

Climate Change Vulnerability, Mitigation, and Adaptation

Climate Change Vulnerability, Mitigation, and Adaptation

Geography/Environmental Studies 339

MATT TURNER

Contents

[Geography/Environmental Studies 339](#)

<u>International Agreements for Climate Change Mitigation</u>	3
<u>International Climate Agreements</u>	3
<u>The Paris Agreement</u>	16
<u>Climate Science Essentials</u>	20
<u>Climate Science 101</u>	20
<u>Important Definitions</u>	22
<u>NASA – Causes of Climate Change</u>	22
<u>Evidence of Climate Change</u>	24
<u>Measuring Climate Change</u>	25
<u>Climate Impacts on Biodiversity</u>	27
<u>Finding Reliable Information on Climate Change</u>	28
<u>You are finished!</u>	30
<u>Climate Impact Case Studies: Bangladesh and the Sahel</u>	31
<u>Climate change as an environmental justice issue</u>	31
<u>Vulnerability to climate change: exposure, sensitivity, and capacity</u>	32
<u>Considering vulnerability: Bangladesh</u>	34
<u>Considering vulnerability: The Sahel</u>	37
<u>Debating Greenhouse Gas Emission Responsibilities</u>	41
<u>Measurement of the warming effect of different greenhouse gases</u>	42
	42
<u>Different human activities lead to the release of greenhouse gases</u>	43
<u>Ethics and Politics of Greenhouse Gas Emission Accounting</u>	45
<u>Assessing Energy Alternatives to Fossil Fuels</u>	51
<u>Form, delivery, and power density of energy supplies</u>	55

<u>Wisconsin Climate Impacts</u>	65
<u>Divergent Energy Policies: Germany and the United States</u>	73
<u>Different Energy Policy Options Available to Government</u>	74
<u>U.S. Energy and Climate Policy</u>	78
<u>German National Policies toward Energiewende</u>	78
<u>International Incentive-based Mechanisms for Reducing GHG Emissions</u>	82
<u>Introduction</u>	82
<u>Emissions Trading</u>	83
<u>Clean Development Mechanism and Joint Implementation</u>	86
<u>Reducing Emissions from Deforestation and Forest Degradation (REDD+)</u>	88
<u>Strengths and Weaknesses of Project-Based International Incentive Programs</u>	89
<u>International Incentive Programs and the Paris Accord</u>	91

GEOGRAPHY/ENVIRONMENTAL STUDIES 339

International Agreements for Climate Change Mitigation

Learning Objectives

By the end of this chapter, you should be able to explain:

- The basic history of international climate change agreements
- The basic architecture of the Kyoto Protocol
- Strengths and weaknesses of the Kyoto Protocol
- The various positions taken by countries in developing Kyoto and negotiating a replacement for Kyoto.
- The basic architecture of the Paris Agreement.

International Climate Agreements

Our atmosphere is truly a global commons shared by us all. It has only been relatively recently that we have recognized that human activities, through changes in the chemical composition of our atmosphere, can strongly shape climate (this new understanding is behind the idea of the Anthropocene). This brief history of international agreements to mitigate our effects on climate begins with the Montreal Protocol and ends with the Paris Climate Accord. While our focus will be on the Kyoto Protocol and Paris Climate Accord, it is important for us to know about earlier agreements since the experience with these has shaped the forms that the Kyoto Protocol and Paris Accord have taken.

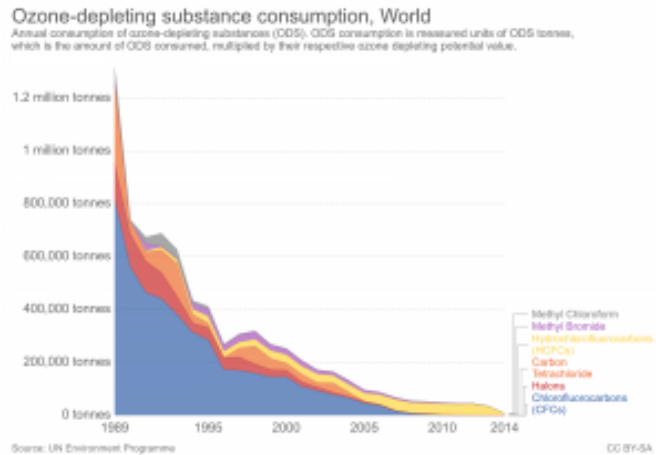
Agreement	Notes
1989 Montreal Protocol on Substances that Deplete the Ozone Layer	Hailed as one of the most successful international environmental agreements. Led to a significant reduction in the production of ozone-depleting substances.
1994 United Nations Framework Convention on Climate Change (UNFCCC)	Came into force in 1994. Committed countries to voluntarily reducing GHG emissions to 1990 levels by the year 2000. Compliance was low.
1997 Passage of the Kyoto Protocol under the UNFCCC coming into force in 2004.	When in force required ratifying industrial countries to reduce their aggregate national GHG emissions by 5-8% of their emissions in 1990 by 2012. Non-industrial countries were exempted from reduction requirements.
2015: Paris Agreement	All countries make individual commitments to reduce GHG emissions with these commitments made binding through ratification.

The Montreal Protocol

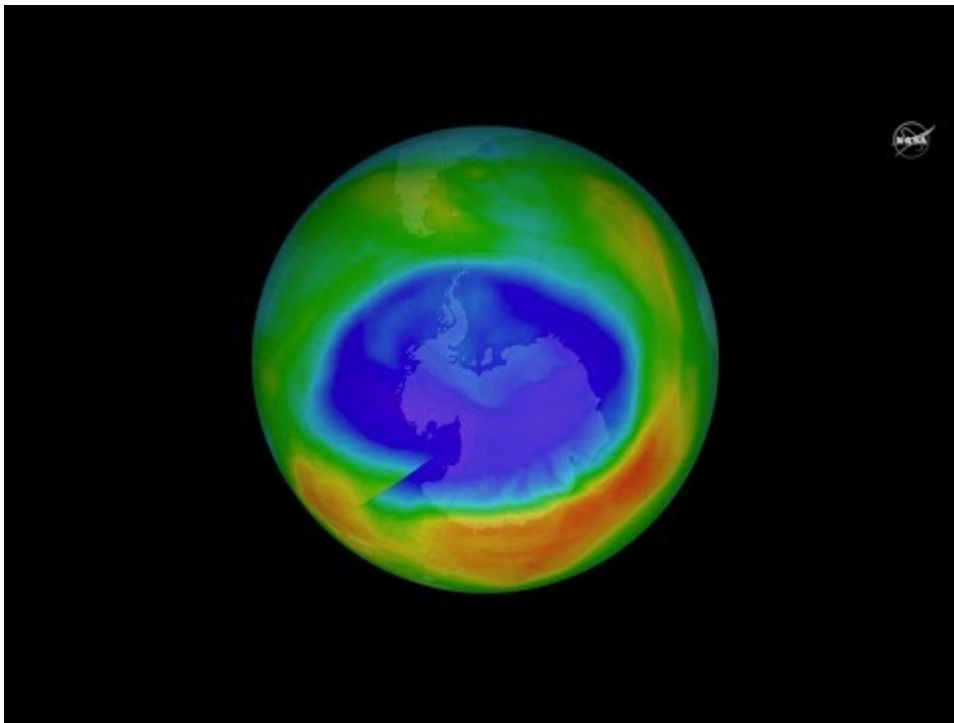
Ozone is a molecule that when in the earth's stratosphere absorbs ultraviolet light which at high levels, is dangerous to life (skin cancers, cataracts etc.). When certain manufactured chemicals, particularly chlorofluorocarbons which are used as foaming agents, refrigerants, aerosols, are broken down in the stratosphere, chemical reactions deplete ozone. This chemical reaction was first described by scientists in the 1970s. An erosion of the stratospheric ozone shield ("ozone hole") was first observed in 1985 over the Antarctica. Among other factors, the colder temperatures there result in conditions that increase rates of depletion. In 1987, an international agreement was signed to eliminate the manufacture and use of "ozone depleting substances". This agreement came into force in 1989 with different phase-out schedules for the manufacture and use of different chemicals. Developing countries were given longer periods of time to comply than industrialized countries.

The agreement led to a drastic global reduction in production and consumption of these chemicals, many of which are potent greenhouse gases as well. The reduced concentration of these chemicals in our atmosphere as led to signs of ozone recovery in the stratosphere and reduction in the ozone hole over the Antarctic. For more information click on Show/Hide toggle:

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From: Hannah Ritchie and Max Roser (2018) – “Ozone Layer”. Published online at OurWorldInData.org. Retrieved from: ‘<https://ourworldindata.org/ozone-layer>’ [Online Resource]



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Kofi Annan, the former UN Secretary-General, in his September 2000 address to the Millennium Assembly of the United Nations referred to the Montreal Protocol as:

“Perhaps the single most successful international environmental agreement to date has been the Montreal Protocol, in which states accepted the need to phase out the use of ozone-depleting substances”

The United Nations' Framework Convention on Climate Change (UNFCCC)

Following the dramatic success of the Montreal Protocol, international attention became focused as well on the need to reduce greenhouse gas (GHG) emissions. While the “greenhouse effect” was first hypothesized near the end of the 19th century, international concern began growing during the 1980s with increased evidence for a rise in global temperatures along with data on an increase in carbon dioxide concentrations in the atmosphere. In 1988, the international scientific body called the Intergovernmental Panel on Climate Change (IPCC) was formed. The IPCC is a scientific organization charged with synthesizing the current knowledge about the causes and consequences of climate change. Its first report was published in 1990 with reports issued every 5-7 years since.

An international treaty, the United Nations' Framework Convention on Climate Change (UNFCCC) was adopted in 1992 and came into force in 1994 (after a sufficient number of countries had ratified it). The treaty committed countries to voluntarily reduce GHG emissions to 1990 levels. This voluntary approach proved not to be successful. Still, the UNFCCC has had a lasting effect on the processes used to negotiate subsequent international treaties (called “protocols” or “agreements”) with respect to climate change mitigation. Under the UNFCCC, climate change conferences have been held yearly. They are referred to as COP or “Conference of Parties” [to the UNFCCC] numbered in consecutive order. The first conference was held in Berlin, Germany in 1995 (COP1) and the more recently in Katowice, Poland in 2018 (COP24).

There are have been two agreements made under UNFCCC:

- The Kyoto Protocol of 1997 (developed at COP3) was an attempt to move from voluntary emission reductions to an agreement with binding reduction targets. This has been the climate change agreement that has been the focus of the international community through 2015.
- A successor agreement was recently approved in Paris in December of 2015. The basic outlines of this agreement will be described at the end of this chapter.

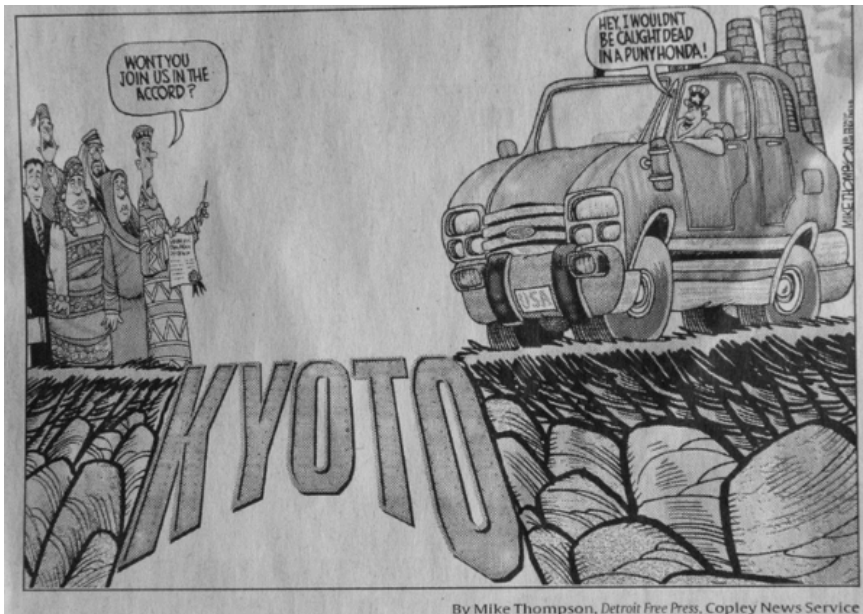
The Kyoto Protocol

Leading up to the 1997 COP3 meeting in Kyoto, Japan, different perspectives were voiced by developing countries (South) and industrial countries (North) about their relative responsibilities to reduce GHG emissions. An influential article (Agarwal and Narain, 1991) presents a common argument in developing countries:

“Can we really equate the carbon dioxide contributions of gas guzzling automobiles in

Europe and North America with the methane emissions of water buffalo and rice fields of subsistence farmers in West Bengal or Thailand? Do these people not have the right to live? No effort has been made to separate the “survival emissions” of the poor, from the “luxury emissions” of the rich.”

Agarwal, A. & S. Narain (1991) Global warming in an unequal world: A case of environmental colonialism. *Earth Island Journal*, Spring, 39-40.

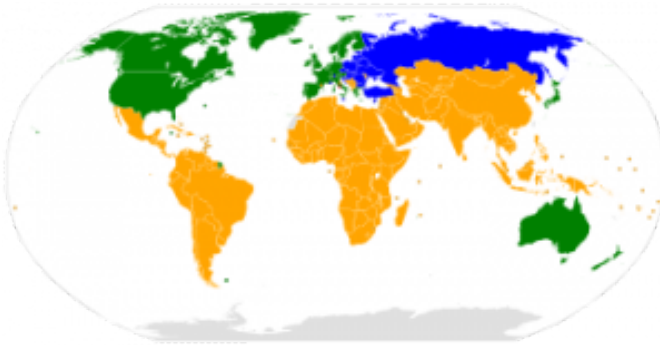


At the same time, the United States took an especially hard line during negotiations with broad bipartisan support. Immediately prior to Kyoto, the U.S. Senate in 1997 unanimously passed the Byrd-Hagel Resolution which stated that United States should not be a signatory to any climate change agreement that: 1. does not include binding targets and timetables for developing as well as industrialized nations; or 2. causes economic harm to the United States.

Seeking compromise

In response to concerns expressed by developing countries, the UNFCCC adopted in the Kyoto Protocol a set of “common but differentiated responsibilities” recognizing that:

- The largest share of historical and current global emissions of greenhouse gases has originated in developed countries;
- Per capita emissions in developing countries are still relatively low;
- The share of global emissions originating in developing countries will need to grow to meet their social and development needs.

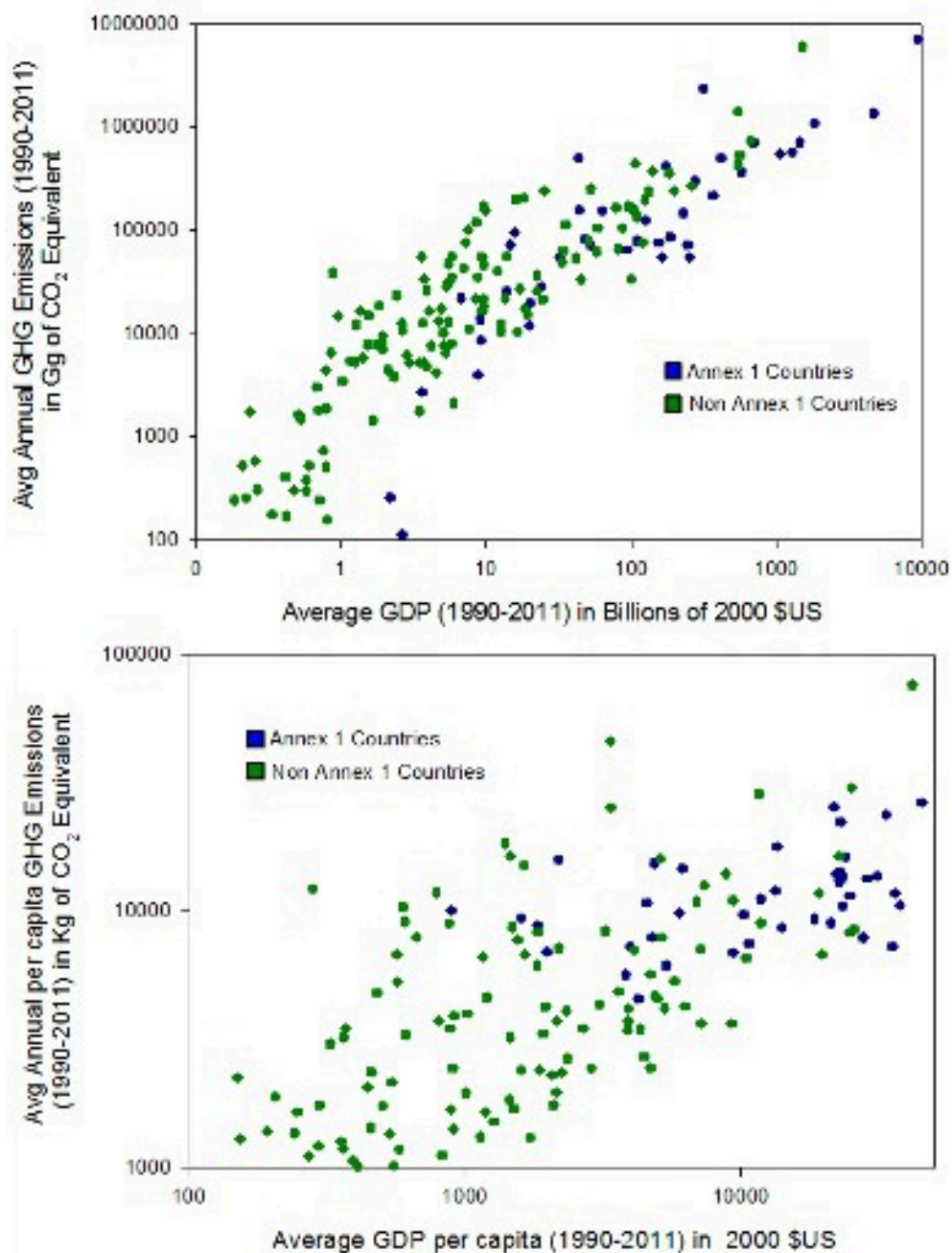


Using the categories introduced in the UNFCCC, countries were classified as industrial (**developed**) countries were designated as **Annex 1** countries and therefore obligated, once ratifying Kyoto, to reduce their emissions to a level generally 5-8% less than their 1990 emissions (shaded green and blue in map). Of these there were countries, largely of the former Soviet Union, that were classified as “Economies in Transition” (shaded blue in map) and as such had fewer obligations under the protocol.

China, India, Brazil and other **developing** countries (shaded yellow in map) were classified as exempt from the reduction requirements of the Kyoto Protocol (**non-Annex 1 countries**)

Annex 1 and Non-Annex 1 emissions and economies

The use of the categories of Annex 1 and non-Annex 1 was made to divide the signatories to the UNFCCC with respect to their relative responsibilities to reduce GHG emissions due to their current emissions, historic emissions and capacities to reduce (give socioeconomic development needs). Any categorization, particularly into only two groups, very much simplifies the diversity of situations of countries. As we will see, the Annex 1/Non-Annex 1 categorization has created controversy about the Kyoto Protocol. To give you some sense of this, we provide two graphs for your consideration. One measure of development status is gross domestic product (GDP) which is the annual value of goods produced and services provided within a country. The graphs below show the relationship between annual average GHG emissions with average GDP (top graph) and annual per capita (per person) GHG emissions with average per capita GDP (bottom graph). Each country is represented by a dot with Annex 1 countries in blue and non-Annex 1 countries in green. Look at these graphs and answer the short answer questions.



