Discussion #12: Impacts of Climate Change

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16 October 2017
HONR 229L: Climate Change: Science, Economics, and Governance

Reading for Wed:

Please read either

a) Chapter 2 (30 pages; solar PV)

*OR*

b) Chapter 3 (29 pages; concentrated solar)

but everyone please read from the words “THESE PHOTOVOLTAIC INVENTORS” on pg 40 to the end of Chapter 2 (middle page 44), because this section on feed-in tariff, carbon tax, and cap-and-trade are vitally important for the rest of the semester.

Gustavo will have to read both. This material is a breeze to read.

Have posted an AT for both chapters; please complete only one.
Please note the manuscript by McGlade & Ekins (hereafter M & E) is a scientific article, the likes of which I have to try to decipher as part of my job, whereas the manuscript by Jakob & Hilaire (J & H) is a “News & Views” piece designed to “interpret” the scientific article for the lay person. Please carefully read J & H and get through as much of M & E as you can.

The thesis of both articles is that, in order to limit the rise of global mean temperature to less than 2°C, about ___, ___, and ___ % of the world’s reserves of coal, gas, and oil would need to stay below the surface. Give these per cents, being sure to associate each number with the particular form of fossil fuel.

These articles claim that to keep the rise in GMST below 2°C:

80% of coal, 50% of natural gas, and 30% of oil reserves

must stay below the surface.

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and this will be a very tall order. Fortunately, our climate model projections indicate less severe restrictions.
Figure 10, Summary for Policy Makers, IPCC (2013)

Cumulative total anthropogenic CO₂ emissions from 1870 (GtCO₂)

Temperature anomaly relative to 1861–1880 (°C)

Remaining Emissions

http://www.ipcc.ch/report/graphics/images/Assessment%20Reports/AR5%20-%20WG1/SPM/thumbnail/ FigSPM-10.jpg
Our rendition of CMIP5 Multi-model mean

Remaining Emissions: ~1450 Gt CO₂
Our rendition of CMIP5 Multi-model mean & results from a recent paper

http://www.nature.com/ngeo/journal/v10/n10/full/ngeo3031.html

Millar et al., *Nature Geoscience*, 2017

Remaining Emissions: ~2000 Gt CO$_2$
Our rendition of CMIP5 Multi-model mean & results from a recent paper & our own projections

Remaining Emissions: ~3200 Gt CO₂

Hope et al. Earth’s Future 2017
Table 1 of M & E is quite a tour de force … using an economically-optimal solution (these words appear right below Figure 2) that maximizes social welfare, they attempt to go beyond global limits on the combustion of fossil fuel by extending the analysis to particular regions.

We could go on and on about this table, but I will limit to a few related questions.

Outside of the Middle East, what country sits on the largest reserves of oil (aka bitumen)?

What fraction of this reserve do M & E suggest should stay in the ground?

Based on the politics of this country (we have discussed but you can also do your own research), do you think this is realistic?

Outside the middle east, based on table 1, Canada is the single country that sits on the largest reserve of oil with 39 billion barrels with Carbon Capture and Storage and 40 billion barrels with no Carbon Capture and Storage. If we ignore CCS then 75% of those reserves should remain untapped in order to continue aiming for the 2°C. Last year the US imported 38% (next closest country was Saudi Arabia with 11%) of its petroleum from Canada, so if Canada were to follow the proposal set forth by M & E then the impact would be significant enough that there may be backlash from the US in attempts to implement such guidelines.

In my opinion, Canada will sell us oil as long as we are willing to purchase this commodity. In order for 75% to stay in the ground, the demand for this resource will need to decline in a precipitous manner.
J & H provide a quote from Sospeter Muhongo. Who is this person and in your own words, what is this person stating?

