Climate Change: Vulnerability, Mitigation, and Adaptation

Climate Change: Vulnerability, Mitigation, and Adaptation

Geography/Environmental Studies 339

MATT TURNER

Contents

GEOGRAPHY/ENVIRONMENTAL STUDIES 339

Climate Science Essentials

Learning Objectives

This chapter provides basic information about climate change for those with limited exposure to the topic before taking this course. The 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:

1. distinguish between climate change and weather;
2. know the definitions of key terms in climate science;
3. understand the primary causes of anthropogenic climate change;
4. know the types of evidence for climate change and features of weather affected by it;
5. 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 a basic introduction to climate change basics sufficient to understand the mitigation and adaptation material covered in this class. Additional resources for further study are also provided.

Climate Science 101

To begin, it is important for you to have a clear understanding of some of the central elements of current scientific understandings of climate change. To learn some important elements of climate science, start by watching the Bill Nye video, then answer the accompanying questions below.

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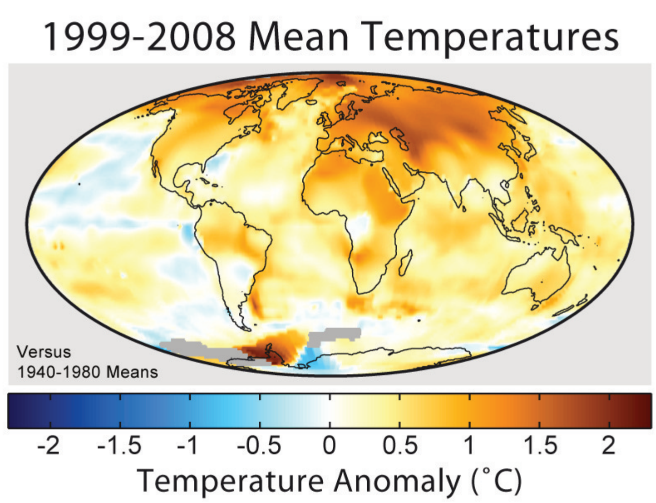
Important Definitions

You know that **weather** 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?



1999-2008 Mean Temperatures

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 "greenhouse effect", "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.

The **greenhouse effect** refers to the warming effect on our atmosphere of greenhouse gases, through the absorption of infrared energy (heat). It is a general term that occurs naturally but is exacerbated by the build-up of greenhouse gases in our atmosphere.

Global warming usually refers specifically to the rise in global average temperatures that is widely believed to be the build-up of greenhouse gases due to human activities (anthropogenic). Average heating of the planet has different local effects on weather.

Climate change formally refers to any change in the long-terms patterns of temperature, precipitation, wind patterns or similar factors. Still it is often used to refer anthropogenic (human-caused) changes in the climate which is a broader term than global warming since it includes climate parameters beyond just temperature.

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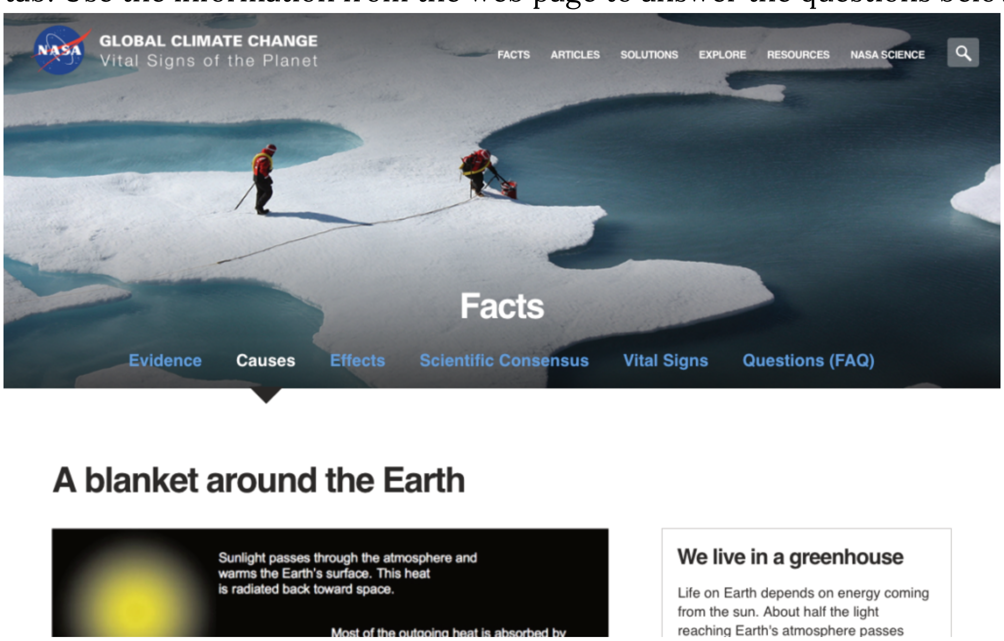
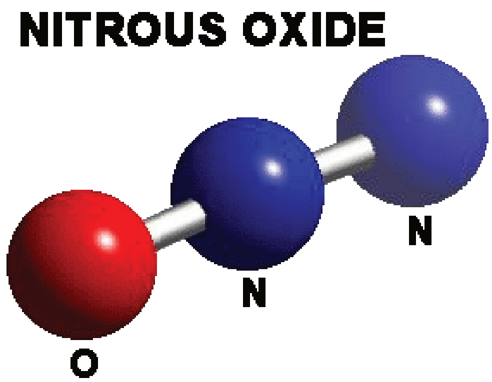
NASA – Causes of Climate Change

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.



Why focus on carbon dioxide?



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 greatest 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 release significantly less methane into the atmosphere. Still, scientists are becoming increasingly concerned about methane. 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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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.

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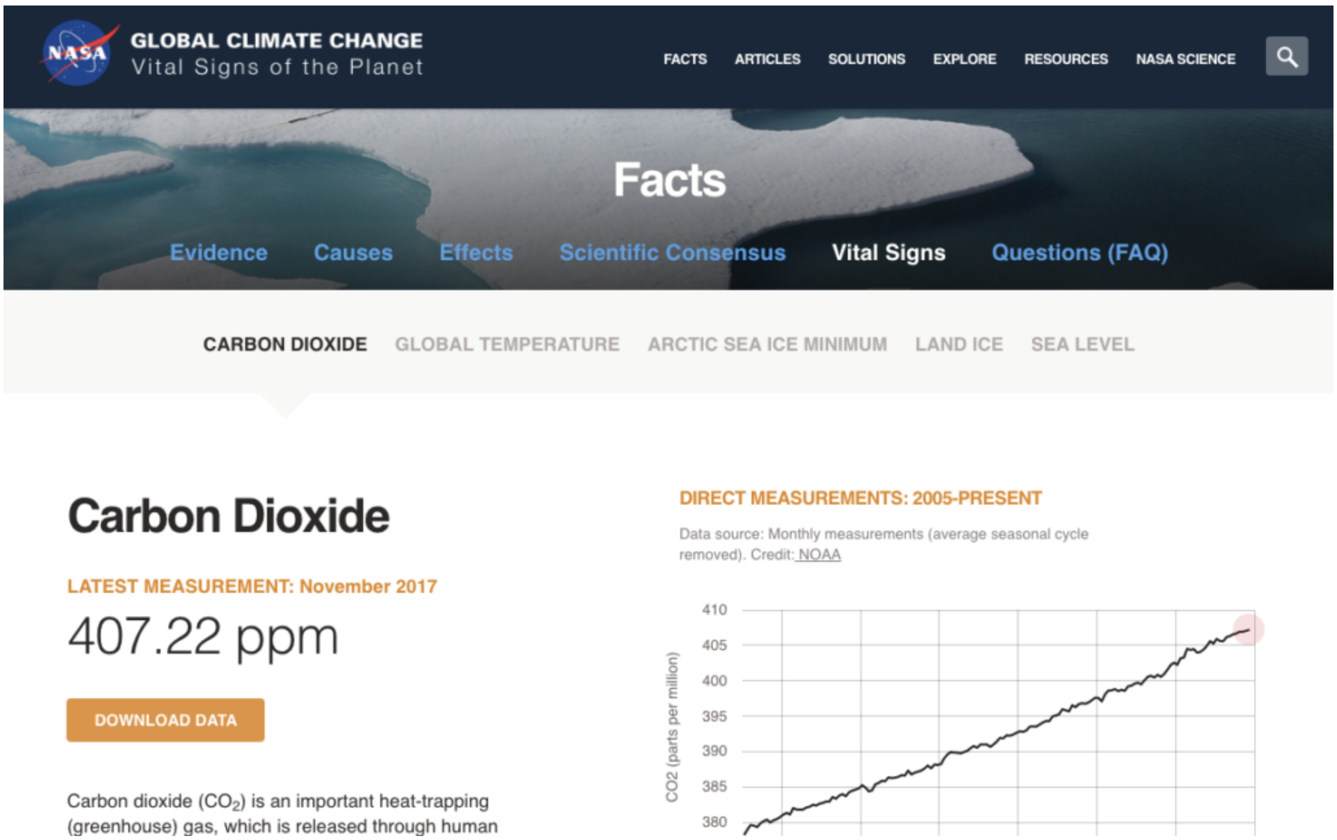
Measuring Climate Change

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.



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Climate Impacts on Biodiversity

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

Sea level rise, shifts in rainfall, and warming will affect 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 or 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 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 move to areas where new climate conditions are conducive to their survival. Moreover, a species' survival depends not only on its own ability to move or physiologically tolerate climate change 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 climate change on biodiversity is shaped by the vulnerabilities of population of species within ecosystems. An individual species' vulnerability is determined by:

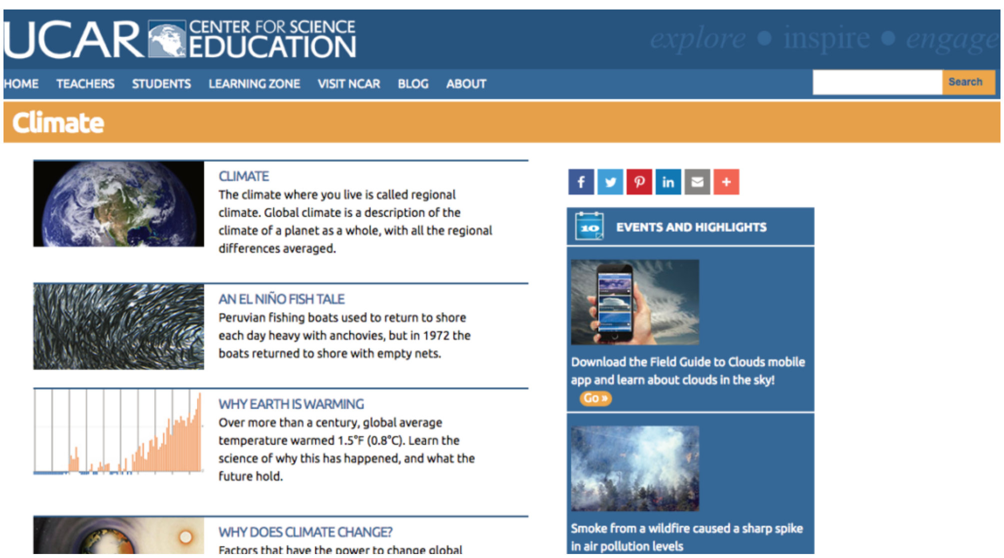
1. its ability shift its range (move) to more suitable habitats as climate changes;
2. its ability to physiological tolerate changed climatic conditions;
3. the effect of climate change on its coexistence with other species on which it depends (food sources, pollinators..etc.);
4. its competitive abilities 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.

