SUSTAINABLE DEVELOPMENT & ENERGY OPTIONS

Dean E. Abrahamson ©

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My name is Dean Abrahamson; I retired as professor of energy & environmental policy from the University of Minnesota in 1998. My first professional job, after physics graduate school, was as a reactor physicist. I then spent a few years as senior research scientist at Honeywell before going to medical school. My first tenured appointment was in the Univ of Minnesota School of Medicine. One thing led to another, along the way I read some biology and economics, and I ended up at what is now the Humphrey Institute of Public Affairs where I focused on energy policy and for about ten years worked on climatic change & wrote a couple of books. I’ve taught energy policy since the early 1970s. I’ve been a Trustee of the NRDC since 1972.
OUTLINE

• The context: Growth v. sustainable development
• Major issues: Middle-East oil, nuclear power, global warming
• Current energy supply
• Energy options
  – Reduce demand for energy
  – Increase energy supply
    • Solar, windpower & other renewables
    • Natural gas
    • Oil
    • Coal
    • Nuclear power
• Global warming & climatic change
• Summary
One of the laws of ecology is *Everything is connected to Everything else.*
Up 300% in my lifetime

Increased 4 X since 1960;
75% increase last 25 years

Have nearly run out of places to build dams

80 countries with 40% of world population have serious shortages

Biologically active Nitrogen from fertilizers exceeds natural rate

Up 90% in last 25 years

Up 45% in last 25 years

Highest in >400,000 years

Holes in stratospheric ozone over both poles

Unless vigorous action is taken soon, committed to a ~4°F global heating

Frequency of extreme weather events increasing

75% of fisheries fished to capacity or overfished

~150 dead zones in oceans the 2nd largest at the mouth of the Mississippi River

At least a third of world forests and half of wetlands have been destroyed

Rate of species extinction now 100-1,000 times normal

Business-as-usual is not sustainable

Major changes are necessary, not the least with our energy system
AMONG THE MAJOR ENERGY-RELATED SUSTAINABILITY ISSUES
Increasing scarcity of conventional oil and increasing dependence on oil from the Middle East. This is resulting in:

- Massive military spending and wars
- Use of non-conventional oil, primarily Tar Sands which are the dirtiest of all fuels.
- Conversion of food to fuels
There is a new, and major, push to build new nuclear power plants even though

- New nuclear power is the most expensive non-carbon energy option
- There are massive external costs.
  - Waste isolation
  - Accidents
  - Risk of proliferation of nuclear weapons
The need to greatly reduce carbon dioxide pollution to limit climatic change. [And similar reductions in the other major greenhouse gases.]

This requires reducing fossil fuel (coal, oil, natural gas) consumption by 60-80% by mid-century and shifting to energy sources that have little or no net emissions of carbon dioxide (CO$_2$) if we are to avoid catastrophic climatic chang.
CURRENT ENERGY SUPPLY
Primary & Secondary Energy

- Primary energy is as found in nature
  - Solar
  - Geothermal
  - Tidal
  - Hydrocarbons (Natural gas, Oil, Coal, Oil shale, Tar sands . . . )
  - Uranium and thorium (Fission fuels)

- Secondary energy, or energy carrier, is the form delivered to the user
  - Electricity
  - Hydrogen
  - Petroleum & natural gas products
  - Heat
Solar Energy

Solar energy usually refers to all systems driven by the flux of solar energy

- Hydropower
- Wind
- Photovoltaics
- Direct heating
- Biofuels
Renewable Energy Supply

• Solar
• Geothermal
• Tidal
Fossil Fuels: >80% Global Primary Energy

Fossil Fuels
>80% of primary energy

~80% of greenhouse gases

Coffman Lecture 2010
Dean Abrahamson
Renewables: ~19% Primary Energy

Wind, solar & geothermal
Plus
Biomass
Supply about 19% of global primary energy
Nuclear 5½ % Primary Energy

Primary Energy (EJ)

1850 1900 1950 2000

0 100 200 300 400 500

Steam engine Electric motor Gasoline engine Vacuum tube Television Commercial aviation Nuclear energy Gas Oil Nuclear Renewable

Coffman Lecture 2010
Dean Abrahamson 20
Energy Options

1. **REDUCE CONSUMPTION** by means that reduce energy use without decreasing energy services, i.e., increase the efficiency with which primary energy is converted to energy services, or by changing our consumption patterns.

