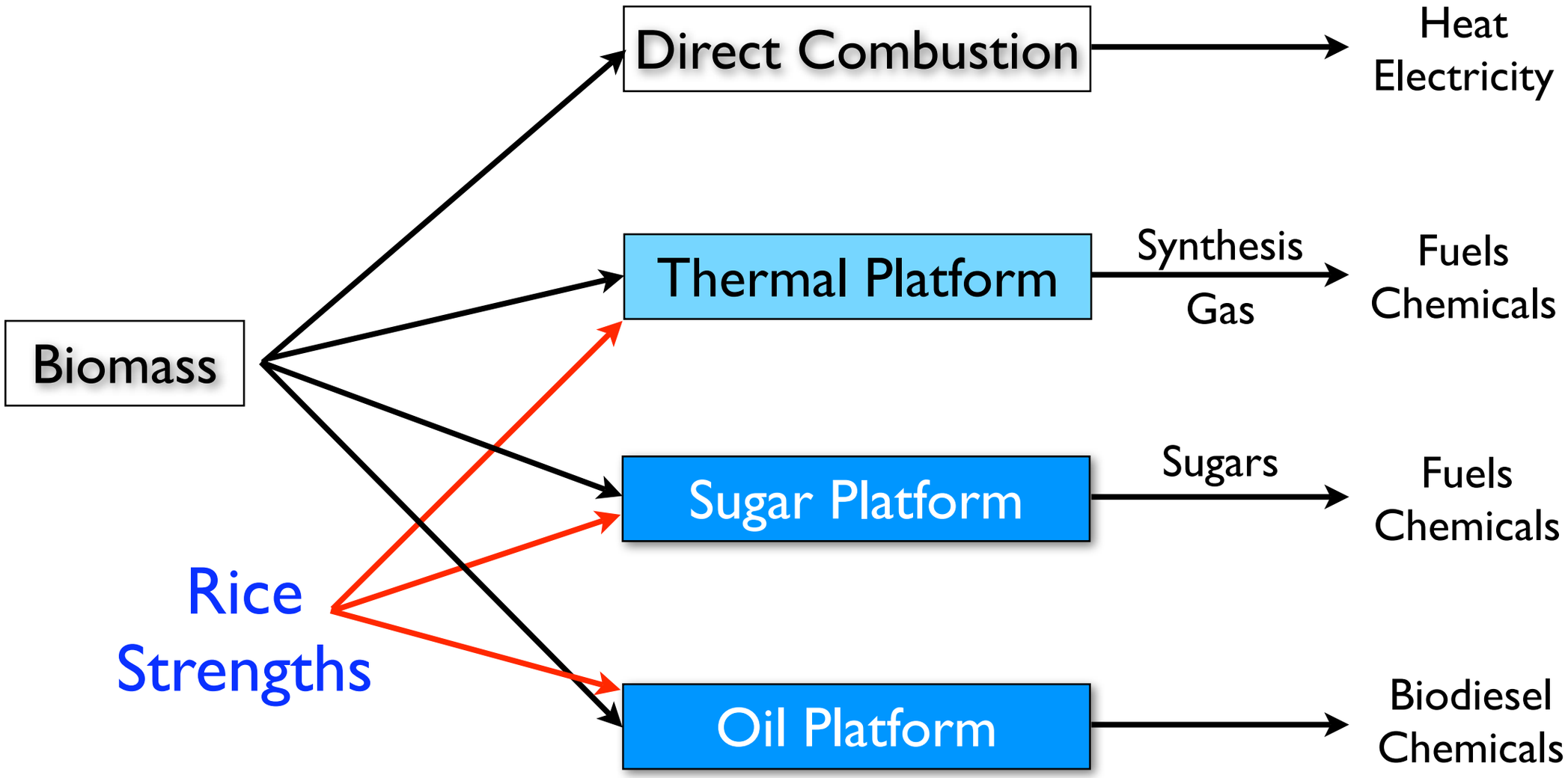
Challenge:

Develop integrated processing systems that can produce bio-based chemicals and biofuels safely and economically (high yields, rates, & concentrations)

A fully integrated processing system will:

- transform all the raw materials into useful, high-value products, and
- minimize the consumption of utilities (electricity, steam, water).

Biomass Utilization



Rice Strengths

Biomass to Chemicals and Fuels		
Sugar	Syngas	Oil
Biobutanol Cellulosic biomass Biodegradable polymers Systems Biology	Catalysis Process and Reactor Design	Glycerol Fermentation Systems Biology Reactor Design Process Integration
Life Cycle Analysis Computational Modeling and Analysis Energy and Environmental Policy Analysis		

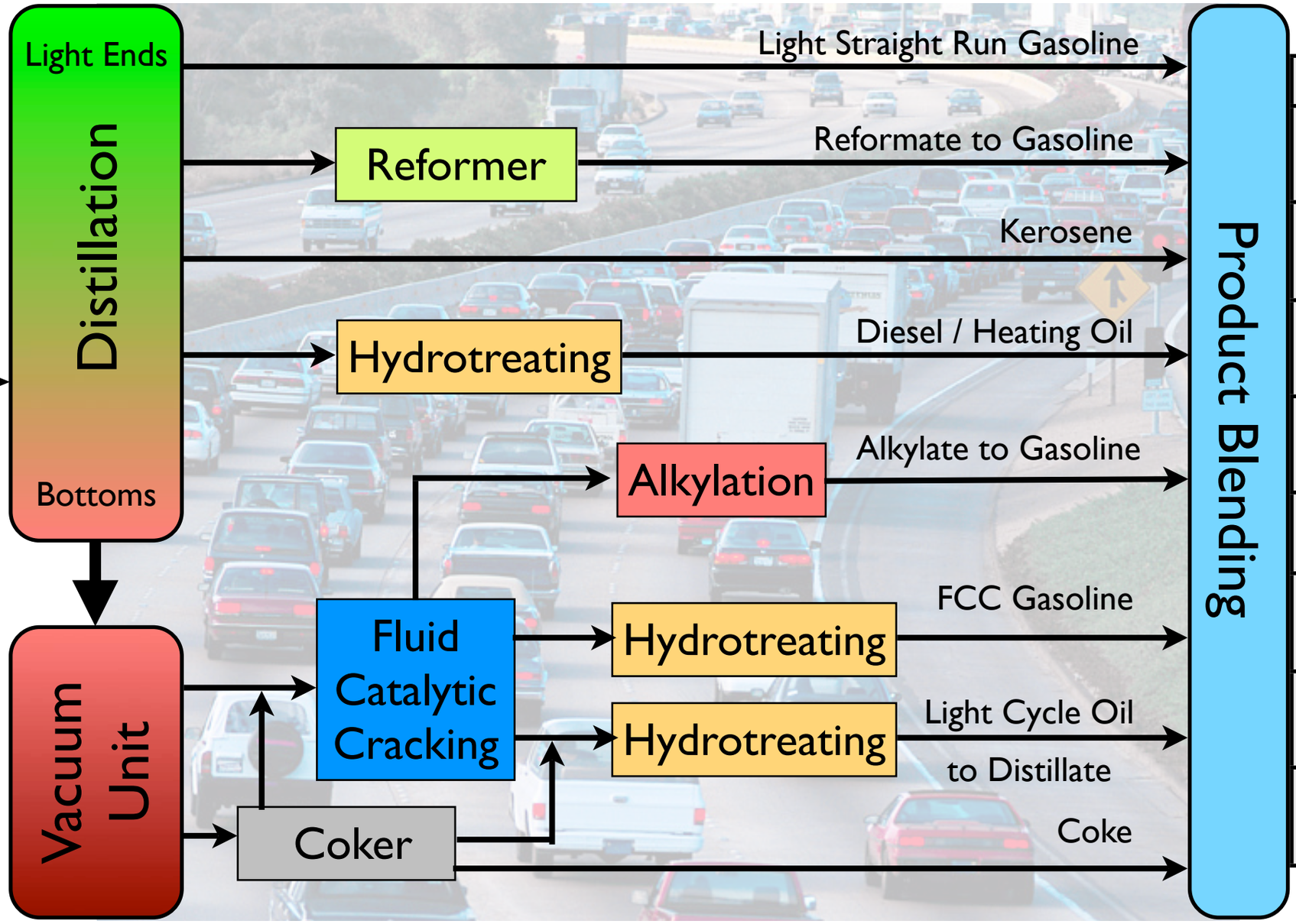
Let the discussion begin!

"Energy"
William M. McVey, Rice '27

Oil Refinery

1 barrel
=
42 gallons

Crude Oil



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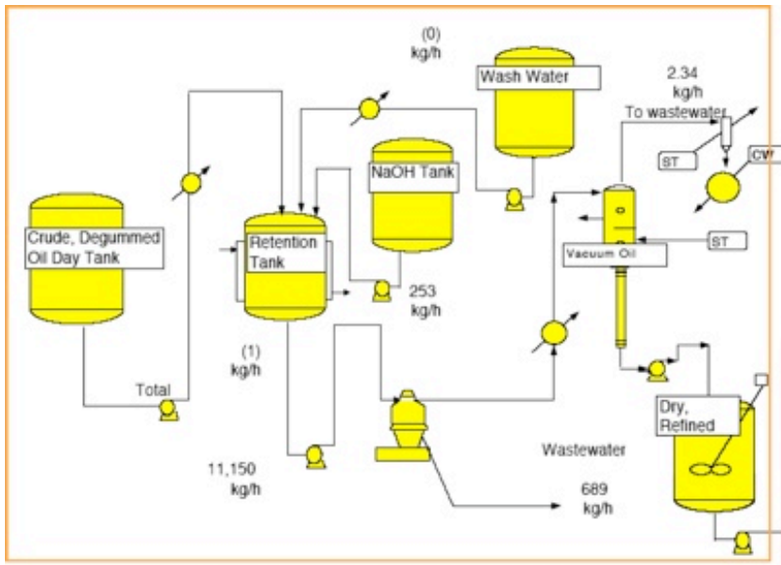
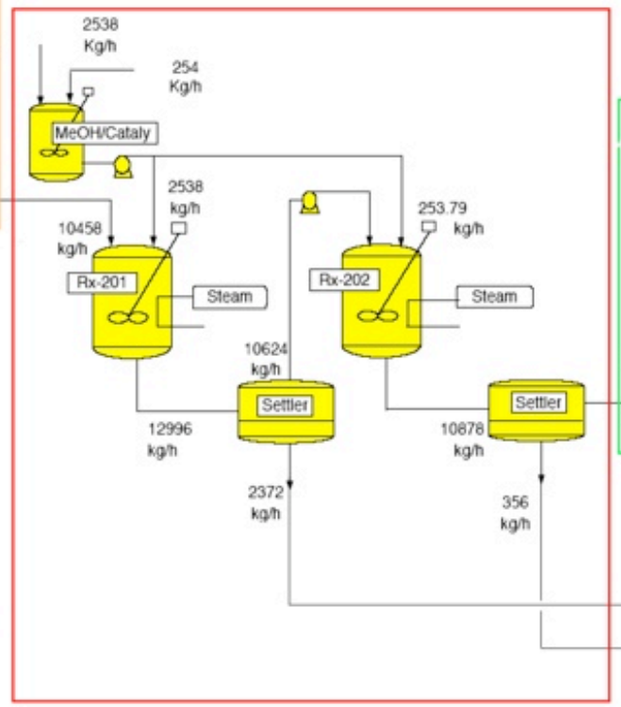
Integration & Optimization

