Climate Changes. Do Policies?

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• Planetary (inc. Earth) temperature is determined by interaction of sunlight warming Earth’s surface, and “greenhouse” gases that absorb infrared radiation (Fourier 1824, Tyndall 1861)

• CO$_2$ is a greenhouse warming gas and emitted from coal, oil, gas (Arrhenius 1896)

• Oceans can only take up a fraction of CO$_2$ produced by combustion (Revelle 1957)
• Atmospheric CO₂ increasing ~ 2 ppm/yr from fossil fuel combustion, with 50% going into land and ocean sinks (Keeling 1960, Tans 1990)

• Short and long term observed warming patterns are linked to greenhouse gases (Callendar 1938, Mann 1999)

• Significant warming in the 20th century is mostly explained by atmospheric CO₂ (Manabe 1967, Hansen 1984)
Figure 1 Greenhouse-gas emissions in 2000, by source

Total emissions in 2000: 42 GtCO2e.
Energy emissions are mostly CO2 (some non-CO2 in industry and other energy-related).
Non-energy emissions are CO2 (land use) and non-CO2 (agriculture and waste).

Source: Prepared by Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 5.0.
Global fossil fuel and cement emissions: 36.1 ± 1.8 GtCO₂ in 2013, 61% over 1990

- Projection for 2014: 37.0 ± 1.9 GtCO₂, 65% over 1990

Estimates for 2011, 2012, and 2013 are preliminary

Source: CDIAC; Le Quéré et al 2014; Global Carbon Budget 2014
Annual Global Average Temperature

Trend=0.70 °C/Century  
Base Line : 1981-2010 Average

Temperature Anomaly (°C)

Year


Anomalies are deviation from baseline (1981-2010 Average).
The black thin line indicates surface temperature anomaly of each year.
The blue line indicates their 5-year running mean.
The red line indicates the long-term linear trend.
Global Mean Surface Temperature Anomalies

- CMIP5 Ensemble mean (95% spread)
- Forcing-adjusted CMIP5 mean + spread

Anomaly (°C) (w.r.t. 1980-1999)

Year

• US per capita fossil fuel emissions exceed most of the world (DOE, GCP). China total emissions now exceeds the US (IEA).

• Climate projections show a 3 C +/- 1.5 C response to doubling of CO$_2$ by 2100 with the primary uncertainty in range of emissions (IPCC 1990, 1995, 2001, 2007, 2013)

• Modest warming (0-2 C) creates both winners and losers; warming above 2C or 550 ppm, losers > winners; warming above 4C, mostly losers (WMO, ExxonMobil, Stern Review, World Bank, NCA, WICCI, DOD 1979-present)
Carbon Emissions per Person

- U.S.: 5.60
- Russia: 2.72
- E.U.: 2.40
- Japan: 2.40
- China: 0.53
- India: 0.25
- Africa: 0.24

~2000

World Average

Center for Sustainability and the Global Environment (SAGE)
University of Wisconsin, Madison
Observed Emissions and Emissions Scenarios

Emissions are on track for 3.2–5.4°C “likely” increase in temperature above pre-industrial.

Large and sustained mitigation is required to keep below 2°C.

Over 1000 scenarios from the IPCC Fifth Assessment Report are shown.

Source: Fuss et al 2014; CDIAC; Global Carbon Budget 2014
**Eventual Temperature change (relative to pre-industrial)**

### Temperature Changes

- **0°C**
  - Food: Severe impacts in marginal Sahel region
  - Water: Small mountain glaciers disappear worldwide—potential threat to water supplies in several areas
  - Ecosystems: Coral reef ecosystems extensively and eventually irreversibly damaged

- **1°C**
  - Food: Falling crop yields in many developing regions
  - Water: Significant changes in water availability. Some study projects more than a billion people suffer water shortages in the 2080s, many in Africa, while a similar number gain water
  - Ecosystems: Many species face extinction (20–50% in one study)

- **2°C**
  - Food: Rising number of people at risk from hunger (25–60% increase in the 2080s in one study with weak carbon fertilisation), with half of the increase in Africa and West Asia. Yields in many developed countries if strong carbon fertilisation
  - Water: Greater than 30% decrease in runoff in Mediterranean and Southern Africa
  - Ecosystems: Possible onset of collapse of part or all of Amazonian rainforest

- **3°C**
  - Food: Entire regions experience major declines in crop yields (e.g., up to one third in Africa)
  - Water: Sea level rise threatens major world cities, including London, Shanghai, New York, Tokyo and Hong Kong

