HARVARD | BUSINESS | SCHOOL

N9-320-087
JANUARY 8, 2020

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Climate Change in 2020: Implications for Business

[The Department of Defense] recognizes the reality of climate change and the significant risk it poses to U.S. interests globally. The National Security Strategy, issued in February 2015, is clear that climate change is an urgent and growing threat to our national security, contributing to increased natural disasters, refugee flows, and conflicts over basic resources such as food and water. These impacts are already occurring, and the scope, scale, and intensity of these impacts are projected to increase over time.

— United States Department of Defense, July 2015[1]

Unchecked climate change presents a profound threat to economic growth and political stability. Average global temperatures have risen by roughly 1^0C since the start of the industrial revolution[2] (**Exhibit 1**), and there is widespread scientific consensus that this warming is caused by human emissions of greenhouse gases (GHGs), and that the consequences of continued warming are likely to be severe. A recent report put together by the Intergovernmental Panel on Climate Change[a] suggested that the world should hold warming to 1.5^0 to avoid significant damages,[3] but despite widespread public concern about the issue (**Exhibit 2**), global emissions of greenhouse gases have not declined (**Exhibit 3**).

There is widespread disagreement about what—if anything—should be done in response. While the benefits of reducing global emissions almost certainly greatly exceed the costs, there is only partial agreement as to what exactly should be done, how quickly it is appropriate to act, and who should pay. As a result, the risk of climate change is emerging as a central issue for the private sector. Some business leaders see climate change as a threat to their firms' viability. Others see opportunity in promoting technologies that will mitigate the risk of climate change. Some are lobbying against government action on climate, while others are aggressively lobbying for such action. This note attempts to summarize what is known about the causes, current impacts, and likely future consequences of climate change; to outline the current debate about what should be done; and to explore the implications for the private sector.

[a] The IPCC) was founded in 1988 "to prepare, based on available scientific information, assessments on all aspects of climate change and its impacts, with a view of formulating realistic response strategies." Scientists are independently nominated for participation by their own governments. In 2016 over 2,000 scientists from 154 countries participated in the IPCC process.

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An Introduction to Climate Change

18 of the last 19 years have been the hottest years since recordkeeping began.[4] There is broad consensus in the scientific community that this warming has been largely driven by increases in atmospheric GHGs, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). (Emissions of GHGs are often measured in equivalent units of CO_2 emissions, or CO_2eq, by indexing the 100-year global warming potential of each gas to that of CO_2.)[5] Since 1880, atmospheric CO_2eq concentrations have risen from around 280 ppm to 454 ppm.[6]

Higher levels of atmospheric GHGs raise temperatures by increasing *radiative forcing*, or the amount of energy arriving on Earth's surface (**Exhibit 4**).[7] Higher GHG concentrations increase the amount of radiation caught by the atmosphere and redirected back toward the surface. The difference between the rate at which energy arrives on the Earth's surface and the rate at which it radiates back is the net heating, with this heat accumulating at and below the surface of Earth's oceans, land, and ice. Currently the Earth retains approximately 816 terawatts of excess heat per year, or more than 50 times the world's entire energy consumption.[8,9] Evidence of this retained heat is discernible in Earth's rising surface temperatures, warming oceans, and melting ice.[10]

Roughly 97% of climate scientists agree that human activity is causing climate change,[11,12] as do the national academies of Brazil, Canada, China, Germany, India, Japan, Russia, the United Kingdom, and the U.S.[13] Some observers claim that climate change is not a man-made phenomenon, blaming factors such as solar cycles (variations in the amount of energy reaching the Earth from the sun) or volcanic activity for recent increases in temperature.[14] Others allege that scientists lack consensus or that global temperatures have cooled.[15] But variations in the sun's radiation are small relative to surface forcing associated with GHGs, and the dominant 11-year cycle in solar output barely registers in global temperatures. In addition to the changes in ocean, ice, and surface temperatures, the pattern of warming as a function of latitude and elevation in the atmosphere has also allowed for the fingerprinting human-caused effects.[16]

The primary sources of GHG emissions are the burning of fossil fuels (coal, oil, and gas), deforestation and agriculture.[17] **Exhibit 5** gives one estimate of emissions by sector, but estimates differ: some experts suggest that deforestation and agriculture contribute as much as 25% of the world's emissions. Emissions vary widely across countries, and the consensus "business as usual" scenario suggests that they will increase significantly over the next thirty years. CO_2eq concentrations are likely to increase to approximately 450 ppm by 2030 and to between 750 ppm and 1,300 ppm by 2100 (**Exhibit 6**).[18]

It is impossible to know precisely what effect these kinds of increases will have on global temperatures. The last time the atmosphere contained atmosphere CO_2eq concentrations of 500 ppm the planet was between five and eight degrees warmer, there were crocodiles in the Antarctic and the sea was about 130 feet higher.[19] The IPCC estimates that if emissions continue to rise global mean surface temperature will increase between 3.7°C to 7.8°C (6.7°F to 14°F) compared to pre-industrial levels, with the consensus expectation being around 4.5°C.[20,21] However, such estimates are probabilistic and temperature increases could be either much greater or—perhaps—smaller **(Exhibit 7)**. Most of the uncertainty involves the upper estimates of possible warming, because temperature changes in response to increased radiative forcing are bounded near zero on the low end but are essentially unbounded on the high end. The reason for this asymmetric uncertainty is the presence of positive feedback loops. For example, global warming reduces the amount of snow and ice covering Earth's surface. Since snow and ice reflect more sunlight back into space than does exposed land, this reduction further accelerates the rate of global warming.[22,23] Similarly, higher temperatures are causing the melting of the permafrost that covers 24% of the Earth's Northern Hemisphere. The permafrost

contains an estimated 1,400 gigatons[b] (Gt) of trapped carbon, between 33 and 114 Gt of which could be released by 2100 if the rate of thawing continues, compared to a total of 850 Gt of carbon already in the atmosphere and anthropogenic carbon emissions of about 10 Gt per year.[24,25,26,27]

One issue that concerns many scientists is that many of global warming's impacts have unfolded significantly faster than expected. For example, in 2007 the IPCC projected that global average sea levels would rise 0.6 meters (2 feet) by 2100, but in 2013 the prediction was revised to as much as 0.98 meters (3.2 feet), and then in 2019 revised upwards again to 2 meters (6.6 feet).[28] Similarly, the IPCC has historically underestimated the pace of Arctic sea ice decline. In 2007, models predicted the first ice-free Arctic summers could arrive in nearly a century, in 2100; but in 2012 the estimate was that this would occur in only 20 to 30 years.[29] Now scientists predict a summer free of sea ice by 2040.[30] Some experts worry that the presence of these kinds of uncertainty mean that the business as usual scenario carries as much as a 10% risk of catastrophic climate change.[31] In the words of one expert:

> The most striking feature of the economics of climate change is that its extreme downside is non-negligible. Deep structural uncertainty about the unknown unknowns of what might go very wrong is coupled with essentially unlimited downside liability on possible planetary damages.[32]

The Impacts of Climate Change

What are the likely effects of a business as usual scenario, or of a 4.5^{0}C increase in average global temperatures? Nobody knows, of course, but some predictions can be made with reasonable certainty.