2. **INCREASE SUPPLY**
   - Renewables
   - Natural Gas
   - Coal
   - Oil
   - Nuclear Power
REDUCING ENERGY USE WITH NO LOSS OF ENERGY SERVICES
The Total Cost of Increasing Efficiency

A 2010 analysis by David B. Goldstein, one of the recognized world experts in energy efficiency, concluded that

Now approaching $10,000

Today nuclear power would average $5,000 or more per kilowatt. By comparison, efficiency improvements typically cost about $300 per kilowatt, and that includes the entire cost, not just the construction costs.

An Example Buildings
Buildings Use 25-40% of Energy Demand

Buildings are one of the largest end users of energy; the building sector accounts for 25-40% of the final energy demand in OECD countries.
Lighting Consumes Most Energy

Kilowatt-hours (KWH) per Square Foot

- Lighting
- Ventilation
- Cooling
- Other
- Refrigeration
- Computers
- Space Heating
- Office Equipment
- Water Heating
- Cooking

Source: Energy Information Administration and Green Econometrics research

According to the EIA, in commercial buildings, lighting fixtures consume the most electric energy, three times the energy consumption of air conditioning.
Electricity Use by Bulb Type

- Conventional Incandescent
- Halogen
- Compact Fluorescent CF
- Light-Emitting Diode LED: 80% Less than conventional bulb
Passive Buildings
Before reconstruction

Reconstruction according to the passive house principle

over 150 kWh/(m²-year)

-90%

15 kWh/(m²-year)

Remember that almost none of us care about energy; we care about energy services—heating, cooling, lighting, transportation . . . There is a huge potential to reduce energy use with no loss of energy services while at the same time saving money for those of us who must pay the energy bill.
INCREASE ENERGY SUPPLY
**Energy Resources**

$TW = 10^{12}$ Watts = 1 Trillion Watts

Present global commercial energy use = 15 TW-yr/yr

<table>
<thead>
<tr>
<th>RENEWABLES: ENERGY FLOWS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
</tr>
<tr>
<td>Geothermal</td>
</tr>
<tr>
<td>Tidal</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MINERAL ENERGY RESOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coal, Tar Sand, Oil Shale</td>
</tr>
<tr>
<td>Natural Gas</td>
</tr>
<tr>
<td>Conventional Oil</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NUCLEAR FUEL RESOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uranium</td>
</tr>
</tbody>
</table>
RENEWABLES
Renewables ~19% Global Final Energy Consumption
In 2008 – and Growing Rapidly


Source: REN2I_2010
Windpower Growing at More than 20%/year

U.S. – Global Is Similar & Higher Than 20% in Many Countries

The U.S. wind industry broke all previous records by installing over 10,000 megawatts (MW) of new generating capacity in 2009.

Total wind installed reached 35,086 MW, including small wind turbines, at the end of 2009.
Solar PV Growing at More than 20%/year

Annual new grid connections 1995 - 2009

GLOBAL

GW

wind
nuclear
PV

year
NATURAL GAS

World Natural Gas Reserves by Country, January 1, 2010

- Russia: 1,680.0 Trillion Cubic Feet
- Iran: 1,045.7 Trillion Cubic Feet
- Qatar: 899.3 Trillion Cubic Feet
- Saudi Arabia: 263.0 Trillion Cubic Feet
- USA: 244.7 Trillion Cubic Feet
- UAE: 214.4 Trillion Cubic Feet
- Nigeria: 185.3 Trillion Cubic Feet
- Venezuela: 176.0 Trillion Cubic Feet
- Algeria: 159.0 Trillion Cubic Feet

