Chapter 5: Fossil Energy

Coal/Natural Gas/Oil.....
Energy Content, $CO_2$ emission, availability

Fossil Energy Technologies......
Combustion engines, hybrids, turbines, Generators Electricity
Energy Flow by Sector and Source
Total = 94.6 Quadrillion Btu

US Energy Information Administration (EIA)
http://205.254.135.24/emeu/aer/consump.html
Non-renewable energy resources

- Oil: 32%
- Coal: 21%
- Natural Gas: 12%
- Biomass: 11%
- Hydropower, geothermal, solar, wind: 7%
- Nuclear power: 6%
Decreasing cost of extraction

Decreasing certainty

Undiscovered

Identified

Reserves

Other resources

Known

Decreasing cost of extraction

Economical

Not economical

Existence
Reserves and Resources: Definitions:

**Reserves:** Resources well known through geologic explorations and are recoverable at current prices and current technology.

**Proven reserves:** reasonably certain of being produced from known reservoirs under existing economic technological conditions.

**Indicated reserves:** can be recovered from known fields using improved recovery techniques.

**Inferred reserves:** deposits expected in identified fields but not yet measured.
Oil

Important questions:

How big are the world’s oil supplies?
How long will they last?

Answer:

There are many theories but nobody knows for sure.

How can we find out?

Everything depends on
Supply and Demand

We know that the world’s supplies are eventually expected to decline gradually when:

- affordable supplies of oil decrease as demand exceeds production and prices increase;
- other energy resources become economically acceptable.
Who has oil?

US has only 2% of the world’s oil reserves

World Reserves of Oil

but it uses about 26% of the oil extracted worldwide each year.

World Oil Use
## Who has the world’s oil supplies?

<table>
<thead>
<tr>
<th>Country</th>
<th>Production ($ \times 10^3$ bbl/day)</th>
<th>Estimated proven reserves ($ \times 10^6$ bbl)</th>
<th>Number of producing wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Former USSR</td>
<td>11,500</td>
<td>57,000</td>
<td>145,000</td>
</tr>
<tr>
<td>U.S.</td>
<td>7,200</td>
<td>26,177</td>
<td>603,000</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>6,215</td>
<td>257,504</td>
<td>858</td>
</tr>
<tr>
<td>Iran</td>
<td>3,120</td>
<td>92,850</td>
<td>361</td>
</tr>
<tr>
<td>China</td>
<td>2,755</td>
<td>24,000</td>
<td>43,700</td>
</tr>
<tr>
<td>Mexico</td>
<td>2,633</td>
<td>51,983</td>
<td>4,740</td>
</tr>
<tr>
<td>Venezuela</td>
<td>2,118</td>
<td>59,040</td>
<td>12,752</td>
</tr>
<tr>
<td>Iraq</td>
<td>2,083</td>
<td>100,000</td>
<td>820</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1,860</td>
<td>3,825</td>
<td>762</td>
</tr>
<tr>
<td>Nigeria</td>
<td>1,808</td>
<td>17,100</td>
<td>1,432</td>
</tr>
</tbody>
</table>

US is the second largest oil producer.  
# of wells in US is very large comparing to Saudi Arabia.  
(oil fields in US are very mature and production is very small)
Passenger vehicles consume about 80% of our imports.

Where does this oil go?

FIGURE 7.7
U.S. oil consumption by end use, 1999. (United States Energy Information Administration)
### TABLE 7.2 Conventional Oil Resources, Reserves, and Production (billion barrels, variable years as noted)

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>World</th>
<th>U.S. Percent of World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources</td>
<td>430&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3345&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.0</td>
</tr>
<tr>
<td>Reserves&lt;sup&gt;c&lt;/sup&gt;</td>
<td>29</td>
<td>1390</td>
<td>2.1</td>
</tr>
<tr>
<td>Annual production</td>
<td>2.5/yr</td>
<td>29.8/yr</td>
<td>8.4</td>
</tr>
<tr>
<td>Annual consumption</td>
<td>7.5/yr</td>
<td>31.1/yr&lt;sup&gt;d&lt;/sup&gt;</td>
<td>24.1</td>
</tr>
</tbody>
</table>

<sup>a</sup>DOE, 2006a, available at fossil.energy.gov/programs/oilgas/eor/Undeveloped_Domestic_Oil_Resources_Provi.html.
<sup>b</sup>NPC, 2007, p. 97.
<sup>d</sup>According to British Petroleum, 2008, discrepancies between world production and consumption “are accounted for by stock changes; consumption of nonpetroleum additives and substitute fuels; and unavoidable disparities in the definition, measurement, or conversion of oil supply and demand data.”

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America’s Energy Future: Technology and Transformation
### Table 7.3: Natural Gas Resources, Reserves, and Production

(Trillion cubic feet, variable years as noted)

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>World</th>
<th>U.S. Percent of World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources</td>
<td>1,525&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15,401&lt;sup&gt;b&lt;/sup&gt;</td>
<td>9.4</td>
</tr>
<tr>
<td>Reserves</td>
<td>211</td>
<td>6,263</td>
<td>3.4</td>
</tr>
<tr>
<td>Annual production</td>
<td>19.3/yr</td>
<td>104.1/yr</td>
<td>18.5</td>
</tr>
<tr>
<td>Annual consumption</td>
<td>23.1/yr</td>
<td>103.5/yr&lt;sup&gt;d&lt;/sup&gt;</td>
<td>22.3</td>
</tr>
</tbody>
</table>

<sup>a</sup>PGC, 2006, available at www.mines.edu/research/pga/.

<sup>b</sup>NPC, 2007, p. 97.


<sup>d</sup>According to British Petroleum, 2008, discrepancies between world production and consumption are “due to variations in stocks at storage facilities and liquefaction plants, together with unavoidable disparities in the definition, measurement or conversion of gas supply and demand data.”
FIGURE 7.2 U.S. Energy Information Administration reference case for U.S. natural gas production, showing the projected increase in the proportion of gas from unconventional sources along with the decline in gas from conventional sources. “Associated” refers to gas produced as a result of oil production.

Source: EIA, 2009b.
# TABLE 7.4 Coal Reserves and Production (million tonnes, variable years as noted)

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>World</th>
<th>U.S. Percent of World Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resources</td>
<td>3,968,000&lt;sup&gt;a&lt;/sup&gt;</td>
<td>9,218,000&lt;sup&gt;b&lt;/sup&gt;</td>
<td>43.0</td>
</tr>
<tr>
<td>Reserves</td>
<td>242,721</td>
<td>847,488</td>
<td>28.6</td>
</tr>
<tr>
<td>Annual production&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,039.2/yr</td>
<td>6,395.6/yr</td>
<td>16.2</td>
</tr>
<tr>
<td>Annual consumption&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1,015.3/yr</td>
<td>6,481.1/yr</td>
<td>15.7</td>
</tr>
</tbody>
</table>

<sup>a</sup>EIA, 1999.

<sup>b</sup>Hermann, 2006.

