Chapter 10

Policy considerations

The purpose of this chapter is to focus on policy issues associated with the water–energy–environment nexus. At first blush this is more than an imposing task since the provision of water and energy services is essential to all human activities. Providing a policy environment that touches all the necessary bases for successful provision of these services is obviously complicated and inevitably contentious, as policy studies and political history clearly document.

So how to proceed? I choose to begin with a definition of 'policy': 'A policy is a deliberate system of principles to guide decisions and achieve national outcomes. A policy is a statement of intent …' (62) For example, as stated by UK Prime Minister Theresa May on 19 February 2018, it is the policy of the United Kingdom to '… have an education system at all levels which serves the needs of every child.' (63) Policy development in areas related to water, energy, and environment was a primary focus of my career in government, and I draw upon that experience in the discussion that follows.

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To a large extent public policies reflect widely held public values. In reviewing the literature of recent years on the policy issues associated with water, energy, and environment, there was one overriding issue: how to address the challenge of global warming and climate change. It encompasses all three elements of the nexus that this book discusses, and arises from a value reflected in all human societies, the need to protect members of those societies and leave a better world for our children and grandchildren. It is in this context that I will discuss policy issues.

10.1 IMPORTANT QUESTIONS

As a first step I list some of the more important questions that an attempt to address climate change must consider:

- Is there a physical basis for understanding global warming and climate change?
- Is there documented evidence for global warming and climate change?
- Can global warming and climate change be attributed to human activities, and what are those activities?
- What are the potential short- and long-term impacts of global warming and climate change with respect to water supply, environment, and health?
- What is the anticipated time scale for these impacts?
- What can be done to mitigate the onset and potential impacts of global warming and climate change?

I will address each of these considerations in turn, discuss its current policy context, and offer policy recommendations.

10.1.1 Is there a physical basis for understanding global warming and climate change?

As discussed in Chapter 4, global warming (also known as the greenhouse effect) is the process by which gases in the

atmosphere allow sunlight to pass through while restricting the outward passage of infrared re-radiation from the Earth's land and water surfaces. This impacts on the energy balance between the Earth and the Sun, and determines the Earth's average temperature. In turn, the energy exchange among the Earth's atmosphere and its oceans and land masses determines climate, which Wikipedia defines as 'the statistics of weather over long periods of time.' The difference between weather and climate is that weather describes the conditions of the atmosphere over a short time period. Climate change refers to the shift in global weather patterns associated with an increase in global average temperatures.

While it is well documented that the climate system can exhibit random changes in global temperatures for short periods of time (up to decades), long-term temperature trends derive from so-called 'external forcings' such as changes in the Earth's orbit around the Sun, changes in the amount of radiation emitted by the Sun, and volcanic eruptions. Changes in the Earth's atmosphere due to increasing concentrations of greenhouse gases such as carbon dioxide and methane also fall into this latter category.

The link between CO_2 and the Earth's temperature was first suggested by Joseph Fourier in 1824. It was experimentally observed in 1860 by John Tyndall, and was first investigated quantitatively in 1896 by the Swedish scientist and Nobel Laureate Svante Arrhenius, who is often referred to as 'the father of climate change science'. His interest in this subject arose from the scientific debate about what could have triggered Earth's many ice ages and whether large swings in levels of atmospheric CO_2 were responsible. The science of this concept was developed further by Guy Stewart Callendar in the period 1930–1960.

Jim Hansen, then NASA's chief climate scientist, drew public attention to global warming with his 1988 testimony to the US Congress about the dangers of human-caused climate change.

This conclusion was questioned by some for many years (though not by the vast majority of the scientific community) but now is widely accepted by scientists and policymakers alike. Today Jim Hansen serves as director of the Program on Climate Science, Awareness and Solutions of the Earth Institute at Columbia University. His work, and that of his scientific predecessors, has laid a solid foundation for understanding the physical basis of global warming. Understanding the global energy exchanges and the weather changes associated with this warming may be the most important scientific activity currently underway.

10.1.2 Is there documented evidence for global warming and climate change?

Global warming is not a theoretical concept. Concern about global warming and associated climate change is based on physical, well documented measurements. Perhaps the most attention-getting are the impacts on water: melting of glaciers, rising sea levels, changes in rainfall patterns, and water and wind damage from more powerful storms. These effects are real, well documented, and increasingly well modeled.

