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ATOC 3500
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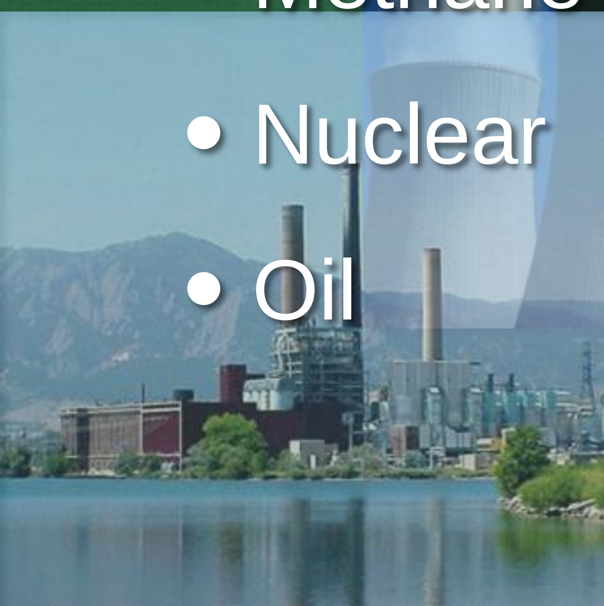
# Energy and Emissions

# Forms of Energy

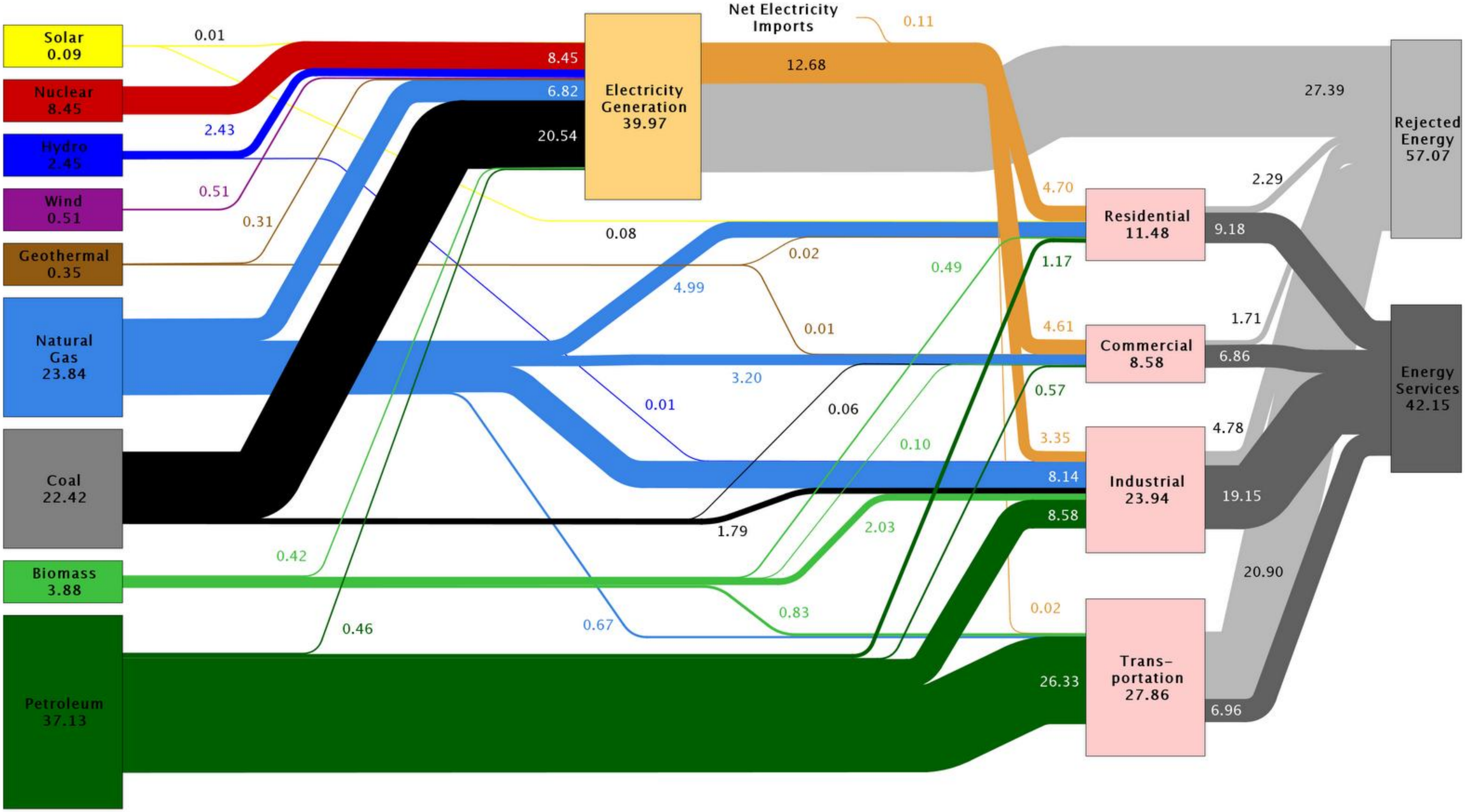
Traditional

- Coal
- Methane
- Nuclear
- Oil


Renewable

- Wind
- Solar
- Hydro
- Ethanol??

# Estimated U.S. Energy Use in 2008: ~99.2 Quads




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

| Fuel Type or Process | 1990 | 1995 | 2000 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Energy Consumption** | | | | | | | | | | |
| Petroleum | 2,185.9 | 2,208.4 | 2,461.3 | 2,469.9 | 2,516.7 | 2,605.4 | 2,625.7 | 2,594.9 | 2,588.6 | 2,436.0 |
| Coal | 1,803.4 | 1,899.9 | 2,138.1 | 2,077.2 | 2,115.6 | 2,140.3 | 2,161.0 | 2,129.9 | 2,154.5 | 2,125.2 |
| Natural Gas | 1,024.7 | 1,183.7 | 1,240.6 | 1,229.5 | 1,194.6 | 1,195.4 | 1,176.1 | 1,157.1 | 1,231.7 | 1,241.8 |
| Renewables[a] | 6.1 | 10.2 | 10.4 | 13.0 | 11.7 | 11.4 | 11.5 | 11.8 | 11.6 | 11.6 |
