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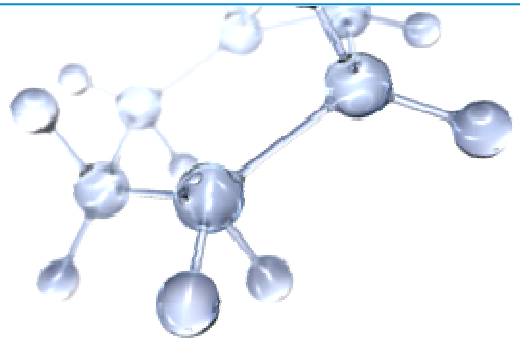
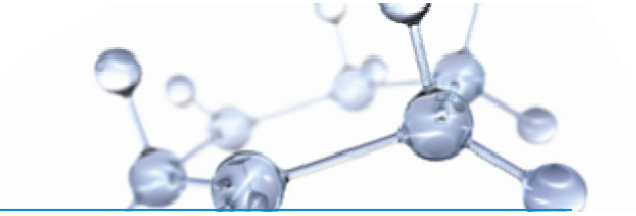
Natural Gas as a Transportation Fuel



Nazeer Bhore
Corporate Strategic Planning, Exxon Mobil Corporation
Transportation Research Board – 90th Annual Meeting
Washington DC, January 25, 2011

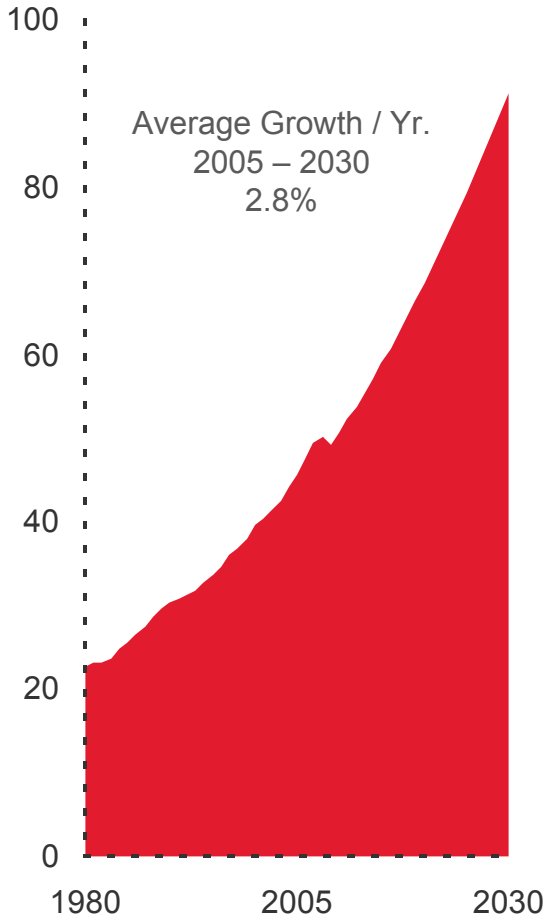
This presentation includes forward-looking statements. Actual future conditions (including economic conditions, energy demand, and energy supply) could differ materially due to changes in technology, the development of new supply sources, political events, demographic changes, and other factors discussed herein and under the heading "Factors Affecting Future Results" in the Investors section of our website at: www.exxonmobil.com. The information provided includes ExxonMobil's internal estimates and forecasts based upon internal data and analyses as well as publically-available information from external sources including the International Energy Agency. This material is not to be reproduced without the permission of Exxon Mobil Corporation.