1000 MW coal plant will emit about 6 million tonnes of CO$_2$/year

Typical density of CO$_2$

1 barrel of oil = 158.987295 liters

1 tonne = 1000 kg
6 x $10^6$ tonnes x 1000kg/tonne = $6 \times 10^9$ kg
$6 \times 10^9$ kg / 1.799 kg/m$^3$ = $3.33 \times 10^9$ m$^3$
1 m$^3$ = 1000 liters
$3.33 \times 10^9$ liters/year

160,000 barrels/day
<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Barrels (billion)</th>
<th>Estimated Cost Range ($/bbl)</th>
<th>Time Period for Significant Recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oil Reserves</strong> (2007 annual U.S. production: 2.5 billion bbl(^a))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional light oil proved reserves(^b)</td>
<td>22</td>
<td>10–20</td>
<td>&lt;2020</td>
</tr>
<tr>
<td>Natural gas liquid proved reserves(^c)</td>
<td>8</td>
<td></td>
<td>&lt;2020</td>
</tr>
<tr>
<td><strong>Technically Recoverable Resources</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light oil EOR(^d)</td>
<td>90</td>
<td>20–45</td>
<td>&lt;2020</td>
</tr>
<tr>
<td>Heavy oil EOR(^b)</td>
<td>20</td>
<td>25–60</td>
<td>&lt;2020</td>
</tr>
<tr>
<td>Residual zone EOR(^c)</td>
<td>20</td>
<td>60–130</td>
<td>2020–2035</td>
</tr>
<tr>
<td>Undiscovered conventional (onshore)(^b)</td>
<td>43</td>
<td>40–60</td>
<td>2010–2035</td>
</tr>
<tr>
<td>Undiscovered conventional (offshore)(^b)</td>
<td>76</td>
<td>75–95</td>
<td>2020–2035</td>
</tr>
<tr>
<td>Undiscovered EOR (onshore)(^b)</td>
<td>22</td>
<td>50–75</td>
<td>&gt;2035</td>
</tr>
<tr>
<td>Undiscovered EOR (offshore)(^b)</td>
<td>38</td>
<td>105–145</td>
<td>&gt;2035</td>
</tr>
<tr>
<td>Reserve growth (conventional recovery)(^b)</td>
<td>71</td>
<td>10–20</td>
<td>&lt;2020</td>
</tr>
<tr>
<td>Reserve growth (EOR)(^b)</td>
<td>40</td>
<td>20–45</td>
<td>2020–2035</td>
</tr>
<tr>
<td>Tar sands(^b)</td>
<td>10</td>
<td>40–95</td>
<td>&gt;2035</td>
</tr>
<tr>
<td>Oil shales(^e)</td>
<td>500</td>
<td>40–95</td>
<td>&gt;2035</td>
</tr>
</tbody>
</table>

\(^a\)British Petroleum, 2008.
\(^b\)DOE, 2006a.
\(^c\)British Petroleum, 2008.
\(^d\)DOE, 2006b.
\(^e\)Bartis et al., 2005.
US imports ~50% of the oil it uses:

23% from Persian Gulf:
  (14% SA, 7% Iraq, 3% Kuwait)
15% from Canada
12% from Mexico
13% from Venezuela
7% from Nigeria

Monthly Oil Imports
Barrels of Oil Imported by the U.S.
362 million in June 2010

% Imported from Foreign Countries
62% in June 2010

Money Sent Overseas
$27.3 Billion in June 2010

http://www.pickensplan.com/oilimports/
Fuel includes oil, gas, coal, nuclear and traditional fuels. The **Middle East** is the region that exports the most fuel. The two biggest fuel exporters are Saudi Arabia and the Russian Federation, both are included in the Middle East region. The third biggest exporter is Norway, in Western Europe. These major exporters are known for their reserves of oil and gas, rather than coal and traditional fuels.

**North America** and **Western Europe** import (US$ gross) the highest values of fuel. The region that imports the least fuel is **Central Africa** - where six of the ten territories reported no fuel imports.
In the United States, most of the oil production (roughly 70%) is concentrated today in only five states.
**FIGURE 7.1** Estimated relative CO$_2$ emissions of alternative sources of hydrocarbon fuels.

*Source: Farrell and Brandt, 2006.*
International transport of oil is a big business; Potential increase of environmental problems.

Example:
Exxon Valdez spill, on Good Friday in 1989 near Prince William Sound. A quarter of a million barrels of oil spilled.

Example:
Oil Spill in the Gulf 2010 4.9 million barrels of oil spilled.
What is petroleum?

• A mixture of: crude oil, natural gas, and heavy asphaltic semisolids.

• Complex mixture of hydrocarbons (compounds containing only) hydrogen and carbon.

• Originates from the decay of organic materials (plants and marine life)
A very small remaining fraction is used to produce chemicals, which are the basis for the so-called petrochemical industry; (pharmaceuticals, cosmetics, plastics, detergents, textiles etc.)
Natural Gas

What is natural gas?  
It is a mixture of light hydrocarbons  
(~ 85% methane and ~ 15% ethane), some propane, butane and highly toxic hydrogen sulfide.  
It is formed from decayed organic material.  
Associated gas lies above most reservoirs of crude oil.  
Non-associated gas is found by itself in other underground sources (usually more costly to recover).
Safe & Responsible Development
How We Produce America’s New Natural Gas

The natural gas industry is at a defining moment that presents an unprecedented opportunity to our nation. Modern technology and vast new discoveries are now unlocking an abundant and sustainable supply of clean natural gas—right here in America—that can power our nation for generations to come.

Clean Energy Opportunities Across Our Nation

Increased utilization of this clean, abundant and domestic energy resource in power generation and transportation will dramatically accelerate U.S. efforts to reduce air pollution.

Natural gas vehicles can help cut our nation’s dependence on foreign sources of energy. And, because natural gas burns cleaner than other fuel sources, with less pollutants and no mercury, increasing its use in power generation could dramatically speed U.S. efforts to reduce greenhouse gas emissions.

Currently natural gas is vastly underutilized for power generation. This means there is substantial potential—right now—to accelerate our nation’s clean energy leadership without additional time and capital expenditures for new plants or new transmission facilities. Natural gas also is a clean, reliable partner with renewables, enabling their continued expansion by providing dependable back-up power on overcast or calm wind days.

Developments in the extraction of natural gas in dense shale formations thousands of feet below the earth’s surface gives us efficient access to vast new supplies of this clean energy resource.

http://www.anga.us/media/206825/hydraulic%20fracturing%20101.pdf
The Power of Progress

The industry has an ongoing commitment to continually reducing its environmental impact. Here are key highlights in our efforts to be good neighbors and good stewards of the land.

Smaller surface impact. The average well-site today is just 30 percent of the size of its 1970s counterpart—and today’s wells can access over 60 times more below-ground area.

Fewer wells, more clean energy. Half as many wells are needed to produce the same amount of clean energy as 20 years ago.

Less waste. We can retrieve the same amount of gas while producing 30 percent less waste than a decade ago.

Fewer air emissions. More efficient operations also mean less energy consumption, and thus less air emissions, per unit of natural gas produced.
How the Process Works

The vast increases in our domestic natural gas supplies over the last few years have been made possible by two technologies that have been improved in recent years to the point where we are now able to tap into deep supplies of natural gas that were once thought to be inaccessible.

The first of these technologies is horizontal drilling. That’s pretty much exactly what it sounds like – we drill one vertical hole that can then branch out into several horizontal cuts once the correct depth has been achieved. This is an important advancement because it significantly reduces the overall environmental impact of drilling activities by giving access to more of the natural gas formation underground from fewer wells above ground. Thanks to horizontal drilling, today’s average well site is just 30 percent of the size of its 1970s counterpart and can access 60 times more below-ground area. Continued technological advancements mean fewer wells recovering even greater reserves and creating less surface disturbance and waste.
The other improved technique that is allowing us to tap into new supplies of natural gas is hydraulic fracturing. As illustrated below, hydraulic fracturing or “fracking” takes place more than a mile below the earth’s surface. Today, the process is minimally invasive and involves drilling a small hole (typically about 15” in diameter), which is lined with multiple layers of steel encased in cement to protect any fresh water supplies and allow for the safe extraction of natural gas. Then pressurized water, sand and additives (less than one percent of the overall mixture) are used to create small, often millimeter-thick fissures in carefully targeted sections of the shale rock. This releases the natural gas, allowing it to safely rise to the surface within the self-contained system.
Multiple protective layers extend from surface to below aquifers.