| **Energy Subtotal** | **5,020.1** | **5,302.3** | **5,850.4** | **5,789.6** | **5,838.6** | **5,952.5** | **5,974.3** | **5,893.7** | **5,986.4** | **5,814.4** |
| *Nonfuel Use Emissions*[b] | *97.1* | *104.9* | *109.8* | *103.7* | *101.7* | *110.8* | *104.7* | *108.9* | *106.7* | *100.2* |
| *Nonfuel Use Sequestration*[c] | *252.7* | *286.6* | *308.2* | *296.0* | *292.1* | *315.4* | *305.1* | *301.9* | *293.7* | *264.2* |
| Adjustments to Energy | -82.9 | -63.1 | -61.7 | -38.2 | -28.7 | -44.6 | -48.8 | -70.9 | -74.9 | -79.0 |
| **Adjusted Energy Subtotal** | **4,937.2** | **5,239.1** | **5,788.7** | **5,751.4** | **5,809.9** | **5,907.9** | **5,925.5** | **5,822.8** | **5,911.5** | **5,735.5** |
| Other Sources | 85.1 | 102.3 | 97.8 | 97.7 | 98.9 | 102.0 | 103.5 | 106.0 | 105.6 | 103.8 |
| **Total** | **5,022.3** | **5,341.5** | **5,886.4** | **5,849.1** | **5,908.8** | **6,009.9** | **6,029.0** | **5,928.7** | **6,017.0** | **5,839.3** |