Economics & Energy Linked



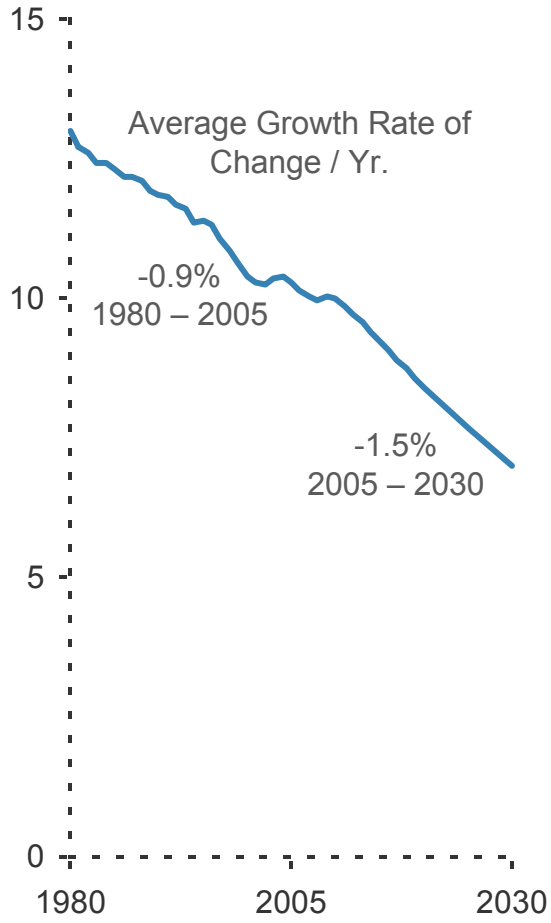
GDP

Trillions in 2005$



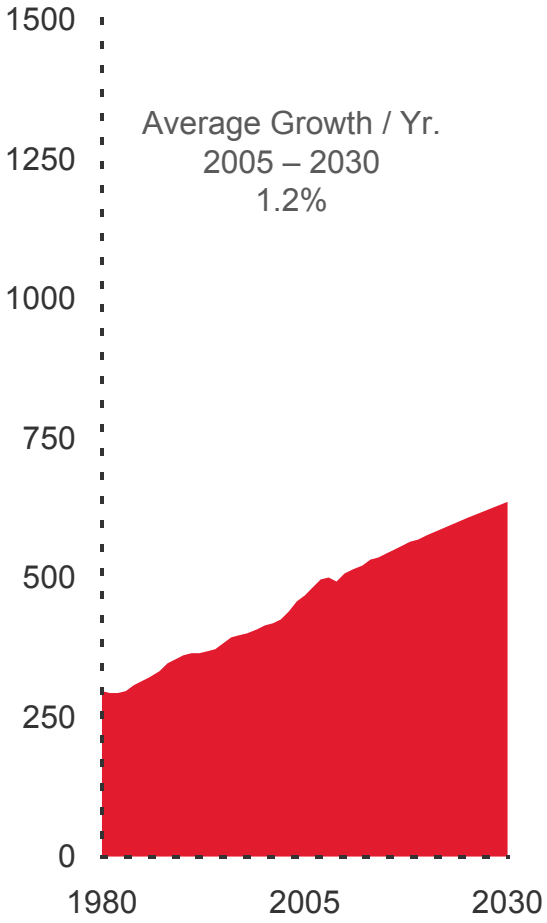
Energy per GDP

MBTU / 2005$k GDP

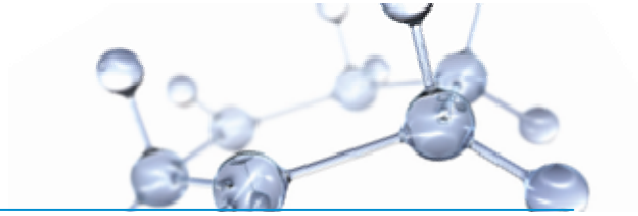


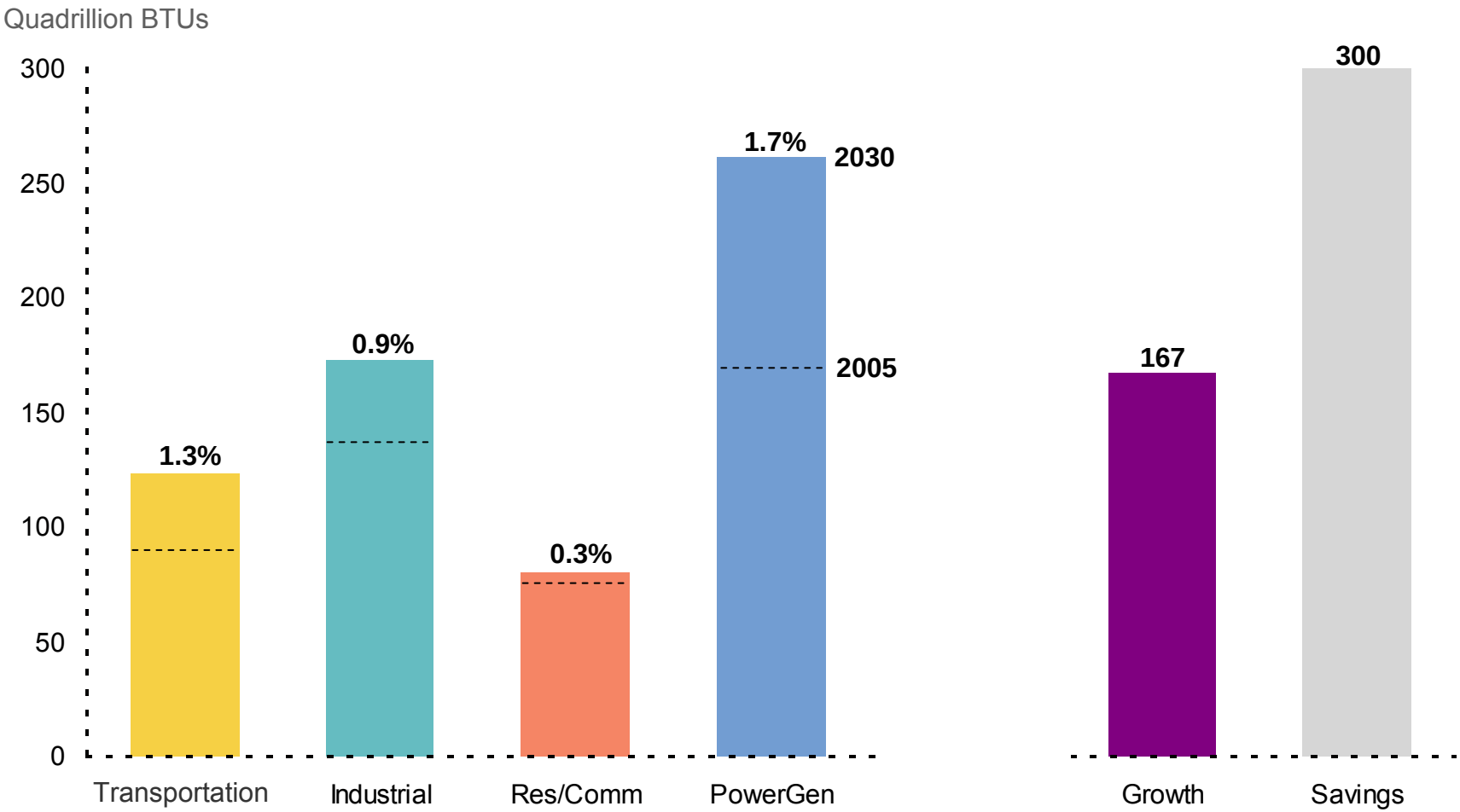
Energy Demand

Quadrillion BTUs

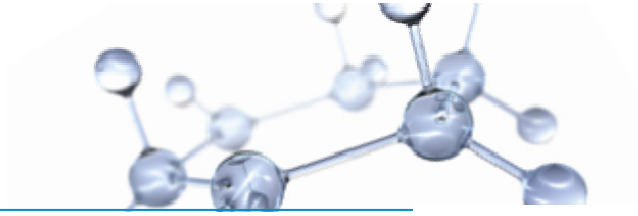


Power Generation Leads Growth

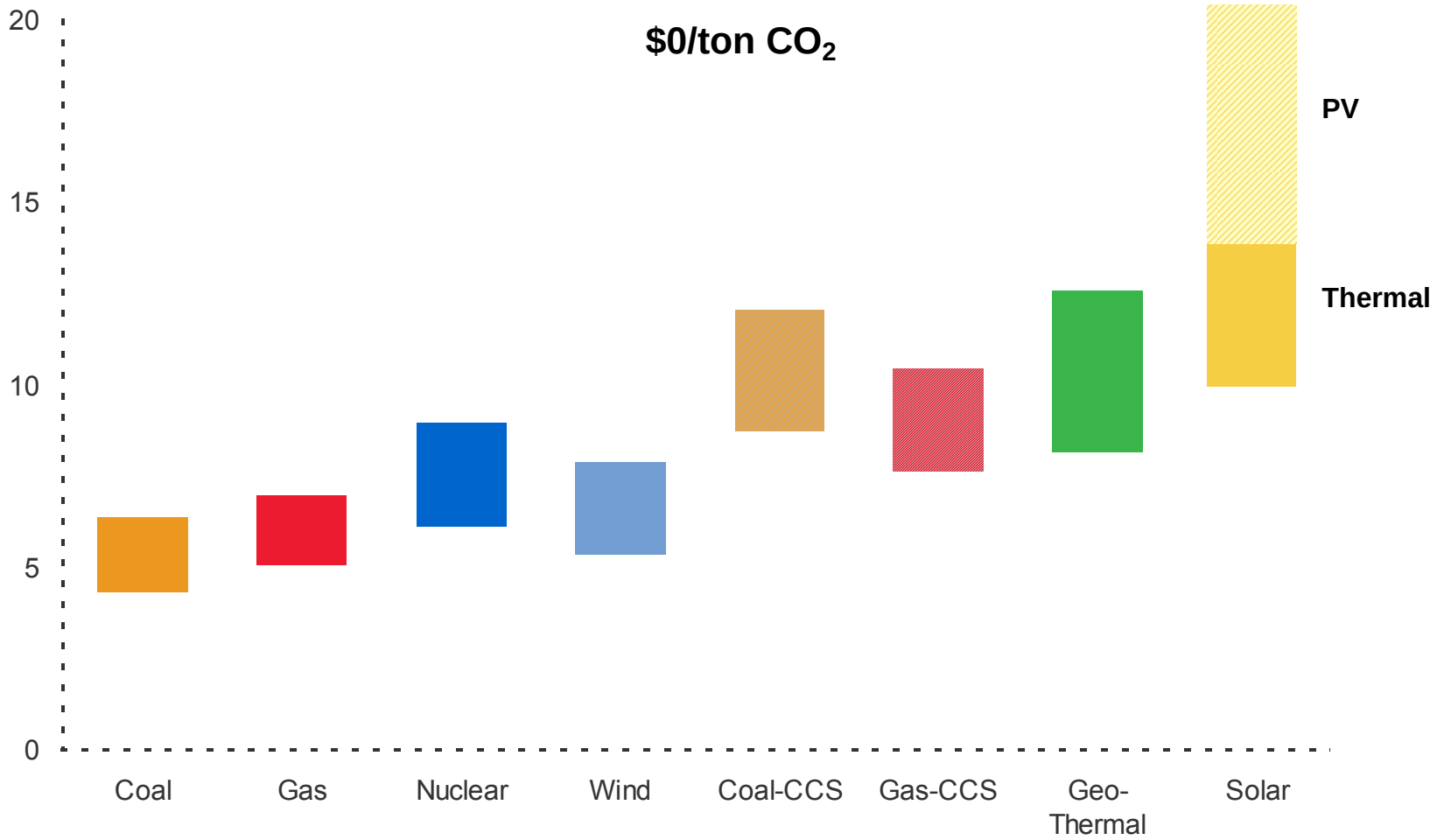




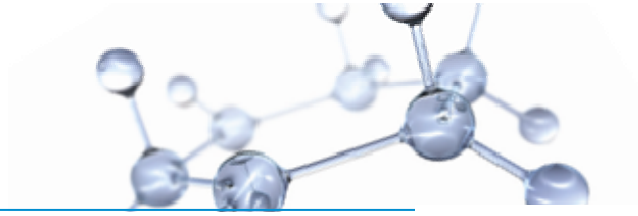
Economic Choices for U.S. Power



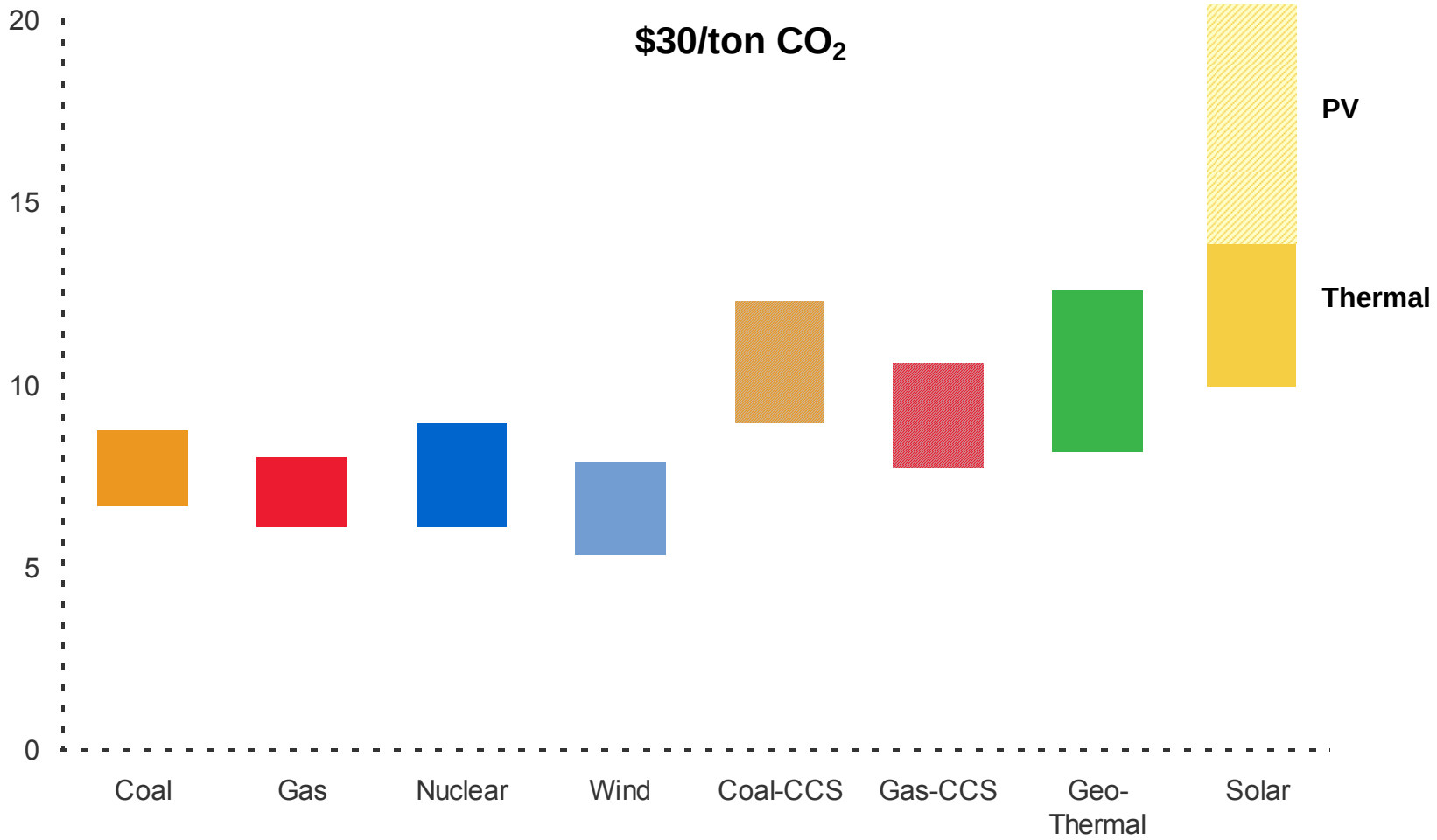
Baseload, Startup 2025
2010 cents/kWh



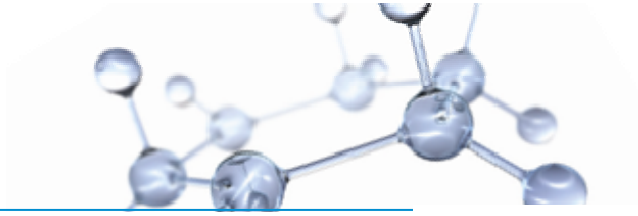
Economic Choices for U.S. Power



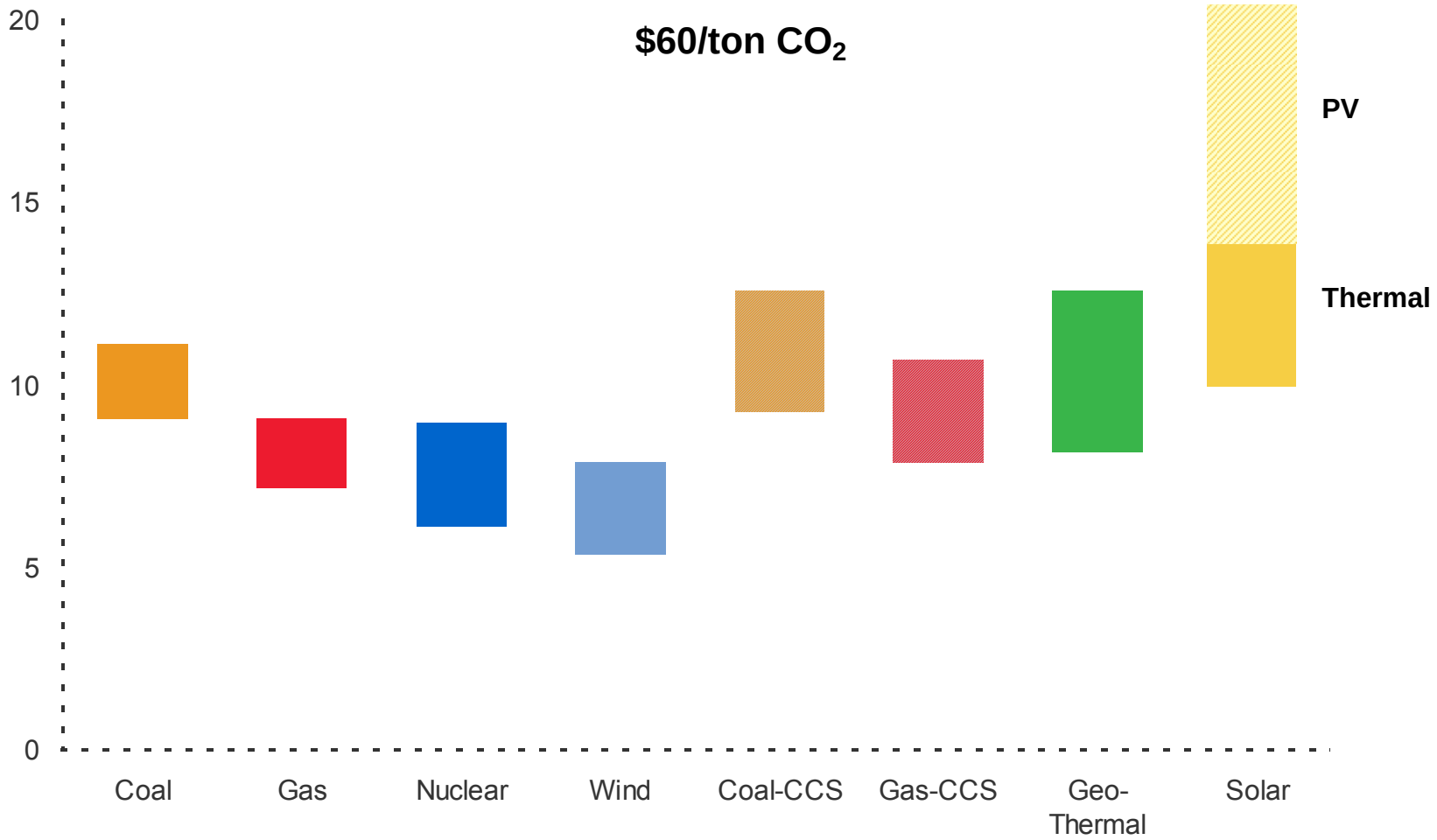
Baseload, Startup 2025
2010 cents/kWh



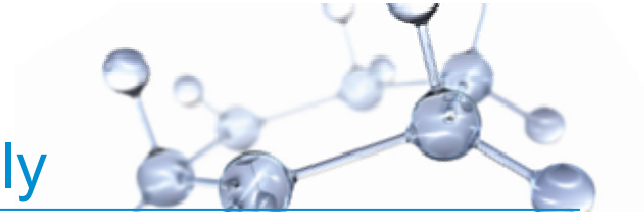
Economic Choices for U.S. Power



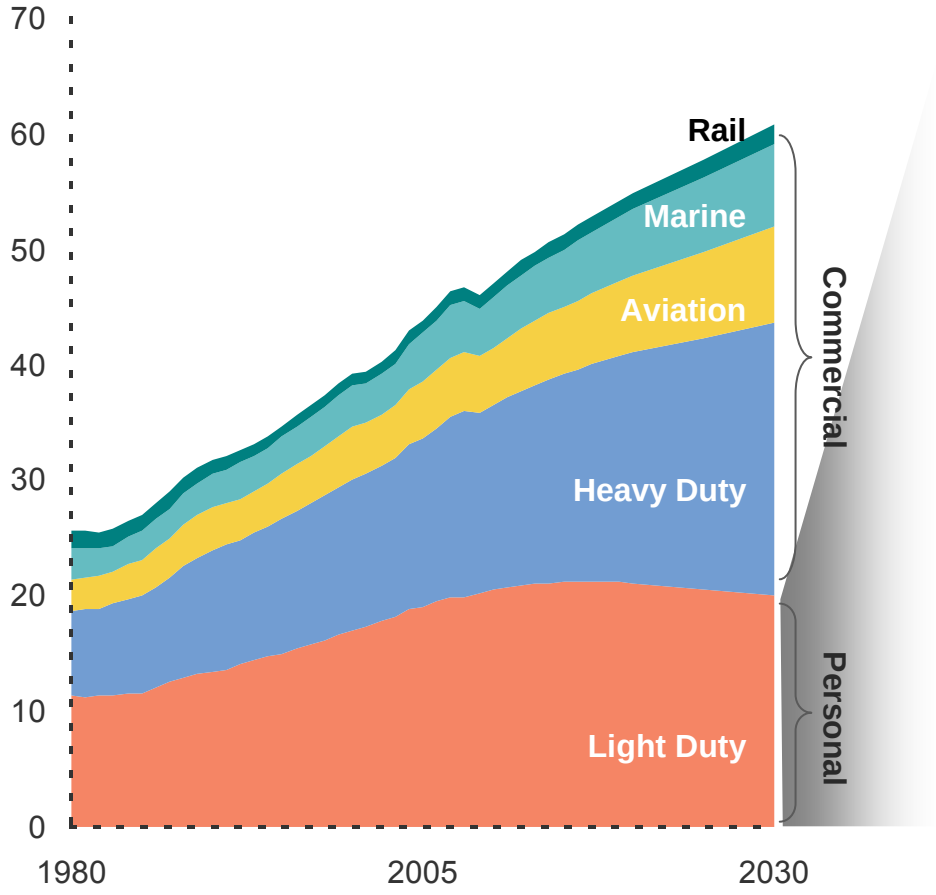