Generated from data available at the UNFCCC flexible GHG data query engine at <http://unfccc.int/di/FlexibleQueries/Event.do?event=go> (accessed 8/21/2013)

Average annual per capita GHG Emissions (1990-2011) in Gg of CO₂ Equivalent plotted against Average GDP in 2000 [top] and Average annual per capita GHG Emissions (1990-2011) in Kg of CO₂ Equivalent plotted against Average GDP per capita (1990-2011) [bottom]



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The U.S. Position on Kyoto



In 1997, the U.S., represented by then Vice President Al Gore signed the Kyoto Protocol. Each signing country to the Protocol needed to ratify it through its own political process. In the U.S. this required approval both Congress and the Executive Branch (the President). In 2001, President Bush formally announced the U.S.'s intention not to ratify the Kyoto Protocol:

“This is a challenge that requires a 100% effort; ours, and the rest of the world’s. The world’s

second-largest emitter of greenhouse gases is the People’s Republic of China. Yet, China was entirely exempted from the requirements of the Kyoto Protocol. India and Germany are among the top emitters. Yet, India was also exempt from Kyoto ... America’s unwillingness to embrace a flawed treaty should not be read by our friends and allies as

any abdication of responsibility. To the contrary, my administration is committed to a leadership role on the issue of climate change ... Our approach must be consistent with the long-term goal of stabilizing greenhouse gas concentrations in the atmosphere.” – The Whitehouse (2001-06-11). President Bush Discusses Global Climate Change. Press release.

In an attempt to provide greater flexibility to Annex 1 countries to meet their obligations and to coax the US into ratifying Kyoto, “flexibility” mechanisms were passed (COP 6-2 meeting in Bonn, Germany 2001) which allow for **emissions trading** or project-based programs that allow industrialized countries to take credit for funding emissions reduction activities outside of their country either in:

other developed countries (Annex 1) (**joint implementation**) or
in developing countries (non-Annex 1) (**clean development mechanism**)

These programs will be the focus of a future chapter.



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Ratification of the Kyoto Protocol

To come into “force” – e.g. a binding agreement – the Kyoto Protocol needed to be ratified by at least 55 countries of which Annex 1 ratifiers together produced at least 55% of global greenhouse gas emissions in 1990. The Kyoto Protocol came “into force” in February, 2005 after the ratification of the protocol by Russia in November, 2004.

Participation in the Kyoto Protocol



Global map depicting participation in the Kyoto Protocol. Non-participants are encoded in red, participants in green.

The United States (depicted in the map above in red) was alone among parties to the UNFCCC in refusing to ratify Kyoto and therefore was not obligated to meet Kyoto GHG reduction targets. The Table below lists the top 15 countries in terms of aggregate GHG emissions in 2010.

Country	CO2 equiv emissions (millions of metric tons)	% of Total	per capita CO2 emissions (metric tons)	Annex 1 Ratifier of Kyoto
China	8,321	26.2	6.3	N/A
United States of America	5,610	17.7	18.1	no
India	1,696	5.3	1.4	N/A
Russia	1,634	5.1	11.7	yes
Japan	1,164	3.7	9.2	yes
Germany	794	2.5	9.6	yes
South Korea	579	1.8	11.9	
Iran	560	1.8	7.3	N/A
Canada	549	1.7	16.3	yes
United Kingdom	532	1.7	8.5	yes
Saudi Arabia	478	1.5	18.6	N/A
South Africa	465	1.5	9.5	N/A
Brazil	454	1.4	2.3	N/A
Mexico	445	1.4	4.0	N/A
Italy	416	1.3	7.2	yes

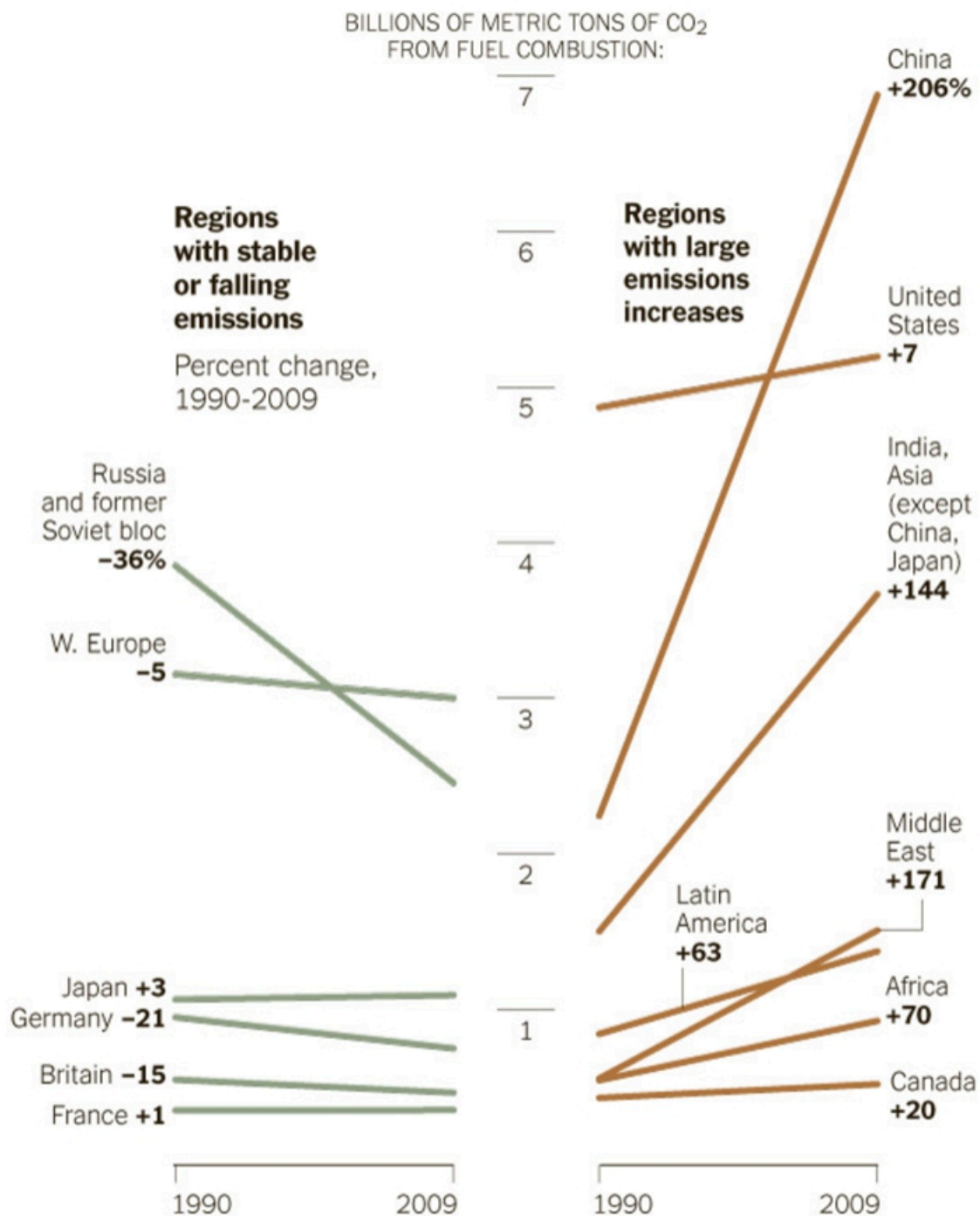


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The Effectiveness of the Kyoto Protocol

Kyoto specifies that Annex 1 ratifiers reduce their GHG emissions by 5-8% from 1990 levels by 2012. This chart shows the change in greenhouse gas emissions by countries from 1990-2011.

Cleaner vs. Dirtier



The New York Times



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Renewal or Replacement of the Kyoto Protocol?

To extend the Kyoto protocol beyond 2012, the agreement had to be either renewed or replaced (as originally stipulated in Kyoto). From November 28 to December 11, 2011, the 17th session of the Conference of the Parties (**COP 17**) to the UNFCCC was held in Durban, South Africa to seek renewal.



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The COP 17 agreed:

- To seek new agreement by 2015 including all countries
- That Kyoto will remain in effect until then (voluntary) – Canada, Russia, Japan stated that they would no longer abide by Kyoto targets
- That a Green Climate Fund will be established to help poor countries adapt to climate change

After the COP17 in Durban, three additional COPs (18-20) were held between 2012-2014, each

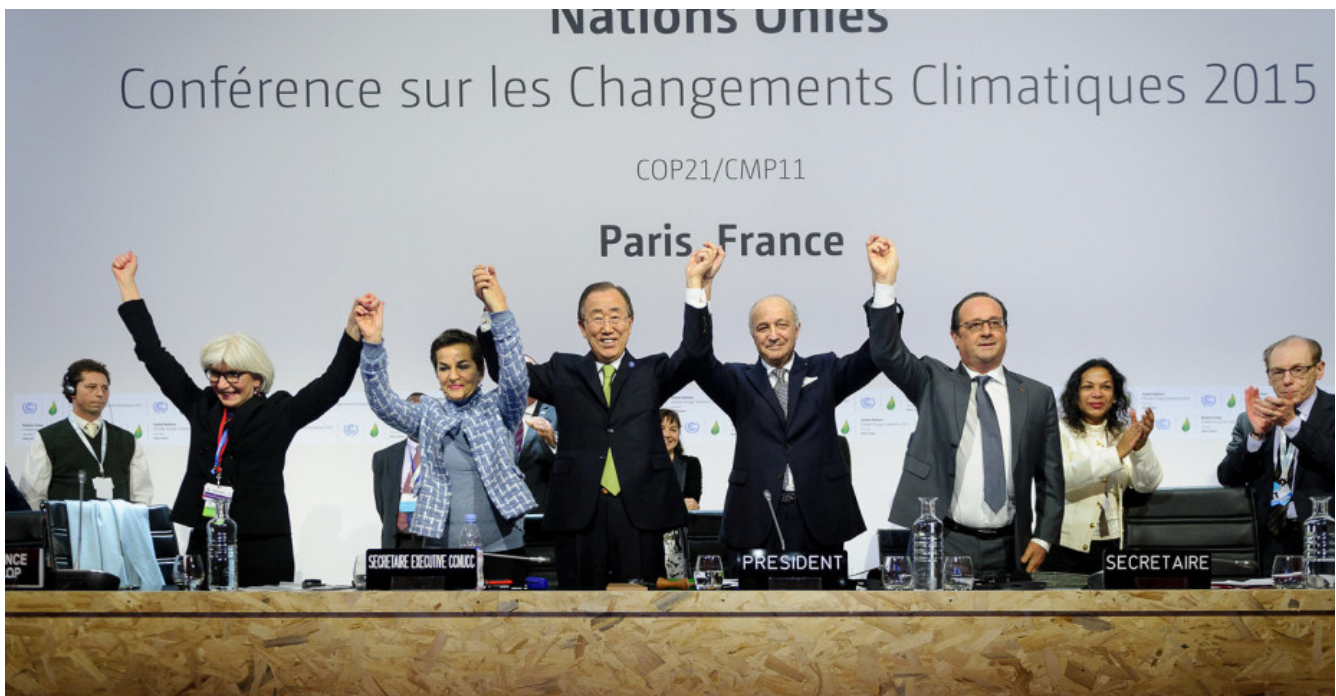
focusing on developing a new agreement to replace the Kyoto Protocol. Three important areas of concern arose during this time:

1. Growing strains in the Developing World Alliance between rapidly-growing middle-income countries emitting relatively large amounts of greenhouse gasses (e.g. China, India, South Korea, Brazil, Mexico) and the poorest countries experiencing many of the impacts of climate change (Island Nations, African countries, Bangladesh, etc.).
2. A greater recognition of the differential impacts of climate change on the poorest of developing countries with a concomitant need for the industrialized world to fund climate change mitigation and adaptation.
3. Considerable anxiety about the need to resolve the stand-off among the largest emitters (China, U.S., and India) about their responsibilities to reduce their GHG emissions.

In 2014, hopes were raised with the news of the joint announcement that the U.S. and China would both seek to reduce their GHG emissions. While not an enforceable treaty, the U.S. stated that it intended to reduce its aggregate emissions by 26%-28% below its 2005 level by 2025. China stated that it intended to start reducing aggregate emissions by 2030.

The Paris Agreement

For COP21, countries were asked to develop statements of “**intended nationally determined contributions**” which represent their commitments to reduce greenhouse gas emissions (mitigation) and/or reduce the vulnerability to climate change (adaptation). These commitments formed the basis for the Paris agreement. Each country made mitigation and/or adaptation commitments that were specific to itself (unlike Kyoto). Like Kyoto, countries are expected to ratify their commitments appropriate to their system of government with the agreement becoming legally binding if ratified by at least 55 countries which together represent at least 55 percent of global greenhouse emissions.



With respect to mitigation, these commitments are highly varied and are normally stated as **reduction target**:

1. Commitments to reduce aggregate greenhouse gas emissions.
2. Commitments to reduce the energy intensity (energy use per unit of GDP) or emissions intensity of its economy (GHG emissions per unit of GDP) **by a certain percentage relative to a specified baseline such as**
 1. The value of the target (aggregate emissions or fossil fuel intensity) in year X.
 2. The projected value of the target by achievement year based on a “business as usual” (BAU) scenario.

to be achieved by a certain year or range of years... with certain conditionalities (normally funding from industrialized countries)

[Follow this link](#) to open a WRI's page (in a separate window) that tracks these commitment by country. Using the “INDC Detailed View” tab on the WRI page, choose the country to read the abstract of its emission reduction commitment:



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The stated overall goal of the Paris Agreement is to keep global temperature increases well below 2 degrees C and closer to 1.5 degrees C. A number of the commentators have made the point that even if these voluntary emission reductions were met within the stated time frames, global temperature increases would likely exceed 2 degrees C.

U.S. announces intention to withdraw from Paris Accord



On June 1, 2017, the U.S. President announced his intention to withdraw from the Paris Climate Accord:

“As president, I can put no other consideration before the wellbeing of American citizens. The Paris climate accord is simply the latest example of Washington entering into an agreement that disadvantages the United States to the exclusive benefit of other countries, leaving American workers – who I love – and taxpayers to absorb the cost in terms of lost jobs, lower wages, shuttered factories, and vastly diminished economic production

For example, under the agreement, China will be able to increase these emissions by a

staggering number of years – 13. They can do whatever they want for 13 years. Not us. India makes its participation contingent on receiving billions and billions and billions of dollars in foreign aid from developed countries. There are many other examples. But the bottom line is that the Paris accord is very unfair, at the highest level, to the United States.”

– **Statement by President Trump on the Paris Climate Accord.** The White House. Office of the Press Secretary. Rose Garden. June 01, 2017.

This statement, while arguably more extreme, reflects the tensions that have existed since negotiations leading to Kyoto about the relative responsibilities to reduce among the largest-emitting countries – particularly between U.S. and those middle-income countries with large populations such as India and China. Two points should be made in reference to this statement:



1. It serves simply as notice that the United States tends to withdraw from the Paris Agreement. Legally, the U.S. cannot begin the process of withdrawing from the Paris Agreement until 4 years after it came into effect which would be November 4, 2020, one day before the next presidential election. As a result, the U.S. continues to participate at the COP meetings although in a grandstanding fashion. An example would come from the 2018 COP 24 in Katowice, Poland where the United States convened a panel extolling the merits of fossil fuel energy, particularly coal (with Australia as other participant) that elicited protests (see photo). Moreover, the United States, along with Russia, Saudi Arabia, and Kuwait were able to water-down the COP24 response to the [IPCC's special report](#) about the impacts of a 1.5 degree C increase in global mean temperature that was elicited by the Paris Agreement itself and released approximately two months before COP24.
2. Despite the US government's lack of support for the Paris Agreement, there have been significant actions taken by local and state governments and private companies in the U.S. to reduce greenhouse gas emissions since the President's statement. These actions are covered in the chapter on energy policy but there are estimates that these actions have advanced us significantly toward our Paris Agreement commitments. For those of you who are interested, a 2018 report making this argument by the climate action committee called America's Pledge on Climate can be accessed through this [link](#).

Climate Science Essentials

Learning Objectives

This chapter provides basic information about climate change for those without prior exposure to climate change before taking this course. This chapter provides a necessary foundation for the material covered in this class which focuses on social, institutional and policy dimensions of climate change mitigation and adaptation. By the end of this chapter, you will be able to:

- Distinguish between climate change and weather.
- Know the definitions of key terms in climate science.
- Understand the primary causes of anthropogenic climate change
- Know the types of evidence for climate change and features of weather affected by it
- Understand how climate change will affect biodiversity

In this course, we will not focus on climate change science but on the institutional aspects of climate change mitigation and adaptation. The goal of this chapter is to provide to those without a prior background, a basic introduction to climate change basics sufficient to understand the mitigation and adaptation material covered in this class. In addition, additional resources for further study are provided.

Climate Science 101

As we begin on the material on climate, it is important that you have a clear understanding of some of the central elements of current scientific understandings of climate change.

To review or learn some important elements of climate science, start by watching the Bill Nye video, then answer the accompanying questions below.



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Important Definitions

You know what **weather** is. It is how the temperature, precipitation and wind are looking when you walk out the door in the morning. Is it cloudy? Is it hot and windy?

Climate, however, is a measurement of long-term average conditions in a location. You could think of it as the average weather over a long period of time. For example, you might talk about the average of winter low temperatures over 20 years and how it has changed. That is a factor in climate.

You will often hear the terms “global warming” and “climate change” used interchangeably. The two terms do have a lot of overlap in meaning for how we will be using the terms in this course.

Global warming usually refers specifically to the rise in global average temperatures that is widely believed to have anthropogenic roots (i.e. be human-caused). Average heating of the planet has different local effects on weather that can range from extremely wet winters to long summer heat waves. Do not confuse these terms with the greenhouse effect.

Climate change also often refers specifically to the anthropogenic changes in the globe’s average temperature, with different localized effects. When we use it in this course, most of the time this is the usage of the term to which we will be referring.

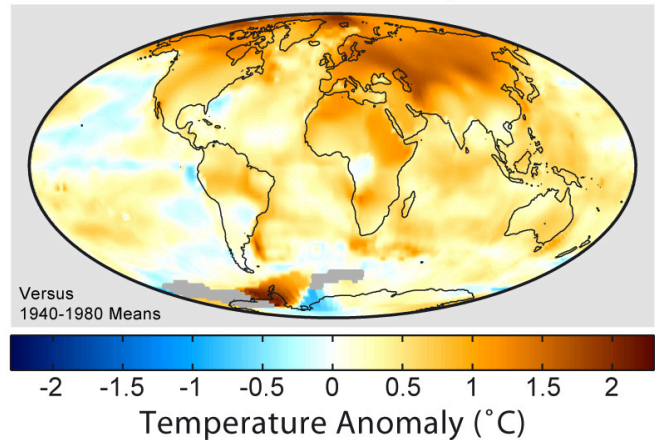
It is important to understand, though, that, depending on context, “climate change” can have a broader meaning. Any change in long-term patterns of temperature, precipitation, wind patterns or similar factors constitutes climate change. So, climate change can refer to changes like the postulated cooling of the Earth 65 millions years go, after an asteroid hit and threw substantial debris into the atmosphere, blocking some of the sun’s radiation.