- **4°C**
  - Food: Yields in many developed regions decline even if strong carbon fertilisation
  - Water: Large fraction of ecosystems unable to maintain current form
  - Ecosystems: Many species face extinction (20–50% in one study)

- **5°C**
  - Food: Rising crop yields in high-latitude developed countries if strong carbon fertilisation
  - Water: Rising intensity of storms, forest fires, droughts, flooding and heat waves
  - Extreme Weather Events: Small increases in hurricane intensity lead to a doubling of damage costs in the US
  - Risk of rapid climate change and major irreversible impacts: Risk of weakening of natural carbon absorption and possible increasing natural methane releases and weakening of the Atlantic THC

- **750 ppm CO₂e**
  - Onset of irreversible melting of the Greenland ice sheet
  - Increasing risk of abrupt, large-scale shifts in the climate system (e.g., collapse of the Atlantic THC and the West Antarctic Ice Sheet)
Climate Change Impacts in the United States

Water Supplies Projected to Decline

No Climate Change Effects

Water Supply Sustainability Risk Index (2050)
- Extreme (29)
- High (271)
- Moderate (821)
- Low (2020)

Climate Change Effects

Water Supply Sustainability Risk Index (2050)
- Extreme (412)
- High (608)
- Moderate (1192)
- Low (929)

http://nca2014.globalchange.gov/
What Are The Options?

• Adaptation

• Mitigation
What Are The Options?

• Adaptation
  – Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  – Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)

• Mitigation
- IPCC SRES A1FI
- Reference (close to SRES A1B)
- Current Pledges
- 50% chance to exceed 2°C
- RCP3PD
- Illustrative low-emission scenario with strong negative CO₂ emissions
- Global sudden stop to emissions in 2016
What Are The Options?

• Adaptation
  – Economic/political (relocation, tech transfer, payments for damages, reduce poverty, educate)
  – Technological (resilient tech, seawalls, genetic hybrids, cure malaria, colonize new planet)

• Mitigation
  – Economic (taxes, cap and trade, R&D)
  – Regulatory (treaties, bans, compacts, fuel/energy standards, public transit, voluntary agreements)
  – Societal (sustainable development, education)
  – Technological (CO₂ capture, geoengineering, green tech, alternative energy, energy efficiency)
\[ F = P \cdot g \cdot e \cdot f \]

- **F** = Global CO₂ emissions
  - Includes combustion, flaring of natural gas, cement production, oxidation of nonfuel hydrocarbons, and transport.
  - 28.56 gigatons CO₂

- **P** = Global population
  - Total number of human beings—call it 6 billion.
  - 6.8 billion people

- **g** = Consumption per person
  - \( \frac{\text{Gross world product}}{\text{Population}} \)
  - \$10,000

- **e** = Energy intensity of gross world product
  - \( \frac{\text{Global energy consumption}}{\text{Gross world product}} \)
  - 7,000 BTUs per dollar

- **f** = Carbon used to make all that energy
  - \( \frac{\text{Global CO₂ emissions}}{\text{Global energy consumption}} \)
  - 60 tons of CO₂ per billion BTUs

**KAYA IDENTITY**

[http://climatemodels.uchicago.edu/kaya/](http://climatemodels.uchicago.edu/kaya/)
U.S. Emissions

- Carbon Capture & Storage

After Pacala and Socolow, 2004;
ARI CarBen3 Spreadsheet
Why is climate policy so hard?
1990
SO, THIS CLIMATE CHANGE THING COULD BE A PROBLEM...

1995
CLIMATE CHANGE: DEFINITELY A PROBLEM.

2001
TEP, WE SHOULD REALLY BE GETTING ON WITH SORTING THIS OUT PRETTY SOON...

2007
LOOK, SORRY TO SOUND LIKE A BROKEN RECORD HERE...

2013
WE REALLY HAVE CHECKED AND WE'RE NOT MAKING THIS UP.

2019
IS THIS THING ON?

TAP TAP TAP
“I am not a scientist myself, but my best assessment of the data is that the world is getting warmer, that human activity contributes to that warming, and that policymakers should therefore consider the risk of negative consequences.”
– Sept. 2012

http://www.sciencedebate.org/debate12/
http://globalchange.mit.edu/focus-areas/uncertainty/gamble
“Higher temperatures and less-predictable weather would hurt poor farmers, most of whom live on the edge and can be devastated by a single bad crop. [...] It would be a terrible injustice to let climate change undo any of the past half-century’s progress against poverty and disease—and doubly unfair because the people who will be hurt the most are the ones doing the least to cause the problem.”
How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming

Merchants of Doubt

Naomi Oreskes & Erik M. Conway
“If you look at global warming alarmists, they don't like to look at the actual facts and the data. The satellite data demonstrate that there has been no significant warming whatsoever for 17 years. [...] I read this morning a Newsweek article from the 1970s talking about global cooling. And it said the science is clear, it is overwhelming, we are in a major cooling period... Now, the data proved to be not backing up that theory. So then all the advocates of global cooling suddenly shifted to global warming [...] and the solution interestingly enough was the exact same solution -- government control of the energy sector and every aspect of our lives.”