Baseload, Startup 2025
2010 cents/kWh



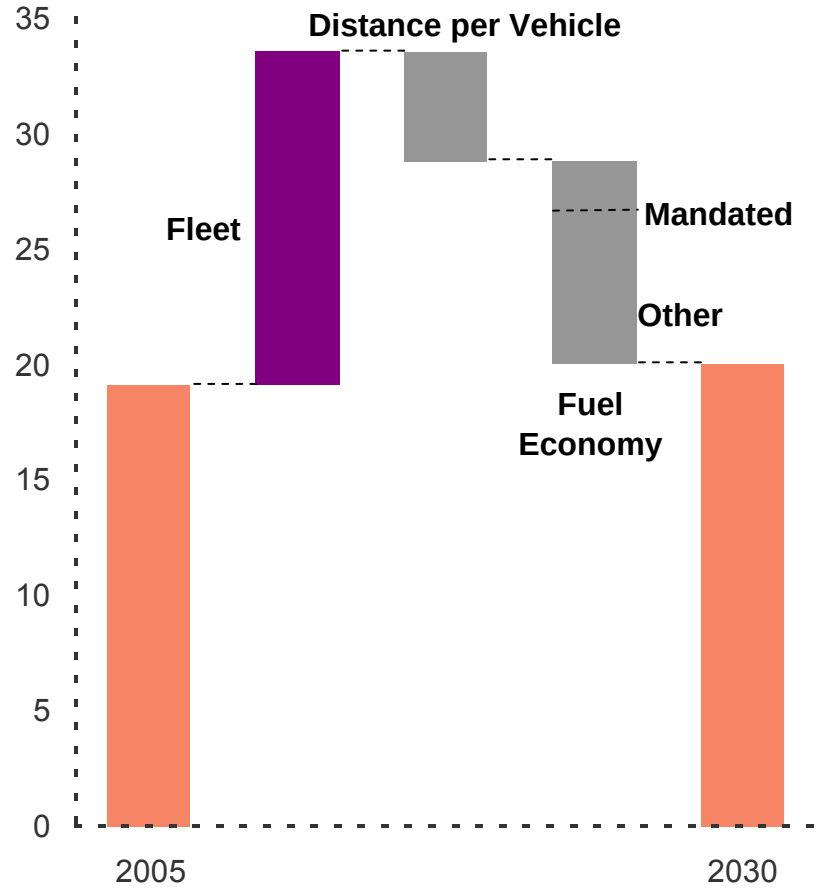
Transportation Demand Grows Steadily



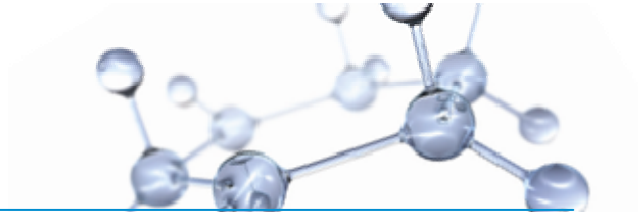
Demand
MBDOE

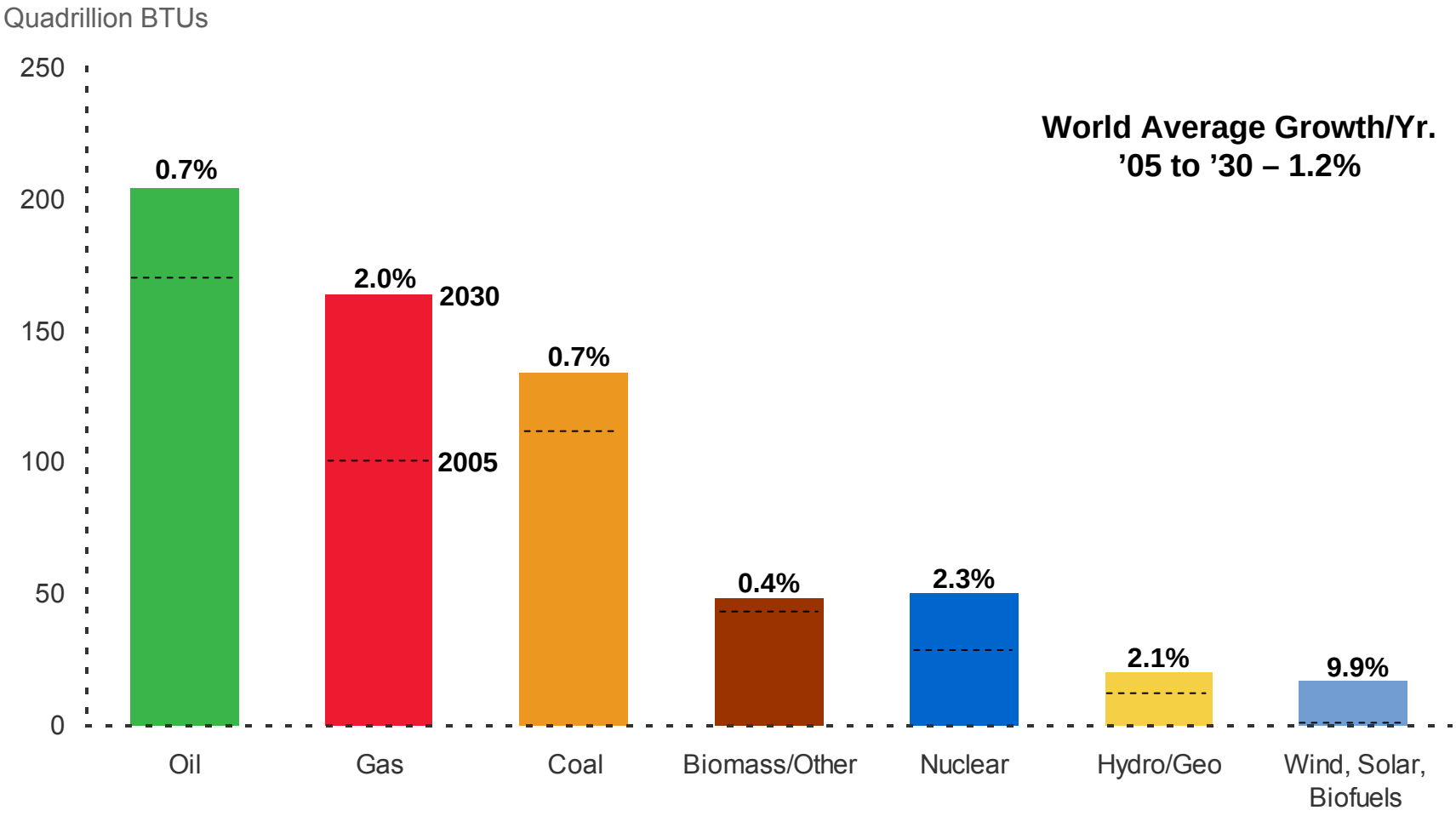


Personal Vehicle Demand Changes
MBDOE

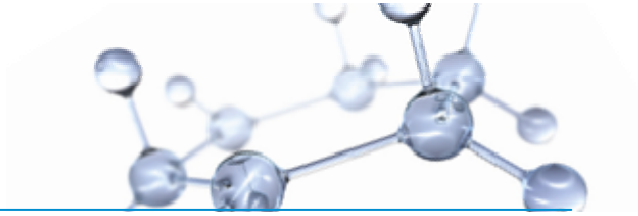


Energy Mix Continues to Evolve



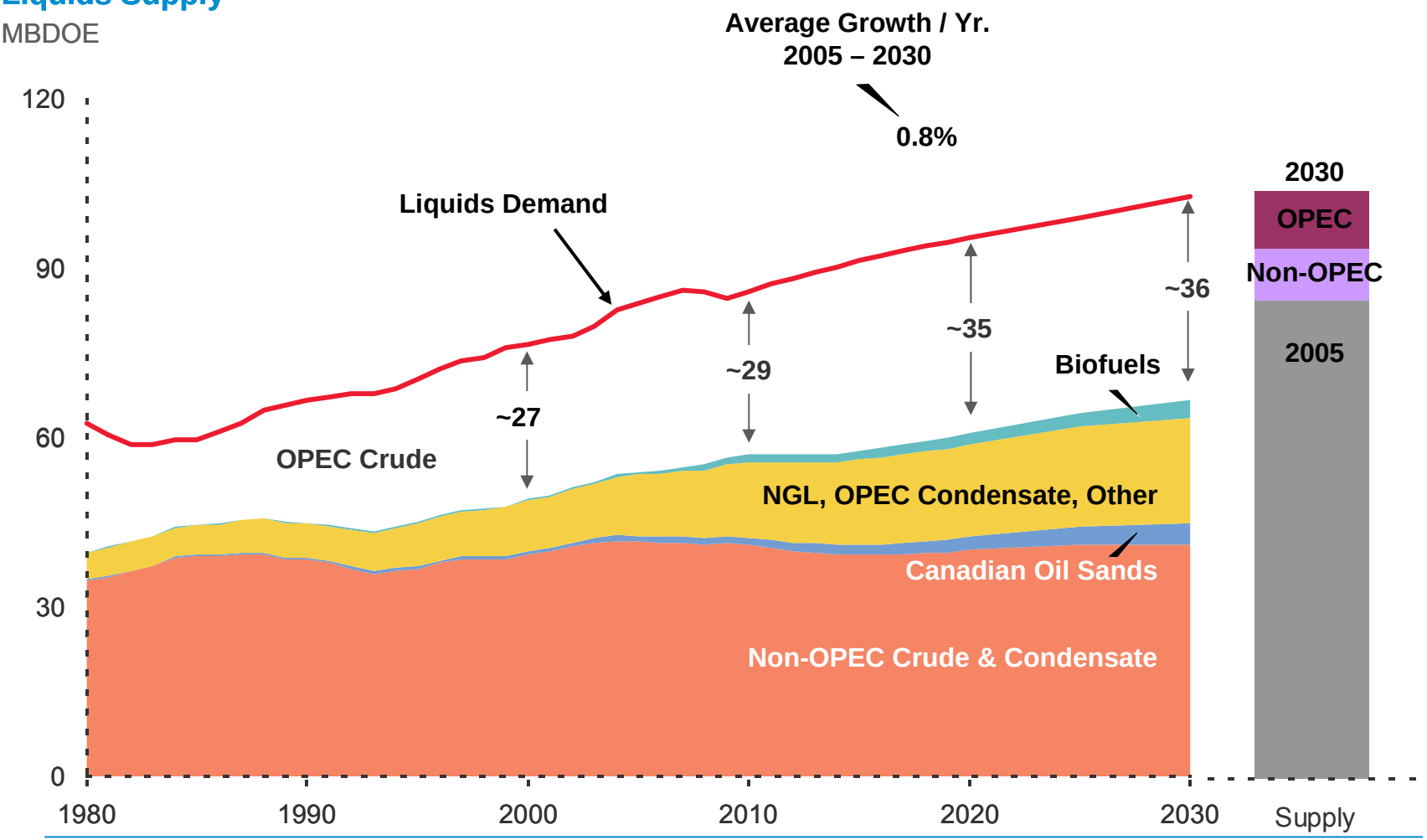


Liquids Support Growing Demand



Liquids Supply

MBDOE



ExxonMobil 2010 Energy Outlook

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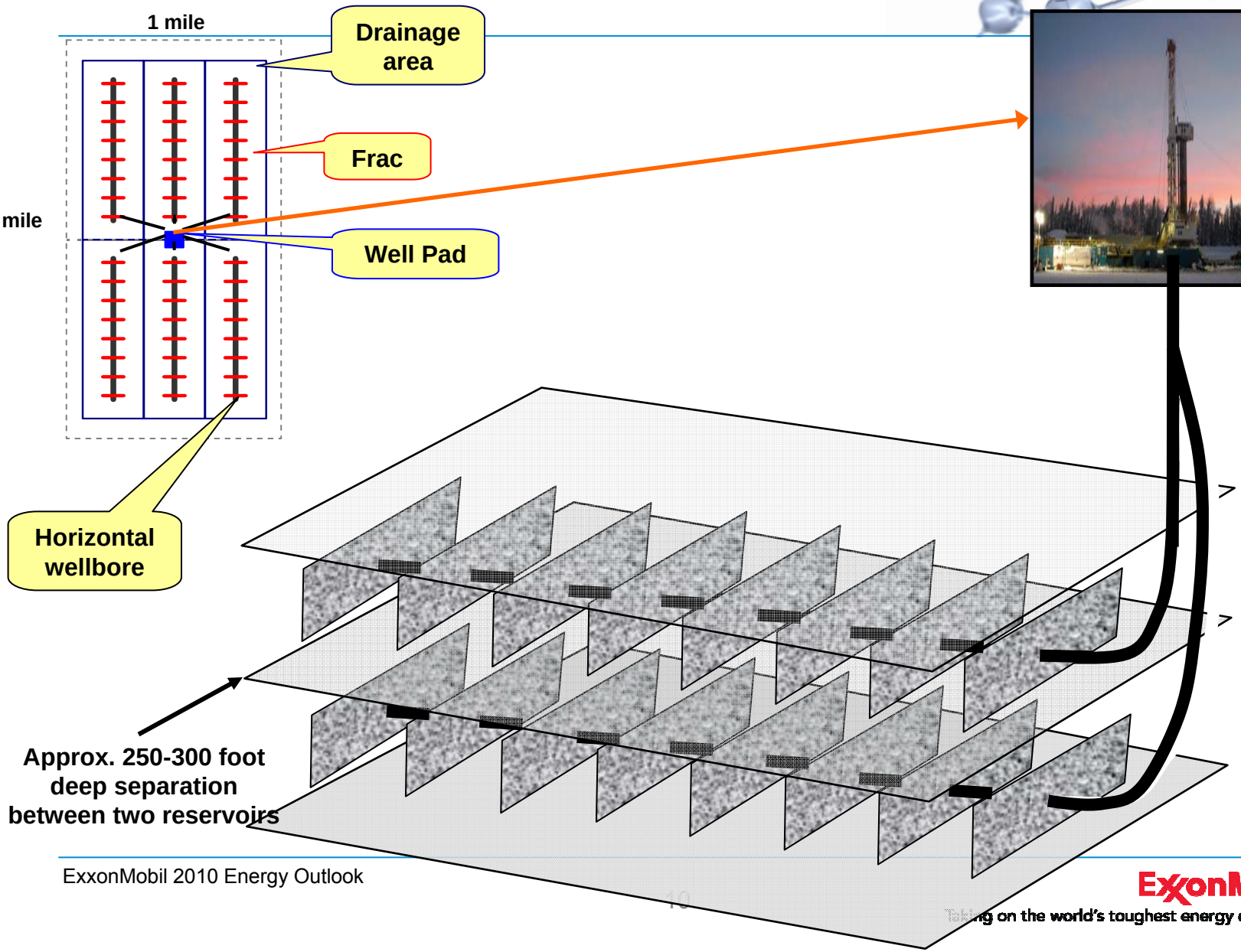
Multi-Zone, Multi-Lateral Production



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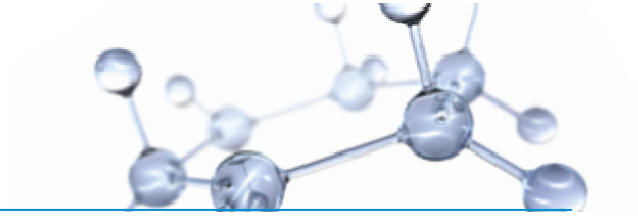
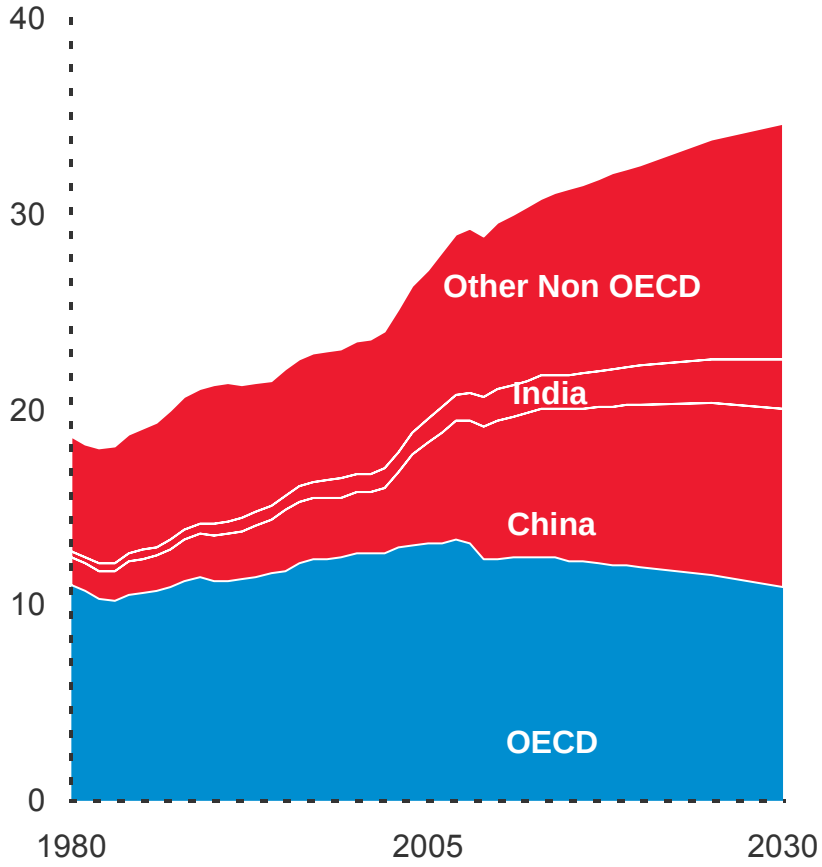
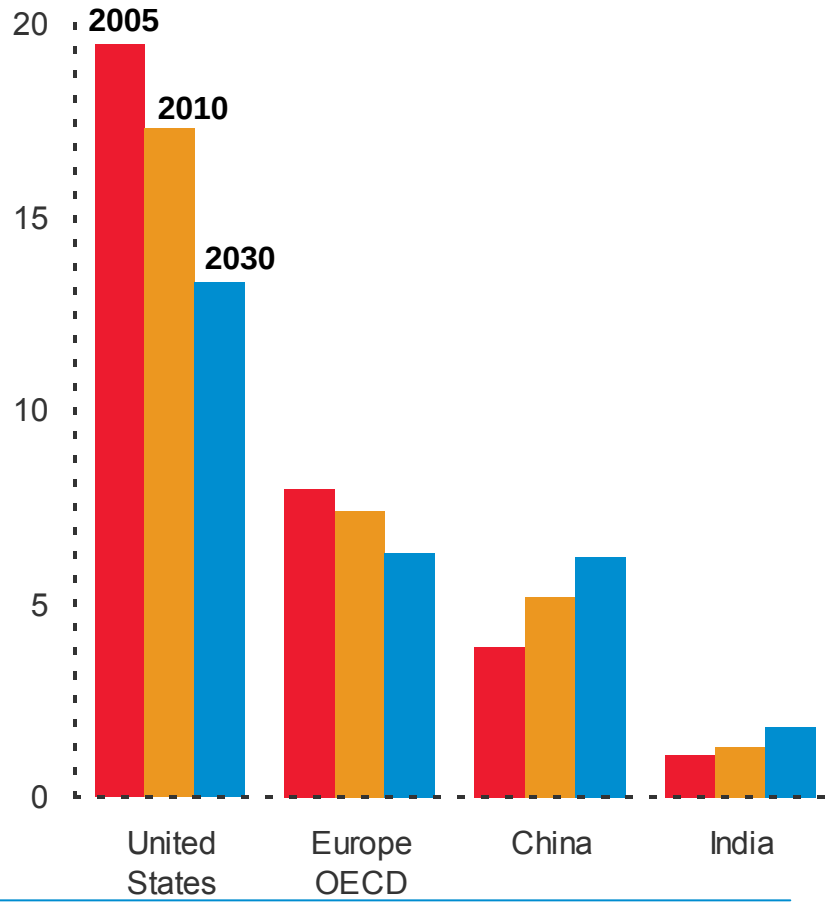
CO_2 Emissions Moderate



