Energy and Society

Physics 20051
Energy 20101
Society Technology and Values 20304

Professor Ani Aprahamian
What does Energy have to do with Society?

Probably the greatest issue of your generation is the question of energy supplies for the human race, and how to deal with dwindling sources of energy that we are now using. To face this challenge, we need to understand energy consumption, i.e., to be “literate” in energy issues.
Course Description: A course developing the basic ideas of energy and power and their applications from a quantitative and qualitative viewpoint. The fossil fuels (coal, oil, natural gas) are studied together with their societal limitations (pollution, global warming, diminishing supply). Nuclear power is similarly studied in the context of the societal concerns that arise (radiation, reactor accidents, nuclear weapons proliferation, high-level waste disposal). The opportunities as well as the risks presented by alternative energy resources, in particular solar energy, wind, geothermal, and hydropower, together with various aspects of energy conservation, are developed and discussed. We will consider the societal impacts and challenges in detail for nuclear energy in terms of the international context.
Scientific Method… Not based on “belief”… based on observation!

Science…
- different than opinion…
- repeating results/predicting/throwing out ideas that don’t work
- statistics
- how it works

Once an observation is proven to be true…
Policy changes…
- Ozone Hole remediation
- Energy Standards on appliances
- Chemical pollution
- Radiation protection

- Pseudoscience
  - Belief, dogma
  - Ideas not testable

- Evaluation of a claim
  1. Are the ‘facts’ true as stated?
  2. Is there an alternative explanation?
  3. Is the claim falsifiable?
  4. Have claims been tested?
  5. Do claims require unreasonable changes in accepted ideas?
Pseudoscience

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Why Science?

Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity.
How are we going to talk about this?

**General properties of energy:**

- Energy is the capacity to do work.
- Energy cannot be created or destroyed.
- Energy comes in different forms, and we obtain useful work by converting energy from one form to another (e.g., the energy stored in gasoline is converted into kinetic energy of the car).
- While energy cannot be destroyed, it can be wasted; e.g., in converting energy in gas into propelling a car, some of the energy turns up as heat. Heat is also energy, but it is useless in this case.
- To deal with useful vs. wasted energy, we need to introduce the concept of **efficiency**: the ratio of useful work to energy input:
  \[ \text{Efficiency} = \frac{\text{useful work}}{\text{energy spent}}. \]
EXAMPLES OF SOURCES OF ENERGY

Fossil fuels, sunlight, falling water, wind, earth’s internal furnace (geothermal), bio-fuels, etc.

The key is to find the means of converting these to usable (e.g., electrical) energy.
Energy consumption by country or region (absolute amounts, in “quads”)
Energy consumption by country or region (percentages)

World Energy Consumption 2002

- North America: 26.8%
- China: 10.5%
- Japan: 5.3%
- Russia: 6.7%
- Africa: 3.1%
- Middle East: 4.6%
- Asia: 12.6%
- Central/South America: 6.8%
- Eastern Europe-FSU: 5.9%
- Western Europe: 17.6%

World Primary Energy Consumption by Country/Region

- United States: 21.7%
- OECD Europe: 17.5%
- China: 14.5%
- Russian Federation: 6.6%
- Middle East: 5.0%
- Central & S America: 5.1%
- Japan: 4.9%
- Other non-OECD Asia: 5.8%
- Other non-OECD Europe: 4.4%
- India: 3.5%
- Africa: 3.1%
- South Korea: 2%
- Mexico: 2%
- Canada: 3.1%
- Australia & New Zealand: 1.4%

Note: US population is about 4.5% of world population
Use by resource in various communities:

**World 2003**
- Coal: 24%
- Natural Gas: 23%
- Nuclear: 6.6%
- Hydro: 6.5%
- Oil: 39%
- Renewables: 1%

**United States 2003**
- Coal: 23%
- Natural Gas: 22.8%
- Nuclear: 8%
- Hydro: 2.8%
- Oil: 36.9%
- Renewables: 3.4%

Adds up to ~14%
Offshore drilling for oil accounts for about 26% of US oil production. About 93% of this oil comes from the Gulf of Mexico.
OFFSHORE OIL: some of the facts
Source National Geographic....