Groundwater aquifers

- Private well, about 500 feet deep
- Public well, about 1,000 feet deep

- Several layers of steel tubes encased in cement protect groundwater supplies
- Protective steel casing encased in cement extends to shale depth

Depth from surface is typically more than a mile
Hydraulic fractionation is a controversial technique already used to extract natural gas in other states like Colorado and Texas. Oil companies pump water into the ground through a gas well with carcinogenic chemicals to break up the shale and take out the natural gas.

Carcinogenic chemicals cause cancer and a portion of the water that contains it remains in the ground. Yet the resource is so profitable that little regulation of it has been placed on oil companies by the state. Just this past June in Clearfield County, Pa., a gas well blew out and spewed polluted water for 16 hours.

“The amount of natural gas currently thought present in Marsellus Shale would supply the United States energy for 20 years but with the amount of gas and people power available, energy companies could actually be drilling for natural gas for the next 100 years. So that’s huge, and there’s a lot of money to be made by extracting this natural gas. Because of that, these energy companies are trying to extract it,” Dr. David Dunbar, associate professor of biology, said.

One of the agreements made this summer to pass the final 2010-2011 Pennsylvania state budget on time was to enact a natural gas severance tax by Oct. 1. Pennsylvania is the only major natural gas-producing state without a severance tax. This tax is placed on non-renewable resources.
WASHINGTON — Federal geologists published new estimates this week for the amount of natural gas that exists in a giant rock formation known as the Marcellus Shale, which stretches from New York to Virginia.

The shale formation has about 84 trillion cubic feet of undiscovered, technically recoverable natural gas, according to the report from the United States Geological Survey. This is drastically lower than the 410 trillion cubic feet that was published earlier this year by the federal Energy Information Administration.

As a result, the Energy Information Administration, which is responsible for quantifying oil and gas supplies, has said it will slash its official estimate for the Marcellus Shale by nearly 80 percent, a move that is likely to generate new questions about how the agency calculates its estimates and why it was so far off in its projections.
LETTERS
How Should New York Proceed on Hydrofracking?
Published: September 17, 2011

To the Editor:

While there is an initial appeal to fast-forwarding this process in times of dire economic downturn, there is a potential cost to such action. Failure to understand fully and plan adequately for the potential adverse consequences of drilling will transfer the risk and cost of such events from drillers to individual citizens or to New York’s taxpayers.
We expect government to play a role in planning for and protection of the public welfare. Therefore, we must resist the political and economic expediency that compressing the review process would provide. The gas is not, after all, a transient resource. It has been there for millennia; it will be there upon completion of an unabridged review and regulatory process.
BETSEY SWAN
President, League of Women Voters of New York State
Menands, N.Y., Sept. 12, 2011
Natural gas, the first cousin to crude oil, is a combustible fossil fuel often found in underground reservoirs and comprised of methane and other hydrocarbon compounds. A century ago, natural gas was considered a waste product in oil fields and flared or vented off. But after a giant gas field was found in the Panhandle in 1918, it was used to manufacture carbon black, which is used to make car tires. Eventually, Americans began using gas to heat their homes and, later, to fire power plants. But it never became as important a fuel as coal, oil or even nuclear power.
World Shale Gas Resources
Republished from an initial assessment of 14 regions outside of the United States by the
Energy Information Administration
The Natural Gas "Game Changer"

The development of shale gas plays has become a “game changer” for the U.S. natural gas market. The proliferation of activity into new shale plays has increased shale gas production in the United States from 0.39 trillion cubic feet in 2000 to 4.87 trillion cubic feet in 2010, or 23 percent of U.S. dry gas production. Shale gas reserves have increased to about 60.6 trillion cubic feet by year-end 2009, when they comprised about 21 percent of overall U.S. natural gas reserves, now at the highest level since 1971. [3]

The growing importance of U.S. shale gas resources is also reflected in EIA’s Annual Energy Outlook 2011 (AEO2011) energy projections, with technically recoverable U.S. shale gas resources now estimated at 862 trillion cubic feet. Given a total natural gas resource base of 2,543 trillion cubic feet in the AEO2011 Reference case, shale gas resources constitute 34 percent of the domestic natural gas resource base represented in the AEO2011 projections and 50 percent of lower 48 onshore resources. As a result, shale gas is the largest contributor to the projected growth in production, and by 2035 shale gas production accounts for 46 percent of U.S. natural gas production.

http://geology.com/energy/world-shale-gas/
Geology and Resources of Some World Oil-Shale Deposits
Why is the gas consumption growing?

→ Relatively clean

→ Relatively cheap

→ Relatively easy to transport through pipelines

How about an overseas transport?

Natural gas can be converted to liquid (LNG; liquefied natural gas) at very low temperatures (-300F). Then it can be shipped over long distances. It takes up only 1/600 of the volume of room temperature gas. Libya, Algeria, Nigeria, Venezuela are possible sources of natural gas that way.
What are the uses of natural gas?

**Commercial Customers 14%**
Use gas mostly for space heating
3.1 tcf

**Utility Customers 15%**
Use gas mostly for boiler and turbine fuel
3.3 tcf

**Residential Customers 21%**
Use gas mostly for home heating and cooking
5.0 tcf

**Industrial Customers 46%**
Use gas mostly for boiler fuel, feedstocks, and processing
9.7 tcf

**Transportation 3%**
0.7 tcf

FIGURE 7.12
U.S. natural gas consumption by end-use sector: 1999. *(United States Energy Information Administration)*
Natural gas can be used to produce electricity.

- More efficient than burning coal, oil, or using nuclear power.
- Produce much less CO$_2$ and smog causing nitrogen oxides
- Gas-fired electrical-generating units can be small (apartments or office building)
Who has the world’s natural gas supplies?

Russia and Kazakhstan 42% of world’s reserves
Iran 15%
Qatar 5%
Saudi Arabia 4%
US, Nigeria and Venezuela 3%(each)
<table>
<thead>
<tr>
<th>Position</th>
<th>Country</th>
<th>Natural Gas Reserves (cu m)</th>
<th>Year of Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Russia</td>
<td>44,800,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>2.</td>
<td>Iran</td>
<td>29,610,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>3.</td>
<td>Qatar</td>
<td>25,370,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>4.</td>
<td>Saudi Arabia</td>
<td>7,807,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>5.</td>
<td>USA</td>
<td>7,716,000,000,000</td>
<td>January 2009 est.</td>
</tr>
<tr>
<td>6.</td>
<td>Turkmenistan</td>
<td>7,504,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>7.</td>
<td>United Arab Emirates</td>
<td>6,453,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>8.</td>
<td>Nigeria</td>
<td>5,292,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>9.</td>
<td>Venezuela</td>
<td>5,065,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>10.</td>
<td>Algeria</td>
<td>4,502,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>11.</td>
<td>Iraq</td>
<td>3,170,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>12.</td>
<td>Australia</td>
<td>3,115,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>13.</td>
<td>Indonesia</td>
<td>3,001,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>14.</td>
<td>Kazakhstan</td>
<td>2,407,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>15.</td>
<td>Malaysia</td>
<td>2,400,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>16.</td>
<td>European Union</td>
<td>2,211,000,000,000</td>
<td>January 2010 est.</td>
</tr>
<tr>
<td>17.</td>
<td>Egypt</td>
<td>2,186,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>18.</td>
<td>Norway</td>
<td>2,039,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>19.</td>
<td>Uzbekistan</td>
<td>1,841,000,000,000</td>
<td>January 2011 est.</td>
</tr>
<tr>
<td>20.</td>
<td>Kuwait</td>
<td>1,798,000,000,000</td>
<td>January 2011 est.</td>
</tr>
</tbody>
</table>

CIA: This entry is the stock of proved reserves of natural gas in cubic meters (cu m). Proved reserves are those quantities of natural gas, which, by analysis of geological and engineering data, can be estimated with a high degree of confidence to be commercially recoverable from a given date forward, from known reservoirs and under current economic conditions.
Coal

Where are the largest supplies?

