Global Climate Change: Impacts, Challenges and Opportunities

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Plenary Presentation to the
XVI Congreso de Investigadores en Economia Social
(CIRIEC-Espana)
Valencia, Spain
October 19, 2016

Motivating Questions

• What do we mean by “global climate change” and what are its causes?
• What are the current and future impacts of climate change that give us concern?
• What measures and policies can we pursue to reduce or avoid dangerous impacts?
• What is the outlook for actions to deal with climate change?
The “Greenhouse Effect”

- Atmospheric gases that absorb Earth’s radiation, and warm the planet, are called greenhouse gases.
- They include carbon dioxide, methane, nitrous oxide, other trace gases, and water vapor.
- Without natural levels of these gases the average temperature of Earth would be –19°C (instead of the actual 15°C).
- The additional 34°C of warming due to these gases is called the “greenhouse effect.”

We have been putting GHGs into the atmosphere at an increasing rate

Atmospheric GHG Levels

Greenhouse gas (GHG) concentrations in the atmosphere have been increasing rapidly as a result of human activities.

Once in the atmosphere, these gases are not easily or quickly removed.

Contribution of GHGs to Total Global Warming Potential

CO₂ from Energy Use is the Dominant Greenhouse Gas

Combined emissions commonly expressed as equivalent CO₂

Source: IPCC, 2001

Source: USEPA, 2007

Source: http://climatechangeconnection.org
Current trends

Global GHG emissions growth has accelerated despite reduction efforts

Current CO₂ Levels and Global Temperature are at Historical Highs

There is no doubt that atmospheric levels of CO₂ are increasing due to human activities

Recent years have been the hottest in history
Global Climate Change Processes

Emissions of greenhouse gases from human activities → Increases in atmospheric concentration → Increases in global temperatures → Changes in climate → Impacts on ecosystems and human welfare

“Climate” is defined as the average weather over 30 years. It includes atmospheric temperature, pressure, humidity, wind and precipitation.

Conclusions from the 2014 IPCC Fifth Assessment Report

Human influence on the climate system is clear

Worldwide Effects
- atmosphere, land, ocean
- extreme events
- water cycle
- sea ice, glaciers, ice sheets
- global mean sea level

The Intergovernmental Panel on Climate Change (IPCC) has been studying climate change impacts for over 25 years

OBSERVED IMPACTS OF CLIMATE CHANGE ARE WIDESPREAD AND CONSEQUENTIAL
Global pattern of impacts in recent decades attributed to climate change

Impact of climate change on yield of four major crops from 1960–2013

Includes tropical and temperate zones. Climate change is making it increasingly difficult to increase crop yields to meet growing demands for food and agricultural products.

PEOPLE, SOCIETIES, AND ECOSYSTEMS AROUND THE WORLD

VULNERABLE AND EXPOSED IN DIFFERENT WAYS

Flooding of a New York street after hurricane Sandy

Another example of current impacts

Reeling From Effects of Climate Change, Alaskan Village Votes to Relocate

By CHRISTOPHER MELE and DANIEL VICTOR AUG. 19, 2015

An abandoned house at the west end of Shishmaref, Alaska, that slid during a storm in 2005. Residents have voted in favor of relocating the community to the mainland.
More extreme events are expected as atmospheric concentration rises.

Baseline projections: Continued increases in GHG emissions and concentrations.

Predicted Temperature Changes for a Doubling of Atmospheric CO₂ Concentration

Without mitigation, global mean surface temperature may increase by 3.7° to 4.8°C over the 21st century.

Increasing magnitudes of warming increase the likelihood of severe and pervasive impacts.
Dangers from climate change increase with higher global temperature

Source: IPCC, 2007

What Options Do We Have?

**Option 1:**
Adaptation
*(adjust to changes)*
The potential for future adaptation also varies around the world. Social and economic systems will play a key role in determining future resiliency and risks of climate-driven impacts.

The Climate Policy Framework

- 1992 U.N. Framework Convention on Climate Change called for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."

How do we define "dangerous anthropogenic interference"?

No more than a 2°C rise in mean global temperature is the climate policy goal.

The 2015 Paris accord seeks a smaller increase.

What Options Do We Have?

Option 2: Mitigation (reduce GHG emissions)
What does it take to limit the increase in global temperature to 2°C?

Atmospheric concentration of GHGs must be stabilized at about 450 ppm CO$_2$ equiv

This requires LARGE REDUCTIONS in GHG EMISSIONS .... Quickly!

Required reduction in global GHG emissions from 2000 to 2050:

50% to 85%


Why are such large emission reductions needed for stabilization?