Washington Post, 2 Aug 2015
Signed and Ratified
Signed with intent to Ratify
Signed with no intent to Ratify
Non-Signatory

UNFCCC and Kyoto Protocol
### BULLSEYE!

<table>
<thead>
<tr>
<th>Country</th>
<th>% on target</th>
<th>% under target</th>
<th>% on target (with “extras”)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greece</td>
<td>Yellow</td>
<td>Blue</td>
<td>Yellow</td>
</tr>
<tr>
<td>Germany</td>
<td>Yellow</td>
<td>Blue</td>
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<tr>
<td>Sweden</td>
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<tr>
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</tbody>
</table>

### ON TARGET

Countries that look like they’re doing very well due to a lack of pre-Kyoto records to compare against.

- Bulgaria
- Czech Republic
- Hungary
- Poland
- Romania
- Slovak Rep.

### DEPENDENT ON “EXTRAS”

Countries that are dependent on “extras” to meet their targets.

- Belgium
- Croatia
- Portugal
- Slovenia
- France
- Netherlands

### OFF TARGET

Countries that are off target.

- Austria
- Finland
- Ireland
- Luxembourg
- Japan
- Norway

### FAIL

Countries that have failed to meet their targets.

- Canada
- Denmark
- Italy
- Scotland
- Spain
- Switzerland

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Despite Kyoto, the EU’s CO2 emissions will increase by 1% by 2012. 

*Source: European Environment Agency*
Global Treaties

- There is no international rules making body!
- Treaties are a game of incentives and disincentives to sign and to comply
- Individual countries weigh costs and benefits
- Compliance and monitoring are contentious issues
<table>
<thead>
<tr>
<th>The Problem</th>
<th>Acid rain</th>
<th>Stratospheric ozone loss</th>
<th>Global warming</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nox, SOX -&gt; rain acidic -&gt; corrosive to fish, lakes, roots/forest</td>
<td>High altitude ozone -&gt; less uv - &gt; less skin cancer CFCs</td>
<td>See previous 45 slides</td>
<td></td>
</tr>
<tr>
<td>Costs/benefits</td>
<td>Energy production Ecosystems -&gt; food chain, forestry</td>
<td>CFC -&gt; DuPont Skin cancer 100000:1</td>
<td>2C -&gt; mix 4C -&gt; bad for all 2:1 1:1</td>
</tr>
<tr>
<td>Solution(s)</td>
<td>CLRTAP – reduce NOX, SOX National regulation -&gt; Clean Air Act,</td>
<td>Ban CFCs -&gt; Vienna Convention, Montreal Protocol</td>
<td>Mitigate Who emits, who vulnerable not safe Players -&gt; Co2 = everyone</td>
</tr>
<tr>
<td>Mechanism</td>
<td>1990 NAAQS Cap and Trade</td>
<td>Alternatives, payment to developing countries</td>
<td>Kyoto -&gt; cap and trade, global/country Pay for damages, tech transfer</td>
</tr>
</tbody>
</table>
“Power plants are the single biggest source of harmful carbon pollution that contributes to climate change. Until now, there have been no federal limits to the amount of carbon pollution plants dump in the air.”
Commitments from COP20

• China: carbon intensity in 2020 40% below 2005 (emissions still rise), peak carbon emissions 2030
• U.S.: 2025 26-28% emissions below 2005 (double earlier pace), 2050 83% below
• South Korea: 30% below business as usual by 2020 (emissions doubled 1990-2005)
• Russia: 25%
• Brazil: 38-42% below 2020 projection, half by deforestation reduction (REDD)
• Australia: 5-20% below 2000 by 2020
• India: carbon intensity 20% lower by 2020
The future?

- Climate scientists will continue to refine projections of future change and impacts in response to emissions and/or policy
- Global treaty progress will likely be slow, but there are successes in deforestation reduction, developing country support, and renewable energy infrastructure
- Bi- or Multi- lateral agreements (e.g., US-China) and within country “energy arms race” may end up having the biggest bang for buck
- Fossil fuel reserves are getting scarcer, but not running out anytime soon. Given lags in climate response, some level of adaptation is inevitable
DISCUSSION?