[a]Includes emissions from electricity generation using nonbiogenic municipal solid waste and geothermal energy.
[b]Emissions from nonfuel uses are included in the energy subtotal above.
[c]The Btu value of carbon sequestered by nonfuel uses is subtracted from energy consumption before emissions are calculated.
Notes: Data in this table are revised from the data contained in the previous EIA report, *Emissions of Greenhouse Gases in the United States 2007*, DOE/EIA-0573(2007) (Washington, DC, December 2008). Totals may not equal sum of components due to independent rounding. Adjusted energy subtotal includes U.S. Territories but excludes international bunker fuels.
Source: EIA estimates.

## Fossil Fuel Emission Levels

**Pounds per Billion Btu of Energy Input**

| Pollutant | Natural Gas | Oil | Coal |
|---|---|---|---|
| Carbon Dioxide | 117,000 | 164,000 | 208,000 |
| Carbon Monoxide | 40 | 33 | 208 |
| Nitrogen Oxides | 92 | 448 | 457 |
| Sulfur Dioxide | 1 | 1,122 | 2,591 |
| Particulates | 7 | 84 | 2,744 |
| Mercury | 0.000 | 0.007 | 0.016 |

# $C + O_2 \rightarrow CO_2$

$C_{137}H_{97}O_9NS$ (bituminous)
$C_{240}H_{90}O_4NS$ (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

- C (s) + $CO_2$ (g) -> 2CO (g)
- N (s) + $O_2$ (g) -> $NO_2$ (g)

  N (s) -> $N_2$ (g)

- S + $O_2$ -> $SO_2$

# Methane

Methane, also known as natural gas.

Net Chemical Equation:

$CH_4 + 2O_2 \rightarrow CO_2 + H_20$

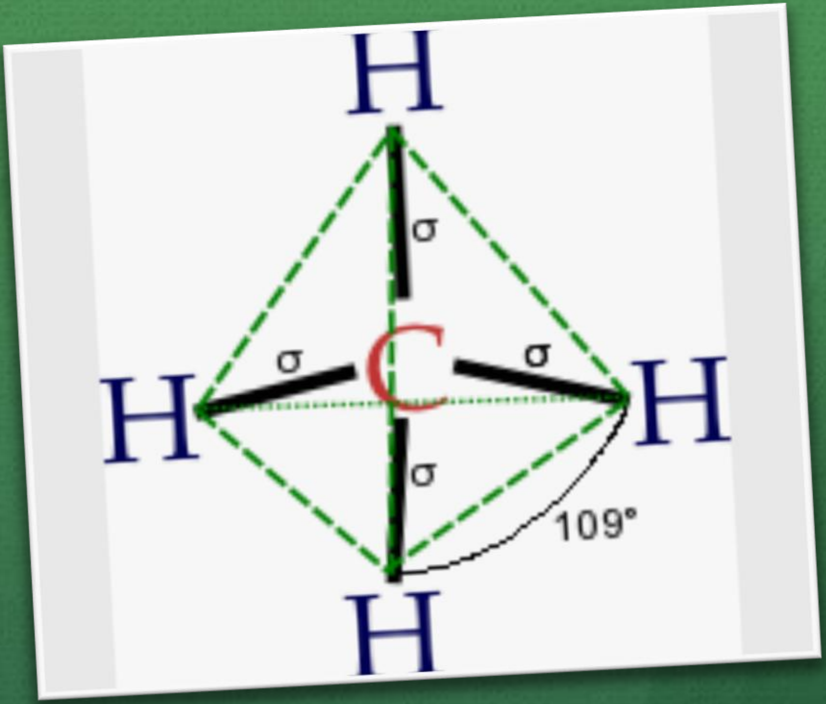
Intermediate Mechanisms:

$CH_4 + O_2 \rightarrow CO + H_2 + H_20$

$H_2 + ½ O_2 \rightarrow H_2O$

$CO + ½ O_2 \rightarrow CO_2$

Natural gas is a mixture of hydrocarbons such as methane ($CH_4$, 80%), ethane ($C_2H_6$, 7%), propane ($C_3h_8$, 6%), butane ($C_4H_{10}$, 4%), and pentane ($C_5H_{12}$, 3%). It also can include $CO_2$, helium, hydrogen sulfide, and nitrogen.