World recoverable reserves of coal

US has about $\frac{1}{4}$ of total reserves.
Twice as much of our energy consumption comes from oil as from coal.

Why?

Transportation

US oil consumption
90% of coal used today is used to produce electricity.  
52% of U.S electricity comes from coal.
Partially decayed plant matter in swamps and bogs; low heat content

Low heat content; low sulfur content; limited supplies in most areas

Extensively used as a fuel because of its high heat content and large supplies; normally has a high sulfur content

Highly desirable fuel because of its high heat content and low sulfur content; supplies are limited in most areas
Future sources of oil

Oil shale

Oil shale is an organic solid combustible compound called kerogen trapped in a rock. Heating the rock produces shale oil.

Good news: 😊
Estimated potential global supplies are about 240 times larger than estimated global supplies of conventional oil.

Bad news: 😞
Most deposits are of such a low grade that it takes more energy and money to mine and convert the kerogen to crude oil than the resulting fuel is worth.
Tar sand (or oil sand)
It is a mixture of clay, sand, water and a combustible organic material called bitumen (a thick and heavy oil with a high sulfur content).
So, how do these fossil fuel facts effect the production of electricity?

How quickly can people be convinced of energy efficiency arguments?

What about coal?

Legislation of CO$_2$ emission will change supply curve

R&D for carbon capture technologies?

If not now? When?
FIGURE 7.13  Locations of coal-fired power plants and potential subsurface formations that could be used for geologic storage of CO$_2$. Source: MIT, 2007.
Global warming has become perhaps the most complicated issue facing world leaders. On the one hand, warnings from the scientific community are becoming louder, as an increasing body of science points to rising dangers from the ongoing buildup of human-related greenhouse gases — produced mainly by the burning of fossil fuels and forests. On the other, the technological, economic and political issues that have to be resolved before a concerted worldwide effort to reduce emissions can begin have gotten no simpler, particularly in the face of a global economic slowdown.
New York Times
### Efficiency

#### Conservation

---


<table>
<thead>
<tr>
<th></th>
<th>Conservative Estimate</th>
<th>Optimistic Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2020</td>
<td>2030</td>
</tr>
<tr>
<td>Buildings, primary (source) electricity</td>
<td>9.4</td>
<td>14.4</td>
</tr>
<tr>
<td>Residential</td>
<td>4.4</td>
<td>6.4</td>
</tr>
<tr>
<td>Commercial</td>
<td>5.0</td>
<td>8.0</td>
</tr>
<tr>
<td>Buildings, natural gas</td>
<td>2.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Residential</td>
<td>1.5</td>
<td>1.5</td>
</tr>
<tr>
<td>Commercial</td>
<td>0.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Transportation, light-duty vehicles</td>
<td>2.0</td>
<td>8.2</td>
</tr>
<tr>
<td>Industry, manufacturing</td>
<td>4.9</td>
<td>4.9</td>
</tr>
<tr>
<td>Total</td>
<td>18.6</td>
<td>30.5</td>
</tr>
</tbody>
</table>

Note: Savings are relative to the reference scenario of the EIA’s *Annual Energy Outlook 2008* (EIA, 2008) or, for transportation, a similar scenario developed by the panel. See Table 1.2 for more information on the baselines used in the panel’s analysis of the buildings, transportation, and industry sectors.
OVERARCHING FINDINGS

Overarching Finding 1

Energy-efficient technologies for residences and commercial buildings, transportation, and industry exist today, or are expected to be developed in the normal course of business, that could potentially save 30 percent of the energy used in the U.S. economy while also saving money. If energy prices are high enough to motivate investment in energy efficiency, or if public policies are put in place that have the same effect, U.S. energy use could be lower than business-as-usual projections by 19–22 quadrillion Btu (17–20 percent) in 2020 and by 30–36 quadrillion Btu (25–31 percent) in 2030.2,3

The transportation fraction would be higher if heavy-duty vehicles and aviation had been included in the panel’s analysis.

The basis for comparison for the buildings and industry sectors is the reference scenario of the U.S. Department of Energy’s Annual Energy Outlook 2008 (EIA, 2008a) and the panel’s similar but slightly modified baseline for the transportation sector.

The AEF Committee’s report (NAS-NAE-NRC, 2009) estimated the amount of possible savings as 15–17 quads (about 15 percent) by 2020 and 32–35 quads (about 30 percent) by 2030. Since the release of that report, further analysis by the panel refined the amount of possible savings in 2020 to 17–20 percent.
Overarching Finding 2

The full deployment of cost-effective, energy-efficient technologies in buildings alone could eliminate the need to add to U.S. electricity generation capacity. Since the estimated electricity savings in buildings exceeds the EIA forecast for new net electricity generation in 2030, implementing these efficiency measures would mean that no new generation would be required except to address regional supply imbalances, replace obsolete generation assets, or substitute more environmentally benign generation sources.
Overarching Finding 3

The barriers to improving energy efficiency are formidable. Overcoming these barriers will require significant public and private support, as well as sustained initiative. The experience of leading states provides valuable lessons for national, state, and local policy makers in the leadership skills required and the policies that are most effective.

Buildings can last decades....capital investment and equipment when a building is built are barriers to implementing energy efficient technologies..
Overarching Finding 4

Long-lived capital stock and infrastructure can lock in patterns of energy use for decades. Thus, it is important to take advantage of opportunities (during the design and construction of new buildings or major subsystems, for example) to insert energy-efficient technologies into these long-lived capital goods.
Total energy consumption in the United States in 2008, by sector and fuel. Shown are electricity consumption—with the losses in generation, transmission and distribution allocated to the end-use sectors—and the fuels used on-site in each sector. Electricity is generated off-site using fossil, renewable, and nuclear energy sources.
Source: EIA 2009a, as updated by EIA, 2009c.

Space heating
Space cooling and ventilation
Lighting....
Household Use

Space Heating/Cooling

Water Heating

Lighting

Appliances

Sustainability?
For humans to live sustainably, the Earth's resources must be used at a rate at which they can be replenished. However, there is now clear scientific evidence that humanity is living unsustainably, and that an unprecedented collective effort is needed to return human use of natural resources to within sustainable limits. Since the 1980s, the idea of human sustainability has become increasingly associated with the integration of economic, social and environmental spheres. In 1989, the World Commission on Environment and Development articulated what has now become a widely accepted definition of sustainability: 

"[to meet] the needs of the present without compromising the ability of future generations to meet their own needs.\"
Significant amounts of energy are flushed out of buildings in the water, air and compost streams. Off the shelf, on-site energy recycling technologies can effectively recapture energy from waste hot water and stale air and transfer that energy into incoming fresh cold water or fresh air. Recapture of energy for uses other than gardening from compost leaving buildings requires centralized anaerobic digesters.
Waste-to-energy (WtE) or energy-from-waste (EfW) is the process of creating energy in the form of \textit{electricity} or \textit{heat} from the incineration of \textit{waste source}. WtE is a form of \textit{energy recovery}. Most WtE processes produce electricity directly through combustion, or produce a combustible fuel commodity, such as \textit{methane}, \textit{methanol}, \textit{ethanol} or synthetic fuels.
What is the role of the government in Energy Conservation?

set mandatory standards...