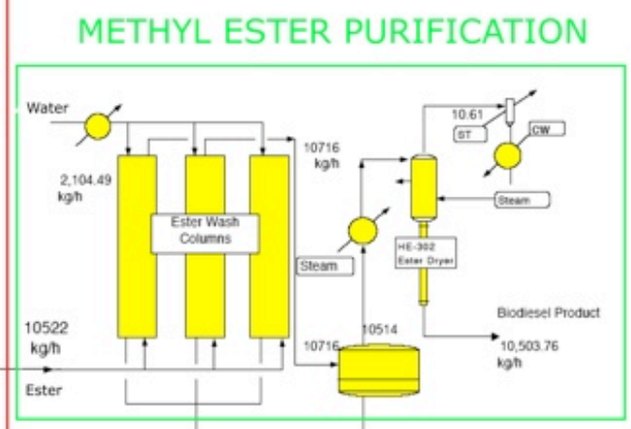
Biodiesel Production



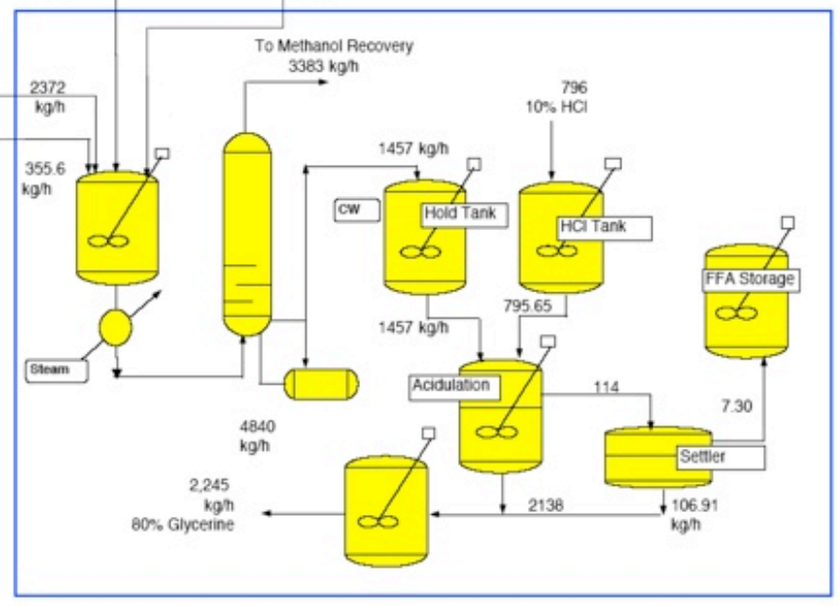
ALKALI REFINING OF CRUDE SOYBEAN OIL



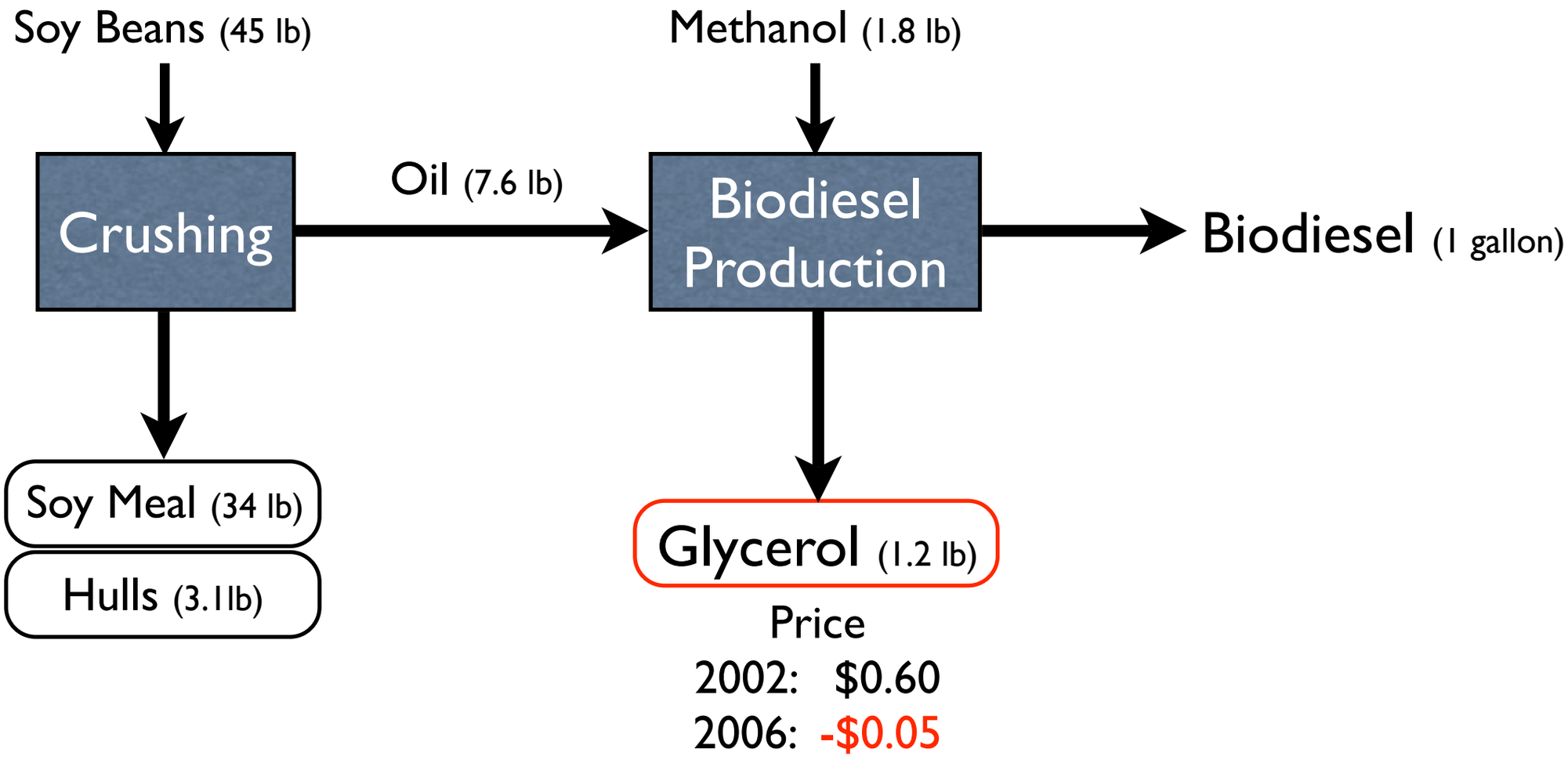
TRANSESTERIFICATION SECTION OF BIODIESEL PRODUCTION FACILITY



RECOVERY OF CRUDE GLYCEROL



Biodiesel from Soy Beans



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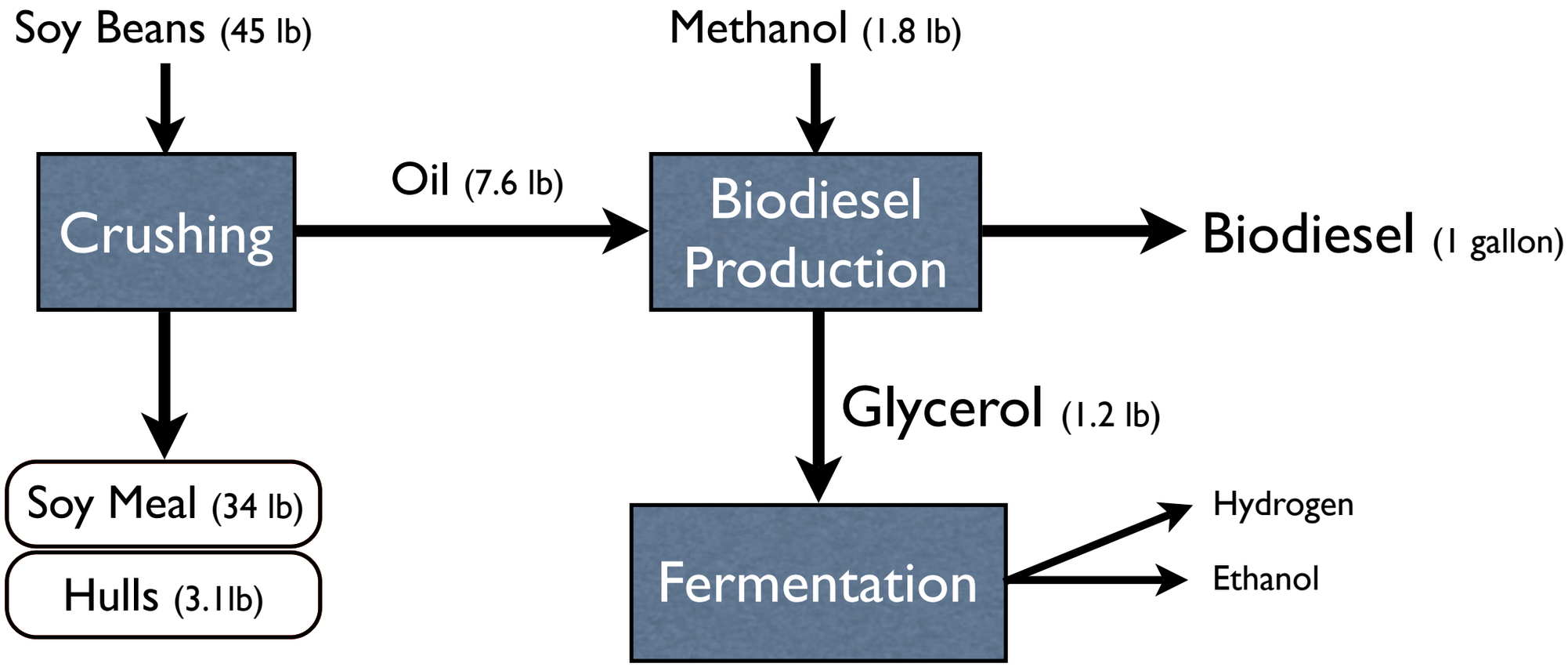

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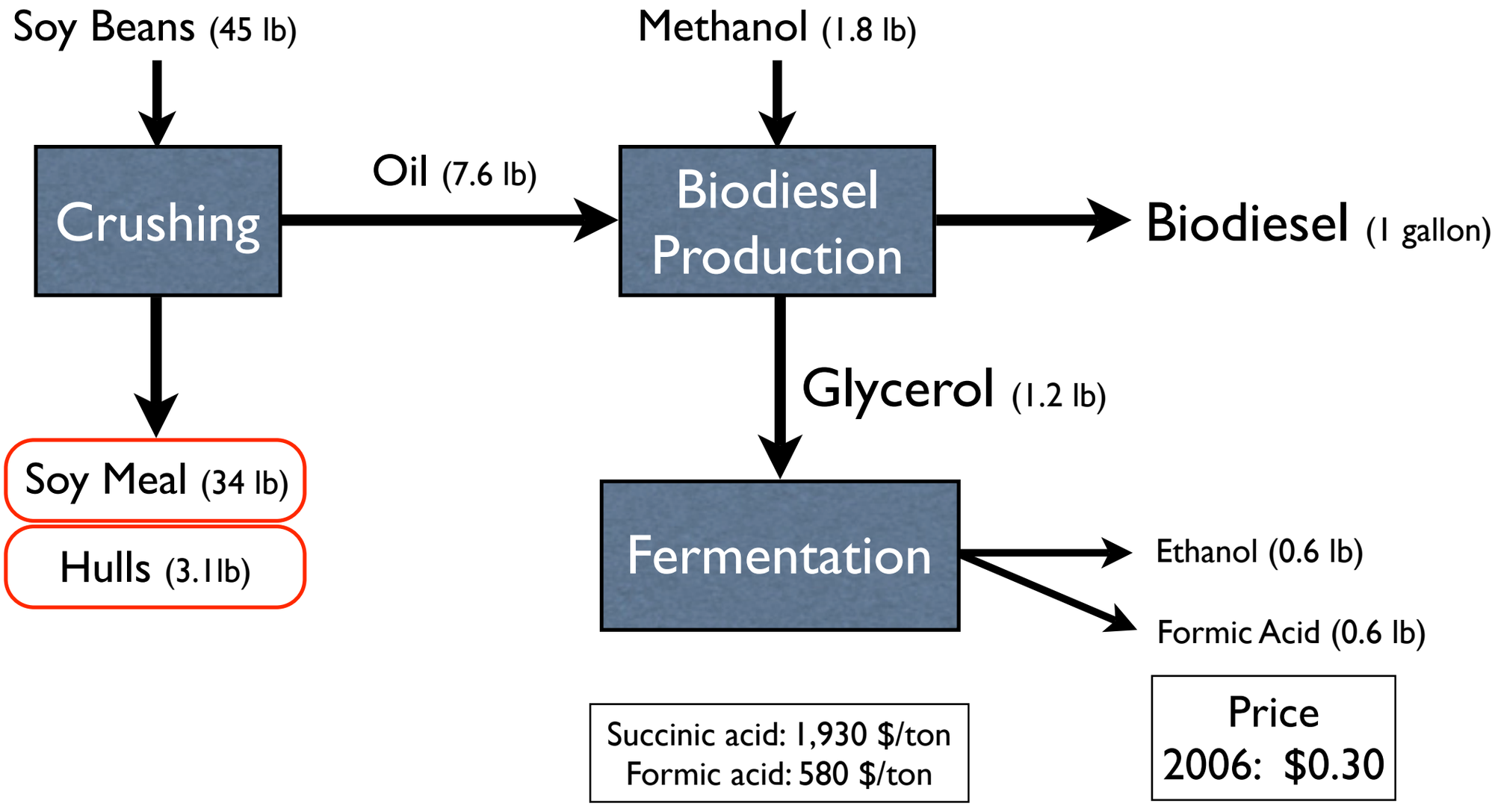