• Unlike conventional air pollutants, most GHGs are not quickly removed by natural processes — so they remain in the atmosphere for centuries or more

• So, to stabilize atmospheric concentrations, GHG emissions must be reduced dramatically

Analogy: To stabilize the water level in a slow-draining bathtub, the faucets must be tightened to a trickle or the water level will continue to rise

General Strategies for Reducing Emissions

The Kaya Identity

CO$_2$ emissions per year =

\[
\text{Population (per year)} \times \left( \frac{\text{GDP}}{\text{per capita}} \right) \times \left( \frac{\text{Energy use}}{\text{per GDP}} \right) \times \left( \frac{\text{CO}_2 \text{ emissions}}{\text{per unit energy}} \right)
\]

These two factors depend strongly on technology

Computer models of global and national energy systems are used to find the combination of measures that can achieve emission reduction goals at the lowest cost to society

How can we get big reductions in GHG emissions?
Technologies Needed to Mitigate CO₂ Emissions

- Technologies and social systems that reduce the demands for energy in all sectors of the economy
- Technologies that use energy more efficiently
- Technologies to produce and use energy sources with low or no GHG emissions (e.g., renewables)
- Technologies for CO₂ capture and sequestration at power plants and other large industrial facilities

Reducing GHG emissions will require major new investments

How do government actions influence technology deployment and innovation?

“Technology Policy” Options

Direct Government Funding of Research and Development (R&D)
- R&D contracts with private firms
- R&D grants and contracts with universities
- Intersessional R&D conducted at govt.’s laboratories
- R&D contracts with consortia (2 or more of the actors above)

Direct or Indirect Support for Commercialization and Production; Indirect Support for Development
- Patent protection
- R&D tax credits
- Production subsidies or tax credits to firms bringing new technologies to market
- Tax credits or rebates for new technology buyers
- Government procurement
- Demonstration projects

Support for Learning and Diffusion of Knowledge and Technology
- Education and training
-Codification and transfer of knowledge
- Technical standard-setting (non-regulatory)
- Technology and/or industrial extension services
- Publicity and consumer information

Provide “carrots” to incentivize innovation & technological change
- Policies influence different phases of the innovation process
Government incentives have played a key role in growth of renewables

Regulatory policies have had a major impact on energy efficiency and emissions

Energy Demand Sectors and Technologies

<table>
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<tr>
<th>BUILDINGS (Residential &amp; Commercial)</th>
<th>TRANSPORTATION SYSTEMS</th>
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<td>Lighting</td>
<td>Light-duty vehicles</td>
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<tr>
<td>Water heating</td>
<td>Trucks, buses, locomotives</td>
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<tr>
<td>Cooking</td>
<td>Aircraft</td>
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<td>Refrigeration</td>
<td>Marine vessels</td>
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<td>Space heating</td>
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<td>Air conditioning</td>
<td>Electricity use (motors, drives, etc.)</td>
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<tr>
<td>Ventilation</td>
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<tr>
<td>Appliances</td>
<td>Cogeneration systems</td>
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<tr>
<td>Building structures</td>
<td>New process technology</td>
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Performance Standards Reduced Refrigerator Energy Use Significantly

- Emissions tax
- Fuels tax
- Cap-and-trade program
- Technology portfolio standards
- Technology performance standards (for pollutant emission rates, efficiency, or other measures)

- Provide "sticks" to incentivize innovation & technological change
- Also influence different phases of the innovation process
Corporate Average Fuel Economy (CAFE) Standards for New Light-Duty Vehicles

U.S. fuel use requirements have been a major stimulus to technology innovation

Renewable Portfolio Standards for Electric Power Systems

Power generation costs for wind and solar energy systems have fallen dramatically as these technologies were deployed in response to requirements

Increasing percentage of global emissions are covered by mitigation plans and strategies …

… but commitments to large emission reductions are still lacking

Two Promising New Developments

Outcomes of the U.N. Climate Change Conference in Paris

Mission Innovation: Accelerating the Clean Energy Revolution

Mission Innovation aims to commercialize and accelerate global clean energy innovation with its objectives:

- Facilitate long-term energy innovation
- Strengthen clean energy innovation ecosystems globally
- Increase investment in clean energy technology
**Key Elements of the Paris Accord**
*(COP 21, December 2015)*

- World nations agreed to **binding commitments** for "nationally determined contributions" to GHG emission reductions and measures to achieve them.
- New plans every five years to cut emissions beyond previous levels.
- Rich countries to help developing nations by providing $100 billion/yr in "climate finance" by 2020, and more after 2025.
- Between 2050 and 2100, limit GHGs emitted by human activities to what can be absorbed naturally.

**“Mission Innovation” Plans**

21 countries pledge to double public spending on energy R&D over 5 years.

**Mission Innovation R&D Areas**

- Increased opportunities for economic development through innovation.

**So What Will the Future Bring?**

- The Paris Agreement is an important step in the effort to mitigate climate change.
- Need for **strong policy drivers** to spur innovation and deployment of clean and sustainable technologies.
- Adaptation and effective social-economic systems also are needed to reduce climate change impacts.
- **WATCH THIS SPACE FOR FUTURE UPDATES.**
Thank You!

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