Increasing Heat Increasing surface temperatures will have direct effects on human's ability to live, work and eat in the most affected regions. As many as 70,000 people died in the 2003 European heat wave, and more than 50,000 died in the 2010 heat wave in Russia.[33,34] In 2019, France recorded record-breaking temperatures and saw an increase of 9.1% in the death rate.[35] More than 6, 000 people have died from heat stress in India since 2010. By 2050 under a business as usual scenario as many as 255,000 people are expected to die world-wide from the direct effects of heat.[36]

Increasing heat will also have a direct impact on the food supply. Plant yields fall by about 10% for every degree of temperature rise, so in principle rising temperatures could cut yields in half by the end of the century. Rising temperatures also reduce the nutritional content of grains and cereals.[37] By 2050 as many as 150 million people will be at risk of protein deficiency as a result, while as many as 1.4 billion could be short of dietary iron.[38] Declines in the nutritional value of rice could threaten the health of 600 million people.[39]

Rising sea levels Two thirds of the world's largest cities are located in low-lying coastal areas, and if—as is expected under the business as usual scenario—sea levels rise by 2 meters (6.60 feet) by 2100, the land on which an estimated 470 million to 760 million people are living will be submerged, including the land underneath London and Shanghai.[40,41] A number of island nations—including 11 of the Solomon Islands—are already submerged or at risk of total destruction. By 2050, between 665,000 and 1.7 million people in the Pacific will probably be forced to migrate due to rising sea levels, including the entire populations of islands such as Fiji, the Marshall Islands, and Tuvalu.[42,43,44] In 2017 floods in South Asia killed more than a thousand people and flooded two thirds of Bangladesh,[45] and by 2100 sea level rise is likely to force nearly 50% of Bangladesh's population to migrate – more than

[b] A Gt is 1 trillion metric tons (t), equivalent to 1,000 kilograms.

80 million people. [46] In the U.S., barring a concerted mitigation effort, $238 billion to $507 billion worth of coastal property are likely be below sea level by 2100.[47] New York, Miami and Boston are in particular danger of inundation, as are many of the great Asian cities.[48]

Droughts, Floods and Storms Although it is difficult to link any single event directly to climate change, rising temperatures means that the atmosphere can hold more water vapor, allowing both for greater rates of rainfall and runoff when the air is saturated and for drier conditions otherwise.[49,50] As a result rainfall patterns are shifting across the world.[51] The Horn of Africa has been in and out of drought since 2011, causing crop failures of up to 30%.[52] The rainy season in 2019 in Somalia was the third driest since 1980 putting the food supply for 6 million people at risk.[53] By 2080, unless emissions drop precipitously, southern Europe will almost certainly be in permanent extreme drought as will Iraq, Syria, some of the most densely populated parts of Africa and South America and the major grain growing regions of China.[54] By the 2090s, without significant reductions in GHG emissions, the proportion of the global land surface in extreme drought could increase from 1% to 3% today to 30%.[55] As early as 2025, estimates suggest that half of the world's population will be living in water stressed areas.[56] At the same time rain storms in the U.S. have become 40% more intense and the incidence of hurricanes has dramatically increased.[57] Houston has been hit by three "500 year floods" in three years[58] and the number of extreme climate-related disasters has doubled since 1990.[59]

Political and security risks Climate change has been linked to increased political instability worldwide.[60] When food prices rose sharply in 2007-2008, dozens of so-called "food riots" caused casualties in Argentina, Cameroon, Haiti, and India.[61] In drylands, extreme droughts have been associated with a 45% increase in violent conflict.[62] Both the Somalian civil war and the Syrian civil war have been linked to drought and famine exacerbated by climate change; around 300,000 Syrian families, after all, were displaced from their farms during the 2007-2010 drought.[63] In the first half of 2019, a record 7 million people were displaced due to extreme weather conditions.[64] Land degradation and climate change is expected to drive another 50-700 million people to migrate mid-century.[65] The U.S. military believes that climate change is "a salient national security concern," which could redraw maps and spheres of engagement while compounding conflicts and resource constraints in some of the world's already vulnerable countries, leading to further instability and even war.[66,67]

Human health risks The burning of fossil fuels—particularly coal—causes enormous damage to human health. The World Health Organization estimates that around 7 million people worldwide die due to fossil fuel related air pollution per year[68] Another study found that in the U.S. the pollution generated by fossil fuel generated electricity costs between $362 billion and $887 billion per year (~2.5% to 6.0% of GDP) as a function of premature mortality, workdays lost, and other direct healthcare costs.[69] In 2030-2050, climate change is expected to cause approximately 250,000 additional deaths per year from malnutrition, malaria, diarrhea, and heart disease.[70] Water- and vector-borne diseases are also projected to increase as insects and other carriers move into higher latitudes.[71] For example, between 2000 and 2013, instances of Lyme disease in the U.S. doubled.[72]

Impact on wildlife and ecosystems Climate change also significantly affects many natural habitats and puts many species at higher risk of extinction.[73] If action is not taken, 1 million species (out of ~8 million worldwide) face extinction within decades.[74] Other studies show a drastic decline in insect population across Europe and North America.[75]

Climate change is also having significant effects on the oceans. Over the last 100 years, it has raised near-surface ocean temperatures by about 0.74° C (1.3° F) and made the sea significantly more acidic, likely affecting marine animals' reproduction and survival.[76,77,78] In some places,—including the Great Barrier Reef—live coral coverage is only half of what it was in the 1960s, and scientists predict that the

world's coral reefs will probably be entirely extinct given a 2° C temperature rise.[79] As many as 1 billion people rely on the fish that live in coral reefs as their primary protein source, and reefs support as much as a quarter of all marine life.[80]

Responding to Climate Change: The Ongoing Debate

The discussion of what should be done in response to climate change is complicated by two distinct but interrelated problems. The first is the sheer magnitude of the changes required to mitigate and/or adapt successfully to climate change, and the second is the global free riding problem that impedes consensus on who should pay for those changes.

