Introduction

• see IEA World Energy Outlook
  – projects 30% increase in world energy demand by 2030
Introduction

Many of the things and almost all of the energy we use are extracted from the Earth. This section discusses the formation, extraction, existing supply, and consequences of energy resources.

• U.S. Energy usage

  – usage has steadily increased, except during oil crises/major recessions [Fig. 15.3a, Keller, 2008]
  – the bulk of usage is at low temperature, i.e. suitable for low “energy content” sources such as solar, geothermal, etc. [Fig. 15.4, Keller, 2008]
  – similar issues underlie the Pickens Plan, which proposes to eliminate dependence on foreign oil imports. Makes sense especially in recession when natural gas is cheap
– the U.S. consumes about 30% of all energy produced in the world (Fig. 1)
– U.S. consumption has exceeded discovery since 1980 [Fig. 15.1, Keller, 2008]
– we have about 3% of the world’s petroleum reserves, and consume about 25% of the world’s petroleum production

● World distribution of energy resources
  – *petroleum* (oil) is highly concentrated in the Middle East (Fig. 2)
    ∗ this certainly affects the U.S. interest in the Middle East (e.g. Alan Greenspan book)
  – *natural gas* is concentrated in the former Soviet Union and Middle East (Fig. 3)
    ∗ some risk of cartel
also heavy dependence on Russian gas in Europe, which affects geopolitics

- coal is relatively uniform world-wide (Fig. 4)
Figure 1: World per-capita energy consumption, after UNEP. See EIA for up-to-date view.
Figure 2: Distribution of petroleum reserves worldwide [Fig. 15.13, Keller, 2005]. Concentration of resources in the Middle East has a dramatic impact on world politics and finance.
Worldwide Natural Gas Distribution

Figure 3: Distribution of natural gas reserves worldwide [Fig. 13.11b, Keller, 2005]. Concentration of resources in the former Soviet Union is important, but overseas export will be difficult.
Worldwide Coal Distribution

Figure 4: Distribution of coal reserves worldwide [Fig. 15.7b, Keller, 2008]. These are relatively uniform, making coal the universal “fallback” energy source.
Coal
Coal

• coal forms from a 3-step process, usually beginning with coastal swamps [Fig. 15.5, Keller, 2008]

• maturation of coal removes volatiles and moisture, increasing the carbon content and *heat value* (energy content) [Fig. 15.6, Keller, 2008]

• most U.S. coal has low sulfur content (i.e. produces less pollution), but is bituminous (moderate heat value) [Fig. 15.7a, Keller, 2008] [Tbl. 15.2, Keller, 2008]

• a list of the largest U.S. coal mines is available from the U.S. EIA most in WY; TX Jewett Canyon is 38th largest) http://www.eia.doe.gov/cneaf/coal/page/acr/table9.html
• impacts of coal mining
  – primarily environmental disruption from *strip mining* [Fig. 15.6, Keller, 2000], *contour mining* [Fig. 15.7, Keller, 2000], and *mountaintop removal* (which primarily disrupts drainage)
  – and *acid rain*
Clean Coal

Somewhat of an oxymoron, this refers to pollution-limiting technologies applied to coal-fired power plants.

- refers to removal of major pollutants, e.g. $\text{SO}_2$, and more recently $\text{CO}_2$

- $\text{CO}_2$ removal and storage is new technology,
  - likely to be expensive
  - will take 10-15 years to implement (e.g. ThisIsReality commercial )
  - may be too late to impact global warming (e.g. Stern report , 2006)
• removing other pollutants is relatively well-established technology (e.g. scrubbing, see Air Pollution chapter)

• coal use likely to decline because of new air pollution controls, cheap natural gas
Petroleum
Petroleum Occurrence

- hydrocarbons (oil and natural gas) are derived from buried organic material that didn’t completely decompose after burial

- the bulk of the source material for hydrocarbons was deposited in a few geologic time periods (e.g. the Cretaceous, 60-120 MY ago)

- the buried hydrocarbons must be metamorphosed by mild heat (by burial 1-3 km deep [Fig. 15.9, Keller, 2000])

- then these matured hydrocarbons migrate in permeable reservoir rocks to locations where they can accumulate (traps) [Fig. 15.10, Keller, 2000]
• world petroleum resources are strongly concentrated near tectonic belts that have been active in the last 60 million years [Fig. 15.11, Keller, 2000]

