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Copenhagen Institute for **Futures** Studies
Instituttet for **Fremtids**forskning

Members' report 1/2020

VISIONS OF A GREENER WORLD

SOLUTIONS FOR TACKLING CLIMATE CHANGE

SUMMARY

A range of solutions to mitigate climate change exist or are on the horizon. Some are well-known, others more novel, and they vary in effectiveness. This report aims to cut through the noise and provide a comprehensive survey of current and future climate solutions, their potential impact and the challenges we need to overcome if they are to be successfully implemented.

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FOREWORD

Pictet Asset Management has been working with the Copenhagen Institute for Futures Studies (CIFS) for over a decade to establish a deeper understanding of megatrends – the powerful secular forces that are changing the environment, society, politics, technology and the economy.

CIFS is a leading global think tank and consultancy. CIFS uses a wide range of research methods, developed over the last 40 years, which include megatrend analysis, scenario planning, risk management, innovation initiatives and strategy development.

Through our partnership with CIFS, we have devised an investment framework that incorporates CIFS' 14 megatrends. The framework – which includes trends such as Demographic Development, the Network Economy, Focus on Health, Sustainability and Technology Development – enhances our thematic equity capabilities and informs the construction and development of our thematic equities strategies such as Water, Robotics or SmartCity.

As CIFS' partner, Pictet Asset Management has access to research into areas not normally covered by the investment analyst community such as changes in societal attitudes and beliefs, the impact this has on the environment and the business sector, and the acceleration of technological development. We are proud to be associated with CIFS and would like to share some of their research with you. We have sponsored this publication and hope you find it as insightful as we do.

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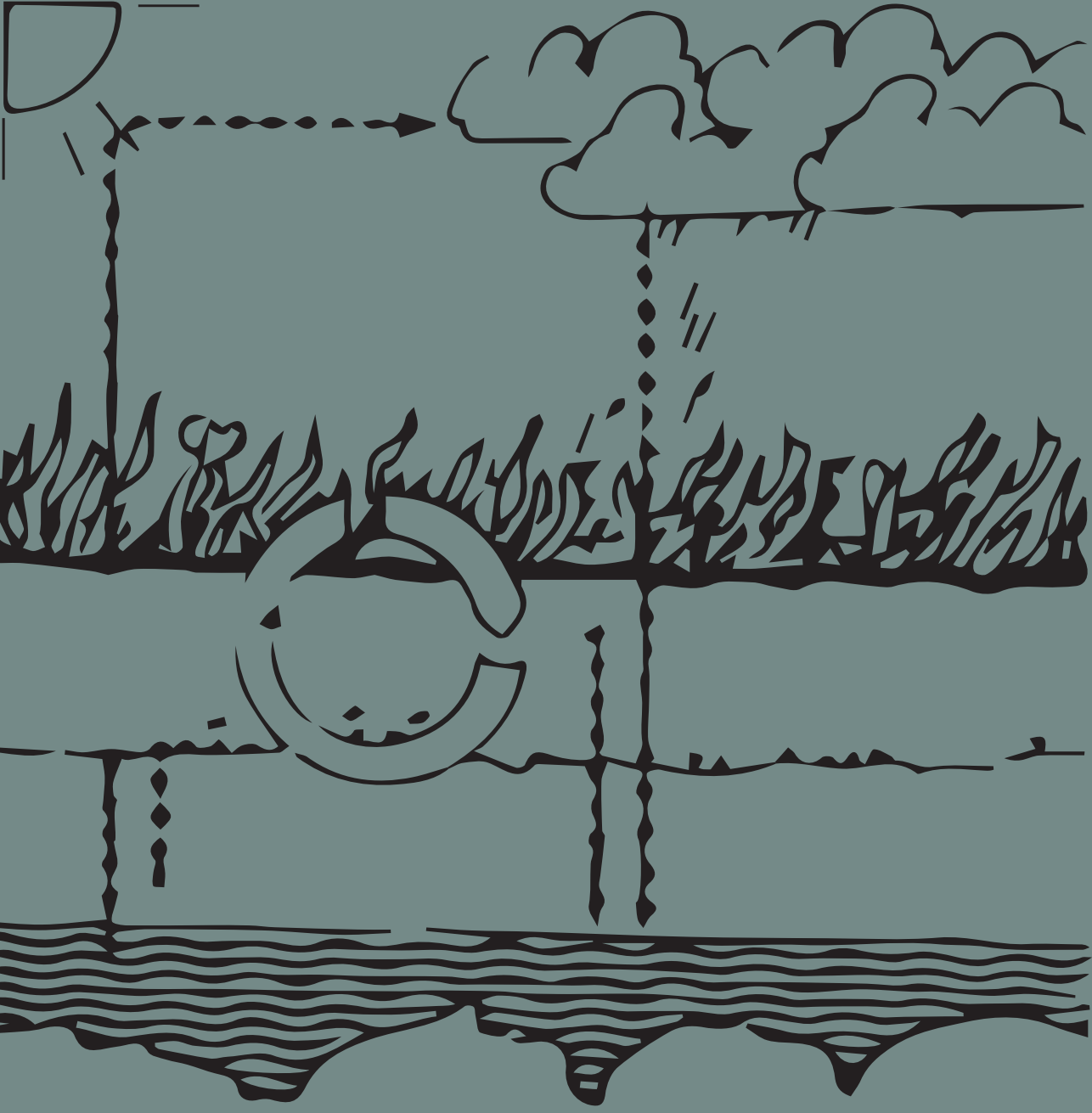
VISIONS OF A GREENER WORLD

SOLUTIONS FOR TACKLING CLIMATE CHANGE



INTRODUCTION

Sustainability and climate have become mainstream topics in media, in board rooms, in classrooms, in parliaments, and in UN assemblies. And yet, we have rarely talked so much and done so little. In the meantime, global emissions hit another record high last year, albeit growing at a slower rate than in the past. If we had been experiencing an intensifying severity and frequency of symptoms to our mental or physical health, we would seek the guidance of a physician. If the symptoms were cause for serious concern, we would get a second opinion. My guess is that by the time we had asked nearly every expert in the world and 97 percent of them had told us the same thing, we would take their advice and do things differently. Or assume the same number of auto mechanics told you that your car was becoming a hazard to your own and your family's safety; wouldn't you spend the money necessary to get it fixed?

According to Global Footprint Network, humans annually spend an ecological resource equivalent of 1.75 Earths. Considering we only have one globe, we must be borrowing the rest from somewhere and someone. Being blunt, with those kind of numbers in mind, one can characterise our inaction and lack of adjustment to the obvious challenges as colonising our future. Think about it: colonisation is about 'settling' in foreign territory and exploiting its natural resources as raw material for your own benefit. For sure the future per se is not ours; the present is, but if the carbon budget is an intertemporal resource, one we share with the generations to come, and every year we come up three-fourths of a planet short for our actual needs, the way we devour resources we are certainly colonising the future.