There is general agreement in the scientific community that global warming needs to be limited to 1.5°C (2.5°F) above pre-industrial levels by the end of the 21st century in order to avoid potentially dangerous impacts.[81] This requires cutting GHG to zero by 2050 – rates that imply reducing emissions by about 10% a year for the next thirty years. [82,]This is almost certainly technologically feasible. In most parts of the world, for example, solar and wind power are already cost competitive with fossil fuels (**Exhibit 8**). Indeed, in some places they are now so cheap that it is worth shutting down existing coal plants.[83] **Appendix A** outlines one pathway through which the world could reach these targets.

But implementing a program along these lines would require sustained investments at the rate of 3-4% of GDP for many years. Replacing fossil fuels in power generation, for example, will require enormous investments in renewables – and, since renewables generate power intermittently, either in large quantities of storage or in significant excess renewable capacity. Excess capacity could be used to generate the liquid hydrogen that could replacing fossil fuels in applications like aviation fuel but it will not be cheap. Getting to zero also requires remaking agriculture – most importantly, by switching to an almost entirely plant-based diet. Beef consumption, for example, is responsible for as much as 10 percent of global GHG emissions (but is only about 2 percent of calories consumed).[84] Switching away from meat could also save $1 trillion in health costs by 2050.[85]

It will also be critical to greatly increase the energy efficiency of every existing building, the food supply chain – at the moment around 30% of all food grown is wasted[86] – and to recycle almost all goods – particularly plastics, clothes and electronics. In short, arresting climate change will require fundamental change across the entire society.

Another possibility is to adopt some form of geoengineering. Possibilities include injecting sulfates into the atmosphere, where their high reflectivity would stop up to 1% of the sun's radiation from reaching the Earth's surface.[87] Preliminary estimates suggest that geoengineering could be relatively cheap, but it would have to be maintained continuously in order to control the Earth's temperature and would not slow the increasing acidification of the oceans.[88] Moreover it is hugely controversial, with many observers concerned about potential side effects, including damage to the ozone layer, drought, and possible disruption to the Asian and African summer monsoons, which support the food supply for billions of people.[89]

The costs of mitigating the effects of climate change are likely to be much lower than the costs of leaving it unchecked. For example, in 2014 the IPCC estimated that keeping GHG emissions to a level that offers a 66% chance of not exceeding 2°C warming would cost 3% to 11% of world consumption by 2100,[90] while business as usual might cost 23% to 74% of global per capita GDP by 2100 in lost agricultural production, health risks, flooded cities, and other major disruptions.[91] Moreover several studies suggest that managed appropriately, a so called "green transition" could generate millions of new jobs.[92]

The fact that the benefits of addressing the problem of climate change almost certainly outweigh the costs—and that the effects of increased emissions are likely to last for thousands of years and affect the wellbeing of billions of people yet to be born—does not make concerted global action to address the problem easy. Indeed, climate change is a difficult problem because addressing it requires dealing with (at least) three thorny issues: discount rates, free riding, and global geopolitics.

Discount rates How much do we value GDP 100 years in the future? If we apply a discount rate based on the conventional cost of capital of 7% to 8% the answer is "not very much." For example, $1,000 discounted at 7% for 100 years is worth only $1.15 in 2020 dollars. Many have argued that this is the wrong calculation and that it cannot be right to place essentially no weight on the wellbeing of our children's children, or on the significant risk that unchecked climate change could have globally catastrophic consequences.[93] But, there is enormous debate about how fast it makes sense to attempt to respond to climate change and how much we should value future benefits against current costs.[94]

Free riding Even given general agreement among nations that the costs of inaction outweigh the costs of action, addressing climate change still requires solving the free riding problem, or the fact that while the costs of reducing emissions must be incurred by particular firms, cities, or nations, the benefits will be experienced by everyone on the planet. GHG emissions are a classic "externality": their emission imposes harm on the entire community, but the emitters themselves—absent some form of cooperative agreement or global regulation—have no incentive to reduce them.[95]

Global geopolitics This issue is further complicated by the fact that many of the countries that are most vulnerable to climate change—primarily poorer developing nations—are those with relatively small historical carbon footprints (**Exhibit 9**). Many of them argue that the developed nations – the countries whose cumulative actions have contributed most to climate change should bear most of the responsibility for cutting emissions.[96] This has proved to be a controversial idea, particularly as developing countries' emissions have increased rapidly, in line with their economic growth. Many developing countries have chosen to pursue cheaper but more GHG-intensive energy sources such as coal-fired power plants to foster development,[97] although some experts believe that some developing countries may be able to "leapfrog" traditional energy-intensive development paths.[98]

Despite these formidable difficulties, the global community has been experimenting with a variety of mechanisms to address climate change. It is widely believed that the most effective way to reduce carbon emissions is to rely on market-based mechanisms such as carbon taxes and/or cap and trade regimes.[99,100] Cap and trade systems issue permits that allow companies to emit a certain amount of GHGs; those companies that emit less than their initial allotments are then allowed to sell their excess permits to companies that wish to emit more than their initial allotment. The U.S. Acid Rain program relied on a cap and trade mechanism and succeeded in reducing sulfur dioxide (SO_2) emissions by 40% and acid rain by 65%. The estimated benefits of the program were $56 billion compared to costs of just $558 million.[101,102,103]

In contrast, a carbon tax places a predetermined price on every ton of CO_2eq emitted into the atmosphere.[104] Both cap and trade systems and carbon tax programs seek to shape behavior by presenting the "real" external cost of emissions to firms and consumers.[c,105] One, study, for example, found that total U.S. emissions could fall by four fifths by 2040 if the U.S. imposed a $25 per ton carbon

[c] Regulations that seek to directly shape behavior by mandating the use of energy efficient appliances can be effective tools for reducing energy consumption or supporting a shift to lower carbon fuels. Many studies have explored the conditions under which this is likely to be the case. Source: "Scientific Assessment of Ozone Depletion: 2006," World Meteorological Organization, pp. 19, available at http://www.esrl.noaa.gov/csd/assessments/ozone/2006/chapters/contentsprefaceexecutivesummary.pdf, accessed September 2014.

tax in 2014 and raised it by 5% every year.[106] The IMF estimates that to limit warming to 2°C, the global tax of carbon should be $75 per ton by 2030.[107] The IPCC price estimates for a pathway below-1.5°C range from $135–6,050 in 2030, $245–14,300 in 2050, $420–19,300 in 2070 and $690–30,100 in 2100.[108]