Source: Oil & Gas Journal, Jan. 1, 2010
U.S. Natural Gas Use

- Residential: 21%
- Industrial: 28%
- Commercial: 13%
- Oil & Gas Industry Operations: 6%
- Pipeline Fuel: 3%
- Vehicle Fuel: 0.1%

Electric Power: 29% and Growing
Natural Gas Pollution is Smaller than from Oil or Coal, but Not Zero

• Less than half as much greenhouse gas pollution as coal or and about 1/3\textsuperscript{rd} as much as from tar sands oil
• No toxic heavy metals
• Relatively low, but far from zero, land-use impact
• Production of non-conventional natural gas from shale deposits raises serious environmental issues.
OIL

36% of global energy
>40% of U.S. energy

The U.S. has about 2% of global oil reserves and consumes about 23% of the world’s oil production.
U.S. Oil Production Peaked in December 1970
Conventional Oil Production Has Peaked in Most Non-OPEC Countries

U.S.A.
Global Conventional Oil Production Has Peaked or Will Soon Peak. We’ll Know in A Couple of Years
60+% of the Remaining Conventional Oil Is in the Middle East Primarily in Five Countries
THE MIDDLE-EAST OIL “SWING COUNTRIES”
NEIGHBORS THAT ARE MUCH IN THE NEWS

ISRAEL
AFGHANISTAN
PAKISTAN
KUWAIT
UAE
SAUDI ARABIA
NUCLEAR WEAPONS IN THE REGION

SYRIA
Nuclear Intentions Unclear

ISRAEL

AFGHANISTAN

PAKISTAN

IN PROGRESS

UAE

SAUDI ARABIA

IRAN

IRAQ

KUWAIT
U.S. IMPORTS: 60+% OF OIL CONSUMPTION

OPEC ~43% of U.S. Imports

= Middle East

www.DollarDaze.org
U.S. Oil Use

US Transportation Oil Use

Data: EIA 2007

- Cars 34%
- Medium & Heavy Trucks 20%
- Pickups & SUV's 28%
- Buses 1%
- Motorcycles 0%
- Air 9%
- Rail 2%
- Water 6%
For the record, the U.S. military is the largest single consumer of oil in the world, burning 16.8 million gallons per day.

Lehrer (2010), p. 81
Major Components of U.S. Oil Policy

- Token auto efficiency standards
- Mandate conversion of corn to ethanol
- Increase imports of Alberta Tar Sands non-conventional oil
- Make war to protect access to Middle East oil
U.S. Auto “Efficiency” About half that of the E.U. and Japan
Nearly 30% of U.S. Corn Goes to Ethanol Production

Source: Data from FAPRI July 2006 Baseline Update for U.S. Agricultural Markets
Corn → Ethanol → SUV
Feed a Person for a Year or Fill Up an SUV?

“While politicians and Big Agriculture insist on casting the need for ethanol in terms of national security, the larger issue is a moral one: are we going to use our precious farmland to grow food, or use it to make motor fuel?”

http://www.alternet.org/environment/48790
By far the largest North American oil resource is Canadian tar sands.
The Alberta tar sands system is the world’s largest industrial program
The Alberta tar sands program has been called the most destructive program on earth.

