Climate Change and Protection: Sustainable Energy Paths

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The Risk of Climate Change
Rise in atmospheric carbon dioxide levels over the past few centuries

History of global temperature

Global Cooling over 60 million years

Ice-age cycle of the past 400,000 years
Changes in CO2 composition of greenhouse gases
Global mean surface temperature measurements

[Graph showing Land-Ocean Temperature Index from 1880 to 2000 with temperature anomaly on the y-axis and years on the x-axis, comparing annual mean and 5-year mean.]
Stabilisation scenarios and temperature increases for different climate sensitivities

Source: IPCC 2001, WG I
Projected regional temperature change

Annual mean change of temperature and its range (unit: °C) for SRES scenario A2 for period 2071 to 2100 relative to the period 1961 to 1990 (IPCC 2001, WG1).
Projected temperature and precipitation change at Great Lakes

Kling et al, 2003, Confronting Climate Change in the Great Lakes Region
Projected sea ice change

Observed Sea Ice September 1979

Observed Sea Ice September 2003

Projected ice extent 2070 to 2090 (5-model average for September) (Source: ACIA 2004)
The WAIS may disintegrate in response to anthropogenic greenhouse gas emissions (Oppenheimer 1998).

- Warming of 2.5 °C ha as a WAIS climate limit.
- Consequences of WAIS collapse: global sea level rise of around 6 meters, disruption of global oceanic circulation patterns. Keller 2005

Two possible positive feedbacks:
- slip rate ↑ = bottom temperature ↑ = slip rate ↑
- temp. ↑ = melting rate ↑ = height ↓ = temp. ↑
Vulnerability of coastal delta populations

Source: IPCC 2007
Changing ocean circulation in the North Atlantic could lead to cooling in Europe
World map of climate risks

- Shutdown of thermohaline circulation
- Collapse West Antarctic Ice Sheet
- Collapse Amazon forest
- Floods
- Loss of coral reefs
- Sea-level rise
- Droughts
- Change in hydrological cycle
- Species loss
- Harvest loss
- Methane outburst
- Species loss
- Monsoon suppression
- Water scarcity
PROBLEMS AND CONFLICTS OF FOSSIL-NUCLEAR ENERGY
Since 1960, about 600,000 persons died due to cyclones, storm surges and floods. November 2007 cyclone SIDR raked Bangladesh's southwest coast with maximum sustained winds of 241 km/h (150 mph), leaving thousands dead and hundreds of thousands homeless.

Climate change would significantly aggravate human insecurity in Bangladesh, one of the poorest and most densely populated countries of the world. During the monsoon about one quarter of Bangladesh is flooded.
Water crisis in the Middle East

Water strategic issue and conflict factor in the Middle East

- Arid climate
- Imbalance between water demand and supply
- Confrontation between key political actors
- Transboundary water resources
- Water disputes coincide with land disputes.

Competition over shared water resources

- Nile
- Euphrate
- Jordan

→ Water wars or water cooperation?
Boundary semi-desert to desert moved southward by 50 to 200 km since 1930s. Significant drop in food production (20%).

Drought & desertification in Sahara increased migration of nomadic groups into more fertile areas of Darfur.

Arabic herders from north migrated south and cattles trampled fields of African farmers.

Darfur is considered a “tragic example of the social breakdown that can result from ecological collapse” (UNEP 2007).
2003 heatwave in Europe: 35,000 people died and agricultural losses reached $15 billion.

A juvenile playing with matches started a Southern California wildfire that scorched more than 38,000 acres and destroyed 63 structures.
90% oil refinery capacity to be shut down.

More than 1,800 deaths; hundreds of thousands homeless.
Climate refugees?

8.4 million registered refugees and 23.7 million of Internally Displaced Persons (2006). At least 25 million environmental migrants mid-1990s and expected 50 million by 2010 and up to 150 million by 2050. Number of environmental migrants likely substantially rise in the future due to the impacts of climate change.
Security risks associated with climate change: Selected hotspots

Source: WBGU 2007
“Climate-related shocks have sparked violent conflict in the past, and conflict is a serious risk in areas such as West Africa, the Nile Basin and Central Asia.” (Stern Review 2006)

The effects of global warming could lead to large-scale migrations, increased border tensions, the spread of disease and conflicts over food and water, all of which could directly involve the US military. Climate change is characterized as a “threat multiplier” in already fragile regions of the world, exacerbating conditions that lead to failed states — the breeding grounds for extremism and terrorism. (National Security and the Threat of Climate Change, April 2007)

The effects of climate change have “long-term security implications for all countries which are far more serious, lasting and destructive than those of international terrorism.”(ORG 2006)

UN Secretary General Ban Ki-Moon warned that climate change may pose as much of a danger to the world as war.
Abrupt climate change and nuclear power: a security risk?