With that in mind, one can only wonder why for some reason, we continue to stall. Sir Nicholas Stern, a professor at the London School of Economics, asks that very same question in his 2015 book with almost that exact title: "Why are we waiting?". Professor Stern underscores what needs to be done, and in order to stay within the 2 °C warming limits set out in the reports by the United Nations Framework Convention on Climate Change (UNFCCC) as the most sustainable

paths, it will require us to achieve zero emissions from electricity around mid-century, zero total emissions by the end of the century and be emission negative in major sectors well before the end of the century. In other words, things have to change, significantly. The good news is that there is an array of solutions and tools at our disposal. Some are technological, some behavioural, some political, and others economic or legal.

In 2014, the American environmentalist and entrepreneur Paul Hawken founded Project Drawdown with the aim of shifting the global conversation about climate change from 'doom and gloom' defeatism to one of possibility, opportunity, action, and empowerment. Today, the project includes a team of scientists and advisors who work to measure and model the most substantive solutions to stop global warming and to communicate those findings to the world. As part of the communication, Project Drawdown has identified the 100 most substantive solutions to prevent climate change and reverse global warming. What may come as a (positive) surprise when one reads the list is the fact that many of these key solutions are not strictly technological, but rather rely on education, behaviour, or applied practices in activities such as land-use or agriculture. Educating girls and family planning make it to spots 6 and 7 on the list of key solutions with the greatest potential for positive impact on climate. At first glance, this doesn't seem like an obvious solution. But increasing the education level of girls and women, especially in the poorer regions, increases the chances of girls having fewer and healthier children, which in turn, has a substantial impact on climate change. Among the recognisable and more conventional solutions on the project's list are solar farms, which follow in 8th place while other 'favourites' such as offshore wind turbines and electrical vehicles land in places 22 and 26, respectively. But perhaps one of the most surprising solutions is solidly ranked as the 3rd most effective option, namely reducing food waste. On the one hand it is an encouraging message, as this is very much something within our grasp to do something about, but on the other hand, that same notion makes it an embarrassment, not to mention the fact that eradicating famine remains another human goal. But if anything, research

like that goes to show that for one, we can not and shall not rely on technology alone, and second, that some of the change is merely a question of doing things differently. This is where our optimism is the highest. This is where the globe deviates from the analogy of the terminal patient or worn-down car. We still have a choice to start doing the right things and doing them correctly.

In this report, we try our best to balance the urgency we believe the issue contains and the many options we still have to decide the path we will end up taking. For starters, we try to imagine a future scenario by 2040 in which we have succeeded in our efforts to curb the current developments, because we believe that imagining success is the first step towards achieving it.

At the same time, we appreciate that there is a myriad of reports and research written by experts within their fields. Most of this research and advocacies have also been passionately debated between those who agree and those who see things differently. But in these heated debates, and due to information overload, it can at times be hard to sort through the noise and know what's what. In part 1 of this report, we present some of the often-debated solutions together with the viewpoints of those in favour and those who speak out against them.

In part 2, we address some of the myths often spun in political discourse and social media spaces, which at best divert our attention from the real issue but have a much graver risk of misguiding pubic opinion and consequently crucial decision- and policy-making.

The ultimate aim of this report is to acknowledge the severity of the situation but also to shed some light at the end of the tunnel. In our attempt to do so, we believe it is important to align our view with the facts and realities and the scientific consensus, dispersing of half-truths and mere gut-feelings. Despite what one of the current prominent world leaders may think, we do not believe that you can have 'an instinct for science'.

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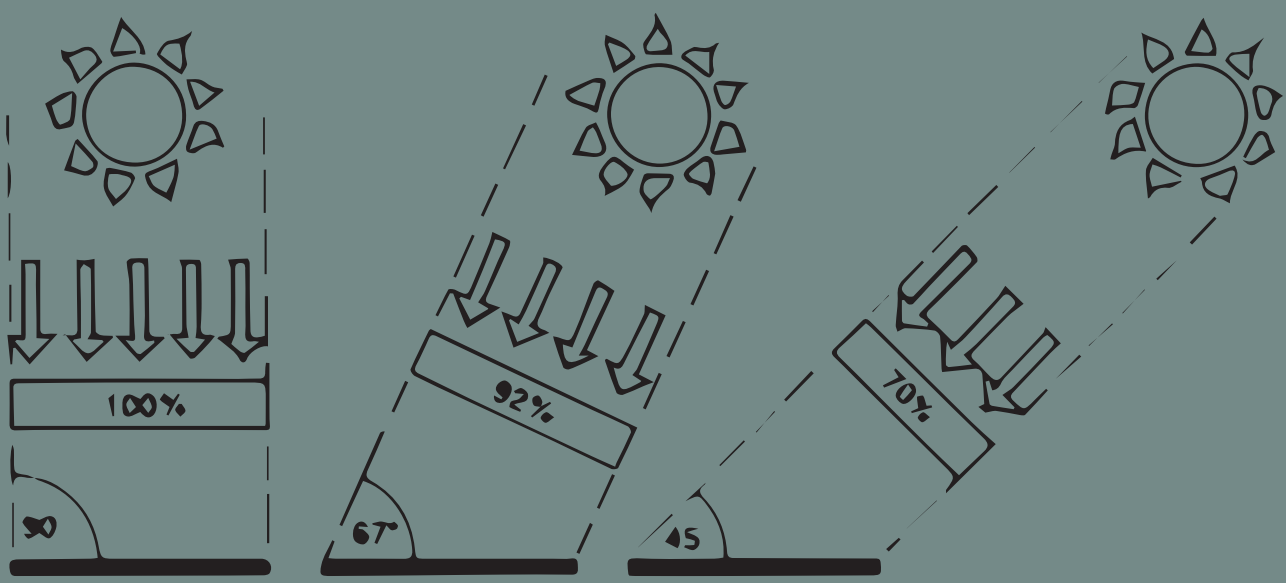
2040:

HOW WE SAVED THE WORLD



The following is a scenario of what the world may look like in 20 years if we take drastic action to limit climate change. It is not a prediction of the future; nor is it the only possible scenario – and probably not even the most likely one. It is meant to illustrate what it will take to get climate change under control before the end of the century and prevent the worst disasters.

It took a while for governments and the global community to come around, but as extreme weather events became more frequent, it drove widespread concern. As forest fires, hurricanes, floods, and droughts became more common, and each year set new weather records, people started to push politicians for change. The recognition that a global climate crisis was underway paved the way for global consensus to leave a planet better and more sustainable for future generations.