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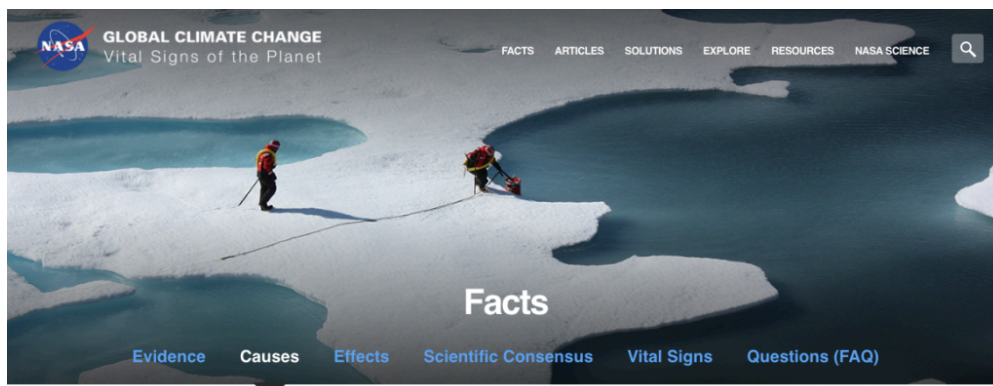
1999-2008 Mean Temperatures



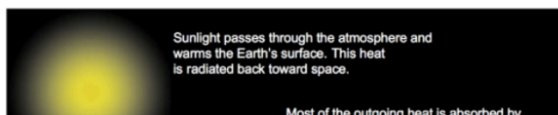
1999-2008 Mean Temperatures

NASA – Causes of Climate Change

Click on the image of the NASA *Global Climate Change* website below. It will open in a new browser tab. Use the information from the web page to answer the questions below.



A blanket around the Earth

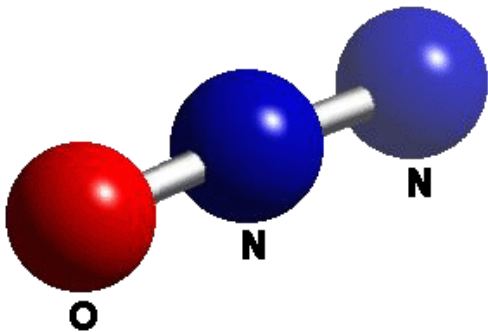


We live in a greenhouse

Life on Earth depends on energy coming from the sun. About half the light reaching Earth's atmosphere passes

Why focus on carbon dioxide?

NITROUS OXIDE



The NASA website lists several gases that contribute to climate change. Some gas molecules, like methane and nitrous oxide, have an especially strong warming effect. We tend to focus most on carbon dioxide, however, because the amount of carbon dioxide we have released into the atmosphere is far greater than the amounts of the other gases we have released. So, it has the most total effect on warming just because there is so much more of it than there used to be.



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Why is methane also important?

We have not been releasing quite as much methane as carbon dioxide. Scientists are becoming increasingly concerned about methane, however. We have long recognized that flooded rice fields and digesting cows produce substantial amounts of methane. However, arctic and sub-arctic ponds and lakes also produce a lot of methane. As they melt with warming temperatures, scientists fear the amount of methane they will release will greatly accelerate climate change.



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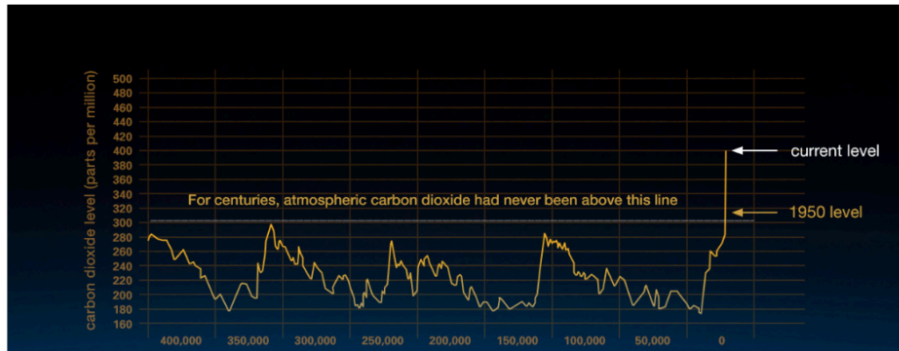
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Evidence of Climate Change

Click on the image of the NASA *Global Climate Change* website below. It will open in a new browser tab. Use the information from the web-page to answer the question below.

Climate change: How do we know?



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Measuring Climate Change

Click on the image of the NASA *Global Climate Change* website below. It will open in a new browser tab. Use the information from the web-page to answer the question below.



Carbon Dioxide

LATEST MEASUREMENT: November 2017

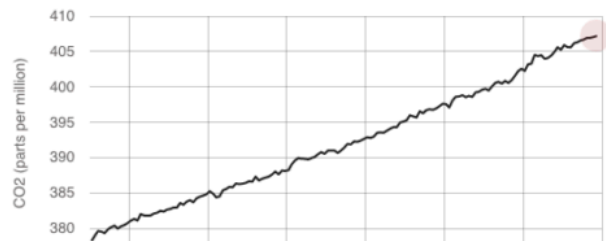
407.22 ppm

DOWNLOAD DATA

Carbon dioxide (CO₂) is an important heat-trapping (greenhouse) gas, which is released through human

DIRECT MEASUREMENTS: 2005-PRESENT

Data source: Monthly measurements (average seasonal cycle removed). Credit: [NOAA](#)



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Climate Impacts on Biodiversity

Sea level rise, shifts in rainfall, and warming will affect the ecosystems around the world. In most all cases, the rate of change will exceed the ability of species to evolve genetically. Therefore, species will only be able to adapt by moving or by showing flexibility to changing temperature and humidity conditions, food sources and competitive pressures. The location of some ecosystems make the first form of adaptation (movement) exceedingly difficult. Coral reefs have proven to be extremely sensitive to increased ocean water temperatures. Coral reef species cannot migrate to land nor to open ocean – they can only migrate along coasts – therefore, the species found in coral reefs are highly vulnerable to climate change. The same is true for land-based coastal environments, alpine ecosystems, and higher latitude ecosystems (in the Arctic for example). In all of these examples, the ability of species and ecological communities to shift their ranges (e.g. move) is extremely limited since they will become increasingly isolated – surrounded by inhospitable environments.

Even in areas where species ranges can feasibly shift with changes in temperature and rainfall, human land uses can limit the potential for species to actually move to areas where new climate conditions are conducive for their survival. Moreover, a species' survival depends not only in its own ability to move or physiologically tolerate change climatic but on the abilities of other species on which it depends – such as pollinators, parasites, and food sources. Finally, these considerations are made even more complicated when one considers that a species' survival is also influenced by its ability to compete with other species for the same food sources and escape new threats from pathogens and predators under changed circumstances.

Therefore, the effect of biodiversity to climate change is shaped by the vulnerabilities of population of species within ecosystems. An individual species vulnerability is determined by: 1. its ability shift its range (move) to more suitable habitats as climate changes; 2. its ability to physiological tolerate changed climatic conditions; 3. the effect of climate change on its coexistence with other species on which it depends (food sources, pollinators..etc.); and 4. its competitive abilities under new ecological and biophysical conditions. In short, the effect of climate change on biodiversity is complex. Still given the rate of climate change, it is very likely that we will see a negative effect on biodiversity with corresponding stresses on the ecosystem services that biodiverse ecosystems provide. The question is the extent of biodiversity loss which is likely to be quite variable geographically.



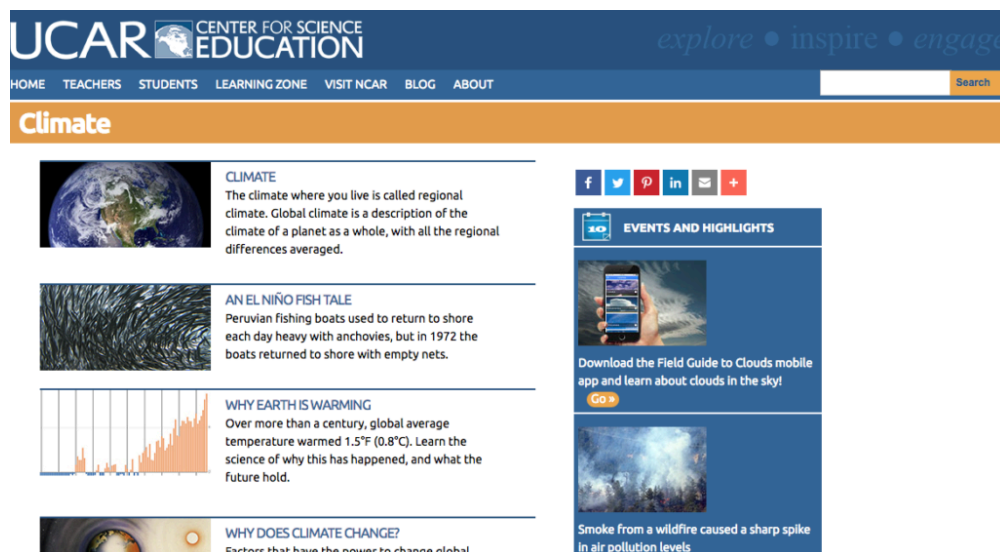
Polar Bears -Ursus maritimus-, female and juvenile on an ice floe in the pack ice, Spitsbergen Island, Svalbard Archipelago, Svalbard and Jan Mayen, Norway

Finding Reliable Information on Climate Change

Where else can you get reliable information about climate change?

Unlike a lot of scientific information out there—say organic chemistry or human biology—there can be a lot (more) of misinformation about climate that parades as good, solid information. So, in the spirit of directing you to more reliable information, here are some additional websites about climate science. Clicking on an image of the image of the websites below will open them in a new browser tab. Also feel free to seek out your own sources, and, if you're curious about the reputability, feel free to ask us!

The University Corporation for Academic Research and National Union for Atmospheric Research climate change education site



The (archived) U.S. Environmental Protection Agency climate change website:

Climate Change

Contact Us Share

How does climate change affect our health?

See our new fact sheets about the health impacts of climate change at different stages of life, and for vulnerable populations. Then, take our new online quiz to see how much you know!

[See fact sheets](#) and [take the quiz >](#)



Featured Climate News Stories:

- NASA/NOAA: [Data Show 2016 Warmest Year on Record Globally](#) (1/18/17)
- NOAA: [2016 Marks Three Consecutive Years of Record Warmth for the Globe](#) (1/18/17)

Climate Newsroom:
[See all releases >>](#)



Why is the climate



How is the climate



What can we do
about this change?

<https://19january2017snapshot.epa.gov/climate-change/climate-change-basic-information>

Climate Connections

- [Climate Change en español](#)
- [Frequent Questions](#)
- [Energy and the](#)

The National Oceanic and Atmospheric Administration climate change overview:

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Search NOAA sites

q

OUR WORK

Climate

From supercomputers and state-of-the-art models to observations and outlooks, we provide data, tools, and information to help people understand and prepare for climate variability and change.

LATEST FEATURES //

The World Resources Institute climate data explorer:

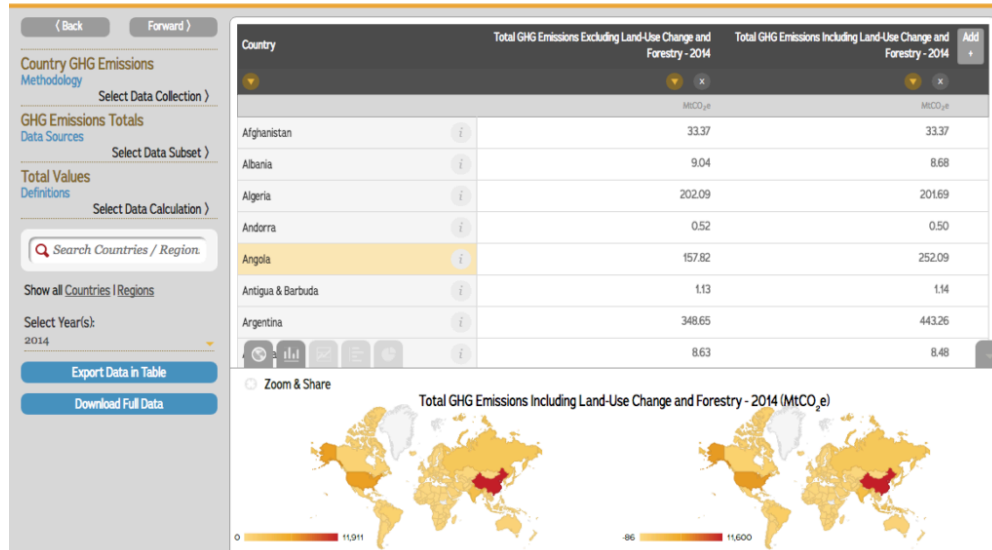
CAIT Climate Data Explorer

► Historical Emissions

Support CAIT

WORLD
RESOURCES
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Menu



The Intergovernmental Panel on Climate Change main page (note that there is a lot of information here. One good place to start is the Summary for Policymakers from the new Fifth Assessment Report. More detailed information from the Fourth Assessment can be found by clicking the “Recent Reports” tab and clicking “Other Reports” near the bottom. Scroll down to find the Fourth Assessment Reports):

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Sitemap

Sixth Assessment Report cycle

The IPCC is currently in its Sixth Assessment cycle. During this cycle, the Panel will produce three Special Reports, a Methodology Report on national greenhouse gas inventories and the Sixth Assessment Report (AR6).

The 43rd Session of the IPCC held in April 2016 agreed that the AR6 Synthesis Report would be finalized in 2022 in time for the first UNFCCC global stocktake when countries will review progress towards their goal of keeping global warming to well below 2 °C while pursuing efforts to limit it to 1.5 °C. The three Working Group contributions to AR6 will be finalized in 2021.

The outlines were approved by the Panel at its 46th Session in early September 2017.

- Approved outlines of the Working Group contributions to the Sixth Assessment Report
 - Working Group I - The Physical Science Basis
 - Working Group II - Impacts, Adaptation, and Vulnerability
 - Working Group III - Mitigation of Climate Change
- Leaflet: The Sixth Assessment cycle
- Strategic Planning Schedule AR6 (updated: 19 December 2017)

AR6 SR15 SROCC SROCL 2019 Refinement AR5

Wishing you happy holidays and a healthy and prosperous 2018!

IPCC Resource Mobilization

Assessments of climate change by the IPCC, drawing on the work of hundreds of scientists from all over the world, enable policymakers at all levels of government to take sound, evidence-based decisions. They represent extraordinary value as the authors volunteer their time and expertise. The running costs of the Secretariat, including the organization of meetings and travel costs of delegates from developing countries and countries with economies in transition, are covered through the IPCC Trust Fund. [En - Ar - Es - Et - Ru - Zh]

Quick Links

IPCC Expert Meeting on Mitigation

You are finished!

Climate Impact Case Studies: Bangladesh and the Sahel

Learning Objectives

This chapter concerns the differences in vulnerability to climate change experienced by different countries and social groups around the world. By working through this chapter, you will be able to:

1. Present the argument for why many view climate change as a global environmental justice issue;
2. Characterize the reasons why different countries or social groups are more or less vulnerable to climate change than others;
3. Describe what is meant by exposure, sensitivity, and capacity to adapt as dimensions of climate change vulnerability;
4. Characterize the vulnerability to climate change of rural peoples in Bangladesh and the Sahelian Region of West Africa
5. Describe how groups in these two areas respond to biophysical changes associated with climate change;
6. Characterize why different groups are more vulnerable than others within these case study areas.

Climate change as an environmental justice issue

Different peoples, economies and countries benefit differently from the human activities that result in greenhouse gas (GHG) emissions – most importantly fossil fuel use and to lesser extents, deforestation and agricultural activities (livestock rearing, rice cultivation). The build-up of greenhouse gases in our atmosphere will affect our climate in an uneven way. Different areas of the world are more vulnerable to the effects of climate change (temperature rise, drought, flooding, sea level rise..etc.). There is no reason to believe that the main beneficiaries of past and current GHG emitting activities will also be the most vulnerable. In fact, as will be developed below, it likely will be the opposite: the major beneficiaries will be the the least vulnerable to climate change effects.

Thus, climate change can be seen as a global environmental justice issue – a social imbalance between the benefits derived from a set of human activities and their environmental costs. In this chapter we will focus on two areas of the world that contribute insignificantly to global

GHG emissions but are seen as the most vulnerable. Before, doing so, we need to develop an understanding of what we mean by vulnerability.

Vulnerability to climate change: exposure, sensitivity, and capacity

Since changes to our climate are necessarily long-term, vulnerability to climate change refers to its more enduring negative effects on human welfare. Vulnerability, so defined, will be unevenly felt and experienced across the globe due to:

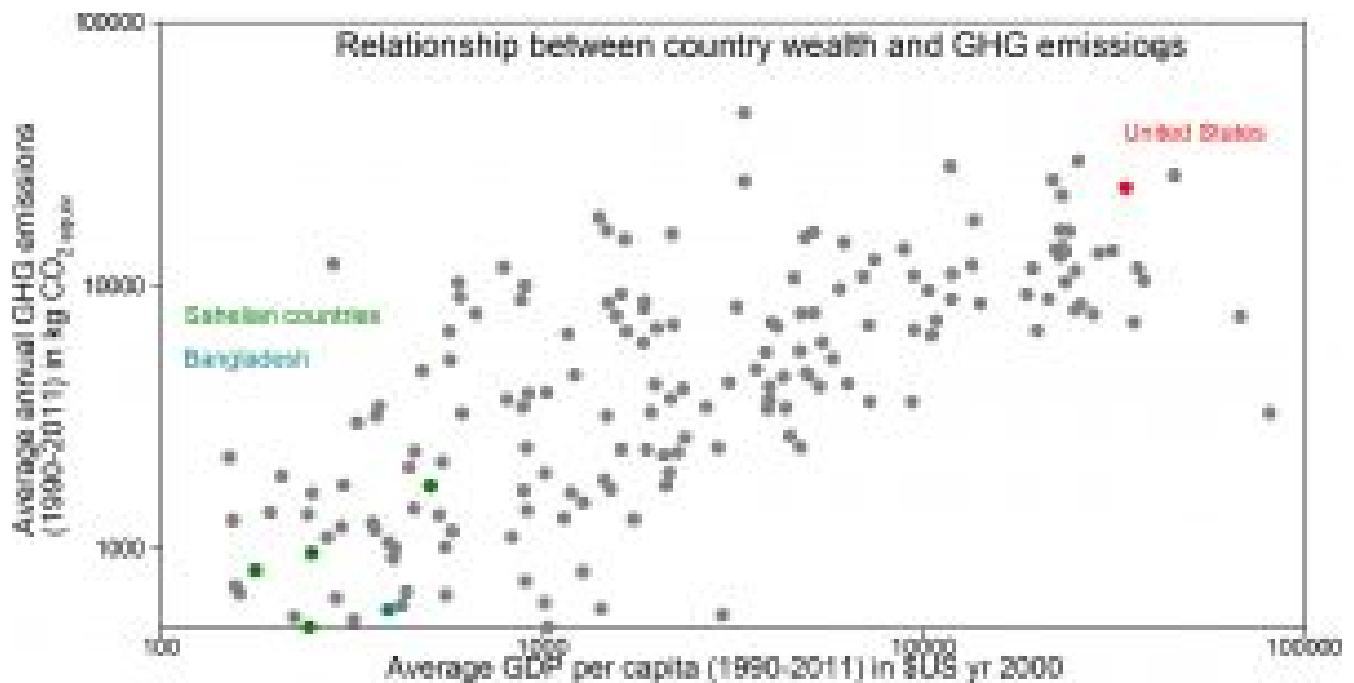
1. Different **exposure to the physical effects** of climate change including sea level rise, drought, flooding, higher temperatures, and other extreme weather events (e.g. hurricanes).
2. **Sensitivity of human welfare** to physical changes of climate change. Human societies who are poor, who have poor overall health; who do not benefit from government safety nets, and who rely heavily on agricultural activities, are seen as more sensitive to physical changes.
3. **Capacity to adapt** to the physical effects of a changing climate. Human societies with limited wealth, lack of education, limited infrastructure, and technological options are seen as having lower capacities to adapt.