Never passed...........

2005...Energy Policy Act
Reduce Natural energy consumption
Tax credits for hybrids/diesel cars

2011...everything derailed
<table>
<thead>
<tr>
<th>Policy or Program</th>
<th>Electricity Savings (TWh/yr)</th>
<th>Primary Energy Savings (Quads/yr)</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAFE vehicle efficiency standards</td>
<td>—</td>
<td>4.80</td>
<td>2006</td>
<td>NRC, 2002(^a)</td>
</tr>
<tr>
<td>Appliance efficiency standards</td>
<td>196</td>
<td>2.58</td>
<td>2006</td>
<td>Nadel et al., 2006(^b)</td>
</tr>
<tr>
<td>PURPA and other CHP initiatives</td>
<td>—</td>
<td>1.62</td>
<td>2006</td>
<td>Shipley et al., 2008(^c)</td>
</tr>
<tr>
<td>ENERGY STAR(^®) labeling and promotion</td>
<td>132</td>
<td>1.52</td>
<td>2006</td>
<td>EPA, 2007(^d)</td>
</tr>
<tr>
<td>Building energy codes</td>
<td>—</td>
<td>1.08</td>
<td>2006</td>
<td>Nadel, 2004(^e)</td>
</tr>
<tr>
<td>Utility and state end-use efficiency programs</td>
<td>90</td>
<td>1.06</td>
<td>2006</td>
<td>York and Kushler, 2006(^f)</td>
</tr>
<tr>
<td>DOE industrial efficiency programs</td>
<td>—</td>
<td>0.40</td>
<td>2005</td>
<td>DOE, 2007(^b)</td>
</tr>
<tr>
<td>Weatherization assistance program</td>
<td>—</td>
<td>0.14</td>
<td>2006</td>
<td>DOE, 2006(^g)</td>
</tr>
<tr>
<td>Federal energy management program</td>
<td>—</td>
<td>0.11</td>
<td>2005</td>
<td>FEMP, 2006(^h)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>—</td>
<td>13.32</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

\(^a\) Extrapolation of fuel savings estimated by the NRC to 2006, and assuming 75 percent of the energy savings from vehicle efficiency improvements are due to the CAFE standards.

\(^b\) Interpolates between savings estimates by ACEEE for 2000 and 2010.

\(^c\) Assumes that 85 percent of the energy savings from all CHP systems installed in 2006 was due to PURPA and other policy initiatives.

\(^d\) Assumes only 75 percent of the energy savings estimated by U.S. EPA in order to avoid double counting savings with utility and state programs.

\(^e\) Increases the energy savings estimate for new buildings constructed during 1990–1999 from Nadel (2004) by 100 percent to account for the impact of codes prior to 1990 and post-1999.

\(^f\) Extrapolates the 2004 national electricity savings estimate to 2006 based on national DSM budget estimates for 2005 and 2006.

\(^g\) Assumes 5.6 million weatherized households and average energy savings of 25 million Btu/yr per household, from Berry and Schweitzer (2003).

\(^h\) Based on the reported reduction in energy use per square foot of floor area during 1985–2005 and actual primary energy use in federal buildings as of 2005 (i.e., excluding energy use by transport vehicles and equipment).
FIGURE 5.2 ENERGY STAR® appliance market shares (percent of new sales), 1997–2006.  
Note: AC = air conditioner.  
FIGURE 5.3 Per capita electricity consumption (not including on-site generation) in California, New York, and the United States, 1960–2006.

FIGURE 5.7 Annual electricity savings from key energy efficiency policies and programs implemented in California, 1975–2003. 
TABLE 5.4  Comparison of Per Capita Electricity Use in the United States and in New York in 2006

<table>
<thead>
<tr>
<th></th>
<th>United States (kWh/person)</th>
<th>New York (kWh/person)</th>
<th>Difference (kWh/person)</th>
<th>Difference (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4,514</td>
<td>2,508</td>
<td>2,006</td>
<td>41</td>
</tr>
<tr>
<td>Commercial</td>
<td>4,341</td>
<td>3,938</td>
<td>403</td>
<td>8</td>
</tr>
<tr>
<td>Industrial</td>
<td>3,378</td>
<td>776</td>
<td>2,602</td>
<td>53</td>
</tr>
<tr>
<td>Transportation</td>
<td>25</td>
<td>145</td>
<td>-121</td>
<td>-2</td>
</tr>
<tr>
<td>Total</td>
<td>12,258</td>
<td>7,367</td>
<td>4,890</td>
<td>100</td>
</tr>
</tbody>
</table>
FIGURE 5.8 New York State’s annual energy efficiency expenditures (in constant 2007 dollars) and achievements, 1990–2007.

Note: EE = energy efficiency; GWh = gigawatt-hours; LIPA = Long Island Power Authority; NYPA = New York Power Authority; NYSERDA = New York State Energy Research and Development Authority.

Source: Courtesy of NYSERDA.
**FIGURE 5.9** New York State’s energy efficiency achievements, 1990 through 2007: annual electricity use.

Note: *EE* = energy efficiency; *LIPA* = Long Island Power Authority; *NYPA* = New York Power Authority; *NYSERDA* = New York State Energy Research and Development Authority.

Source: Courtesy of NYSERDA.
2005...Energy Policy Act

changed US energy policy by providing tax incentives and loan guarantees for energy production of various types.

In Congressional bills an "authorization" of a discretionary program is a permission to spend money, while an "appropriation" is the actual decision to spend it; none of the authorizations will mean anything if the money is never appropriated.

Tax reductions by subject area
$4.3 billion for nuclear power\[^9\]
$2.8 billion for fossil fuel production
$2.7 billion to extend the renewable electricity production credit
$1.6 billion in tax incentives for investments in clean coal facilities
$1.3 billion for conservation and energy efficiency
$1.3 billion for alternative motor vehicles and fuels (bioethanol, biomethane, liquified natural gas, propane)
$500 million Clean Renewable Energy Bonds (CREBS) for government agencies for renewable energy projects.
General provisions

Authorizes loan guarantees for "innovative technologies" that avoid greenhouse gases, which might include advanced nuclear reactor designs (such as PBMR) as well as clean coal and renewable energy;

Increases the amount of biofuel (usually ethanol) that must be mixed with gasoline sold in the United States to 4 billion gallons by 2006, 6.1 billion gallons by 2009 and 7.5 billion gallons by 2012;

Seeks to increase coal as an energy source while also reducing air pollution, through authorizing $200 million annually for clean coal initiatives, repealing the current 160-acre cap on coal leases, allowing the advanced payment of royalties from coal mines and requiring an assessment of coal resources on federal lands that are not national parks;

Authorizes subsidies for wind and other alternative energy producers;

Adds ocean energy sources including wave and tidal power for the first time as separately identified, renewable technologies;
Authorizes $50 million annually over the life of the law for biomass grants;

Contains provisions aimed at making geothermal energy more competitive with fossil fuels in generating electricity;

Requires the US Department of Energy to study and report on existing natural energy resources including wind, solar, waves and tides;

Authorizes the Department of the Interior to grant leases for activity that involves the production, transportation or transmission of energy on Outer Continental Shelf lands from sources other than gas and oil (Section 388);

Requires the U.S. Department of Energy to study and report on national benefits of demand response and make a recommendation on achieving specific levels of benefits and encourages time-based pricing and other forms of demand response as a policy decision;

Requires all public electric utilities to offer net metering on request to their customers;
Outer continental Shelf
Requires the DOE to designate National Interest Electric Transmission Corridors where there are significant transmission limitations adversely affecting the public. The Federal Energy Regulatory Commission may authorize federal permits for transmission projects in these regions.