The R.I.C.E. Concept:
Rice Husks to Fertilizers

Rice

Paddies

Rice

Husks

Fast Pyrolysis Reactor

Bio-Oil

Fertilizers

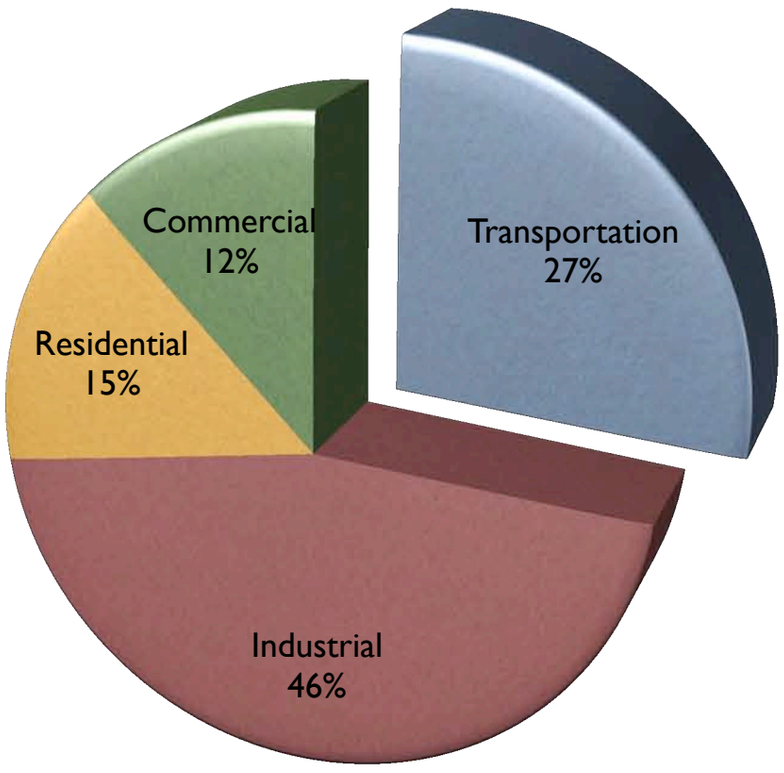
Hydrogen

Reformer

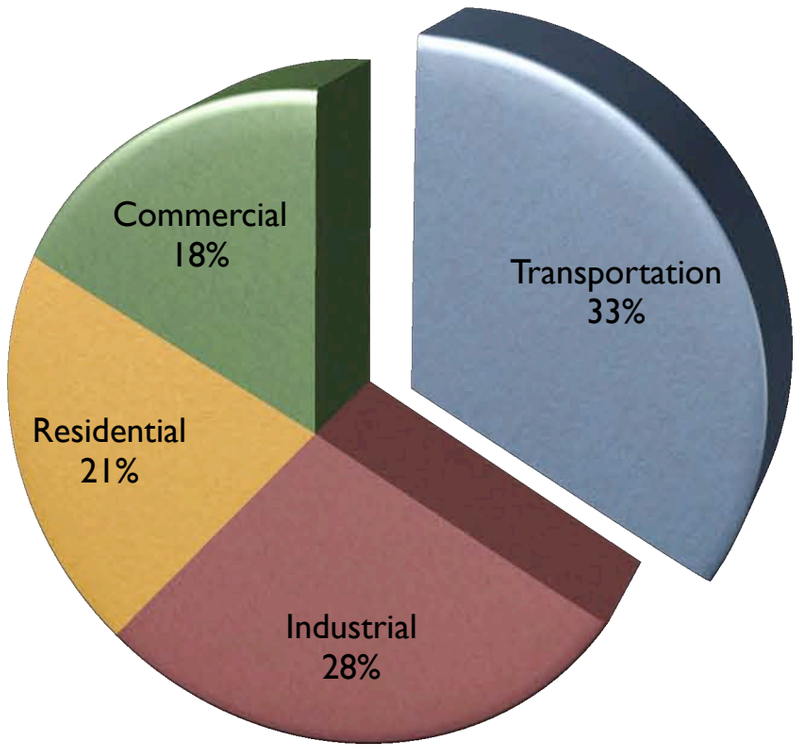
Ammonia Production

Back

CO_2 Emissions by Sector



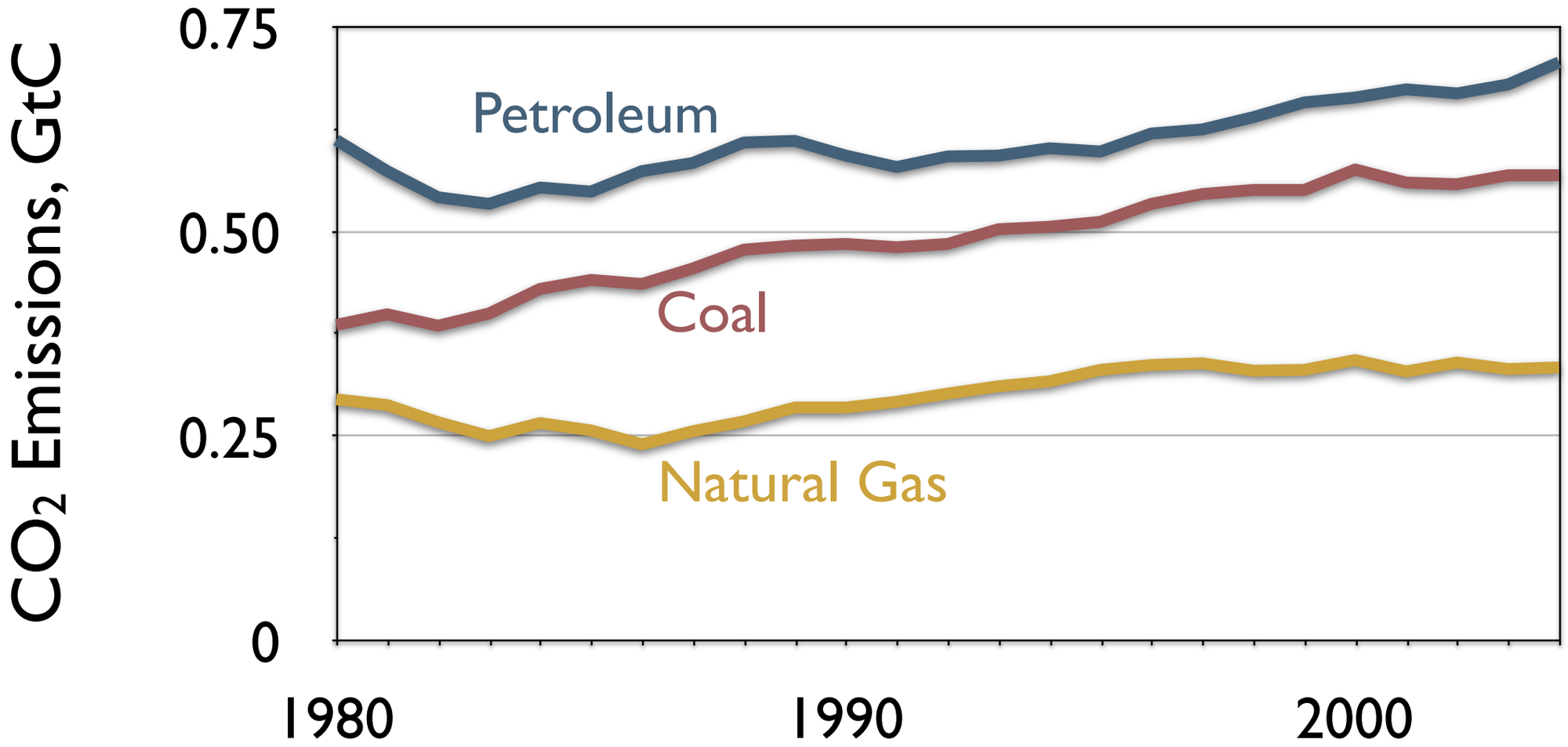
1950 CO_2 Emissions



2004 CO_2 Emissions

Source: DOE / EIA, December 2005

CO_2 Emissions by Fuel Type



Source: DOE / EIA, December 2005

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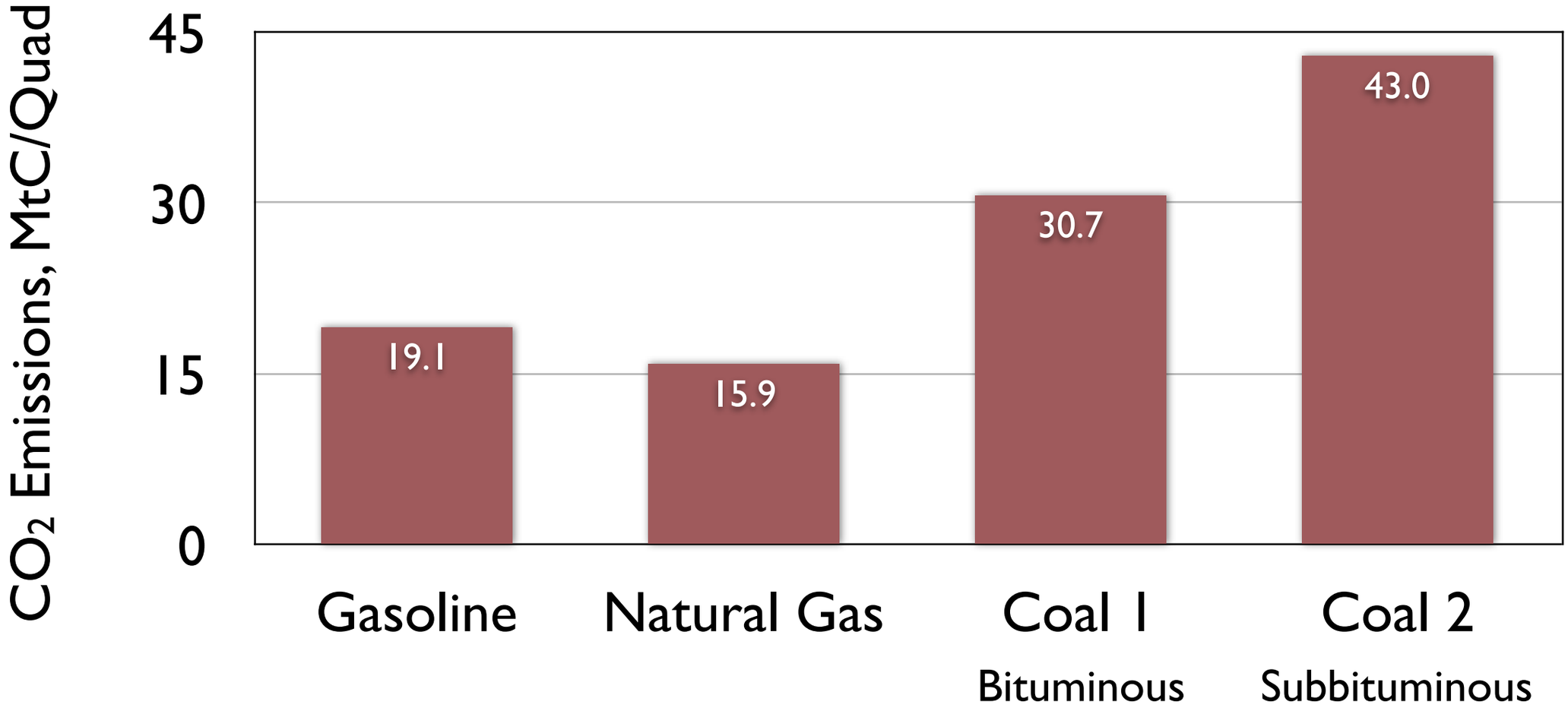
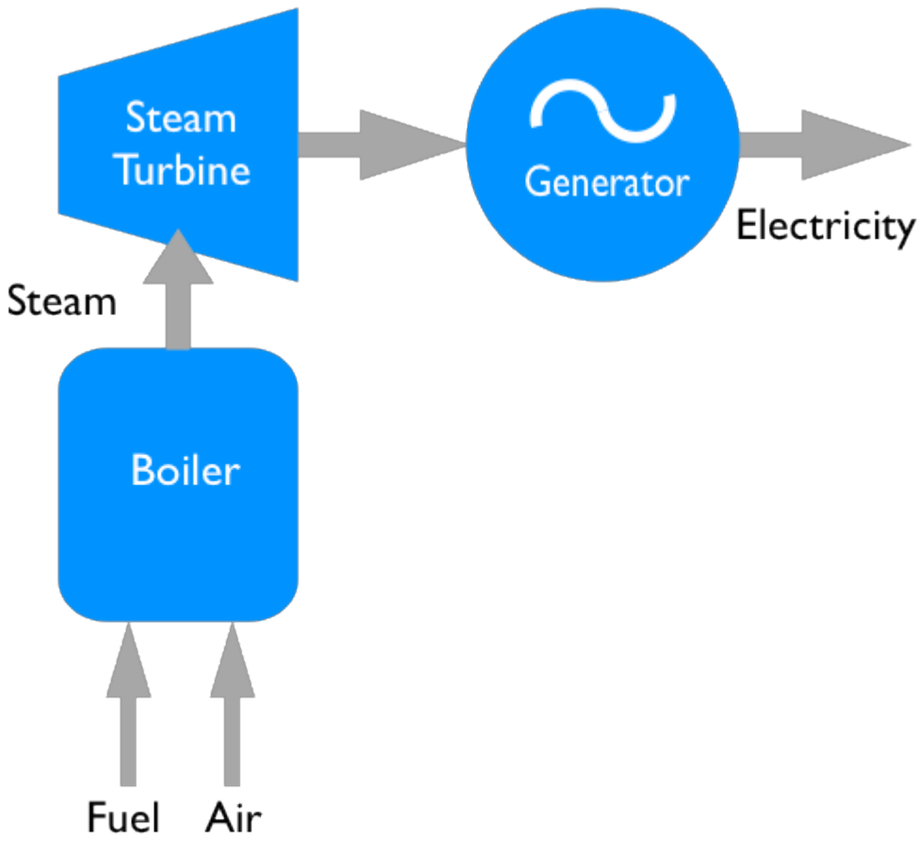
Carbon Emissions for 1 Quad of Energy

