High Energy Society

Why do we care about energy?

Original slides provided by Dr. Daniel Holland.
What is Energy

• We will look at the “Physics” definition in a bit, but essentially, it is the ability to make something move.

• Experiment: Stand up and start doing deep knee bends at a rate of about 1 per 2 seconds.

• You are working (using energy) at a rate of approximately 100W. (We’ll come back to this later.)
Energy and Power

- A joule is a measure of the amount of energy.
- A watt (1 J/s) is a measure of the rate of energy use.
- It would take the same amount of energy to do 10 deep knee bends in 20 min as it would in 20 sec, but by doing it in 20 sec, you use energy at a faster rate.
• The rate of using energy is called POWER. Something that is powerful uses a lot of energy quickly.

    Power = Energy/Time

• This is a Rate Equation (More soon.)

• Common Unit of Power is a Kilowatt = kW = 1000 W.
Energy = (Power) x (Time)

Common Unit of Energy = kWh (Kilowatt-hour)

1 kWh is the amount of energy you would use if you consume energy at the rate of 1 kW for 1 hr. (10 people doing deep knee bend for an hour.)
Other Units of Energy and Power

- $1 \text{kWh} = 3,600,000 \text{ Joule}$
- $1 \text{ Btu} = 1055 \text{ Joule}$
- $1 \text{ Calorie} = 4186 \text{ Joule}$
- $1 \text{ Calorie} = 1000 \text{ calorie}$
- $1 \text{ hp} = 746 \text{ Watts}$
Why do we care about energy?

• The bottom line is that using energy is strongly correlated to standard of living (as measured by GDP per capita.)

• For most of history we could rely on our own body or animals to do work. This is a few hundred watts of power at most.
• Today in the US we consume energy at a rate of 11kW per person.
• You may think of this as having 110 “energy servants” doing work for you 24/7.
• Typically less wealthy nations have a lot fewer “servants”
Energy use is directly tied to GDP (2006)
energy demand and GDP per capita (1980-2002)

Source: UN and DOE EIA
We are doing better on a GDP per kWh basis.
Which state would you guess has the highest per capita energy use?

1. Alaska
2. Louisiana
3. California
4. Illinois
Videos

This one may be defective
http://news.bbc.co.uk/2/hi/science/nature/8392451.stm

This one worked last time I checked
https://www.youtube.com/watch?v=C93cL_zDVIM
A number of figures are taken from the U.S. Energy Information Administration (EIA). All of them should report the EIA as the source.
Forecast of U.S. total energy production and consumption over the next couple of decades (in quadrillion BTU). The data for this plot is dated, so it lets us look at how good the prediction was. How good was it? Check the previous slide.

Table 1.1 Primary Energy Overview

<table>
<thead>
<tr>
<th>Quadrillion Btu</th>
</tr>
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<tbody>
<tr>
<td>150</td>
</tr>
<tr>
<td>100</td>
</tr>
<tr>
<td>50</td>
</tr>
<tr>
<td>0</td>
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</table>

<table>
<thead>
<tr>
<th>Years</th>
<th>Total Primary Energy Production</th>
<th>Primary Energy Imports</th>
<th>Primary Energy Exports</th>
<th>Total Primary Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1960</td>
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<td>2010</td>
<td></td>
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</tr>
</tbody>
</table>

Source: U.S. Energy Information Administration

... and an updated version (2018). What is the most important change?
So the forecast was off just a bit. Now the gap is expected to close by about 2025.
Energy production (Reference case)
quadrillion British thermal units

What are the big changes since 2008?
About 84% of our energy was from fossil fuels in 2000. Now it looks like it is about 78%. See the EIA website or this document (https://www.eia.gov/totalenergy/data/browser/?tbl=T01.03#/?f=A) for details.
U.S. Oil Supply & Demand

Production Data:
1900-1937: World Energy Council
1938-1953: C.J. Campbell, "The Coming Oil Crisis"
1954-2002:
EIA: Annual Energy Review, Table 1.2, Crude Oil Production and Oil Well Productivity
Consumption Data:
1900-1949:
Est. Production = Consumption
1949-2002:
EIA: Annual Energy Review Table 5.1, Petroleum Overview
http://en.wikipedia.org/wiki/Energy_in_the_United_States

The next few charts are dated but present the data in a very nice way.

Total = 99.305 Quadrillion Btu

- Petroleum: 37%
- Natural Gas: 24%
- Coal: 23%
- Nuclear Electric Power: 9%
- Renewable Energy: 7%
- Geothermal: 5%
- Hydro-power: 34%
- Biomass: 53%

Solar: 1%

Note: Sum of components may not equal 100% due to independent rounding.