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If we consider a society's sensitivity and capacity to adapt to climate change (items 2 and 3 above), one simple conclusion is that poorer societies are more likely to be more vulnerable to climate change effects (assuming for now that exposure to physical effects are equal). The figure below plots average per capita (per person) GHG emissions against average per capita GDP for the world's countries. GDP stands for gross domestic product, a measure of the economic output of a country and which is often used as a coarse measure of its wealth and level of economic development.



Please note that there is a strong positive relationship between a country's wealth and its greenhouse gas emissions. Since a country's wealth is thought to reduce its sensitivity and increase its capacity to adapt to climate change, vulnerability to climate change is most likely highest among those countries who have contributed least to its cause (GHG emissions).

Please note the quite different positions of the United States (red dot) and the two areas that will serve as our case studies in this chapter: 1. Bangladesh in South Asia (cyan dot); and 2 Sahelian countries in West Africa including the countries of Senegal, Mali, Burkina Faso and Niger (green dots). These two case studies are examples of places in the world that have contributed very little to the problem of global warming while at the same time are extremely vulnerable due to sensitivity and limited capacity, but also to high exposure. Both locations that climate models predict will experience substantial but different impacts from climate change. As a low-lying coastal country, Bangladesh is exposed to sea level rise. The Sahelian region, lying just south of the Sahara desert, is exposed to increased variability of rainfall affecting the incidence of drought and flooding. Both offer examples of 1) the ways in which vulnerable populations may be affected, and 2) the adaptation measures that may be necessary for individuals, households and governments to adopt.



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Make sure that you can find Bangladesh on the map of South Asia to the left and the West African Sahelian countries (Senegal, Mali, Burkina Faso and Niger) on the map of Africa to the right.

Considering vulnerability: Bangladesh

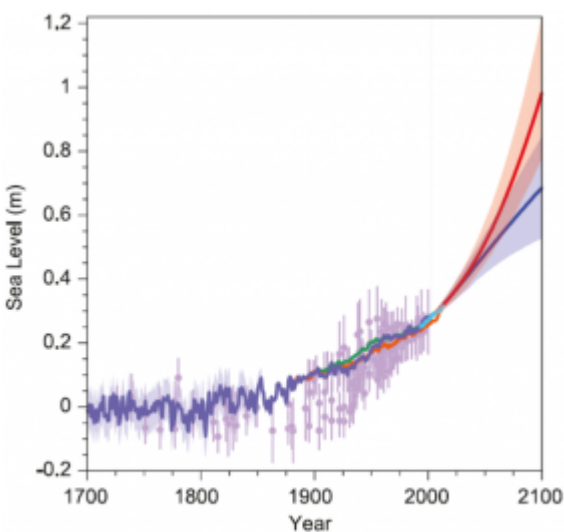


Fig. 1. Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.

Sea level rise is expected to be a major effect of the warming of the earth's climate due to the melting of particularly land-based ice with the released water ending up in the oceans. Due to this phenomena, various estimates have been made about predicted sea level rise. For example in 2014, the Intergovernmental Panel on Climate Change, the international scientific body charged with synthesizing the available data on the effects of climate change, estimated global mean sea level rise under a range of scenarios with blue line predicted if steep cuts in emissions were to occur and the red line representing continued high GHG emissions (see figure to the right).

Subsequent estimates, that incorporate new understandings

Population living on land exposed to inundation by 2100

Under new sea-level rise projections (millions of people)

Region	Sharp carbon cuts (RCP 2.6)	Unchecked pollution (RCP 8.5)
World	97.4	152.5
United States	1.8	2.8
China	26.9	42.9
Bangladesh	8.0	14.0
India	7.1	11.5
Indonesia	5.6	9.8
Vietnam	11.7	17

of a more rapid breakup of the Antarctic ice

sheet with warming predict more rapid sea level rise. Using these estimates, a [study](#) by the research organization, Climate Central, predicts that the numbers of people currently living on land that will be lost due to rising sea levels by 2100 based on the same IPCC scenarios described above. While this provides only a partial list of the countries affected, this and other studies point to South, Southeast and East Asia being particularly exposed to future sea-level rise.

Sea Level Risks - Bangladesh

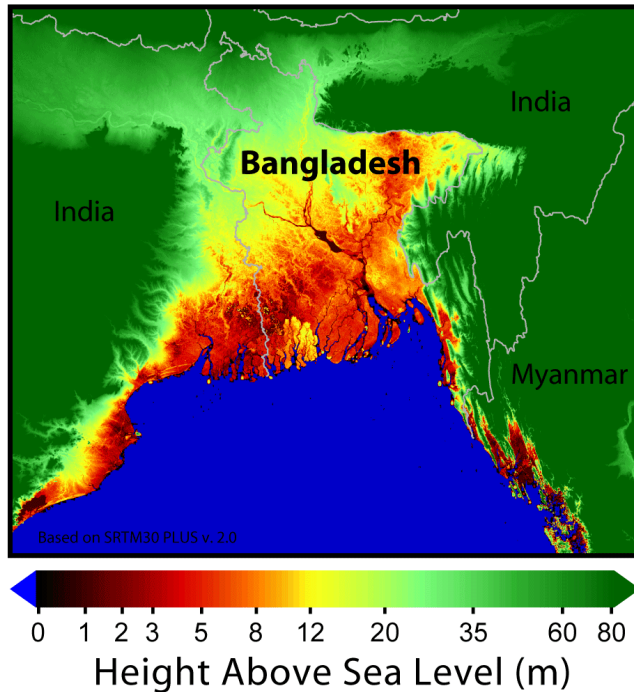


Image created by Robert A. Rohde / Global Warming Art

These effect of these exposures are magnified by the sensitivity of Bangladeshi society to them. This sensitivity is due in large part to widespread poverty and that almost two-thirds of the population lives in rural areas (2016 statistics) and thus at least is indirectly depends on agriculture. In this way, Bangladesh represents a range of developing countries vulnerable to sea-level rise such as Vietnam, India, Thailand, China, and Myanmar as well as Island Nations such as the Maldives, the Philippines, and the Marshall Islands.

Bangladesh is one of the world's most exposed countries to sea-level rise. This reflects the significant percentage of its land area that is within the several meters of the current sea level. The added risks of sea level rise are not simply those caused by the gradual inundation of land as sea levels exceed the land's elevation. Increased risks of salt water intrusion as well as the increased flooding and top soil erosion caused by more destructive storm surges at higher sea levels are probably more important. In addition, climate models suggest that changes in rainfall patterns tied to the monsoons will also increase the chance of flooding under climate change.



Flooding in Bangladesh



Woman and child in Bangladesh
http://www.maristopes.org.uk/imagecontent/Bangladesh_woman_and_child.JPG

In evaluating how people are vulnerable though, it is very important to consider the social and economic systems that affect peoples' lives. For example, in a country like Bangladesh, where women tend to have fewer resources to acquire income than do men, gender affects vulnerability. A female-headed household may be more vulnerable to flooding or sea level rise than a male-headed household simply because a woman will have a harder time finding income to repair the family's house and to reestablish fields.

Watch the two videos on Bangladesh climate migrants below. As you watch, consider the following questions:

1. People in the US who have resources to fall back on during hard times often have savings accounts in banks or retirement accounts. What kinds of resources do Bangladeshi villagers depend on? Why are those resources less transferable (than, say, a bank account) when they migrate?
2. What kinds of resources are offered to Bangladeshis who have lost their homes in storms?
3. Is there a difference between Bangladeshis and Americans who lose their homes to weather events? How are their experiences different? Why?



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Considering vulnerability: The Sahel

As Bangladesh, the Sahelian region lies in the tropics (+/- 23.5 degrees latitude) but it is farther from the equator and therefore drier. “The word “Sahel” means “shore” in Arabic – the region which serves as sparsely-vegetated shore of the “sea” which is the Sahara Desert. It has long been an area of variable and sparse rainfall with native vegetation best described as steppe (brush land) grading, with increasing average rainfall, into savanna as one moves south from the desert edge. Rains always come during the rainy season, which is the northern hemisphere’s summer. Within that period though, rains are often highly variable.

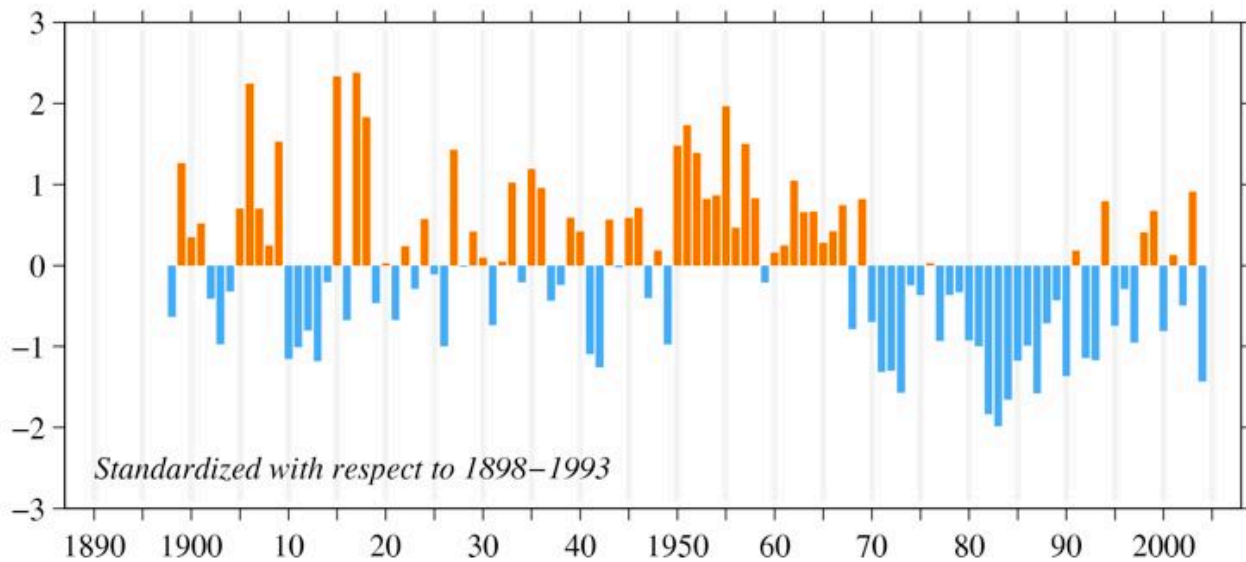
Predicting changes in rainfall with climate change is difficult and is especially difficult for the tropics. In general, climate change in the tropics is predicted to make dry areas farther from the equator drier and wet areas, closer to the equator, wetter. The Sahel, as a drier region, has been



Map of the location of the Sahel, stretching east to west across Africa just south of the Sahara Desert

thought to become drier with climate change. The historical record of rainfall support this. The figure below shows annual deviations of regional rainfall for Sahel from its long-term average.

Rainfall in the Sahel: 1895 – 2005



Rainfall in the Sahel: 1895 – 2005: Orange bars show higher than average rainfall, blue bars are lower than average rainfall

Since the early 1970s, there has been a significant drying trend with some recovery of rains since 2000. The rainfall “recovery” has been marked by changes in the distribution of rainfall within the rainy season with more rain falling in large events separated by dry periods (associated with early cessation of the rainy season). This explains in some recent years of flooding during the same year of harvest failure.



Flooding in Niger (http://news.bbc.co.uk/2/hi/in_pictures/6742541.stm<http://www.worldvision.org.nz>)



Similar to Bangladesh, the people of the Sahel are some of the world's poorest with large fractions of the population dependent on the agriculture. The changes in the climate, with rains coming late or ending early, or even causing flash floods, affect how farmers grow their crops. Inadequate or poorly timed rains can mean farmers get no harvest. Sahelian farmers have been dealing with these kinds of conditions for a very long time, but conditions are becoming increasingly difficult. Grain (millet or sorghum) is the staple food for all families with local grain prices all rising rapidly

during periods of shortage – drought years and near the end of the dry season when grain stocks become depleted. While different ethnic groups may specialize in particular livelihood activities, most all rural families attempt to reduce the risk of food shortage and malnutrition by being involved in crop agriculture (provides the major food staple), livestock husbandry (livestock is major store of wealth that can move to where rain occurs), and seasonal labor emigration to more resource-rich areas to the south (source of cash). Small families and those lacking land and livestock are the most vulnerable. Women, due to their limited access to agricultural land, are often very vulnerable as widows if their husbands have left to find work elsewhere. Thus, while there are significant differences in the risks facing Sahelian societies, the distribution of these risks show some similarities to the situation in Bangladesh.



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Nice Work! You are finished.

Debating Greenhouse Gas Emission Responsibilities

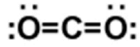
Learning Objectives

By the end of this chapter, you should be able to describe:

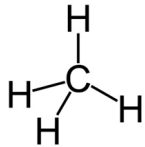
1. The general distribution of greenhouse gas (GHG) emissions around the world
2. Arguments about the ethical responsibilities of different countries to reduce their GHG emissions
3. The strengths and weaknesses of different metrics to measure GHG emission responsibility among countries that could be used as a basis for international agreements.

To reduce the extent of climate change, society needs to reduce the release of greenhouse gases (GHG). To do so, there is a need to develop agreements, policies or rules that lead to such reductions. These in turn requires measurement of the responsibilities for greenhouse emissions within and between countries. In this chapter, you will learn about the different ways in which the responsibility for greenhouse gas emissions can be measured. While going through this material, you should be thinking about what you feel would be a fair and effective accounting system for reducing GHG emissions.

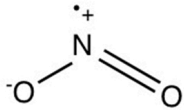
Measurement of the warming effect of different greenhouse gases



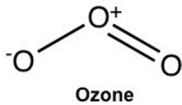
Carbon dioxide



Methane



Nitrogen Dioxide



Ozone

Any agreement must rely on an accounting of the warming effect of different GHG emissions. While carbon dioxide is the most prevalent greenhouse gas, other gases also absorb heat including methane, water vapor, ozone, and nitrous oxides. The molecules of these gases have different capacities to absorb heat. In addition, they remain in the atmosphere, on average, for different time periods. To estimate the relative global warming potential of a given gas emission one must account for both their different heat absorbing capacities and how long on average the gas molecules remain in the atmosphere after being released. For GHG accounting, the releases of other greenhouse gases are translated into CO₂equiv which typically accounts for the gas's absorptive capacity and removal from the atmosphere generally estimated over a 100 years.¹ It is important to recognize that when we refer to CO₂equiv in this and other chapters, the greenhouse warming effect of the release of all GHG gases is captured. The warming potential of gases are thus most often expressed relative to carbon dioxide.

1. The choice of 100 years is somewhat arbitrary and we must be aware that a given quantity of a greenhouse gas will represent a larger number of CO₂equiv if evaluated over a shorter time period if that gas tends to leave the atmosphere more quickly than CO₂.

Gas	Greenhouse Gas Warming Potential (over 100-year period)*
Carbon dioxide	1
Methane	28-36
Nitrous oxide	265-298

*Please note that ranges reflect differences in how warming potential is estimated. See [EPA website](#) for explanation.

Different human activities lead to the release of greenhouse gases

As you are all aware, different human activities result in the net release of greenhouse gases. These activities include fossil fuel combustion (to produce electricity, move cars, and heat homes); the net removal of vegetation, particularly forests (deforestation); declines in the carbon content in soils; and the release of methane through livestock production, rice cultivation, and from landfills.



As shown in the figure below, global greenhouse gas emissions are most associated with fossil fuels (75%) with agriculture (livestock and rice), land uses (net deforestation and burning), and waste (methane produced in landfills) accounting for the rest.

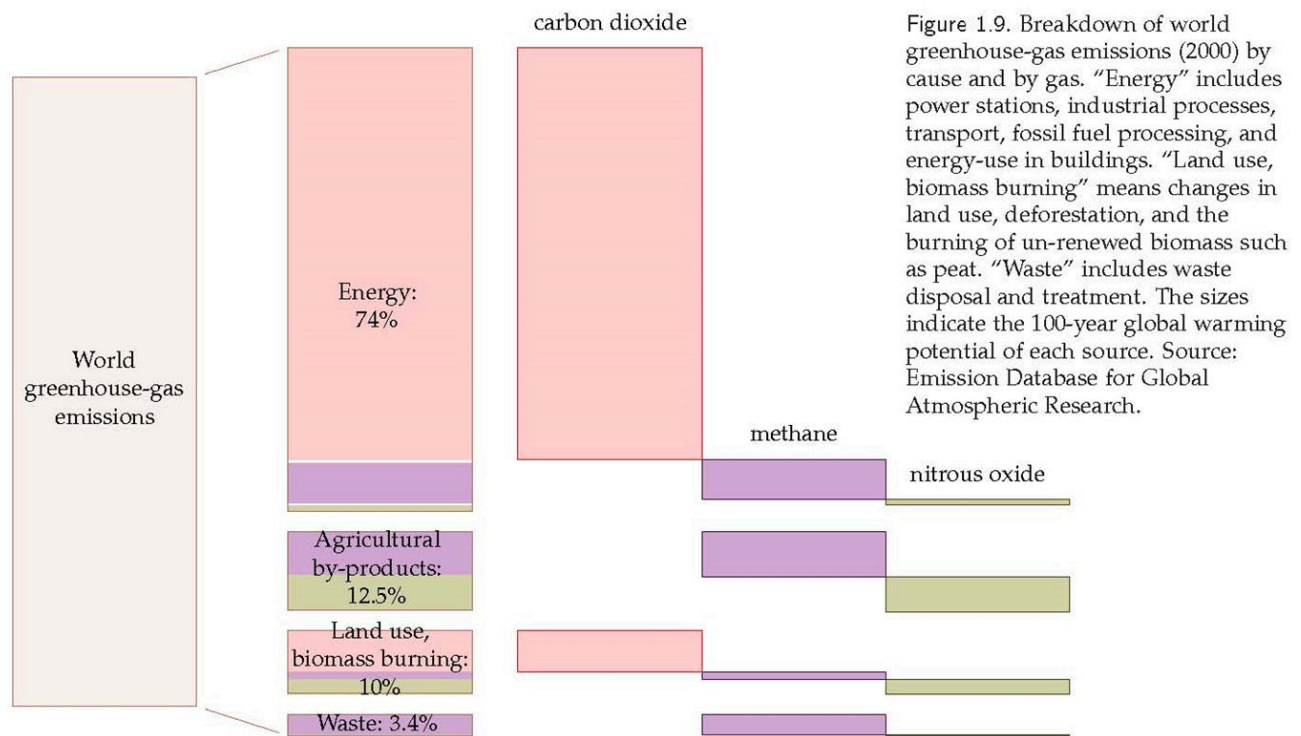


Figure 1.9. Breakdown of world greenhouse-gas emissions (2000) by cause and by gas. "Energy" includes power stations, industrial processes, transport, fossil fuel processing, and energy-use in buildings. "Land use, biomass burning" means changes in land use, deforestation, and the burning of un-renewed biomass such as peat. "Waste" includes waste disposal and treatment. The sizes indicate the 100-year global warming potential of each source. Source: Emission Database for Global Atmospheric Research.

from: MacKay, D. J. C.. 2008. Motivations. Pgs 2-21 In Sustainable Energy – Without the Hot Air. Cambridge, UK: UIT Cambridge

Now let's consider the appropriate the type of institutions needed to address the challenge of climate change.



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Ethics and Politics of Greenhouse Gas Emission Accounting

Responsibilities to reduce greenhouse gas emissions require an accounting of the emissions by countries (for international agreements) and by individuals/companies (within countries). Such an accounting is a first step in assigning responsibilities to reduce GHG emissions? Should the assignment vary depending on the type of emissions or capacity to reduce emissions? Let's look at each case.