Sospeter Muhongo is the energy minister of Tanzania. Muhongo asserts Tanzania will use whatever natural resources it has access to to get ahead in the world economy. McGlade and Ekins assigned various goals to regions that extract fossil fuels. Many countries support a greener Earth for the health of their citizens but few countries are willing to invest the effort and resources into actually making a change. In the past, Africa was treated as a toy in the eyes of Europeans, each fighting for a piece of Africa without considering the damage they left in their wake. The effects of neocolonialism still damage Africa today, and the imbalance Europeans left ruined Africa's shot at a healthy developmental phase. Now, as Africa seeks to grow in ways similar to Western nations, the highly developed Western nations frown upon Africa's similar path only because the "growing pains" of the Western nations are in the past. If one were to build a bench would they leave tools such as a hammer and saw in the toolbox? Africa merely wants to use its allotted tools to build a better future.
J & H provide a quote from Sospeter Muhongo. Who is this person and in your own words, what is this person stating?

Many countries with imperialist pasts have exploited countries with abundant natural resources,. … a good example would be the former Belgian Congo (now the Democratic Republic of the Congo), a country rich in natural resources. For countries like the Congo, to ask them to refrain from using their resources to their problems is not only unfair, it is often downright hypocritical. European colonial powers as well as the USA industrialized by burning fossil fuels and ruining much of their environments … without poorer countries in Africa, Asia, and South America ever receiving any of the benefits.

As the article from Scientific American states, the majority of African residents -- more than 60% of the entire continent -- lack "basic energy services", and in order to raise the standard of living quickly for those people, coal and other nonrenewable resources must be used to some extent … it may take some time before large-scale clean energy solutions, free of fossil fuel usage, can be realistically implemented in Africa. In the meantime, with the large oil reserves it has at its disposal, the continent would be well served in using at least some of its oil resources to "bridge the gap", as the article says, and begin providing inhabitants with energy. While this infrastructure is being built, clean energy solutions that harness renewable resources in Africa (such as solar cells) can be explored and implemented in smaller scales.

Through a mixture of fossil fuel usage and clean energy solutions, African communities can begin to modernize, but in a less harmful way than the first industrialized countries did.
J & H provide a quote from Sospeter Muhongo. Who is this person and in your own words, what is this person stating?

The US, judging by the table, does not have their entire future to lose by leaving that small of a percent of their fossil fuels in the ground, whereas use of all of Tanzania's may be necessary for their development.

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It would be woefully unfair for us in the West to look at countries like Tanzania and say that their economic growth is insignificant compared to climate change issues that individuals living in poverty cannot afford to care about. Luckily, Africa is endowed with many natural resources conducive to a robust renewable energy landscape. If the West truly wants to take leadership in the fight against climate change, we will need to invest heavily in developing regions such as sub-Saharan Africa in terms of money and technology to ensure that the trend of "intensifying the utilization of coal" that Muhongo speaks of is replaced by developing cleaner sources of energy as much as possible.
Impacts of Climate Change

Luis Paz

16 October 2017
Admission Ticket

a. Where in the reading is the threat to Arctic sea ice discussed?
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   – Threat to Arctic sea ice is briefly discussed in the diagram titled "Widespread Impacts in a Changing World"
   – Assessment Box on Human Interference with the Climate System where the Arctic sea ice is described as one of the "unique and threatened systems"
The figure below detail the decline in Arctic Sea Ice over the past 38 years (left) and a map showing the extent of Arctic Sea Ice as of Sep 2017 to the extent of the Arctic Sea Ice in 1979.

Source: [http://nsidc.org/arcticseaicenews](http://nsidc.org/arcticseaicenews)

Arctic sea ice extent in Sep 2017 was 4.87 million square kilometers (1.88 million square miles). Red line shows the extent of sea ice in 1979; black circle indicates North Pole.
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b. Do you believe the discussion of Arctic sea ice in the reading does justice to this issue?
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c. If the Arctic becomes ice free, who loses?

d. If the Arctic becomes ice free, who wins?
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c. If the Arctic becomes ice free, who loses?
   – Resulting methane release from the melting of permafrost acts as positive feedback to climate change

d. If the Arctic becomes ice free, who wins?
A ship sails the Northern Sea Route, which offers a faster route for some shipments between Europe and Asia, largely for oil products.

PhotoXpress/Zuma Press

http://www.wsj.com/articles/arctic-cargo-shipping-volume-is-rising-as-ice-melts-1414612143
What effect does melting sea ice have on sea level?
What effect does melting sea ice have on sea level?