U.S. energy consumption by energy source, 2017

Total = 97.7 quadrillion
British thermal units (Btu)

- Petroleum: 37%
- Natural gas: 29%
- Coal: 14%
- Nuclear electric power: 9%
- Renewable energy: 11%

Total = 11.0 quadrillion Btu

- Biomass and waste: 4%
- Biofuels: 21%
- Wind: 21%
- Solar: 6%
- Geothermal: 2%

Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, Monthly Energy Review, Table 1.3 and 10.1, April 2018, preliminary data
U.S. Primary Energy Consumption by Source and Sector, 2008

Total U.S. Energy = 99.3 Quadrillion Btu
Renewables

Renewable Energy Total Consumption and Major Sources, 1949-2008

- Total
- Hydroelectric Power
- Wood
- Biofuels
- Wind

Quadrillion Btu

This is the latest Renewable energy plot from June 2018. What has changed from the previous plot? Notice that wood and biofuels are grouped together in this plot.

Why am I showing you old plots and new plots?
This chart includes major commercially traded fuels only. Although important in many countries, reliable consumption statistics for fuels such as wood, peat and animal waste are not available.

How Much Is There?

- Proven Reserves: Resource that we know is there AND we can extract it at current prices with current technology.
- We can increase Proven Reserves by
  1) Finding new reserves.
  2) Improvements in technology
  3) Changes in economic conditions
• Note: We never totally extract all of the energy, it just gets too difficult to get after a while.

• Unproven Reserves: We think that it is there based on testing/experience

        OR

We know that it is there but it is too expensive to extract with current technology/economics.
How long do you think that the world’s oil supply will last?

1. 10 to 20 years.
2. 20 to 50 years.
3. 50 to 100 years.
4. More than 100 years.
How Long Will Fossil Fuels Last?

• Simplest analysis (Rate Equation and Linear Picture)

• If we know (or can guess) how much we started with \((Q_\infty)\) and we know the rate we are using it \((R)\) and how much we have already used \((Q_u)\)

\[
\text{Time} = \frac{(Q_\infty - Q_u)}{R}
\]
• The linear picture is a really bad approximation because it does not take into account changes in rate of use.
• The demand for energy has been constantly increasing so rate equation time is probably too long, but still interesting.
• Remember energy use and GDP are linked.
• Each person tends to use energy at an increasing rate and the population is increasing.
Exponential Growth Model

- Amount of growth depends on current amount, i.e. we have a certain percentage change.
- Examples include: Cost of living (3% / year), Cost of a college education (4% / year), Health care (6.5% / year)
- Financial Example: Start with $1000 and have it gain interest at 10% per year.
<table>
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<th>Year</th>
<th>Amount</th>
<th>Interest</th>
<th>Total</th>
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<td>2</td>
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<td>8</td>
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</tr>
</tbody>
</table>

Note: Money had just about doubled after 7 years. If we had just added $100 per year (constant rate) we would have only had $1700 after 7 years. (really get a big effect for longer times)
Doubling Time

- In general, if our percentage growth per unit time is \( P \) (%/unit time) then the time for our initial quantity to double is \( DT \) where:
  \[
  DT = \frac{70}{P} \\
  \]

Example: If \( P = 10\% \)/year then

\[
DT = \left(\frac{70}{10}\right) \text{years} = 7 \text{ years}
\]

(This is a simple to remember estimate)
If we start with $1000, approximately how much money will we have at the end of 21 years if it earns interest at 10% per year?

1. $3100
2. $5300
3. $8000
4. $1600
Between 1960 and 1970, US energy consumption grew by 4.5%/yr. This would mean energy use would double in only $70/4.5 = 15.5$ years!

With constant rate if we double our reserves, we double their expected life. With exponential growth, doubling reserves will only add a short amount of time.

Obviously exponential growth in energy demand CANNOT go on for very long.
• With an energy consumption doubling time of 20 years, we would be using energy at 32 times the current rate in 100 years. Put another way, what amounts to a 320 year supply of energy now will only last for 10 years at the increased rate.
Hubbert Analysis

- Works for just about any natural resource. (Not just fossil fuels)
- Initially a new resource show a period of rapid growth. Easy to find, new markets, etc.
- As high quality, easy to find resources are depleted, production will peak and then decline.
Figure 20 - Ultimate world crude-oil production based upon initial reserves of 1.250 billion barrels.
• Production will have a “Bell Shaped” Curve.

• Data up to 2007
WORLD OIL RESERVES BY COUNTRY WITH U.S. OIL SHALE RESOURCES

SOURCE: EIA, INTERNATIONAL OIL OUTLOOK 2011, HTTP://WWW.EIA.GOV/FORECASTS/IEO/TEABLES5.CFM
• In the 1950’s, Hubert predicted that the US oil production would peak in the 1970’s….It did.
• Current models predict world oil production will peak in 0-20 years…watch out!
• Much more when we get to each fossil fuel source.