Historical energy overview & why there is no consensus for the future

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There are widely divergent viewpoints on the future of energy resources & technology
Limits to Growth ... resource constraints are real

• Main conclusions
  – “... global ecological constraints (related to resource use and emissions) would have significant influence on global developments in the twenty-first century.”
  – “... humanity might have to divert much capital and manpower to battle these constraints – possibly so much that the average quality of life would decline sometime during the twenty-first century.”
  – Early action could reduce damage caused by approaching global limits
The Bottomless Well .... we will not run out of energy

• “What lies at the bottom of the bottomless well isn’t oil, it’s logic. Fuels recede, demand grows, efficiency makes things worse, but logic ascends, and with the rise of logic we attain the impossible – infinite energy, perpetual motion, and the triumph of power. It will all run out but we will always find more.”

• Energy efficiency leads to more consumption
  – Rebound effect, or Jevons’ Paradox
  – More energy consumption is always better
Global Energy Trends
World Population and Energy: Current Lives

Population (millions)

Energy (Quads)

Year

- 1940
- 1960
- 1980
- 2000
- 2020

- Population
- Energy

- AT&T Cellular Network
- OPEC/Arab Oil Embargo
- Myspace
- Commercial Internet
- Internet
- AT&T Cellular Network
- OPEC/Arab Oil Embargo
- Myspace
- Commercial Internet

Population and Energy Chart:
- Population and Energy trends from 1940 to 2020
- Key events: AT&T Cellular Network, OPEC/Arab Oil Embargo, Myspace, Commercial Internet

Carey W. King, Ph.D.
UT Energy Seminar, September 1, 2011
World Population and Energy: Industrial Times

Population (millions)

- Newcomen’s Steam Engine
- United States formed!
- Phonograph, Light bulb

Energy (Quads)

- Parson’s Steam Turbine (electricity)
- First TV

Year

- 1600
- 1700
- 1800
- 1900
- 2000
- 2100

Population: 0, 100, 200, 300, 400, 500

Energy: 0, 100, 200, 300, 400, 500
World Population and Energy: Human Civilization

- Egyptian Pyramids
- Ancient Greeks
- Middle Ages
- Fall of Roman Empire
- Age of Fossil Fuels
### Snapshot of World Energy Reserves

(~ 28,000 EJ cumulative since 0 A.D.; 18,000 EJ since 1950)

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Proved Reserves (EJ)</th>
<th>Additional Resource (EJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal (^{(WEC)})</td>
<td>20,000 - 25,000</td>
<td>--</td>
</tr>
<tr>
<td>Oil and NG Liquids (^{(WEC)})</td>
<td>6,800</td>
<td>3,450</td>
</tr>
<tr>
<td>Oil Shale, bitumen, Extra Heavy-Oil (^{(WEC, 1)})</td>
<td>~1,900</td>
<td>41,000</td>
</tr>
<tr>
<td>Natural Gas (^{(WEC)})</td>
<td>7,000</td>
<td>--</td>
</tr>
<tr>
<td>Uranium (^{(2)}) (&lt; $130/kg)</td>
<td>1,400 – 2,200</td>
<td>600 – 1,000</td>
</tr>
<tr>
<td><strong>TOTAL “Fossil”</strong></td>
<td>37,000 – 43,000</td>
<td>45,000</td>
</tr>
<tr>
<td>Hydropower (^{(WEC)})</td>
<td>59/yr</td>
<td>148/yr</td>
</tr>
<tr>
<td>Biomass (terrestrial NPP)</td>
<td>27 (^{(3a)})</td>
<td>1,900 (^{(3b)})</td>
</tr>
<tr>
<td>Solar (^{(4)}) (total resource)</td>
<td>N/A</td>
<td>2,780,000/yr</td>
</tr>
<tr>
<td><strong>TOTAL “Renewable/yr”</strong></td>
<td>~ 100 + ?</td>
<td>2,780,000</td>
</tr>
</tbody>
</table>

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1. Resource for bitumen and heavy oil is estimated discovered oil in place.
2. Assuming use in light water reactors and open fuel cycle.
3a. “Proved Reserves” ~ sustainable (Field et al., 2008. *Trends in Ecology and Evolution*).
4. Solar insolation to Earth surface.