Provides tax breaks for those making energy conservation improvements to their homes;

Provides incentives to companies drilling for oil in the Gulf of Mexico;

Exempts oil and gas producers from certain requirements of the Safe Drinking Water Act;

Extends daylight saving time by four to five weeks, depending upon the year (see below);

Requires that no drilling for gas or oil may be done in or underneath the Great Lakes;

Requires that Federal Fleet vehicles capable of operating on alternative fuels be operated on these fuels exclusively (Section 701.);

Sets federal reliability standards regulating the electrical grid (done in response to the Blackout of 2003);[1]
Nuclear-specific provisions:[6]

• Extends the Price-Anderson Nuclear Industries Indemnity Act through 2025;

• Authorizes cost-overrun support of up to $2 billion total for up to six new nuclear power plants;

• Authorizes a production tax credit of up to $125 million total per year, estimated at 1.8 US$/kWh during the first eight years of operation for the first 6,000 MW of capacity[7]; consistent with renewables;

• Authorizes $1.25 billion for the Department of Energy to build a nuclear reactor to generate both electricity and hydrogen;

• Allows nuclear plant employees and certain contractors to carry firearms;

• Prohibits the sale, export or transfer of nuclear materials and "sensitive nuclear technology" to any state sponsor of terrorist activities;

• Updates tax treatment of decommissioning funds;

• A provision for the U.S. Department of Energy to report in one year on how to dispose of high-level nuclear waste;
Directs the Secretary of the Interior to complete a programmatic environmental impact statement for a commercial leasing program for oil shale and tar sands resources on public lands with an emphasis on the most geologically prospective lands within each of the states of Colorado, Utah, and Wyoming.[8]
Commercial building deduction

The Act contains provisions for commercial buildings that make improvements to their energy systems. Energy improvements completed in 2006 and 2007 are eligible for tax deductions of as much as $1.80 per square foot. The incentives focus on improvements to lighting, HVAC and building envelope. Improvements are compared to a baseline of ASHRAE 2001 standards.

ASHRAE: American Society of Heating, Refrigeration, and Air-Conditioning Engineers

Many buildings are eligible for tax deductions for improvements completed or planned within the normal course of business, and can thus "free ride" for the new incentives. Achievement of these benefits requires cooperation between the facilities/energy division of a business and its tax department. A tax advisor with engineers on staff may serve as a bridge between these two historically separate business divisions. For municipal buildings, benefits are passed through to the primary designers/architects in an attempt to encourage innovative municipal design.
Energy management

The commercial building tax deductions can be used to improve the payback period of a prospective energy improvement investment.

Often the deductions are combined with participation in demand response programs where buildings agree to curtail usage at peak times for a premium.

The most common qualifying projects are in the lighting area. Industrial spaces such as Manufacturing, Warehouse and Distribution Centers are typically lit with 400W Metal Halide fixtures. These fixtures are commonly being upgraded with Hi-Bay Fluorescent fixtures that can cut energy use in half as well as qualify the building for tax deductions. In the Northeast paybacks for this project can get below one year.
Congressional Budget Office (CBO) cost estimate

The Congressional Budget Office review of the conference version of the bill estimated the Act will increase direct spending by $1.6 billion, and reduce revenue by $12.3 billion between 2006 and 2015. The CBO noted that the bill could have additional effects on discretionary spending, but did not attempt to estimate those effects.
Criticisms

The *Washington Post* contended that the spending bill is a broad collection of subsidies for United States energy companies; in particular, the nuclear and oil industries.

Texas companies in particular benefit from the bill. This criticism is heightened by the fact that President *George W. Bush*, the *House Majority Leader* (Tom DeLay), and the Chairman of the *House Energy & Commerce Committee* (Joe Barton) were all from Texas. The fact that the bill passed 66-29 with wide support from Democrats for the bill has not calmed this criticism (a *Philadelphia Inquirer* editorial on *July 28, 2005*, suggested Congress had a "let's pass it and claim we did something" attitude).

Speaking for the National Republicans for Environmental Protection Association, President Martha Marks said that the organization was disappointed in the bill: it did not give enough support to conservation, and continued to subsidize the well-established oil and gas industries that don't require subsidizing.

The bill did not include provisions for drilling in the Arctic National Wildlife Refuge (ANWR) even though some Republicans claim "access to the abundant oil reserves in ANWR would strengthen America's energy independence without harming the environment."

**HOME ENERGY EFFICIENCY IMPROVEMENT TAX CREDITS**
Consumers who purchase and install specific products, such as energy-efficient windows, insulation, doors, roofs, and heating and cooling equipment in existing homes can receive a tax credit for 30% of the cost, up to $1,500, for improvements "placed in service" starting January 1, 2009, through December 31, 2010.

See EnergyStar.gov's [Federal Tax Credits for Energy Efficiency](http://www.energystar.gov) for a complete summary of energy efficiency tax credits available to consumers.

**RESIDENTIAL RENEWABLE ENERGY TAX CREDITS**
Consumers who install solar energy systems (including solar water heating and solar electric systems), small wind systems, geothermal heat pumps, and residential fuel cell and microturbine systems can receive a 30% tax credit for systems placed in service before December 31, 2016; the previous tax credit cap no longer applies.

[http://www.energy.gov/media/HR_1424.pdf](http://www.energy.gov/media/HR_1424.pdf) Energy Tax Incentives
Example: A 1500 ft$^2$ wall has an R-value of 11 hr.F.ft$^2$/Btu, including the effects of inside and outside air layers. How many Btu are lost through this wall in a 5600 degree day heating season?

\[
Q = \left( \frac{\text{Area}}{\text{Total R value}} \right) (\Delta T) \text{ (time)}
\]

\[
Q = \left[ \frac{1500 \text{ ft}^2}{11 \text{ hr.F.ft}^2/\text{Btu}} \right] (5600 \text{ degree day})(24 \text{ hrs/day})
\]

\[
Q = 183272272 \text{ Btu}
\]

\[
Q = 1.83 \times 10^8 \text{ Btu}
\]

- R value of plywood (3/4 inch): 0.94
- Urea foam per inch: 5.25
- Poured concrete: 0.08
- Fiberglass per inch: 3.70
Example: Suppose it costs a utility $0.04/kWh to generate electricity, long-distance energy transport is $0.0002/kWh/km and that local transport costs $0.016/kWh/km.