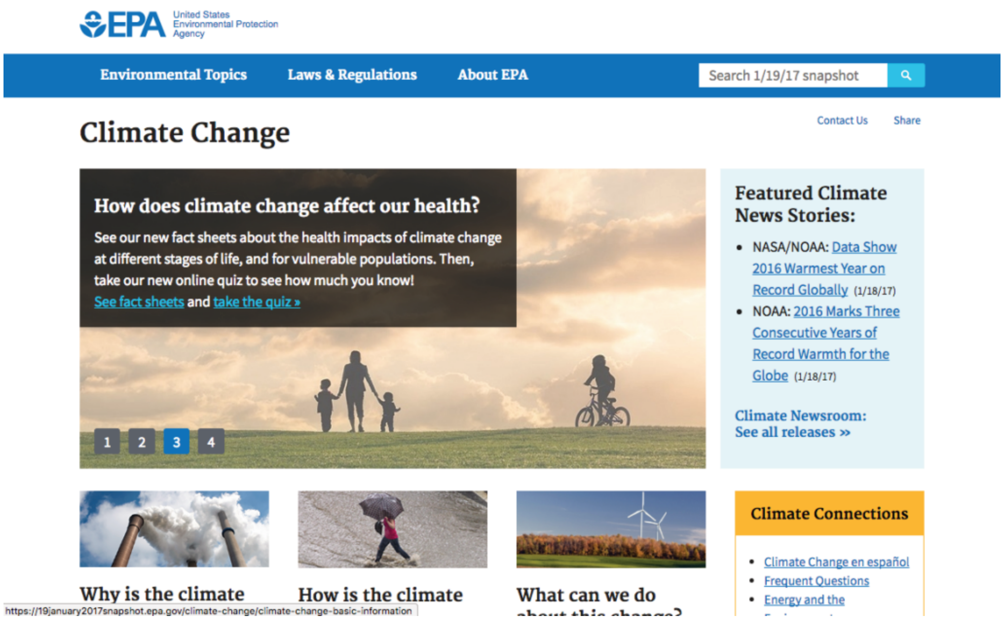
Finding Reliable Information on Climate Change

Unlike a lot of scientific information out there–say organic chemistry or human biology–there is a lot 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 any of the websites below will open it 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.

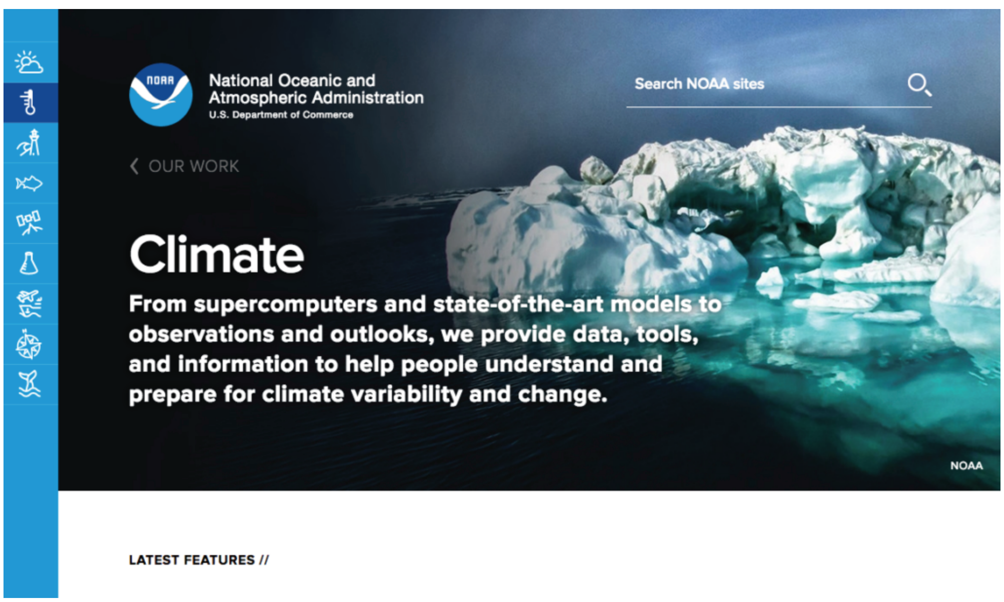
The University Corporation for Academic Research and National Union for Atmospheric Research climate change education site



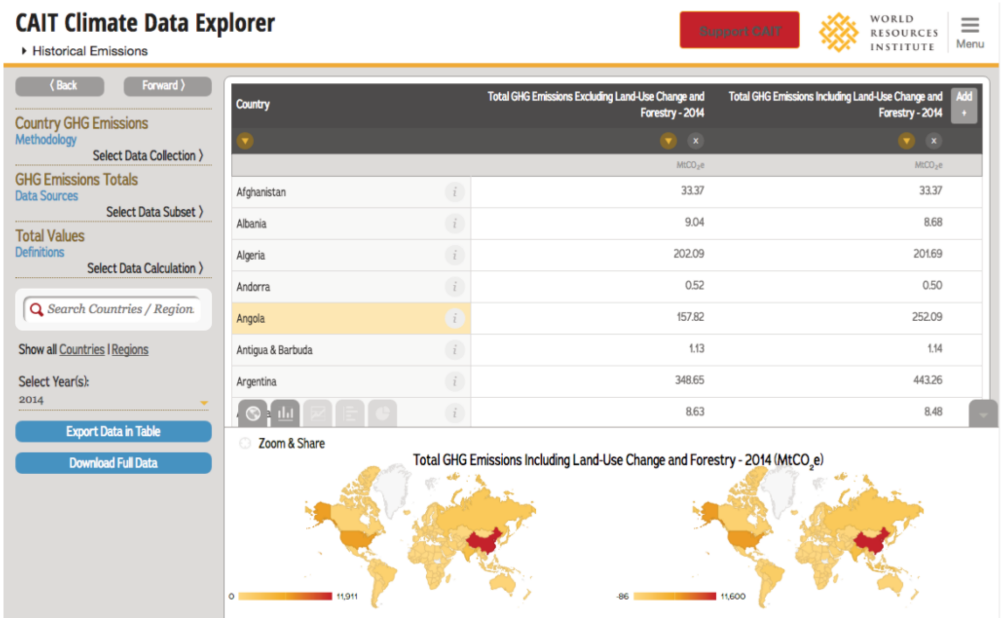
The (archived) U.S. Environmental Protection Agency climate change website:



The National Oceanic and Atmospheric Administration climate change overview:



The World Resources Institute climate data explorer:



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 Assesment Reports):

You are finished!

Assignment: 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; and
6. Characterize why different groups are more vulnerable than others within these case study areas.

Climate change as an environmental justice issue

Peoples, economies and countries each 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 buildup of greenhouse gases in our atmosphere affects 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 entities that have profited from the release of GHG emissions will also be the most vulnerable. In fact, as will be discussed below, the opposite is more likely true: 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 also 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** to physical changes of climate change. Societies that are poor, that have low overall health, that do not benefit from government safety nets, and that 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 few technological options are seen as having lower capacities to adapt.

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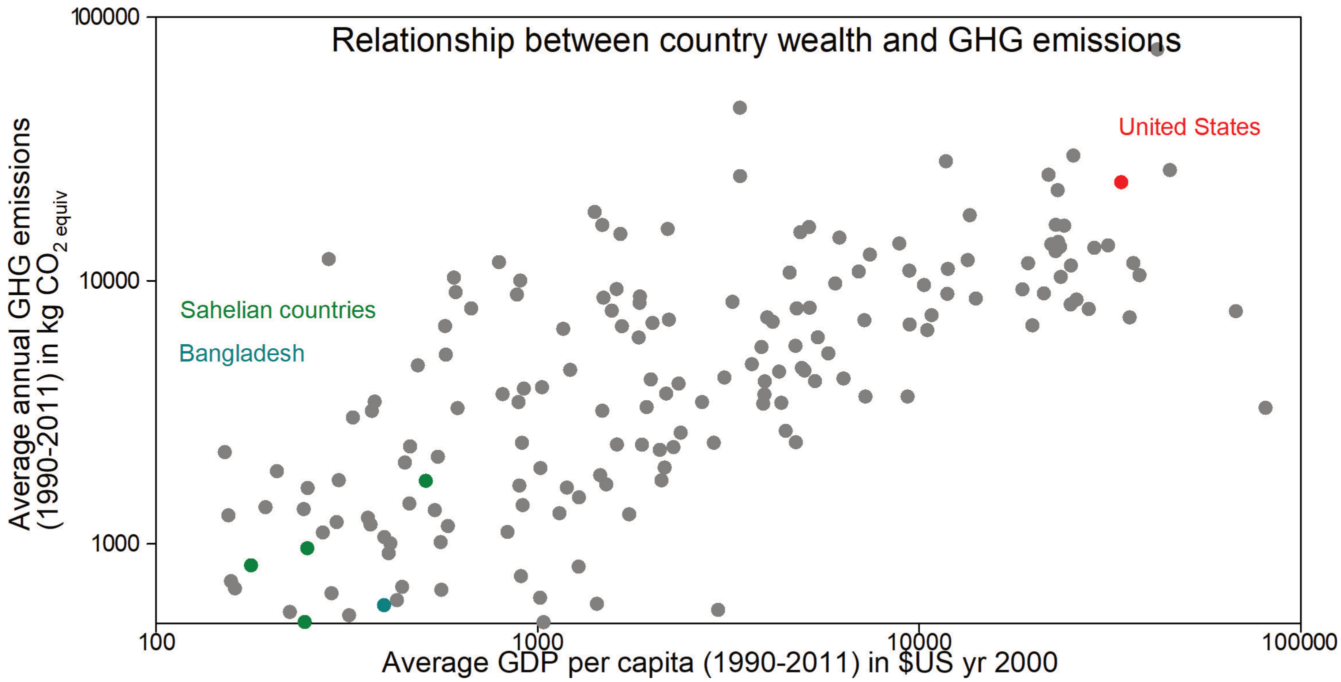
If we consider a society's sensitivity and capacity to adapt to climate change (items 2 and 3 above), one simple conclusion is that poorer societies are more likely to be more vulnerable to climate change effects (assuming for now that exposure to physical effects are equal). The figure below plots average 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 that is often used as a coarse measure of its wealth and level of economic development.



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).

Also 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 due to high exposure. Both are 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

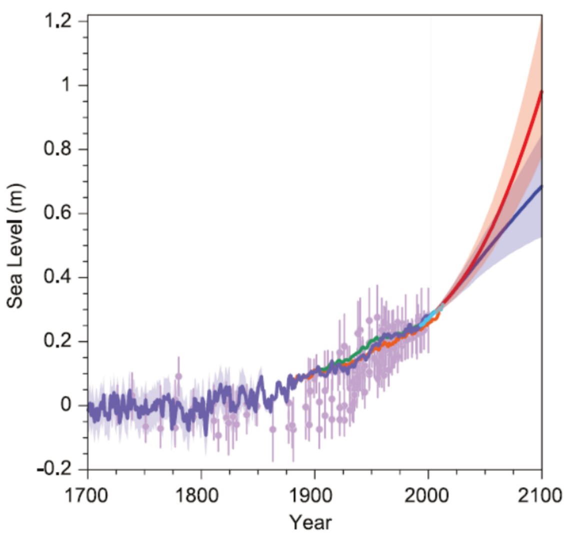

Fig. 1. Past and future sea-level rise. For the past, proxy data are shown in light purple and tide gauge data in blue. For the future, the IPCC projections for very high emissions (red, RCP8.5 scenario) and very low emissions (blue, RCP2.6 scenario) are shown. Source: IPCC AR5 Fig. 13.27.

Sea level rise is expected to be a major effect of the warming of the earth's climate due to the melting of 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 a blue line, representing sea level rise if steep cuts in emissions were to occur and the red line representing sea level rise with 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 resulting in a more rapid sea level rise. Using these estimates, a study by the research organization Climate Central predicts the land that will be lost, and the associated number of people affected 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.