Since the implementation of the Paris Agreement in 2016, the world steadily moved away from a fossil fuel-based economy and set ambitious targets to reduce the global carbon footprint. One of the first acts of the newly-elected Democratic US President in 2021 was to re-join the Paris Agreement, and the 2024 election for the European Parliament increased the representation and power of green parties, initiating a massive reboot of investment in mitigating climate change. The global political community has managed to regulate CO_2 emissions through high carbon taxes, which have concurrently enabled a fast transition toward a low-carbon global economy. The rapid shift away from a carbon-intensive economy has disrupted industries that failed to adapt, while investments in more sustainable technologies drive wide-spread industry integration.

It's not just politicians who have begun to take action. Citizens around the world pay closer attention to environmentally sustainable behaviour on all levels of society, politics, economy, and personal behaviour. 'Less is more' and 'quality over quantity' have become the guiding principles in consumption. Corporations that

practice planned obsolescence face boycotts, and the fashion industry focuses more on catering to consumers' individual style choices than accelerating seasonal cycles. Disposable plastics and cardboard have given way to more sustainable and recyclable packaging. There is a demand for innovators who can create new system designs and forge new partnerships and collaborations across the value chain. Companies collaborate to integrate circular economic principles throughout the supply chain to comply with new regulatory frameworks.

By 2040, CO_2 emissions have been greatly reduced. Electrical devices run on energy from renewable power sources, and improved insulation, rooftop solar panels or wind turbines, and low-energy solutions have made new and renovated homes carbon neutral. The sale of diesel and petrol cars in Europe took a steep dive beginning in 2030. Food is increasingly plant-based and food waste has been reduced considerably. Meat and dairy are still diet staples, but mainly come from organic free-range farming with natural fertilisation and high biodiversity. This comes with a cost, but it is a cost that most consumers are willing to pay.

Taxes have shifted to being more consumption-based; products you buy are taxed according to their externalities. As a consequence, air travel has seen a steep increase in price. Recycling has become much easier with robotic waste-management, and strict design criteria has made waste the new gold. For brands, carbon neutrality has become a hygiene factor. A Louis Vuitton handbag is not just made from the highest quality raw materials; it also comes with 10 tonnes of CO_2 abated and the slogan 'Proud wearer of Louis Vuitton'. The carbon market has become more efficient and carbon prices are 10 times their 2020 rate and pegged against the price of CO_2 removal – it is just as expensive to release CO_2 as it is to capture and store it.

Even in this best-case scenario, we still have a long way to go before getting where we want. Fossil fuels are still responsible for two-thirds of our energy production, and while that is a huge step forward compared to the 85 percent in 2020, overall energy production has increased to accommodate the growing world population and not least, the growing global middle class, so the overall use of fossil fuels isn't much reduced. Still, almost all new energy production comes from renewables, and a sizeable percentage of old fossil-fuel plants have been equipped with direct air capture CO_2 removal (DAC), catching CO_2 at the source before it is released into the atmosphere, to be stored underground or turned into useful products. It is very expensive but necessary if we are to avoid catastrophic climate change in the coming decades.

The cost of renewable energy – solar, wind, hydroelectricity and geothermal – has been reduced to the point where it makes little sense to build new non-renewable energy plants for electricity and heating. The compactness of fossil fuels still makes them a viable choice for vehicles, but electricity, biofuels, hydrogen, and various hybrid solutions are rapidly taking over the market for automobiles, trucks, ships, and even lighter airplanes. Renewables are increasingly used for local energy production, even at the household level, in developing countries that lack a strong, centralised energy infrastructure.

Efforts to replant forests and greening cities have begun to take effect, and the world is greener than it was 20 years ago. The rapid loss in biodiversity has been halted in many regions, and wood and fast-growing crops like bamboo and industrial hemp are quickly becoming alternatives to less climate-friendly materials like concrete, steel, and plastics. Projects are also underway to restore coral reefs and remove plastics from our oceans, seeing as marine plant life is responsible for the main part of the natural carbon capture and oxygen production in the world.

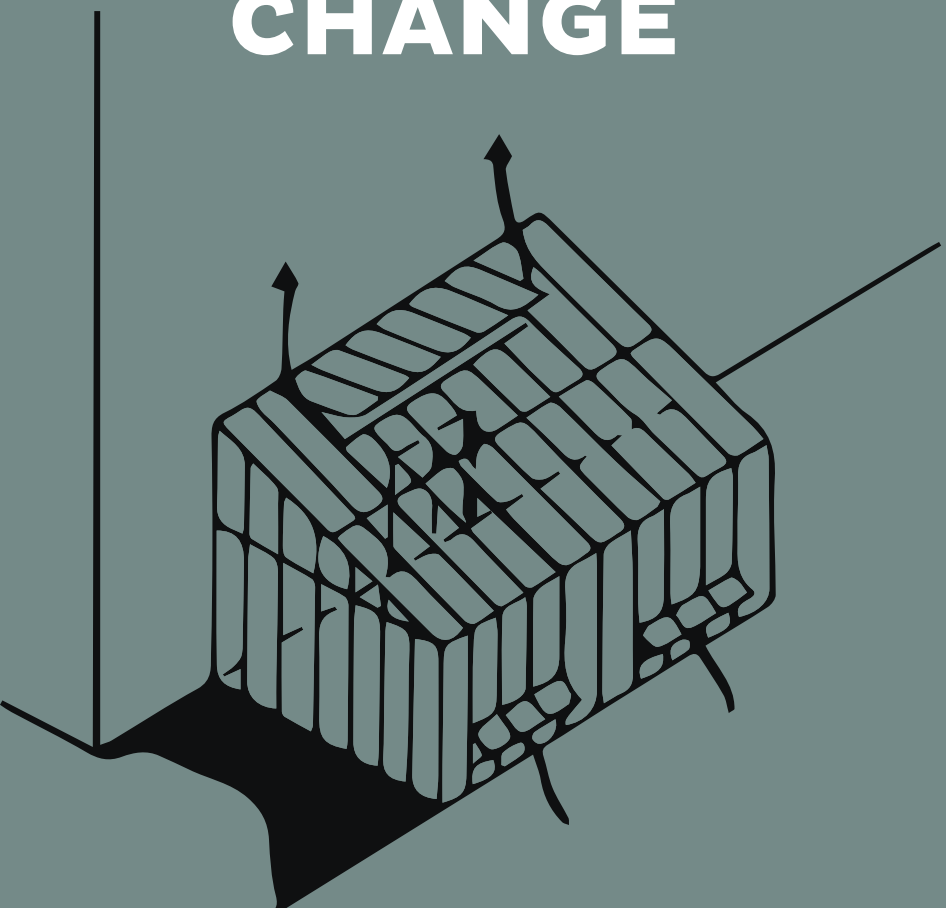
Even with all these efforts, we still see more extreme weather events – hurricanes, flooding, droughts, and heat waves – than 20 years ago, and we can look forward to even more in the future. Coastal cities and infrastructure are being strengthened against storms and rising sea levels, and cities in equatorial regions are preparing for extreme heat as well as levels of rainfall ranging from zero for months on end to raging torrents in just a few days.

