Climate Change

- Explain how humans are affecting the carbon cycle.
- Interpret diagrams of the global carbon cycle and energy flow to explain issues associated with climate change.
- Describe the history of recent climate change and the longer history of climate change as understood from the use of proxies.
- Discuss the current and potential future consequences of climate change for human an non-human life.
- Interpret figures and tables associated with climate change.
- Propose and describe solutions to address climate change.
WORLD CLIMATE SUMMIT
PARIS, FRANCE, 2015

United Nations
Framework Convention on
Climate Change

http://www.copenhagendiagnosis.com/
CONUS + Puerto Rico: Current 30-Day Observed Precipitation
Valid at 5/24/2015 1200 UTC - Created 5/25/15 0:26 UTC
Ice Age Temperature Changes

EPICA

Vostok

Low

Ice Volume

High

Thousands of Years Ago

The Copenhagen Diagnosis

http://www.copenhagendiagnosis.com/
Atmospheric Carbon Dioxide
Measured at Mauna Loa, Hawaii

Carbon dioxide concentration (ppmv)


Annual Cycle

Jan Apr Jul Oct Jan

The Copenhagen Diagnosis
Updating the World on the Latest Climate Science

http://www.copenhagendiagnosis.com/
Figure 21: Reconstructed, observed and future warming projections
Figure 19: Northern Hemisphere reconstructed temperature change since 200AD
Figure 20: Arctic air temperature change reconstructed (blue), observed (red)
Global Temperatures

- Annual Average
- Five Year Average

Temperature Anomaly (°C)

1860 1880 1900 1920 1940 1960 1980 2000
Figure 1: Global CO$_2$ Emissions from Fossil Fuels
Figure 2: Atmospheric concentration of carbon dioxide (CO$_2$) and methane (CH$_4$)
Figure 3: (Top) Mean temperature change between 1950’s and 2000’s: (Bottom) Global average temperature change from 1850
Figure 4: Global Temperature Change since 1980 from GISS data
Figure 5: Human versus Solar influence since 1980 and projections to 2030
Climate “velocity” .25mi/year average
California’s diverse topography
Insular nature of reserves
Residence times 100 years average
Reduced winter precip & earlier spring snowmelt; longer growing seasons and drought.

Western U.S. increased spring/summer temp 1.6 deg C
Fires season lengthened 78 days.
Higher temps; increase evaporative water loss; increasing risk of large fires 12 – 53% by 2100.
Figure 9: Greenland ice-melt since 1979
Figure 11: Jakobshaven Isbrae ice shelf calving since 1851
Figure 12: Minimum arctic sea-ice extent from 1979 to 2007
Figure 13: Observed and modeled Arctic sea-ice extent
Figure 14: Observed Antarctic Warming Trend (°C/decade) from 1957-2006
Figure 16: Sea-level change 1970-2010
Figure 17: Past and future sea-level projections
Global climate: a non-linear complex system

Figure 18: Major tipping-points in the climate system
Figure 22: Emissions pathways to give 75% chance of limiting global warming to 2°C.
Estimated U.S. Energy Use in 2010: ~98.0 Quads

Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. 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 hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant “heat rate.” (see EIA report for explanation of change to geothermal in 2010). 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-MA-410527

https://flowcharts.llnl.gov/content/energy/energy_archive/energy_flow_2010/LLNLUSEnergy2010.png

http://www.copenhagendiagnosis.com/
Estimated U.S. Carbon Dioxide Emissions in 2005:
~5982 Million Metric Tons

Source: LLNL 2006. Data is based on DOE/EIA-0384(2007), June 2008. 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. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

http://www.copenhagendiagnosis.com/
BIOFUELS

- Corn-based ethanol
- Biodiesel
- Sugar-cane
- Cellulosic ethanol
- Crop waste
- Tree farms
- Algal farms
• Cradle-to-grave “full-cost & benefit accounting
Small Scale Solar Systems

Issues to consider

- Reduce high tier rates
- Time of use
- Up-front costs; pay-off time
- Tax credits
- Lease programs
Large-scale solar power
WIND POWER

- Cost
- Reliability
- Disadvantages
HYDRO-ELECTRIC POWER

- Large-scale
- Small diversions
- Reversible systems
What are we addicted to?
<table>
<thead>
<tr>
<th>LIGHT BULB CHOICES:</th>
<th>Incandescent</th>
<th>CFL</th>
<th>LED</th>
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<td>10000hrs</td>
<td>50000hrs</td>
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<tr>
<td>Watts (for equivalent light output)</td>
<td>60</td>
<td>14</td>
<td>10</td>
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<tr>
<td>Cost per bulb</td>
<td>$0.00</td>
<td>$4.00</td>
<td>$35.00</td>
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<tr>
<td>Bulbs needed for 50K hours</td>
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<tr>
<td>Cost of bulbs</td>
<td>$0.00</td>
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<td>$35.00</td>
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<tr>
<td>Electricity consumed (KWH) /50K hours</td>
<td>3000</td>
<td>700</td>
<td>500</td>
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<tr>
<td>Cost of electricity @ $0.10/KWH</td>
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<td>$70.00</td>
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<tr>
<td>Total cost</td>
<td>$300.0</td>
<td>$90.00</td>
<td>$85.00</td>
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WWJD?
## ECONOMIC ANALYSIS OF FUEL COSTS WHEN DRIVEN 100,000 MILES