- Non-conventional oil from tar sands produce more greenhouse gas pollution than any other fuel used in the U.S.
- Massive land use disturbance.
- Massive water use and water pollution
- Major impact on native culture
Primary U.S. Middle East Oil Policy

"The gas is only $1.39. The aircraft carrier is $470, the tank is $125, the stealth fighter is $330, the gas mask is $45 and the gun adds $30 a gallon."
The True Cost of Oil

✓ Crude oil now costs ~$70/Bbl (per barrel)
  $1.67/gallon [1 Barrel Oil = 42 gallons]
✓ The cost of gasoline at the pump, in the
  U.S., is about $3/gal
✓ Military cost protecting access to Middle
  East oil; estimated at $7.41/gal
✓ Total economic costs are estimated at
  $480/bbl ~$11/gal)
✓ Plus direct subsidies
✓ Plus environmental cost
✓ Plus health costs
✓ And more

http://www.energyandcapital.com/articles/oil-gas-crude/461
U.S. Direct Federal Tax Subsidies to Oil Companies

Federal tax breaks that directly benefit oil companies include: the Percentage Depletion Allowance (a subsidy of $784 million to $1 billion per year), the Nonconventional Fuel Production Credit ($769 to $900 million), immediate expensing of exploration and development costs ($200 to $255 million), the Enhanced Oil Recovery Credit ($26.3 to $100 million), foreign tax credits ($1.11 to $3.4 billion), foreign income deferrals ($183 to $318 million), and accelerated depreciation allowances ($1.0 to $4.5 billion).

http://www.progress.org/2003/energy22.htm
And, there are problems like the BP oil blowout in the Gulf of Mexico – the greatest single environmental disaster in U.S. history.
COAL
The U.S. Has the World’s Largest Coal Resource

World Coal Resources
American Supply is Abundant and Affordable

- United States: 28%
- Russia: 19%
- China: 13%
- Australia/New Zealand: 9%
- India: 7%
- Rest of the World: 24%

EIA’s Total Recoverable Coal — Source CRS
The U.S. Consumes Nearly 20% of Global Coal Production
Coal is Used to Produce about 70% of Global Electricity
Coal Produces 45% of U.S. Electricity

2009 U.S. Electricity Generation by Source

- Coal: 44.9%
- Natural Gas: 23.4%
- Nuclear: 20.3%
- Hydroelectric Conventional: 6.9%
- Other Renewables: 3.6%
- Petroleum: 1.0%
Coal Comes From Strip Mines in e.g., Wyoming
Coal is Extracted by Mountain Top Removal Throughout Appalachia
Coal is Hauled by Unit Trains

100-120 Cars/train: 10,000 to 15,000 tons coal/train

A large power plant uses 1-3 trains of coal per day
CO₂ From Electricity Production

Coal

Nat. Gas

Nuclear

Renewables

g CO₂/kWh
COAL SUMMARY

• Huge Resource
• Very High Greenhouse Gas Pollution
• Very High pollution from toxic heavy metals, e.g., mercury
• Very High small particle pollution (Particulates cause the most important health effects from air pollution)
• Very High Land-Use Impacts Including Mountain Top Removal
EXPANDING NUCLEAR POWER
A NUCLEAR POWER REACTOR PRODUCES

- Electricity
- Waste heat
- Radioactive waste
- Plutonium
NUCLEAR PRODUCES ABOUT 5½ % OF GLOBAL PRIMARY ENERGY AND ABOUT 14% OF ELECTRICITY
It had been recognized from the dawn of the atomic age that nuclear power brings with it three imperatives
I

The *safeguards* problem.

To safeguard potential nuclear explosives, both uranium-235 and the plutonium created as an inevitable by-product of the fission process.
II

The safety problem.

To prevent accidents that could release radioactivity beyond the plant boundaries.
The waste problem.

To isolate the radioactive wastes from the biosphere for at least 200,000 years.
FORECASTS FOR NEW NUCLEAR POWER

- There are about as many forecasts for future nuclear power as there are forecasters.
- Forecasts range from no nuclear power by mid-century to thousands of plants.
NUCLEAR POWER COSTS

- As with oil, it is very difficult to establish the total cost of nuclear power. This is so because the largest costs have been externalized, that is, removed from the market place by government action.

- External costs are not paid by the firm involved with the activity, e.g., electricity utility or by the user of the electricity, but are paid by society at large.