Crops are very susceptible to climate change, and with a growing world population, food security has become a global priority. Scientists around the world are hard at work breeding or genetically modifying crops that can better handle extreme weather and more saline conditions – or that just have higher yields. The greater use of GM crops is being met with resistance from some consumers and activist groups, but most people realise that the alternative is likely mass starvation.

In recent years, we have seen a rising number of refugees and migrants from regions devastated by the effects of climate change. The countries that are hit the hardest by climate change are also the ones that can least afford to invest in climate resilience. Most advanced economies realise this and provide aid to vulnerable countries and regions, hoping to reduce the number of refugees. Still, more funds are spent blocking climate refugees by building walls, patrolling waters, or erecting other barriers than are spent on preparing exposed countries for climate change. Some things, it seems, are hard to change.

PART 1

SOLUTIONS FOR TACKLING CLIMATE CHANGE



In order to arrive at our best-case scenario for 2040, drastic action will need to be taken across nations and industries. In this part, we discuss a range of possible climate solutions and evaluate their possible impacts, as well as the most frequently made arguments for and against. Some of the solutions, like a shift from fossil fuels to renewable energy, are familiar, while others may be overlooked. No single solution by itself can stave off climate change by itself, and it will be necessary to use a wide palette of approaches. Even with that, we may need levers which do not yet exist.

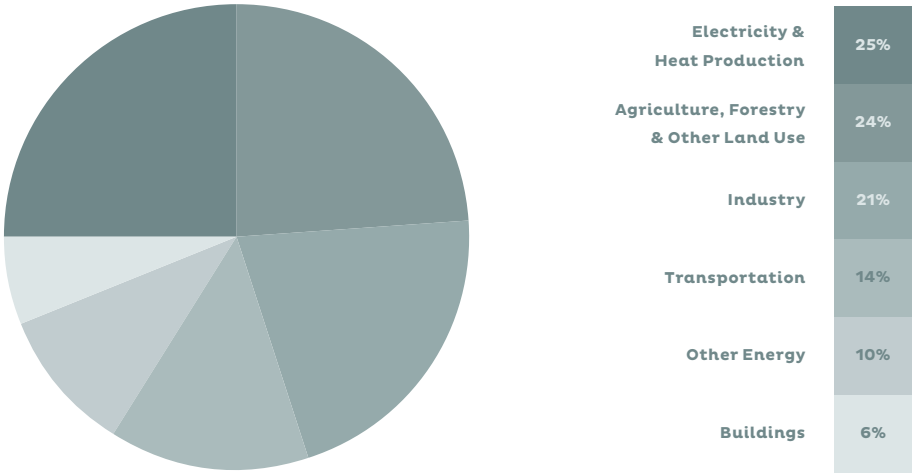
REDUCING GREENHOUSE GAS EMISSIONS

The greatest cause of global warming is the atmospheric content presence of greenhouse gases, of which carbon dioxide (CO_2) is the most important; not because it is the most efficient greenhouse gas per volume, but because it is the largest contributor due to the magnitude of annual emissions. An estimated 76% of greenhouse gas emissions is carbon dioxide, followed by methane (16%) and nitrous oxide (6%), with fluorinated gases making up the remaining 2%.[1] Reducing greenhouse gas emissions may be the most important step in combating climate change. In just 120 years, global emissions of carbon dioxide have increased 15-fold, from 2 billion tonnes in 1900 to over 36 billion tonnes today. The current concentration of CO_2 in the atmosphere is now well above 400 parts per million (ppm). In the 800,000 years before the Industrial Revolution, it never exceeded 300 ppm.[2] The major part of carbon emissions comes from fossil-fuel use and industrial processes, while methane and nitrous oxide emissions are mainly associated with farming and waste management. There are a number of known approaches to reducing greenhouse gas emissions. In the following, we will examine and discuss them.

Shift to renewable energy

Energy production, including that which is used for transport, is the main contributor to global CO_2 emissions.

FIGURE 1.1: **GLOBAL GREENHOUSE GAS EMISSIONS BY ECONOMIC SECTOR**



Source: IPCC.

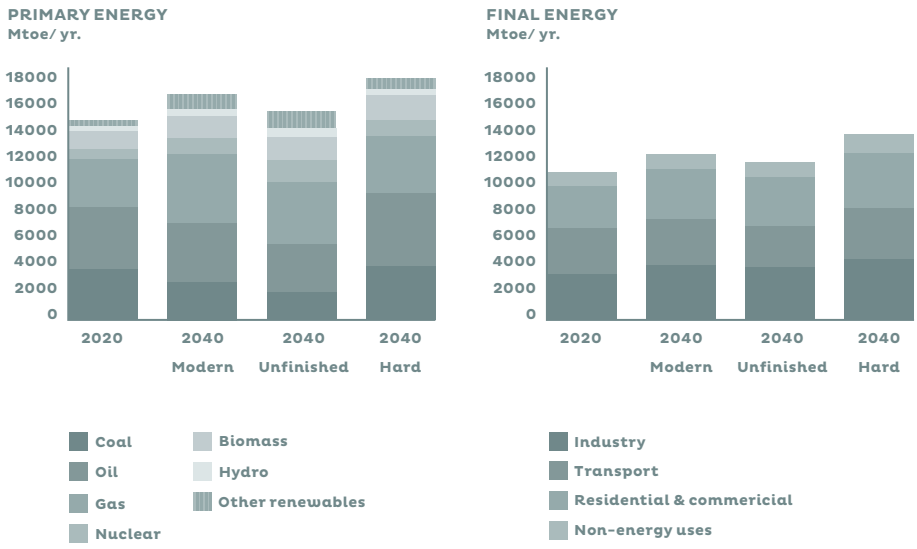
According to studies by BP,[3] 85.2% of global energy consumption in 2018 came from fossil fuels (oil, coal, natural gas), with hydroelectricity supplying 7.8%, nuclear power 4.4%, and renewables 4.1%. A shift in energy production towards clean sources thus has huge potential towards reducing CO_2 emissions. However, with a growing world population and growing global middle class, overall energy consumption is expected to rise, and in two of three energy scenarios for 2040 by the World Energy Council,[4] the use of fossil fuels is also expected to rise, even though clean energy is expected to be responsible for a growing share of energy production (see figure 1.2).