Type of emissions

In thinking about responsibilities to reduce greenhouse gases, should a molecule of a certain greenhouse gas be counted the same no matter how it was produced? More specifically, should greenhouse gas emissions produced by certain human activities be counted differently than from other activities. Even more specifically, should the gases produced by the subsistence activities of the world's poor be treated the same as those produced by what have been called the "luxury" emissions of the world's rich? In other words, to what extent should we distinguish between:

Emissions associated with the high levels of consumption of relatively few people such as that in the United States



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FROM

Emissions associated with the subsistence activities of the world's poor such as herders raising livestock, those dependent on landfills, farmers growing rice, and those clearing forest for small fields.



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Capacity to reduce emissions



To reduce greenhouse gas emissions, while maintaining economic viability, requires economic resources, technical sophistication, and institutional capacity. In many ways, industrial countries, contributing a significant fraction of the world's greenhouse gas emissions, have the most capacity to reduce emissions. Their capacity stems in large part to the their economic development which was driven by cheap fossil fuels. Therefore, it could be argued that they should be expected to reduce more than developing countries.



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How should reduction targets be determined?

Any agreement, whether binding or voluntary, requires reduction targets. An international agreement could simply state that all countries should reduce their GHG emissions by same absolute amount (X tons of CO₂ equiv per year) or should there be percentage reduction? This has huge implications. If a percentage reduction would be required larger emitters be required to reduce more than lower emitting countries. Given the huge imbalance of emissions among

countries, a percentage reduction is the only method that has been considered.² In fact, a percentage reduction is the only the method that has been seriously considered in international negotiations.

So, the question now becomes, the reduction should be a percentage of what? Here are some possibilities:



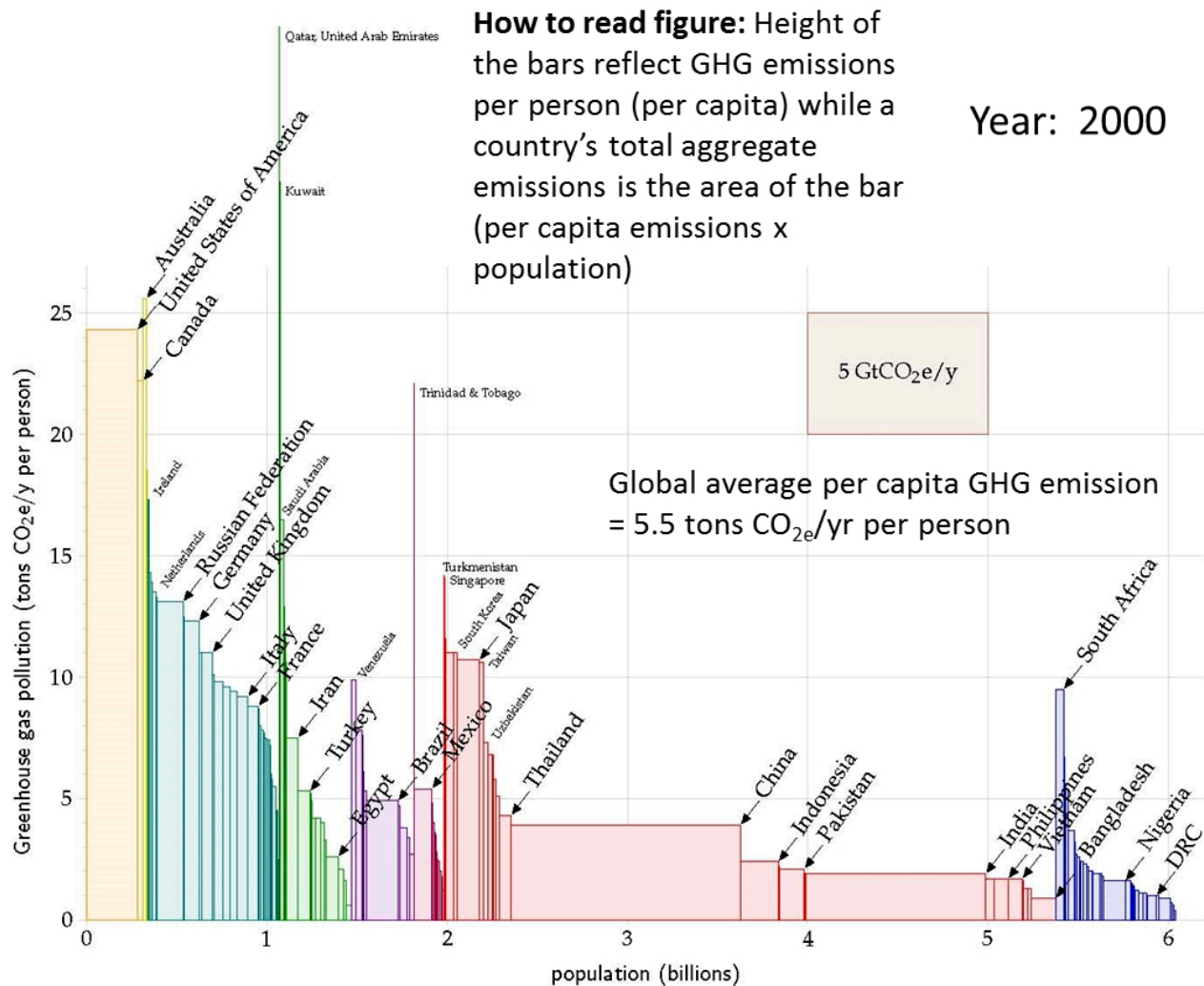
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Let's consider the implications of these different accounting metrics

Consider the implications of basing emission reduction targets in relation to aggregate national emissions or the national average emission rate per person.

2. Even if one was not interested in equity considerations, a absolute reduction is not practical since it could lead for mandated annual reductions exceeding what a country emits during a year.



From MacKay, D. J. C.. 2008. Motivations. Pgs 2-21 In Sustainable Energy – Without the Hot Air. Cambridge, UK: UIT Cambridge

The area of the rectangles in this graph, represent the aggregate national emissions of countries around the world in 2000.



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The height of the rectangles in this graph represent average per capita emissions of countries around the world in 2000.



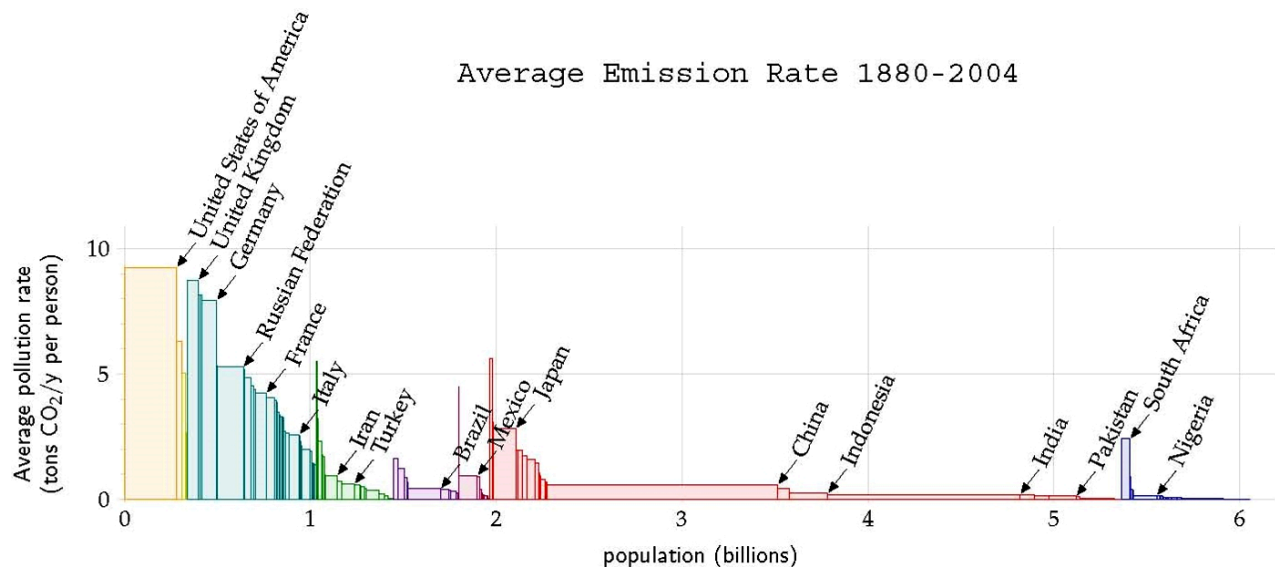
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The residence time of emitted carbon dioxide is around 100 years, now let's consider how responsibility for GHG reductions would shift if we were to consider cumulative emissions since the onset of the industrial revolution.



The graph above is the same as presented in the previous page but the area of each rectangle represents the cumulative greenhouse gas emissions for each country from 1880-2004. The width of each rectangle is population of the country in 2000 while the height is the “average” per capita emissions per year over the period calculated by dividing the cumulative emissions from 1880-2004 by population in 2000 and by 124 years.



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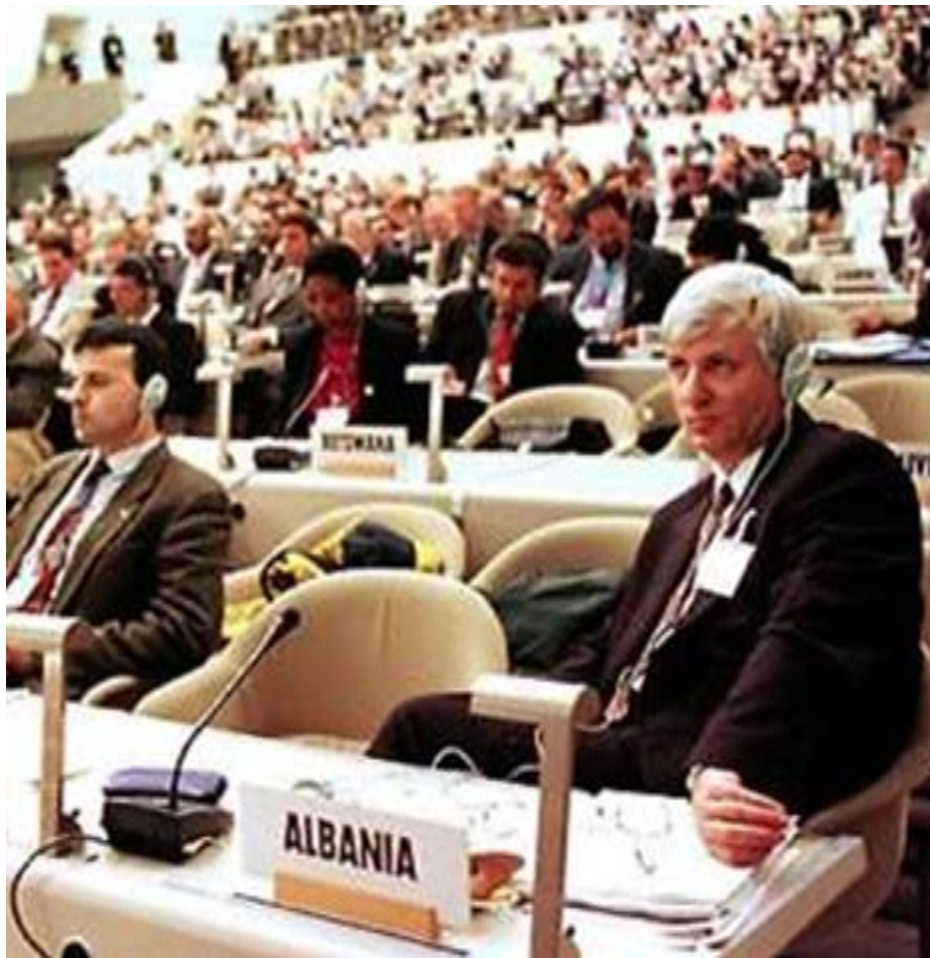
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These ethical and institutional challenges are what the international community has faced and continues to face when working toward agreements to reduce global greenhouse gas emissions. In preparation for class, think through these dilemmas while imagining yourself as a climate agreement negotiator for different countries.

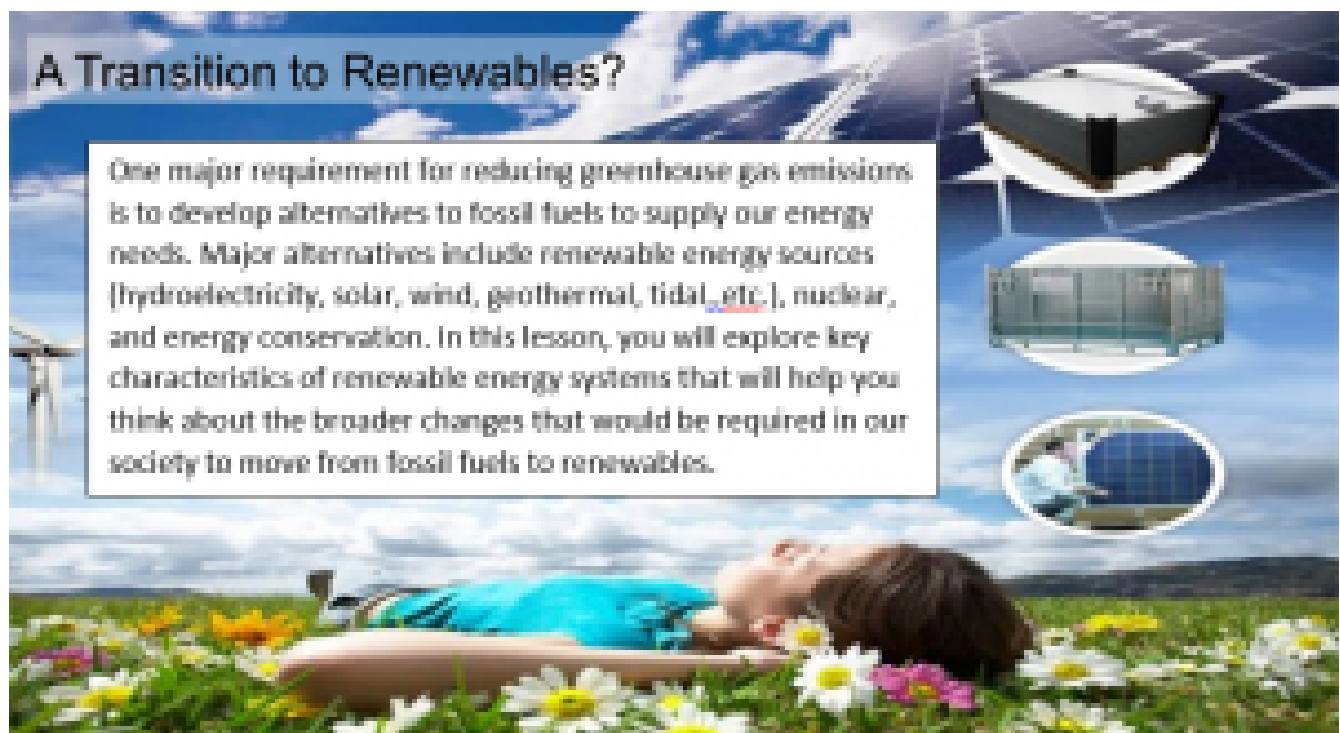


Assessing Energy Alternatives to Fossil Fuels

Learning Objectives

After completing this chapter, you will:

- Be able to explain how different alternative energy systems differ in terms of the form of supply, form of delivery and power densities
- Be able to assess (qualitatively) how energy storage and transmission infrastructure will need to change in a transition away from fossil fuels
- Understand the continued controversy surrounding nuclear power and its future prospects in a carbon-free future
- Be prepared to perform “back-the-envelope” calculations to assess different energy transition scenarios



Understanding the potential of renewable energy to meet our energy needs is complicated. Unfortunately, listening to politicians from both the right and left in the US often does little to clarify the issues. An example comes from Donald Trump in a [speech](#) comparing wind power with coal.

“You can blow up a pipeline, you can blow up the windmills. You know, the wind wheels, [mimics windmill noise, mimes shooting gun] “Bing!” That’s the end of that one. If the birds don’t kill it first. The birds could kill it first. They kill so many birds. You look underneath some of those windmills, it’s like a killing field, the birds. But uh, you know, that’s what they were going to, they were going to windmills. And you know, don’t worry about wind, when the wind doesn’t blow, I said, “What happens when the wind doesn’t blow?” Well, then we have a problem. Okay good. They were putting him in areas where they didn’t have much wind, too. And it’s a subsidiary [sic] – you need subsidy for windmills. You need subsidy. Who wants to have energy where you need subsidy? So, uh, the coal is doing great.”

Donald Trump, speech in Utica, New York, August 13, 2018

This quote displays significant ignorance of current energy technology and economics.

A quite different example comes from a speech some ten years earlier by Al Gore – one of the most informed politicians on energy issues. This is a famous speech on energy policy and for those of you who would like to watch the speech in full, click [here](#). While these excerpts display a greater understanding of the potential of renewables as the previous, it still lacks clarity. How much of the sun’s energy can we convert into electricity? How much land would be required for to supply our electricity demand through solar? What is the economic feasibility of wind power? How would energy produced when and where the sun shines and the wind blows could be stored and transferred to when and where the energy is needed? These are all questions that need to

“Scientists have confirmed that enough solar energy falls on the surface of the earth every 40 minutes to meet 100 percent of the entire world’s energy needs for a full year. Tapping just a small portion of this solar energy could provide all of the electricity America uses.”

“And enough wind power blows through the Midwest corridor every day to also meet 100 percent of US electricity demand.”

“Geothermal energy, similarly, is capable of providing enormous supplies of electricity for America.”

“I challenge our nation to commit to producing 100 percent of our electricity from renewable energy and truly clean carbon-free sources within 10 years. The leading experts predict that we have less than 10 years to make dramatic changes in our global warming pollution lest we lose our ability to ever recover from this environmental crisis.”

Al Gore, Speech in Washington, D.C., July 17, 2008

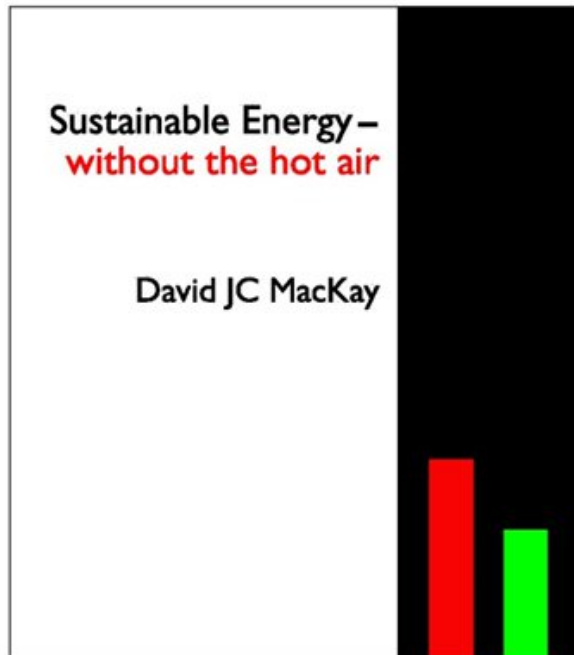
be debated, debated, and eventually understood not only by experts but the general population. As citizens and students of environmental conservation, we need to gain a better understanding of our energy supply and consumption options in order to make the right decisions for the future. In so doing, we will find that the necessary transition away from GHG-producing fossil fuels is not

impossible as some would say nor will it be easy. It will require a fundamental transformation of our economy and infrastructure.