- The internalized cost of new plants is increasing steadily. (Internalized costs are those that appear on the books of the firm conducting the activity.)
Nuclear Reactor Investment Costs Have Shown Negative “Economies of Scale”

Cumulative Nuclear Installed: GW

US average
France best guess

The cost of a new reactor is now about $10 billion.
New Nuclear Power

Only a few of the new reactors are in countries that choose nuclear capacity through free market processes. Some of these countries may be using civilian nuclear power as a cover for a nuclear weapons program.


http://www.world-nuclear.org/info/inf17.html
New U.S. Nuclear Power

• Following recent U.S. legislation which authorized massive federal subsidies, there were 18 applications for 27 new nuclear power plants from U.S. utilities & merchant power companies.
• In no case has a builder made a firm decision to go forward.
• The number is dwindling month by month
• Most recently, in October 2010, Consolidated Energy cancelled the proposed $10 billion Calvert Cliffs #3 unit in Maryland. [This caused waves throughout the global nuclear industry as it may mean no new U.S. reactors in the foreseeable future]

http://nuclear-news.net/2010/10/12/no-saving-prospects-for-nuclear-industry-on-the-cliff-edge/
NUKESPEAK

The history of nuclear development has been profoundly shaped by the manipulation of information... and the use of information-management techniques. For example:

- **Accidents** are now referred to as **incidents** or **operational problems**
- Reactor licensing applications used to include **Hazard Analyses**. These morphed into **Safety Analyses**
- **Explosions** have been called **Prompt Disassembly Events**
- So it goes. There are Nukespeak dictionaries

http://www.amazon.com/s/ref=nb_sb_noss?url=search-alias%3Dus-stripbooks-tree&field-keywords=nukespeak&x=0&y=0
NUCLEAR POWER
EXTERNAL COSTS
WASTE ISOLATION

The highly radioactive nuclear waste must be kept out of the biosphere for on order 200,000 years.

Nuclear power is the only energy technology where the waste is so dangerous that the government has to assume responsibility for disposal of the waste.
LIABILITY FOR MAJOR ACCIDENTS

Nuclear power is the only energy technology where the government has to assume the liability for catastrophic accidents.

The U.S. mechanism is the *Price-Anderson Nuclear Industries Indemnity Act*.  

REGULATORY AND SECURITY

Nuclear power is unique among energy supply options in that it requires large regulatory costs and large security costs at individual plants.
SAFEGUARDS

Nuclear Power is the only existing energy technology that requires an international safeguards regime to prevent countries from making nuclear weapons using “civilian” nuclear fuel cycle facilities and materials
Nuclear Terrorism Now Judged to be "Single Biggest Threat"

President Obama 11 April 2010: “The central focus of this nuclear summit is the fact that the single biggest threat to U.S. security—both short term, medium term and long term—would be the possibility of a terrorist organization obtaining a nuclear weapon.”

http://www.president-obama.org/obama-officials-stress-nuclear-threat-u-s-strength

New York Times reported: The Obama administration’s classified review of nuclear weapons policy will for the first time make thwarting nuclear-armed terrorists a central aim of American strategic nuclear planning

http://nuclear-news.net/2010/01/13/obama-recognising-nuclear-terrorism-as-the-greatest-risk
There is a very, very thin line between a civilian nuclear power system and a military weapons system.
A Curious Thing

It has always seemed curious that so-called “small-government” conservatives are among the most vigorous advocates for nuclear power, although nuclear power absolutely requires governmental control.

It began as, and continues to be, a technology of the State.
Climatic Change
GLOBAL GREENHOUSE WARMING

[Diagram showing Earth's energy balance, including incoming solar radiation, absorption by greenhouse gases, and radiated energy out to space.]
U.S. National Academy of Sciences
Underscores Needed Climatic Change Actions
May 2010

U.S. National Academy of Sciences
http://americasclimatechoices.org/
"Climate change is occurring, is caused largely by human activities, and poses significant risks for — and in many cases is already affecting — a broad range of human and natural systems."