Stocks in the ground (stored there for free).

Flows in the environment (mostly not stored for free).
Why do we care about energy?

• Fundamentally high quality energy supplies (mostly fossil) have enabled economic growth and prosperity as the modern world knows it today.

• Most technologies are not possible without cheap and high quality energy supplies.

• Economic growth has a hard time continuing without cheap energy supplies.
Country Comparison: HDI vs. Energy per Person

- Human Development Index
  - Life expectancy index
  - Education Index (2/3 literacy, 1/3 enrollment)
  - GDP index

What’s the difference?

An inflection seems to emerge near 100 GJ/person/yr

- Human Development Index
  - Life expectancy index
  - Education Index (2/3 literacy, 1/3 enrollment)
  - GDP index

Less than 1.5 billion people at > 100 GJ/person

World Average ~ 77 GJ/person

23% of population at 100 GJ/person
Historical → Today: What is energy for?

A decreasing number of hours for agriculture translated to economic growth, new job types

• US farming
  – 373 million hectares¹

• If all farming was wheat
  – @ 3 hrs/ha/yr \(\rightarrow\) 0.3% of work hours

  – < 5% of Western labor employed by agriculture

• Fossil fuels dominate after 1800

  “Ours is a fossil-fueled civilization, and its dependence on coals and hydrocarbons cannot be shed without profoundly reshaping the entire society.” (Smil, 2008)

Expansion of energy & technology post-WW II

People consume energy that’s available to substitute for physical work/labor

• Physical labor has decreased considerably since 1800s
  – Energy = Force × distance (= work)
  – Pre-1800 UK coal mining involved carrying coal on backs of women, children, and men
  – We traded ‘fuels + technology’ for physical labor

• Since we’re not ‘working’ physically as much, we have a different economy
How do we decide among current and future energy options?
Holistic view of energy tradeoffs create different visions of the future

National Security

Environment

Economics

Tend to be few options here
Let’s think about the Environment

National Security

Environment

Economics
1 Bgal of coal ash breaches Tennessee Valley Authority earthen dam in TN (Dec 2008)

- 26 homes damaged
- 49/431 coal-ash storage facilities as “high hazard”
EPA proposed rule to limit water intake at power plants

• New generation units subject to closed loop cooling towers
  – Possible some existing power and industrial facilities

• 1,260 total existing facilities (760 likely already comply)
  – Minimum fish kill requirement or max. intake velocity

http://www.surfrider.org/coastal-blog/entry/new-rulemaking-for-coastal-power-plants
Hydraulic fracturing shale for gas/oil becoming more extensive in practice ... and debate

• Energy Policy Act (2005) exempted hydraulic fracturing from federal Safe Drinking Water Act
  – States still regulate groundwater
  – EPA reviewing, looking into drinking water impacts
  – Creates animosity public and competing industries

• A lot of water or a little?
  – Millions of gallons per well
  – ~ 1-10 gallons of water/MMBtu of Barnett Shale NG (2005)\(^1\)
  – Akin to historic oil production

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No: Don’t just frac it

Drilling emits Nitrogen Oxide & Volatile Organic Compounds, resulting in destructive surface smog.

http://gaslandthemovie.com/
No: Don’t just frac it

Texas license plate

Yes: Just “FRAC IT”

http://gaslandthemovie.com/
Many fuel alternatives seem to consume more water than petroleum travel. (King & Webber, 2008). *Env. Sci. & Tech.* 42 (21), 7866-7872.
Environmentalists vs. Environmentalists

- “Wind turbines kill birds”
- “Wind turbines are eyesores” — Texas Coast (King Ranch vs. Kennedy Ranch)

Those dog gone cats!

Policies for alternative measures to GDP focus on environmental limits

"Ecological Footprint" measures how much water and land area a human population requires

U.S. national security

National Security

Environment

Economics
If the US has large energy resources, why the security concern?