One important source of clarity is the use of numbers. In this module, you will learn the nuts and bolts of using simple calculations to determine viable mixes of future non-carbon energy sources. If you are suddenly consumed by math anxiety math anxiety....Don't worry! We will walk you through the simple back-of-the-envelope calculations you will need based on the clear presentations contained in David McKay's book entitled: Sustainable Energy – Without Hot Air.

As a scientist, David MacKay takes climate change seriously. He sees a transition from a fossil fuel economy as vital. As a physicist, he looks at the potential of current renewable energy technologies in supplying current energy consumption. Please note that he is considering primarily energy sources that are currently technically feasible and ignores, to a certain extent, economic cost. Still, the book was written in 2008 and the technical and economic feasibility of renewable energy supplies have changed.



Now read the pages 1-7 of the synopsis of MacKay's book to better have a sense of his general approach for developing energy plans for Great Britain. We will use a similar approach – same calculations but with different numbers – to do the same for the United States.

[McKay synopsis](#)

(For those of you who would like to access the full book, follow this [link](#))

DEDICATION: "To those who will not have the benefit of two billion year's accumulated energy reserves"-David MacKay



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Form, delivery, and power density of energy supplies

Before we begin, we need to understand some differences in the characteristics of energy supplies. We will focus on three characteristics of energy supply: its natural form before conversion, its form after conversion, and the spatial density of the power produced.

Fossil fuels are remarkable stores of chemical energy with a large amount of energy stored in chemical bonds by unit weight or volume. Not only are these fuels of high energy density but the energy bonds in fossil fuels are relatively stable over time. One can store and transport coal, oil, and natural gas over long distances without losing the quality of this energy. As a result, fossil fuels (particularly petroleum) are ideal portable fuel supplies on which transportation systems have developed based on the internal combustion engine. Therefore, on economic and technical grounds, society has benefited from characteristics of fossil fuels.

The forms in which renewable energy types are supplied are quite different. Most cannot be seen as as energy stores but flows. As flows, solar and wind energy must be captured and converted to different forms to be useful. Renewable energy systems generally derive directly from the energy absorbed by the earth system from the sun. Solar and wind energy are flow systems – they must be used as they are produced. Both wind and solar are most abundant at certain times of day, and so must be stored for use when they are absent. Biomass (e.g biofuels) are chemical stores of energy but with a much shorter shelf life compared to fossil fuels. They decompose relatively quickly. Hydroelectric is generated from converted solar energy that drives the water cycle and does have storage abilities, since water can be held behind a dam rather than being released.

Type	Storage	End-use Form
Photovoltaic Solar	Flow	Electricity
Thermal Solar	Flow	Heat
Wind	Flow	Electricity
Biomass	Store-- couple of months	Liquid Fuel
Hydroelectric	Reservoir	Electricity



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When captured, renewable energy supplies are converted into a particular energy form for delivery. Solar photovoltaic cells convert sunlight directly into electricity while solar hot water systems convert sunlight to heat. Many of our renewable options (including tidal and geothermal not listed in table) supply energy to end uses in the form of electricity. Considering that electricity now supplies less than 40% of our energy end uses (the rest being largely fossil fuels), a renewable future would require not only significant changes in energy generation and storage but energy supply systems.

Our transportation sector, which consumes more than a quarter of US energy supply, currently depends on petroleum-based liquid fuels (94%). Think about our dependence on the internal combustion engine....Movement away from fossil fuels will require some combination of drastically increased electricity use (fuel cells, hybrids, electric vehicles) and biofuels in the transportation sector. The infrastructure changes associated with such a transformation would be significant.



Energy supply or consumption facilities	Power Density (W/m ²)
PRODUCTION^a	
Wind	2
Offshore Wind	3
Tidal	3-6
Solar PV panels	5-20
Plants (biomass)	0.5
Hydroelectric	11
Gas or oil well	30
Nuclear Power Plant	56
CONSUMPTION^b	
Cities	5-100
Houses	20-100
Steel mills/refineries	300-500

^aRenewable energy values derived from table 18.10. on page 112 of MacKay 2009. The fossil fuel facility values from Bryce, R. 2010. The real problem with renewables. Forbes <http://www.forbes.com/2010/05/11/renewables-energy-oil-economy-opinions-contributors-robert-bryce.html>

^bDerived from Smil, V. Energy: A Beginner's Guide. Oxford: One World Press

rate of energy flow per unit land area. Why should you care about what seems like a dry engineering concept? You should care because this is a characteristic of energy supply that shapes our infrastructure and settlement patterns. In many ways we can say that our cities are in part the outcome of the HIGH power densities provided by fossil fuels.

We can think of the power density of energy supply as the energy flow (watts) that can be captured or produced per unit land area through a particular energy supply. We can also think about energy consumption in this way – the amount of energy consumed per unit land area. For instance, one would expect the a skyscraper to have a higher energy power consumptive density than a single-story house.

Take a look at the table to the right. Watts (W) are units of the rate of energy flow (power) and therefore power density is the energy flow per unit land area (m^2). The table presents power density of energy-producing (wind farms, hydroelectric plants, corn fields) and consuming sources and entities houses, cities..etc) facilities. Please note that renewable energy power densities are much lower than fossil fuel facilities – renewable energy supply is diffuse.

Reflecting about this table should help you answer questions such as:

- Can our cities be powered with roof-top photovoltaics?
- How can our cities be powered through renewables?
- What kinds of energy supply and transport infrastructure would be required?



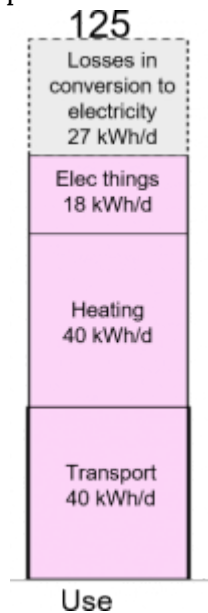
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In class, we will follow the approach that MacKay uses for Great Britain for assessing the potential for transforming the U.S. energy system away from fossil fuels. For Great Britain, MacKay expresses current energy use in terms of KW-hrs/person-day. He uses this notation to make numbers more meaningful to the individual. If one wishes to know Great Britain's total average daily energy use, one simply multiples MacKay's per person value by the population of Great Britain. If one wants to know the total annual energy consumption, one would multiply the total daily consumption by 365.

It is important that you understand that KW-hrs/person-day is a rate of use. KW refers to Kilowatts or 1000 Watts. As mentioned earlier, a watt is rate of energy flow and thus KW-hrs (equal to rate (energy/time) x time) is a measure of energy use or production. For instance, the electrical energy used illuminating a 60 W light bulb all day is equal to $60\text{W} \times 24 \text{ hours} = 1440 \text{ W-hrs}$ or 1.44 kWh. MacKay expresses Great Britain's current energy use by the average total amount

of energy used per person per day for different uses (electricity, heating, and transport). This is equal to 125 kWh per day per person.



The stacked-bar figure to the right is MacKay's summary of Great Britain's current energy consumption. Virtually, all electricity produced is generated through the burning of fossil fuels. This fossil fuel use is equal to 45 kWh/person-day. A major difference between renewables and fossil fuels is that the former directly produces electricity while fossil fuels need to be burned in power plants to produce electricity. If one considers that only 40% of the energy contained in fossil fuels is converted into electricity in typical power plants, shifting to renewable energy supply could supply Great Britain's electricity needs with less energy consumed (60% less). This is represented by the grey portion of the stacked bar. Therefore while 125 kWh/person-day is required to supply Great Britain's needs, only 98 kWh/person-day of renewable energy would be required ($125 \text{ kWh/person-day} - (0.6 \times 45 \text{ kWh/person-day})$). Make sure that you understand this.

Moving from this quantification of current energy needs, MacKay follows these steps to assess the potential of renewables and energy conservation to achieve a transition to a carbon-free economy:

1. Consider the technical potential of renewable energy systems to supply current energy needs
2. Consider the potential of energy conservation in reducing our need for energy
3. Consider what realistically may be the gap between energy needs with conservation and what renewable energy systems can supply
4. Consider a mix of other carbon-neutral alternatives to cover the gap such as nuclear, clean coal, or the importation of energy produced from renewable supplies elsewhere (e.g. electricity produced from solar farms in the Saharan desert).

In reviewing McKay's estimates, some of you might rightfully ask why nuclear power is seen as only a stop-gap energy source in this stepped process. This could be seen as an implicit assumption by

McKay that compared to renewables, nuclear is seen as less preferred given its risks. Still please note that nuclear power figures prominently in McKay's "Economist's Plan" – the plan that is seen as being most economically feasible. If you are not aware of the controversy that surrounds nuclear power as a way to address climate change, please review these topics.

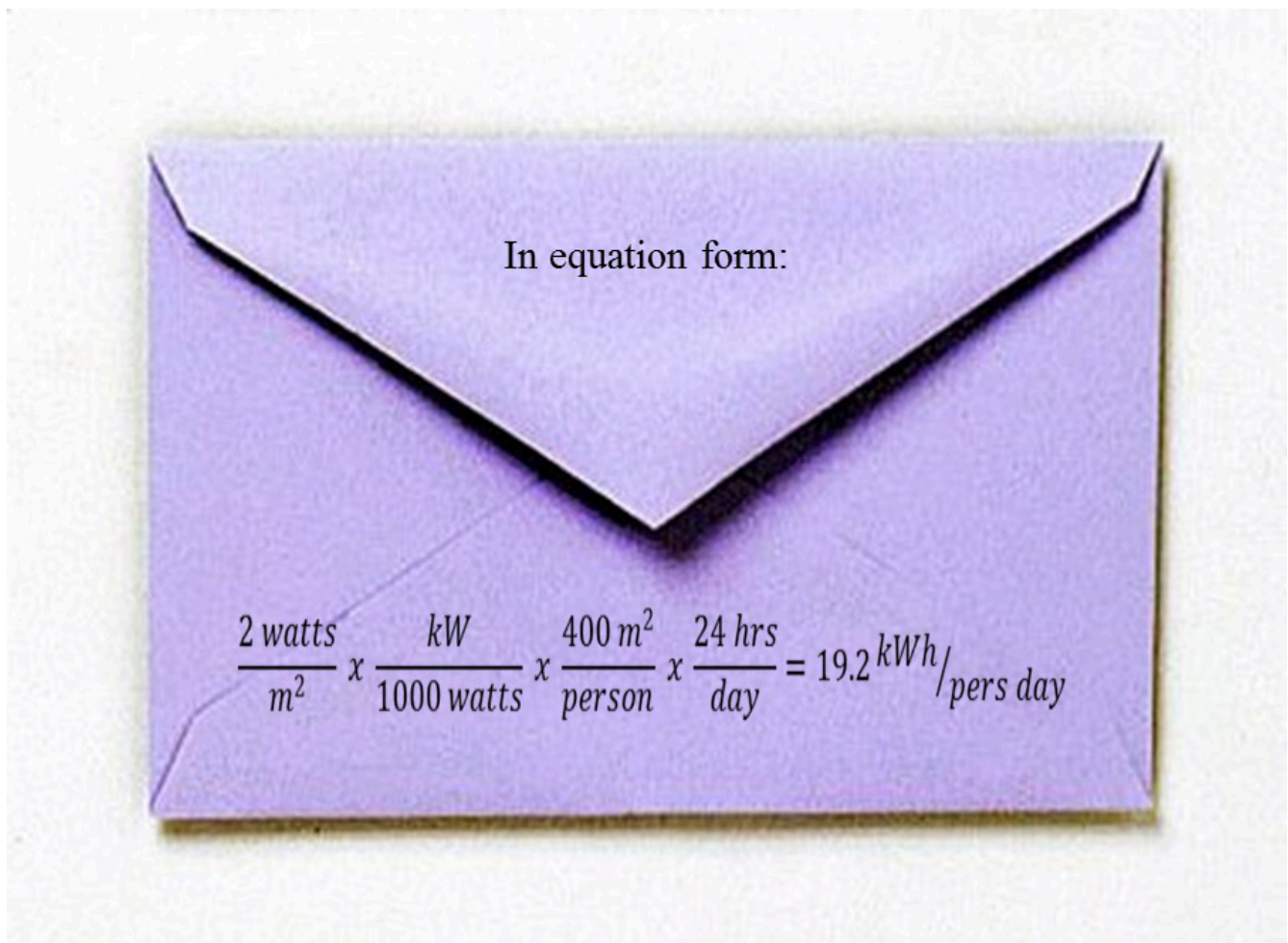


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In class, we will work through examples of the McKay's estimates together, using the same approach he used for Great Britain to consider the potential for renewable energy systems in the U.S. Our calculations and conclusions will be different than MacKay – not only because of the significant differences in renewable energy potentials in the United States compared to Great Britain but because we will be using numbers that better reflect current technology. In preparation for class, please consider how McKay estimates the wind power potential for Great Britain. He expresses wind power potential as the average amount of energy (kWh) that could be supplied per person each day. His back-of-the-envelope calculation assumes that the windiest 10% of country, equal to 400 m² of land per person, is covered in windmills that can produce 2 watts/m² of electricity on average. Electricity production per unit land x amount of land available/person-day is the basis for his estimate (along with necessary conversion factors watts to kW; hrs to days) for Great Britain's wind power potential of 19.2 kWh/per-day. See the equation below:



Make sure to spend some time to understand this calculation before you come to class. To nudge you in this direction, answer the following question.



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YOU ARE FINISHED!

Together, we will together utilize McKay's back-of-the-envelope approach to considering the technical options available for the U.S. to transition away from a fossil fuel economy. Bring your calculators and the left sides of your brains!



Wisconsin Climate Impacts

Module Objectives

1. You will be able to describe how Wisconsin's climate has changed up to now and how it is expected to change in the future.
2. You will be able to describe impacts and suggested adaptation strategies in detail for two areas studied by WICCI working groups.

In this chapter, we turn to the topic of the effect of climate change on Wisconsin and strategies to adapt to the changes that we are experiencing now and ecosystems, economy, and . climate impacts In our lecture period, you will be tasked with an analysis of how climate changes in Wisconsin will affect the state's economy, wildlife, recreation and quality of life, and expected to come up with recommendations to a state panel. The state panel will want to hear your expert opinion on what needs to be done here in Wisconsin, and why. Should we make state government changes? Create local incentives? Provide information to homeowners? In short, what are the best approaches? To prepare for that analysis, you need to understand what has changed and what is expected to change as the global average temperature rises.

So far, you have learned how climate change will affect distant places like Bangladesh. But what are the specific impacts expected in Wisconsin?



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Start with this overview video, considering the following questions as

you watch:

1. How have climate factors like temperature, precipitation and season-length changed in Wisconsin?
2. How are they predicted to change into the future?



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You now have a good general idea of the trends Wisconsin has already experienced and will undergo in the future. With the **slideshow** at right, you will start filling in the details. Open the **Word document** below, and take careful notes on each of the past and expected changes. You will need to bring these notes with you to class to work with your group to analyze Wisconsin's future.

To view the slideshow, first open the webpage by clicking on the image of it at right. To open the slideshow, please scroll down the the lower, right half of the webpage at right, and click on the black button labeled "click to view slideshow." Once the slideshow opens, you will see red buttons on the right. Note that you need to take notes on the contents of each red button. **The Word document provides a table for your note-taking.**

Notice that if you go to the right or bottom of the window at right, you will be able to access scroll bars to move around the window.

[Word document](#)

CHANGING CLIMATE

CLICK TO play

New Video: Wisconsin's Changing Climate

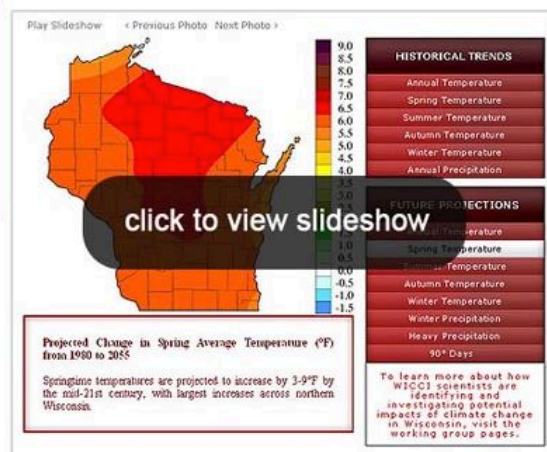
Watch as Daniel Vimont, Science Council member and Co-Chair of the WICCI Climate Working Group, provides an overview of current and likely future climate change across the state.

Now available! WICCI scientists have created a mapping tool that answers the question: "What climates today are most similar to the projected future climate of my location?" Also known as climate analogs, these maps show you locations in the U.S. that currently resemble what the climate is projected to be like in Wisconsin in the future. Explore this new feature now.

WICCI climate scientists have "down-scaled" global climate models to project how Wisconsin's climate has been changing and how it might change in the years to come.

Click on the map to activate a slideshow of the recent results of the efforts to map climate change in Wisconsin.

If you would like to see a more extensive set of climate maps, visit the [interactive mapping page](#). You may also download a pdf of the



Your next step is to start to consider what these changes will mean to people in Wisconsin. **Please read & follow the left hand column first.**

Remember, you can scroll around the window that contains the map by going to the right or bottom to use the scroll bars.

About the map: The map at right shows **proxies** for Wisconsin's future climate. You will click on a location, and the new rectangles (pop-up boxes) on the map to the right will tell you which

current climates are likely to resemble your chosen location's future climate. Read the directions (in grey) carefully before you begin. Click "Begin Using Map" when you have read the directions.

Practice example of using the map: click on Madison on the lefthand map. According to the average of all of the climate models (the line & rectangle in red), which Illinois city has a climate similar to what Madison's will be like in the middle of the 21st century? **Note that you can click and drag the map to see different areas of it.** (The answer is Springfield).



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Directions for using proxies to consider future impacts and adaptation:

For 2046-2065: Now, choose a city, perhaps your hometown.

- Choose the earlier of the two time periods in the top center drop-down box (2046-2065).
- Choose a future emissions scenario in the top left drop-down box.
- Write down your choices in the Word document you already opened.

Describe how you think the climate might be different at your chosen location based on its future proxy.

For 2081-2100: Now, use the same selections for town and emissions scenario, but choose the later time period (2081-2100).

On your Word document, describe how you think the climate in your selected town may be different in 70-90 years based on its proxy in that time period.

In preparation for each of the future periods you viewed, how do you think the location might need to adapt?

How is Wisconsin's CLIMATE CHANGING?

IE Users: if you are not seeing the map below, please adjust your protection settings by double-clicking 'Protected Mode' at the bottom of the browser or selecting Tools/Internet Options/Security from the menu at the top.

Future scenario: A1B (middle) | Climate model: All | Time: 2046-2065 AD | Help: Overview, Using this interface | **Begin Using Map**

Choose a WI location (double-click) | Closest analogues for Wisconsin's future climates

This website allows you to ask a simple question: **what climates today most resemble the future climates projected for my location?** Answers to this question can help us adapt and plan for the consequences of global warming. For example, farmers can use this website to identify possible crop types and hybrids that may do well in Wisconsin's future climates, while epidemiologists and land managers can use this information to identify diseases and pests that may be poised to enter Wisconsin.

Start by double-clicking on the left-hand map to choose a Wisconsin location. Once you've done this, the right-hand map will show a set of rectangles with arrows pointing to the chosen Wisconsin location. These rectangles are places whose contemporary climates most resemble the future climates projected for your Wisconsin location. We call these places the **closest analogues** for Wisconsin's future climates.

The Comparison plot at bottom shows the distance and bearing between your Wisconsin location and its closest analogues. By moving the mouse over the locations in the right-hand map or the circles in the Comparison plot, you can see more detailed information about the projected climate changes.

You may want to experiment with different future greenhouse gas emission scenarios, different choices of general circulation models, and different time periods. These can all be changed using the dropdown menus at top.