“Substantially reducing greenhouse gas emissions will require prompt and sustained efforts to promote major technological and behavioral changes.”

“The U.S. should act now to reduce greenhouse gas emissions and develop a national strategy to adapt to the inevitable impacts of climate change.”

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**The Main Greenhouse Gases**

<table>
<thead>
<tr>
<th>Greenhouse gases</th>
<th>Chemical formula</th>
<th>Human Activity Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon-dioxide</td>
<td>CO₂</td>
<td>Fossil fuel combustion, Land use conversion, Cement production</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>Fossil fuels, Rice paddies, Waste dumps, Livestock</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O</td>
<td>Fertilizer, industrial processes, combustion</td>
</tr>
<tr>
<td>CFC-12</td>
<td>CCl₂F₂</td>
<td>Liquid coolants, Foams</td>
</tr>
<tr>
<td>HCFC-22</td>
<td>CHClF₂</td>
<td>Liquid coolants</td>
</tr>
<tr>
<td>Perfluoromethane</td>
<td>CF₄</td>
<td>Production of aluminium</td>
</tr>
<tr>
<td>Sulphur hexa-fluoride</td>
<td>SF₆</td>
<td>Dielectric fluid</td>
</tr>
</tbody>
</table>

- CO₂ is the big one, three times as much global heating as methane & N₂O together.
- A group of industrial chemicals that together produce about the same global heating as does methane.
Fossil Fuels Produce ~80% of Carbon Dioxide Pollution

The 3rd largest anthropogenic source is cement production about 4% of CO₂ pollution
Carbon Dioxide (CO₂) Causes Over Half of Global Warming

1.6+ Watts per meter² of earth surface
Global Temperature & Atmospheric Carbon Dioxide
Global annual average surface temperature increased by 0.74 ± 0.18 °C (1.33 ± 0.32 °F) during the 20th century
Of 1,218 weather stations in the contiguous United States, with data going back to 1895, 153 locations recorded their hottest summer on record in 2010 and nearly one in three stations recorded average temperatures among their five hottest on record.
See the Following for A Sample of What Global Warming of About 1.3°F Looks Like

http://www.youtube.com/watch?v=pG41xDxrzl8
How Much Warming is Legally (By International Treaty) Considered to Be Dangerous?

The United Nations Framework Convention on Climate Change (UNFCCC), been ratified by 187 nations, commits signatories' governments to reduce atmospheric concentrations of greenhouse gases with the goal of "preventing dangerous anthropogenic [human activity] interference with Earth's climate system."

At the 2009 Copenhagen meeting of the parties to the UNFCCC it was agreed that this will require keeping greenhouse warming to less than 2°C (3.8°F).
To Avoid Devastating Climatic Change

It is likely that keeping global warming to less than 2°C (3.8°F) requires reducing the concentration of atmospheric carbon dioxide to about **350 parts-per-million (ppm)**

This requires reducing carbon emissions from human activities by **60% to 80% by mid-century.** [The later we start, the more emissions must be reduced.]

This means shifting to energy sources and systems that result in essentially **zero carbon dioxide emissions.**
Global Emission Pathways to An Average Annual Global Warming of 2°C

Source: (WBGU 2009)
Global Emission Pathways to An Average Annual Global Warming of 2°C

Because CO₂ stays in the atmosphere for a very long, the total global heating depends on cumulative emissions, not of annual emissions.
The Powerful U.S. Coal Lobby and Reactionary “Conservatives” Continue to Block Attempts to Limit Carbon Emissions in the U.S.