When combustion occurs, methane turns into $CO_2$ and $H_2O$. When released into the atmosphere as $CH_4$, it is 20 more potent a greenhouse gas.

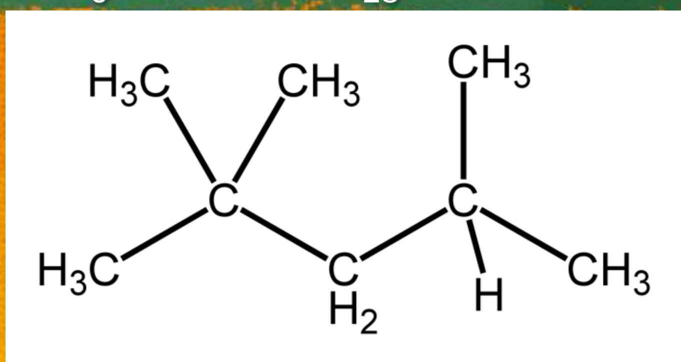
Due to incomplete combustion, CO is certainly produced from burning any hydrocarbon.

# Petroleum

**$C_7H_{16}$ + $11O_2$ $7CO_2$ + $8H_2O$ + energy**

2 $C_4H_{10}$(g) + 13 $O_2$(g) -> 8 $CO_2$(g) + 10 $H_{2O}$

Gasoline can be a mix of hydrocarbons from $C_6$ mixes to $C_{18}$.



Gasoline is mixed with different octances. 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, $NO_X$, $SO_2$, particulates, and trace amounts of mercury. We've learned that $No_x$ contributes to Ozone production and photochemical smog.