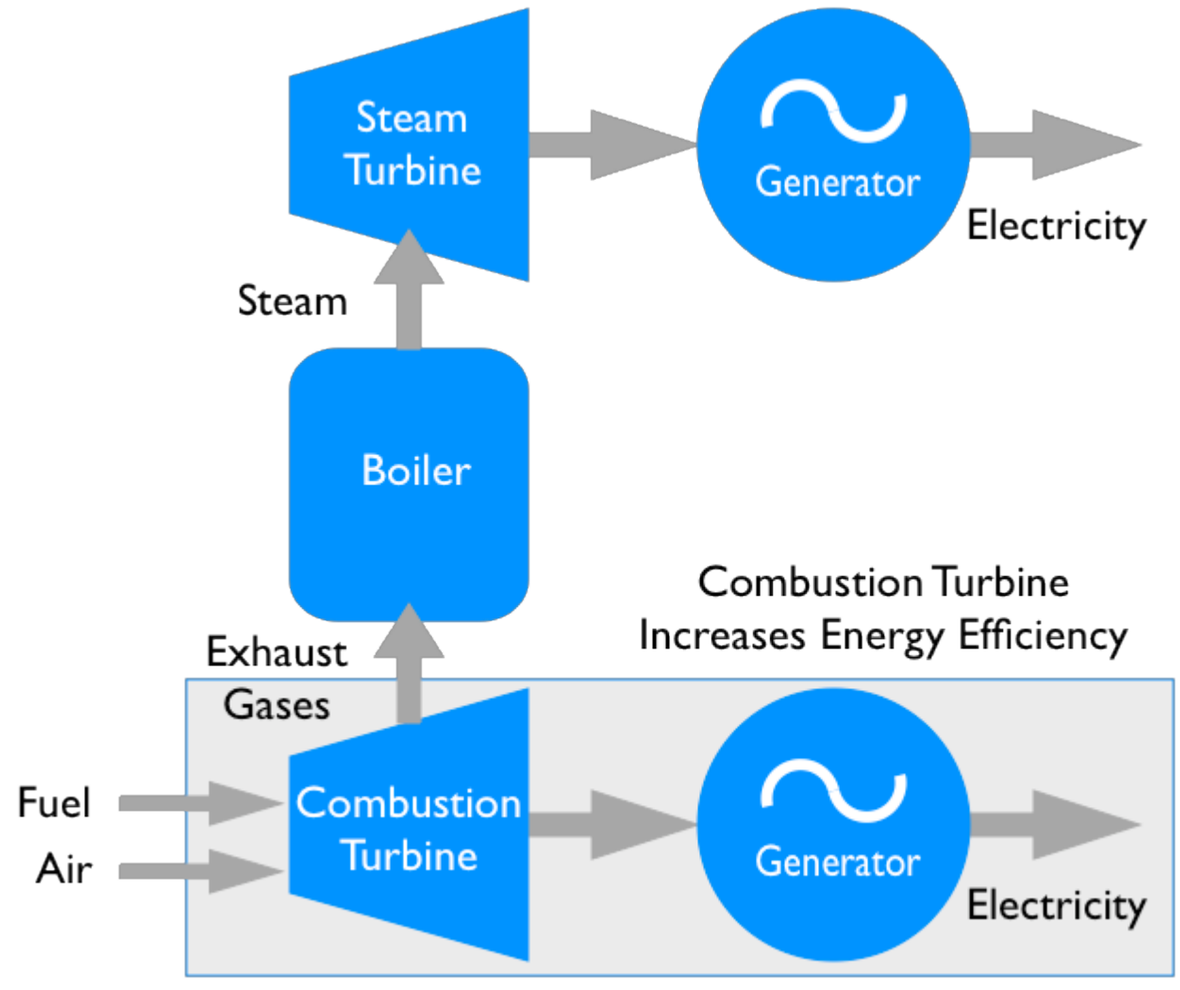


Power Plant Technology

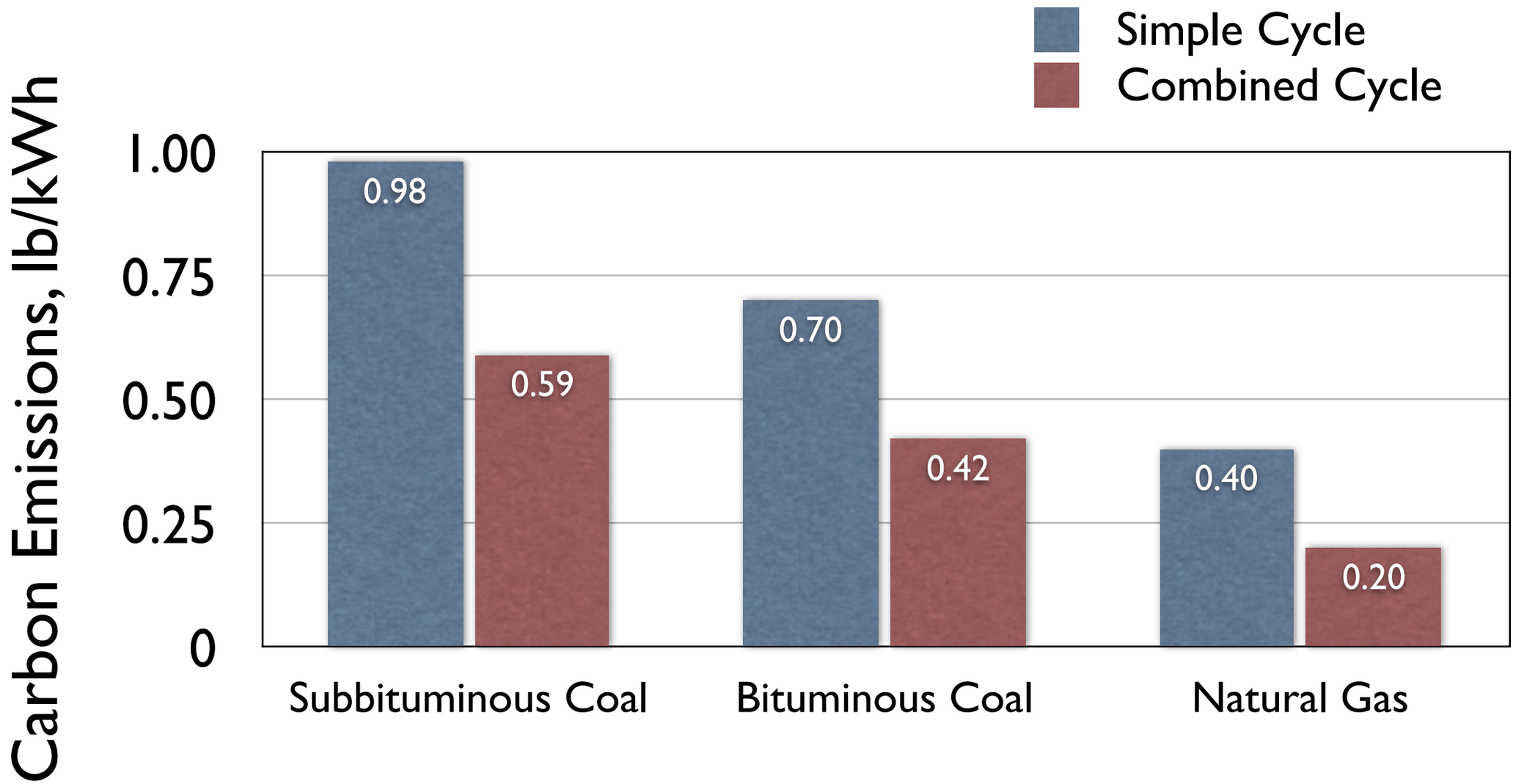
Simple Cycle
33% Efficiency



Advanced Combined Cycle
58% Efficiency



Power Plant Carbon Emissions



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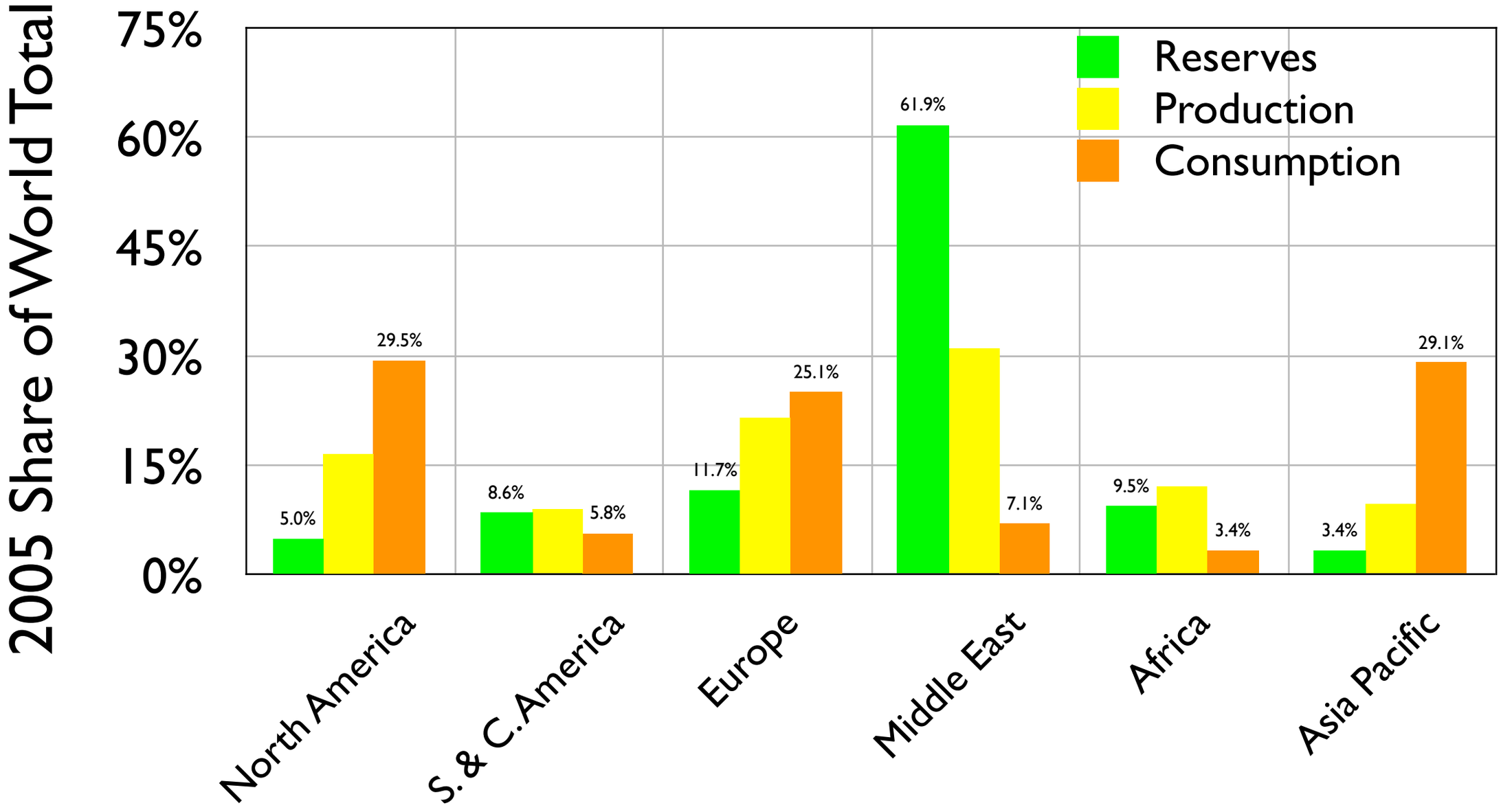
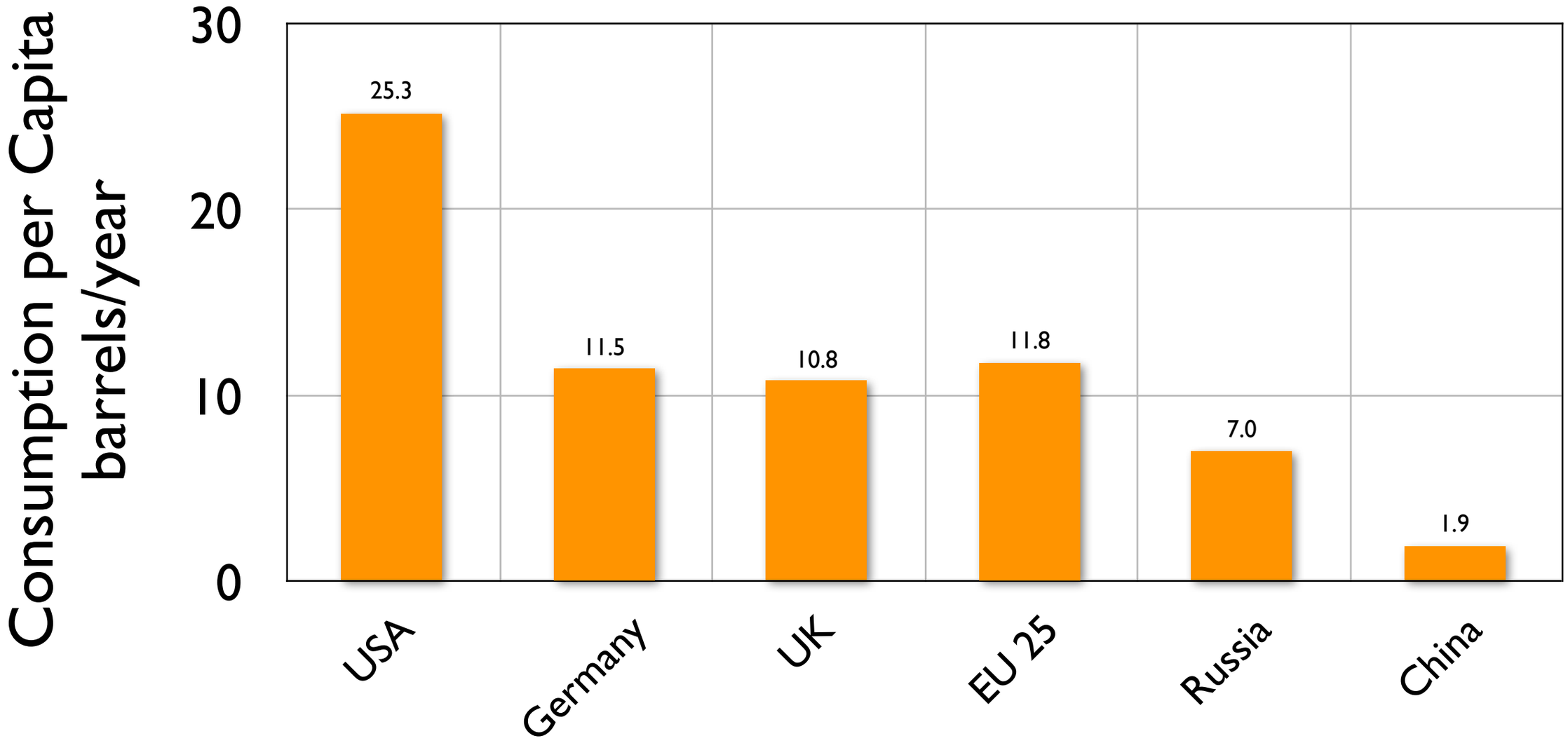
Oil Consumption, Production and Reserves