Accurate measurements of atmospheric CO_2 were begun by Dave Keeling at Caltech in the early 1950s and moved to Mauna Loa in Hawaii in 1958. These measurements continue to this day, and similar measurements are now made routinely at many sites around the world.

Based on these measurements, deep geological core measurements, and related scientific analysis, it is understood that CO_2 concentrations have varied widely over the past 400,000 years, from about 180 ppm during periods of extensive glacier formation to 280 ppm during the interglacial periods (see Figure 10.1).

With the advent of the industrial revolution in the 1800s, and the increasing use of fossil fuels, atmospheric CO_2 concentrations have grown steadily (64), and as of 2018 have

reached 410 ppm. Based on scientific estimates, this may be the highest level in millions of years.

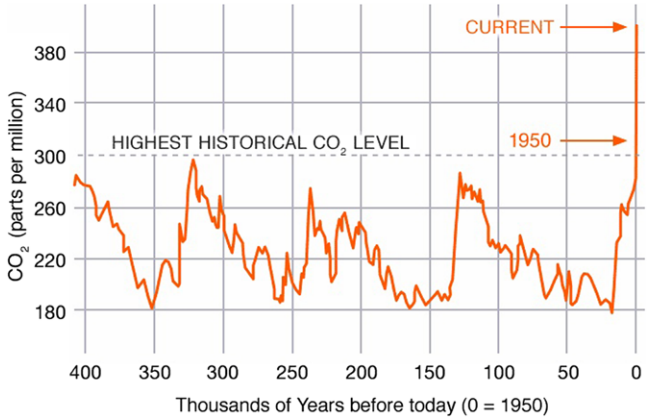

Figure 10.1 Carbon dioxide concentrations over time. (*Source*: U.S. National Aeronautics and Space Administration)

The impact on global temperature is shown in the so-called 'hockey stick chart' (65), which has been called by *The Atlantic* magazine 'The most controversial chart in science' (see Figure 10.2).

The sharp jump in the temperature curve from about 1900 to the present is the basis of the hockey stick analogy. When the chart was released in 1999 it was repeatedly attacked, and so were the authors of the accompanying article. Eventually, the US Congress got involved, no doubt encouraged by supporters of fossil fuels, and it was only after the National Academy of Sciences reviewed the issue in 2006, and declared the hockey stick to be good science, did the attacks begin to taper off. Today, research on the potential impacts of adding greenhouse gases to the atmosphere (which includes gases such as N_2O and chlorofluorocarbons in addition to CO_2 and CH_4), and their timing, are major foci of government and academic research. While there is some current opposition to such research by

some governments (e.g., in the US and countries dependent on revenue from sale of fossil fuels), it is being supported by international scientific collaborations.

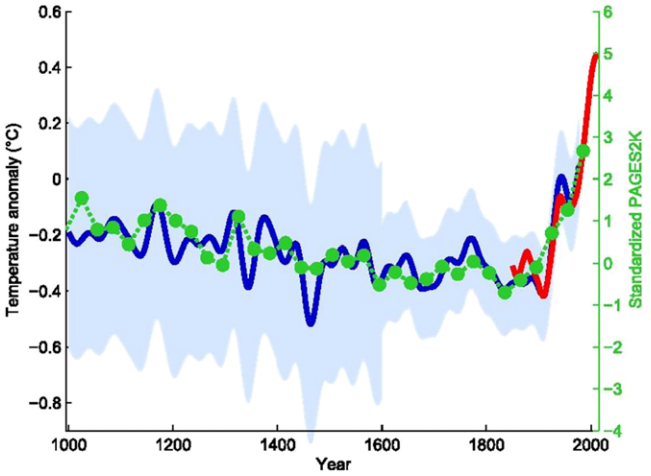

Figure 10.2 The original hockey stick chart (65) (*Source*: Wikipedia).