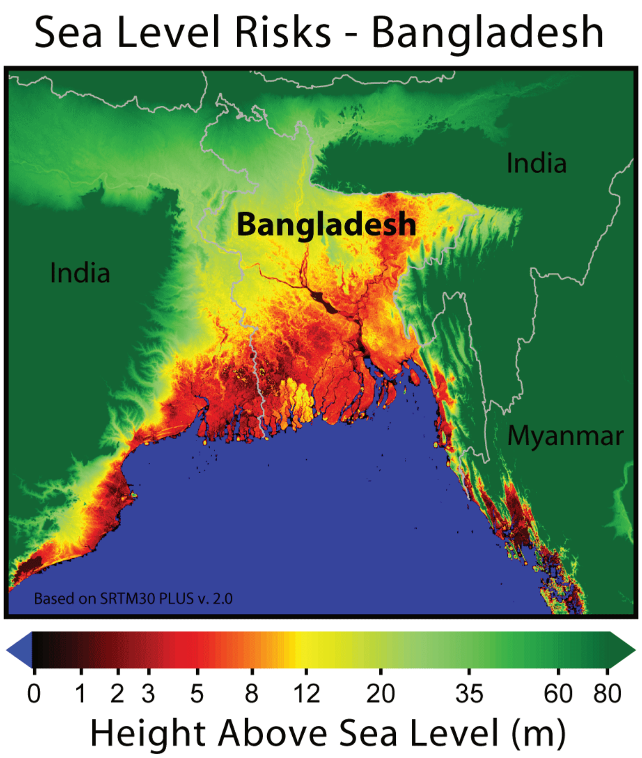

Image created by Robert A. Rohde / Global Warming Art

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 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.

The effect of these exposures are magnified by the sensitivity of Bangladeshi society to them due to widespread poverty and to the fact that almost two-thirds of the population lives in rural areas (2016 statistics) and thus 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.

Flooding in Bangladesh

Woman and child in Bangladesh
http://www.mariestopes.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 when they lose their homes to weather events? How are their experiences different? Why?

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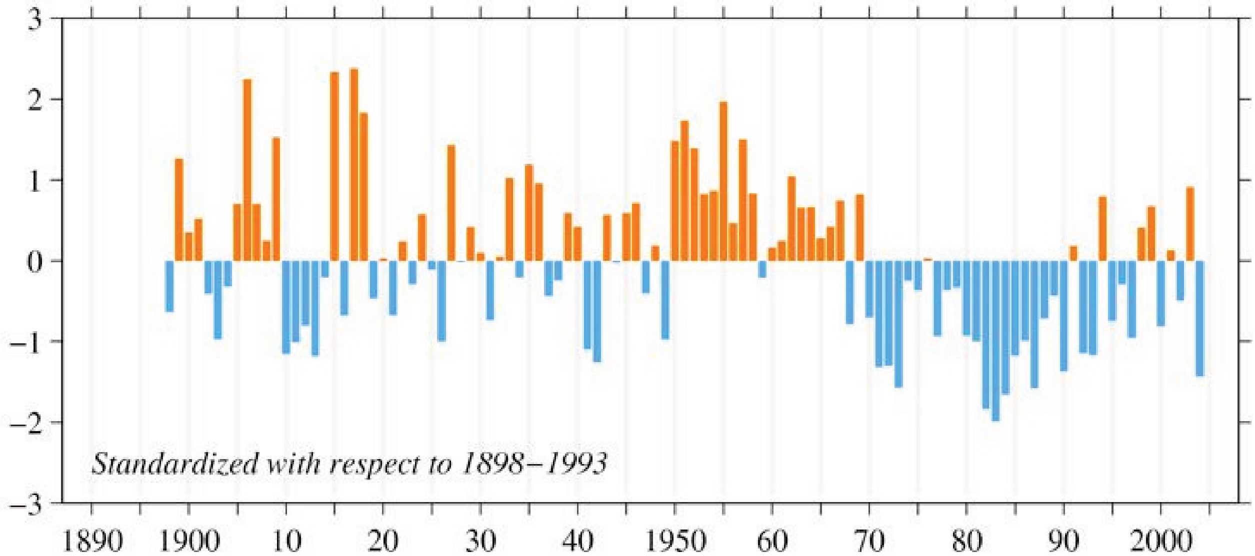
Considering vulnerability: The Sahel

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) changing, 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.

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

Predicting changes in rainfall due to climate change is difficult anywhere 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 thought to become drier with climate change. The historical record of rainfall supports this. The figure below shows annual deviations of regional rainfall for the 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 the flooding that has occurred during some recent years of harvest failure.

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

As in Bangladesh, the people of the Sahel are some of the world's poorest, with large fractions of the population dependent on 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 rural families attempt to reduce the risk of food shortage and malnutrition through involvement multiple livelihood activities including crop agriculture (which provides major food staples), 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 (a 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 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.

Assignment: Debating Greenhouse Gas Emission Responsibilities

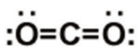
Learning Objectives

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

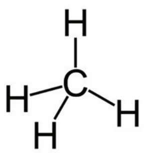
1. The general distribution of greenhouse gas (GHG) emissions around the world;
2. Arguments about the ethical responsibilities of different countries to reduce their GHG emissions; and
3. The strengths and weaknesses of different metrics to measure GHG emission responsibility among countries that could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

To reduce the extent of climate change, the release of greenhouse gases (GHG) must be reduced. To do so, there is a need to develop agreements, policies or rules that lead to such reductions. These in turn require 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.

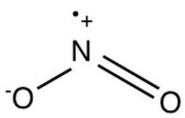
Measurement of the warming effect of different greenhouse gases



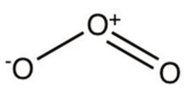
Carbon dioxide



Methane



Nitrogen Dioxide



Ozone

Any agreement must account for 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 its 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 CO_{2equiv} which typically accounts for the gas's absorptive capacity and removal from the atmosphere generally estimated over 100 years.[1] It is important to recognize that when we refer to CO_{2equiv} 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 CO_{2equiv} 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 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 produced by the burning of fossil fuels (75%) with agriculture (livestock and rice), land uses (net deforestation and burning), and waste (methane produced in landfills) accounting for the rest.

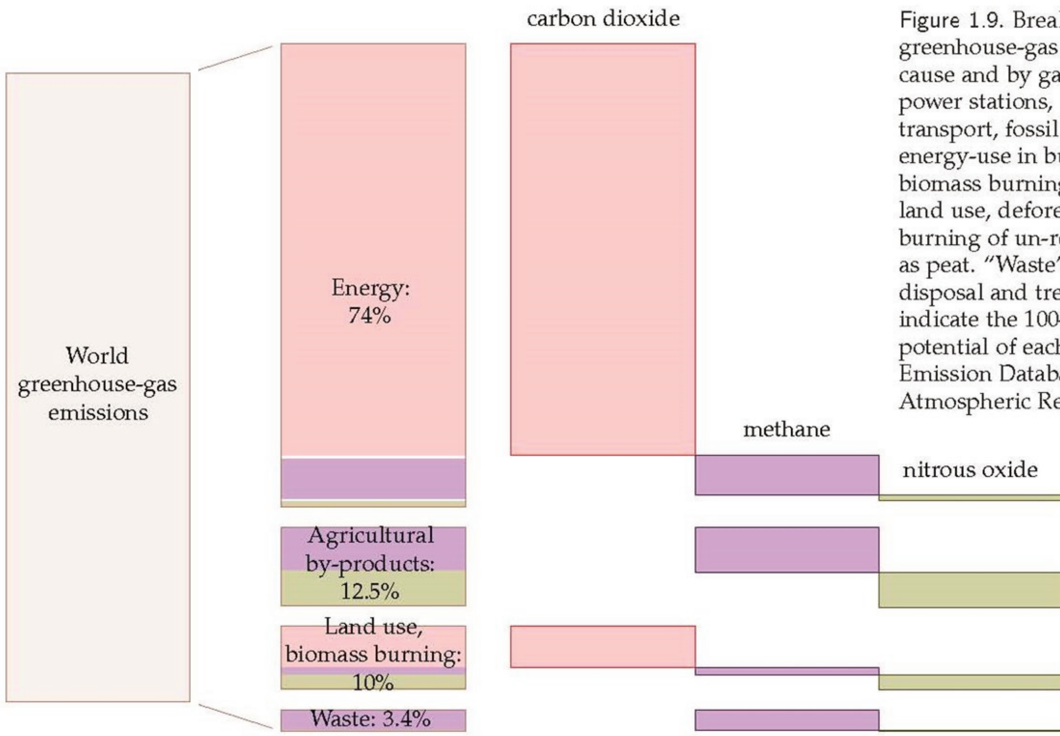


Figure 1.9. Breakdown of world greenhouse-gas emissions (2000) by cause and by gas. "Energy" includes power stations, industrial processes, transport, fossil fuel processing, and energy-use in buildings. "Land use, biomass burning" means changes in land use, deforestation, and the burning of un-renewed 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

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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). Is such an accounting 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 those by the United States

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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

Reducing greenhouse gas emissions 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. Should an international agreement simply state that all countries should reduce their GHG emissions by the same absolute amount (X tons of $CO_{2\ equiv}$ per year) or should there be a 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 international negotiations. So, the question now becomes, the reduction should be a percentage of what? Here are some possibilities:

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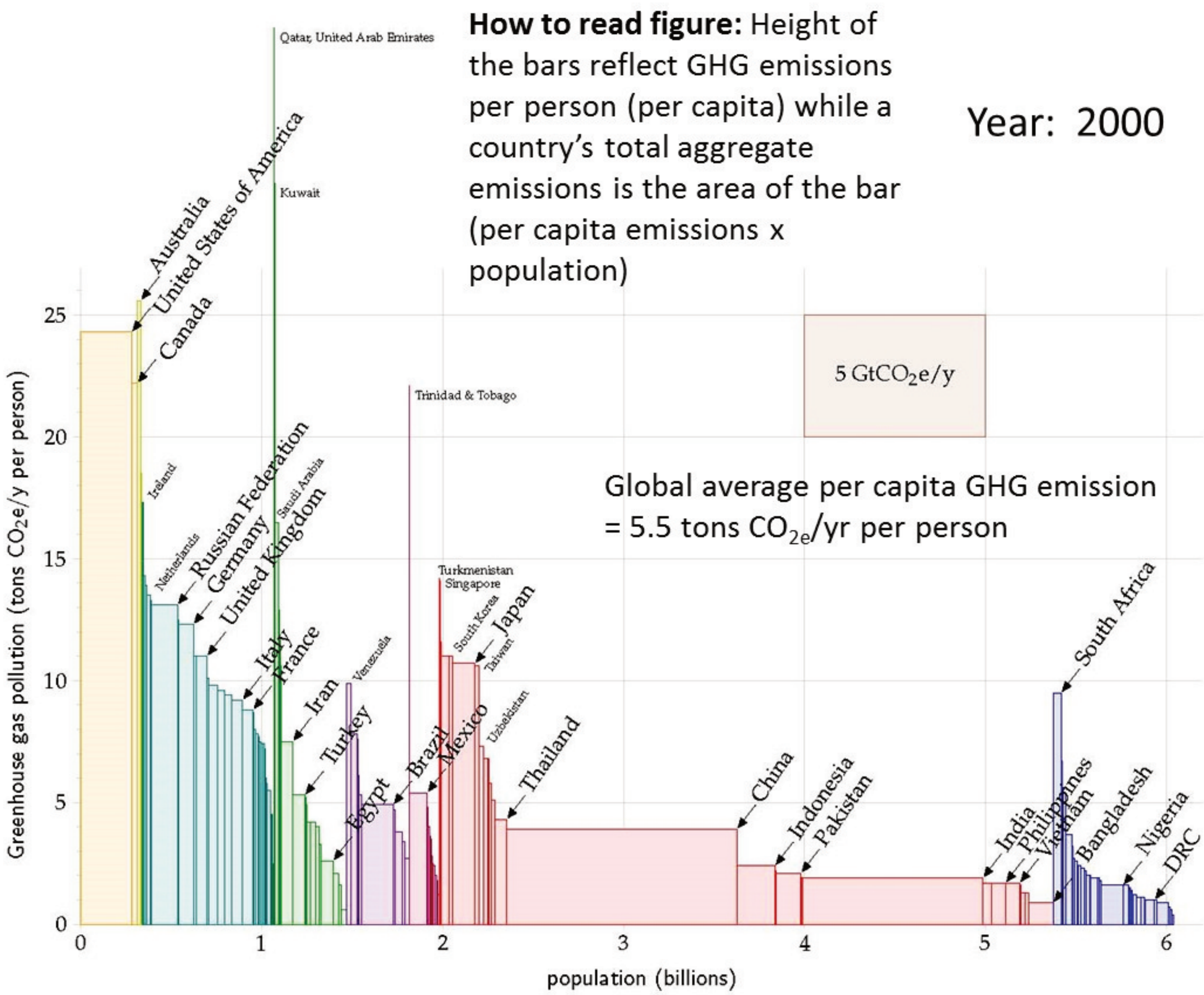
Let's consider the implications of these different accounting metrics

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, an absolute reduction is not practical since it could lead to 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. The height of the rectangles in this graph represent average per capita emissions of countries around the world in 2000.