The most positive scenario, *Unfinished Symphony*, with a moderate reduction of fossil-fuel use, requires 'a strong, coordinated, policy-led world, with long-term planning and united global action to address connected challenges'. The *Modern Jazz* scenario features a market-led, digitally disrupted world with fast-paced and uneven economic growth, while *Hard Rock* features a fragmented world with inward-looking policies, lower growth, and less global cooperation. *Unfinished*

Symphony achieves a compound annual reduction of CO_2 emissions of 1.1% from 2020 to 2040; *Modern Jazz* achieves a 0.06% compound annual reduction to 2040; and *Hard Rock* experiences a compound annual increase of 0.6% to 2040. None of the scenarios lead to very significant reductions of carbon emissions, and even the most positive scenario leads to global temperature increases towards 2100 above the target of 2 °C.

A compounding factor is the world political picture we see when looking out the window in 2020. Indecisiveness and fragmentation on the part of the global community can serve either as an obstacle to achieving any tangible progress or as a strong warning and motivation to come together under this one global cause.

FIGURE 1.2: **PRIMARY ENERGY BY SOURCE (MTOE/YR.) AND FINAL ENERGY BY DEMAND SECTOR**



Source: The World Energy Council.

It is, however, possible to imagine a scenario with a more rapid shift towards renewables. The cost of solar and wind energy is declining rapidly, making sun and wind increasingly cost-competitive with fossil fuels. Solar power, in particular, has seen rapidly declining costs as a result of government policies, economies of scale, and research that has increased the efficiency of solar panels (the amount of incoming solar energy that is transformed to electrical energy) from 15% to 20% in less than a decade.

A widescale shift to renewable energy is among the most effective potential climate solutions. What are the arguments for and against this approach?

Proponents say: Renewable energy sources have low or zero CO_2 emissions, production capacity can be expanded quickly, and the energy cost is decreasing rapidly. Moreover, renewable energy production can be decentralised down to the household level with small solar panels, wind turbines, and biogas units, which may be especially important in developing countries with poor energy infrastructure and expected higher growth in per capita energy demand.

Opponents say: Renewable energy generation tends to be inconstant, depending on weather and season, and is hence not dependable. Excess energy can be stored for times with low production, but the capacity to do this is far from in place. In addition, wind farms and solar farms require a lot of space, often at the expense of nature or farmland. It is hence not realistic that all the world's energy needs can be met by renewable energy. Liquid or gas fuels made from renewable sources have far lower energy density than fossil fuels and are not as suitable for vehicles.

In 2018 alone, the global weighted-average cost of electricity from photovoltaic (PV) solar power dropped 13%, while electricity from concentrated solar power plants (CSP) dropped no less than 26%. Other forms of renewable energy also experienced declining costs in 2018, with bioenergy falling 14%, onshore wind falling 13%, and hydropower falling 11%.[5] The cost of geothermal energy and off-

shore wind only fell 1%, possibly due to greater establishment costs and slower construction rates. In comparison, the trend for cost of renewables has been a decrease of ca. 14% annual costs. Since renewable energy is already cost-comparative with the electricity generation from fossil fuels, an increased reduction of energy cost could eventually make fossil fuels obsolete, for example in a peak-demand scenario, providing that the capacity can grow to meet the needs. Obstacles could occur in diminishing returns as the most suitable locations for wind and solar power are already in use, or because there is a limit to how much economy of scale can drive down prices, or because gains in efficiency will peak, or because of nimbyism in public opinion, or lobbyism from fossil-fuel companies.

Nuclear power

Nuclear power is often touted as a clean, emissions-free energy source. While this isn't strictly true – there are emissions associated with the mining, milling, conversion, and enrichment of uranium, as well as reactor construction, reactor decommissioning, fuel reprocessing, nuclear waste disposal, mine site rehabilitation, and transport – nuclear is fairly clean, emissions wise, according to most (though not all) estimates.[6]

A major issue with nuclear power is the matter of nuclear waste, which can remain radioactive and dangerous to human health for tens or even hundreds of thousands of years – far longer than recorded human history. Then there are the – fortunately few – examples of reactor meltdowns, with the most famous being the Three Mile Island incident in 1979, the Chernobyl explosion in 1986, and the Fukushima Daiichi nuclear disaster in 2011. To this, we can add more than a hundred leaks and other accidents, with the majority occurring after Chernobyl. Even though few accidents have caused direct damage, the overall cost of an accident and clean-up usually comes to several million dollars, sometimes hundreds of millions. Then there is the issue, which often takes centre stage in political debates, of how fissionable nuclear fuel and radioactive waste may be weaponised for atomic and dirty bombs.

It may be possible to improve nuclear power plants to mitigate these issues. Terrapower, founded by Bill Gates, is a nuclear innovation company that strives to improve the world through nuclear energy and science.[7] A focus area of Terrapower is travelling wave reactors (TWR). Rather than relying exclusively on enriched uranium, travelling wave reactors are designed to use depleted uranium as a reload fuel. After starting with enriched uranium, the reactors can continue to run on depleted uranium for decades. Other innovative reactor designs like thorium

plants could also reduce the above-mentioned problems, and several projects indicate that we may have commercial fusion power within a few decades.[8]

A shift from fossil to nuclear power could help reduce emissions. What are the commonly used arguments for and against?

Proponents say: Nuclear power is clean, and though nuclear power today supplies less than 5% of our energy, it can be expanded to supply all our energy needs. Past problems can be solved with innovative design. Additionally, only three major accidents have occurred in over 17,000 cumulative reactor-years across 33 countries. The price of nuclear power can be lowered by mass production of plants. Nuclear power has the additional advantage compared renewables of securing a steady predictable supply of energy.

Critics say: Nuclear power plants are quite expensive, and building takes time, which makes nuclear power a slow and expensive solution to climate change, according to the 2019 World Nuclear Industry Status Report (WNISR).[9] The report also states that the cost of nuclear power generation has increased 23% over the last decade, making nuclear power more than three times as expensive as renewables today and likely even more expensive in the future. We cannot ignore the long-term issue of nuclear waste, and while processes with little or no long-term waste are possible, they may not be ready for several decades.

Dietary change and food waste reduction

According to Our World in Data, food is responsible for approximately 26% of global greenhouse gas (GHG) emissions, with roughly equal parts coming from land use, crop production, livestock & fisheries, and the supply chain (see figure 1.3 on page 20).[10] Many assume that eating local is key to a low-carbon diet; however, transport emissions globally only account for 6% of food's total GHG emissions.