- US has abundant energy resources that are roughly economic today
- Coal: (largest world reserves)
- Natural Gas: (> 100 yrs @ current consumption and new shale estimates – much debated)
- Oil: US is world’s 3rd largest producer (< Russia, Saudi Arabia)
  - 5.5 MMBBL/day crude oil + condensate (2010)
- Wind and solar: insolation & area are good
US energy security is based upon our high consumption of oil

- Because transportation is still dominated by oil, US energy security centers on oil
    - 22% of world consumption
    - < 5% of world population
    - US has only ~ 2% of world oil reserves
    - US imports ~ 50%-60% of petroleum for consumption

- Oil is ‘unique’ in that it is the only fuel US consumes much more than domestic production
We can do it: Turning oil into salt
(enable different fuels; stop $ to OPEC)
Forget oil and salt security ... Coal keeps the monsters away!

Our new, advanced coal plants could generate ENERGY FOR OVER 5 MILLION new homes and enough power to keep the monsters away.

and enough power to keep the monsters away
Oil is the most economically influential energy resource

National Security

Environment

Economics
Important indicators are the percentage of our expenditures and income going to energy

2007 US median income
~ $31,000
$4K/$31K ~ 13%
If energy gets too expensive, GDP stops ↑

Oil expenditures as % of GDP seem to indicate a threshold for recessions

Future oil supplies are costlier: lower net energy (EROI) = higher price

Converting to end-use fuels raises price (and lowers EROI) more

EROI = Energy Return on Investment = $E_{out}/E_{in}$

Oil expenditures have fluctuated the most, and the US consumes more oil than it has, …
... US energy policy is fragmented, perceived to be dominated by ‘BIG OIL’, ...
... many energy options have environmental tradeoffs we don’t want, ...
... but we still think we can get all energy without building anything, ...

NIMBY: Not In My BackYard

BANANA: Build Absolutely Nothing Anywhere Near Anyone

http://www.cafepress.com/frackingnope
... if we’re not killing the environment, we might be indirectly killing ourselves (oil $ → terrorism),
... or if not helping terrorists, then maybe state-backed antipathy toward the U.S., ...
... so the US goal has clearly (!) been to reduce oil imports, ...

In 2010 US spent ~ $300 Billion for imports
Terrorists of 9/11/01 needed < $1 million
Value of US Energy Imports

... and the world has caught up to the traditional economic powers (US, EU, Japan).

- Emerging markets can grow more on higher-priced energy than can developed markets.
U.S. sectoral energy consumption saw shifts in 1970s and 2000s

Figure 2.1a Energy Consumption by Sector Overview

Offshoring? Globalization?

Lack of transition to higher quality fuels is exemplified by use of coal in China, and ...

EIA. Uses $2005 at Purchasing Power Parity (PPP).
Lack of transition to higher quality fuels is exemplified by use of coal in China, and …

EIA. Uses $2005 at Purchasing Power Parity (PPP).
Any International cooperation for GHG must deal with global economic transition.

Figure 5.8: Energy-Related CO₂ Emissions by Region, 1900-2005*

Long-term energy future is a big guess
Fuel transition models do not hold to simple pattern – Energy production technologies are very different than energy consumption technologies

Marchetti, 1977; Luís de Sousa - http://europe.theoildrum.com/node/2746
Recent US petroleum consumption projections keep getting revised downward

- Oil price rise and economic downturn post-2008 weighs heavily on oil consumption prospects

US EIA Annual Energy Outlooks 2004 to 2011, Reference cases
The Limits to Growth conclusion

• “There is no question about whether growth in the ecological footprint will stop; the only questions are when and by what means.”

The Bottomless Well conclusion

• “Societies that expand and improve their energy supplies overwhelm those that don’t.”

• “Humanity is destined to find and consume more energy, and still more, forever”
The past has shown considerable change …

... but short and long term viewpoints create different perspectives on future prospects.
What will change and stay the same?

Namtso Lake, Tibet – 15,500 ft

PV Solar Cell (new energy)

Yak Dung (old energy)