„With a scarcity of energy supply – and a growing need for access -- nuclear energy will become a critical source of power, and this will accelerate nuclear proliferation as countries develop enrichment and reprocessing capabilities to ensure their national security. China, India, Pakistan, Japan, South Korea, Great Britain, France, and Germany will all have nuclear weapons capability, as will Israel, Iran, Egypt, and North Korea.“ (Schwartz/Randall 2003)
The two perils have a great deal in common. Both are fruit of swollen human power—in the one case, the destructive power of war; in the other, the productive of fossil-fuel energy. Both put stakes on the table of a magnitude never present before in human decision making. Both threaten life on a planetary scale. Both require a global response. Anyone concerned by the one should be concerned with the other. It would be a shame to save Earth from slowly warming only to burn it up in an insidious nuclear war.” Jonathan Schell, The Seventh Decade
Global warming may “induce large-scale migration and lead to greater competition for the earth's resources” and result in “increased danger of violent conflicts and wars, within and between states”

Nobel Peace Prize Committee 2007
SUSTAINABLE ENERGY PATHS
Exploitation of fossil fuels in historic context

Source: Hubbert 1969
Share of energy sources in global primary energy use

Source: Nakicenovic et al., 1998
Oil exploration vs. production

The Growing Gap

- Past Discovery
- Future Discovery
- Production
Oil price and conflict

- Iranian revolution
- OPEC cuts production
- End of Iranian hostage crisis
- Yom Kippur war
- OPEC cuts production
- OPEC cartel collapses
- Invasion of Kuwait
- Start of second war in Iraq
Growing US foreign oil dependence

Million barrels per day

Source: EIA, DOE prognosis

Year
UN Framework Convention on Climate Change

UNFCCC Article 2 ultimate objective (Rio 1992):

“stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.”

1997 Kyoto Protocol to the UNFCCC:

- GHG emission reductions average -5.2% of 1990 level until 2008-2012
- Enters into force February 16, 2005
Emission per capita in different world regions

USA & Canada: 24.7%
Japan, Australia, NZ: 6.4%
Economies in Transition: 12.6%
OECD Europe: 14.9%
Middle East: 4.9%
Latin America: 6.5%
Centrally Planned Asia: 14.6%
Remaining Asia: 11.6%
Africa: 3.8%
Annex 1: 58.6%
Non-Annex 1: 41.4%
Growing gap between projected U.S. fossil fuel carbon emissions the required 60% to 80% reduction by 2050
Integrated strategies for US emission reductions

ONE PLAN FOR THE U.S.

Savings from:
- Electricity end-use efficiency
- Other end-use efficiency
- Passenger vehicle efficiency
- Other transport efficiency
- Renewables
- Carbon capture and storage

Carbon Emissions (billion tons a year)

Year

Scientific American, Sept. 2006
World in a boat: Where to go and how fast?

- Critical threshold?
- Uncertainty
  - Collapse Amazon forest
  - Tropical Monsoon suppression
  - Shutdown of thermohaline circulation
  - Floods
  - Droughts
  - Water scarcity
  - Sea-level rise
  - Change in hydrological cycle
- Trend
- Control
- Adaptation

- Glacier retreat
- Loss of polar ice
- Species loss
- Harvest loss
- Storms
- Loss of coral reefs
- Diseases

Critical threshold? Uncertainty
Climate COP in Bali: Drama of the Commons
Fuelling Change in the USA

- Over 700 U.S. cities signed to meet Kyoto Protocol
- California mandated 25% reduction in greenhouse gases by 2020
- Shadow U.S. delegation in Bali including Al Gore, John Kerry, Michael Bloomberg, officials from California
- Al Gore: "My own country, the United States, is principally responsible for obstructing progress here. ... We all know that. ... We are going to change in the U.S."
- European Union officials threatened to boycott U.S.-sponsored climate talks in Washington
“The time is over. The science is in. The time to act is now. Global warming is a serious issue for the world and California has an historic step…”