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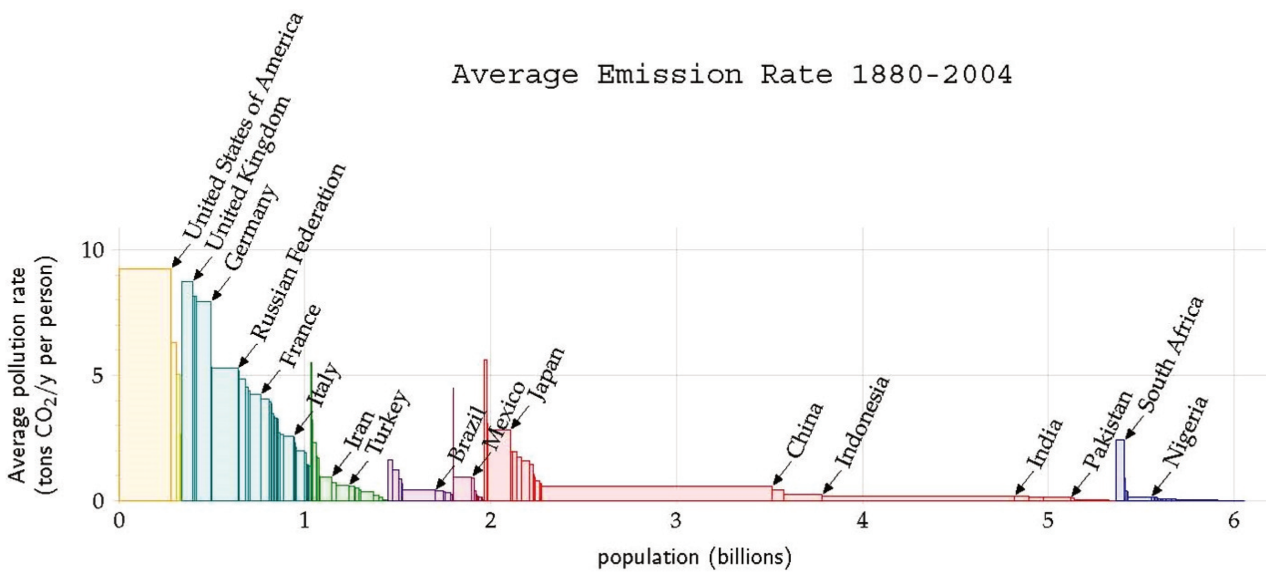
The residence time of emitted carbon dioxide in the atmosphere is around 100 years. Now let's look at how responsibility for GHG reductions would shift if we were to consider cumulative emissions since the onset of the industrial revolution.



The graph above is the same as the graph presented above but the area of each rectangle represents the cumulative greenhouse gas emissions for each country from 1880-2004. The width of each rectangle is the 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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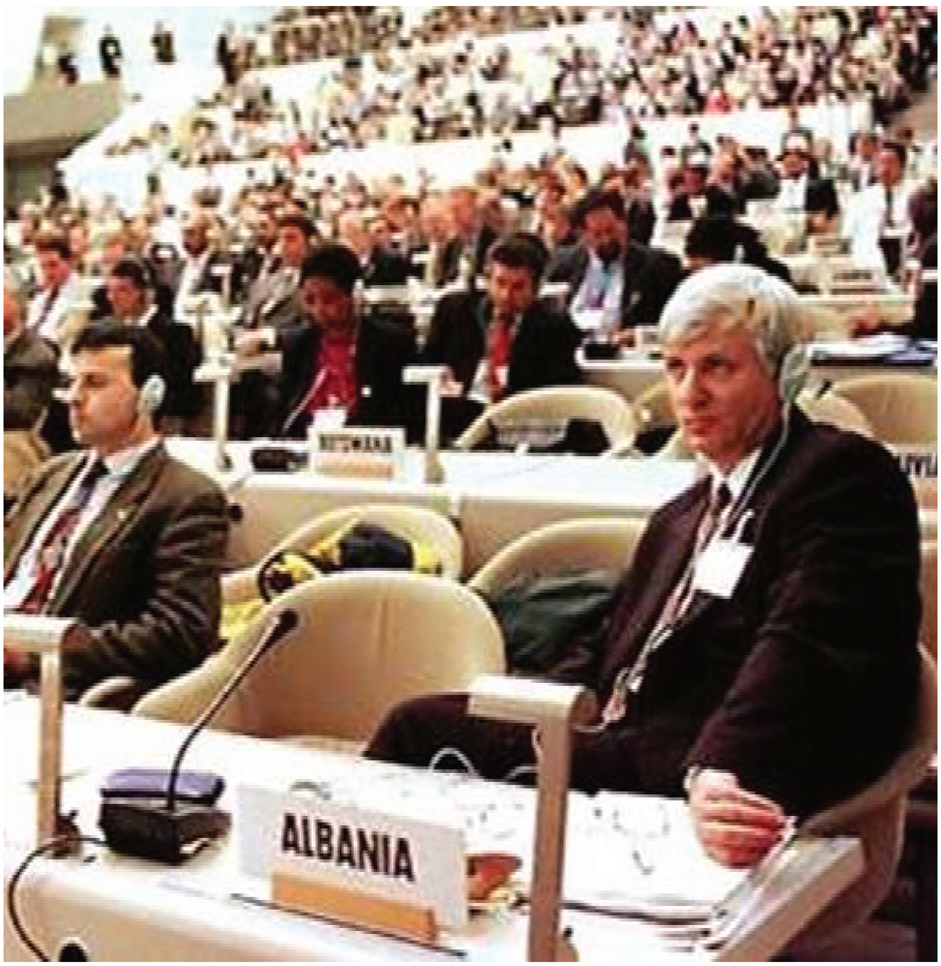
These ethical and institutional challenges are what the international community has faced and continues to face when working toward agreements to reduce global greenhouse gas emissions. In preparation for class, think through these dilemmas while imagining yourself as a climate agreement negotiator for different countries.



Assignment: 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; and
- 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 change our 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 these have shaped the Kyoto Protocol and the Paris Accord.

Agreement	Notes
1989 Montreal Protocol on Substances the 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 Nation's 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 UNCC coming into force in 2004.	When in force required ratifying industrial countries to reduce by 2012 their aggregate national GHG emissions by 5-8% of their emissions in 1990. 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, and 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 dramatic global reduction in the production and consumption of these chemicals, many of which are potent greenhouse gases as well. The reduced concentration of these chemicals in our atmosphere has 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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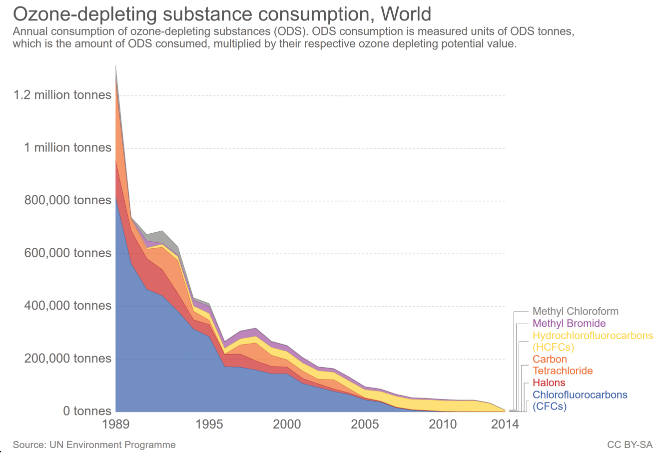

From: Hannah Ritchie and Max Roser (2018) – "Ozone Layer". Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/ozone-layer' [Online Resource]

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Kofi Annan, the former UN Secretary-General, in his September 2000 address to the Millennium Assembly of the United Nations, stated the following regarding 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 most recent in Katowice, Poland in 2018 (COP24).

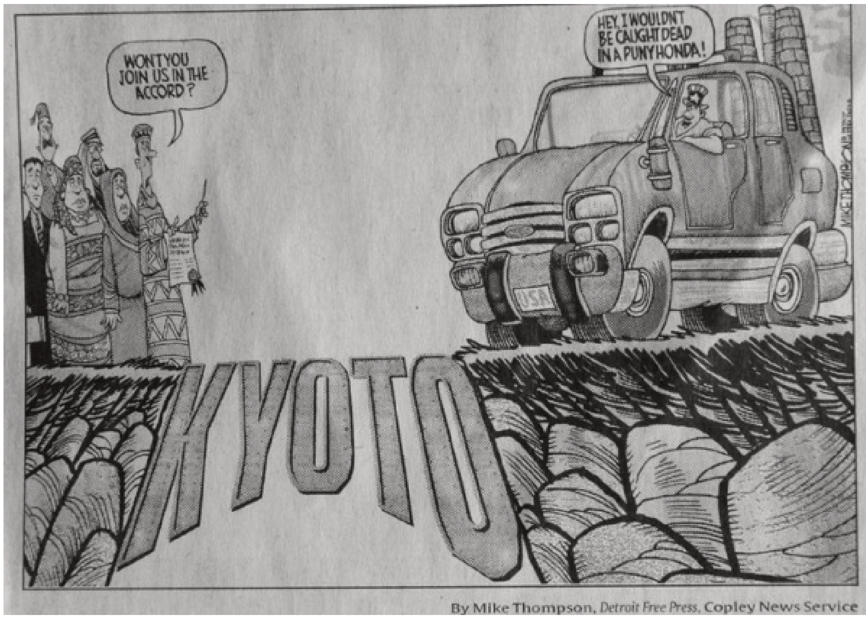
There are have been two agreements made under UNFCCC:

- 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 was 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 files 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.



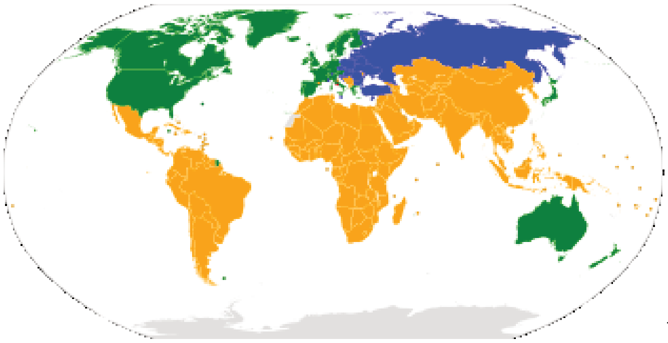
By Mike Thompson, *Detroit Free Press*, Copley News Service

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 the 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 UNFCC 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.