A major contributor to emissions associated with livestock is that cattle produce

methane through their digestive processes (enteric fermentation). The methane is not produced by the cows themselves, but by microbes in their gut. While methane is a far more potent greenhouse gas than CO_2, scientists like professor Frank Mitloehner from UC Davis argue that methane arising from farming should be treated differently than long-lived greenhouse gases, such as CO_2 and nitrous oxide, because methane only lasts in the atmosphere for ten years or so, whereas CO_2 and nitrous oxide persist for several hundred years. With constant methane emissions, atmospheric methane content will soon level out, whereas CO_2 accumulates for centuries.[11] If cattle farming grows worldwide, however, the atmospheric methane content will grow proportionally, and research has indeed shown that methane has contributed to sea level increase over the last centuries.[12]

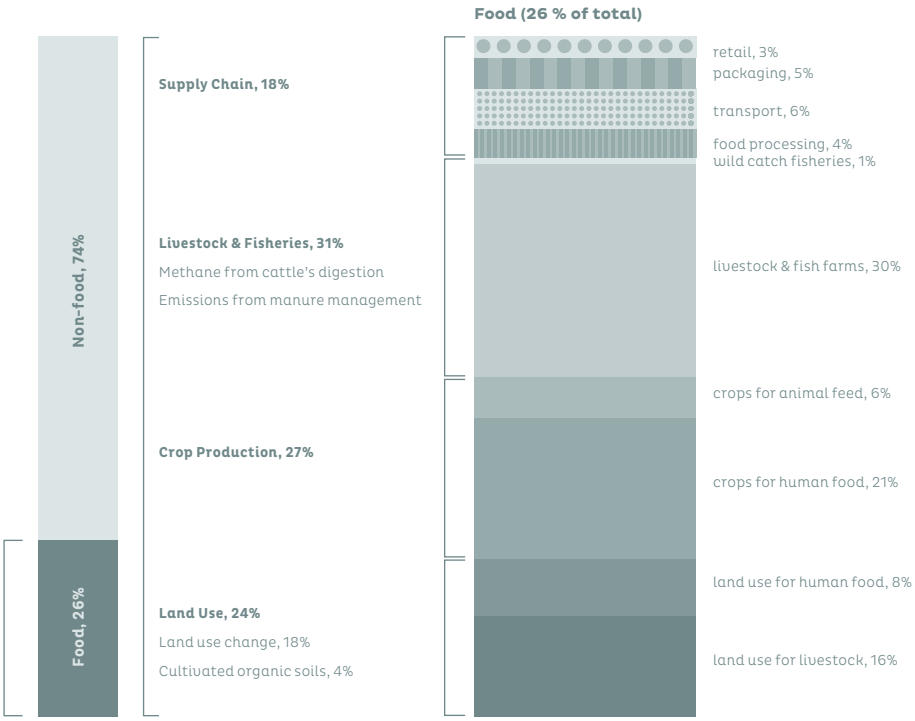
A lot of research is done to remedy cattle methane production through changes in diet and intestinal flora or through genetic engineering. There are several promising results, including adding a type of seaweed to feedstock that significantly reduces methane production, or breeding and/or genetically modifying cows to emit less methane.[13]

Genetically modified crops could also play a major part. For instance, genetic editing to fix a fault in photosynthesis has been shown to increase the crop yield of test crops by no less than 40%, reducing the need for extra farmland as the world's population rises. Crops have also been genetically modified to need less water.[14]

It is often suggested that we should change our diet to be more climate friendly. We should eat more insects in lieu of mammalian meat, or we should stop eating animal products entirely and go vegan. While the arguments are no doubt put forward in good faith, there are several barriers that hinder this approach from being very effective. On the contrary, foregoing meat entirely may not be very good for the climate. Cropland needs fertiliser, and we would need a lot more chemical fertiliser, which has a high climate footprint, to replace natural fertiliser from meat and dairy producing animals. In addition, land for grazing exhibits far greater biodiversity than cropland, especially if the cropland is sprayed with pesticides. For every three food products produced, one is wasted globally. Throughout the supply chain, from farm to fork, there are conversion losses of input, waste of capital, and emissions. Food waste accounts for roughly 8% of global emissions and is not limited to the developed countries; it occurs globally for different reasons and at different stages in the supply chain. In the developing regions, food spoils before reaching the final consumer and therefore, improving infrastructure for storage, processing, and transportation is essential. In the richer regions, food

remains unconsumed and expires; up to 35% of food in high-income economies is thrown out by consumers, calling for policies to drive change, including food-waste targets.

FIGURE 1.3: **GLOBAL GREENHOUSE GAS EMISSIONS FROM FOOD PRODUCTION**



Source: Our World in Data.

According to some estimates, a 50% reduction in food waste can be achieved by 2050, supported by the adoption of plant-rich diets, whereby avoided emissions

could reach 26 gt CO_2. Another 44 gt can be avoided as reductions in food waste lower the need for deforestation for additional farmland. The estimates are based on regional waste estimated from farm to household.[15]

Changes to food production and a decrease in food waste are potential climate solutions. What are the most commonly used arguments for and against?

Proponents say: We can significantly reduce GHG emissions related to food by radically changing our own diet and that of our livestock or by reducing food waste. Through genetic engineering, we can eliminate much of the climate footprint of livestock and crops – we just need to overcome people's fear of GMO.

Critics say: Changing people's diet takes time, and there may be nutritional problems (especially for children) with a predominantly plant-based diet. Persuading people to eat GMO food may be a hard sell, even if it benefits the climate. Also, how food production affects the climate is a very complicated issue,[16] and removing animals from farm ecosystems in favour of producing more crops may have serious climate issues of its own.

GEOENGINEERING

If we can't reduce CO_2 emissions, then maybe we can remove CO_2 from the atmosphere and store it or transform it into useful raw materials. Or we could find ways to cool the planet to offset global warming. This is the guiding principle of geoengineering. Effective geoengineering may mean that we don't have to limit our consumption of fossil fuels – and our consumption in general. In other words, it can be used as a last resort if we fail to limit CO_2 emissions due to short-sightedness or unwillingness to change our consumption patterns.

Planting forests and fast-growing crops

Deforestation contributes to rising CO_2 content in the atmosphere because it reduces the ability of nature to absorb CO_2. Furthermore, when forests are burned to make way for pastureland, carbon stored in trees is released back into the atmosphere. According to research by Our World in Data, tropical forest loss cur-

rently accounts for 8% of the world's annual CO_2 emissions in this manner – just below what the United States emits.[17] In 2018, the yearly rate of forest loss reached 260,000 km², or more than the area of the United Kingdom. This is an increase of 43% since 2014, which makes the UN goal to halt deforestation by 2030 look extremely unlikely to be met.[18] These numbers are from before the devastating 2019 wildfires in California, Brazil, and Australia. Estimated forest loss from the 2019 Australian fires alone are around 50,000 km².