Source: BP Statistical Review of World Energy 2006



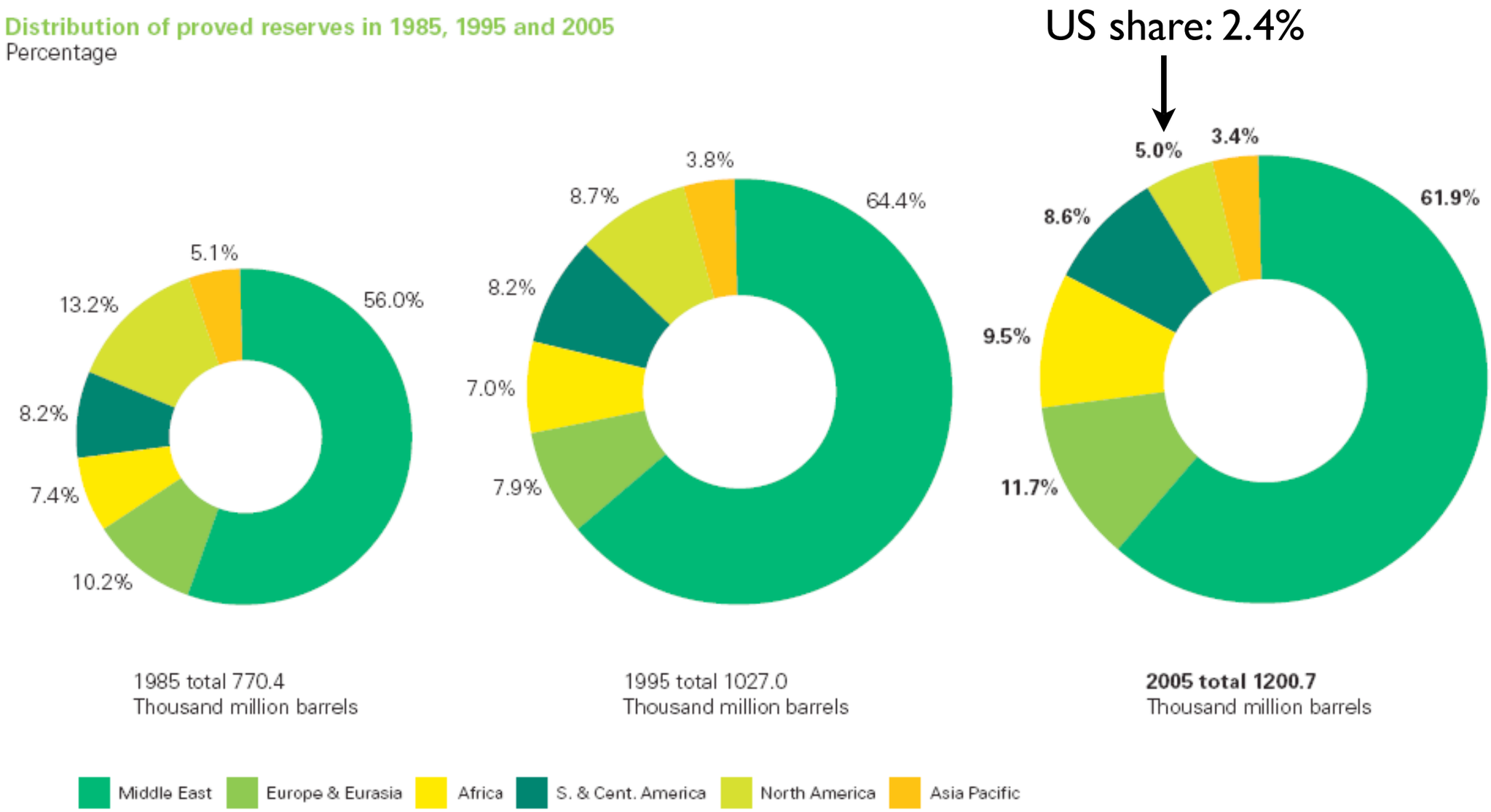
Oil Consumption per Capita

Gasoline Prices, May 2006 → $3.12 — $6.53 — $6.78



Source: BP Statistical Review of World Energy 2006

Oil Reserves



Source: BP Statistical Review of World Energy 2006

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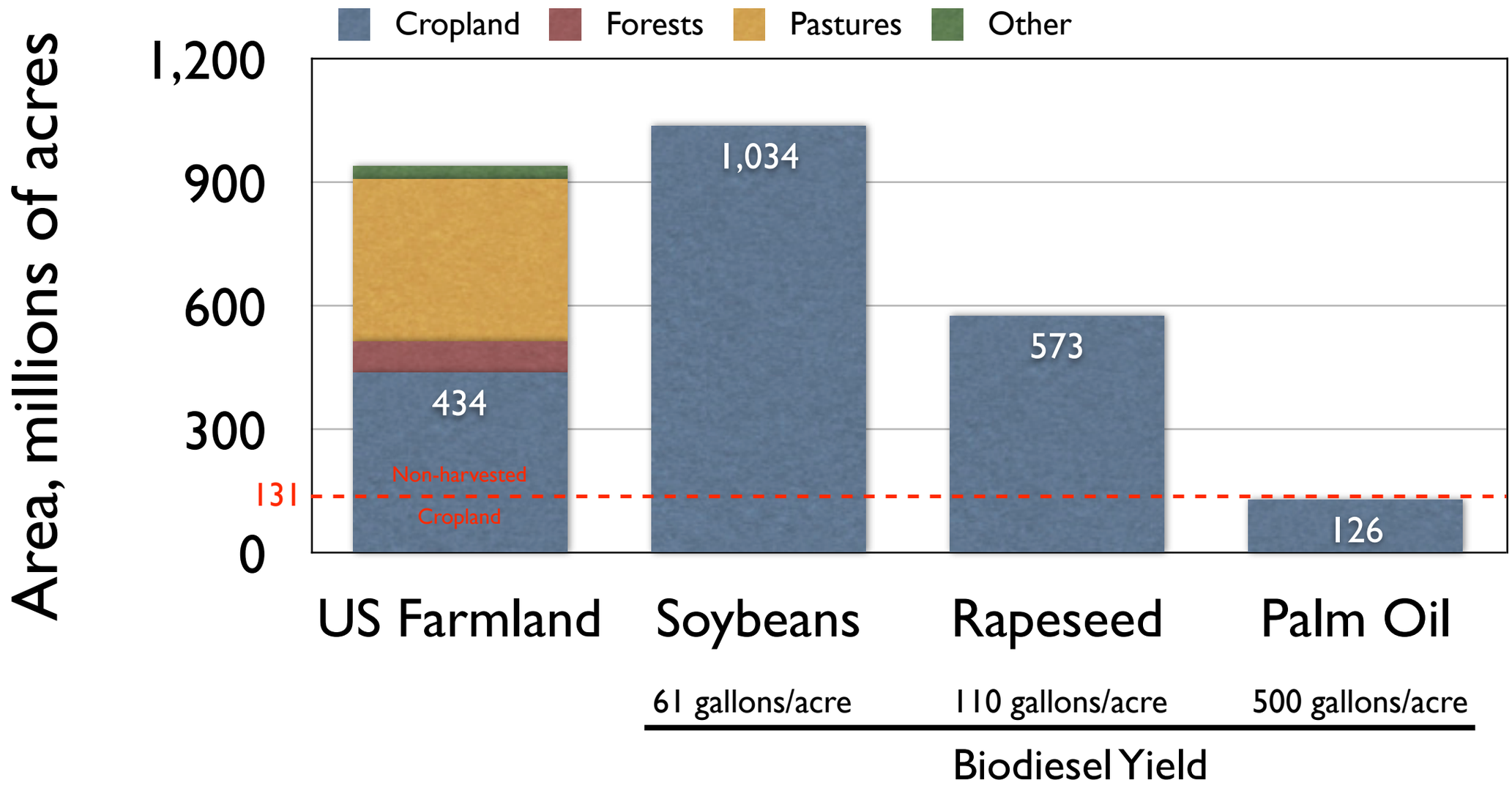
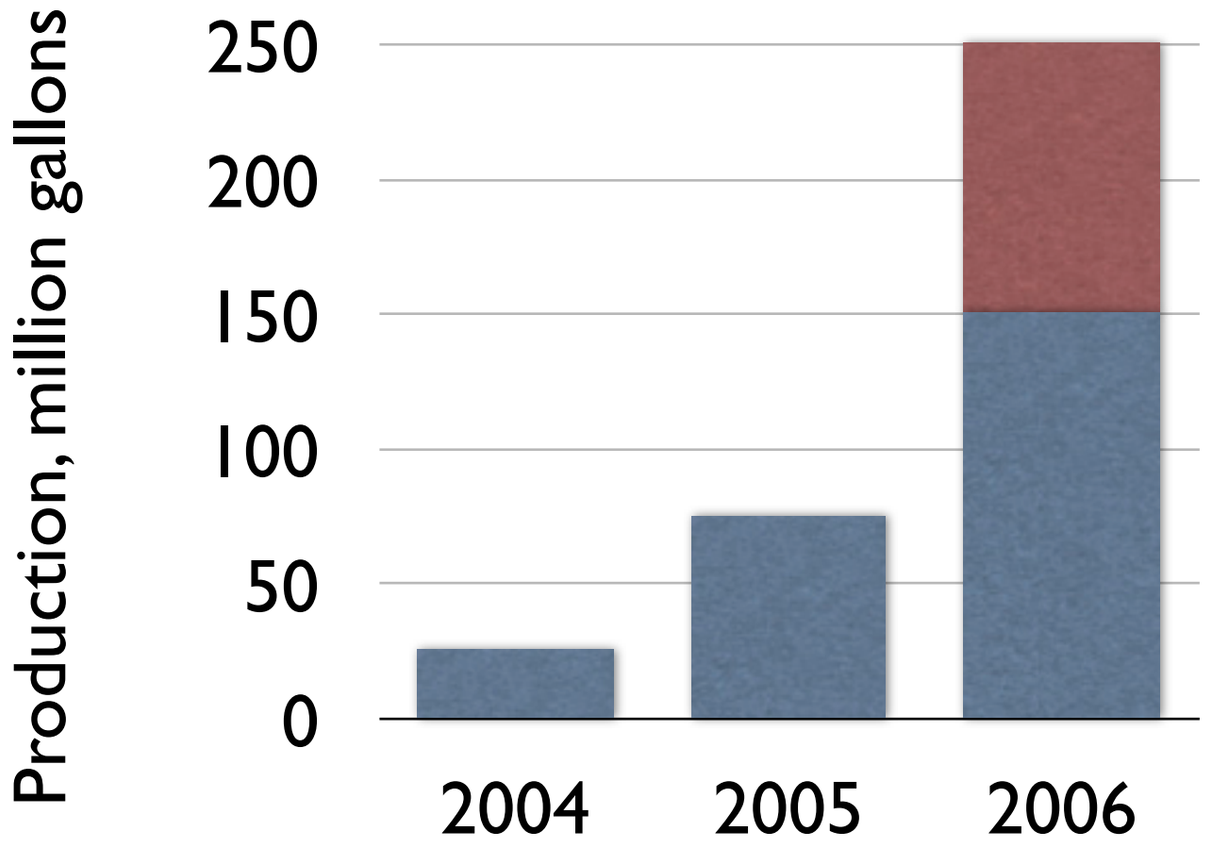
Replacing Petrodiesel with Biodiesel

Target: 63 billion gallons of diesel per year



US Biodiesel Production



Note:

2005 US consumption of diesel fuel and heating oil was 63 billion gallons

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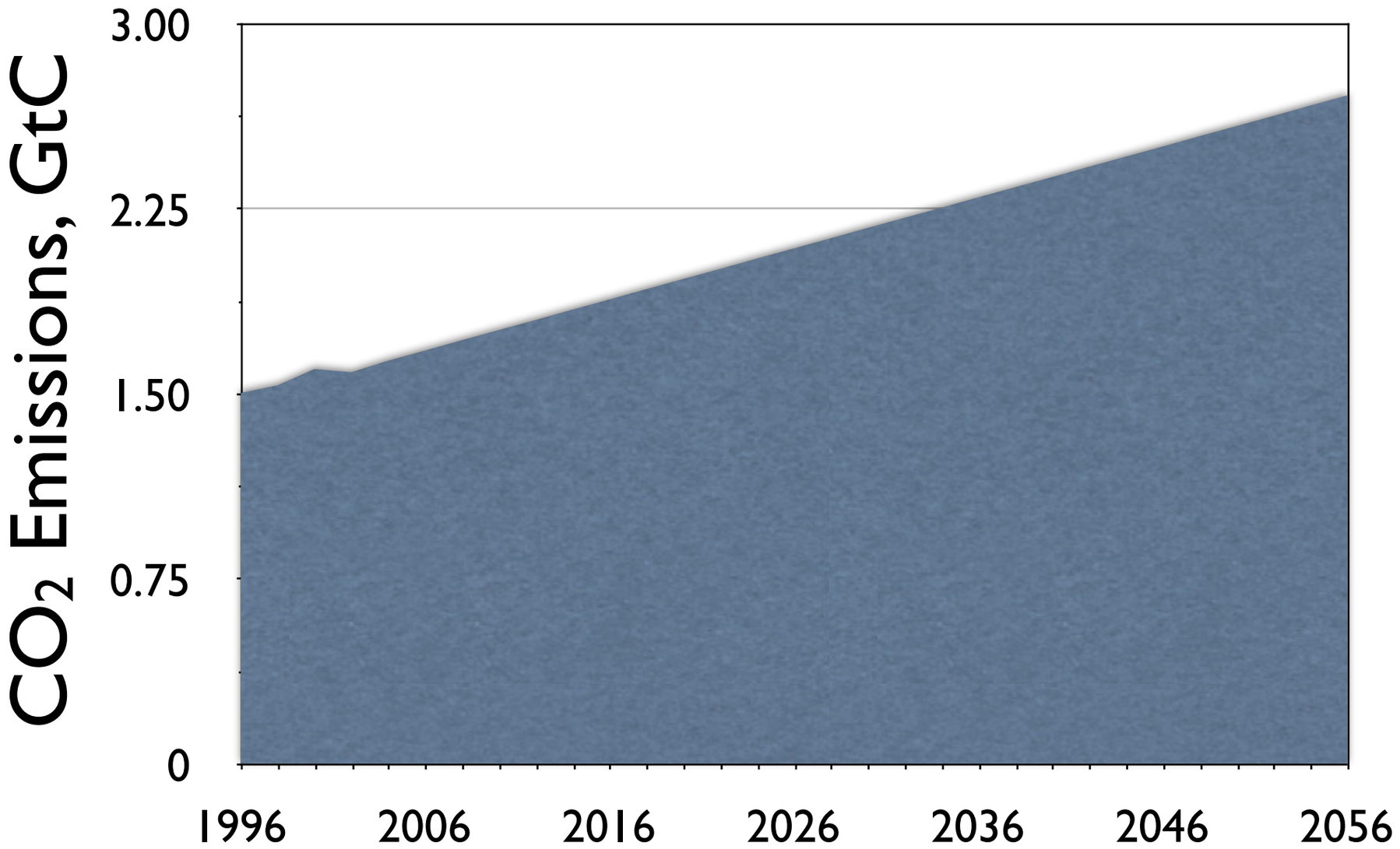
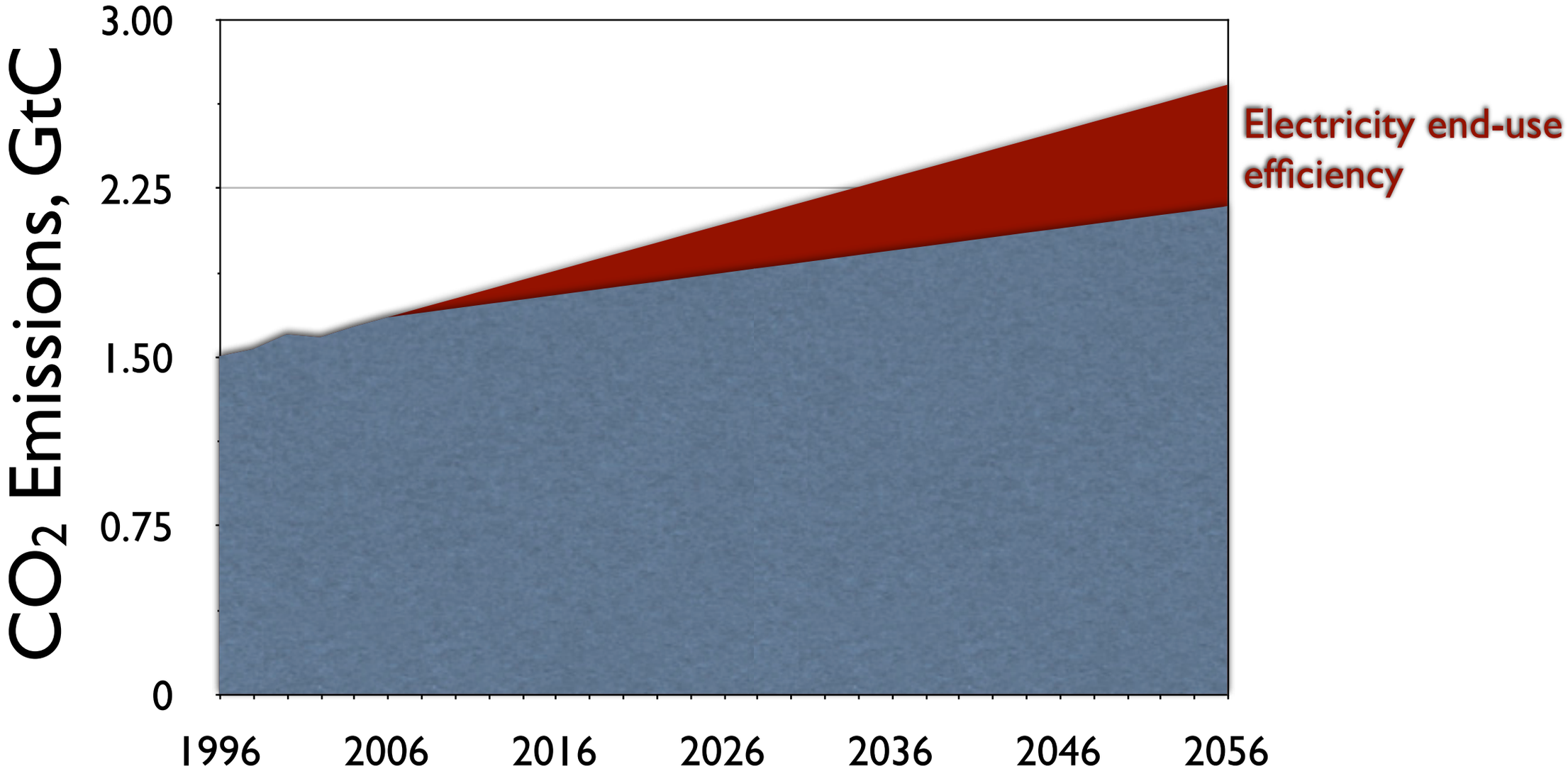
Can We Stabilize CO_2?

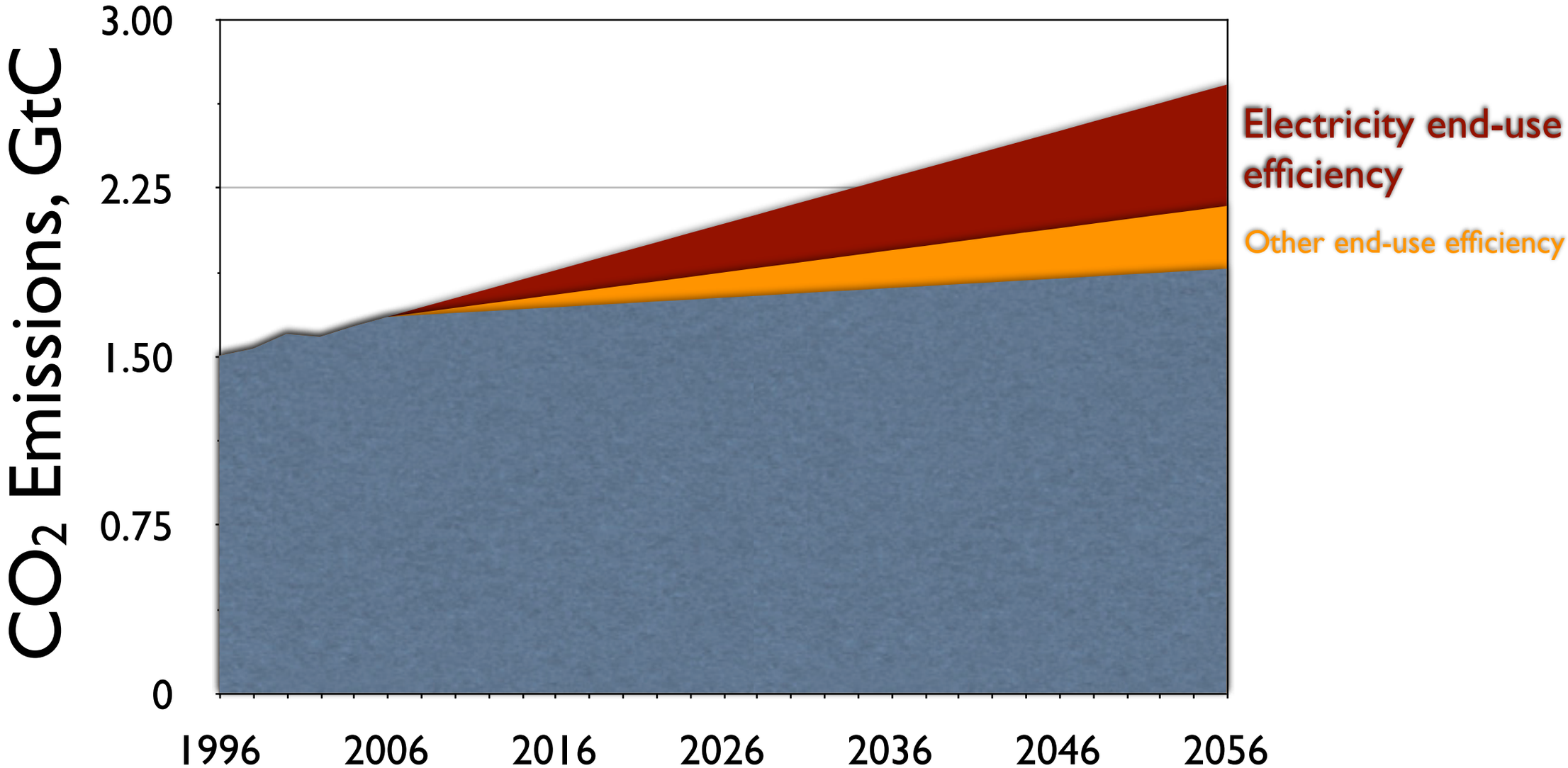


A broad portfolio of technologies must be developed to achieve CO_2 stabilization at or below 450 ppm.