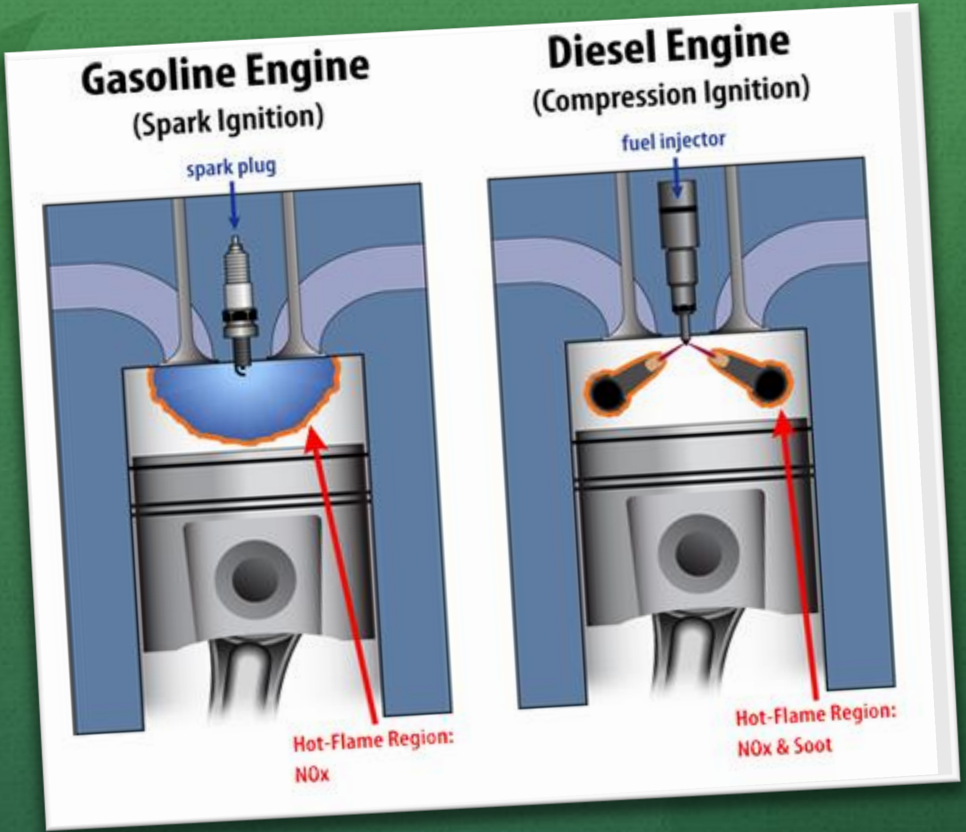
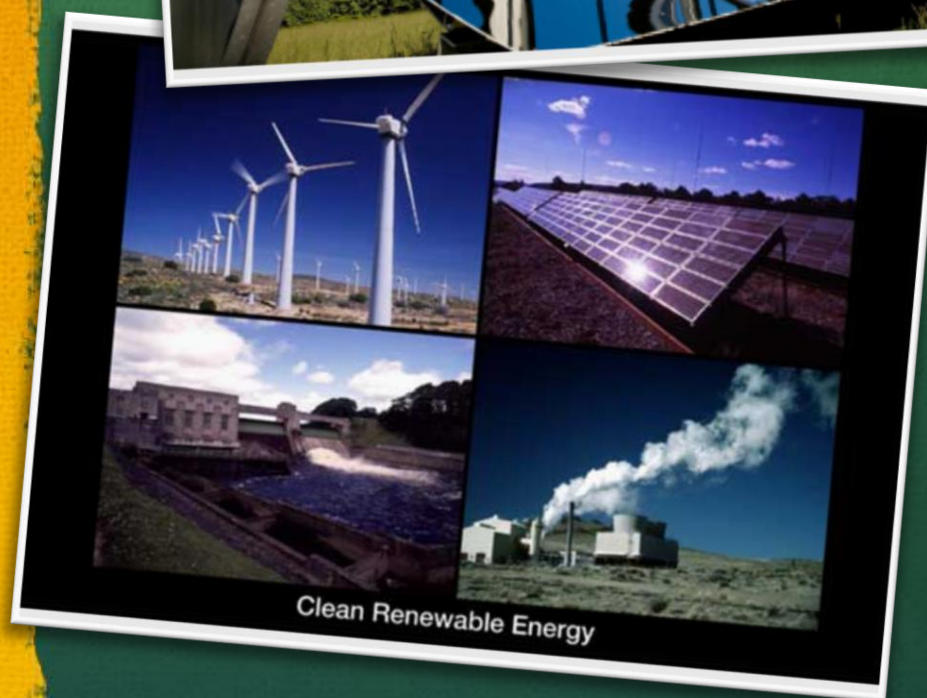