10.1.3 Can global warming and climate change be attributed to human activities, and what are those activities?

The CO_2 concentration chart and the hockey stick chart, together with large amounts of subsequent data gathering and related scientific analysis, provide a clear picture that something changed significantly after the industrial revolution gained momentum. The work of Arrhenius and others has illuminated the role of greenhouse gases in global warming. While some climate change deniers and minimalizers still attribute global temperature changes to normal global warming cycles, the vast majority of climate change scientists, and a steadily increasing number of policymakers and the general public, accept that combustion of fossil fuels and the subsequent release of CO_2, is responsible for recent increases in global temperatures.

While there is a release of CO_2 from natural biological processes, the observed recent temperature changes clearly have another origin. These 'extra' CO_2 emissions derive from the combustion of coal, oil, and natural gas in electricity production, the combustion of oil in transportation vehicles, and the combustion of fossil fuels in industrial processes. The increasing use of lower-cost natural gas (a powerful greenhouse gas) in power production and industrial processes, possibly resulting in increased leakage into the atmosphere through insufficiently sealed infrastructure, is also a major concern. In addition, the release of N_2O, another powerful greenhouse gas, from increased use of agricultural fertilizers, is a topic of increasing scientific study and concern.

Finally, it should be noted that as global warming proceeds, and more and more water vapor enters the atmosphere, this can have a feedback effect on global warming. For example, more clouds can bounce more solar radiation back into space, reducing the heating effect (negative feedback); but the presence of more water vapor can also amplify the global warming effect because water vapor absorbs infrared re-radiation from the oceans and land masses, a positive feedback mechanism. Volcanic eruptions can also have a mixed impact: the clouds of material produced by these eruptions, which can circle the globe, can reflect sunlight, but the small, dark-colored particulate matter they introduce into the atmosphere can absorb the Sun's radiation and increase the heating effect. Other positive feedback mechanisms exist as well. Melting of Arctic Ocean ice changes the albedo (reflectivity) of the ocean from reflecting to absorbing, allowing increased ocean heating. The thawing of cold region permafrost, frozen layers below the Earth's surface, can also exacerbate global warming by releasing trapped CH_4 and other hydrocarbons, which are powerful greenhouse gases. All in all, a complicated set of physical phenomena that many people are working hard to understand.

10.1.4 What are the potential short- and long-term impacts of global warming and climate change with respect to water supply, environment, and health? What is the anticipated time scale for these impacts?

I admit to being extremely concerned about global warming and its many potential impacts on human welfare. I am disturbed by the fact that those least responsible for global warming and the resultant climate change – for example, island nations – are likely to suffer the most serious impacts. I am also disappointed with those scientists and politicians who continue to deny the scientific basis for concern about global warming when the consensus among scientists is overwhelming, an unusual situation in science. I believe it is a failure for which the climate deniers and minimizers should be held accountable.

As stated earlier in Chapter 4, 'climate change is worthy of our most careful attention.' In most countries these concerns would lead to executive action and legislative hearings as a precursor to legislative responses. Such hearings took place in the US during the Obama Administration, and much useful testimony on the potential impacts of global warming and climate change was obtained from climate science experts (66). I will draw on this testimony to answer the question of potential impacts. (*Note*: With the advent of the Trump Administration, and the control of both houses of the US Congress by the Republican Party, no further hearings on global warming have been held.) In the following I quote from the highlights of their testimonies.

Dr Donald Wuebbles, Professor and Atmospheric Scientist, Department of Atmospheric Sciences, University of Illinois

- 'The US and the global climate is changing now and this change is apparent across a wide range of observations. The evidence indicates that most of the climate change of the past 50 years is primarily due to human activities.'

- 'Heavy downpours are increasing in most regions of the US, especially over the last three to five decades. Certain types of other extreme weather events, including heat waves, and floods and droughts in some regions have become more frequent and intense. The trends are projected to continue.'
- 'Scientific analyses are now indicating a strong link between changing trends in severe weather events and the changing climate.'
- 'There has been an increase in the overall strength of hurricanes and in the number of strong (Category 4 and 5) hurricanes in the North Atlantic since the early 1980s. The intensity of the strongest hurricanes is projected to continue to increase as the oceans continue to warm.'
- 'Global sea level has risen by about 8 inches since 1880. It is projected to rise another 1 to 4 feet by 2100. Many coastal areas of the US will be increasingly affected.'