Why is local transport more expensive than long-distance transport?

a. If the plant is 250km from the substation and the substation is 25 km from home, what is the cost of 1 kWh of electricity in your home?

b. How much of the cost is for local as opposed to long-distance transmission?

c. Can the utility sell for for $0.06/kWh and make a profit?

\[
1 \text{kWh} \times 250 \text{km} \times 0.0002/\text{kWh/km} = $0.05 \text{ cost of long distance transmission}
\]

\[
1 \text{kWh} \times 25 \text{km} \times 0.016/\text{kWh/km} = $0.04 \text{ cost of local transmission}
\]

\[
0.04 + 0.05 + 0.04 = $0.13/\text{kWh}
\]

\[
0.04/0.13 \times 100 = 30.8\%
\]
In 2006, you have a choice between keeping your 13-year old model refrigerator that uses 515 kWh/yr or buying a new one that uses 440 kWh/yr. Given the average lifetime of 19 yrs for a refrigerator, would you save money or spend money overall by 2012 if you bought the efficient model at $500? $0.10/kWh

6 yrs x 515 kWh/yr = 3090 kWh
6 yrs x 440 kWh/yr = 2640 kWh

3090 kWh x $0.10/kWh = $309.0
$309.0

New one in 2006 until 2012:
2640 kWh x 0.10 /kWh + $500 = $764.40
For 13 more years $44/yr = $572.00
$1336 (by 2025)

Would you change your mind if you knew that the best available would be 380 kWh/yr

380 kWh/yr x $0.10/kWh x 6 yrs = $228.0 + $500 = $728
What can we do about Transportation?

Energy Efficiency with respect to transportation

Near term
- improve efficiencies of cars/trains/etc.
- improve engines/diesel/hybrids/transmissions/weight of automobiles

Medium term
- changes in power-train and vehicle technologies
- hybrid-electric
- fully battery-electric vehicles

Longer term
- new technologies
- hydrogen fuel cells? Hydrogen distribution infrastructure
Transportation
Global ~22% Carbon Emissions: ~30%

Residential, Industrial, Commercial

28% Transportation
72% Other

Fuels Used in Transportation
62% Gasoline (petroleum)
24% Diesel (petroleum)
8% Jet Fuel (petroleum)
2% Natural Gas
4% Other
Natural gas combined cycle...carbon dioxide capture and storage
FIGURE 2.14 Estimated gasoline-equivalent costs of alternative liquid fuels. For comparison, the costs of gasoline at crude oil prices of $60 per barrel and $100 per barrel are shown on the left. Estimated costs assume that a zero price is assigned to CO₂ emissions. Liquid fuels would be produced using biochemical conversion to produce ethanol from Miscanthus or using thermochemical conversion via Fischer-Tropsch or methanol-to-gasoline. All costs are in 2007 dollars and are rounded to the nearest $5.

Note: BTL = biomass-to-liquid fuel; CBTL = coal-and-biomass-to-liquid fuel; CCS = carbon capture and storage; CTL = coal-to-liquid fuel.
Energy Use by type of vehicle

- Automobiles: 32%
- Light Trucks: 28%
- Other Trucks: 16%
- Aircraft: 9%
- Water: 5%
- Construction & Agriculture: 4%
- Pipelines: 3%
- Trains & Buses: 3%
What are the issues?

- Efficiency
- Conservation
- New Technologies
http://youtu.be/xr19m8tRZ4g

23.6 km/l
3.785 liters = 1 gallon
Did you know that the bicycle is the most energy efficient transportation mode? It is 3 times more efficient than walking, 5 times more efficient than using the train and 15 to 20 times more efficient than driving a car.
Physics:

Power = Energy / time

Energy = force x distance

Force for moving a car ..................
Forces for moving a car.......................... Total Force

Forces due to accelerating
+ 
Forces of going upward (hills)
+ 
Forces for resisting rolling
+ 
Forces associated with aerodynamic drag
= Total Force
Forces for moving a car.................. Total Force
first piece:
Forces due to acceleration
\[ F = ma \]
= \text{mass of the car} \times \text{acceleration}
= \text{mass of the car} \times (\text{change in velocity})

Driving:

0-60 miles per hour in 10 seconds..

1 mile = 5280 feet

Initial velocity = 0 mph
Final velocity = 60 mph
Change in velocity = 60 mph/10 seconds
60 miles/hr \times 5280\text{ft/mi} \times 1\text{hr}/3600s = 88 \text{ft/s}
Per 10 s......

Acceleration = 8.8 \text{ ft/s}^2
Forces for moving a car.................................. Total Force

Forces due to accelerating (F=ma)

+ 

Forces of going upward (hills)

= mgh

= m \times g \times \text{incline or steepness (slope)}

= mgs
Forces for moving a car.......................... Total Force

Forces due to accelerating (F=ma)

+ Forces of going upward (hills) (F=mgs)

+ Forces from resistance

\[ F = C_r m v \]

\( C_r \) is specific to a car

...of course so is the mass...
Forces for moving a car

Forces due to accelerating \((F=ma)\) 

+ 

Forces of going upward (hills) \((F=mgs)\) 

+ 

Forces from resistance \((F= C_r mv)\) 

+ 

Forces from aerodynamic drag
Forces for moving a car

Total Force

Forces due to accelerating \((F=ma)\)

+ Forces of going upward (hills) \((F=mg\sin\theta)\)

+ Forces from resistance \((F=Cr\text{mv})\)

+ Forces from aerodynamic drag

\(F\) is proportional to \(C_D A_f v^2\)

\(C_D\) is aerodynamic drag coefficient

\(A_f\) is the frontal Area of the car

\(v\) is velocity...it goes as velocity squared
Physics:

Power = Energy / time

Energy = force x distance

Force for moving a car
In gasoline-powered vehicles, over 62 percent of the fuel's energy is lost in the internal combustion engine (ICE). ICE engines are very inefficient at converting the fuel's chemical energy to mechanical energy, losing energy to engine friction, pumping air into and out of the engine, and wasted heat.
What speed should you drive to get the best mileage???

In general, smaller, lighter, more aerodynamic cars will get their best mileage at higher speeds. Bigger, heavier, less aerodynamic vehicles will get their best mileage at lower speeds.
## Motor Fuel Tax Rates for Selected Countries

<table>
<thead>
<tr>
<th>COUNTRY</th>
<th>GASOLINE</th>
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WASHINGTON (Reuters) - The U.S. government on Friday imposed the first increase in mileage standards for passenger cars and boosted the floor for sport utilities and pickups beginning with model year 2011 vehicles.

"These standards are important steps in the nation's quest to achieve energy independence," said Transportation Secretary Ray LaHood, who added that work on future mileage programs must take into account the health of U.S.
The standard, which is expected to cost industry $1.4 billion in vehicle design and other changes, would require compacts, sedans and other passenger cars to average 30.2 miles per gallon in combined city/highway driving, up from the 27.5 mpg standard that was established in the late 1970s under the Corporate Average Fuel Economy (CAFE) program.
Toyota Motor Corp expects its 2010 Prius hybrid to get 46 mpg while estimates for the Insight hybrid made by Honda Motor Co is 41 mpg. Detroit's efforts to revamp its fleet include the Ford Fusion hybrid sedan, due in showrooms this spring, that gets 41 mpg/city.

Light trucks, which include pickups and SUVs, would have to average 24.1 mpg in 2011, compared with 23.5 mpg the previous year. Overall fleet performance would be 27.3 mpg, a 2 mpg increase over 2010, according to the 857-page regulation.

The new standards would save nearly 900 million gallons of fuel and reduce carbon dioxide emissions by 8.3 million metric tons over the lifetime of model year 2011 vehicles, the Transportation Department said. The administration calculates more than $2 billion in overall benefits to consumers from the program, including less money spent on fuel. Congress has required that the U.S. fleet of cars and light trucks average 35 mpg by 2020, a 40 percent increase over today's performance.
What is the CAFÉ standard?

Corporate Average Fuel Economy

First enacted by Congress in 1975, the purpose of CAFE is to reduce energy consumption by increasing the fuel economy of cars and light trucks. Regulating CAFE is the responsibility of NHTSA and the Environmental Protection Agency (EPA). NHTSA sets fuel economy standards for cars and light trucks sold in the U.S.; EPA calculates the average fuel economy for each manufacturer.