The first attempt to implement a global cap and trade regime to reduce GHG emissions was embodied in the 1997 Kyoto Protocol, under which the developed countries committed to reduce their overall GHG emissions to 5% below their 1990 levels between 2008 and 2012.[109] In 2015, at COP21 in Paris, 195 countries signed what became known as "the Paris Agreement" – committing to reductions that, if executed, would hold warming in 2100 to about 3^0C. But in June 2017, President Trump announced that the United States would withdraw from the Paris Agreement, and by 2019 very few nations had made progress against their Paris commitments.[110]

In the absence of binding global commitments, some states and regions have imposed their own carbon taxes and cap and trade regimes. Currently, there are 57 such initiatives already in place or scheduled for implementation, covering around 20% of global GHG emissions. In 2019 the Canadian Prime Minister Justin Trudeau introduced a nationwide tax of $15 per ton, which is slated increase to $30 per ton in 2022. Most of the revenue will be refunded to citizens to offset higher energy costs. British Columbia has a $30 per ton tax. The North Eastern United States have a cap and trade program in place for power plant emissions which has reduced emissions by over 50% while generating more than $4bn in economic growth and reducing energy costs by $773m.[111] China is expected to start a national cap-and-trade program in 2020 and to cover around 30% of emissions.[112]

A number of countries have experimented with a range of other policies designed to reduce emissions. Many have offered subsidies to offset the costs of developing and producing renewable energy, such as simple lump-sum rebates or grants. Such policies can help to level the playing field as globally fossil fuels receive nearly $5 trillion in subsidies.[113,114] For example, in 2015 China led the world with $103 billion in renewable energy investments, 36% of the world's total,[115] and in the same year over 20% of China's energy generation came from renewable sources.[116] Many American states have imposed renewable portfolio standards, mandating that a certain proportion of electricity supply must be generated from renewable sources.[117] Congestion charging has led to significant reductions in car usage in places such as Singapore, London, and Stockholm. Tax credits have been used to incentivize investments such as renewable energy projects or residential efficiency improvements; and performance standards mandating the use of lower-energy technologies are found in many countries.[118]

Implications for the Private Sector

The risk of unchecked climate change presents the private sector with both risks and opportunities. Some observers fear that the financial markets are suffering from a "carbon bubble," caused by the fact that investors have not yet fully priced in the fact that much of the coal, oil and gas currently on balance sheets will never be burned, and that accessing climate change presents significant risks to much of the world's infrastructure that has not yet been fully accounted for.[119] One bank estimated that 40% to 60% of the current market value of the oil and gas sector may be at risk and noted that the top 200 companies in the sector have a total market value of $4 trillion.[120,121] In 2015, for example, General Electric paid $14bn for Alstom, a maker of the gas turbines used in gas fired powered plants, and two years later they paid $30bn for Baker Hughes, an oil and gas services company. Sales of gas turbines subsequently fell by more than 50%, and GE's power business came under enormous pressure. GE sold Baker-Hughes at a two thirds discount, and took a $23 billion write down for its power segment.[122] Between 2017 and 2019 GE lost over half of its market value, or about $500 billion.

In April 2019 Mark Carney, the governor of the Bank of England, and François Villeroy de Galhua, the governor of the Banque de France, issued a joint statement suggesting that the financial markets were significantly overpriced, drawing an analogy to the ways in which the banks overreached before the 2008 financial crisis, and warning that those companies and industries that failed to adjust to climate change might cease to exist.[123] These warnings were echoed by analysts who warned that investors were significantly underestimating the physical risks to which climate change exposes the economy.[124] The insurance companies Swiss Re and Prudential have declined to offer policies for properties at risk of coastal erosion attributable to climate change, and the Hartford Insurance company has announced that it will begin phasing out its relationships with coal producers. [125, 126]

In agriculture, widespread concern that climate change threatens the supply of key commodities such as tea, fish, and cocoa has led some of the largest firms to adopt sustainable farming and fishing practices. Many of the world's largest food companies believe this threat is compounded by the risk that being seen to contribute to climate change will increasingly become a public relations liability.[127] For example, in response to NGO accusations that they were contributing to deforestation, McDonald's spearheaded industry-wide efforts to preserve the Amazon rainforest; Unilever helped to found the Roundtable for Sustainable Palm Oil; and Kimberly Clark committed to sourcing 50% of wood fiber from natural growth forests by 2025.[128,129,130]

The threat of climate change also opens up enormous business opportunities. In the U.S., solar is now an $84 billion industry and employs more people than coal, nuclear, and wind combined.[131] In 2018 total global investment in clean energy was $332.1 billion and new solar and wind capacity was about half of all new energy generation.[132, 133] In 2019 India cancelled fourteen large coal-fired power stations because the price of solar energy has fallen so dramatically.[134]

Two million plug-in electric vehicles were sold last year, and sales are growing exponentially.[135] In 2018, the global electric car fleet increased by 2 million, reaching a total of 5.1 million cars Current projections suggest that by 2040 there will be 56 million electric vehicles on the road.[136] Tesla is now the most valuable automobile company in US history – more valuable than GM or Ford at their peak, and the firm is now worth almost as much as GM and Ford together.[137] Global automakers are reportedly planning to spend $300 billion on electric vehicle technology over the next 5-10 years.[138]

The market for alternatives to meat is expected to be a $140 billion industry within the next ten years.[139] In May 2019, Beyond Meat, which makes a meatless, plant-based burger with something very close to the taste and texture of real beef, had one of the most successful IPOs of the last ten years. On the first day of trading the stock surged 163 percent, and the company closed that day with a value of $3.83 billion.[140]

KKR, one of the world's largest private equity firms, claims to have saved over $1.2 billion in energy costs and now routinely requires every firm that it buys to undergo an energy and water audit because the financial returns to such audits are so high.[141] Johnson Controls had 2015 revenues of over $10.5 billion in its building efficiency business.[142,143] Schneider Electric, a $29 billion revenue global energy giant, recently repositioned itself as the "global specialist in energy management," aiming for 75% of its product revenue to be derived from products featuring its "Green Premium"™ eco-label.[144,145] The energy efficient light bulb business is now a $170+ billion industry,[146] while in agriculture, the micro-irrigation market is growing at double digit rates.[147] 25% of Wal-Mart operations are powered by renewables, and the company claims that from 2005 to 2016 its stores reduced energy use by 20% for a total savings of $1 billion.[148]