Dr James McCarthy, Professor of Biological Oceanography, Harvard University

- 'Ocean processes are linked to many types of extreme weather and recent ocean studies are helping us understand the growing intensity of extreme weather events on land. Some of the observed changes in the ocean, which only a few decades ago were thought unimaginable in our lifetimes, are now occurring as a result of human-caused climate change.'
- 'The additional heat in the climate system caused by the greenhouse gases that we release with the burning of fossil fuels and land-use practices is now penetrating deep within the oceans.'
- 'For many of us in ocean science the compelling evidence for human-caused climate change came with the observations of deep ocean warming, the ice core data that demonstrates linkages between Earth's past

temperature and atmospheric greenhouse gas content, the acceleration in sea level rise, the abrupt melting of land ice and ice shelves that had been in place for many thousands of years, and global changes in ocean chemistry. Such changes in these phenomena can only be consistently explained by an unusual rate of greenhouse gas release to the atmosphere.'

Dr J. Marshall Shepherd, President, American Meteorological Society, and Professor of Geography and Director, Atmospheric Sciences Program, University of Georgia

- 'Key Takeaway Points:
  - This topic is about impact to people – your constituents, my fellow citizens, my two kids – not just polar bears.
  - Most of the warming of the past 50 years is due to human activity, and extensive evidence supports this conclusion.
  - Climate change is increasing the probability of extreme events, and in some cases maybe strengthening their intensity or increasing their frequency (i.e., we are loading the dice towards more Sandy or blizzard type storms).
  - There is strong evidence that increases in some types of extremes are linked to human induced climate change, notably extreme heat, coastal flooding, and heavy downpours. For other types of extremes, such as tornadoes, current evidence is much more limited.'

Dr John M. Balbus, Senior Advisor for Public Health, National Institute of Environmental Health Sciences and Lead Author/ Human Health, 2013 US National Climate Assessment

- 'Rising temperature will increase human exposure to mold, microbial pathogens and infectious diseases. … studies are indicating that the greatest heat-related harm may come not from extreme exposure but rather from the lower but more frequent stress of increasingly hot summer days.'

- '… we've seen the geographical range of ticks that cause Lyme disease shift northward, and is predicted to shift further northward in the United States and Canada …'

Opposing views on global warming and climate change do exist, and are perhaps most strongly expressed by The Heartland Institute (67). As described in Wikipedia, 'The Heartland Institute is an American conservative and libertarian public policy think tank based in Chicago, which advocates free-market policies. In the 1990s, the group worked with the tobacco company Philip Morris to question the science linking secondhand smoke to health risks, and to lobby against government public health reforms. More recently, The Institute has focused on questioning the science of human-caused climate change, and was described by the New York Times as 'the primary American organization pushing climate change skepticism. … The Institute has sponsored meetings of climate change skeptics, and has been reported to promote public school curricula challenging the scientific consensus on human-caused climate change.' What they are saying, in their own words, is the following:

- 'The environmental movement needs voices devoted to sound science and market-based, rather than government-based, solutions to environmental problems.'
- *Roosters of the Apocalypse: How the Junk Science of Global Warming Nearly Bankrupted the Western World* (published in April 2012 by the Heartland Institute)
  - It 'compares societal belief in climate change to a prophecy that instructed the tribe to massacre its livestock, resulting in the death of 35,000 people and slavery for the survivors. … A similar 'economic suicide' is looming for the United States of America if Americans continue to pursue policies restricting the use of fossil fuels in order to avoid a false climate 'apocalypse'…' (68)
  - 'human emissions have an impact on the environment, but it is so small that people and the economy won't be

> affected … a scientific myth … believing in man-made global warming – after all the scientific discoveries and Revelations that point against this theory – is more than a little nutty. In fact, some really crazy people use it to justify immoral and frightening behavior.' (69)

A highly respected source of information on atmospheric and climate changes in the 21st century is the NASA Goddard Institute for Space Studies, which was established in 1961 and led by Jim Hansen from 1981 to 2013. In January 2018 it reported that:

- Earth's surface temperatures in 2017 were the second warmest since 1880, when global estimates first become feasible.
- Global temperatures in 2017 were second only to 2016, which still holds the record for the hottest year. However, 2017 was the warmest year without an El Niño. (*Note*: In a separate, independent analysis, NOAA scientists found that 2017 was the third-warmest year in their records. The minor difference is due to different methods to analyze global temperatures used by the two agencies, although over the long-term the records remain in strong agreement.)