Planting – or replanting – forests is a natural and inexpensive approach to geo-engineering that aims to reduce CO_2 in the atmosphere while helping to preserve biodiversity. However, a lot of trees will need to be planted for this approach to have a real effect. Thomas Crowther and colleagues at Swiss university ETH Zurich have calculated that planting 1.2 trillion trees could reverse one decade of CO_2 emissions.[19] This is a 40% increase over the estimated 3 trillion trees that exist in the world today, and more trees would have to be planted if deforestation continues at the current rate. In addition, it takes four decades for a typical deciduous tree to absorb 1 ton of CO_2, so this is no quick fix. In addition, forests absorb more sunlight than plains and farmland and themselves emit chemicals that may have a warming effect, offsetting some (or even all) of the climate benefits.[20] Trees can store CO_2 for decades or even centuries, but eventually, forests reach an equilibrium where as much CO_2 is released through rot and wildfires as is absorbed. To remedy this, adult trees can be cut down and used as building materials before they die. Furniture, walls, and floorboards can store carbon for many decades. Using wood as a construction material is thus a less obvious and low-tech but potentially impactful solution. Some cities have taken steps in this direction. An example is Seattle, where wood is utilised heavily in buildings in dense urban environments and permitting heavy timber building types up to 18 stories tall.

It matters what sort of trees you plant. A hectare of Douglas fir absorbs around 16 tonnes of CO_2 a year, while a hectare of oak only absorbs 8 tonnes. However, other plants grow even faster, with bamboo and industrial hemp being prime examples. They can be grown without toxic pesticides or herbicides and require little or no fertiliser. However, replanting hemp in the same field for more than three of four consecutive seasons can make the crop susceptible to pests and disease, which makes it necessary to rotate with other crops. Bamboo grows thick, crowding out other weeds and plants, and its fallen leaves are enough to nourish the soil. Both plants can be used for textile fibres superior to cotton, with a lower climate footprint, and for building materials, and hemp produces better-quality paper than wood pulp.

Planting forests and fast-growing crops can help reduce CO_2 levels. What are the typical arguments for and against this approach?

Proponents say: Plants are natural CO_2 absorbers, and planting forests have other benefits like preserving biodiversity, as well as psychological benefits. Plant-based materials are excellent alternatives to concrete, plastic, and other materials with a heavy carbon footprint.

Critics say: What the proponents say is true, but planting forests isn't a very effective way to combat climate change. It takes decades to have a significant effect, and by then, it may be too late to make a difference. The net effect of a building-with-wood value chain remains uncertain, despite the recognition of its climate potential, and some issues remain unsolved such as insects, deterioration, and the consistent treatment of wood.

Carbon capture and storage

Carbon Capture and Storage (CCS) is a technology that captures CO_2 emissions produced from the use of fossil fuels in electricity generation and industrial processes. CO_2 can even be extracted from the fuel before burning by turning the fuel into a mixture of hydrogen and CO_2, with the latter being pumped away. CCS implies capturing CO_2, transporting it, and securely storing it underground in depleted oil and gas fields or deep saline aquifer formations, which the Intergovernmental Panel on Climate Change (IPCC) says can retain 99% of the pollutant over a 1000-year period.

It is also possible to use the stored CO_2 as a raw material for various products, including fuel, plastic, and pure carbon.[21] Finnish company Solar Food even claims to be able to create a protein-rich food product simply by combining captured CO_2 with water, vitamins, and nutrients using solar power – though it is unclear what the sources of the vitamins and nutrients are.[22]

Proponents claim that 90% of the CO_2 produced when fossil fuels are burned to create electricity can be captured and stored. Captured CO_2 can be combined

with renewable biomass to create a 'carbon-negative' mode that goes one step further by removing CO_2 from the planet.[23]

A drawback of CCS is that every step of the process requires energy, which reduces its net effect. It can also be very expensive to establish. In addition, actual CCS facilities are far less effective than the hype would lead us to believe. For instance, the Petra Nova CCS project in Texas, finished in 2017, only captures 6.2% of the power station's CO_2 emissions, and an estimated 30% of that is lost before reaching the oil well where it is stored. Similarly, the $1.5bn Canadian Boundary Dam CCS project, which in 2014 became the first in the world to successfully use CCS technology, only captured about 600,000 tonnes of CO_2 during each of its first years of operation.[24]

Carbon capture and storage is a proposed method for lowering the amount of CO_2 in the atmosphere. What are the typical arguments for and against?

Proponents say: CCS may not be perfect, but it is the most cost-effective way to reduce atmospheric CO_2 content in the short and medium terms. Captured CO_2 may even be used to turn renewable energy into liquid fuel that can be stored or used in cars.[25] And frankly, reducing emissions alone is no longer enough, we need to be extracting some of the CO_2 already out there.

Critics say: It makes more economic sense to build up renewable energy production than to capture and store CO_2 from fossil-fuel energy. CCS projects are mainly attempting to greenwash coal- and oil-based energy generation.

A recent study by Mark Z. Jacobson from Stanford University finds that CCS reduces only a small fraction of carbon emissions, and it usually increases air pollution. Jacobson calculated the net CO_2 reduction and total cost of the carbon capture process of a coal-based electric power plant with carbon capture and a plant that removes carbon from the air directly. In both cases, he found that the equipment captured the equivalent of only 10-11% of the emissions they produced,

averaged over 20 years. His research also looked at the social cost of carbon capture – including air pollution, potential health problems, economic costs, and overall contributions to climate change – and concluded that those are always higher than not capturing carbon at all. Even when the capture equipment is powered by renewable electricity, Jacobson concluded that it is better, from a social cost perspective, to instead use the renewable electricity to replace coal or natural gas electricity or to do nothing.[26]

It is, however, worth noting that future facilities may be both more effective and less expensive. For instance, the proposed H21 North of England project will, as part of a greater plan, store 20 million tonnes of CO_2 each year by 2035, at an estimated cost of less than £6 per tonne,[27] a quarter of the 2019 cost of buying emission permission in the EU Emissions Trading System (ETS).

Solar radiation management

To counteract global warming, we may need to cool the planet by reflecting more sunlight back into space before it reaches the ground; something known as 'sun-dimming' or *solar radiation management* (SRM).

An often-suggested approach to SRM is shooting particles into the stratosphere – the layer of the atmosphere 10-50 km above sea level. This is known to work: When Mount Pinatubo erupted in the Philippines in 1991, it injected an estimated 20 million tonnes of sulphur dioxide into the stratosphere, creating a particle haze that cooled the planet by around 0.5 °C for about 18 months. While sulphur dioxide is very efficient at reflecting sunlight (an estimate says we could temporarily reduce the global average temperature by 0.2 °C for each million tonnes of sulphur dioxide injected the right way),[28] we may not want to inject millions of tonnes of sulphur into the atmosphere. Calcium carbonate, for instance, is a much safer alternative,[29] which may even counteract the acidification of air and sea that is a side-effect of some sorts of pollution. Spraying reflective particles into the atmosphere could cool the planet's surface by 1.5 °C at an annual cost of $10 million, according to one estimate.