Many firms are finding that consumers are delighted when existing products and services become more sustainable. 73% of global consumers claim they would change their consumption behavior to

help the environment and 49% that they are willing to pay more for a product "from a company known for being environmentally friendly."[149] To date few consumers seem to be willing to actually pay more for sustainability, but those firms who have been able to persuade their consumers that going green doesn't mean giving up anything by way of quality or value have seen significant share gains. For example, in 2019 Unilever claimed that those of its brands that were "taking action for people and the planet" were growing 69% faster than their more conventional brands.[150]

Exploring Collective Action

The growing recognition that climate change is a problem that can only be solved through collective action has led a number of investors and firms to band together. Climate Action 100+ (CA100+), for example was founded in 2017 with the goal of persuading the world's one hundred most important carbon emitters to "cut the financial risk associated with catastrophe."[151] The group is an affiliation of more than three hundred investors who between them control nearly half the world's invested capital.[152] They have three goals. The first is ensuring that every firm in which they invest has a board-level process in place to evaluate the firm's climate risk and to oversee plans for dealing with it. The second is to have every company clearly disclose these risks while the third is to persuade each firm to take action to reduce GHG emissions across its value chain rapidly enough to be consistent with the Paris Agreement's goal of limiting global average temperature increase to well below 2°C.[153]

The group's work is done through a mix of public letters, formal and informal conversations with company management, and the filing of "shareholder resolutions"—investor proposals for action that are submitted to a vote of the entire shareholder base at the company's annual general meeting. Individual investors take responsibility for coordinating action with respect to a particular company, building a coalition among the company's investors to press for change. For example, in December 2018, a group of investors representing more than $11 trillion in assets published a letter in saying, in part:

> We require power companies, including power generators, grid operators and distributors, to plan for their future in a net-zero carbon economy. Specifically, we request companies to set out transition plans consistent with the goal of the Paris Agreement, including compatibility of capital expenditure plans. We expect explicit timelines and commitments for the rapid elimination of coal use by utilities in EU and OECD countries by no later than 2030, defining how companies will manage near-future write downs from fossil fuel infrastructure.[154]

In 2017, when President Trump declared that he was going to withdraw the United States from the Paris Agreement[155]—joining Syria and Nicaragua as the only countries not committed to taking action against climate change—the CEOs of thirty US companies, including those from Apple, Gap, Google, HP, and Levi Strauss—published an open letter urging him to rethink the decision. Elon Musk, the CEO of Tesla, and Bob Iger, the CEO of Disney, resigned from the President's Advisory Council in protest.[156]

"We Are Still In" is an even more ambitious collaborative effort that now includes "3,500 representatives from all 50 states, spanning large and small businesses, mayors and governors, university presidents, faith leaders, tribal leaders, and cultural institutions." It is committed to catalyzing action at the local level to ensuring that the United States meets its commitments under the Paris Agreement. [157]As of this writing more than two thousand businesses are signatories to the agreement, all of them formally committed to working with national governments and local communities to reduce GHG emissions. The coalition attended the international climate negotiations

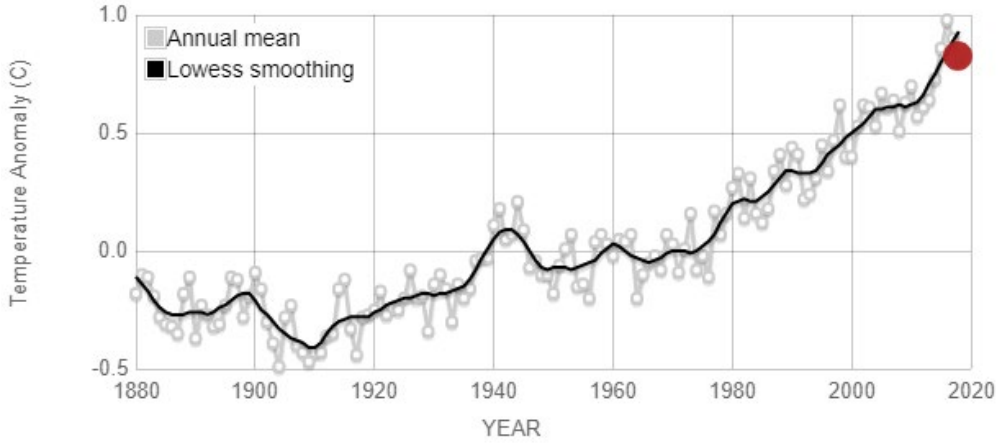
at COP25 in December 2019, acting as a "shadow delegation" and meeting with national governments and delegates to the conference to make the case for a strong set of rules to operationalize the Paris Agreement.[158]

Looking to the Future

Climate change is a systemic issue that has far-reaching consequences for global health, security, and prosperity. But despite continued efforts, the world's emissions continue to increase, and 2018 was the fourth warmest year on record behind 2016, 2017 and 2015.[d] Climate change mitigation will require a concerted global effort to enact systemic change, and many questions remain as to what shape such an effort should take. Should developed and developing nations be expected to participate equally in climate change reduction? How fast should such an effort move, and where should it focus? Will developing countries be able to leapfrog traditional energy-intensive development paths, or will they continue to face a trade-off between growth and low-carbon development? And what role should the private sector play in driving change?

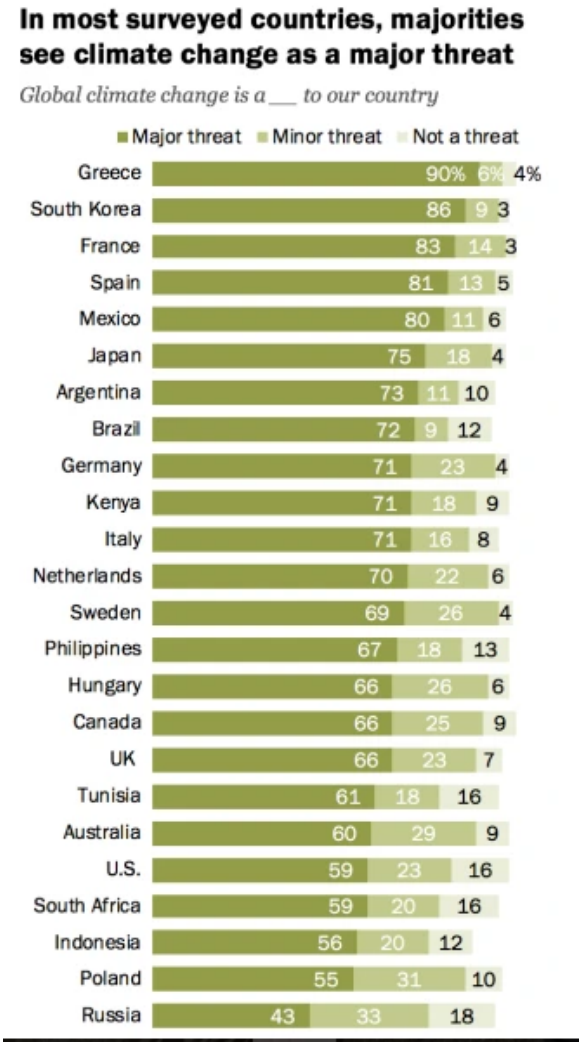
[d] https://www.theguardian.com/environment/2019/feb/06/global-temperatures-2018-record-climate-change-global-warming.