Each day billions of gallons of oil are pumped from the Gulf of Mexico, but how important is this body of water to our survival? What other types of life thrive there? And what else do we know about this famous gulf?

By the middle of the 1900s, between 20 and 25 percent of the total 228 billion cubic feet of natural gas produced in the world every day was released from offshore sites.

The mainland shoreline of the Gulf of Mexico spans 4,000 miles.

Scientists still are not completely certain about the gulf’s geological origins; some say that it is a continental crust which has been flooded by the ocean.

The outer continental shelf of the United States is one of the world’s most plentiful sources of offshore oil.

13.9 billion cubic feet of natural gas and 1.3 million barrels of oil are removed from the outer continental shelf each day.

Why are we digging miles in the ocean to get at oil?
What is the problem?

Why are we digging miles in the ocean to get at oil?
Which of these energy resources should we use now, and in the future?

Each resource has advantages and disadvantages, financial and environmental

Alternative resources?
It takes ~ 50 years* and huge $$$ to phase in new energy alternatives to the point where they provide 10-20% of total energy used.

* Please note lack of compatibility between this time scale and the time scale of $$$ decision-makers (industry and political leaders).
How are resources being used?

- Commercial: 17.8%
- Residential: 21.6%
- Transportation: 27.3%
- Industry: 33.1%

End-Use Sector Shares of Total Energy Consumption, 2007

- Commercial: 18.0%
- Residential: 21.0%
- Transportation: 29.0%
- Industrial: 32.0%

Facts:
1: 60% of the Residential and Commercial sectors' energy consumption is attributed to motors.
2: 75% of the Industrial sector's energy consumption is attributed to motors.

Source: US DOE Energy Information Administration, Annual Energy Review 2007, P. 74
Why do we use so much energy?

Way of life:

⇒ Transportation (cars vs. public transportation)
⇒ Large fraction of our population lives in separate homes.

We do not use the energy resources efficiently:

≈ 80% of all commercial energy used in USA is wasted.
≈ 40% due to second law of thermodynamics
≈ 40% unnecessarily:
    using fuel wasting devices (motor vehicle, furnaces)
    poorly designed and poorly insulated buildings)
Total energy flow in the US: in Quads of BTU

- Coal 22.31
- Natural gas 19.64
- Crude oil 12.15
- NGPL 2.34
- Nuclear 7.97
- Renewables 6.15
- Crude oil and products 26.21
- Other 4.82

Supply 102.20
- Domestic production 70.47
- Imports 31.02
- Adjustments 0.71

Coal 22.71
- Fossil fuels 84.34
- Natural gas 22.51
- Petroleum 39.07
- Nuclear 7.97
- Renewables 6.15
- Other 2.93

Exports 4.05
- Residential and commercial 38.78
- Industrial 32.52
- Transportation 26.86
Future projections

Figure 13. World Energy Consumption, 1970-2020

Quadrillion Btu

History

1970: 207
1975: 243
1980: 285
1985: 311
1990: 346
1995: 366
1999: 382

Projections

2005: 439
2010: 490
2015: 547
2020: 607

Projection of world energy consumption in BTU per annum. Note correlation with population growth (but that is not the only factor).
Population growth even as we speak

Current Population Clock
U.S. 314,205,312
World 7,034,217,275
9:45 AM  Today Aug 21, 2012
Population growth
US energy consumption by type of fuel
Projection of US annual energy consumption per person

Total US energy consumption: $\sim 300 \times 10^6 \times 350 \times 10^6 \approx 100 \times 10^{15}$ BTU
Projection of energy consumption by different communities

- **Industrialized**
- **Developing**
- **EE/FSU**
Example:
Why has the industrial world's *per capita* use of energy remained about the same in the past decade, even though the world's economy has increased by 50%?