California Governor Schwarzenegger launching his global warming initiative to cut emissions by 80% by 2050 in June 2005.
RPS is state policy that requires electricity providers to obtain a minimum percentage of their power from renewable energy resources by a certain date. Four other states, Illinois, Missouri, Virginia, and Vermont, have nonbinding goals for adoption of renewable energy instead of an RPS.
U.S. map with potential contributions from energy efficiency and renewable energy by 2030
Required growth of cellulosic Ethanol to supply 30% of U.S. Gasoline demand by 2030

Source: Stanley R. Bull, NREL
US Biomass inventory = 1.3 billion tons

- Corn stover: 19.9%
- Wheat straw: 6.1%
- Soy: 6.2%
- Crop residues: 7.6%
- Grains: 5.2%
- Manure: 4.1%
- Urban waste: 2.9%
- Perennial crops: 35.2%
- Forest: 12.8%

From: Billion ton Vision, DOE & USDA 2005
Critical issues of biofuels

- Energy balance
- Carbon balance
- Land use
- Competition with food
- Water needs
- Fertilizer and chemical inputs
- Biodiversity, monoculture, invasive species
- Safety and security
- Cost of harvest and distribution
- Jobs
- Legal issues
# Energy ratio and carbon emissions of ethanol

<table>
<thead>
<tr>
<th>Ethanol from:</th>
<th>Corn</th>
<th>Cellulose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fossil energy used in production</td>
<td><img src="image1" alt="Diagram" /> 1.3 times</td>
<td><img src="image2" alt="Diagram" /> 10 times</td>
</tr>
<tr>
<td>Energy produced</td>
<td><img src="image3" alt="Diagram" /> 12% to 26%</td>
<td><img src="image4" alt="Diagram" /> 82% to 85%</td>
</tr>
</tbody>
</table>

*Technology Review, Jan. 2008*
Cumulative wind power capacity

Top 10 cumulative installed capacity (Dec. 2005)

<table>
<thead>
<tr>
<th>Country</th>
<th>Total capacity</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>18,428</td>
<td>31.0</td>
</tr>
<tr>
<td>Spain</td>
<td>10,027</td>
<td>16.9</td>
</tr>
<tr>
<td>US</td>
<td>9,149</td>
<td>15.4</td>
</tr>
<tr>
<td>India</td>
<td>4,430</td>
<td>7.5</td>
</tr>
<tr>
<td>Denmark</td>
<td>3,122</td>
<td>5.3</td>
</tr>
<tr>
<td>Italy</td>
<td>1,717</td>
<td>2.9</td>
</tr>
<tr>
<td>UK</td>
<td>1,353</td>
<td>2.3</td>
</tr>
<tr>
<td>China</td>
<td>1,260</td>
<td>2.1</td>
</tr>
<tr>
<td>Japan</td>
<td>1,231</td>
<td>2.1</td>
</tr>
<tr>
<td>NL</td>
<td>1,219</td>
<td>2.1</td>
</tr>
<tr>
<td><strong>Top 10 – Total</strong></td>
<td><strong>51,936</strong></td>
<td><strong>87.5</strong></td>
</tr>
<tr>
<td><strong>Rest of the world</strong></td>
<td><strong>7,368</strong></td>
<td><strong>12.5</strong></td>
</tr>
<tr>
<td><strong>World total</strong></td>
<td><strong>59,322</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>
Declining costs of wind power
Solar power
Solar learning: Declining price of photovoltaics with usage

Source: DPG 2005

Photovoltaic world production (in MW)
Microenergy and rural development: Solar Home Systems in Bangladesh

Sales of solar panels by Grameen Energy in Bangladesh
(Source: www.tu-berlin.de/zek/microenergy-project)
The many uses of hydrogen
Extracting and Storing Carbon Dioxide

1. Coal, water, and oxygen are fed into a high-pressure gasifier in which the coal is partially oxidized and converted into syngas.

2. The syngas is reacted with steam to produce a gaseous mixture of mostly carbon dioxide and hydrogen (H₂) from which CO₂ is extracted for burial (yellow pathways at bottom).

3. Hydrogen-rich syngas is burned, and the combustion products drive a gas turbine-generator.

4. The hot gas turbine exhaust passes to a heat-recovery steam generator, which converts water to steam that turns a steam turbine-generator.

CO₂ is compressed and sent via pipeline systems to permanent underground storage sites.

CO₂ can be sent into "saline formations"—saltwater-filled strata capped with impermeable rock.

At mature oil wells, CO₂ storage injections can boost the recovery of petroleum.
The challenge:
Decarbonizing energy and the economy
Towards a peaceful and sustainable energy future