- If you place water and an ice cube in a cup so that the cup is entirely full to the brim, what happens to the level of water as the ice melts?
- Does it rise (overflow the cup), stay the same, or lower?
What effect does melting sea ice have on sea level?

• If you place water and an ice cube in a cup so that the cup is entirely full to the brim, what happens to the level of water as the ice melts?
• Does it rise (overflow the cup), stay the same, or lower?

• The water level **will not change** as the ice cube melts
What effect does melting sea ice have on sea level?

• What about when the ice cube is in salt water?
What effect does melting sea ice have on sea level?

• What about when the ice cube is in salt water?
• Once melted to fresh water, the water level will rise to account for the additional volume (5%)
  – Ice cube will take the same volume as before (when the ice cube melted in fresh water) but it was dispersing less when floating
a) How many feet in 1 meter?

b) If the entire Greenland ice sheet were to melt, how much would sea level rise?
a) How many feet in 1 meter? \( \approx 3.3 \)

b) If the entire Greenland ice sheet were to melt, how much would sea level rise? 7 m

- Collapse of the Greenland ice sheet causes sea level to rise because this ice sheet lies on top of land: i.e., Greenland is a continental sized land mass.
- Sea ice, on the other hand, lies on top of the ocean.
- Reading states collapse of Greenland ice sheet would take a millennium.

![Global mean sea level rise](http://www.atmos.umd.edu/~rjs/class/honr229L/readings/WG1AR5_SPM_FINAL_carbon.pdf)
a) Which US states are more vulnerable to sea-level rise?

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Florida, Louisiana, and Maryland

Maryland Susceptibility

- IPCC forecasts sea level to rise by 1 meter if RCP 8.5 scenario for GHGs holds
- Images end at 6 meter rise in sea level, which is just under the 7 meter rise

Source: Jeremy Weiss and Jonathan Overpeck, University of Arizona
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Source: Jeremy Weiss and Jonathan Overpeck, University of Arizona
Animation for 1.5 m, 3.6 m, and 7.6 m
Observed Impacts, Vulnerability, and Exposure
“In recent decades, changes in climate have caused impacts on natural and human systems on all continents and across the oceans.”
Admission Ticket

a) The New York Times article in Auxiliary Readings discusses the threat of climate change to Bangladesh, home to 156 million people. Do you believe this Summary for Policy Makers, does justice to the vulnerability to climate change of nations such as Bangladesh?
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• IPCC report attempts to summarize the results of climate change around the world while not describing enough to emphasize the uneven impacts and vulnerabilities of nations like Bangladesh.
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• Climate change is "projected to increase displacement of people"
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• Bangladesh accounts for only "0.3 percent of the emissions driving climate change" it is one of the nations who could suffer the most from the consequences of climate change
• Some leaders have even gone on to say that developed countries should open their borders to climate migrants.
“A woman stood where her house was before Cyclone Aila destroyed it in 2009. Scientists expect rising sea levels to submerge 17 percent of Bangladesh's land and displace 18 million people in the next 40 years.”
The goal of the Paris Climate Agreement is to keep the rise in global mean surface temperature (GMST) to 1.5°C below pre-industrial, with an upper limit of no more than 2°C warming.

a) What figure in the reading could be used to relate additional risks due to climate change, per degree rise in GMST?

b) Based on this figure, describe a single bleak outcome (in your own words) if the Paris Climate Agreement fails, and GMST actually rises by 4°C.
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Assessment Box SPM.1 Figure 1

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Assessment Box SPM.1 Figure 1
Admission Ticket

Freshwater Mollusks, Plant-feeding Insects, Primates, Trees, Rodents, Herbaceous Plants, Carnivorous Mammals, Split-hoofed Mammals
a) Summarize, in a few sentences, the message of Figure SPM.5.
b) If climate change advances at 40 km per decade, what group is at most risk?
a) Summarize, in a few sentences, the message of Figure SPM.5.
b) If climate change advances at 40 km per decade, what group is at most risk?
c) What would Jared Diamond have to say?
Impacts of Climate Change: The Last Word