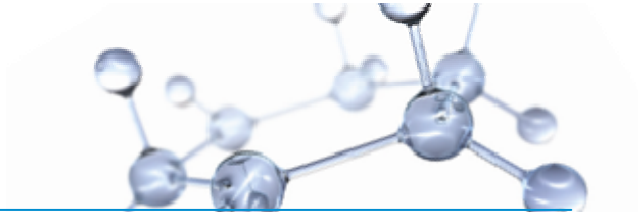
By Region
Billion Tons



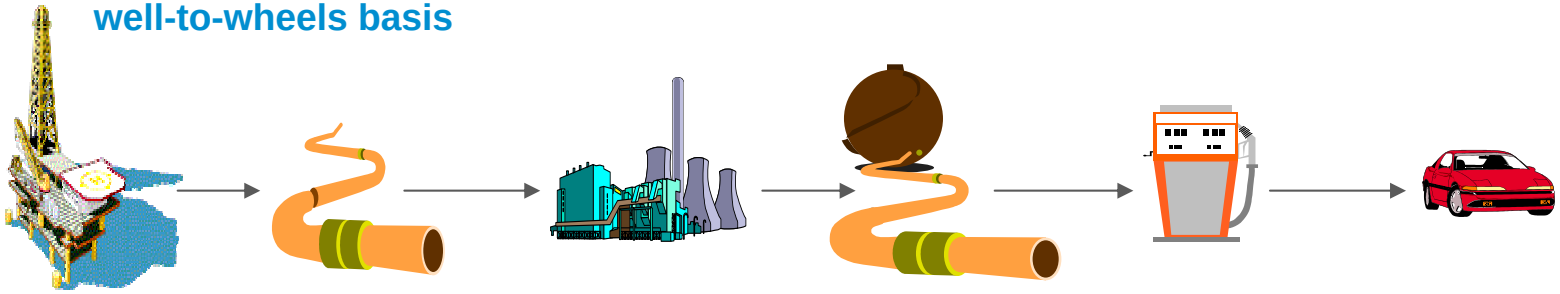
Emissions per Capita
Tons per Person



technologies for light duty transport



well-to-wheels basis



crude recovery → *crude transportation* → *crude refining to products* → *product storage & transportation* → *retail site* → *gasoline vehicle*

← production of fuel 20% GHG/mile → ← Consumers' use of fuel 80% GHG/mile →

technologies for fuel production

shorter-term
- energy efficiency
- flare reduction
- cogeneration

longer-term
- second generation bio-fuels
- Carbon Capture and Storage (CCS)

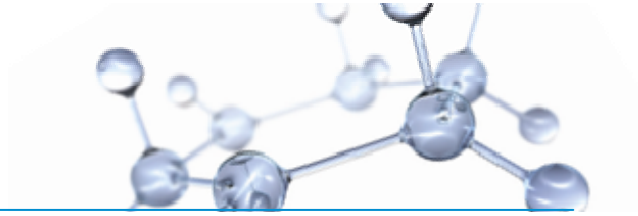
technologies for consumers' use of fuel

shorter-term
- conventional vehicle technology improvements
  - engines (e.g. adv. lubricants); efficient transmissions
  - others (e.g. tire liners, low weight plastics)
- advanced vehicles
  - hybrid (e.g. lithium ion battery materials)
  - advanced diesel
  - CNG

longer-term
- breakthrough vehicles
  - "HCCI" or "CAI"; fuel cell (e.g. on-board H_2 generator)
  - plug-in hybrid and EV (e.g. lithium ion battery materials)

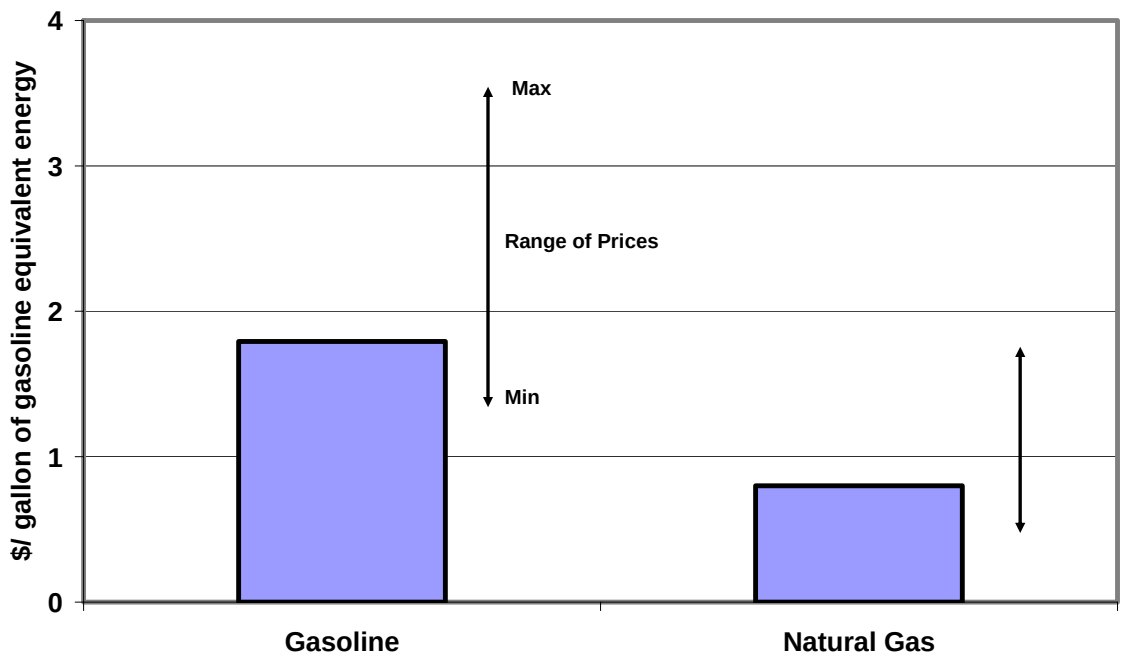
Source: U.S. Basis - WTW Study, Argonne National Lab, 2005

CNG Attributes



- CNG technology is mature and available today
- Pipeline natural gas is usually less expensive than wholesale gasoline per unit energy
  - Average of 2002-2009, natural gas and gasoline prices at wholesale

Wholesale Price Comparison



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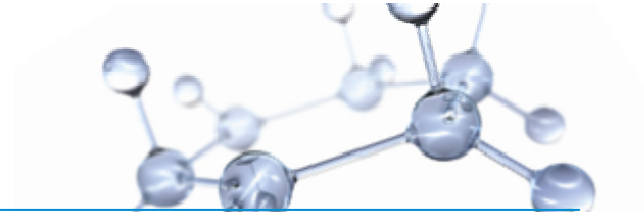
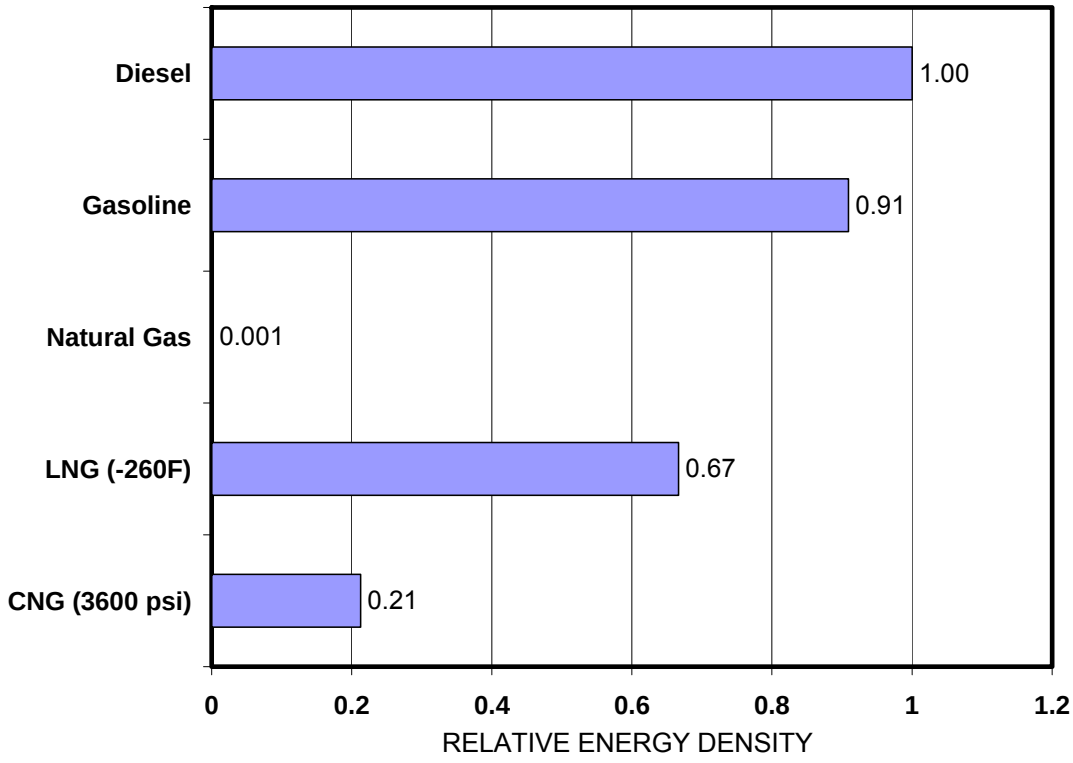
Gasoline prices are at wholesale, excluding taxes and retailers cost/margin
NG prices are from EIA as supply to electric power stations

Natural Gas Energy Density



Natural Gas (NG) has low energy density (BTU/gal), therefore need to:

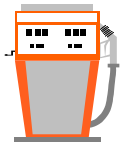
1. Cool NG to -260F at an industrial site to produce LNG, distribute via tanker trucks, and retail LNG
2. Pump NG to high pressure CNG at retail sites, and store CNG in larger heavier tanks, or



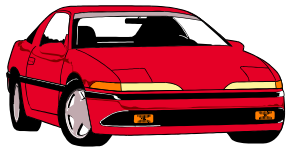
CNG Investments

- CNG use requires investments in retail service stations and vehicles

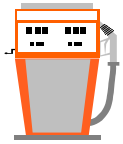
Gasoline →



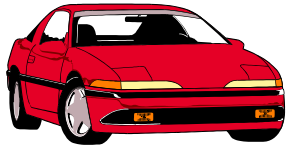
retail site →



Natural Gas →



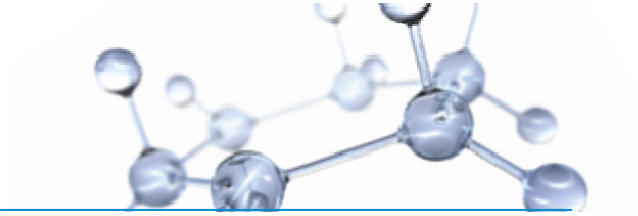
CNG retail site → 3600 psig →



- Retail service station investments
  - ~$0.3M for retail fuel island for cars
  - ~$2M for a truck station
- Requires more frequent fuel filling
- Higher maintenance

- Costs $6-7K more per vehicle
- Reduces trunk space by 50%
- Reduces driving distance by 33%
- driving costs savings may depend on natural gas and gasoline prices

Personal Vehicle CNG Economics

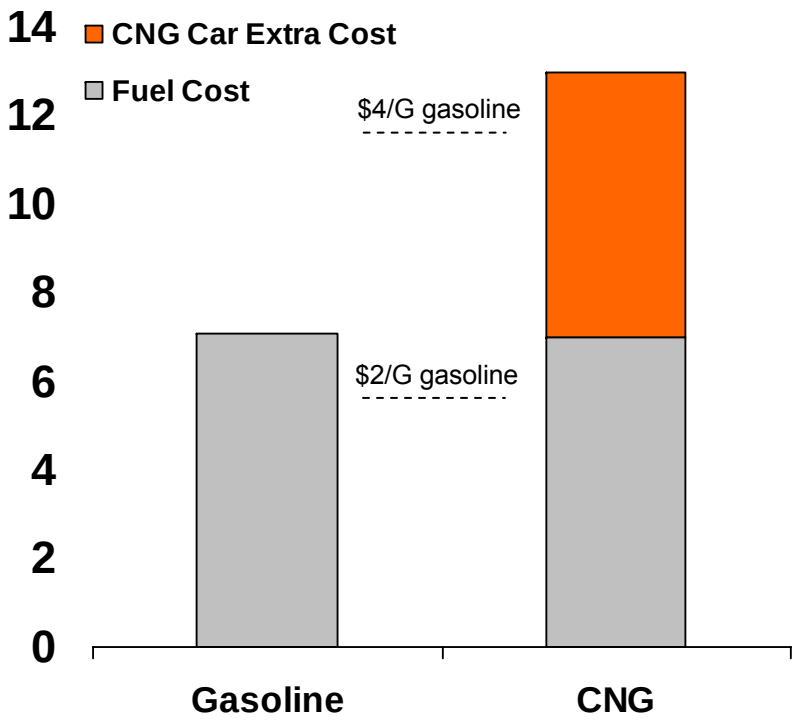


CNG Assumptions - 2010

	Gasoline	CNG
Fuel Price, $ per gasoline equivalent gallon	2.50	2.45
Fuel Price to Retailer*	1.80	0.80
Retailers expense and margin	0.20	0.25
Capital charge for CNG station	0.00	0.90
Fuel taxes	0.50	0.50
5-YR Fuel Costs, $K	7.1	7.0
Incremental Vehicle Costs, $K	Base	+6.0

CNG Vehicles vs. Conventional

Incremental 5-yr costs, $k



* Average U.S. wholesale price from 2002 to 2009, EIA

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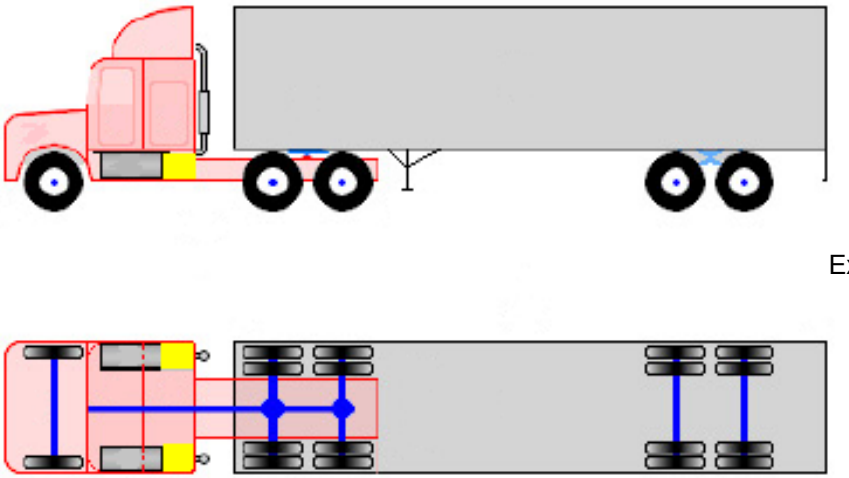
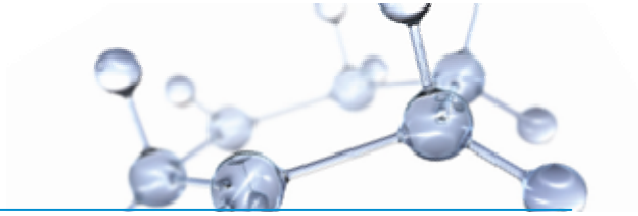
CNG Use for Heavy Duty Trucks