• petroleum production requires a complex system (Fig. 5) of wells, pipelines, refineries and disposal systems (e.g. for oilfield brines)

• alternative sources of petroleum are tar sands, where oil can be mined directly (e.g. Alberta, Canada), and oil shales (e.g. Colorado-Utah) [Fig. 15.13, Keller, 2000]
Petroleum Production System

Figure 5: Extraction and distribution for petroleum reserves in Arctic conditions [Fig. 15.15a, Keller, 2008].
Oil Supply Limitations

• “Peak Oil”
  – world oil production should peak, projected 2015 (see Peak Oil chart section, neglects 2008 recession)
  – see also Wikipedia images
  – good U.S. summary of production peaks for non-OPEC nations (Fig. 6-7)

• Oil company executives note expense of production will cause costs to rapidly increase

• former head of Royal Dutch Shell echoes these sentiments “Sleepwalking into oil crisis”
• rumors of inflated worldwide reserves persist, based on sudden increases in stated reserves unaccompanied by announcements of major discoveries, with strong profit motives for overstating reserves (see potentially biased summary)

”[World] reserves are confused and in fact inflated. Many of the so-called reserves are in fact resources. They’re not delineated, they’re not accessible, they’re not available for production.”
Sadad I. Al-Husseini, former VP of Aramco, presentation to the Oil and Money conference, October 2007.

• latest refinement is concept of peak price, where world demand reduces as prices rise. Right now that price is $\sim$100/bbl
Figure 6: Peak oil prediction by ASPO. This is the bleakest prediction, based on suspicion of inflated world reserves estimates and acknowledged declines in production in 38 of the 44 largest oil producing countries. See also “Peak is Now” Energy Watch Group report.
Oil Economics

- petroleum prices are extremely volatile, as should be expected for a commodity

- a useful energy outlook is provided by the U.S. Government. See overview

- updates to Peak Oil theories indicate peak somewhere 2008-2018. See figures

- as U.S. consumption climbs and production declines, our dependence on imported oil (Fig. 14) continues to grow. In general this weakens our security . . .

- we regularly re-learn that cheap oil is coming to an end:
1998 Scientific American article “The End of Cheap Oil”
2007 Dallas Morning News ‘ ‘Over a Barrel: The days of cheap oil are probably over”

- U.S. petroleum exploration is becoming decoupled from price as reserves dwindle
Arctic National Wildlife Refuge

- drilling in this nature preserve north of the Arctic Circle in Alaska (Fig. 7) is very controversial

- development would threaten caribou herds and general environmental health

- resulting oil supply is estimated to be no more than 6-month’s total supply for the U.S. (7.7 billion barrels)

- world oil price impact would be minimal. From the EIA in March 2004:
  
  "It is expected that the price of ANWR coastal plain production might reduce world oil prices by as much as"
30 to 50 cents per barrel... Assuming that world oil markets continue to work as they do today, the OPEC could countermand any potential price impact of ANWR coastal plain production by reducing its exports by an equal amount.”

- so we must be careful not to let the ANWR debate distract us from the much larger energy import problem faced by the U.S.
Figure 7: Location of the Arctic National Wildlife Refuge [Fig. 13.12a, Keller, 2005].
Offshore U.S. Drilling

Offshore Oil Predictions

<table>
<thead>
<tr>
<th>Estimated results from expanded drilling in Outer Continental Shelf</th>
<th>EIA</th>
<th>NPC/ARI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added barrels per day, 2025</td>
<td>220,000</td>
<td>990,000</td>
</tr>
<tr>
<td>% of total U.S. crude-oil consumption</td>
<td>1.4%</td>
<td>6.1%</td>
</tr>
<tr>
<td>Years to start first production</td>
<td>4-6</td>
<td>3</td>
</tr>
</tbody>
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Figure 8: Estimated output from offshore drilling, after FactCheck.org. EIA is U.S. Energy Info. Agency estimate, NPC is National Petroleum Council (industry group).
Fossil Fuels and Acid Rain
Acid Rain Details

• fossil fuels rich in sulfur dioxide yield sulfur compounds in smokestack and tailpipe effluent [Fig. 15.17, Keller, 2008]

• these accumulate in precipitation and surface water bodies.

• concentrated in Eastern U.S.