See the excellent report, “As the World Burns”, in the 11 October 2010 issue of The New Yorker.

http://www.newyorker.com/reporting/2010/10/11/101011fa_fact_lizza

European countries and China have imposed carbon taxes or the equivalent
<table>
<thead>
<tr>
<th>OPTION ISSUE</th>
<th>INCREASE EFFICIENCY</th>
<th>RENEWABLES</th>
<th>COAL &amp; OTHER SOLID HYDROCARBONS</th>
<th>NUCLEAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource Base</td>
<td>Limited only by imagination &amp; thermodynamics</td>
<td>Huge</td>
<td>Very large</td>
<td>Very large</td>
</tr>
<tr>
<td>Public &amp; Occupational Safety</td>
<td>None</td>
<td>Minor issues except large dam failure</td>
<td>Major air pollution and coal miner health and safety</td>
<td>Major issues</td>
</tr>
<tr>
<td>Waste</td>
<td>None</td>
<td>Minor issues</td>
<td>Huge issues</td>
<td>Huge issues</td>
</tr>
<tr>
<td>Climate</td>
<td>None</td>
<td>Essentially zero</td>
<td>Huge issues</td>
<td>Small but not zero</td>
</tr>
<tr>
<td>Weapons Proliferation</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Huge issues</td>
</tr>
<tr>
<td>Availability</td>
<td>Always</td>
<td>Solar &amp; wind are intermittent</td>
<td>High capacity factor</td>
<td>High capacity factor in old plants but prone to unscheduled outages</td>
</tr>
<tr>
<td>Employment</td>
<td>Many professional &amp; relatively unskilled</td>
<td>Many professional &amp; relatively unskilled</td>
<td>Many coal mining jobs in a few states</td>
<td>Only highly-trained professional jobs</td>
</tr>
<tr>
<td>Regulation needed</td>
<td>None</td>
<td>Local land-use</td>
<td>National &amp; international absolutely necessary [Climate]</td>
<td>National &amp; international absolutely necessary [Weapons proliferation, safety, waste]</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Very low</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>Operating Cost</td>
<td>Zero</td>
<td>Low</td>
<td>High</td>
<td>Lower than coal Higher than natural gas</td>
</tr>
<tr>
<td>External Costs</td>
<td>Virtually none</td>
<td>Very low</td>
<td>Huge</td>
<td>Huge</td>
</tr>
<tr>
<td>System Requirements</td>
<td>Fits any system</td>
<td>Distributed &amp; centralized systems</td>
<td>Highly centralized</td>
<td>Absolutely requires large, highly centralized systems</td>
</tr>
<tr>
<td>Political Implications</td>
<td>None</td>
<td>Largely local</td>
<td>Political Power highly concentrated</td>
<td>Political power very highly concentrated</td>
</tr>
</tbody>
</table>
Of all environmental problems, the most threatening and in many respects the most intractable is global climate change.

The only other external energy cost that might match the devastating impact of global climate change is the risk of causing or aggravating large-scale military conflict. One such threat is the potential for conflict over access to petroleum resources.

Another threat is the link between nuclear energy and the spread of nuclear weapons. The issue is hardly less complex and controversial than the link between carbon dioxide and climate; many analysts, including me, think it is threatening indeed.

The decision to pay the monetary costs of solar energy, if it is made, will represent the ultimate internalization of the environmental costs of the options that solar energy would displace.

Components of U.S. Energy Policy

• Mandate conversion of corn to ethanol
• Increase imports of Alberta Tar Sands oil
• Make war to protect access to Middle East oil
• Token support for conservation and efficiency
• Insipid federal support for R&D on sustainable energy
• Much talk, but little meaningful action on climatic change
• Failure to set a price on greenhouse gas pollution
• Huge subsidies for nuclear power being offered, but even with these, the price and risks have been too high for utilities to swallow.
The Overreaching Goal of U.S. Energy Policy

Keep energy prices as low as possible, mollify every conventional energy lobby and damn-the-consequences!
Energy Is the Ultimate Resource
and
The Ultimate Pollutant
We Must **All** Do Much More Than Business-As-Usual With It’s Very Slow Incremental Change

**APPROPRIATE POLICIES ARE SUGGESTED IN**