This website was developed with support from Wisconsin Focus on Energy, the Cartography Lab in the Department of Geography at the University of Wisconsin, and the Climate, People, and Environment Program at the Nelson Institute Center for Climatic Research. Thanks to all!

WI base map: Road map, Aerial map, Hybrid (both) | Hybrid (both) | ipsl_cm4 | miroc3_hires_2 | giss_aom | csiro_mk3_0 | cccma_cgcm3_1

Ok, on the last page you had to make some guesses and estimates about what proxies suggested about on-the-ground impacts. Now you will take a look at actual, predicted impacts on the economy, recreation and other aspects of life in Wisconsin.

In class you will be using this information to create your own analysis of and response to climate change in Wisconsin. Coming back to the assignment outlined on page 1:

Recall that you are completing an analysis of how climate changes in Wisconsin will affect the state's economy, wildlife, recreation and quality of life, and you are expected to come up with recommendations to a state panel. The state panel will want to hear your expert opinion on what needs to be done here in Wisconsin, and why. Should we make state government changes? Create local incentives? Provide information to homeowners? In short, what are the best approaches? Make sure you are clear about the approach you would plan to use (Through government? Through formal or informal education? Through improved infrastructure?).

In preparation for your recommendations, you should familiarize yourself with the impacts and recommended adaptations produced by the Wisconsin Initiative on Climate Change Impacts.



(c) Dennis Franke

[WI module lecture assignments ABC](#)

You should take notes on the two topics assigned to you to the left. Make sure to write down your group number as well. Using the information in the links at the right side of the WICCI Working Groups web page, you should learn as much as you can about potential impacts and recommended adaptation strategies in Wisconsin. In class, you will work with other students who were assigned different topics to come up with a plan of action to recommend to the state panel mentioned at the beginning of this module. Feel free to do additional research if you feel that you need more information.

Use the Word document you have already opened to take your notes, and make sure to bring it with you to class.


INITIATIVE ON
CLIMATE
CHANGE
IMPACTS

[Climate Change](#)

[Impacts](#)

[Adaptation](#)

[Resources](#)



WORKING GROUPS

Working Groups are created by the Science Council to conduct science-based assessments of potential climate change impacts on specific regions, ecosystems, communities and industries in Wisconsin and to make recommendations on adaptation strategies. Scientists, experts and practitioners work together in each group.

[< About WICCI](#)

Adaptation

Compiling information and advising Working Groups regarding the definitions, scholarly discourses, and applied strategies related to adaptation.

Agriculture

Assessing the potential impacts of climate change on Wisconsin's diverse agriculture industry.

Central Sands Hydrology

Researching how climate change may influence the agriculture, agricultural demands for irrigation water, and the water resources of the Central Sands region of Wisconsin.

Climate

Modeling how Wisconsin's climate could change in coming years and providing support to other Working Groups on how they can use these models.

Working Groups Home

- [Adaptation](#)
- [Agriculture](#)
- [Central Sands Hydrology](#)
- [Climate](#)
- [Coastal Communities](#)
- [Coldwater Fish & Fisheries](#)
- [Forestry](#)
- [Green Bay](#)
- [Human Health](#)
- [Milwaukee](#)
- [Plants & Natural Communities](#)
- [Soil Conservation](#)

In-class objective: You will be able to apply what they know about Wisconsin's expected climate

changes and their impacts to suggest measures that municipalities, counties and the state should make to better prepare Wisconsin for its climatic future. You should be able to offer evidence and solid reasoning for your recommendations.

You are finished!

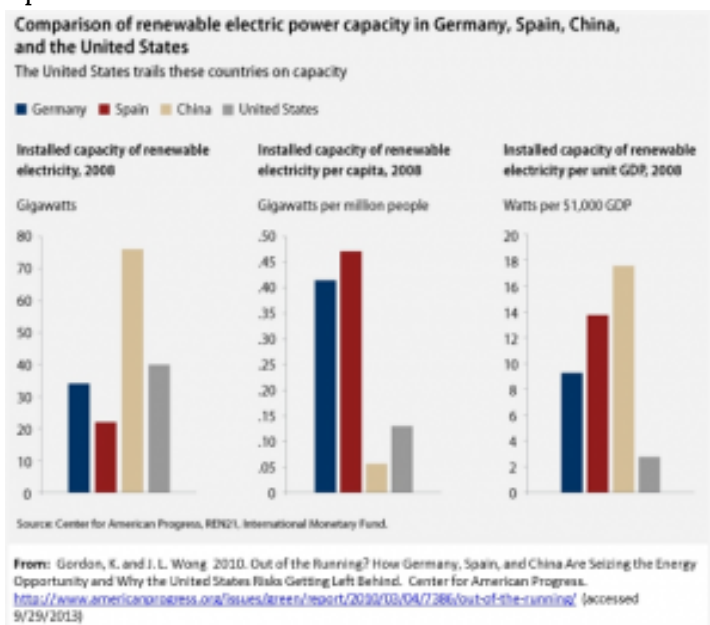
Divergent Energy Policies: Germany and the United States

Learning Objectives

By completing this chapter, you will :

- understand the rationale for government intervention in the energy sector
- know the strengths and weaknesses of major types of energy policy options
- know the recent history of U.S. energy policy initiatives in response to climate change
- understand the contrasting approach taken by Germany (Energiewende)

If the world takes climate change seriously, renewable energy alternatives need to be stimulated through policy. Ratifiers of the Paris Accord have made pledges to reduce greenhouse gas emissions with most of the opportunities to make such reductions tied to a reduced dependence on fossil fuels. The rationale for government involvement is that the full costs of fossil fuels are not captured in free-market fossil fuel prices. The environmental and public health costs of climate change and of other forms of pollution tied to fossil fuel combustion are ignored in pricing. This is a widely-accepted reason for government involvement in the energy sector. The focus of this chapter is the form in which such involvement should take.



When we speak of energy policy, we

generally refer to policies enacted at the national and local levels within countries. While we have learned about international agreements that allow for emission reduction credits to move across international borders, the incentives to seek such credits are necessarily produced by national and local governments – not by the UNFCCC. After a brief review of different policy options available to governments, we will compare the national energy policies of Germany and the United States. Both are highly industrialized countries but have shown quite different levels of government involvement in supporting a transition away from fossil fuels. As early as 2010, we see significant differences in renewable energy supply as shown in the figure above. This difference has only expanded since.



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Different Energy Policy Options Available to Government

In very basic terms, government policies can support transitions away from fossil fuels through a combination of rule-based regulation and incentive-based efforts through subsidy of alternatives or increasing the cost of fossil fuels. It is important to recognize that any energy policy relies on some combination of these approaches. Moreover, incentive-based programs need regulations to establish new rules for the market or to introduce new markets into the private sector.

Subsidies

Government can help elicit changes in our energy supply through subsidy. Due in part to security concerns related to our energy supply and the strengths of fossil fuel lobbying efforts, the United States has a long history of the fossil fuel industry. Historically, the fossil fuel sector received approximately two-thirds of government subsidies (since 1916). Since 2006, subsidies directed at energy conservation and renewables have been added to those long directed at fossil fuels and nuclear power with the [government estimating](#) that renewable subsidies exceeding those supporting fossil fuels in 2016. Subsidies include government-sponsored research, price premiums, tax incentives, low-interest loans, and grants. Through 2011, a major subsidy to renewables came through the tax credits provided to blenders of ethanol-supplemented fuel. Another example of the use of subsidies would be the American Recovery & Reinvestment Act (ARRA) of 2009 (\$800 billion) passed during Obama's first term. Of this \$800 billion economic stimulus package, approximately one-tenth went to support green energy (research, weatherization programs, green jobs training, smart-grid, tax credits to solar, biomass, wind).



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Solyndra, a solar photovoltaic company, received \$535 million loan through ARRA but

subsequently filed for bankruptcy in September 2011. The Solyndra case was used by detractors of ARRA as an example that the government does a poor job in picking winners through its subsidy programs.

Increasing the price of carbon

A different approach is to increase the costs of the use of fossil fuels. A common approach that we have already learned about is emissions allowance trading or “cap-and-trade.” The European Union’s international emissions trading program is a prominent example of this approach. The regulatory agency places a cap on the magnitude of emissions within the geographical area covered by the program. It then distributes emissions allowances to GHG emitters who then are free to buy and sell these allowances so that their annual emissions are equal to the number of allowances they hold. Those exceeding their allowance quota are fined. In 2017, China has launched the first phase of a national emission trading program covering the country’s electrical generating plants.

During its first term, Obama Administration has pursued a “cap and trade” approach in its climate (energy) legislation. Passed the House but failed in the Senate in 2010 where detractors calling it the “cap and tax” approach. Since the government generally does not collect revenue and instead money is transferred among private emitting companies, emissions trading is not taxation. Still, emissions trading does work work to increase the costs of emitting greenhouse gases and thus creates incentives to reduce GHG emissions.



While national policy initiatives for an emissions trading program have failed in the United States,

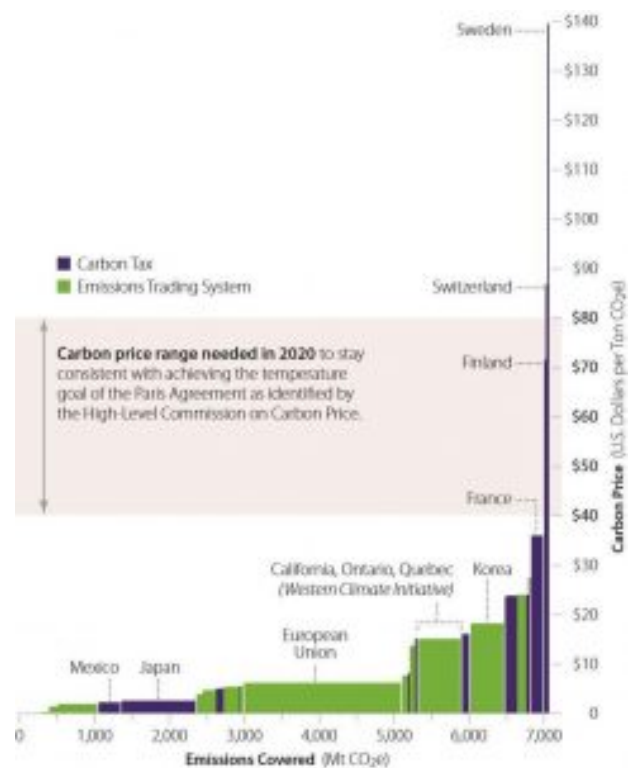
there has been more success at the level of the states. programs to reduce greenhouse gas emissions have been put in place:

1. For electric utilities in ten New England states since 2005; and
2. In California for large stationary sources since 2012 (see website to the right).

A true taxation approach is what is most often favored by economists to reduce GHG emissions. The so-called “carbon tax” would be a tax on fossil fuel use. In the United States, this approach has not been favored due to resistance from largely Republican legislators against the introduction of a new tax. There has however been an increase in bipartisan support within Congress and increased calls from the [private sector](#) for a carbon tax. At the state level, Washington State voted on a statewide carbon tax initiative in 2018 (it failed with 56% against).

Compared to cap-and-trade, a carbon tax has a number of advantages. While cap-and-trade can only be implemented with larger stationary sources of GHG emissions, a carbon tax would provide incentives throughout the economy to reduce GHG emissions from fossil fuel use. Products that use more fossil fuel to manufacture and transport would see their costs rise relative to alternatives using less fossil fuel. Consumers would face a new set of incentives to reduce energy consumption and to develop energy technologies as alternatives to fossil fuel technologies.

The [World Bank](#) estimates that about 40 nations have either introduced a carbon tax (Canada, Mexico, Japan, France, Finland, Switzerland, Sweden) or emissions trading program (EU, South Korea, China). Together these programs cover approximately 12% of global GHG emissions with approximately two-thirds as emission trading and one-third as a carbon tax. The bars in the figure to the right represent these programs with emissions trading programs in green and carbon tax programs in blue. The width of the bars in the figure to the right represents the emissions covered by the program and the height of the bar is the carbon price resulting from the program’s operation (it is variable). It has been argued that despite the rather widespread and growing implementation of these programs, the resulting carbon prices are too low to elicit the reductions of GHG emissions required to achieve the goals of the Paris Accord (40-\$80 per ton of CO₂equiv).



From: Harvey, H., R. Orvis, J. Rissman. Carbon Pricing is key to fighting climate change – but it's no silver bullet. *Forbes* November 30, 2018.



Restricting carbon emission allowances or rising a carbon tax is not simply an economic decision but also a political one. While the 2018 protests in France by the *gilets jaunes* (yellow vests) were motivated by a range of grievances, a major initiating factor was the introduction of fuel taxes by the government which postponed these tax hikes as a result of the protests.

Source: <https://france3-regions.francetvinfo.fr/bretagne/gilets-jaunes-acte-vii-manifestations-rennes-vannes-saint-brieuc-marche-prevue-brest-1599033.html>



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Regulation

As mentioned above, all programs that subsidize renewables or increase the price of fossil fuel use require some forms of regulation. Still, regulation can be used independent of these other types of energy policy. This was made most clear here in the United States by administrative actions taken by the Obama Administration. In response to stalemate due to resistance by Congressional Republicans to new climate or energy policy legislation, the EPA sought to use its executive authority to implement the Clean Air Act to pass new rules to reduce GHG emissions. In particular, the following actions were taken (click on Obama's action to learn of the Trump Administration's response):



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This experience points to the limitations of relying on rule changes based on reinterpretations of existing law (Clean Air Act).



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U.S. Energy and Climate Policy

Political stalemate during the Obama Administration followed by Trump Administration disinterest has not produced a coherent national energy or climate policy. The Trump administration has announced its intention to not abide by U.S. commitments to the Paris Accord. At the same time, it has sought, as described above, to reverse Obama Administration regulations to reduce greenhouse gas emissions. Donald Trump has consistently made statements in support of coal, the fossil fuel that produces the most GHG emissions per unit of electricity produced. These statements though have done little to reinvigorate the coal industry which has not been able to compete economically given the large amounts of natural gas (supplied by fracking) and an expansion of renewable energy supplied at declining prices (particularly wind). These economic realities along with actions to reduce GHG emissions at state and local levels, have, despite little national support, led to an expansion of renewable production of electricity. In fact, it has been at state and local levels where utilities, corporations, and governments have taken actions and made investments to mitigate climate change since 2017.

We turn to the case of Germany who provides a stark contrast to the United States in terms of national government initiative to address climate change. Its efforts to transform its energy system from fossil fuels and nuclear power is referred to as *Energiewende*.



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German National Policies toward *Energiewende*

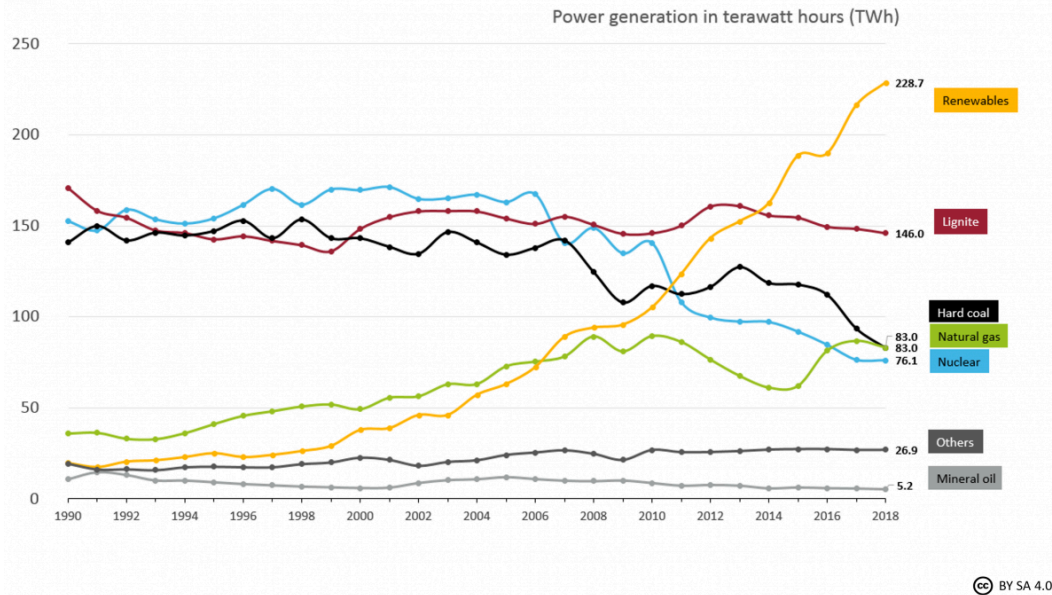
The country of Germany has a large, dynamic economy based on manufacturing. Thus, the ambitious commitment taken by the German government to transition its energy system completely away from nuclear and fossil fuels has been seen as a very important case internationally. Its success has been most notable in the area of electricity production.

Gross power production in Germany 1990 - 2018, by source.

Data: AG Energiebilanzen 2018, data preliminary.



Source:
<https://www.cleaneenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts>



This figure traces Germany's electricity production from 1990-2018. As can be seen, electricity production through renewables (wind and solar) have increased dramatically with production from nuclear and hard coal declining. Natural gas and soft coal (lignite) have remained the same over the past 15 years. This is a significant shift driven in part by Germany's participation in the EU's emission trading system but more importantly by its policy of providing incentives to home owners and other small producers of solar and wind power for the electricity they sell back into the grid. [Click here and read the 2012 article, "Germany Has Built Clean Energy Economy That U.S. Rejected 30 Years Ago"](#) that describes this incentive program for small-scale electricity producers.



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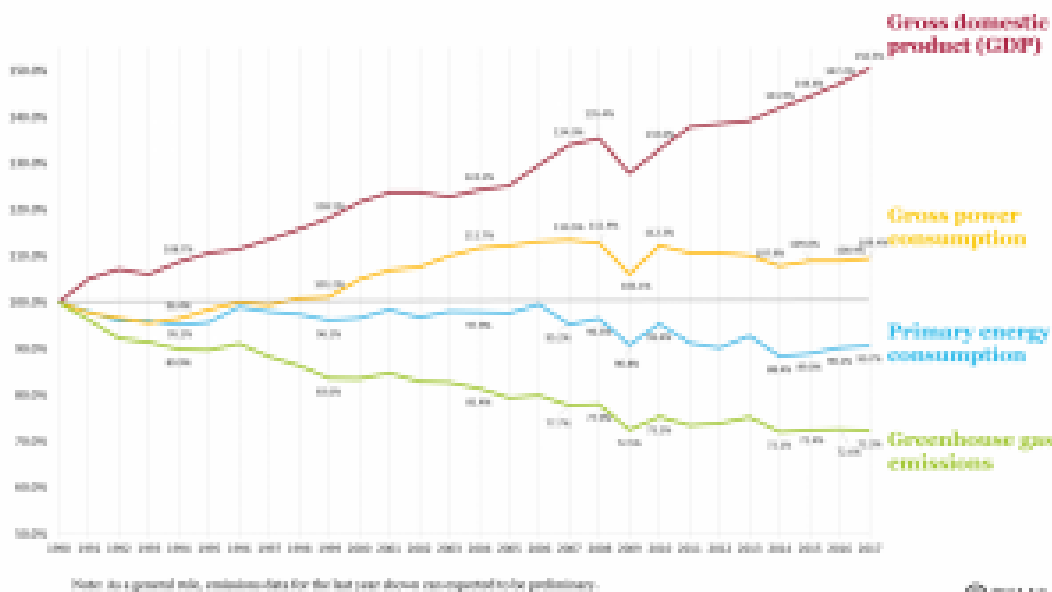
The article that you have just read presents Energiewende in a very positive light. Despite progress, the German government [announced in 2018](#) that it would fail to reach its 2020 emissions reduction target. The success of Energiewende has largely been in the realm of electricity production – there has been much less success in the transportation and heating sectors that Energiewende planners see as being major foci in subsequent phases. Still, the decline in greenhouse gas emissions despite the growth of the German economy is noteworthy:

Economic growth, power & energy consumption, GHG emissions 1990 - 2017.

