Energy and Emissions
Forms of Energy

Traditional
- Coal
- Methane
- Nuclear
- Oil

Renewable
- Wind
- Solar
- Hydro
- Ethanol??
Estimated U.S. Energy Use in 2008: ~99.2 Quads

Solar 0.09
Nuclear 8.45
Hydro 2.45
Wind 0.51
Geothermal 0.35
Natural Gas 23.84
Coal 22.42
Biomass 3.88
Petroleum 37.13

Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527
Carbon Based Energy

Coal, Natural Gas, Oil
Carbon Emissions

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Natural Gas</th>
<th>Oil</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>117,000</td>
<td>164,000</td>
<td>208,000</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>40</td>
<td>33</td>
<td>208</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>92</td>
<td>448</td>
<td>457</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>1</td>
<td>1,122</td>
<td>2,591</td>
</tr>
<tr>
<td>Particulates</td>
<td>7</td>
<td>84</td>
<td>2,744</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.000</td>
<td>0.007</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Table 5. U.S. Carbon Dioxide Emissions from Energy and Industry, 1990-2008
(Million Metric Tons Carbon Dioxide)

Fossil Fuel Emission Levels
Pounds per Billion Btu of Energy

Input

\*Includes emissions from electricity generation using nonbiogenic municipal solid waste and geothermal energy.
\*Emissions from nonfuel uses are included in the energy subtotal above.
\*The Btu value of carbon sequestered by nonfuel uses is subtracted from energy consumption before emissions are calculated.


Source: EIA estimates.
C + O$_2$ -> CO$_2$

C$_{137}$H$_{97}$O$_9$NS (bituminous)
C$_{240}$H$_{90}$O$_4$NS (anthracite)

Coal is mined in anthracite, bituminous, sub-bituminous, and lignite forms. These forms all have different, but similar chemical composition.

SO$_2$, NO$_x$, Particulates, Mercury
More Coal Emissions

- Incomplete combustion:
  - Nitrogen also released from nitrogen present in coal.

- Also Sulfur is released, mainly from sulfur-rich coal from Appalachia

\[
\begin{align*}
C (s) + CO_2 (g) & \rightarrow 2CO (g) \\
N (s) + O_2 (g) & \rightarrow NO_2 (g) \\
N (s) & \rightarrow N_2 (g) \\
S + O_2 & \rightarrow SO_2
\end{align*}
\]
Methane

Methane, also known as natural gas.

Net Chemical Equation: \[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

Intermediate Mechanisms:

\[ \text{CH}_4 + \text{O}_2 \rightarrow \text{CO} + \text{H}_2 + \text{H}_2\text{O} \]
\[ \text{H}_2 + \frac{1}{2} \text{O}_2 \rightarrow \text{H}_2\text{O} \]
\[ \text{CO} + \frac{1}{2} \text{O}_2 \rightarrow \text{CO}_2 \]

When combustion occurs, methane turns into \( \text{CO}_2 \) and \( \text{H}_2\text{O} \). When released into the atmosphere as \( \text{CH}_4 \), it is 20 more potent a greenhouse gas.

Natural gas is a mixture of hydrocarbons such as methane (\( \text{CH}_4 \), 80%), ethane (\( \text{C}_2\text{H}_6 \), 7%), propane (\( \text{C}_3\text{H}_8 \), 6%), butane (\( \text{C}_4\text{H}_{10} \), 4%), and pentane (\( \text{C}_5\text{H}_{12} \), 3%). It also can include \( \text{CO}_2 \), helium, hydrogen sulfide, and nitrogen.