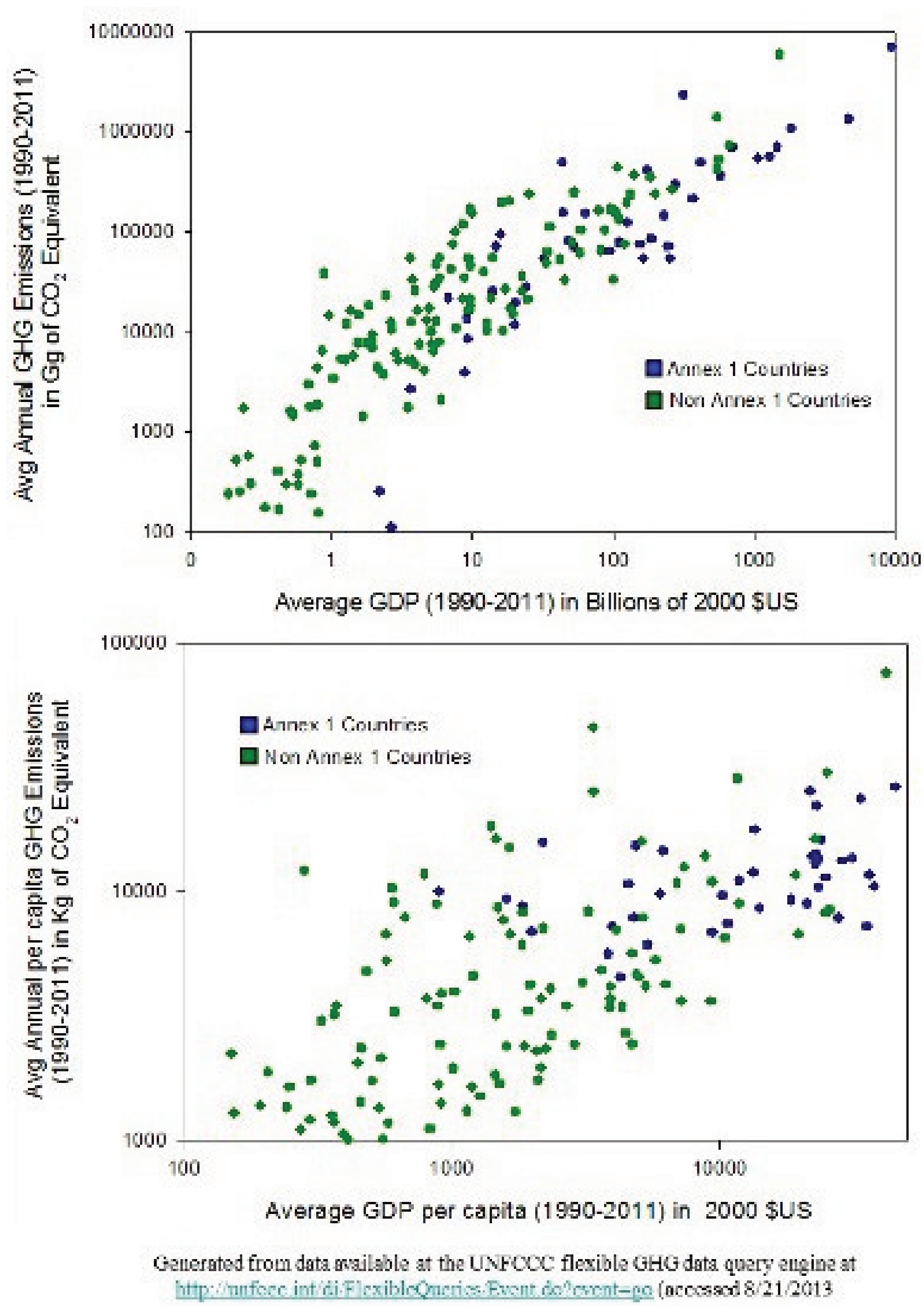


Using the categories introduced in the UNFCCC, countries classified as industrial **(developed)** were designated as **Annex 1** countries and therefore obligated, once ratifying Kyoto, to reduce their emissions to a level generally 5-8% less than their 1990 emissions (shaded green and blue in map).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



Average annual per capita GHG Emissions (1990-2011) in Gg of CO_2 Equivalent plotted against Average GDP in 2000 [top] and Average annual per capita GHG Emissions (1990-2011) in Kg of CO_2 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 by 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) that 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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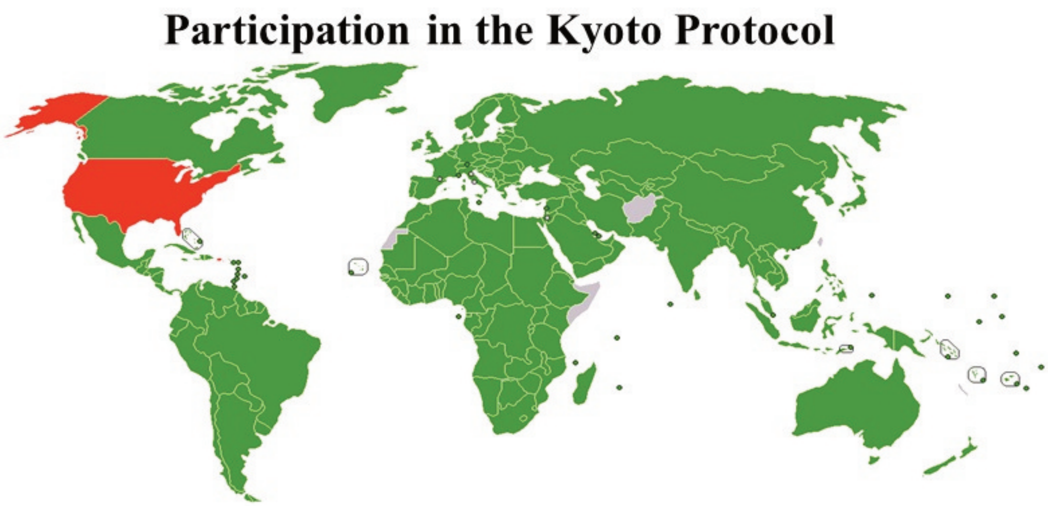
Ratification of the Kyoto Protocol

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 had to constitute the production of 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.



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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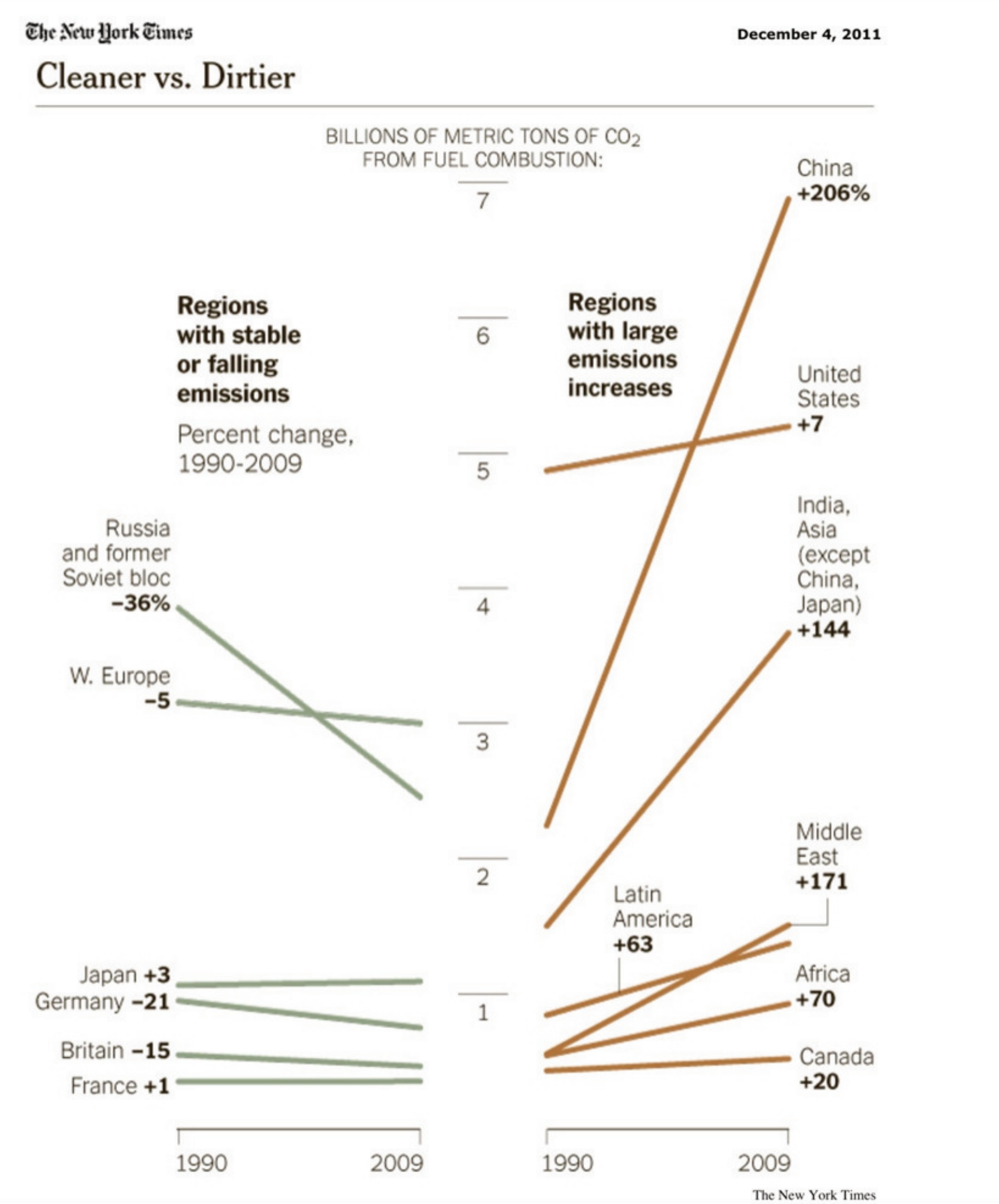
The Effectiveness of the Kyoto Protocol

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



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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 a 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; and
- 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 gases (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 a **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 the World Resources Institute's page (in a separate window) that tracks these commitments 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 overallgoal 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 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, U.S. President Trump 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 State 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 regarding the relative responsibilities among the largest-emitting countries to reduce – particularly between U.S. and 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 th[illegible]at 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 the other participant) that elicited protests (see photo). Moreover, the United States, along with Russia, Saudia Arabia, and Kuwait were able to waterdown 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 U.S. 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.