NASA also reports that global surface temperature relative to an average for the years 1951–1980 had increased by 0.9°C (1.6°F) by 2017 (70). See Figure 10.3.

To add to this discussion of potential global warming impacts I mention two disturbing newspaper articles that caught my attention. They both point out the seriousness and potential scale of these impacts and the timescales involved. The first, by Dana Milbank, appeared in the *Washington Post* on 12 June 2013. Entitled 'Bloomberg's race to protect NYC from climate change' it discussed the $19.5 billion plan announced by Michael Bloomberg (then Mayor of New York) to 'prepare for the impacts of a changing climate.' In his remarks announcing the plan Bloomberg addressed the 'inevitability that rising

temperatures and sea levels would bring even worse than the damage from Hurricane Sandy.' He also stated that 'By mid-century, up to a quarter of all New York City's land area, where 800,000 residents live today, will be in the flood plain, and 40 miles of our waterfront could see flooding on a regular basis just during normal high tides. We no longer have the luxury of ideological debate. The bottom line is we can't run the risk.'

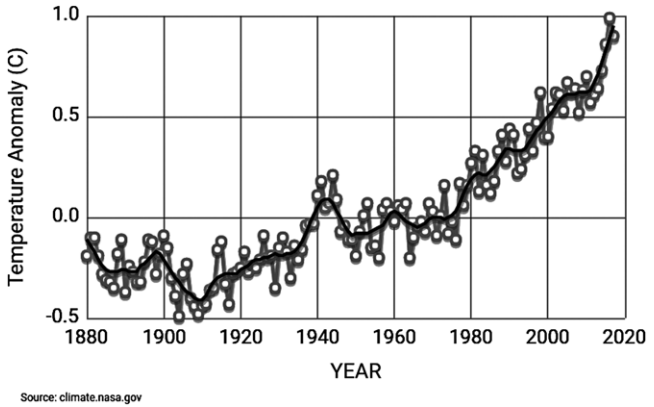

Figure 10.3 Global surface temperature. (*Source*: U.S. National Aeronautics and Space Administration)

To me an even more disturbing article, by Justin Gillis published in the *New York Times* on 12 August 2013, discussed in some detail the potential future implications of possible sea level rise. He quotes the work of Dr John Mercer who 'pointed out the unusual topography of the ice sheet sitting over the western part of Antarctica' and speculated that 'climatic warming could cause the whole thing to degrade rapidly on a geologic timescale, leading to a possible rise in sea level of 16 feet.' He also refers to a paper (71) co-authored by Dr Michael O'Leary of Curtin University in Australia, who together with five colleagues 'spent more than a decade exploring the remote

western coast of Australia, considered one of the best places in the world to study sea levels of the past.' To quote further from the Gillis article, 'the paper focuses on a warm period in the Earth's history that preceded the most recent ice age. In that epoch, sometimes called the Eemian, the planetary temperature was similar to levels we may see in coming decades as a result of human emissions, so it is considered a possible indicator of things to come.'

'Examining elevated fossil beaches and coral reefs along more than a thousand miles of coast, Dr O'Leary's group confirm something we pretty much already knew. In the warmer world of the Eemian, sea level stabilized for several thousand years at about 10 to 12 feet above modern sea level. The interesting part is what happened after that. Dr O'Leary's Group found what they consider to be compelling evidence that near the end of the Eemian, sea level jumped by another 17 feet or so, to settle at close to 30 feet above the modern level, before beginning to fall as the ice age set in. In an interview, Dr. O'Leary told me he was confident that the 17 foot jump happened in less than a thousand years – how much less, he cannot be sure.' Of course, this group's findings must be subject to critical scrutiny, but 'if the work does hold up, the implications are profound. The only possible explanation for such a large, rapid jump in sea level is the catastrophic collapse of a polar ice sheet, on either Greenland or Antarctica. Dr. O'Leary is not prepared to say which; figuring that out is the group's next project. But a 17 foot rise in less than a thousand years, a geologic instant, has to mean that one or both ice sheets contain some profound instability that can be set off by a warmer climate. That, of course, augers poorly for humans. Scientists at Stanford calculated recently that human emissions are causing the climate to change many times faster than at any point since the dinosaurs died out. We are pushing the climate system so hard that, if the ice sheets do have a threshold of some kind, we stand a good chance of exceeding it.'