Due to incomplete combustion, \( \text{CO} \) is certainly produced from burning any hydrocarbon.
Gasoline is mixed with different octanes. For example, 87-octane gasoline would be 87% volume iso-octane (2, 2, 4-trimethylpentane) and 13% heptane.
Other Elements in Oil Combustion

As stated in previous slide, petroleum products, when combusted also produce CO, NO\textsubscript{x}, SO\textsubscript{2}, particulates, and trace amounts of mercury. We’ve learned that NO\textsubscript{x} contributes to Ozone production and photochemical smog.

| Table 2 Ash analysis of Huadian oil shale (mass%) |
|-----------------|----------|----------|--------|--------|----------|--------|--------|--------|
| SiO\textsubscript{2} | Al\textsubscript{2}O\textsubscript{3} | Fe\textsubscript{2}O\textsubscript{3} | CaO | MgO | TiO\textsubscript{2} | Na\textsubscript{2}O | K\textsubscript{2}O |
| 52.9 | 17.74 | 6.65 | 14.77 | 2.99 | 0.55 | 0.89 | 1.27 |
Renewables

Wind,
Solar,
Hydro,
Geothermal

Clean Renewable Energy
Wind Turbines
Cradle to Grave Lifecycle Analysis

Analyzing 1 p life cycle 'LCA Vestas V90'; Method: Eco-indicator 99 (H) V2.03 / Europe EI 99 H/H / characterization
Figure 3. Model for wind turbine in SimaPro
# Wind Turbines

## Cradle
- Total of 7405 MWh of electricity are needed
- Steel production
- Glass fibre, reinforced plastic
- Cast iron
- Copper
- Aluminum
- Concrete (on site)
- Transportation and erection (5382 kg diesel)

## Grave
- Maintenance emits little, except from transportation
- 90% of steel and cast iron is recycled
- 90% of copper is recycled
- 100% of glass products are incinerated
- 100% concrete is land filled
- Transportation emissions

All Data for wind turbines came from *Life Cycle Assessment of a Wind Turbine*, Nalukowe
Difference in emissions and resource use with different energy sources.

If the production and erection of wind turbines is eventually powered by wind turbines, the net impact of new turbines will be next to negligible, especially when it comes to atmospheric effects.
Solar PV & Concentrated Solar

- Solar Photovoltaic Cells contain a good amount of harsh chemicals and minerals, but most of them don’t reach the gaseous phase in their lifecycle.

- Concentrated Solar Panels are produced from covering a smooth surface, historically glass, with a silver or aluminum coating.

“In the best case scenario, one square meter of solar cells carries a burden of 75 kilograms of CO2. In the worst case scenario, that becomes 314 kilograms of CO2. With a solar insolation of 1,700 kWh/m²/yr an average household needs 8 to 10 square meters of solar panels, with a solar insolation of 900 kWh/m²/yr this becomes 16 to 20 square meters. Which means that the total CO2 debt of a solar installation is 600 to 3,140 kilograms of CO2 in sunny places, and 1,200 to 6,280 kilograms of CO2 in less sunny regions. These numbers equate to 2 to 20 flights Brussels-Lissabon (up and down, per passenger).”

- Low Tech Magazine
While I display obvious bias towards the implementation of a strong clean energy bill, I think the science clearly explains the reasoning behind a clean energy bill. Not only would it be stimulating economically, it would greatly reduce greenhouse gas emissions and local pollution.

As shown by the life cycle assessment for a wind turbine, once renewable energy is installed, the effect of all production, not only wind turbine production, would decrease. While there is not doubt that there are impacts of all energy forms, it seems that renewables would largely decrease such impacts.
Picture References

- http://www.climatechangeconnection.org/Solutions/Nuclearenergy.htm
- http://www.energyinsights.net/cgi-script/csArticles/articles/000001/000128.htm
- https://www-pls.llnl.gov/?url=science_and_technology-chemistry-combustion
- http://upload.wikimedia.org/wikipedia/commons/7/79/Isooctane.png
- http://dev.nsta.org/evwebs/3368/images/solar_cells_panels_array_monocrystaline.jpg
References

http://telstar.ote.cmu.edu/environ/m3/s3/09fossil.shtml

http://www.naturalgas.org/environment/naturalgas.asp

http://chemed.chem.purdue.edu/genchem/topicreview/bp/1organic/coal.html

http://www.unctad.org/infocomm/anglais/gas/characteristics.htm

http://www.openchemistry.co.uk/open_chemistry/ch9/oil_combustion.pdf

http://www.springerlink.com/content/0146655505197363/fulltext.pdf