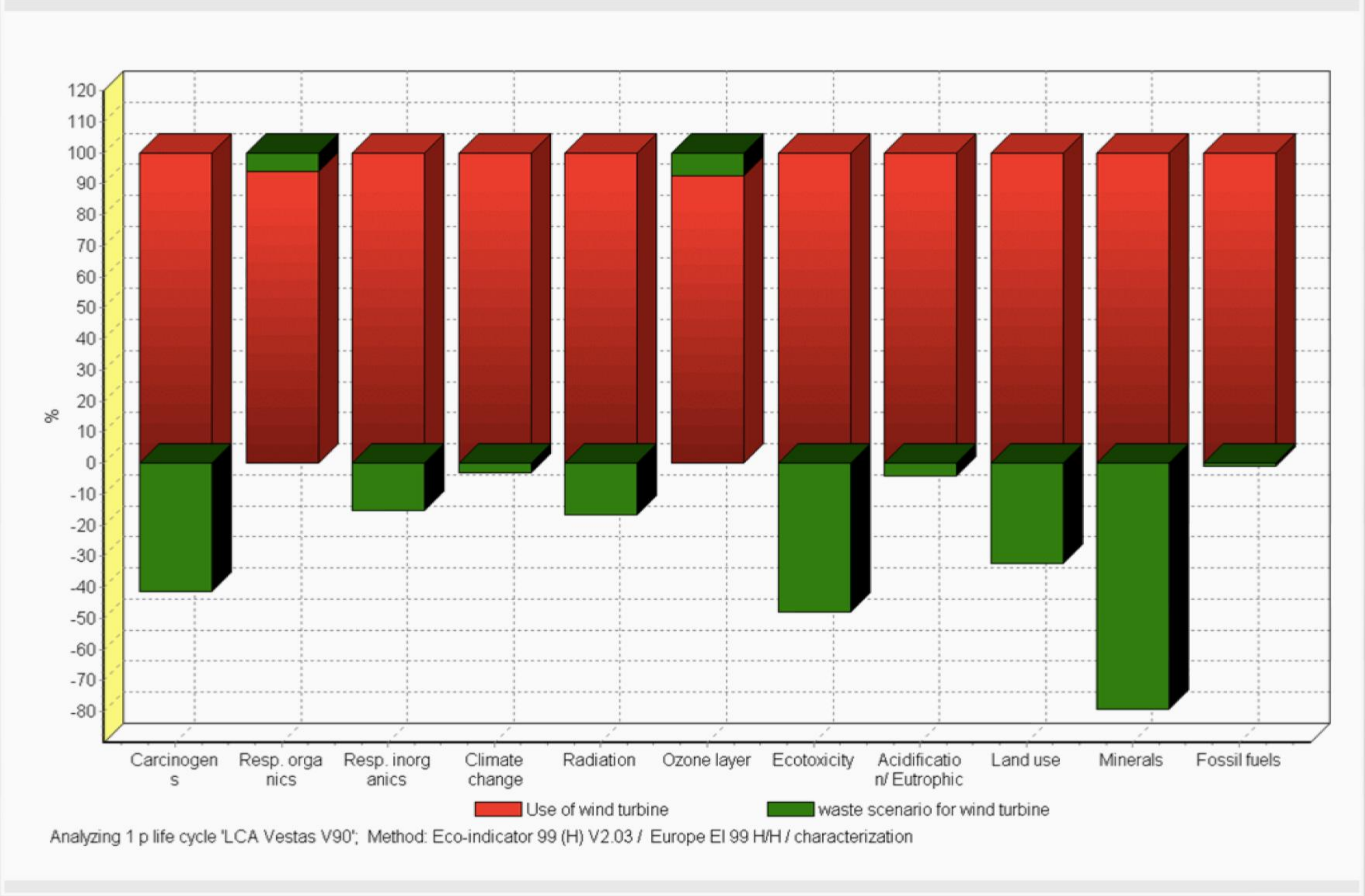

**Table 2 Ash analysis of Huadian oil shale (mass%)**

| $SiO_2$ | $Al_2O_3$ | $Fe_2O_3$ | CaO | MgO | $TiO_2$ | $Na_2O$ | $K_20$ |
|---|---|---|---|---|---|---|---|
| 52.9 | 17.74 | 6.65 | 14.77 | 2.99 | 0.55 | 0.89 | 1.27 |