Extra fuel tank volume shown in yellow

- CNG Trucks need 4.5 times the diesel volume to achieve same distance
- Heavy duty tractor-trailers trucks have limited fuel storage space
  - Maximum: 2 times current diesel volumes
  - Extra CNG tanks could be mounted on the back frame – requires redesign, safety assessment
- CNG use may be attractive for some centrally fuelled truck fleets with limited driving distances and high annual mileage

Heavy Duty Truck CNG Economics

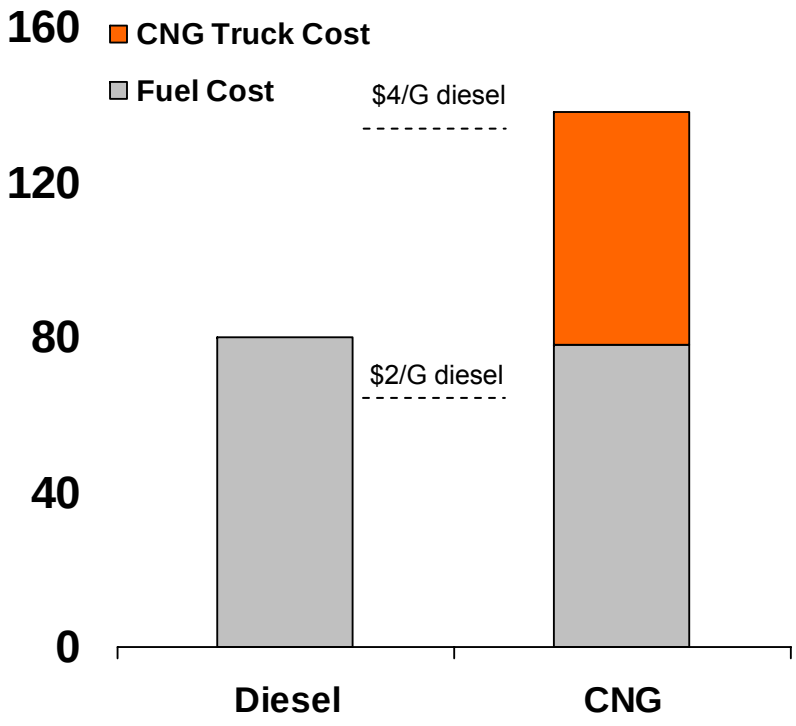


CNG Assumptions - 2010

	Diesel	CNG
Fuel Price, $ per diesel equivalent gallon	2.40	2.30
Fuel Price to Retailer*	1.70	1.00
Retailers expense and margin	0.20	0.20
Capital charge for CNG station	0.00	0.60
Fuel taxes	0.50	0.50
5-YR Fuel Costs, $K	80	78
Incremental Vehicle Costs, $K	Base	+60

CNG Truck vs. Conventional

Incremental 5-yr costs, $k



* Average U.S. wholesale price from 2002 to 2009, EIA

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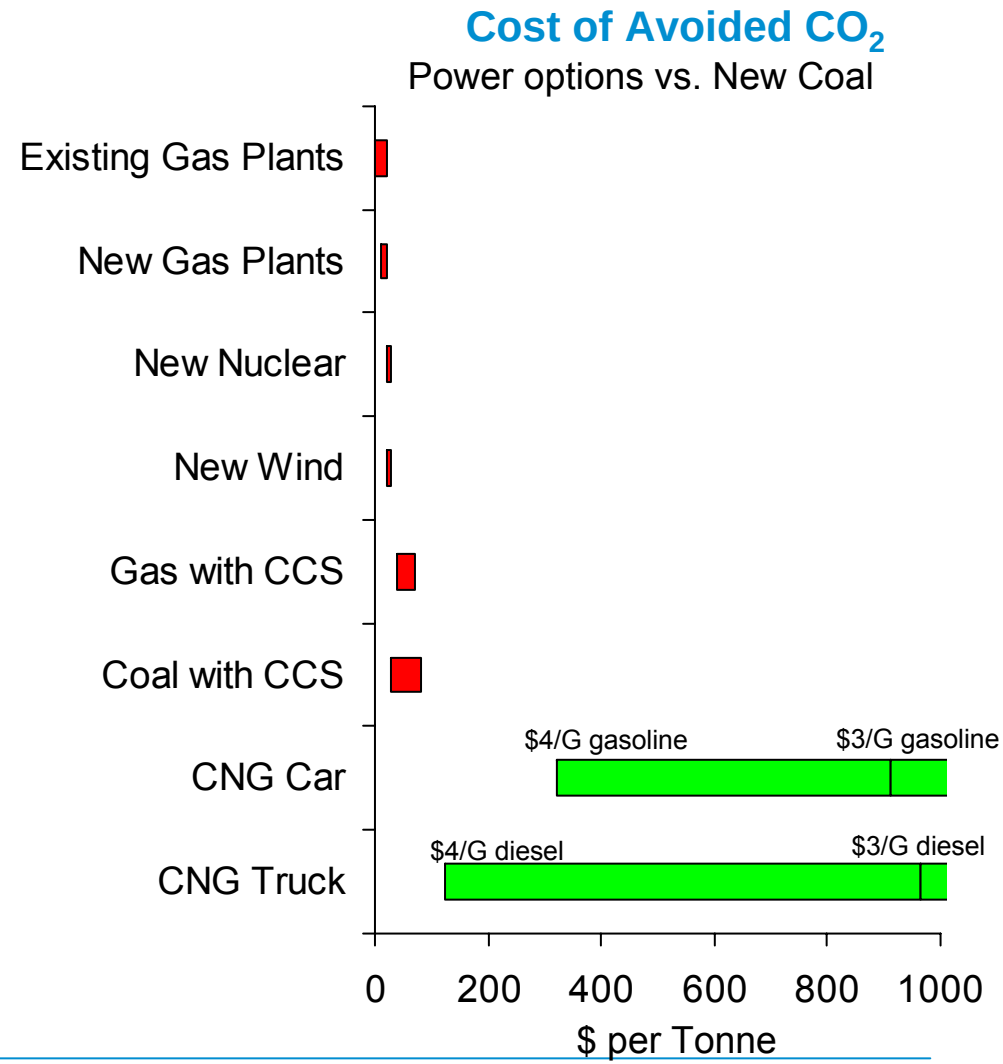
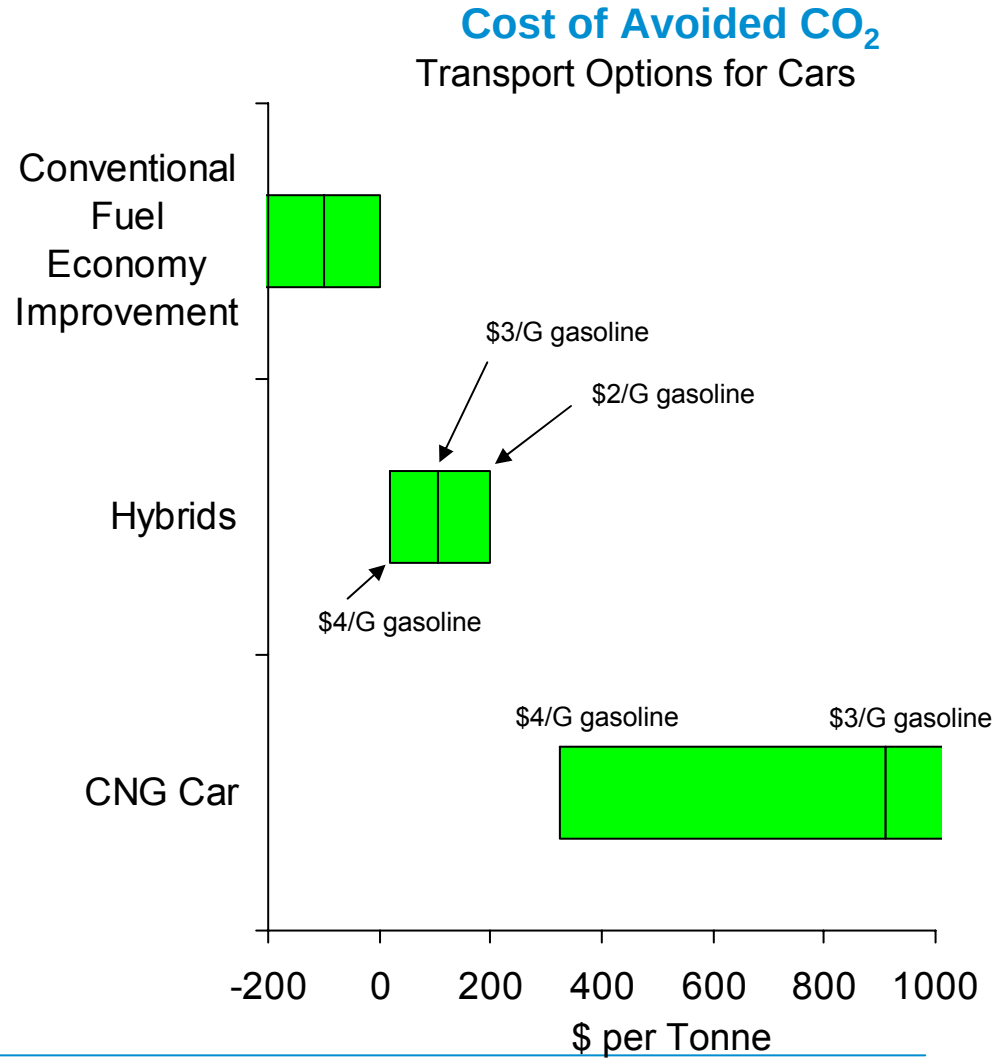
Greenhouse Gas Mitigation with CNG

- CNG vehicles and trucks can reduce well-to-wheels Greenhouse Gas (GHG) emissions by 15%
- Gas use in power generation can reduce GHG emissions by up to 60% vs. coal
- Use of NG in power generation (vs. coal) yields larger and more cost-effective GHG reductions



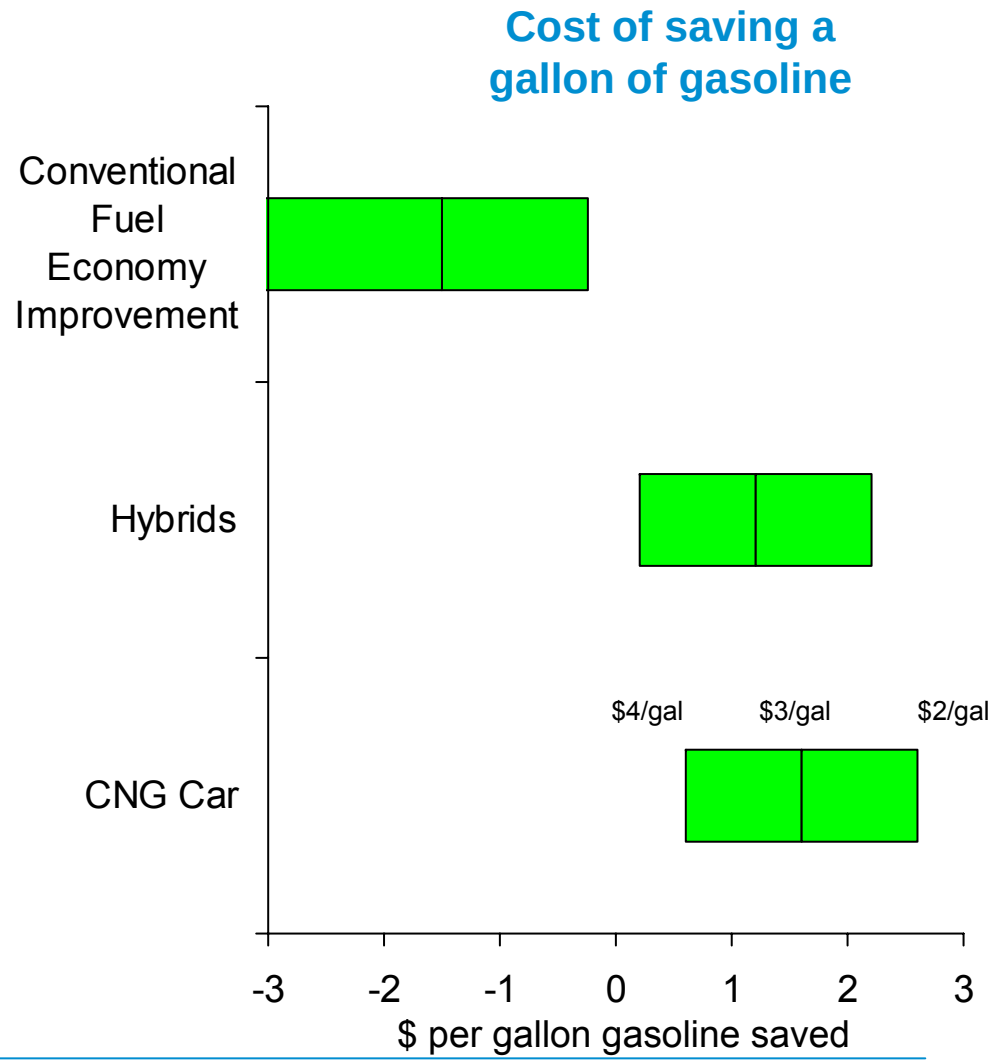
Greenhouse Gas Mitigation with CNG

- Conventional vehicle improvements are much more cost-effective than use of CNG for petroleum demand or GHG emissions reduction.
- Examples of conventional fuel economy improvements are:
  - Improved engines
  - Better transmissions
  - Light weighting materials
  - Higher performance tires
  - Improved aerodynamics



Petroleum Demand Reduction with CNG

- Conventional vehicle improvements are much more cost-effective than use of CNG for petroleum demand reduction



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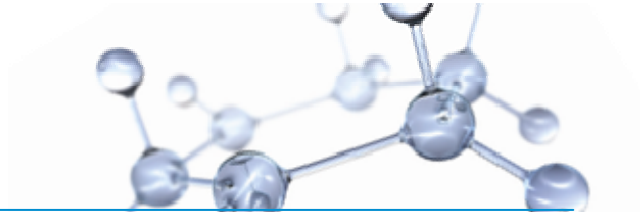
CNG vs. LNG as a Transportation Fuel

- CNG is a well-established transportation fuel globally

- LNG is an emerging transportation fuel for trucks– further work is needed to understand life cycle greenhouse gas emissions during LNG refueling and vehicle use
  - LNG's main advantage over CNG is increased energy density
  - LNG is a "use it or lose it" fuel for cars and trucks due to lack of hardware to capture vented natural gas from boil-off
    - In large-scale LNG applications for power generation and other sectors, facilities have the hardware to re-liquefy or compress NG into an existing pipeline or use NG for other needs
  - LNG retail fueling and vehicle tank boil-off losses are not well assessed
    - Boil-off losses depend on fuel station utilization, station design, type of on-board fuel tank, vehicle utilization, etc.
    - Small amount of LNG boil-off losses can result in an increase of life cycle greenhouse gas emissions, potentially beyond that of a diesel vehicle
  - An assessment of LNG fueling retailing losses is suggested as the next step