Congress specifies that CAFE standards must be set at the "maximum feasible level" given consideration for

1. technological feasibility;
2. economic practicality;
3. effect of other standards on fuel economy; and
4. need of the nation to conserve energy.
If the average fuel economy of a manufacturer's annual fleet of car and/or truck production falls below the defined standard, the manufacturer must pay a penalty, currently $5.50 USD per 0.1 mpg under the standard, multiplied by the manufacturer's total production for the U.S. domestic market.

But everything is changing ....
Café Standards
President Obama Debuts 54.5 mpg CAFE Fuel Economy Standard for 2025
Ben Timmins on July 29 2011 4:30 PM

Taking a break from talking about trillions of dollars in national debt, President Obama took a few minutes to announce a deal with automakers to raise Corporate Average Fuel Economy standards to 54.5 mpg by 2025 — essentially double the current mandate.

CAFE standards were already reset in May of 2009, when President Obama mandated that the fuel economy average of an automaker’s product portfolio must reach 35.5 mpg by 2016. Today’s announcement is a continuation of that plan and also the largest mandatory fuel economy increase in history.

Read more: http://wot.motortrend.com/president-obama-debuts-54-5-mpg-cafe-fuel-economy-standard-for-2025-102217.html#ixzz1ZlYg9xAT
Yesterday, the Obama administration raised the corporate average fuel efficiency (CAFE) standards for the U.S. automobile fleet from 27.5 miles per gallon (mpg) to 35.5 mpg by 2016. According to the government, the new standards will add about $1,000 to the price of new automobiles, but drivers will be able to recoup the cost through buying less gasoline over the life of the vehicles. Maybe. But this convoluted effort to reduce American consumption of gasoline actually functions as a kind of inefficient stealth tax on driving. It's inefficient because drivers pay more, car companies make less money, and state and federal governments don't get any extra revenues.

In 2002, the National Academy of Sciences issued a report on CAFE standards which correctly observed:
There is a marked inconsistency between pressing automotive manufacturers for improved fuel economy from new vehicles on the one hand and insisting on low real gasoline prices on the other. Higher real prices for gasoline—through increased gasoline taxes—would create both the demand for fuel efficient new vehicles and an incentive for owners of existing vehicles to drive them less."

In other words, taxing gasoline would achieve the Obama administration’s stated goals of reducing imports of foreign oil and cutting greenhouse gas emissions much more efficiently than labyrinthine CAFE standards—since taxes would apply to all vehicles, not just new ones.

Ultimately, there is no getting around the fact that setting higher CAFE standards is just a way for cowardly politicians to avoid telling their fellow citizens that they should pay more for the privilege of driving.
What are our choices?

Better Technology...more fuel efficient cars

.......no fuel cars

China Vies to Be World’s Leader in Electric Cars

By KEITH BRADSHIER
PUBLISHED: APRIL 1, 2009

TIANJIN, China — Chinese leaders have adopted a plan aimed at turning the country into one of the leading producers of hybrid and all-electric vehicles within three years, and making it the world leader in electric cars and buses after that.

To some extent, China is making a virtue of a liability. It is behind the United States, Japan and other countries when it comes to making gas-powered vehicles, but by skipping the current technology, China hopes to get a jump on the next.
But electric vehicles may do little to clear the country’s smog-darkened sky or curb its rapidly rising emissions of global warming gases. China gets three-fourths of its electricity from coal, which produces more soot and more greenhouse gases than other fuels.

A report by McKinsey & Company last autumn estimated that replacing a gasoline-powered car with a similar-size electric car in China would reduce greenhouse emissions by only 19%. It would reduce urban pollution, however, by shifting the source of smog from car exhaust pipes to power plants, which are often located outside cities.

Beyond manufacturing, subsidies of up to $8,800 are being offered to taxi fleets and local government agencies in 13 Chinese cities for each hybrid or all-electric vehicle they purchase. The state electricity grid has been ordered to set up electric car charging stations in Beijing, Shanghai and Tianjin.
Government research subsidies for electric car designs are increasing rapidly. And an interagency panel is planning tax credits for consumers who buy alternative energy Vehicles. China wants to raise its annual production capacity to 500,000 hybrid or all-electric cars and buses by the end of 2011, from 2,100 last year, government officials and Chinese auto executives said. By comparison, CSM Worldwide, a consulting firm that does forecasts for automakers, predicts that Japan and South Korea together will be producing 1.1 million hybrid or all-electric light vehicles by then and North America will be making 267,000.

The United States Department of Energy has its own $25 billion program to develop electric-powered cars and improve battery technology, and will receive another $2 B for battery development as part of the economic stimulus program enacted by Congress.

Premier Wen Jiabao highlighted the importance of electric cars two years ago with his unlikely choice to become minister of science and technology: Wan Gang, a Shanghai-born former Audi auto engineer in Germany who later became the chief scientist for the Chinese government’s research panel on electric vehicles.
How green are electric cars?

Internal combustion engine 15% efficient

Electricity has to be produced somehow

Efficiency of plants to produce electricity from petroleum ... 38%

Efficiency of electric cars ... 40%

0.40 x 0.38 = 0.15 about the same... as ICE
Storage of energy/power in an electric car?

Batteries....slow to charge
........................lose power while charging
........................can’t store very much energy
How does a battery work?
How does a battery work?

In any battery, an electrochemical reaction occurs. This reaction moves electrons from one pole to the other. The actual metals and electrolytes used control the voltage of the battery -- each different reaction has a characteristic voltage. For example, here's what happens in one cell of a car's lead-acid battery:

The cell has one plate made of lead and another plate made of lead dioxide, with a strong sulfuric acid electrolyte in which the plates are immersed.

Lead combines with SO4 (sulfate) to create PbSO4 (lead sulfate), plus one electron.

Lead dioxide, hydrogen ions and SO4 ions, plus electrons from the lead plate, create PbSO4 and water on the lead dioxide plate.

As the battery discharges, both plates build up PbSO4 and water builds up in the acid.

The characteristic voltage is about 2 volts per cell, so by combining six cells you get a 12-volt battery.
Hybrids- two or more distinct power systems....

Power sources include:
On-board or out-board **rechargeable energy storage system** (RESS)
- **Gasoline** or **Diesel fuel**
- **Hydrogen**
- **Compressed air**
- **Human powered** e.g. pedaling or rowing
- **Wind**
- **Compressed** or **liquefied natural gas**
- **Solar**
- Coal, wood or other solid combustibles
- Electromagnetic fields, Radio waves

**Battery-diesel**
**Electric-petroleum**
**Sails-steam**

**Trains**
**Ships**
**Planes**
**Cars**
Fuel Cells

A fuel cell is an electrochemical conversion device. It produces electricity from fuel (on the anode side) and an oxidant (on the cathode side), which react in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.

Fuel Cell vs. Battery

Fuel cells are different from electrochemical cell batteries in that they consume reactant from an external source, which must be replenished. By contrast batteries store electrical energy chemically and hence represent a thermodynamically closed system.

Hydrogen Fuel Cells

Many combinations of fuel and oxidant are possible. A hydrogen cell uses hydrogen as fuel and oxygen (usually from air) as oxidant. Other fuels include hydrocarbons and alcohols.
Critics charge that the time frame for overcoming the technical and economic challenges to implementing wide-scale use of hydrogen vehicles is likely to be at least several decades, and hydrogen vehicles may never become broadly available. They believe that the focus on the use of the hydrogen car is a dangerous detour from more readily available solutions to reducing the use of fossil fuels in vehicles.