Assignment: 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; and
- 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 that pays 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 sulfur dioxide (SO_2) from power plants provides cleaner power plants with payments 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 "one 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, that 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 are 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

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," whereby 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 SO_2 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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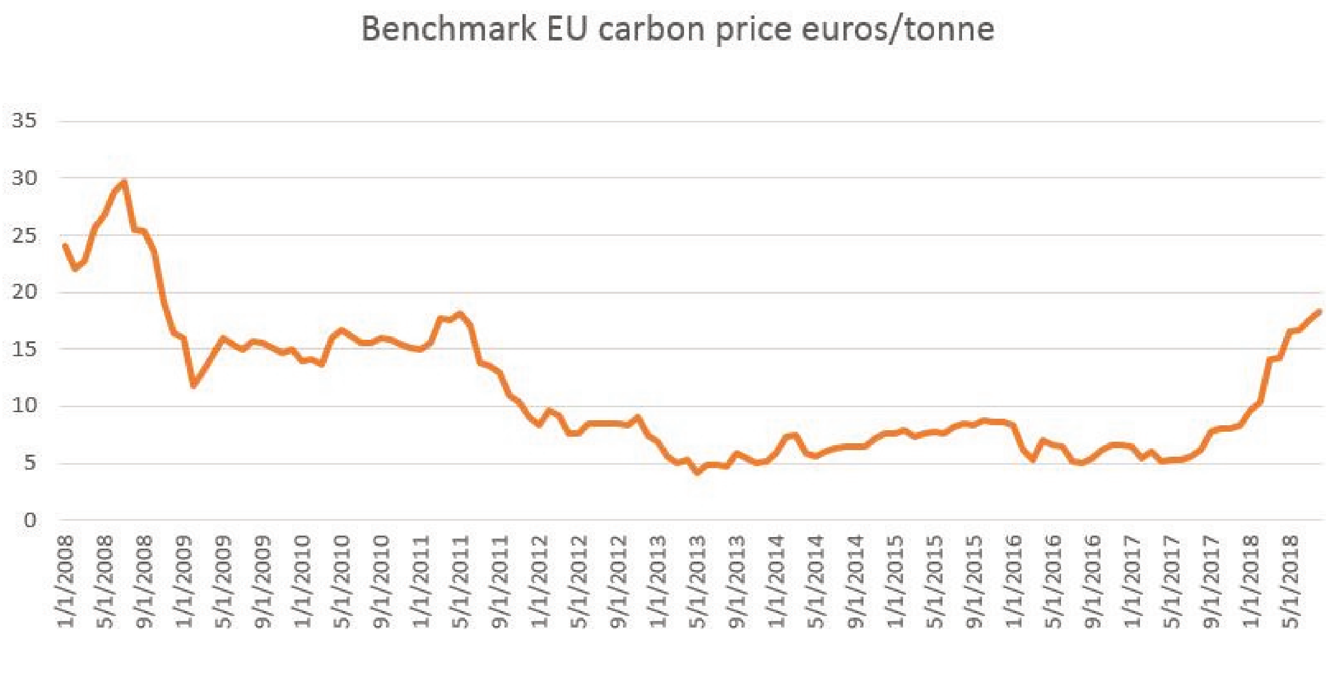

Source: Thomson Reuters

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. The EU carbon price has recovered due to a combination of broader economic changes as well as the more effective removal of emission allowances 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 LivermoreFROM 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 01:08 PM   Print Feedback

Aug 31, 2018, 01:59am

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

https://www.forbes.com/sites/davekeating/2018/08/31/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

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

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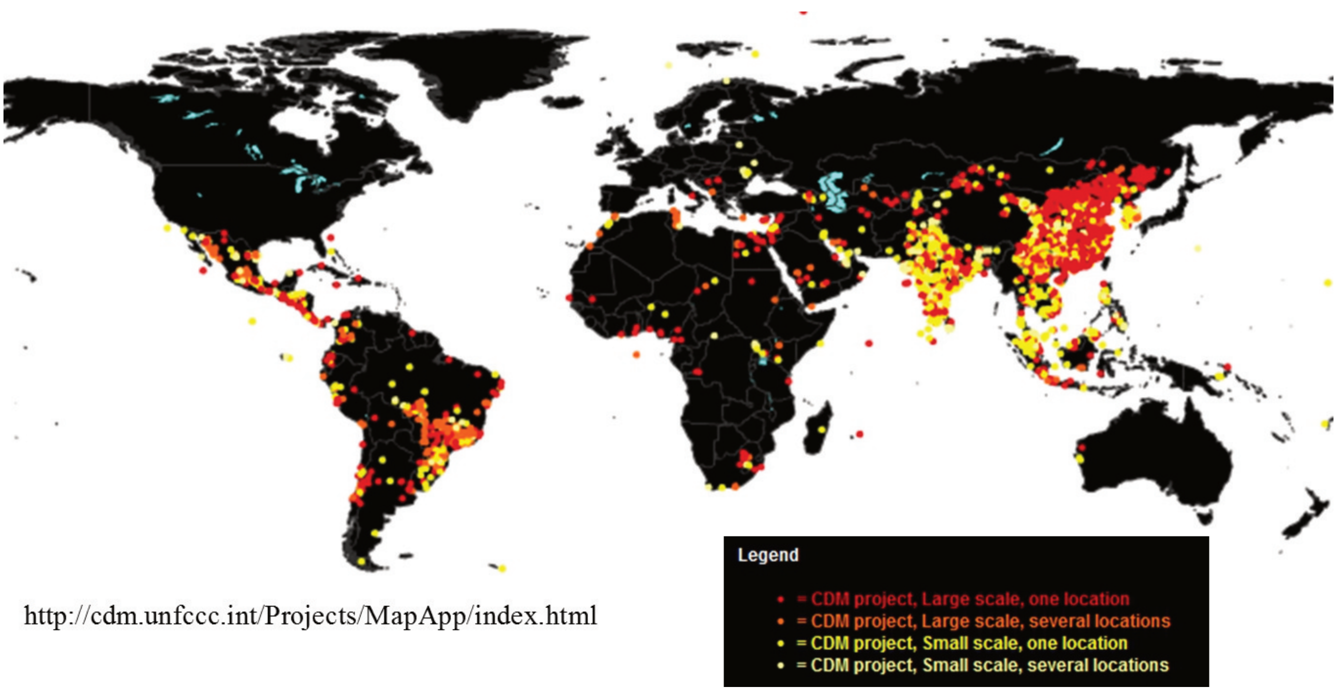
Clean Development Mechanism and Joint Implementation

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 programs are similar; the major difference is 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), which 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

Rhodia's adipic acid plant in Paulinia, Brazil

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 milion 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 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 CO_2 equivalents (nitrous oxide is 298 times the warming potential of CO_2), 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 that 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 the 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 to a deterioration of gas production and equipment. In 2018, only 57% of the biogas digesters were still operational.

> *An interactive or media element has been excluded from this version of the text. You can view it online here: https://wisc.pb.unizin.org/geography339/?p=361*

UN-REDD PROGRAMME

Reducing Emissions from Deforestation and Forest Degradation (REDD+)

A more recent UNFCCC-sanctioned program, not formally tied to the Kyoto Protocol, 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. As presently envisioned, the program will estimate that the potential release of carbon into the atmosphere due to deforestation from measurements of the amount of carbon stored in forests and current deforestation trends within the project area. This information, coupled with monitoring of the project area's 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 that can 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 the 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 the possibility 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. Similarily, 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 requires 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 ongoing 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.

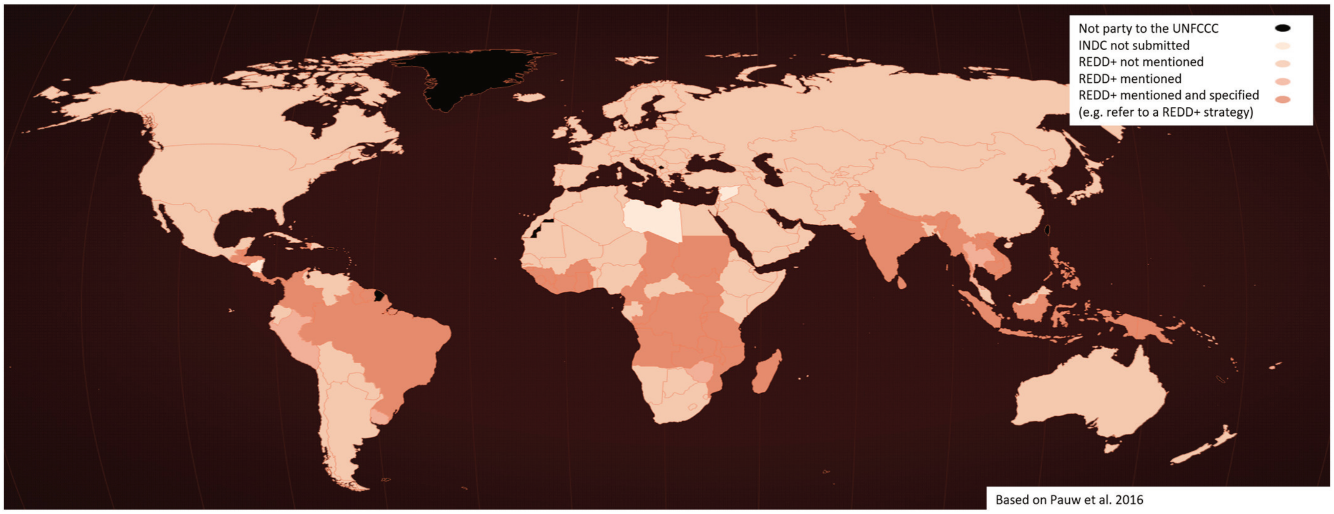
MEETING / 28 SEP, 2017

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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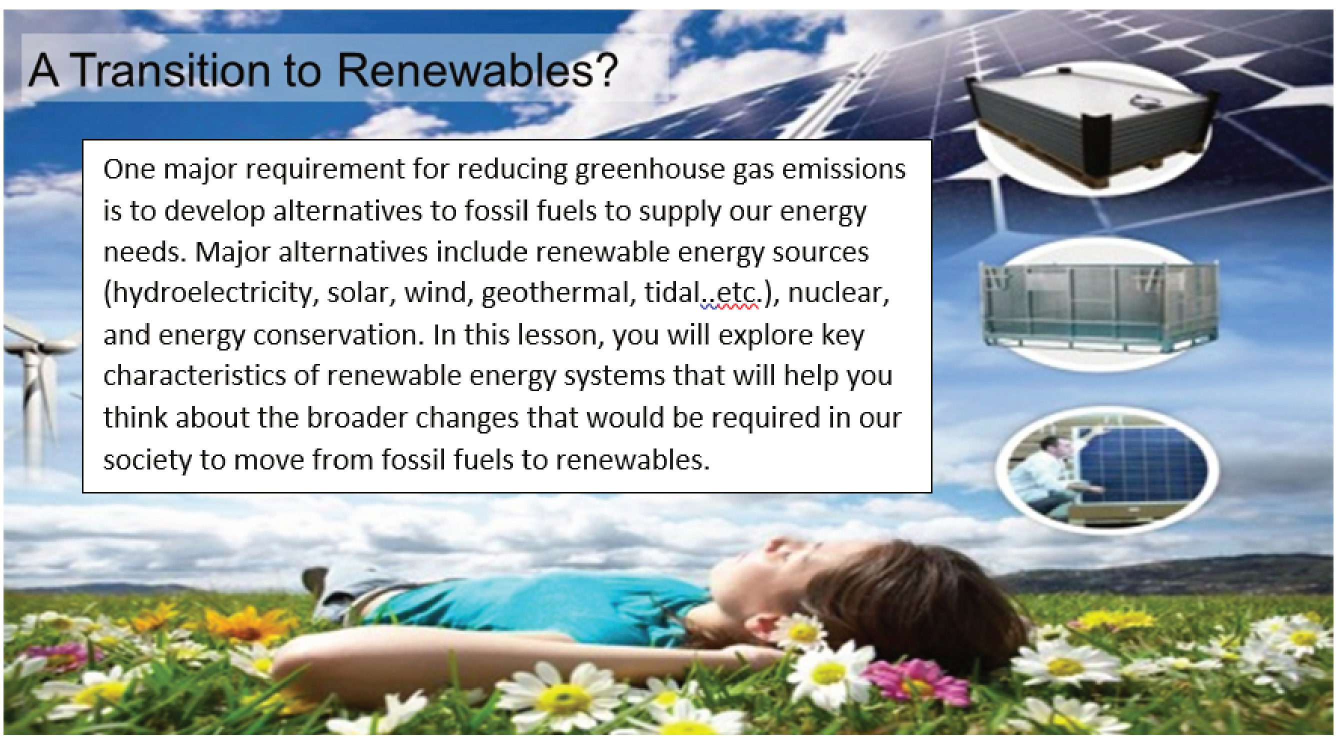
You are finished!

Assignment: 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-of-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 them in areas where they didn't have much wind, too. And it's a subsidary [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.