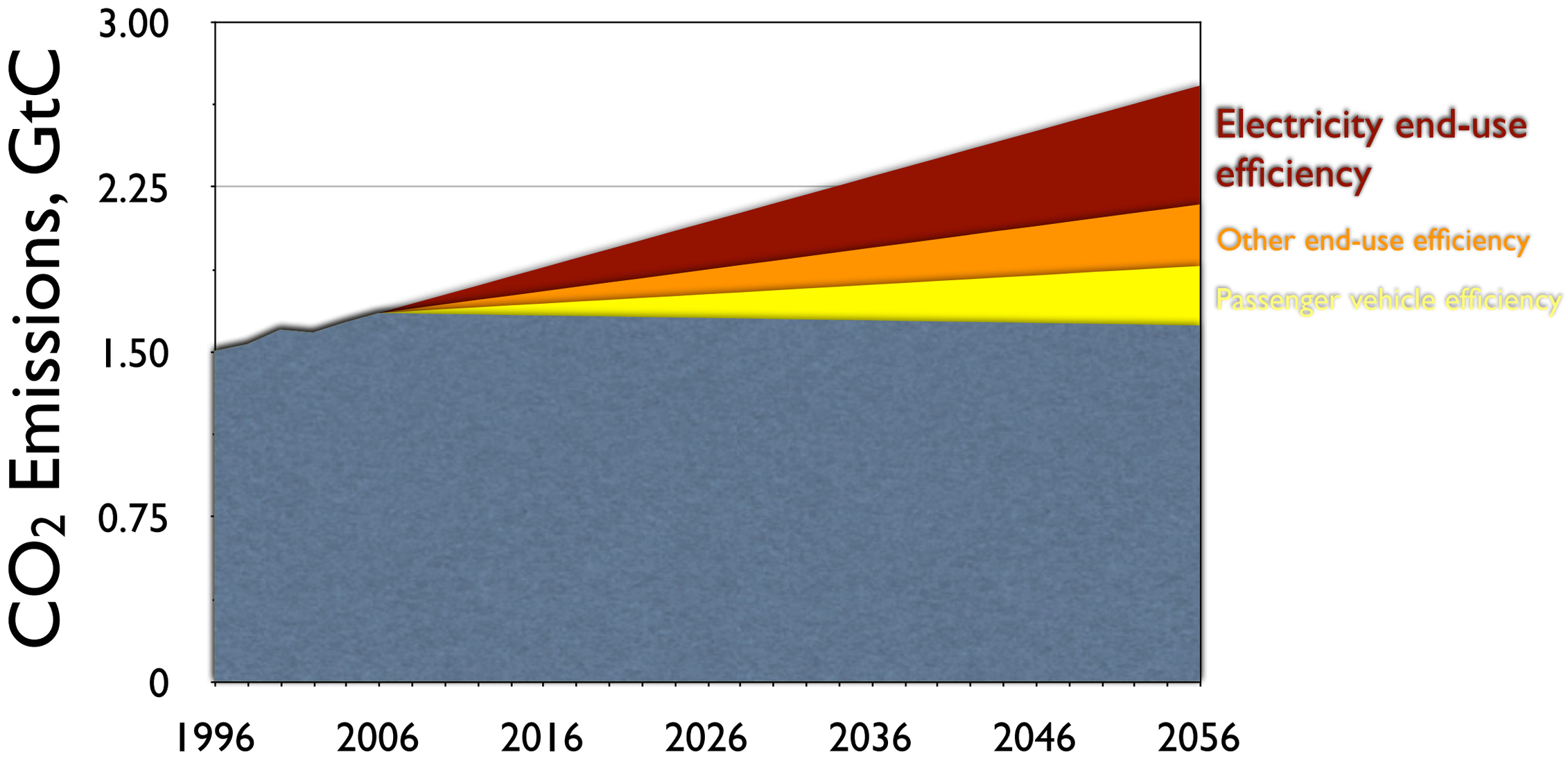
CO_2 Stabilization Wedges



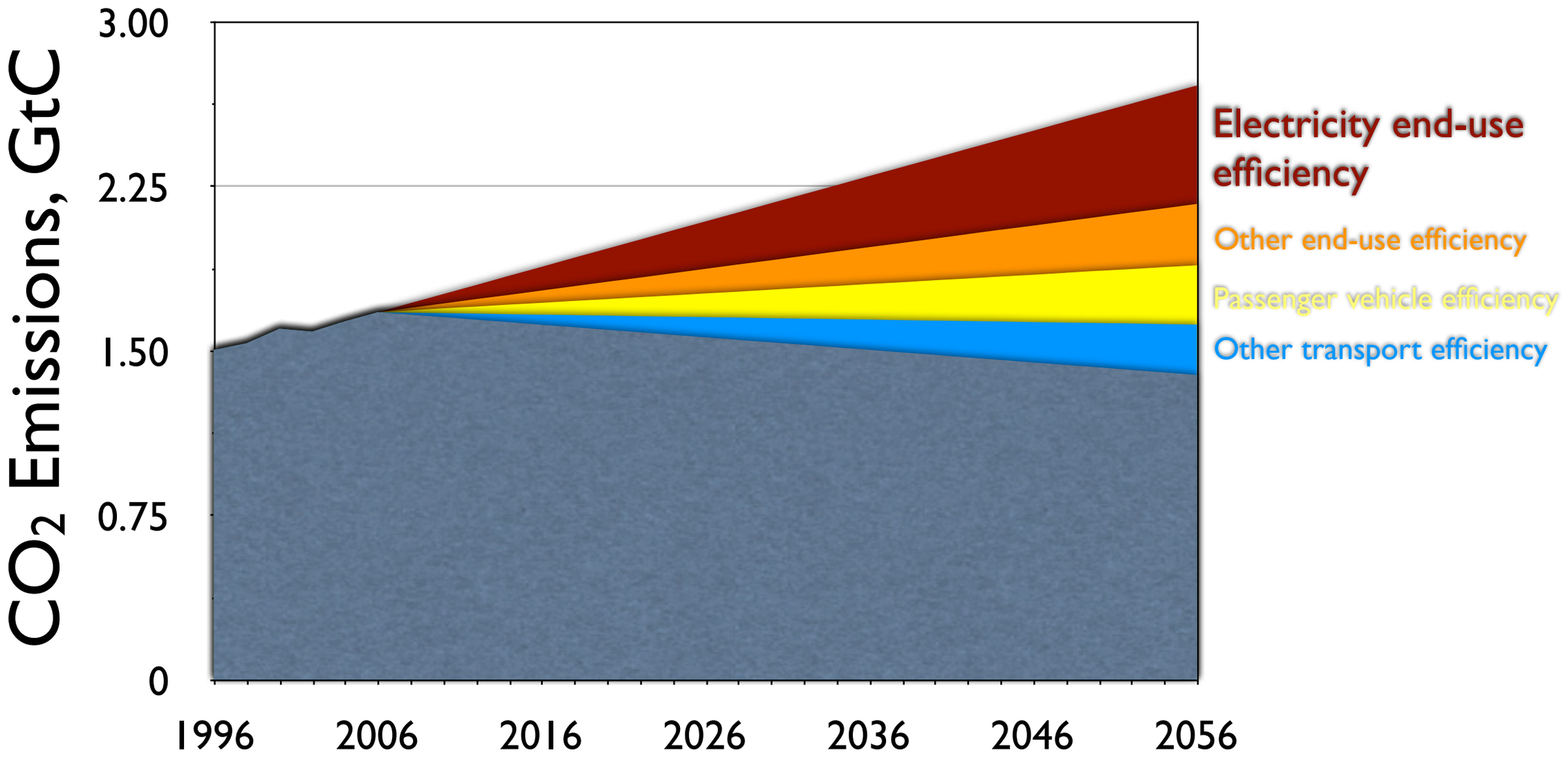
CO_2 Stabilization Wedges



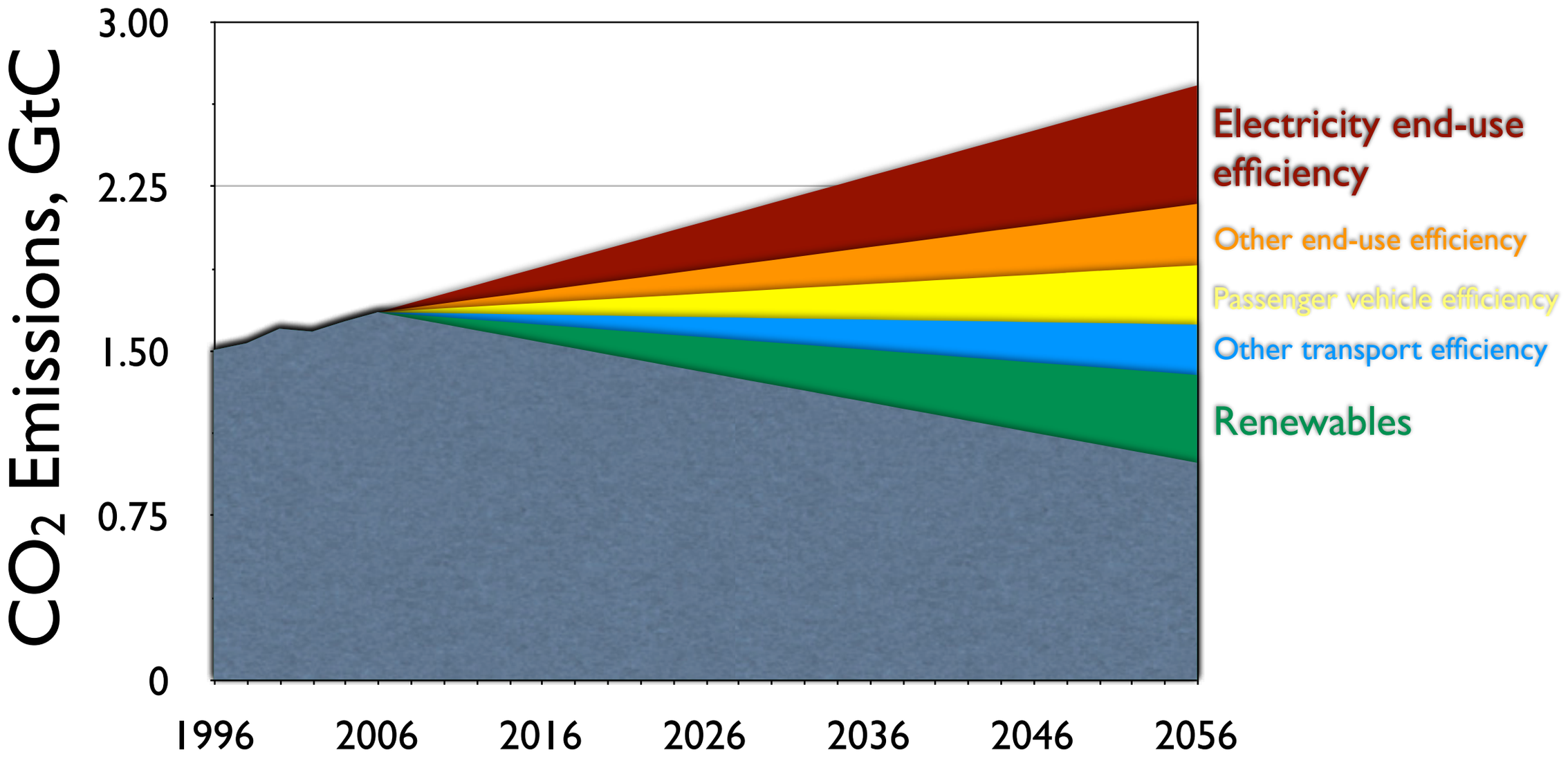
CO_2 Stabilization Wedges



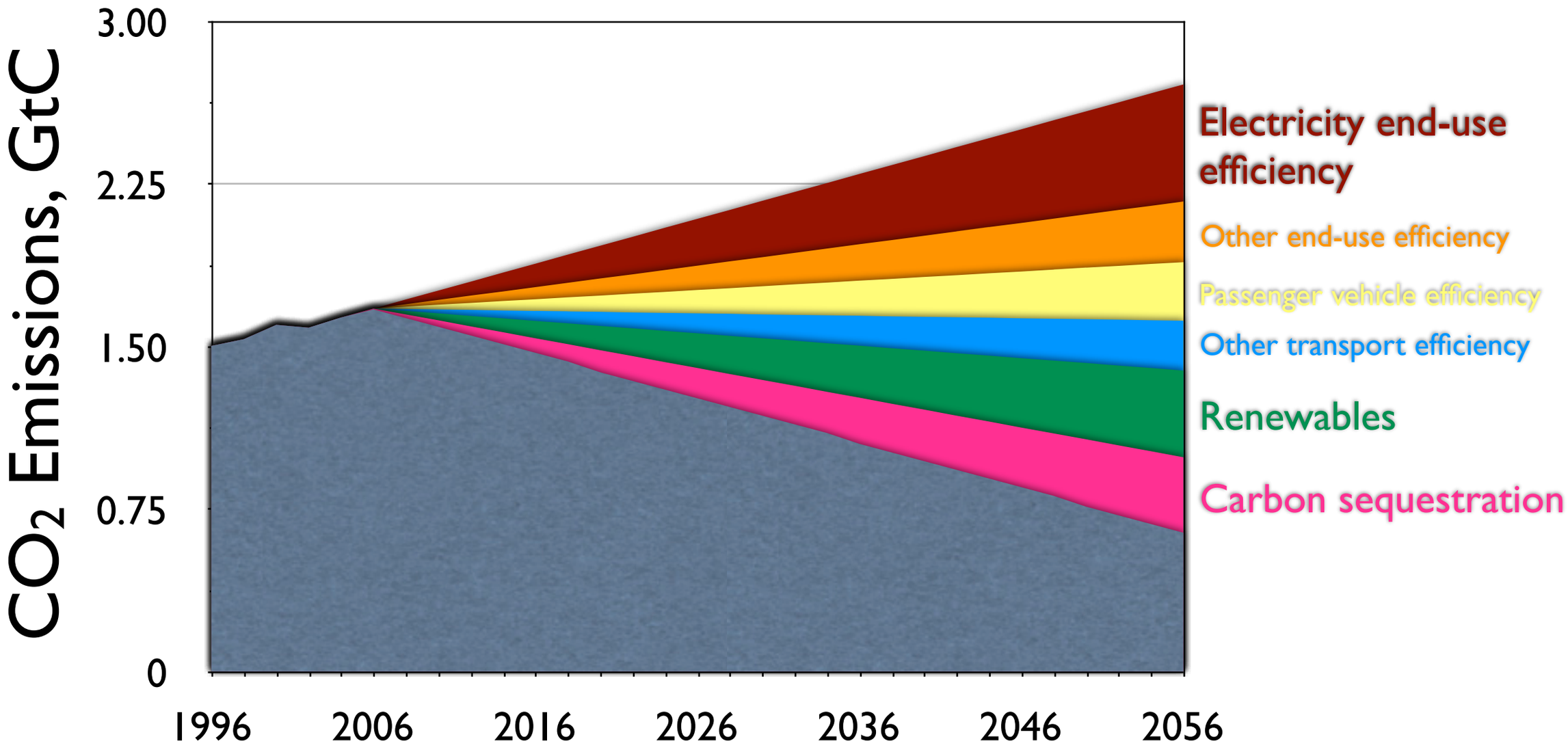
CO_2 Stabilization Wedges



CO_2 Stabilization Wedges



CO_2 Stabilization Wedges



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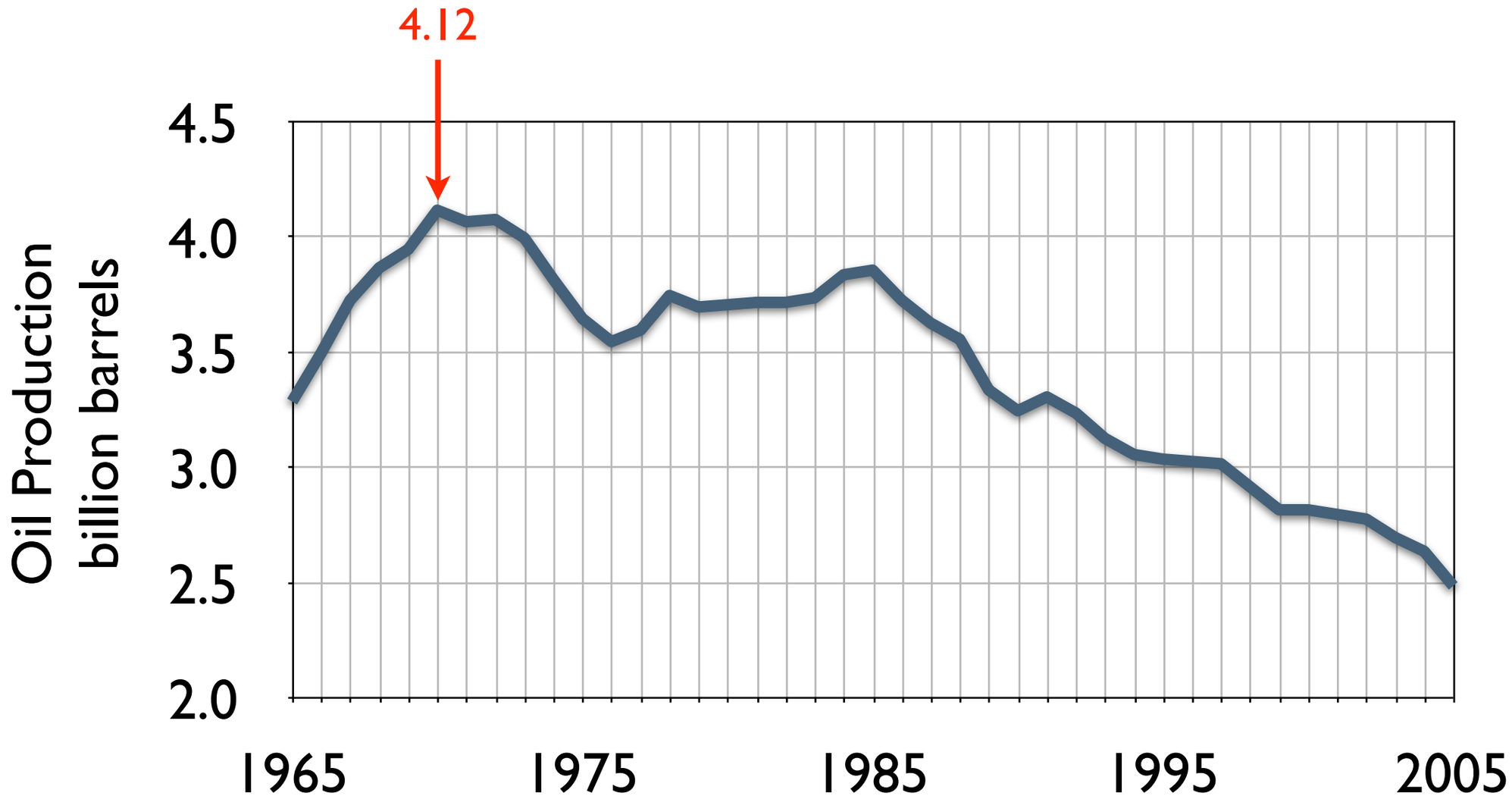
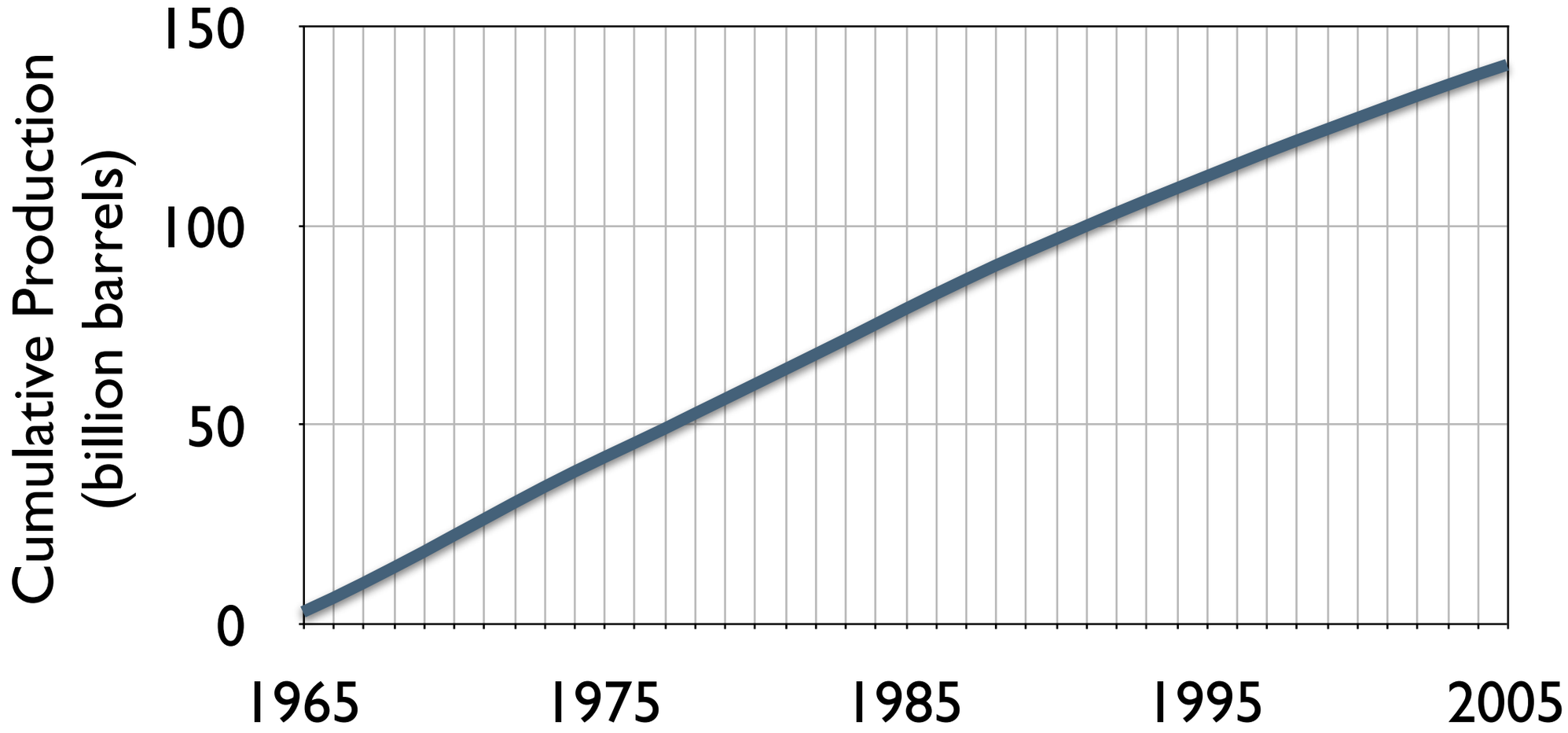