Answer:
Much of the economic growth has been in developing countries, which have accordingly progressed from low energy use per capita to increasingly higher use. At the same time there has been a marked increase in **efficiency** of energy use in the industrial world.
US Energy Consumption as % of World

Comparison of energy consumption of developed and developing world

zJ means Zetta Joules, i.e., $10^{21}$ joules.
[1.0 ton of oil equivalent = 40x10^6 BTU]
If the world use of oil is about 78 MBPD, how long would you expect this resource to last at this consumption rate?

\[
\frac{1213 \times 10^9 \text{ bbl}}{78 \times 10^6 \text{ bbl/day}} = 15.6 \times 10^3 \text{ days} = 43.8 \text{ years}. 
\]

**Table 1.1  WORLD AND UNITED STATES PROVEN RESERVES: 2003**

<table>
<thead>
<tr>
<th>Resource</th>
<th>World</th>
<th>United States</th>
<th>Lifetime*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>$1213 \times 10^9 \text{ bbl}$</td>
<td>$22.7 \times 10^9 \text{ bbl}$</td>
<td>10 years</td>
</tr>
<tr>
<td></td>
<td>$7.0 \times 10^{18} \text{ Btu}$</td>
<td>$0.12 \times 10^{18} \text{ Btu}$</td>
<td></td>
</tr>
<tr>
<td>Natural gas</td>
<td>$5505 \times 10^{12} \text{ cf}$</td>
<td>$187 \times 10^{12} \text{ cf}$</td>
<td>9 years</td>
</tr>
<tr>
<td></td>
<td>$5.4 \times 10^{18} \text{ Btu}$</td>
<td>$0.19 \times 10^{18} \text{ Btu}$</td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>$1.08 \times 10^{12} \text{ tons}$</td>
<td>$0.27 \times 10^{12} \text{ tons}$</td>
<td>250 years</td>
</tr>
<tr>
<td></td>
<td>$27 \times 10^{18} \text{ Btu}$</td>
<td>$7 \times 10^{18} \text{ Btu}$</td>
<td></td>
</tr>
<tr>
<td>Oil sands</td>
<td>$272 \times 10^9 \text{ bbl}$</td>
<td>$22 \times 10^9 \text{ bbl}$</td>
<td>8 years</td>
</tr>
<tr>
<td></td>
<td>$1.5 \times 10^{18} \text{ Btu}$</td>
<td>$0.12 \times 10^{18} \text{ Btu}$</td>
<td></td>
</tr>
</tbody>
</table>

*Ratio of U.S. reserves to 2003 U.S. production rate.

**Answer:**

oil will last

\[(1213 \times 10^9 \text{ bbl})/(78 \times 10^6 \text{ bbl/day}) = 15.6 \times 10^3 \text{ days} = 43.8 \text{ years}.
\]
List reasons why U. S. *per capita* consumption of energy over the past three generations has risen by almost a factor of four?

**Answer:**
- Increase in travel,
- Moves to single family homes from apartments,
- Leisure time,
- Increased number of appliances,
- Higher per capita income to spend,
- Electrification, etc.
A ray of hope (literally): Comparison of existing resources vs. world energy usage. The problem is that today we don’t know how to get energy from these sources.

Add to this geothermal: Even today, much more electricity is produced from geothermal sources than from solar and wind resources combined.

TW means terawatts, i.e., $10^{12}$ watts.
What does Energy have to do with Society?

But now...more than energy supply and still significant consequences associated with traditional pollution and resource extraction is the impact on global climate change, brought about largely by the emissions from fossil fuel combustion.

Climate change...no national boundaries
Enter the Anthropocene—Age of Man

It’s a new name for a new geologic epoch—one defined by our own massive impact on the planet. That mark will endure in the geologic record long after our cities have crumbled.
What is the problem with fossil fuels?