Ross Salawitch
Arctic sea ice concentration over the last 100 years (through 2013) using reconstruction provided by National Snow and Ice Data Center. Boulder CO. Data after 1979 is based on satellite observations. Animation of by Zachary Labe, graduate student at UC Irvine.

http://sites.uci.edu/zlabe/arctic-sea-ice-figures/
Polar Bear Status Report

http://www.polarbearsinternational.org/status-and-threats/polar-bear-status-report

Tables on this website updated frequently:
http://pbsg.npolar.no/en/status/status-table.html

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1. Rising sea-level threatens many populated coastal regions, including Maryland


Leuliette and Nerem, 2016
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Consequences of Climate Change


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Animation of NASA Grace satellite data by Zachary Labe, graduate student at UC Irvine

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1 meter = 3.2 feet

If all of Greenland were to melt, SLR would be ~20 feet (6 meters)
If all of Antarctica were to melt, SLR would be ~200 feet (60 meters)
Consequences of Climate Change

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RCP 8.5

RCP 2.6
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1. Rising sea-level threatens many populated coastal regions, including Maryland.

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If all of Greenland were to melt, SLR would be 7 meters (23 feet)

If all of Antarctica were to melt, SLR would be...
Consequences of Climate Change

1. Rising sea-level threatens many populated coastal regions, including Maryland

1 meter = 3.2 feet

If all of Greenland were to melt, SLR would be 7 meters (23 feet)

If all of Antarctica were to melt, SLR would be 60 meters (200 feet)
Consequences of Climate Change

2. Desert are expanding and permafrost is melting, threatening agriculture, Arctic habitat, water supply to populated regions

3. World is becoming more “tropical”, including poleward migration of ecosystems, weather patterns, and tropical diseases
Consequences of Climate Change

4. Hurricane intensity is increasing, affecting populations that reside in coastal regions

• Projection of the effect of global warming on hurricanes requires conducting calculations on a ~20-km grid (“serious supercomputer”)

• Some simulation project that at end of century, rising GHGs will lead to:
  a) ~30% decrease in annual mean occurrence number of tropical cyclones, due to larger increases in T at 250 mbar than at surface, which causes a more stable atmosphere
  b) increase in maximum surface winds of the tropical cyclones that do occur:
     i.e., hurricanes less frequent but more powerful  Oouchi et al., Journal Meteor. Soc. Japan, 2006

• Confounding factor:

http://www.c2es.org/science-impacts/extreme-weather/hurricanes
Consequences of Climate Change

5. Ocean is becoming increasingly acidic, threatening vast portions of the ocean ecosystem

Future ocean uptake of atmospheric CO₂ will lead to **ocean acidification**

Bad news for ocean dwelling organisms that precipitate shells (basic materials)

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**THE (RAGGED) FUTURE OF ARAGONITE**

Diminishing pH levels will weaken the ability of certain marine organisms to build their hard parts and will be felt most severely by those creatures that make those parts of aragonite, the form of calcium carbonate that is most prone to dissolution. The degree of threat will vary regionally.

Before the Industrial Revolution (left), most surface waters were substantially 'oversaturated' with respect to aragonite (light blue), allowing marine organisms to form this mineral readily. But now (center), polar surface waters are only marginally oversaturated (dark blue). At the end of this century (right), such chilly waters, particularly those surrounding Antarctica, are expected to become undersaturated (purple), making it difficult for organisms to make aragonite and causing aragonite already formed to dissolve.

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Pteropods form a key link in the food chain throughout the Southern Ocean. For these animals and creatures that depend on them, the coming changes may be disastrous, as the images at the right suggest. The shell of a pteropod kept for 48 hours in water undersaturated with respect to aragonite shows corrosion on the surface (a), seen most clearly at high magnification (b). The shell of a normal pteropod shows no dissolution (c).