• Particularly along the East Coast the net effect has been marked [Fig. 15.16, Keller, 2008]

• vegetation is most harmed by acid rain, followed by man-made structures. Mountainous areas are most sensitive to acid rain [Fig. 15.18, Keller, 2008]
• switching to low-sulfur fuels and/or addition of smokestack controls can greatly reduce acid rain
Nuclear Energy
Nuclear Fission

• Many, including hardcore environmentalists believe nuclear energy is our best future option

• *fission* produces energy when atomic nuclei are split apart by neutron bombardment. The process can produce a self-sustaining *chain reaction* [Fig. 15.20, Keller, 2008]

• nuclear power plants produce energy by heating water or other liquids which expand to drive a turbine [Fig. 15.21b, Keller, 2008] functioning the same way as a conventional power plant [Fig. 15.21a, Keller, 2008]

• see also animation
• since nuclear fuel utilizes a self-sustaining reaction, dampers (neutron absorbers) or control rods are used to control the reaction [Fig. 15.22a, Keller, 2008] inside of a containment structure designed to withstand at least minor runaway reactions.

• the U.S. produces about 20% of its electricity from nuclear, other nations such as France much more

• Risks:
  – runaway reaction, e.g. Chernobyl (Fig. 9) and [Fig. 15.E, Keller, 2000]
    * accident caused by severe operator error
    * 90% of radioactive materials remain at site
    * to be shielded by a steel cover in 2008 meant to last
100 yrs
- long-lived toxic waste (high-level nuclear waste) that must be stored for thousands of years, e.g. the WIPP site in New Mexico [Fig. 15.23, Keller, 2008] or Yucca Mountain [Fig. 15.24, Keller, 2008]
Figure 9: Radiation map from Chernobyl reactor accident. After CIA study.
Nuclear Fusion

- *nuclear fusion* is the assembly or combination of light elements to make heavier elements [Fig. 15.24, Keller, 2000]

- this process is the source of the Sun’s energy

- essentially non-polluting

- very safe, since the reaction halts if there is any breakdown in containment

- slow progress on development, although recent European test was the first output more energy than was consumed for containment
Radioactive Waste
Waste Disposal Methods

- two main categories, low and high-level waste

- Low-Level Waste: [Fig. 12.15, Keller, 2000].
  - typically medical wastes, etc.
  - must be kept away from accessible environment for 500 years
  - typically 2-3 states will form a compact and bury each other’s wastes.
  - Texas had a compact with Vermont and Maine which seemed likely to be controversial
    * we would store waste first
    * after about 20 years, Vermont or Maine would store our waste
• High-Level Waste

– very nasty, must be kept away from accessible environment for 10,000 years [Fig. 12.14, Keller, 2000].
– a few centralized facilities are available
  * WIPP site for defense-related waste in NM [Fig.15.23, Keller, 2008]
  * Yucca Mountain, NV, still being evaluated
  * Yucca Mountain Repository likely to be abandoned as of Spring 2009
  * Skull Valley, UT proposed for “temporary” surface storage of commercial reactor waste. Viewed as an important potential source of income by a very poor Indian tribe
– very problematic to try to understand and predict system
for that time period:

* WIPP site is in salt, and is experiencing great problems with liquid migrating as isolated pores in the malleable salt [Bredehoeft, 1988]

* Yucca Mountain was found to have 10-100 times more water moving through the proposed repository than predicted [Flint et al., 2001]
Renewable Energy
Geothermal Energy

- geothermal energy utilizes the Earth’s heat to produce electricity, or for direct cooling or heating

- often a magmatic heat source is nearby [Fig. 15.27, Keller, 2008]

- geothermal energy is most cost-effective where the geothermal gradient is highest [Fig. 15.25a, Keller, 2008], and that is in the Western U.S. where igneous activity and crustal thinning are relatively common [Fig. 15.25b, Keller, 2008], contributing to high surface heat-flow

- elsewhere in the U.S., geothermal (or ground source) heat pumps can be valuable, exchanging heat with the subsurface
(which remains at around 55 F) to reduce energy used for heating/cooling. See also Wikipedia.