Exhibit 1 Global Land-Ocean Temperature Index, 1880-2019



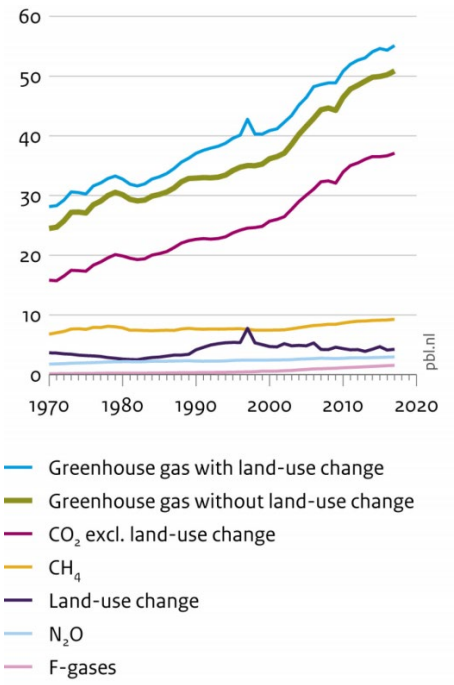
Source: NASA's Goddard Institute for Space (GISS), "Global Temperature," NASA website, http://climate.nasa.gov/vital-signs/global-temperature/, accessed October 2019.

Exhibit 2 Global public opinion with respect to climate change



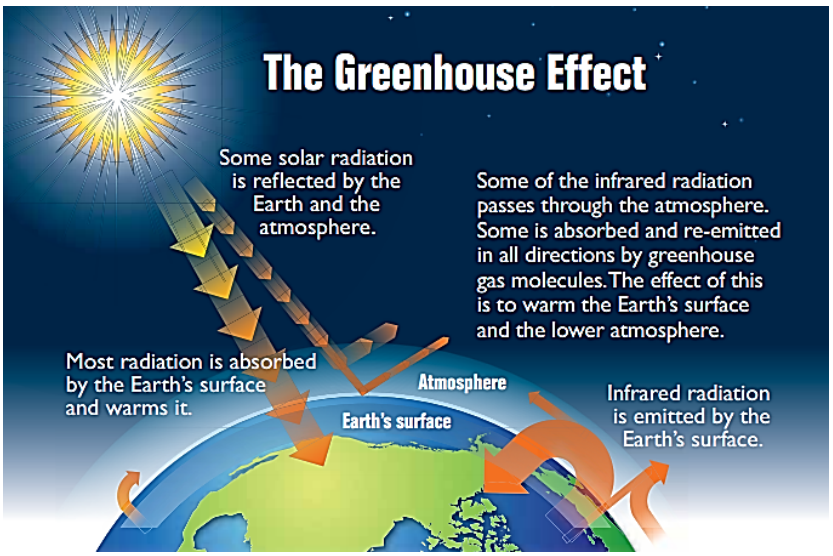
Source: Fagan, Moira, and Christine Huang. "A Look at How People around the World View Climate Change." *Pew Research Center*, Pew Research Center, 18 Apr. 2019, https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/, accessed January 2020.

Exhibit 3 Global greenhouse gas emissions over time



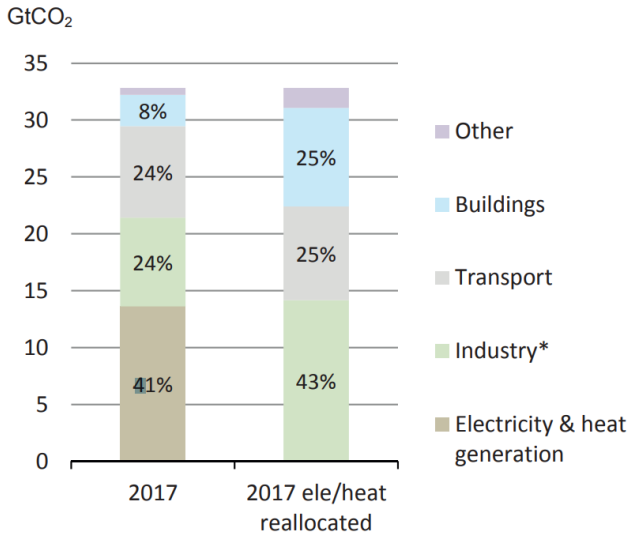
Source: Olivier J.G.J. and Peters J.A.H.W. (2018), Trends in global CO2 and total greenhouse gas emissions: 2018 report. PBL Netherlands Environmental Assessment Agency, The Hague. https://www.pbl.nl/sites/default/files/downloads/pbl-2018-trends-in-global-co2-and-total-greenhouse-gas-emissons-2018-report_3125_0.pdf, accessed January 2020.

Exhibit 4 Radiative Forcing and the Greenhouse Gas Effect



Source: "Climate Change Indicators in the United States, 2014," U.S. Environmental Protection Agency, 3rd Ed., 2014, p. 4, https://www3.epa.gov/climatechange/pdfs/climateindicators-full-2014.pdf, accessed May 2016.

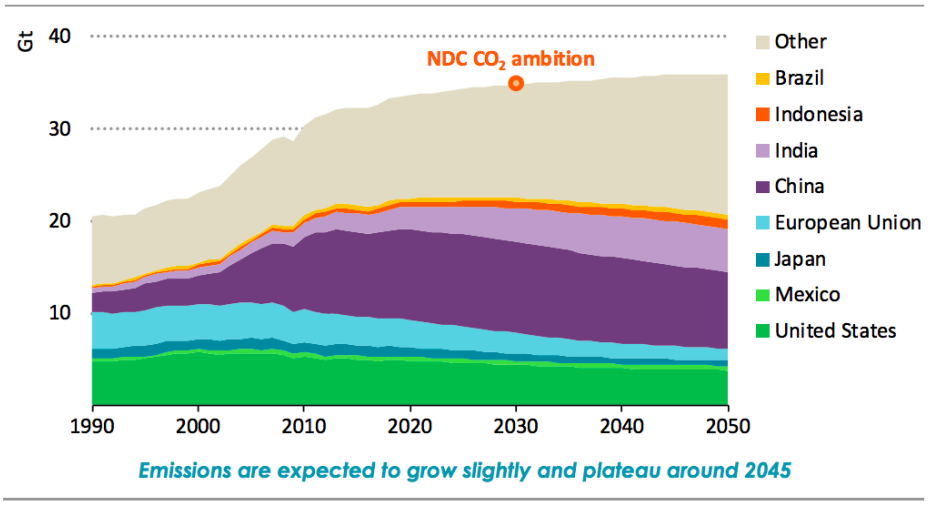
Exhibit 5 Global GHG emissions by sector, 2017



Source: IEA (2019), CO2 Emissions from Fuel Combustion: Highlights. All rights reserved. https://webstore.iea.org/co2-emissions-from-fuel-combustion-2019-highlights, accessed January 2020.