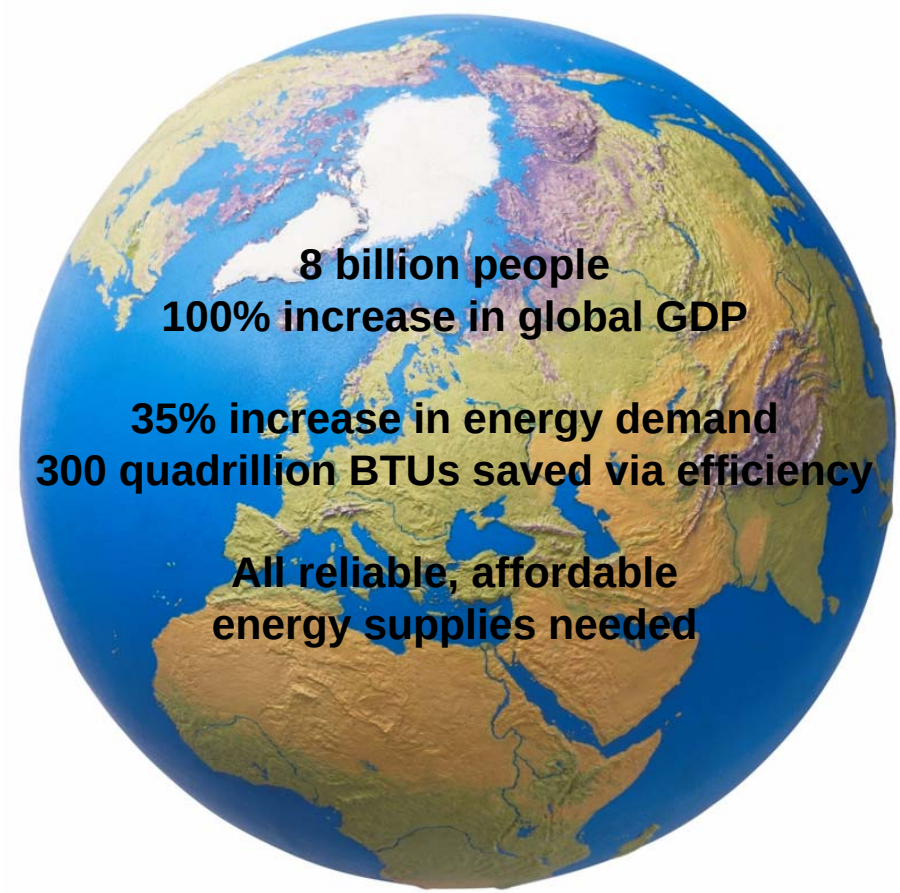
CNG Summary



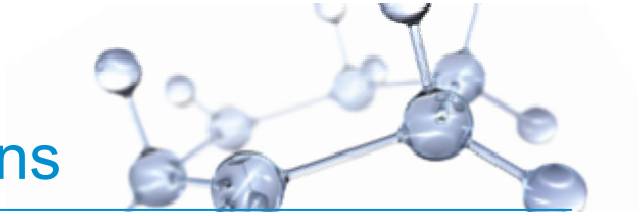
- CNG technology is available today
- CNG Vehicles require large investments in fuels and vehicle infrastructure
- CNG is more likely to be used for fleets before it is used in a widespread manner by consumers and truckers.
- CNG could be economically attractive for some centrally fueled fleets with
  - limited driving distances, high annual miles traveled, higher fuels infrastructure use
  - higher price spreads between liquids fuels and natural gas
- Conventional vehicle improvements are much more cost-effective than use of CNG for reduction of petroleum demand or GHG emissions
- Use of NG in power generation (vs. coal) yields larger and more cost-effective reductions
- LNG is an emerging fuel for transportation – further work is needed to understand life cycle greenhouse gas impacts
- ExxonMobil supports market-driven use of CNG

Development Challenges and Solutions

World development continues, while lives improve and economies grow



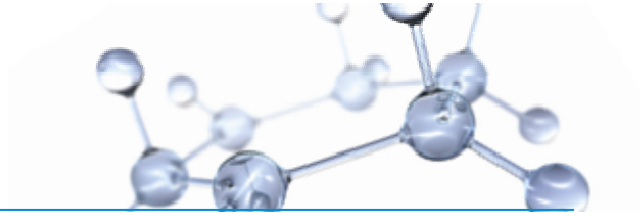
Development Challenges and Solutions



Increase Efficiency

Mitigate Emissions

Expand Supplies



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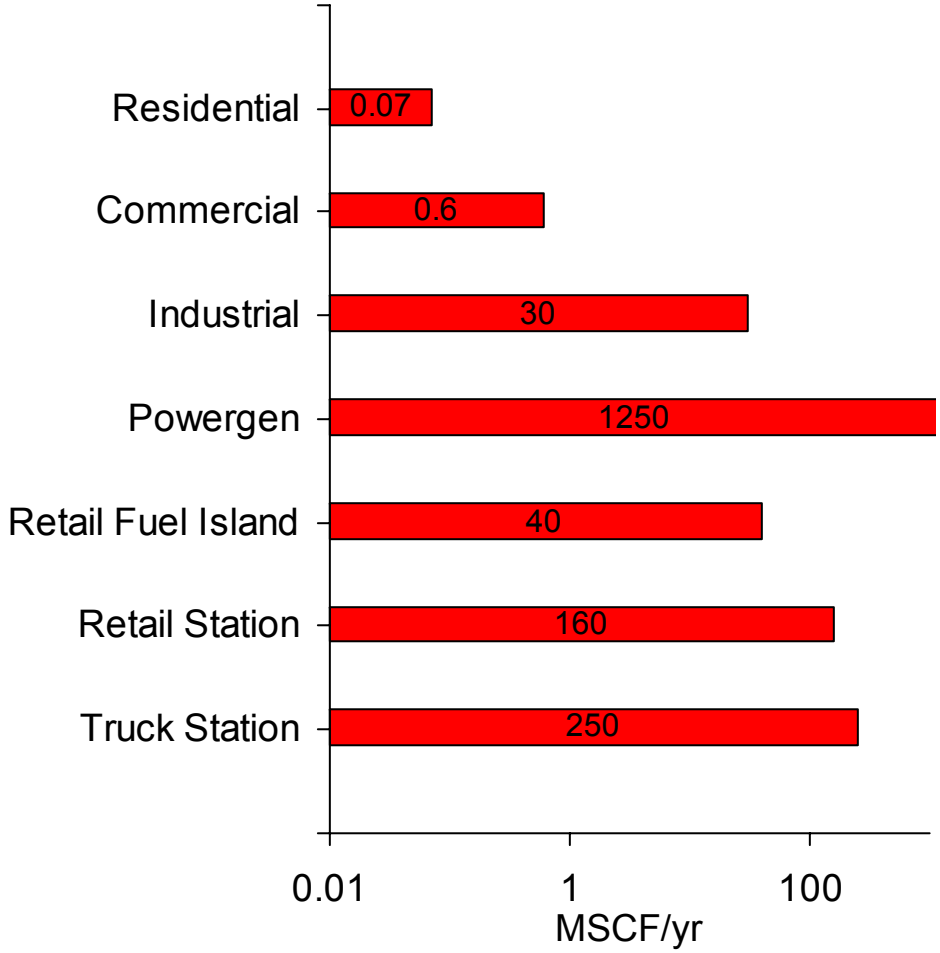
Backup

Natural Gas Infrastructure for CNG

- A CNG car retail station consumes NG equivalent to:
  - ~ 5 industrial customers
  - ~2000 residential customers
- New larger service lines will have to be installed to accommodate CNG refueling station
  - Pipeline to feeder line cost ~0.3-0.5M per mile – adding another $0.3-0.5/gallon/mile cost
  - Initial stations may need to be near feeder lines

NG Consumption per Customer



Retail Fuel Island = 2 nozzles; Retail Station = 8 nozzles

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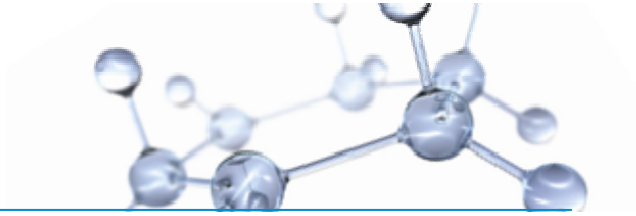
Personal Vehicle CNG Economics



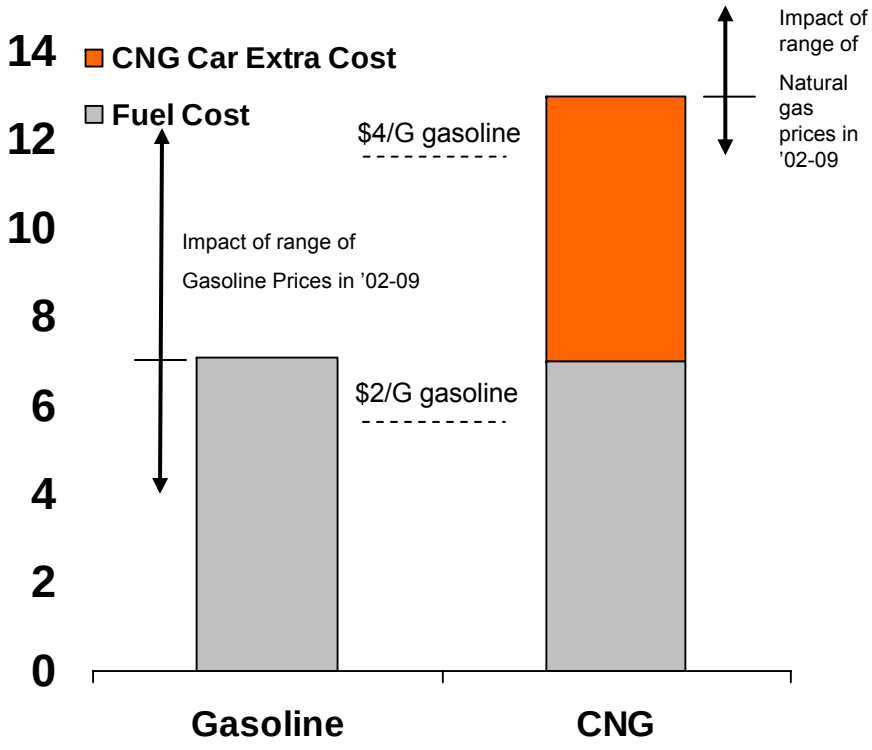
CNG Assumptions - 2010

	Gasoline	CNG
Fuel Price, $ per gasoline equivalent gallon	2.50	2.45
Fuel Price to Retailer*	1.80	0.80
Retailers expense and margin	0.20	0.25
Capital charge for CNG station	0.00	0.90
Fuel taxes	0.50	0.50
5-YR Fuel Costs, $K	7.1	7.0
Incremental Vehicle Costs, $K	0.0	6.0

* Average U.S. wholesale price from 2002 to 2009, EIA

CNG Vehicles vs. Conventional

Incremental 5-yr costs, $k



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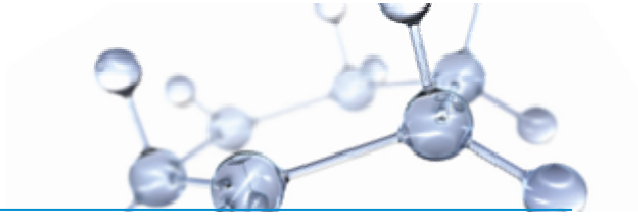
Heavy Duty Truck CNG Economics

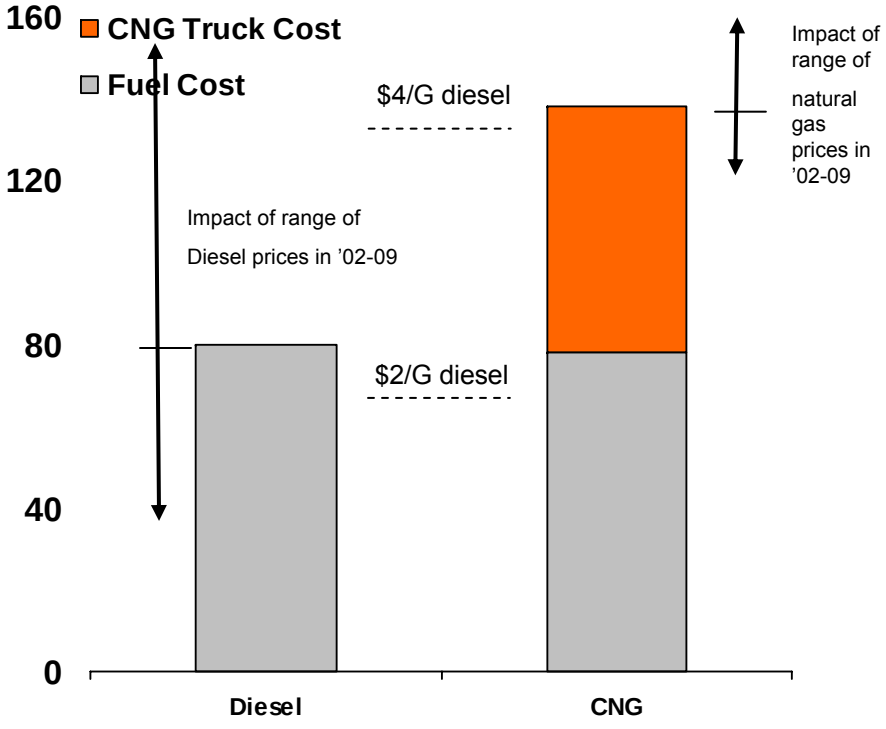


CNG Assumptions - 2010

	Diesel	CNG
Fuel Price, $ per diesel equivalent gallon	2.40	2.30
Fuel Price to Retailer*	1.70	1.00
Retailers expense and margin	0.20	0.20
Capital charge for CNG station	0.00	0.60
Fuel taxes	0.50	0.50
5-YR Fuel Costs, $K	80	78
Incremental Vehicle Costs, $K	0.0	60