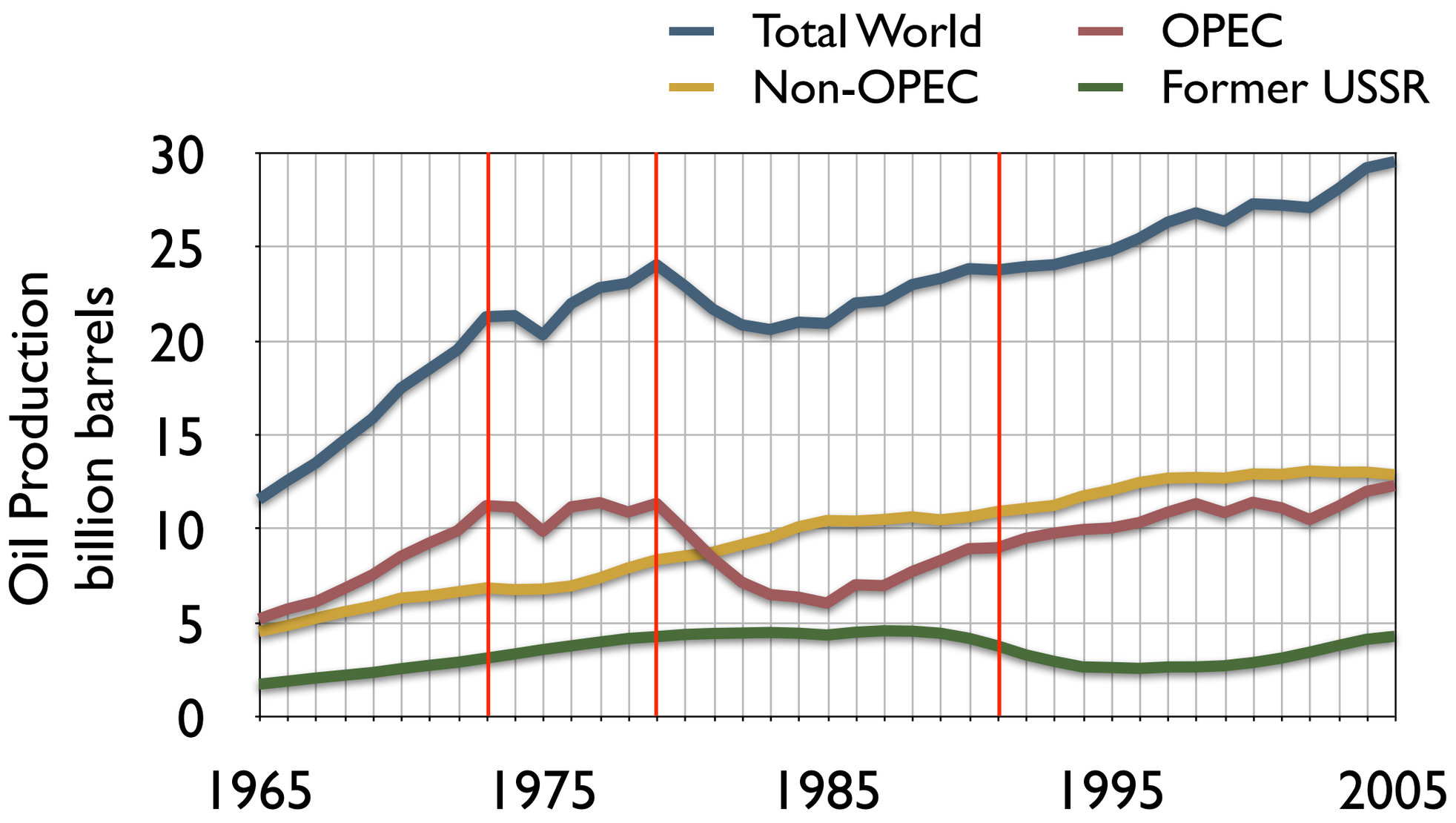
US Domestic Oil Production



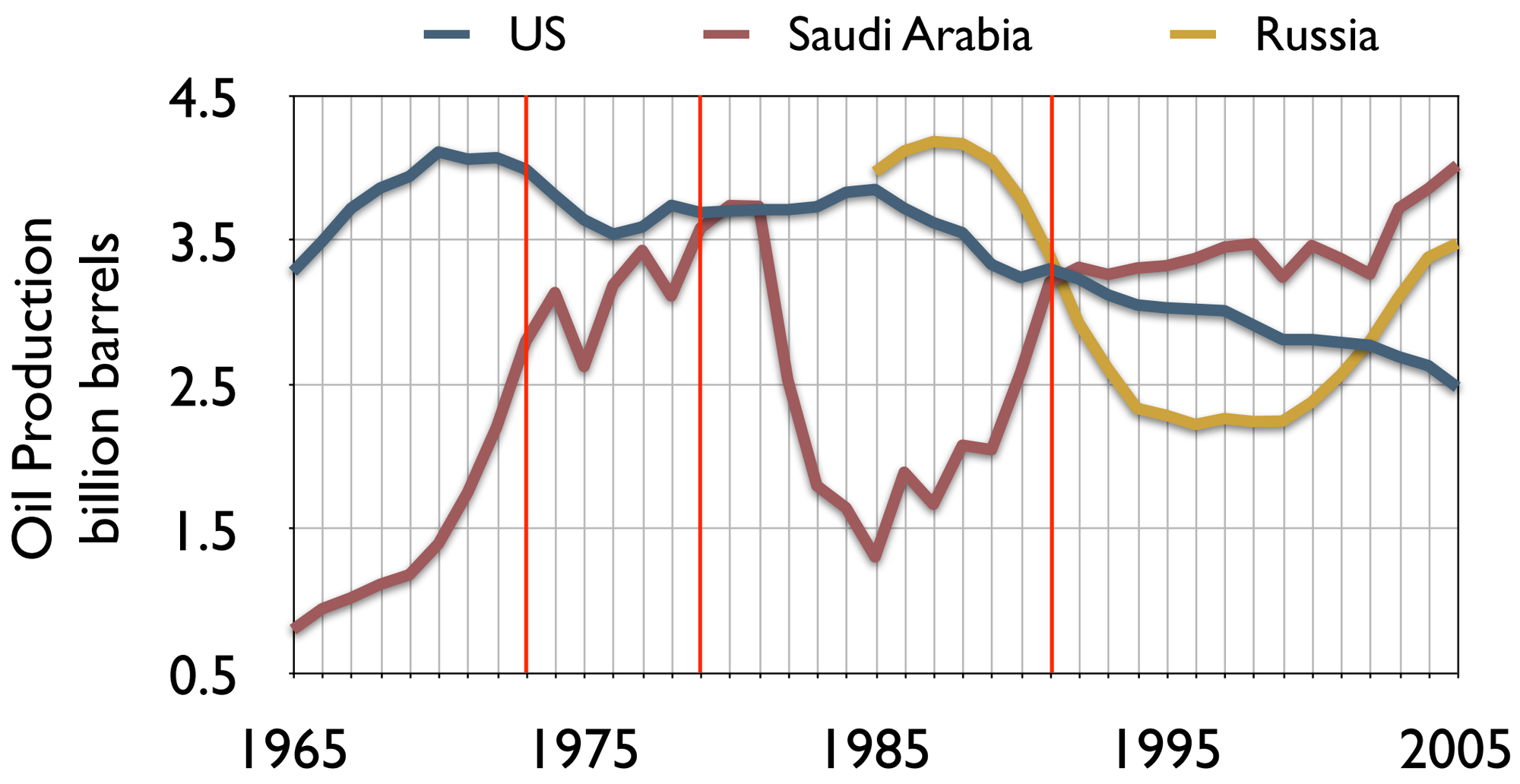
US Domestic Oil Production



World Oil Production



2005 Top Oil Producers



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Flex Fuel Vehicles

Starting in 2006, GM will produce more than 400,000 flexible fuel vehicles annually -- vehicles that can also operate on gasoline or E85 ethanol without any modifications or special switches.