- Fossil fuels will not last forever
  
  By 2040 oil reserves depleted
  By 2080 natural gas reserves depleted
  By 2300 coal reserves depleted

- Their use is dangerous to the environment
  \( CO_2 \) emission

Limited Supply
New Flood Warnings Raise Fears in Pakistan

Photographs from NY Times

THE LATEST: FLOODING DEVASTATES THE NATION
August 24, 2010 (NY times)

The summer of 2010 produced Pakistan's worst flooding in 80 years (more on Pakistan's 2010 floods here). In a televised address on August 14, Prime Minister Yusuf Raza Gilani said that 20 million people, about one-ninth of the population, had been displaced by the disaster. Millions were left without food, shelter and clean water. Flooding began on July 22 in the province of Baluchistan. The swollen waters then poured across the Khyber-Pakhtunkhwa Province in the northwest before flowing south into Punjab and Sindh.
Powerful Quake and Tsunami Devastate Northern Japan

An area in Sendai City, in northeastern Japan, that had been swept by the tsunami. More Photos »

By MARTIN FACKLER
Published: March 11, 2011
2011 Japan Nuclear Crisis: Overview
The earthquake and tsunami that hit northern Japan on March 11, 2011 created the worst nuclear crisis since the Chernobyl disaster. The three active reactors at the Fukushima Daiichi Nuclear Power Station 170 miles north of Tokyo suffered meltdowns after the quake knocked out the plant's power and the tsunami disabled the backup generators meant to keep cooling systems working. A series of explosions and fires led to the release of radioactive gases.

But recently, in a historic shift, more than a dozen companies around the United States have suddenly become eager to build new nuclear reactors. Growing electric demand, higher prices for coal and gas, a generous Congress and a public support for radical cuts in carbon dioxide emissions have all combined to change the prospects for reactors, and many companies were ready to try again.
ECOLOGICAL IMPACTS OF CLIMATE CHANGE

A presentation developed by the National Academy of Sciences based on its report *Ecological Impacts of Climate Change*: www.nas.edu/climatechange.
The Climate is Changing

- Temperatures are rising
- Sea levels are rising
- The ocean is acidifying
- Climate change is reflected in water cycle changes and in extreme weather

Temperature rise, indicated by color (red=higher rate of increase). Earth’s surface temperature has risen ~1.3° F since 1850.

Ecological Impacts

Living things are intimately connected to their physical surroundings.

Ecosystems are affected by changes in:

- temperature
- rainfall/moisture
- pH
- salinity (saltiness)
- activities & distribution of other species
- ...many other factors
Global Changes, Local Impacts

Although climate change is global, the ecological impacts are often local.

What’s happening in your backyard?
The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

http://drought.unl.edu/dm
We are going to address some of the impact of Energy Use from fossil fuels

Issue has been politicized beyond recognition

Important for National Security


http://youtu.be/YPmiSwt-RLU
Chair of Intergovernmental panel on climate change...Rajendra Pachauri
Expressing our opinions

Article from New York Review of Books by Tony Judt
Words

July 15, 2010

In “Politics and the English Language,” Orwell castigated contemporaries for using language to mystify rather than inform. His critique was directed at bad faith: people wrote poorly because they were trying to say something unclear or else deliberately prevaricating. Our problem, it seems to me, is different. Shoddy prose today bespeaks intellectual insecurity: we speak and write badly because we don’t feel confident in what we think and are reluctant to assert it unambiguously (“It’s only my opinion...”). Rather than suffering from the onset of “newspeak,” we risk the rise of “nospeak.”
Course Description: A course developing the basic ideas of energy and power and their applications from a quantitative and qualitative viewpoint. The fossil fuels (coal, oil, natural gas) are studied together with their societal limitations (pollution, global warming, diminishing supply). Nuclear power is similarly studied in the context of the societal concerns that arise (radiation, reactor accidents, nuclear weapons proliferation, high-level waste disposal). The opportunities as well as the risks presented by alternative energy resources, in particular solar energy, wind, geothermal, and hydropower, together with various aspects of energy conservation, are developed and discussed. We will consider the societal impacts and challenges in detail for nuclear energy in terms of the international context.
Aspects of Energy production/efficiency/transport