CNG Truck vs. Conventional

Incremental 5-yr costs, $k



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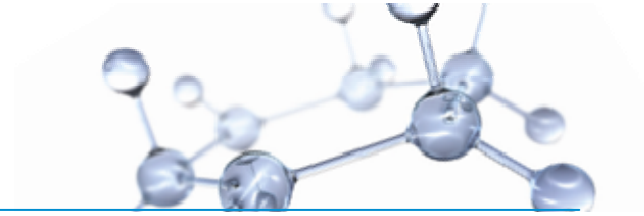
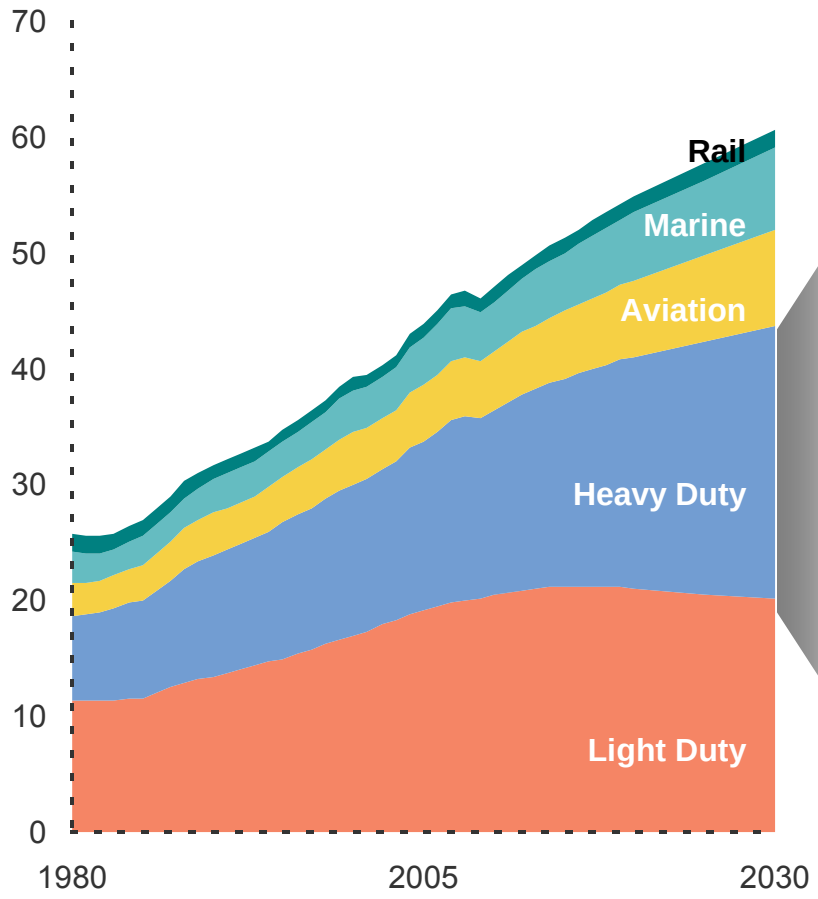
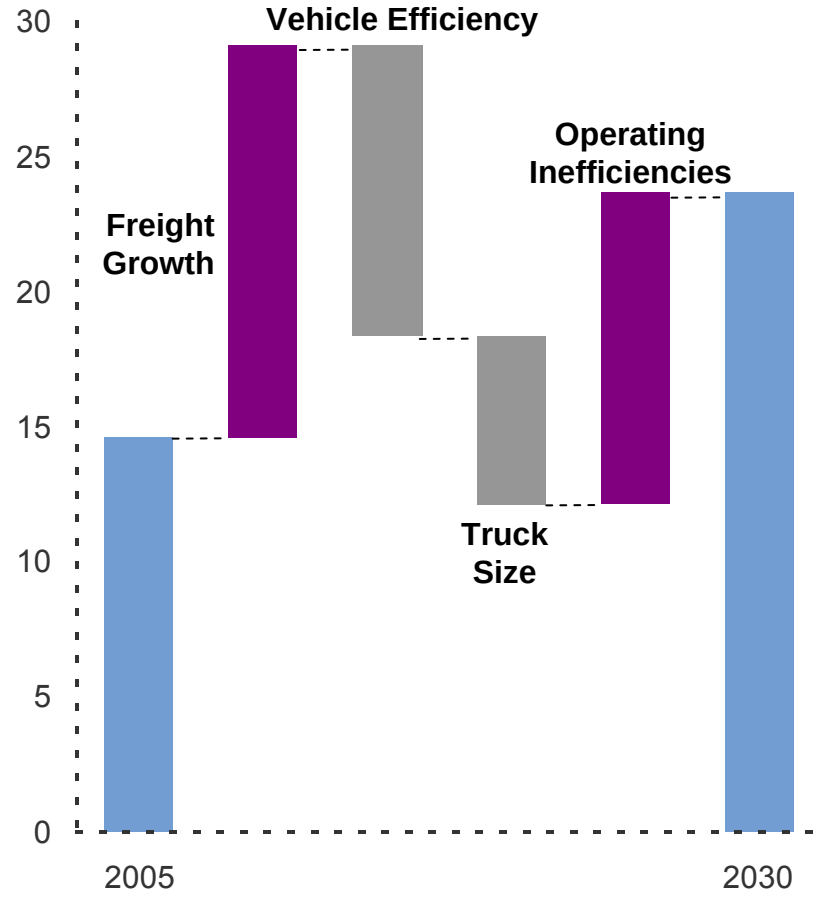
Heavy Duty Dominates Growth



Demand
MBDOE



Heavy Duty Demand Changes
MBDOE



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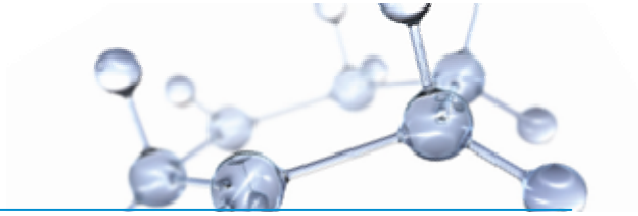
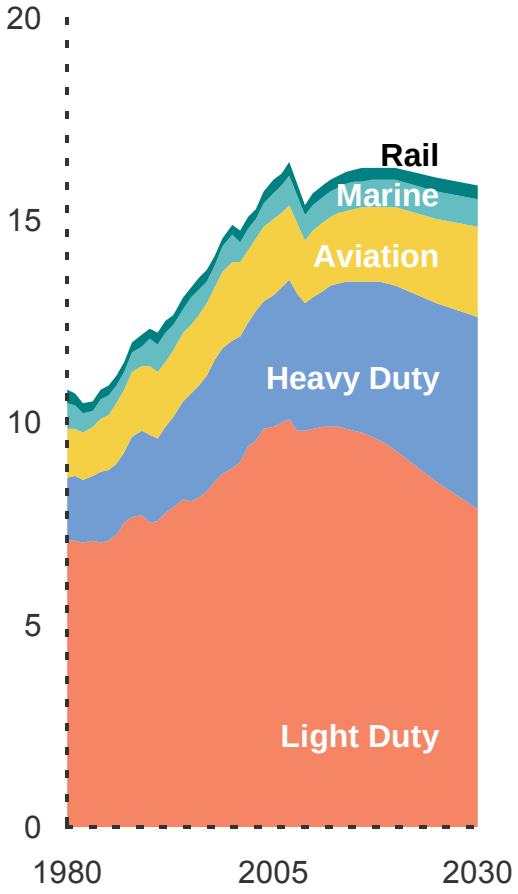
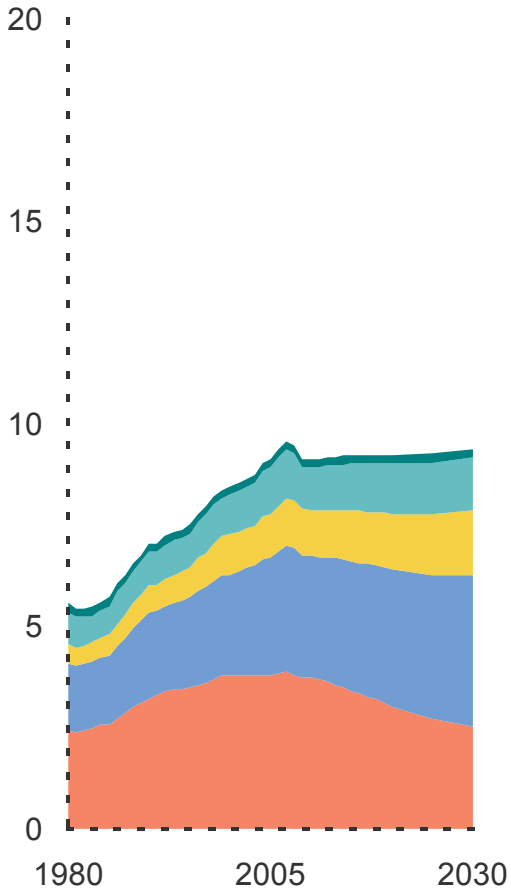
Commercial Transport Drives Growth



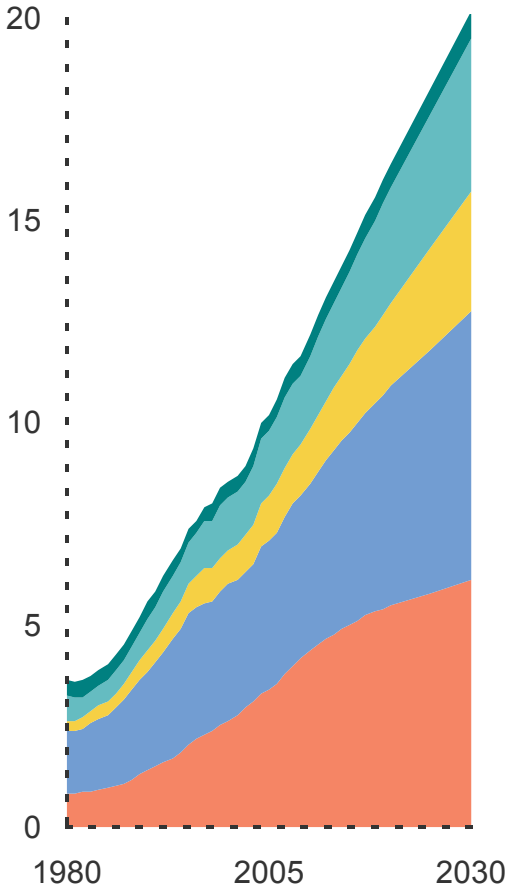
North America
MBDOE



Europe
MBDOE



Asia Pacific
MBDOE



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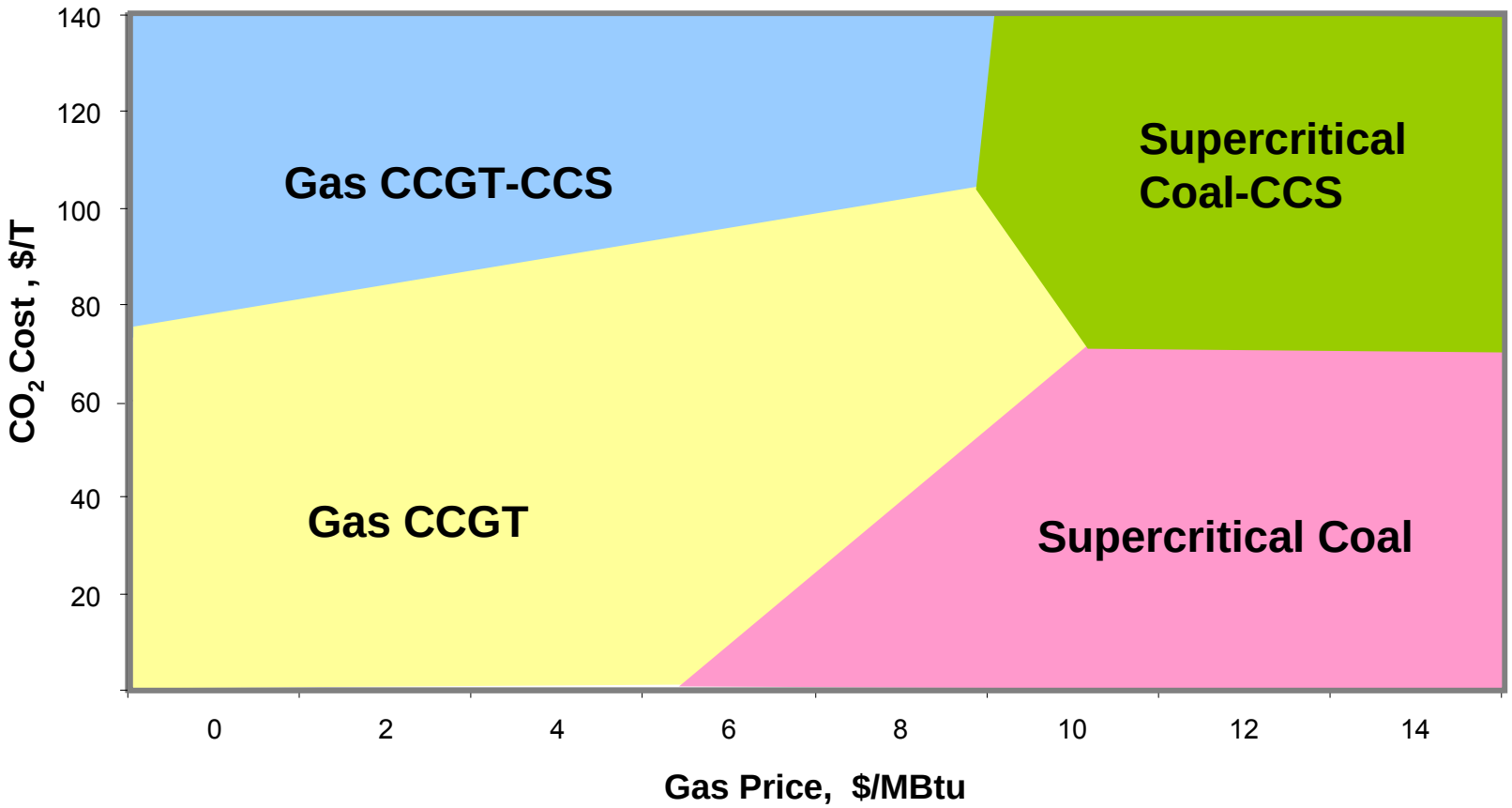
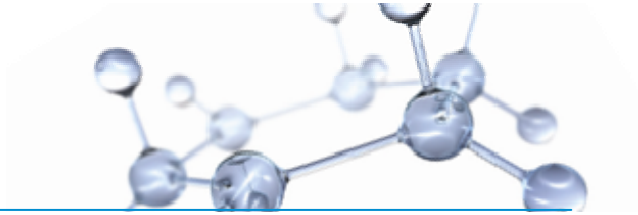
Opportunities for CCS: power generation

Least Cost Generation Technology Zones



shorter-term technologies



energy efficiency

improving energy efficiency in our facilities

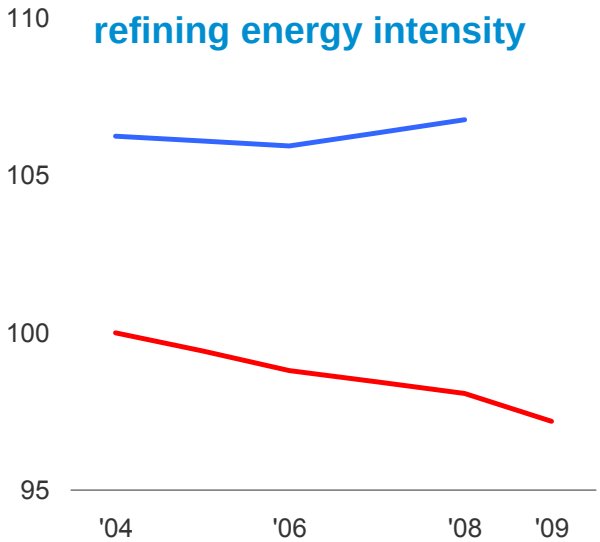
flare reduction

reduction of routine flaring of natural gas that is a byproduct of oil production

cogeneration

heat generated during generation of electricity is captured and used for other purposes

refining energy intensity

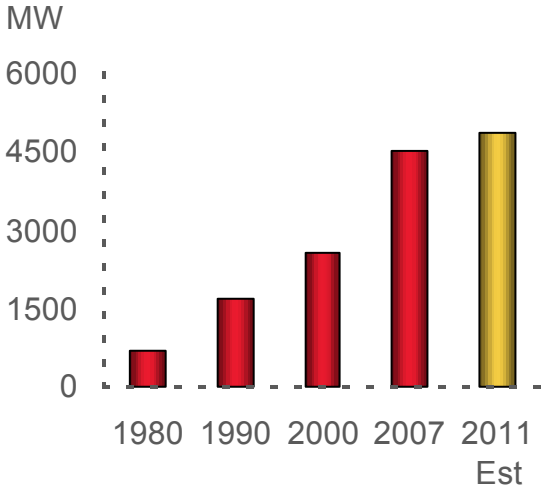


Source: Solomon Associates fuels refining benchmarking data through '08 available on even years;