Note: * Industry includes also energy industries own use.

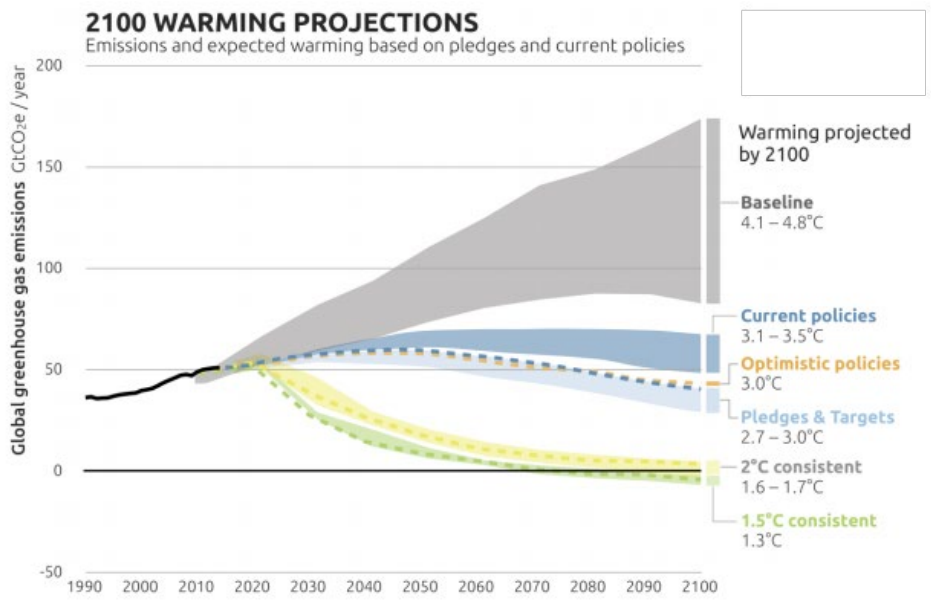
Exhibit 6 Energy-related CO2 emissions by region in the Stated Policies Scenario



Note: NDC = Nationally Determined Contribution.

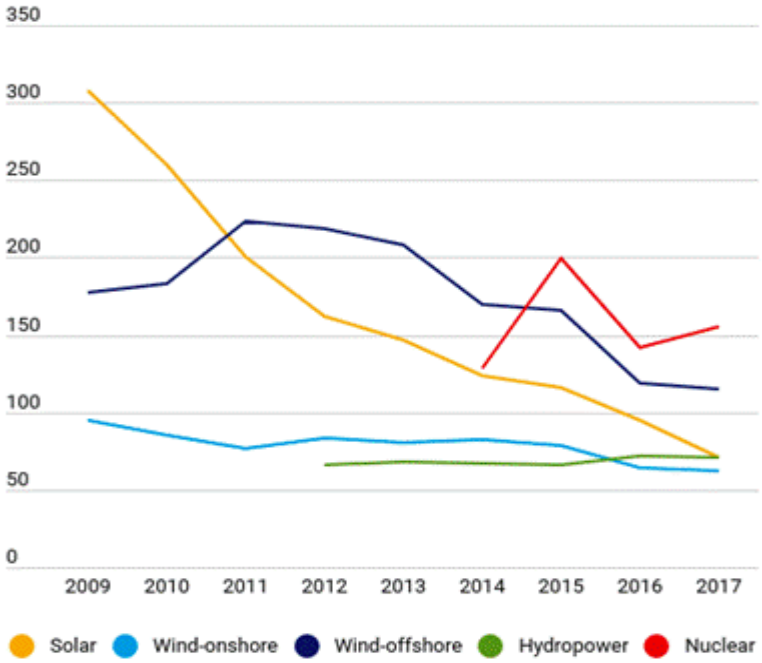
Source: IEA (2019), World Energy Outlook 2019. https://www.iea.org/reports/world-energy-outlook-2019. All rights reserved, accessed January 2020.

Exhibit 7 Global Mean Temperature Changes Forecasted Through 2100



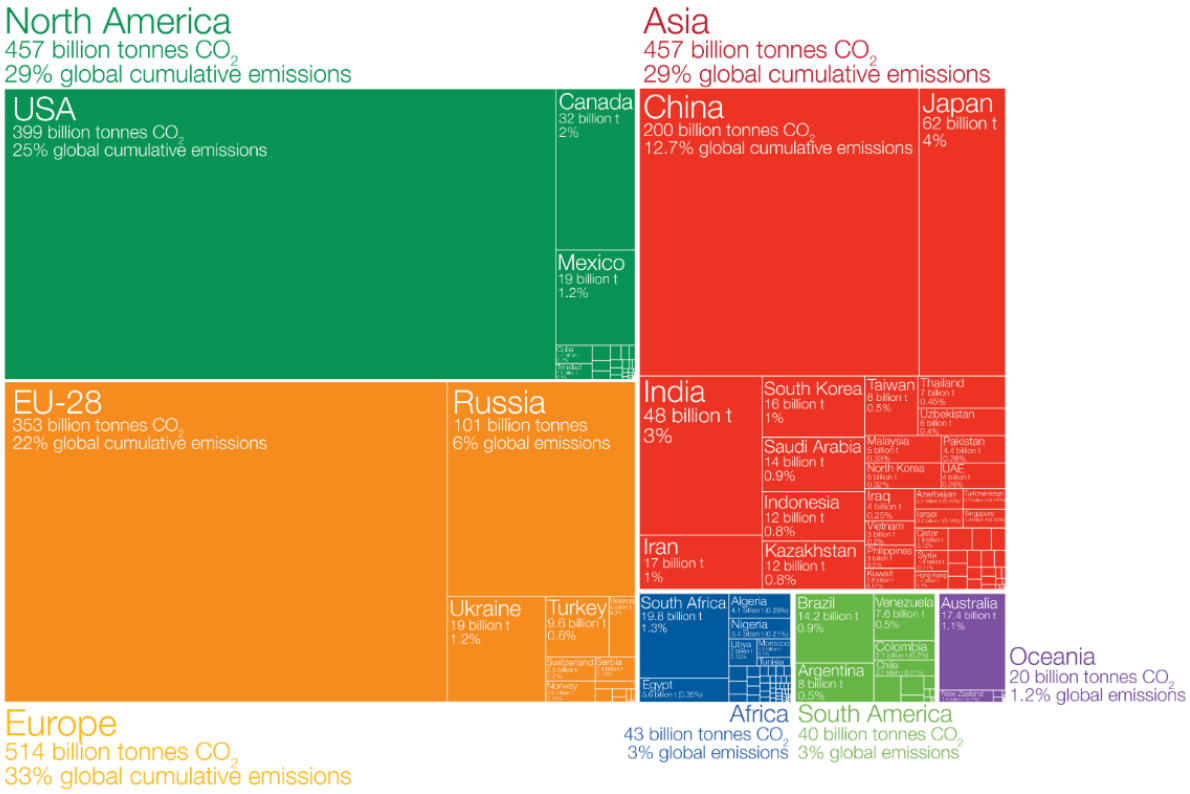
Source: Climate Action Tracker, https://climateactiontracker.org/global/temperatures/, accessed January 2020.