# Renewables

Wind,
Solar,
Hydro,
Geothermal






# Wind Turbines

## Cradle to Grave Lifecycle Analysis

**Life Cycle Assessment for Wind Turbine**

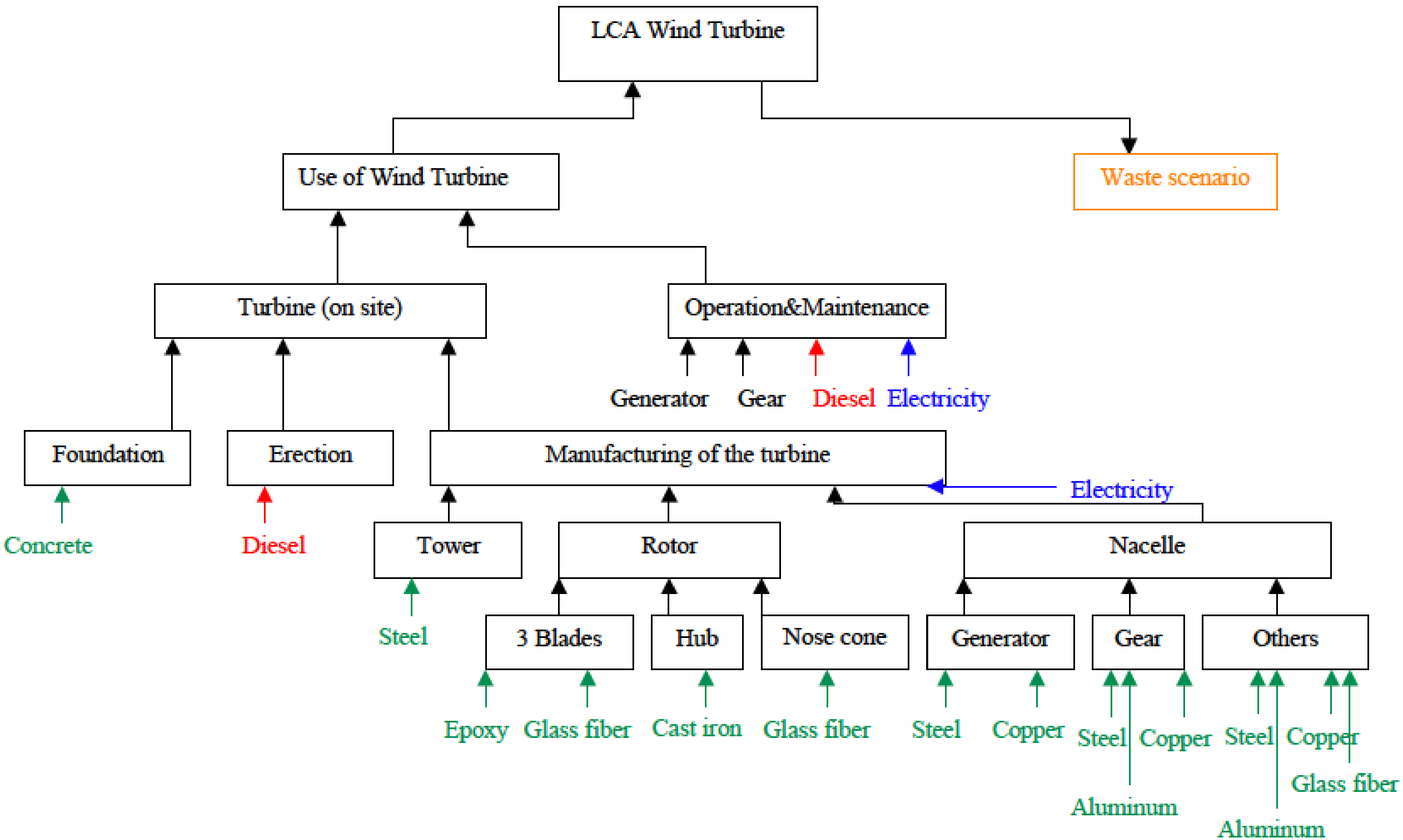



**Figure 3. Model for wind turbine in SimaPro**

# Wind Turbines

## Cradle

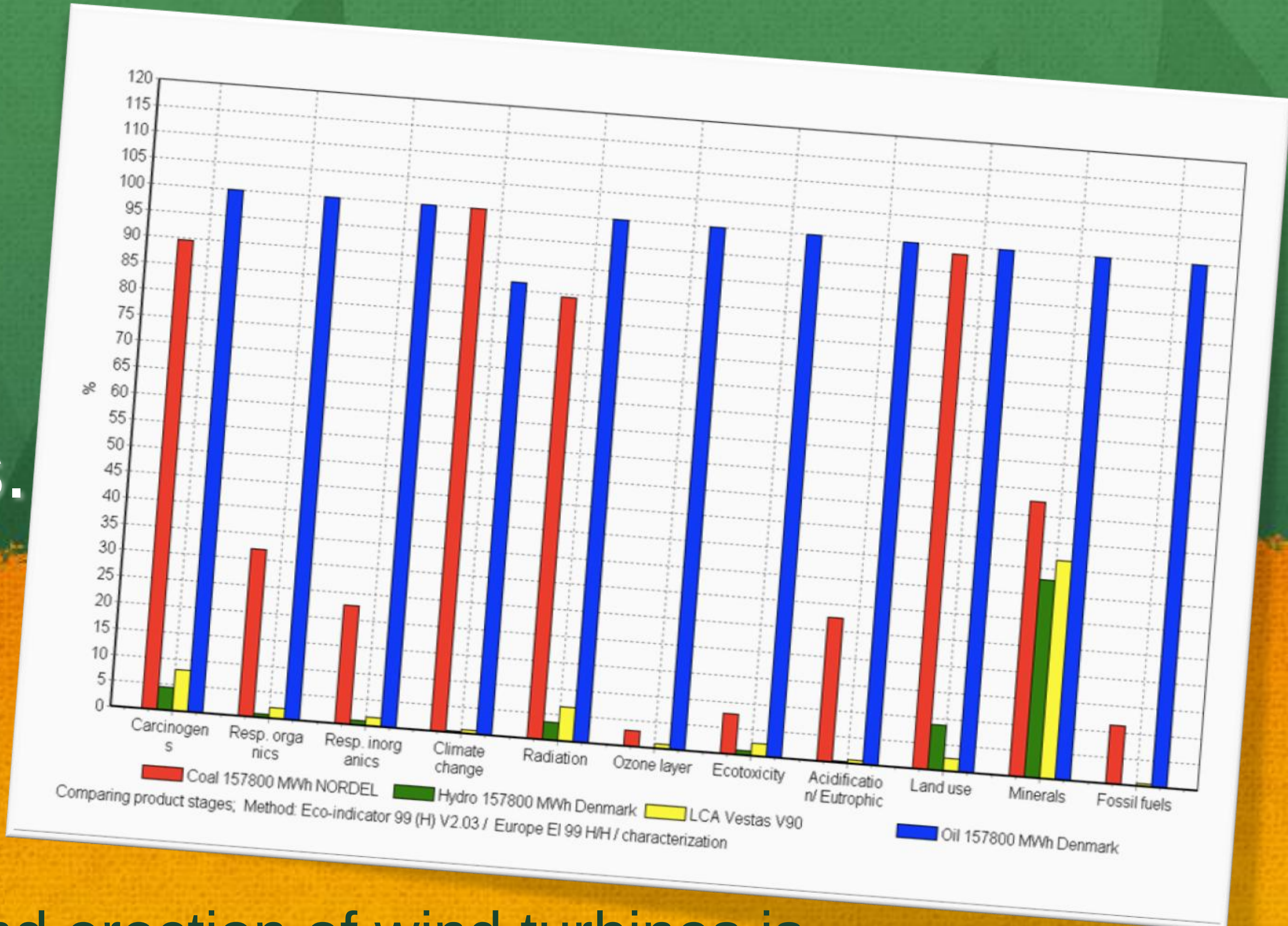
- Total of 7405 MWh of electricity are needed
- Steel production
- Glass fibre, reinforced plastic
- Cast iron
- Copper
- Aluminum
- Concrete (on site)
- Transportation and erection (5382 kg diesel)

## 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

# Policy Recommendation

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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