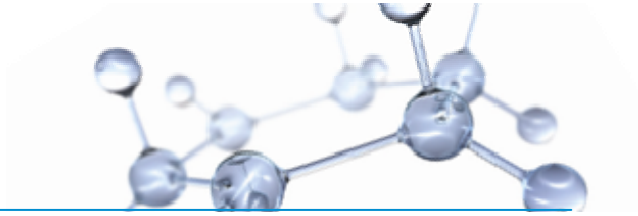
ExxonMobil estimate for '09; Data indexed to ExxonMobil ('04)

Beaumont Cogen
Texas, USA

cogeneration capacity in which ExxonMobil has an interest

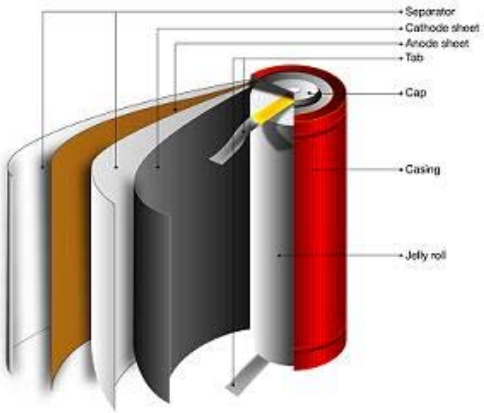


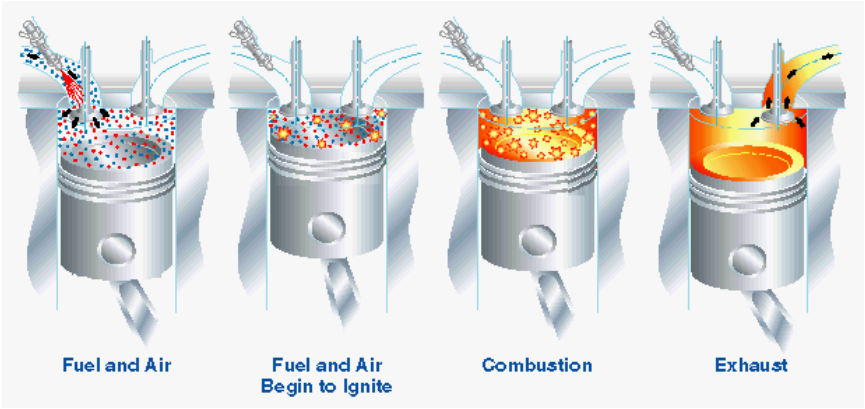
improving consumers' use of energy



lithium-ion battery materials*

new separator technology for lighter and safer hybrid and electric vehicle batteries





advanced engines and fuels research

potential for improved fuel economy vs. gasoline engines

on-board hydrogen generator for fuel cell vehicles

converts hydrocarbon fuels into hydrogen to power a fuel cell – all on-board the vehicle

Since 4Q'09 Lithium Ion Battery Separator films are produced and marketed by Toray Tonen Specialty Separator Godo Kaisha, a joint venture in which ExxonMobil has a 25% interest.

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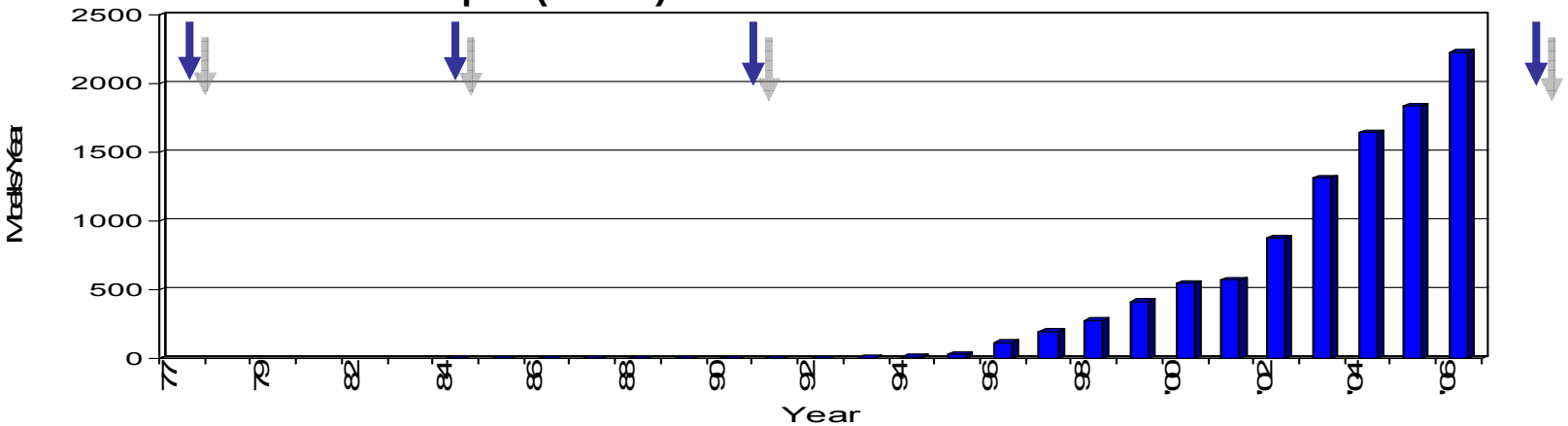
history of Li-ion batteries

Early Exxon Li-ion Battery at EV show Chicago, '77

Invention of microporous PE separator by Exxon and Mobil Affiliate In Japan (Tonen)

Tonen Separator used in world's first consumer LIB

Tonen - Toray JV formed



Applications: Cellphone, laptop, camcorder, digital camera, power tool, *e*bikes,…

1 Ah

14 Ah

70 Ah

220 Ah

4000+ Ah

Electrovaya's Maya-300

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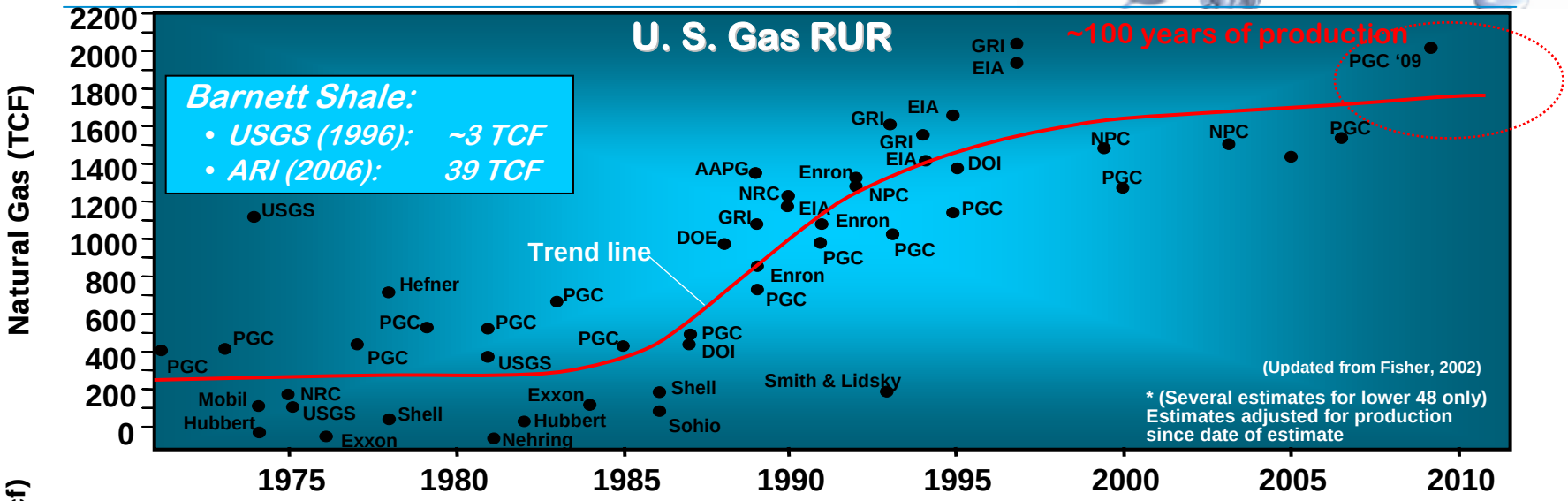
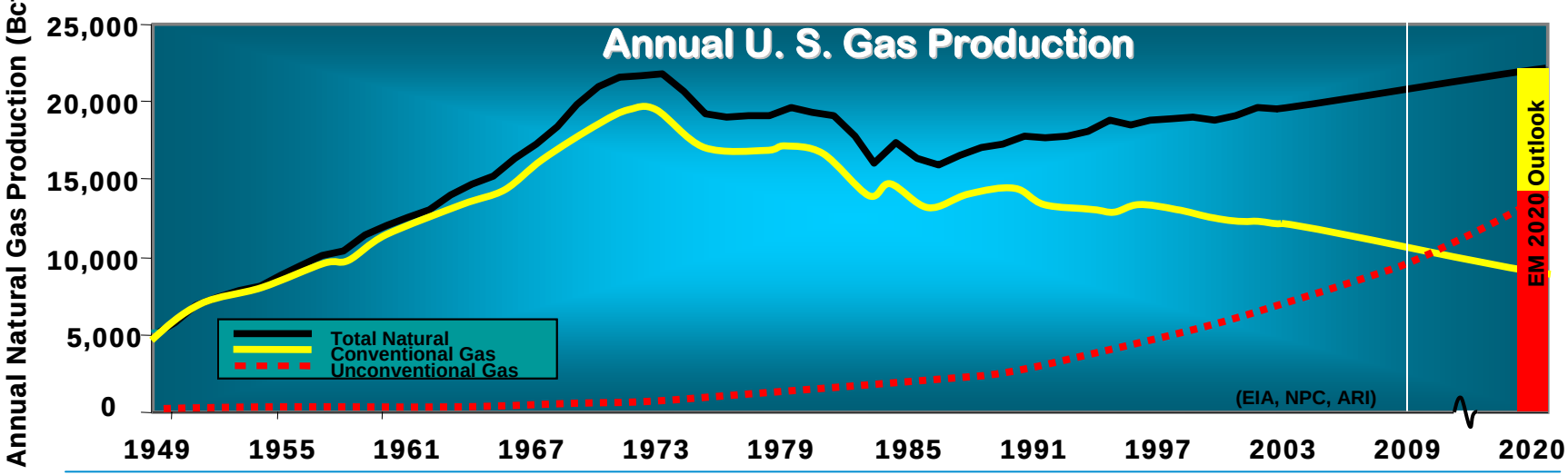
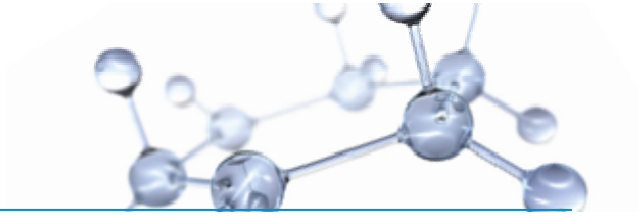
U. S. Gas RUR and Production

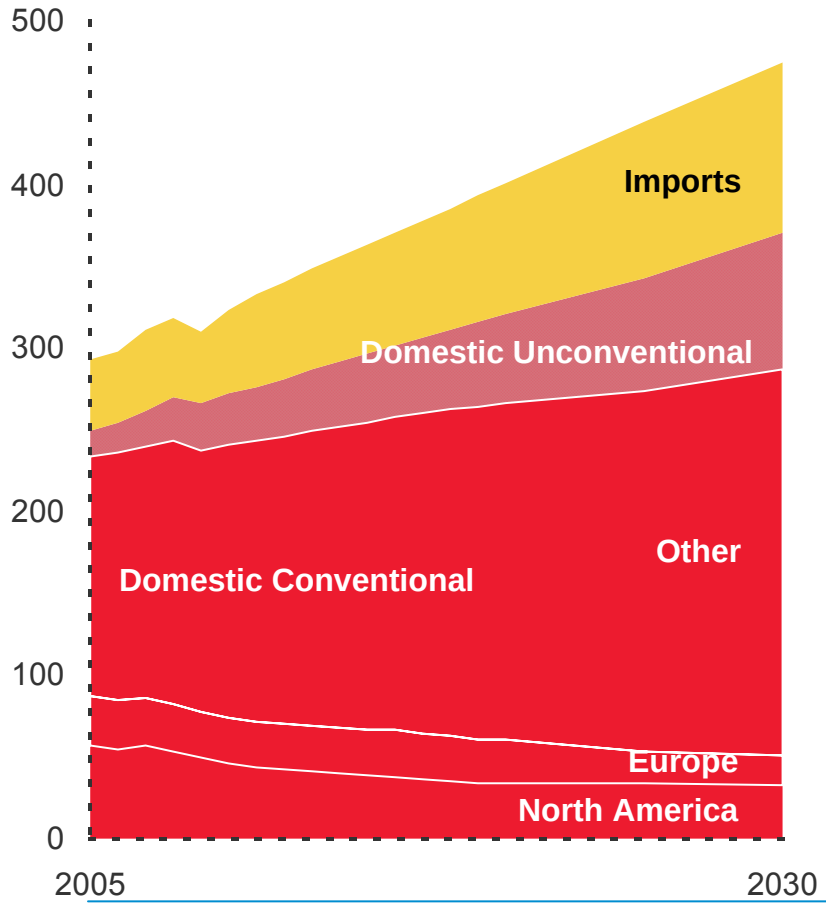




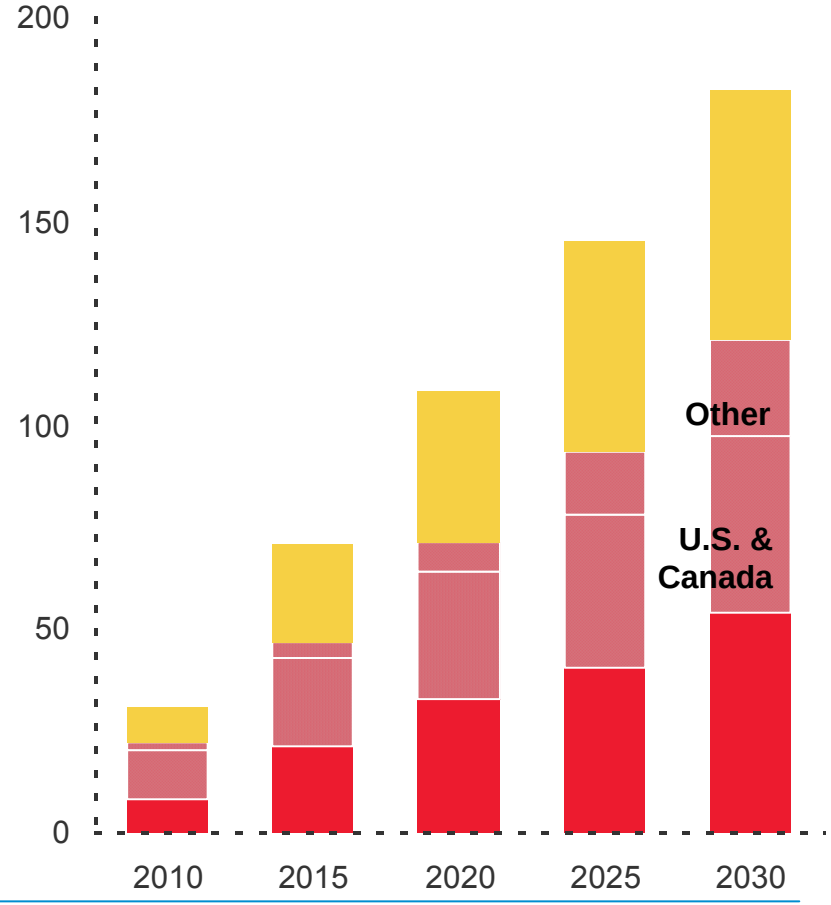
Natural Gas Supplies Diversify



Supply
BCFD



Growth 2005 to 2030
BCFD



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