Exhibit 8 Falling costs of renewable energy, US dollar per megawatt hour



Source: Bloomberg New Energy Finance; Federal Reserve Economic Data, and IMF calculations; https://blogs.imf.org/2019/04/26/falling-costs-make-wind-solar-more-affordable/, accessed January 2020.

Exhibit 9 Cumulative CO2 emissions, 1751-2017



Source: Hannah Ritchie and Max Roser "CO_2 and Greenhouse Gas Emissions," Global Carbon Project; OurWorldinData.org, https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions, May 2017. Accessed January 2020.

Appendix A: A pathway to "net zero"

Reaching "net zero" – or a world in which net GHG emissions have fallen to zero, requires replacing fossil fuels, radically reform global agriculture and land use, replacing chlorinated gases for applications such as refrigeration and capturing the CO2 resulting from cement manufacture.

Replacing oil, gas and coal.

The first step towards full decarbonisation is to meet as many of our energy needs with electricity as possible. Transport is the most important single use of fossil fuels and almost all surface transport can be moved to electric power. So can much residential and commercial heating. Solar and wind power can provide most of this electricity. Although renewable sources are now as cheap, or cheaper, than new coal or gas power stations around the world, renewables only provide "intermittent" power while electricity networks need consistent availability. Batteries can help cover short gaps in availability but in their current form they are unsuitable for dealing with week or month long deficiencies.

One solution to this problem is to build far more renewable capacity than is necessary to meet maximum electricity demand. This would mean that even when the wind was not blowing or clouds were obscuring the sun, renewables supplemented by batteries should be able to provide continuous power. Under this scenario, most of the time renewables would be generating far more electricity than is needed. The surplus could be used to electrolyze water to create hydrogen. Hydrogen can be stored for later use. It can then be used to power turbines to make electricity, to substitute for natural gas in heating buildings, to provide the heat necessary for making materials like steel and cement and as the key ingredient in making synthetic fuels for activities such as aviation and heavy shipping that cannot be easily switched to electric power. Hydrogen can also be used to make green petrochemicals to replace existing plastics.

Hydrogen can also replace natural gas in heating buildings. Some homes and offices can be converted to electric heating, probably using highly efficient heat pumps. Others can use a centralized source that pipes hot water to the house. 'District heating' provides most of the heat for homes in Sweden, for example. It will also be vital to hugely improve the energy efficiency of the existing building stock by, for example, installing much more insulation.

The physics of cement manufacturing is such that it inevitably produces CO2. This will need to be captured to make the process carbon neutral.

Food and land use

Agriculture and land use change are the most important sources of greenhouse gas emissions after fossil fuel combustion. Estimates vary substantially, but most sources suggest that up to a quarter of climate changing gases arise from food production. Deforestation adds to this number.

Agricultural emissions are principally caused by methane (a greenhouse gas with a more powerful short term effect than CO2) which comes from fermentation in the stomachs of ruminant animals such as cows, the cultivation of rice in paddies and the rotting of animal manures. The adoption of a diet that largely avoid meat, particularly beef, is the single most important means of reducing greenhouse gases from the food system. It is also important is to shift agriculture away from a reliance on chemical fertilizers, since when conventional fertilizers are used on soils they often result in emissions of nitrous oxide, another powerful greenhouse gas.

One consequence of cutting the amount of meat production is that vast amounts of land will become available and the pressure on global forests will diminish.[159] One-third of global arable **land** is **used** to grow animal feed, while 26% of the Earth's ice-free terrestrial surface is **used** for **grazing**.[160] Switching large portions of this space to growing trees would provide many benefits, including natural carbon capture by photosynthesis. This would help counterbalance remaining emissions.

Other important steps

Reducing consumption – particularly of clothing and electronic goods – through better design and the development of a fully "circular economy" will make achieving net zero immensely easier.

There will almost certainly be emissions that cannot be easily decarbonized Substantial reforestation will help absorb these emissions but it will probably still be necessary to capture CO2 directly the air. A small number of companies are already pioneering the technologies for achieving this but it remains expensive. One leading innovator has suggested that costs may eventually fall to less than $100/tonne.

Ensuring that moving to net zero does not further exacerbate inequality

Moving to a 'net zero' world will require huge capital investments, particularly in energy generation, that will need to continue for several decades at a rate of several percent of GDP per year. Existing energy assets worth many trillions of dollars will eventually become valueless. The livelihoods of many people will be lost. At the same time, new opportunities will arise for employment and entrepreneurship. If the transition is to succeed it is critically important that societies manage these changes in ways that protect and improves the living standards of the less well off. Carbon taxation, for example, will need to be implemented in ways that do not reduce living standards. The good news is that by relocalising energy generation and food production, moving to net zero has the potential to be profoundly beneficial to local communities.

Source: Summarized, with permission, from Christopher Goodall, "What We Need To do Now." Profile Books, 2020.

Note: See also "Stabilization Wedges," Carbon Mitigation Initiative, Princeton Environmental Institute, Princeton University, https://cmi.princeton.edu/wedges, accessed September 2019.

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