Other scientific research supports the conclusion that even if greenhouse gas emissions were to stop tomorrow we have probably locked in several feet of sea-level rise over the long-term. As a result, adaptation is the current buzzword in global warming/climate change circles, a recognition that climate change is with us and the world has no choice but to adapt or suffer serious consequences. To repeat a point made in an earlier chapter, an important impact that is already showing up is the impact on precipitation patterns which affect water supplies. Many people see access to clean water as a principal, if not the principal, 21st century environmental, public health, and even national security issue.

10.1.5 What can be done to mitigate the onset and potential impacts of global warming and climate change?

This of course is the '$64,000 question' and a major focus of scientific and legislative policy work. Nevertheless, a number of important suggestions have been made as to how to address this question.

It is widely recognized that in the short-term very little can be done. The initial response to global warming in the US and Europe was 'mitigation', that is, reducing the amount of CO_2 going into the atmosphere. This was unsuccessful, as developing nations with growing economies became the principal source of atmospheric CO_2. While reducing CO_2 emissions is still a critical goal, and is being pursued worldwide, considerable effort is going into adaptation.

Some of the mitigation measures we can undertake include:

- To move, in the long term, to low- or zero-carbon fuels as replacements for hydrocarbon fuels, and restrict the release of both CO_2 and other greenhouse gases.

- This is consistent with the historical pattern over the past few centuries to move to lower and lower carbon content fuels, from coal to oil, to natural gas.
- Other long-term energy options are to move to both renewable energy and nuclear power, subject to resolution of the concerns associated with nuclear power discussed in Chapter 7.
- A 2015 interdisciplinary MIT study, 'The Future of Solar Energy', in its Summary for Policymakers, concluded that 'massive expansion of solar generation worldwide by mid-century is likely a necessary component of any serious strategy to mitigate climate change.'
- The MIT report goes on to state: 'Fortunately the solar resource dwarfs current and projected future electricity demand. In recent years, solar costs have fallen substantially and installed capacity has grown very rapidly. Even so, solar energy today accounts for only about 1% of US and global electricity generation. Particularly if a substantial price is not put on carbon dioxide emissions, expanding solar output to the level appropriate to the climate challenge likely will not be possible at tolerable cost without significant changes in government policies.'
- Another possible goal is an energy economy that makes extensive use of hydrogen. Sometimes, hydrogen is referred to as 'the hydrocarbon without the carbon.' Not only can it be burned cleanly (its principal combustion products are water and heat), it can also serve as a source of clean electricity via its use in fuel cells if it is produced via electrolysis of water (H_2O), using electricity sources (renewables, nuclear) that do not put carbon in the atmosphere.
- Hydrogen may also play a critical role in energy storage. It can be stored in gaseous and liquid form, and in recoverable form in solid-state matrices.

As far as adaptation is concerned, government officials in many cities around the world are already taking steps to protect their threatened infrastructures. For them a critical question is exactly how long will it take for impacts to be felt? To quote again from the Gillis article: 'On that crucial point, alas, our science is still nearly blind. Scientists can look at the rocks and see indisputable evidence of jumps in sea level, and they can associate those with relatively modest increases in global temperature. But the nature of the evidence is such that it is hard to tell the difference between something that happened in a thousand years and something that happened in a hundred. On the human timescale, of course, that is all the difference in the world. If sea level is going to rise by say, 30 feet over several thousand years, that is quite a lot of time to adjust – to pull back from the beaches, to reinforce major cities and to develop technologies to help us cope. But if sea level is capable of rising several feet per century, as Dr O'Leary's paper would seem to imply and as many other scientists believe, then babies being born now could live to see the early stages of a global calamity.' We surely live in uncertain and dangerous times.