Commercial
Residential
Industrial
Transportation

Energy demands in industry, Fossil Fuels and societal limitations
Coal
Natural gas
oil

What about Nuclear Energy?

Alternative energy resources and resources needed
solar energy
wind
geothermal
hydropower
new discoveries that change everything?
energy conservation as a solution?
America's Energy Future

There is a growing sense of national urgency about the role of energy in long-term U.S. economic vitality, national security, and climate change. The U.S. has the resources to combat this energy challenge; the dilemma is to identify which solutions will be right for our country, and how to address the massive technological and social changes to come.

To fill this information gap, the National Academies launched the America’s Energy Future study in 2007. This four-year project explored energy technologies, providing authoritative estimates and analysis of the current and future supply of and demand for energy; new and existing technologies to meet those demands; their associated impacts; and their projected costs.

http://sites.nationalacademies.org/Energy/

Youtube video  by Secretary of Energy Steve Chu
How are we going to do this?

Part I: Instructor (lectures, guests)
- Energy Fundamentals
- Fossil Fuels
- Renewable Energy Resources (Wind, Solar, Geothermal, BioMass)
- Nuclear Energy
- Energy Conservation
- Transportation
- Architecture (Residential and Industrial)
- Global Effects
Part II: Class

1. Homework problems and essays on technical challenges/policy issues
2. Classroom participation and discussions
3. Keeping track of the latest developments in the news/www/etc.
4. Examinations (3)
5. Final Examination
Moral and Ethical Issues of Consumption
National Security of garnering the necessary energy resources (fossil fuels, other)
Political and Geopolitical Instabilities associated with Energy requirements
Financial Considerations of energy transitions (wood to fossil fuels to other energy resources)
Science for a Secure and Sustainable Energy Future
How to address the challenges of Energy in the US?
  • Energy Independence.
  • Environmental Sustainability.
  • Economic Opportunity.
Reducing Greenhouse Gases, Is it possible?
Cooling the Earth?
Efficiency: Electricity Transmission and Distribution? The GRID
Efficiency: Appliances, Automobiles, Architecture
Challenges of Nuclear Energy
Challenges of Solar Energy/Wind/Geothermal/Hydropower/etc.
Marketing Energy Conservation to the public: What are the real prospects?
Energy policies in G-20 countries (or some subset of countries: Eurozone, Asia, South America, etc.)
Nuclear Issues in Australia and Beyond; One Perspective

Professor George Dracoulis, Fellow of the Australian Academy of Sciences
Australian National University

Nuclear issues in Australia have had, at best, a conflicted history: A country with significant uranium resources but no nuclear power. In this talk I will cover selected aspects of uranium production, nuclear fission, the scale of present and future nuclear power world-wide, life-cycle greenhouse gas emissions from competing technologies, and the demand and comparative cost of electricity generation in Australia. As far as time permits, I will try to touch on the numerous topics that underlie the debate including politics, risk, public perception and public acceptance in the year following the 25\textsuperscript{th} anniversary of Chernobyl and dramatic events in Japan, with likely ramifications for the nuclear industry.

George Dracoulis has been a member of Department of Nuclear Physics at the Australian National University since 1973, and was Head from 1992 to July 2009. He was appointed Professor Emeritus in 2010. During 2006 he was a member of the Prime Minister’s task force that reviewed the prospects for uranium mining and nuclear energy in Australia, and he has been involved in public engagement on nuclear policy issues, locally and abroad.