<table>
<thead>
<tr>
<th>MPG DRIVEN</th>
<th>MIDSIZE (ACCORD 22/32MPG)</th>
<th>MIDSIZE (TAURUS 24.5/30MPG)</th>
<th>MINIVAN (CARRAN)</th>
<th>PICKUP (F150 15/19MPG)</th>
<th>SUV (EXPLORER 13/19MPG)</th>
<th>SUV (EXPEDITION 12/17MPG)</th>
<th>COMPACT (CIVIC 36/25MPG)</th>
<th>TURBO DIESEL (JETTA 38.5/2597)</th>
<th>HYBRID (CIVIC 43/41.5MPG)</th>
<th>HYBRID (PRIUS 51/49.5MPG)</th>
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</thead>
<tbody>
<tr>
<td>26</td>
<td>5,769</td>
<td>6,122</td>
<td>7,500</td>
<td>8,333</td>
<td>9,375</td>
<td>10,345</td>
<td>4,412</td>
<td>3,896</td>
<td>3,614</td>
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<td>22</td>
<td>7,692</td>
<td>8,163</td>
<td>10,000</td>
<td>11,111</td>
<td>12,500</td>
<td>13,793</td>
<td>5,882</td>
<td>5,195</td>
<td>4,819</td>
<td>4,040</td>
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<td>21</td>
<td>9,615</td>
<td>10,204</td>
<td>12,500</td>
<td>13,889</td>
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<td>7,353</td>
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<td>18,750</td>
<td>20,690</td>
<td>8,824</td>
<td>7,792</td>
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<td>27,586</td>
<td>11,765</td>
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<td>8,081</td>
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<td>19,231</td>
<td>20,408</td>
<td>25,000</td>
<td>27,778</td>
<td>31,250</td>
<td>34,483</td>
<td>14,706</td>
<td>12,987</td>
<td>12,048</td>
<td>10,101</td>
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<table>
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<tr>
<th>PRICE OF GAS (DOLLARS PER GALLON)</th>
<th>$1.50</th>
<th>$2.00</th>
<th>$2.50</th>
<th>$3.00</th>
<th>$4.00</th>
<th>$5.00</th>
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<tbody>
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<td>MIDSIZE (ACCORD 22/32MPG)</td>
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<tr>
<td>MIDSIZE (TAURUS 24.5/30MPG)</td>
<td></td>
<td>4,082</td>
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<tr>
<td>MINIVAN (CARRAN)</td>
<td></td>
<td></td>
<td>5,000</td>
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<tr>
<td>PICKUP (F150 15/19MPG)</td>
<td>5,556</td>
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<tr>
<td>SUV (EXPLORER 13/19MPG)</td>
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<td>6,250</td>
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<td>SUV (EXPEDITION 12/17MPG)</td>
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<td>6,897</td>
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<td>COMPACT (CIVIC 36/25MPG)</td>
<td>2,941</td>
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<td>TURBO DIESEL (JETTA 38.5/2597)</td>
<td>2,597</td>
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<td>HYBRID (CIVIC 43/41.5MPG)</td>
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<td>HYBRID (PRIUS 51/49.5MPG)</td>
<td>2,020</td>
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</tbody>
</table>
## Economic Analysis of Fuel Price of Gas (Dollars per Gallon)

### Efficient Cars 2012

#### Driven 100,000 Miles

<table>
<thead>
<tr>
<th>MPG</th>
<th>Gallons</th>
<th>Vehicle:</th>
<th>Fuel:</th>
<th>Total:</th>
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</thead>
<tbody>
<tr>
<td>Toyota Prius Hybrid</td>
<td>48</td>
<td>2,083</td>
<td>3,125</td>
<td>4,167</td>
</tr>
<tr>
<td>Toyota Camry</td>
<td>35</td>
<td>2,857</td>
<td>4,286</td>
<td>5,714</td>
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<tr>
<td>Toyota Corolla</td>
<td>34</td>
<td>2,941</td>
<td>4,412</td>
<td>5,882</td>
</tr>
<tr>
<td>Toyota 4Runner</td>
<td>23</td>
<td>4,348</td>
<td>6,522</td>
<td>8,696</td>
</tr>
<tr>
<td>Honda Insight Hybrid</td>
<td>44</td>
<td>2,273</td>
<td>3,409</td>
<td>4,545</td>
</tr>
<tr>
<td>Volkswagen Jetta TDI</td>
<td>42</td>
<td>2,381</td>
<td>3,571</td>
<td>4,762</td>
</tr>
</tbody>
</table>
Lifestyle choices: hidden carbon; indirect consequences; shalom