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Excellent book on consequences of climate change:

https://www.amazon.com/Six-Degrees-Future-Hotter-Planet

Summary:

http://www.sustainablewoodstock.co.uk/onetwo%20degrees%20summary.pdf
Possible Impacts of Climate Change

• 1°C (already committed to this)
  – Loss of glacial waters in Africa & Asia, with regional declines in food production
  – Tropical islands such as Tuvalu, **Kiribati**, Marshall Islands, and Maldives severely threatened

*Six Degrees: Our Future on a Hotter Planet* by Mark Lynas
**Kiribati**: Population 110,000 as of 2015

- Undergoing intrusion of salt water into freshwater supplies
- Some farmers unable to grow food because of saltwater intrusion
- Government has promoted “migration with dignity,” urging residents to consider moving abroad with employable skills. It bought nearly 6,000 acres in Fiji, an island nation more than 1,000 miles away, as a potential refuge. Fiji’s higher elevation and more stable shoreline make it less vulnerable.

Kiribati: Population 112,000 as of 2015

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Kianteata Bwaurei, 70, has decided not to replant his crops after they were inundated.

Possible Impacts of Climate Change

• 1°C (already committed to this)
  – Loss of glacial waters in Africa & Asia, with regional declines in food production
  – Tropical islands such as Tuvalu, Kiribati, Marshall Islands, and Maldives severely threatened

• 2°C (Paris Climate Agreement Upper Limit)
  – Polar bear habitat under severe threat
  – Glacial melt rate doubles; disappearance of glaciers will create water shortages in places such as India, Peru, Ecuador, and Bolivia
  – Stability of Greenland ice sheet threatened

• 3°C (occurs in ~2050 according to IPCC climate models using RCP 8.5)
  – 80% of Arctic sea ice melted
  – Loss of Himalayan glaciers threaten water supply of Pakistan & China’s hydroelectric industry
  – Australia becomes world’s driest nation; Perth particularly vulnerable
  – Indian monsoon, essential to 60% or world’s population, more variable and possibly fails on a persistent basis
  – Many plant species become extinct if they can not adapt, which is an ecological catastrophe but also a source of atmospheric carbon

Six Degrees: Our Future on a Hotter Planet by Mark Lynas
Possible Impacts of Climate Change

• 4°C (occurs in ~2080 according to IPCC climate models using RCP 8.5)
  – Mass displacement of populations from places such as Bangladesh, Egypt, etc
  – Major flooding in Mumbai, Shanghai, Boston, New York, London, etc
  – Australia supports little to no agriculture
  – Stability of Antarctic ice sheet threatened

• 5°C (possibly end of this century)
  – Stability of all of world’s ice sheets threatened, leading to drastic change in coastline geography
Present Day

Possible Impacts of Climate Change

• **4°C (occurs in ~2080 according to IPCC climate models using RCP 8.5)**
  – Mass displacement of populations from places such as Bangladesh, Egypt, etc
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  – Australia supports little to no agriculture
  – Stability of Antarctic ice sheet threatened

• **5°C (possibly end of this century)**
  – Stability of all of world’s ice sheets threatened, leading to drastic change in coastline geography
  – Risk of methane release from hydrates, a strong positive feedback that is considered one of several tipping points
  – Possible massive decline in supportable, global population

• **6°C (next century)**
  – Sea level rise could be 20 meters (65 feet!)
  – Dystopian world

*Six Degrees: Our Future on a Hotter Planet* by Mark Lynas
Energy and Power

Simple equation connects energy and power:

\[ \text{Energy} = \text{Power} \times \text{Time} \]

**Size** of a **power** plant is commonly measured in units of power:

- kW (kilo: \(10^3\) Watts): Home solar
- MW (mega: \(10^6\) Watts): Industrial
- GW (giga: \(10^9\) Watts): Massive Hydroelectric
- TW (terra: \(10^{12}\) Watts): Large Nation and/or Global

(Footnote, pg 18, Krupp & Horn)

**Output** of a **power** plant in units of energy:

- kWh (kilo: \(10^3\) W hour)
- MWh (mega: \(10^6\) W hour)
- GWh (gig: \(10^9\) W hour)

Capacity Factor: actual output of a power plant (energy) divided by maximum output if plant could run 24/7/365 at full capacity

(Footnote, pg 47, Krupp & Horn)