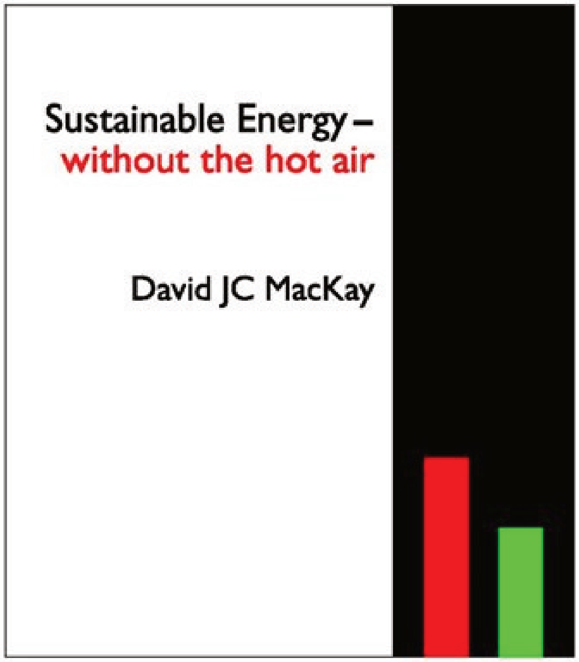
A quite different example comes from a speech some ten years earlier by Al Gore – one of the most informed politicians on energy issues. This is a famous speech on energy policy and for those of you who would like to watch the speech in full, click here. While these excerpts display a much greater understanding 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 that is produced when and where the sun shines and the wind blows be stored and transferred to when and where the energy is needed? These are all questions that need to be 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

> "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**

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….Don't worry! We will walk you though 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. Also note that the book was written in 2008 and the technical and economic feasibility of renewable energy supplies have changed.



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

Now read 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)

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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 key 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 that are based on the internal combustion engine. Therefore, on economic and technical grounds, society has benefited from the characteristics of fossil fuels.

The forms in which renewable energy types are supplied are quite different. Most cannot be seen as energy stores but flows. As flows, solar and wind energy must be captured and converted to different forms to be useful. Both 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 in 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.


HEARTLAND CO-OP


ELECTRIC
VEHICLE
CHARGING
STATION
ChargePoint
mychargepoint.net

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]	
Cites	5-100
Houses	20-100
Steel mills/refineries	300-500

[a]Renewable 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

[b]Derived from Smil, V. Energy: A Beginner's Guide. Oxford: One World Press

Power density refers to the

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 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). 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 rooftop photovoltaics?
- How can our cities be powered through renewables?
- What kinds of energy supply and transport infrastructure would be required?

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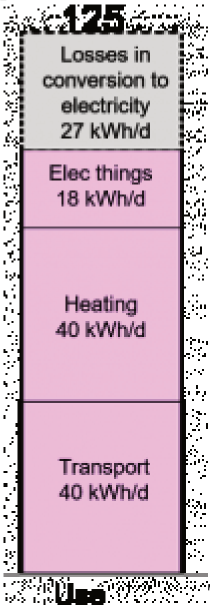
In class, we will follow the approach that MacKay uses for Great Britain to assess the potential for transforming the U.S. energy system away from fossil fuels. For Great Britain, MacKay expresses current energy use in terms of KW-hrs/person-day. He uses this notation to make numbers more meaningful to the individual. If one wishes to know Great Britain's total average daily energy use, one simply multiplies 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 the 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 to illuminate a 60 W light bulb all day is equal to 60W x 24 hours = 1440 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 kWh/person-day – (0.6 x 45 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; and
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, 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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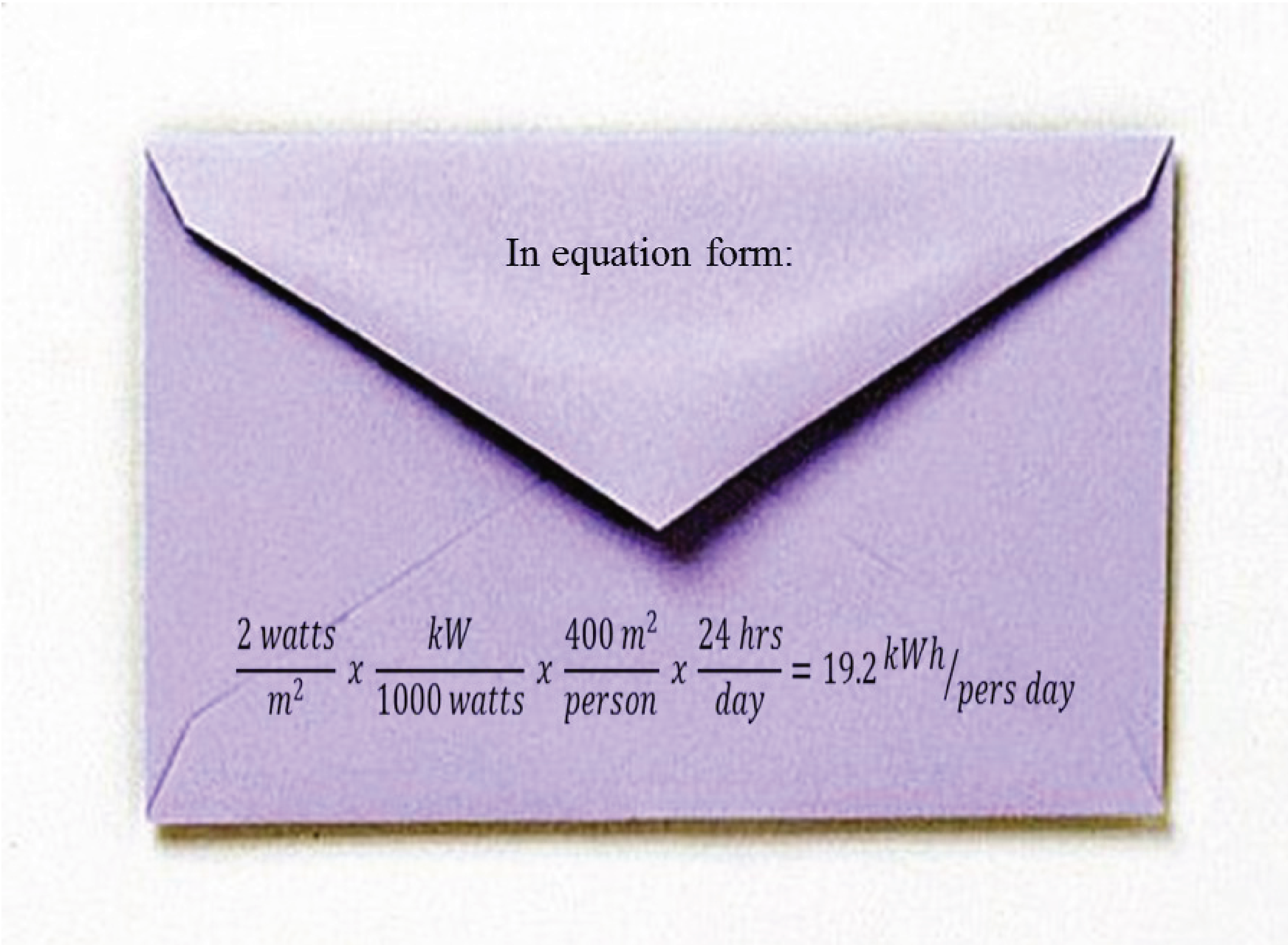
In class, we will work through examples of McKay's estimates together, using the same approach he used for Great Britain to consider the potential for renewable energy systems in the U.S. Our calculations and conclusions will be different than MacKay – not only because of the significant differences in renewable energy potential 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-enevelope calculation assumes that the windiest 10% of the 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 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!

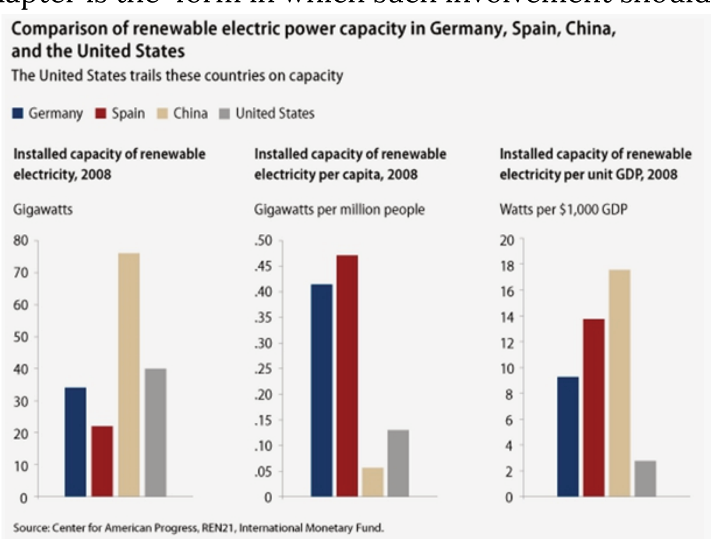
Assignment: Divergent Energy Policies: Germany and the United States

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; and
- 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.



From: Gordon, K. and J. L. Wong 2010. Out of the Running? How Germany, Spain, and China Are Seizing the Energy Opportunity and Why the United States Risks Getting Left Behind. Center for American Progress. http://www.americanprogress.org/issues/green/report/2010/03/04/7386/out-of-the-running/ (accessed 9/29/2013)

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 supporting 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 exceeded 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).

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.

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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, the Obama Administration pursued a "cap and trade" approach in its climate (energy) legislation. Legislation passed the House but failed in the Senate in 2010; detractors called 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 to increase the costs of emitting greenhouse gases and thus creates incentives to reduce GHG emissions.

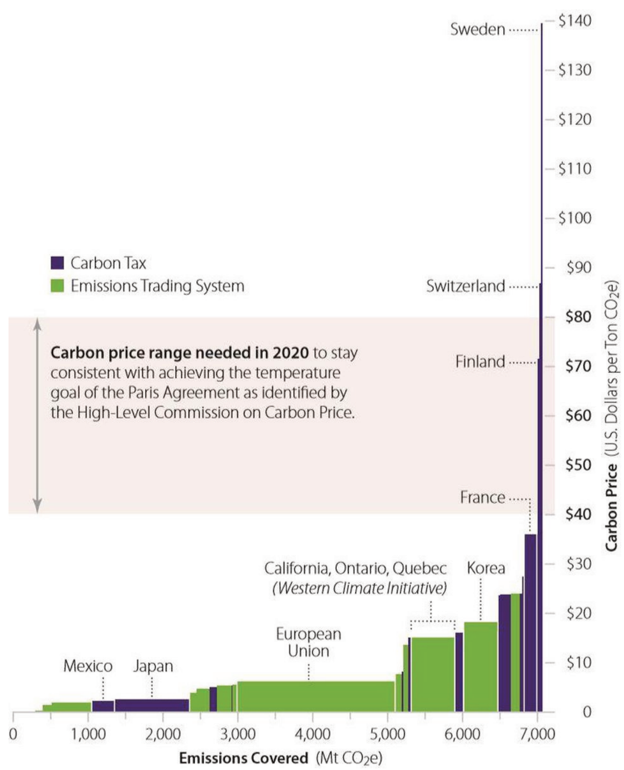
While national policy initiatives for an emissions trading program have failed in the United States, there has been more success at the level of the states. programs to reduce greenhouse gas emissions have been put in place

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 (including 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 CO_{2equiv}).