Data: BMWi 2018, UBA 2018.



Source:
<https://www.cleaneenergywire.org/factsheets/germanys-energy-consumption-and-power-mix-charts>



Even for electricity production, important technical and political challenges have arisen. Technical challenges include the need to develop electricity transmission infrastructure as the sites of electricity production diversify. In particular, wind power generated in the northern part of the country needs to be transported more efficiently to southern industrial areas. Moreover, as electricity production becomes more dominated by renewables, there is a need to develop electricity storage given the intermittent nature of wind and solar supplies. Politically, Germany must deal with the dependence of eastern parts of Germany on coal production (in economically-depressed areas of the former East Germany). Along with controversy surrounding Germany's acceptance of large numbers of immigrants in 2015, the coal issue has given strength to the

political right. These difficult politics explain [Germany's continued dependence on coal](#) for electricity production despite its leadership on climate change issues.



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For those of you are interested in reading further about Energiewende, this [website](#) provides very useful information.



Building from the Germany-US comparison, you should come prepared to discuss US energy/climate policy in class.

Questions that you and your group will be asked to address include:

1. What differences exist between the U.S. and Germany that contribute to their different policy trajectories?
2. What do you think is the best mix of policies for U.S. to stimulate alternatives to fossil fuels from a management and economic perspective (research subsidies, price premiums (ala Germany), cap-and-trade, carbon taxes...etc.)?
3. Revisit your response to question #2 and consider the political barriers to your proposal.

You are finished!

International Incentive-based Mechanisms for Reducing GHG Emissions

Learning Objectives

By the end of this chapter, you will be able to:

- Describe how each of the four international incentive-based programs to reduce greenhouse gas emissions within the UNFCCC operate.
- Outline the advantages of these programs compared to programs simply working within individual nations.
- Outline the challenges that these programs face in terms of providing sufficient incentives, monitoring requirements, and equity of outcomes.
- Explain how these programs may change with the implementation of the Paris Agreement.

Introduction

Incentive-based approaches to conservation provide financial incentives for actions that support conservation goals. A water utility may pay farmers within the watershed supplying its water to maintain a certain land cover to protect water quality is an example of a “payments for ecosystem” (PES) program. The operation of an emission trading system to reduce the production of SO₂ from power plants results in cleaner power plants being paid for pollution emission allowances by plants for which pollution reductions are more costly. In both cases, actors (farmers or plant operators) are being paid for behavior that is environmentally advantageous. As has been discussed in class, these programs are seen to have the potential to reduce environmentally-harmful activities at lower economic costs compared to “once size fits all” forms of environmental regulation.

As was described in the previous chapter on International agreements to mitigate greenhouse gas (GHG) emissions, three “flexibility mechanisms” were added to the Kyoto protocol at the urging of the United States. These provide greater flexibility to Annex 1 countries to meet their reduction obligations by allowing them to take credit for funding reductions in other countries at lower economic cost. Emissions trading allows those actors (power plants, factories etc.) that

reduce GHG emissions to sell emission allowances to actors in other countries. In addition, “flexibility mechanisms” include project-based programs that allow industrialized countries (Annex 1 countries) to take credit for funding emission reduction activities in either other Annex 1 countries (joint implementation) or in developing countries (clean development mechanism). A reduction produced through these mechanisms in country X can be claimed as a reduction by country Y if country Y or one of its regulated industries has funded the activity that led to this reduction. A fourth program, not explicitly part of Kyoto but sanctioned by the UNFCCC, provides incentives to developing countries (non-Annex 1) to reduce rates of deforestation will also be discussed (REDD+).

With the replacement of the Kyoto Protocol by the Paris Agreement, these programs remain operational although their future is uncertain. This is particularly the case for the project-based programs. Still, while these programs may carry different names in the future, the structures of the new programs is likely to be quite similar to those today. Therefore, understanding their strengths and weaknesses is important as the international community decides how they will be modified with new or different names.



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Emissions Trading

Allows carbon credit trade between developed countries to meet their Kyoto Obligations. The most common emissions trading program is called “cap-and-trade” where a regulatory body “caps” the total number of emissions allowed within a given area; distributes emission allowances among polluting entities; and then allows these allowances to be bought and sold within the private sector. An early and quite successful [cap-and-trade program](#) was developed in the United States to reduce SO₂ emissions that lead to acid rain (as allowed in the 1990 amendments to the Clean Air Act). Most emissions trading examples operate within countries but international emissions trading was introduced as part of Kyoto to allow all countries within the trading system to contribute in different ways to the reduction of their aggregate GHG emissions.

The most important example of such a system is that of the emissions trading program of the European Union – composed of Annex 1 countries to the Kyoto Protocol. To provide incentives to reduce greenhouse gas emissions to meet their Kyoto-mandated reduction targets, the European Union (EU) developed a “cap-and-trade” system in 2005 that caps the overall amount of carbon emissions produced by large stationary emitters of GHGs in the EU (power plants and factories) and then allows these emitting companies within the EU to buy and sell carbon emission allowances among each other to achieve overall GHG emission reductions. It is

now the largest carbon emissions trading program in the world. WATCH THE VIDEO BELOW AND ANSWER QUESTIONS



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Source: <https://youtu.be/qxdxBfZKoa0?t=39>. Published on 10 Sep 2015



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Benchmark EU carbon price euros/tonne



Source: Thomson Reuters

The figure above shows the price of EU emissions allowances (often simply described as “carbon price”) over time. The fluctuation of the price has resulted in changing views of the viability of the EU’s emission trading system. For example, after drops in the carbon emission allowances, portrayals of the program were very negative. For example in 2009, serious questions about the viability of the system were raised. With further declines, these questions only increased.

Recovery of the EU carbon price has recovered due to a combination of broader economic changes as well more effective removal of emission allowances from the market by EU regulators. As a result, we see a change in media portrayals of the program.

OPINION EUROPE

Cap and Trade Doesn't Work

Obama can learn a thing or two from Europe's scheme.

By Martin Livermore FROM TODAY'S WALL STREET JOURNAL EUROPE
Updated June 25, 2009 11:59 p.m. ET
<https://www.wsj.com/articles/SB124587942001349765>

CO2 Emissions Trading

Financial Crisis Drives Down Price of Pollution

As the economic effects of the financial crisis deepen, it has become surprisingly cheap to pollute. Prices for carbon dioxide emissions permits have fallen below 12 euro per ton. Some companies are selling them to generate much needed cash.

<http://www.spiegel.de/international/europe/co2-emissions-trading-financial-crisis-drives-down-price-of-pollution-a-603521.html>

January 26, 2009 05:08 PM [Print](#) [Feedback](#)

Aug 21, 2018, 01:59am

EU Carbon Trading Is Working Again – And Power Prices Are Rising

<https://www.forbes.com/sites/daveknoting/2018/08/21/eu-carbon-trading-is-working-again-and-power-prices-are-rising/#668982741435>

10 Dec 2018, 14:00 Benjamin Wehrmann

Germany cashes in on emissions allowances as ETS price rises

#Climate & CO2 #Finance [f](#) [t](#) [in](#)

<https://www.cleanenergywire.org/news/germany-cashes-emissions-allowances-ets-price-rises>



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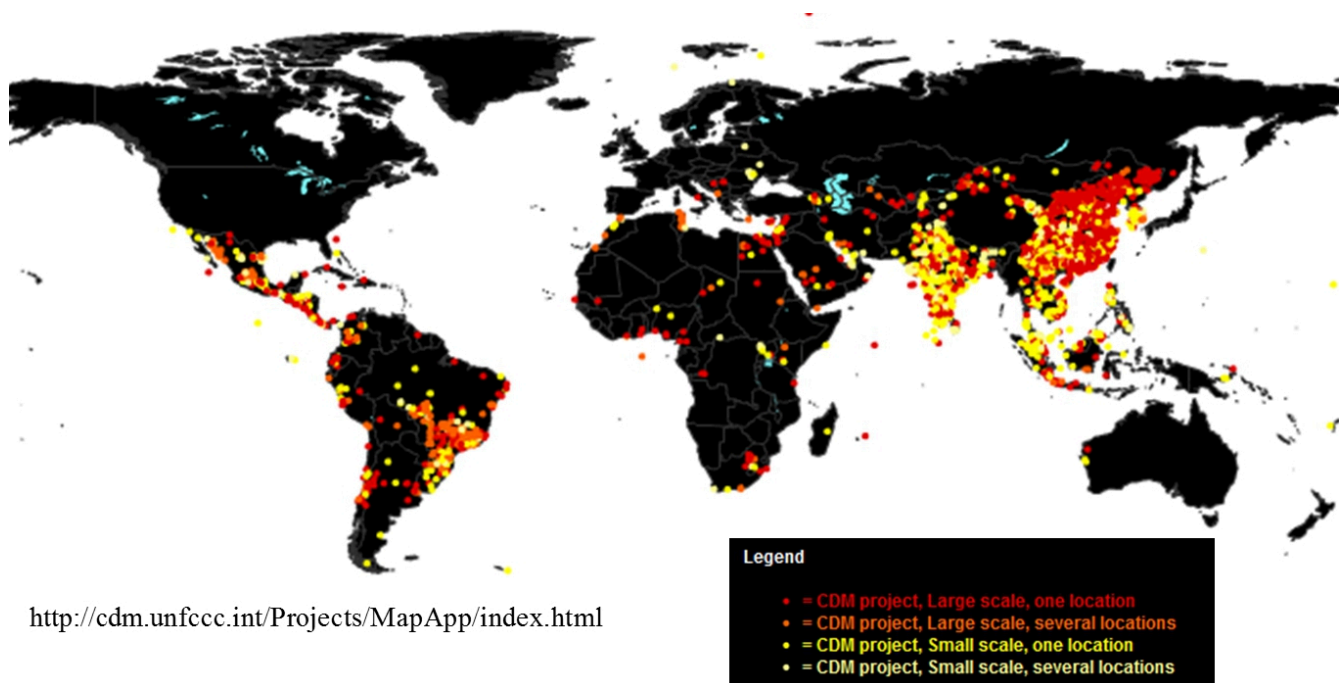
Clean Development Mechanism and Joint Implementation

Beyond emissions trading, two other flexibility mechanisms directly sanctioned by the Kyoto protocol allow Annex 1 countries to take credit for GHG emission reductions produced by projects that they finance in other countries. These two programs are: joint implementation (JI) and the clean development mechanism (CDM). These two programs are similar with the major difference being where they are implemented – JI projects are in other Annex 1 countries and CDM in developing countries (non Annex 1 countries).

Both programs install new renewable energy systems (biomass, wind, solar, hydro), improve efficiency of fossil fuel use, eliminate GHG emissions from industrial facilities, or trap the release of methane from landfills. These initiatives are funded by private industry or governments in the Developed World (Annex 1) who in turn claim certified emission reductions (CERs) for the resulting net reductions in greenhouse gas emissions. The initial financing for projects can come from different sources with these sources owning the produced (offset) credits to be kept or sold.

The UNFCCC is in charge of certifying the CERs produced. These CERs can be purchased to offset emissions to meet compulsory reductions by entities in Annex 1 countries. In addition, purchases can occur voluntarily by anyone or any institution who so chooses.

Where are these projects located? Most joint implementation projects are found in eastern Europe and the former Soviet Union – so-called “economies in transition” in Kyoto Protocol documents. The number of credits produced in JI projects are about half of CDM credits. Here is map of the location of CDM projects:





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Examples of a CDM projects

Example 1: The French company Rhodia has two CDM projects in South Korea and Brazil at its factories where the chemical adipic acid is produced (used for making nylon). Nitrous oxide, a potent GHG, is released in the process of making adipic acid. The company has invested approximately 20 million euros in equipment that destroys the nitrous acid at the two plants. This equipment has already been installed by Rhodia and other companies in most plants within the developed world (due to environmental regulations) but Rhodia had not



Rhodia's adipic acid plant in Paulinia, Brazil

done so in its plants in South Korea and Brazil. As a CDM project, Rhodia receives credit for this GHG reduction of 15 million certified emission reductions expressed in CO₂ equivalents (nitrous oxide is 298 times the warming potential of CO₂) which can be used in its ledger in Europe (or sold on the EU exchange). In 2007 Rhodia earned approximately 280 million euros in these credits – while the price of carbon credits have declined since these CDM projects represent a profitable investment for Rhodia – more profits than from the actual production of adipic acid itself.

Example 2: The biogas CDM Project of Bagepalli Coolie Sangha was established in 2005. It is run by a community organization of poor rural Indians (38,000 families across 900 villages). The CDM project initially planned to construct over time 5,500 biogas digesters (animal manure/organic waste + anerobic conditions = biogas composed of methane and carbon monoxide/dioxide which can be burned for cooking and water heating). The emissions benefit is the replacement of kerosene and nonrenewable wood fuel from local forests. The funding for the program was provided by the FairClimateFund, a nongovernmental organization who provides funding for small-scale pro-poor emission reduction projects. While farmers provide their labor, FairClimateFund provides resources necessary to purchase materials for digester construction and upkeep. FairClimateFund was initially paid by a French utility company for the CERs projected to be produced through the project's first 7 years (around 1 million euros). Similar small-scale

biogas programs have been operating in neighboring Nepal. A major challenge these programs face is the difficulty of monitoring and documenting the net reductions in GHG emissions that result from the proper functioning of all of these digesters. [The project](#) reportedly went well until the project area suffered significant drought from 2013–2017. This coupled with low sales of produced CERs (due in part to slumping carbon prices in EU emission trading system) has led a deterioration of gas production and equipment. In 2018, only 57% of the biogas digesters were still operational.



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UN-REDD

P R O G R A M M E

Reducing Emissions from Deforestation and Forest Degradation (REDD+)

A more recent UNFCCC-sanctioned program, not formally tied to the Kyoto Protocol, is REDD+, was established in 2007 (COP13). It provides funding to developing countries for the protection and better management of tropical forests. REDD+ programs seek to reduce the loss of carbon

(and release as GHGs) stored in healthy tropical forests due to deforestation. The way the program is presently envisioned is that the potential release of carbon into the atmosphere due to deforestation is estimated from measurements of the amount of carbon stored in forests and current deforestation trends within the project area. This information coupled with monitoring of project areas forest (on-the-ground fieldwork plus remote sensing) will, in theory, allow the estimation of the avoided loss of forests due to REDD+ program management. This requires significant monitoring and institutional capacity within developing countries. For this reason, the REDD+ program has structured into phases with early “readiness” phases preceding a final implementation phase. The UN’s REDD Programme provides assistance to help develop these capacities. While most developing countries have not reached the full implementation phase, the goal is that the financing for implementation will come from multilateral funding sources such as the Green Climate Fund as well as from developed countries or companies who may use the carbon credits purchased to meet their reduction obligations.



Strengths and Weaknesses of Project-Based International Incentive Programs

Project-based incentive programs such as CDM and REDD+ are evolving. Their future evolution will be shaped by efforts to address the challenges they face while seeking to maintain their advantages. The potential advantages of these programs are clear. They provide flexibility to entities in developed countries to seek opportunities outside of their own country to reduce GHG emissions at lowest economic cost. Moreover, they can be seen as a North-South compromise

by providing much needed funding to developing countries to reduce their greenhouse gas emissions. Finally, they provide benefits beyond their primary goal of GHG emission reduction. For example, REDD+, by maintaining standing forests, also protects biodiversity.

Still, these programs face challenges and are not without controversy. These challenges include:

- **Additionality** An incentive program seeks to elicit behavior that would not have occurred without the incentive. The term “additionality” refers to the question of whether a program is producing changes or is simply subsidizing activities that would have occurred without the program. The case of the Rhodia CDM program described above is a case in point.
- **Leakage** Does a program lead to a displacement of GHG-producing activities outside of the program’s geographical area. If so, the project’s reduction of GHG emissions within its action area could be misleading because these reductions are achieved from the migration of GHG producing activities outside of the project area. This refers to “leakage” and is most often a concern with REDD+ projects which, by restricting forest conversion in one location, may lead to greater pressure elsewhere. This is why REDD+ programs have increasingly focused on reducing deforestation nation-wide, rather than in a particular area within a country.
- **Time horizon** The time horizon of the GHG emission reductions associated with a project is also a challenge. These programs require long-term compliance monitoring to ensure that changes attached to the project are not reversed in the future. A major controversy of privately-run reforestation projects producing carbon credits is they are insufficiently monitored leading to speculation that carbon credits could be sold with few measures to ensure that the reforested plot is deforested in the future.
- **Equity issues** Resources (garbage, natural forests) are suddenly of higher value for governments which may result in the poor being excluded from these resources. An example is described in this [article](#) about a CDM project in India. Similarly, REDD+ projects may lead to a recentralization of forest governance to the detriment of the rural poor. For example, a government may seek REDD+ funding by claiming forested areas for the government and excluding long-time residents, who may have been using these forests sustainably.
- **Sensitivity to carbon price** As with emissions trading, these incentive programs are sensitive to “carbon price.” In particular, funding for these programs require entities in the developed world to pay for certified emission reductions (CERs). Given its size, the operation of the EU’s emission trading system has had a strong effect on the demand for CERs. A low price for EU emission allowances, due to a downturn in the global economy, will reduce demand for CERs. The inability of the Bagepalli Coolie Sangha CDM project to sell CERs since 2013 is due to a lack of demand from developed countries.

These are on-going challenges need to be addressed before these international incentive programs reach their potential of reducing GHG emissions without significant unintended consequences.



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International Incentive Programs and the Paris Accord

While they remain in force under Kyoto till 2020, the future of the Kyoto flexibility mechanisms is somewhat uncertain under the Paris Agreement (particularly the clean development mechanism and joint implementation). Article 6 of the [Paris Agreement](#) supports “cooperative approaches” that allow countries to use internationally transferred mitigation outcomes toward their intended nationally-determined contributions (INDCs) but provide no more specific framework for doing so. Thus the language of the Paris Agreement is consistent with country X claiming credits for its funding of mitigation actions in country Y. However, a major potential problem is double counting. Under Kyoto, only one of the parties to CDM and JI were required to reduce. Under the Paris Accord, all parties are expected to voluntarily reduce their emissions based on their INDCs. Thus, there is the potential for both parties to claim the reductions resulting from a joint project such as those related to CDM or JI.

MEETING / 28 SEP. 2017

UN's Clean Development Mechanism Is Important to Achieve Goals Set Out In Paris



Source: <https://unfccc.int/news/forum-calls-for-clarity-on-future-of-clean-development-mechanism-under-paris-agreement>

While there is strong support for the continuation of these programs in some form under Paris, they are likely to be modified prior to their expiration in 2020. A modified version will likely

combine JI and CDM (since there is no longer any reason to distinguish them) and be named something different. Still, the basic structure will remain the same with some additional protections to avoid double counting among parties to these projects.

Article 5 of the Paris Agreement specifically mentions the importance of protecting and expanding carbon sinks – particularly forests. For this reason, the Paris Agreement is supportive of the REDD+ program. As shown in the map below, the REDD+ program is mentioned in a large fraction of the INDCs of the developing countries in the tropics. Still, the issue of double counting remains an important issue to overcome.



From: Hein, J., Guarin, A., Frommé, E., Pauw, P., 2018. Deforestation and the Paris climate agreement: An assessment of REDD+ in the national climate action plans. *Forest Policy and Economics* 90, 7–11.



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