Click a year to view the vehicles:

2007
Chevy Avalanche (LC9 or LMG 5.3L V8 engines)
Chevy Impala (3.5L V6 LZE engine)
Chevy Monte Carlo (3.5L V6 LZE engine)
Chevy Silverado (LC9 or LMG 5.3L V8 engines)
Chevy Suburban (LC9 or LMG 5.3L V8 engines)
Chevy Tahoe (LC9 or LMG 5.3L V8 engines)
GMC Sierra (LC9 or LMG 5.3L V8 engines)
GMC Yukon (LC9 or LMG 5.3L V8 engines)
GMC Yukon XL (LC9 or LMG 5.3L V8 engines)

2006
Chevy Avalanche (L59 5.3L V8 engine)
Chevy Impala (LZE 3.5L V6 engine)
Chevy Monte Carlo (LZE 3.5L V6 engine)
Chevy Silverado (L59 5.3L V8 engine)
Chevy Suburban (L59 5.3L V8 engine)
Chevy Tahoe (L59 5.3L V8 engine)
GMC Sierra (L59 5.3L V8 engine)
GMC Yukon (L59 5.3L V8 engine)
GMC Yukon XL (L59 5.3L V8 engine)

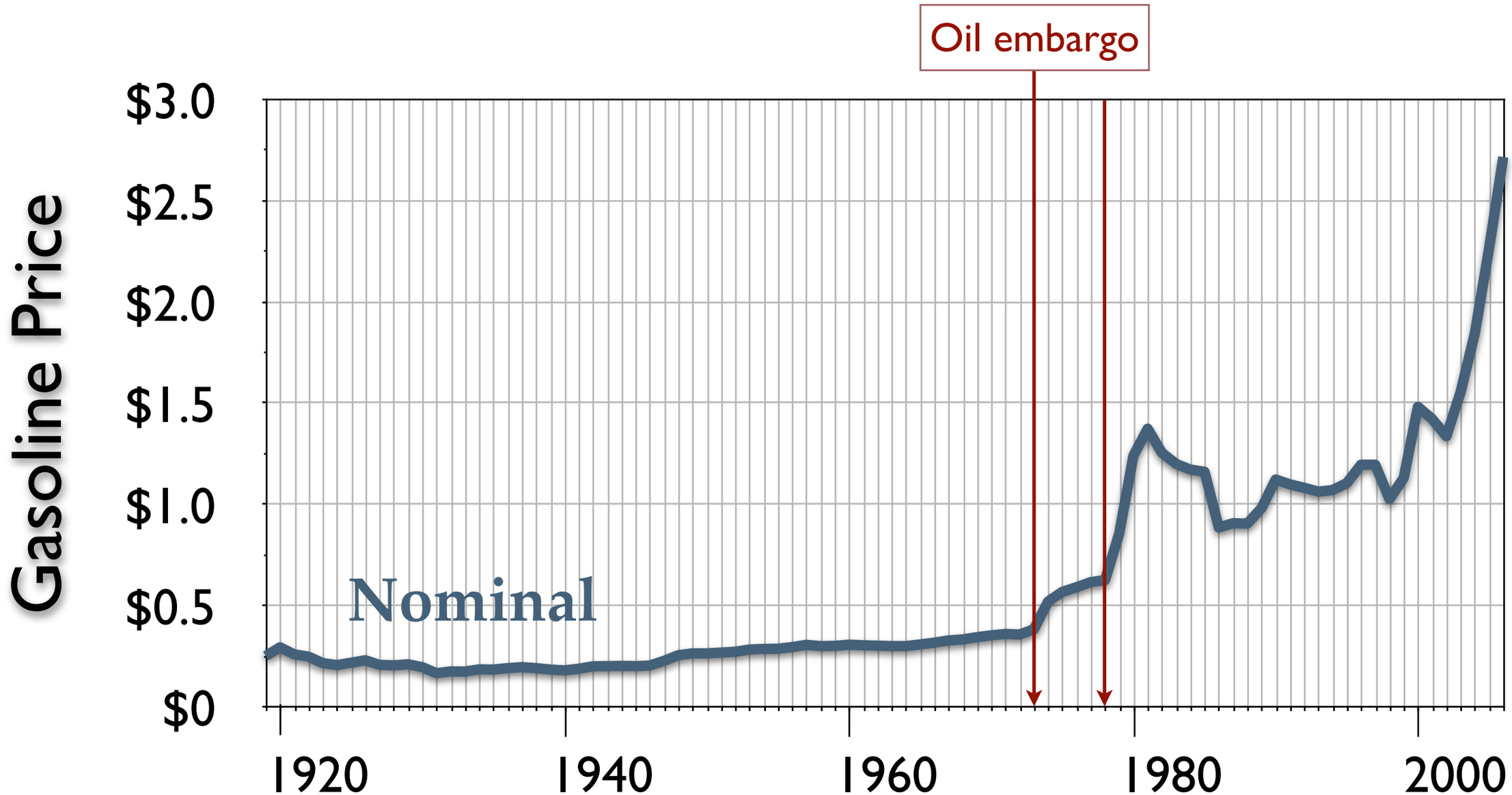
Also

- Ford Crown Victoria (4.6L V8 engine)
- Mercury Grand marquis (4.6L V8 engine)
- Lincoln Town Car (4.6L v8 engine)
- Mercedes-Benz C230 (2.5L V6 engine)

From www.fueleconomy.gov

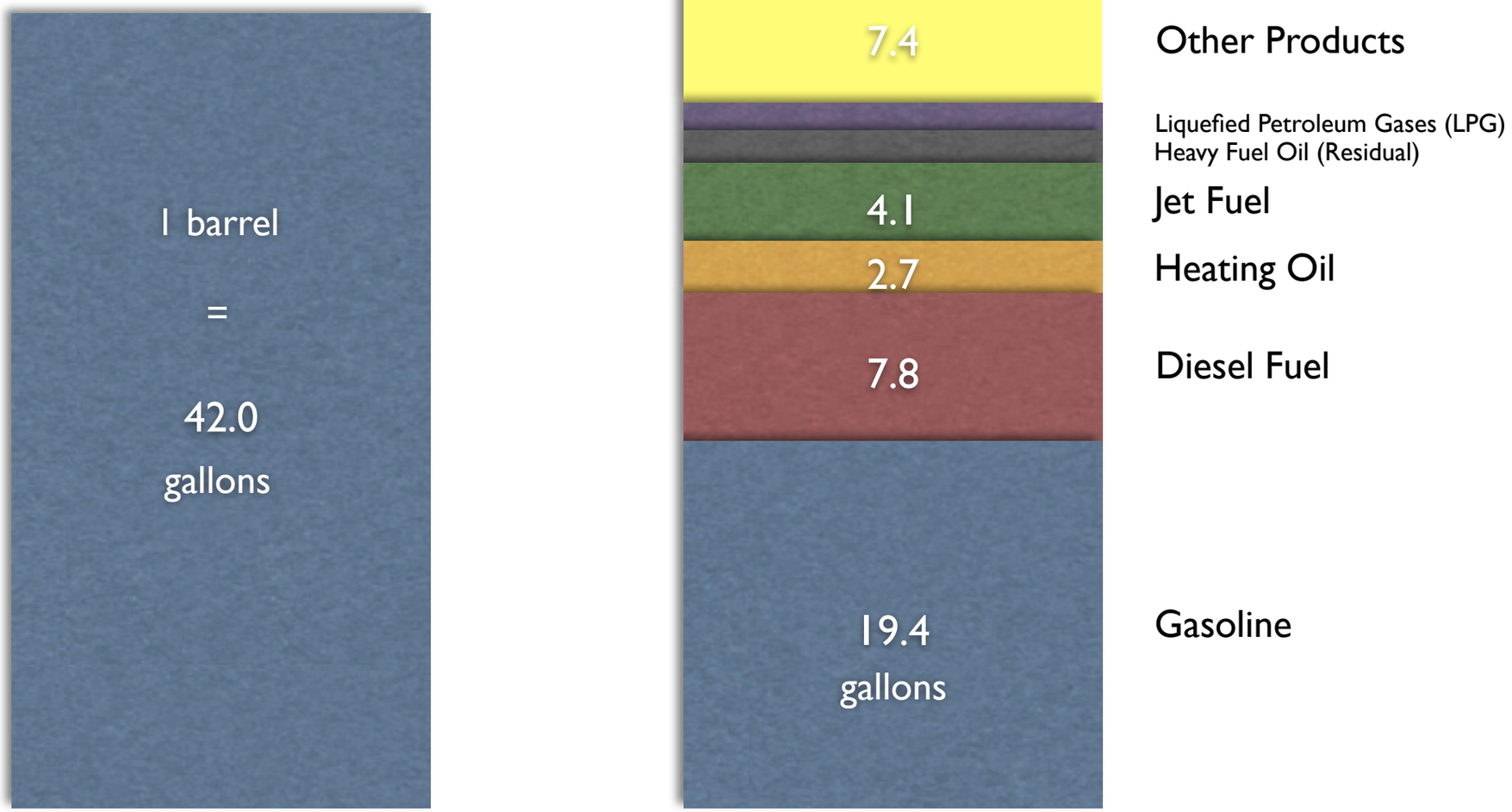
Chevrolet Tahoe 1500 2WD: Rated at 21 mpg for CAFE purposes
But, rating goes to 35 mpg with FFV credit (x $1^2/_3$)

Why Are We Addicted to Oil?

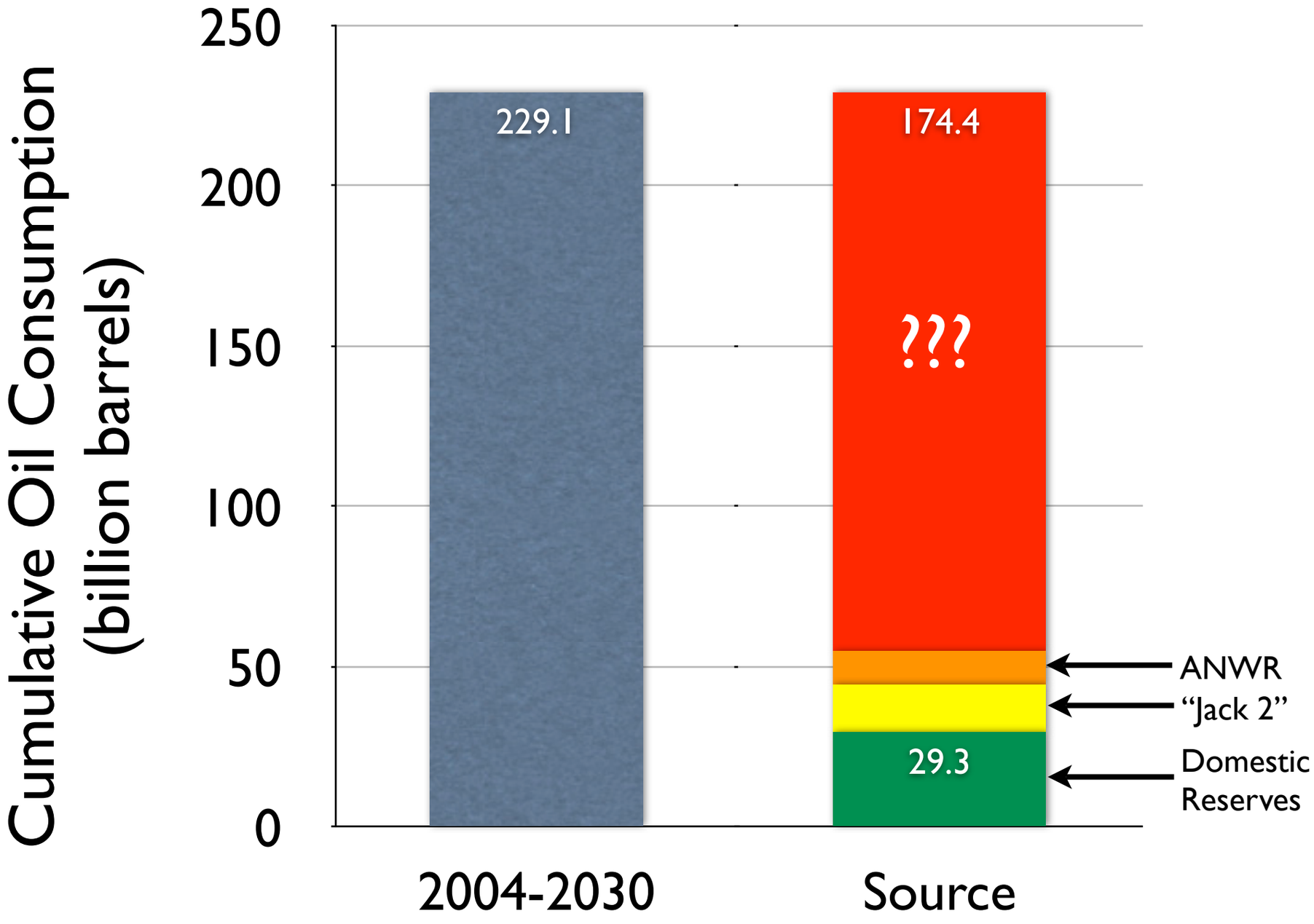


Source: Energy Information Administration (EIA), 2006

Products Made from a Barrel of Crude



Cumulative US Oil Consumption from 2004 to 2030



"I shall be content if my History is pronounced useful
by those who will want to know
exactly what happened in the past
but also
what will happen again in the future
and in very similar fashion,
because such is human nature."

Thucydides, Historia, A, 22

Energy Potential of Biomass

Region	Energy Demand (Quads)		Potential Energy Production from Biomass (Quads)
	2000	2050	
North America	90	**120**	**40**
Europe	110	130	15
Africa	15	200	55
World Total	385	1,500	285

1 Quad = 10^{15} Btu

Source: Larson (1993)