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

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

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

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Regulation

As mentioned above, all programs that subsidize renewables or increase the price of fossil fuel use require some form 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 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. President 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, which provides a stark contrast to the United States in terms of national government initiatives 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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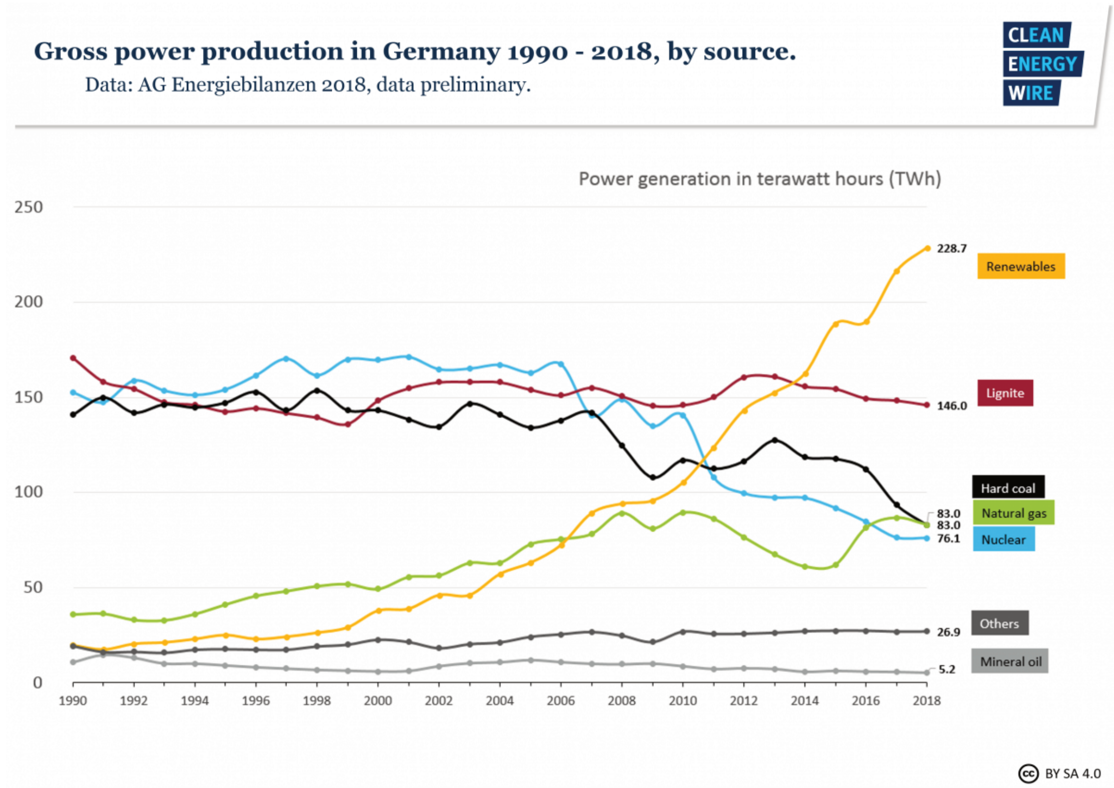
German National Policies toward *Energiewende*

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.



Source: https://www.cleanenergywire.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 homeowners 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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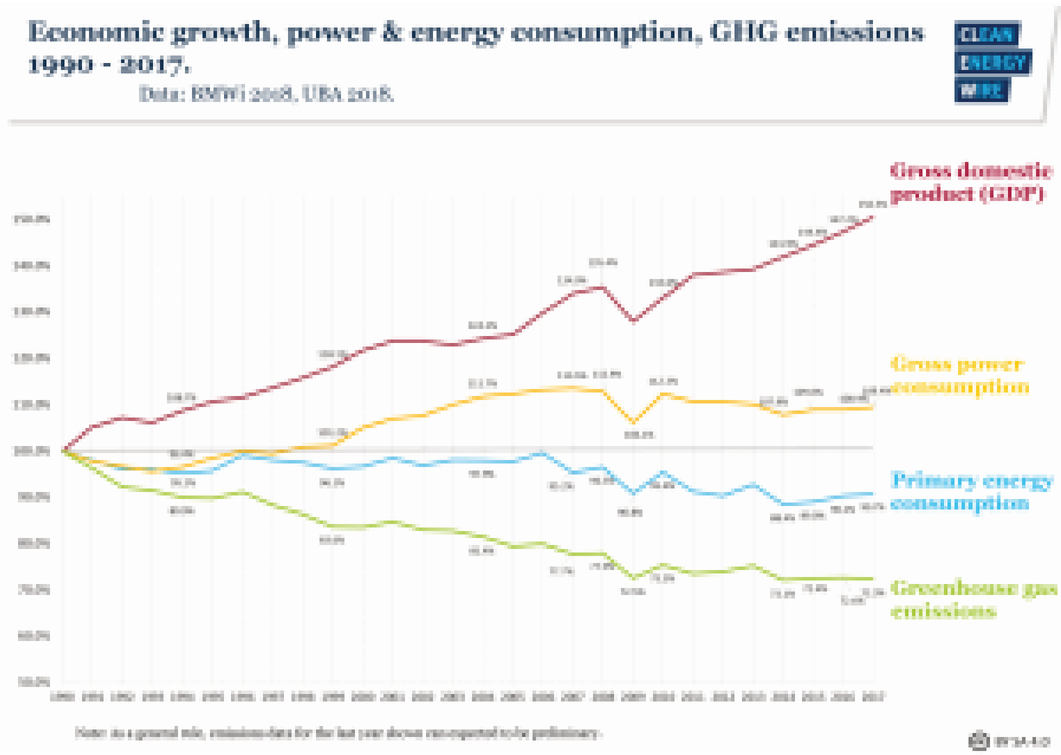
The article that you have just read presents Energiewende in a very positive light. Despite progress, the German government announced in 2018 that it would fail to reach its 2020 emissions reduction target. The success of Energiewende has largely been in the realm of electricity production – there has 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.



Source: https://www.cleanenergywire.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-U.S. comparison, you should come prepared to discuss U.S. 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 the 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!

Assignment: Wisconsin Climate Impacts

Learning Objectives

By completing this chapter, you will:

1. Be able to describe the changes in precipitation and temperature in Wisconsin that have occurred over the past 60 years;
2. Be able to describe the predicted changes in precipitation and temperature in Wisconsin to 2055;
3. Investigate the effect of these changes on one of four issues important to the state: biodiversity, agriculture, human health or water resources/stormwater; and
4. Outline the strategies that can be taken by state government, local government, and civil society to reduce negative impacts on the issue assigned to you.

So far, you have learned how climate change will affect distant places like Bangladesh. But what are the specific impacts expected in Wisconsin? In this chapter, we turn to the effect of climate change on Wisconsin and strategies to adapt to the changes that we have experienced and are likely to experience over the next 40 years. We will start by first reviewing changes in precipitation and temperature that we have experienced and what is predicted we will experience over the next forty years. We then turn to how these changes are expected to affect the state's biodiversity, agriculture, human health and water resources. Each of you will be assigned to investigate one of these important issue areas by using the links supplied in this chapter. These links will also provide ideas of how we can reduce these impacts or adapt or reduce our vulnerability to them. You will be expected to fully investigate your topic area prior to class when you will be tasked in small groups to develop an analysis of how climate changes in Wisconsin will affect the state's biodiversity, agriculture, human health and water resources with adaptation recommendations to a state panel. You will be the only member of your group to have investigated your assigned topic area so come prepared because your group will depend on you!

Changes in Wisconsin's Climate

Three key climate parameters affecting ecology, economy and human health in Wisconsin are temperature, precipitation, and season length. A great resource is the website of the Wisconsin Initiative for Climate Change Impacts (WICCI) that was developed by a range of climate change experts here in Wisconsin with many of them faculty or staff here at University of Wisconsin-Madison. 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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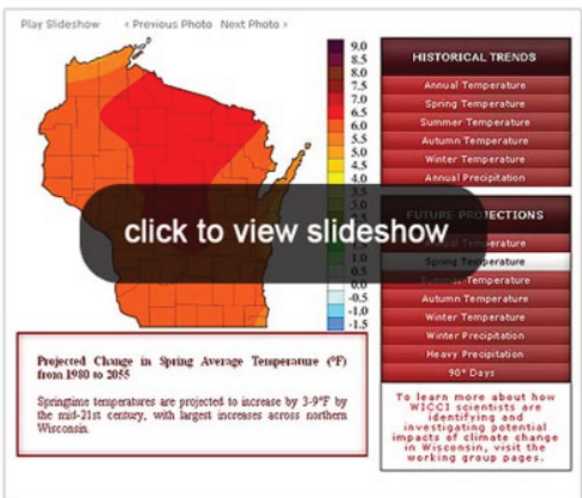

You now have a good general idea of the trends Wisconsin has already experienced and will undergo in the future. A slide show on the WICCI site provides very useful information. To access the slide show, first open the WICCI webpage and then scroll down the lower right half of the webpage to the image displayed 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 divided into two sections: historical trends and future projections. Click on these buttons to answer the following questions.

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Another nice feature of the WICCI site is an interactive map that shows proxies for Wisconsin's future climate based on different climate model predictions. Follow this link. A new tab should open resembling the image to the right. When you will click on a location in Wisconsin, the left box 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 based on different climate model predictions. Read the directions (in grey) carefully before you begin. Click "Begin Using Map" when you have read the directions.

The map gives you an option to choose future scenario of greenhouse gas emissions, climate model, and future time period. Please explore the map! For those of you who are from Wisconsin – make sure to see the locations for your home town's future climate. You can zoom in to each map using the slide bar to the left and navigate in the map by point and drag using your touchpad or mouse. After exploring the map a bit, click on Madison using the A1B (middle) scenario and all climate models to answer the following questions.

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Impacts of Climate Change in Wisconsin

Given the predicted changes in Wisconsin's climate, it is not hard to imagine how it may influence the state's biodiversity, agriculture, human health, and water resources. Given what you now know about climate change trends in Wisconsin, answer the following questions about climate change impacts.

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Now we are ready to investigate Wisconsin's climate vulnerabilities and possible actions to reduce these vulnerabilities in more detail. In this regard, we will focus on four areas: biodiversity, agriculture, human health and water resources. Find your name in the spreadsheet below to identify your assignment.

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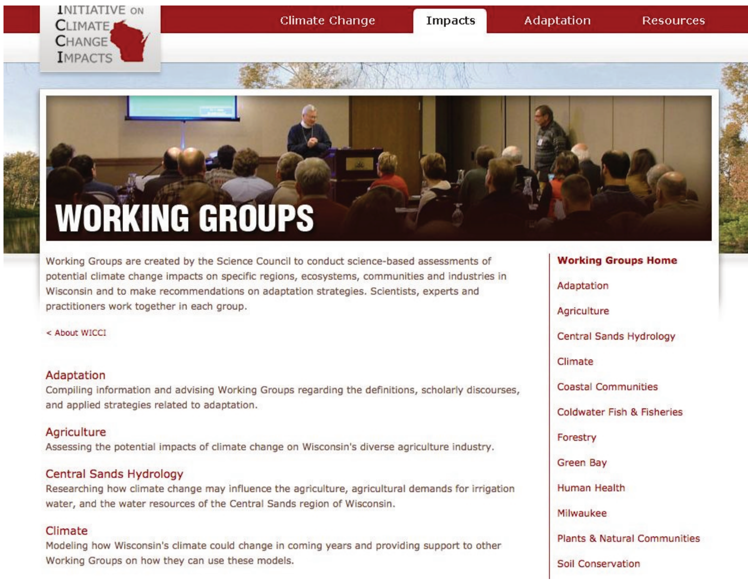

You will need to read/skim and take notes from resources we provide you in preparation for our in-class activity. One set of materials will come from specified working group reports presented on the WICCI site (see image to right). In class, you will join three others to prepare a presentation to a state panel on climate change that outlines Wisconsin's vulnerabilities to climate change in these four areas and proposes a strategy that best addresses these vulnerabilities. The strategy should be clear about the responsibilities of state, local, companies/utilities and citizens for needed actions and how these actions will be funded. 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? Based on your assigned topic, follow the links below to access information resources. (*Please note that these resources are of mixed length and quality – please skim and extract useful information*):

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Once you have completed your review (taking notes!) of the resources, you are finished with this chapter. Please bring your notes and novel adaptation ideas with you to class!

(c) Dennis Franke