• Very important in areas like Iceland, where abundant renewable energy has sparked a major industrial boom (aluminum production)
Wind Energy

- becoming important in many areas of the U.S., e.g. Texas had 4,600 MW of installed wind-power capacity in 2007

- especially the mid-west has excellent wind resources (Fig. 10)

- Locations take advantage of geographic features such as mountain passes that focus wind [Fig. 15.32, Keller, 2008] or regionally windy areas

- unreliable (can’t be scheduled, e.g. Feb. 2008 TX wind “failure” )
• needed: ways to transport produced energy to cities, and to store the energy
Figure 10: Average wind speed over land, U.S. and World. Large turbines need speeds $\geq 7 \frac{\text{m}}{\text{sec}}$. From NASA.
Other Renewables

- generally renewable energy sources are directly or indirectly derived from the Sun [Fig. 15.29, Keller, 2008],

- solar energy can be used to heat water for turbine-electricity generation, [Fig. 15.36, Keller, 2000], but most often photovoltaic cells [Fig. 15.33, Keller, 2000] are used for direct electricity generation, or passive solar energy is used to heat water for direct use or space heating

- almost all of the U.S. has sufficient solar usability to allow solar energy development [Fig. 15.31, Keller, 2000]

- hydroelectric uses dams to pool water to drive turbines, and is an important source of electricity in the U.S.

Future
hydroelectric development will be very limited because most suitable rivers have already been developed
Biofuels

• another potential energy source is alcohol or methane generated from agricultural or other products (see DOE Biomass webpage)

• often politically popular since this approach allows existing farm subsidies to be applied to energy problems (e.g. see BioWillie)

• generally energy inefficient:
  – agricultural biofuels require 1 unit of fossil fuels to produce 2-3 units of biofuel (see EEC report)
  – corn is worse, requiring 7 units of fossil fuel to produce 8 of corn-based ethanol (based on 2002 farming efficiency data)
* see also 2006 “Corn Can’t Solve Our Problem”

– recent [Wu et al., 2006] indicate sources like switchgrass (celulosic sources), processed carefully, used in E-85 hybrid vehicles, can reduce petroleum usage by 90% per vehicle mile (Fig. 11)

– natural byproduct biofuels (e.g. from logging waste) produce up to 17 units of biofuel for each unit of fossil fuel required

– waste cooking oil is often combined with diesel fuel to make biodiesel

– automotive fuel efficiency declines significantly (around 20%) when ethanol fuels are used

– biofuels tend to release high amounts of NO2, a strong greenhouse gas. So while biofuels may reduce mass of greenhouse gases released per gallon, the greenhouse effect
per gallon may be increased.
Figure 11: Theoretical optimum energy savings and greenhouse gas (GHG) emissions reduction for biofuels. Corn ethanol is starch-based, requiring much fossil energy usage, cellulosic fuels produced using waste biomass as energy source. Use of high-efficiency production and consumption (i.e. biofuel-hybrid vehicles) is assumed, after Wu et al. [2006].
U.S. Energy Supply

• de-politicising conservation issues often quite effective (e.g. better than Al Gore). See [DOE Case Studies](#)
Texas Deregulation

- Texas deregulated the former electric utility monopoly in 2002
- since then consumers can choose their electric provider
- a **central website** provided by the TX Public Utilities Commission gives comparative quotes
- each utility provides an *energy facts label* giving fuels mix, waste/CO2 generation, etc.
- independent consumer organizations also publish useful reviews. E.g. **Consumers Union** clarifies the fine print
and notes that single-digit savings (10%) were most likely in 2002.

- hurricane damage in Fall 2005 drove natural gas prices up just as rates were set for the next 6 months, leading to a 25% increase. Despite later relaxation of natural gas prices, electricity rates did not decline (see Dallas Morning News, Nov. 8, 2006)

- at the end of 2006 the “price to beat” will be discontinued, and rates can fluctuate at will
Other Resources
Useful Links

This is intended to be an ever-evolving list of useful links on the general topic of this note set.


• good summary of world production/demand/consumption by BP. For 2007 global oil production fell for the first time in five years, down 0.2%, while consumption increased by 1.1%

• MSNBC Answer Desk quick summary of drilling vs. conservation

• USGS study of likely Arctic oil resources
• FactCheck.org relatively unbiased assessment of “tire inflation vs. offshore drilling” controversy

• American Wind Energy Assn.

• Barnett Shale information
  – summary of history and status as of 2007

• U.S. Military warning of Peak Oil by 2015

• see IEA World Energy Outlook
Bibliography