Another approach is whitening clouds over our oceans by spraying seawater into them. According to Stephen Salter, Emeritus professor at the University of Edinburgh, spraying about 10 tonnes of seawater per second into the atmosphere from a fleet of robot ships could undo all the global warming damage we've done to the world up until now, at an annual cost of $100-200 million a year – less than it costs to host the annual UN Climate Conference.[30]

Other suggested methods of SRM aim to reflect sunlight from the Earth's surface, for example by painting roofs white, erecting reflective sheets in deserts, or planting crops with a higher albedo (reflectiveness), but it is generally agreed that these methods are insufficient. Finally, it has been suggested that we cool the planet by launching space mirrors that reflect sunlight even before it hits the atmosphere.[31]

SRM has been proposed as a method for cooling the planet and counteracting climate change. What are the most common arguments for and against?

Proponents say: We will have to consider solar radiation management because it is unlikely that we will reduce GHG emissions sufficiently to limit global warming. It also looks to be a cost-effective solution. Even if we stop all GHG emissions tomorrow, the already-elevated atmospheric content will continue to warm the planet for decades or even centuries. Solar radiation management may be the best, or even the only, way to reverse global warming.

Critics say: Reducing the amount of sunlight that reaches our planet's surface may have unforeseen consequences on the biosphere, e.g. reducing crop yield, and it will reduce the effectiveness of solar power. Since the effects are temporary, it will be necessary to keep spraying aerosols into the atmosphere to maintain the benefit, even at a constant GHG content. Ground-based methods are too inefficient, and space-based solutions too expensive. Besides, the promise of solar radiation management may reduce the willingness to reduce carbon emissions.

ECONOMIC AND LEGAL INSTRUMENTS

We often look to technology for solutions to the climate challenge, but there are other levers at our disposal. Just as industrialisation is one of the drivers of emissions and current environmental challenges, economic mechanisms such as the Gross Domestic Product (GDP) and traditional corporate valuations have fuelled the wealth and growth paradigm as we know it, which has led to the over-exploitation of resources, aggressive tax schemes, and inequality. But if

these elements were part of the problem, they may well also be part of the solution. We are already seeing significant shifts in investments away from fossil fuels, which in recent years has led to energy being the worst performing sector in the S&P 500. In 1980, oil and gas companies accounted for 28% of the index – last year they represented less than 5%.[32]

Policy and regulation

The more conventional economic instruments at our disposal are carbon taxes, carbon credits and trading systems, the reduction or elimination of subsidies supporting fossil fuels, and the introduction of subsidies to propel innovation to reduce carbon dependency. Eliminating fossil energy subsidies can be addressed both by the private sector in their investments as well as by governments through a policy of promotion of clean-technology research and development.[33] Meanwhile a tax of, say, $35 per tonne of CO_2 in 2030 would naturally increase prices for coal, electricity, and gasoline. This supports incentives for investment in low-carbon technologies, such as renewables. However, measures equivalent to an average global carbon price of at least $75 a ton—would be needed to reduce emissions to a level consistent with a 2˚C target. Subsidising renewable energy sources is an additional measure to pursue in conjunction with carbon taxes as well as implementing carbon emissions trading, which would allow companies to buy or sell a predetermined amount of quotas of carbon dioxide output.

Stricter economic regulation can be a solution to the over-exploitation of resources. What are the most common arguments for and against?

Proponents say: First of all, carbon taxes are a straightforward mechanism which can be integrated into existing tax designs on fossil products, in most countries. Additionally, they are an effective way of influencing the behaviour of consumers, as well as investors and businesses. Last, but not least, carbon taxes will generate revenue which can be channelled to offset potential effects of the price increases, such as unemployment or investment slowdown.

Critics say: A carbon tax, implemented only nationally or maybe even regionally, has the risk of leading to carbon leakage to countries or regions with less environmental restrictions, costing economic activity in the country of origin

and making no difference to climate change. Additionally, the 'yellow vests' movement in France, which was sparked by a removal of fuel subsidies, is just one example of the asymmetric effect punitive taxes may have in society, as it will disproportionally impact those who already have the least and hence spend a bigger share of their income on fuel and energy.

Beyond GDP

For sake of argument, consider a fully loaded oil tanker heading into port. Just before it reaches its destination, it suffers an incident which results in an oil spill. Now, intuitively we understand that an oil spill can hardly be a good thing, which is why it is even more absurd that it may actually be GDP positive, as a clean-up implies work and economic activity. Go figure. Similarly, the existing financial valuation mechanisms either do not, or only vaguely, reflect the externalities and costs they implicitly infer on the environmental, social, and governance (ESG) parameters. According to the European Commission, effectively and transparently measuring progress, wealth, and well-being calls for indices that are as clear and appealing as GDP, but ones that include social and environmental issues, a measure that goes Beyond GDP. Currently, a whole range of indicators exists in different countries, such as:

GNH – Gross National Happiness: Includes living standards, health, good governance, ecological diversity, resilience, time use, psychological wellbeing, cultural diversity and resilience, and community vitality.
TPI – Thriving Places Index asks if it is a fair and equal place to live. Is it sustainable enough so that future generations can flourish? Are the conditions present for everyone to do well?
HPI – Happy Planet Index covers ecological footprint, inequality, wellbeing, and life expectancy.
HDI – Human Development Index measures opportunity and capability, rather than just economic growth or environmental sustainability and compares expected years of schooling and the actual mean years of schooling, so that nations can see where communities fall short of expectations.
GGDP – Green Gross Domestic Product adjusts the measurements by monetising environmental damage factors to help countries better understand exactly where they stand environmentally.
GPI – Genuine Progress Indicator considers all the same factors as the GDP,

while also accounting for things like the cost of crime, ozone depletion, and lost leisure time.
BLI – The Better Life Index measures facets that are essential to wellbeing – housing, income, jobs, community, education, environment, civic engagement, health, life satisfaction, safety, and work-life balance.

Alternative metrics for measuring prosperity and progress have been proposed that include climate- and sustainability-related factors. What are the most common arguments for and against?

Proponents say: The Beyond GDP initiative is about developing indicators that are more inclusive of environmental and social aspects of progress, i.e. more sustainable. Considering the counterintuitive positive effects of negative events on GDP, we are in dire need of more adequate indicators to assess and address the global challenges of the 21st century such as climate change, poverty, resource depletion, health, and quality of life. In the end, 'you can't manage what you don't measure'.

Critics say: There are hardly any opponents to the idea of Beyond GDP; the problem is rather that despite its relatively long history (first measures after WWII), there is still no agreement on a common language, standard, or what components should be included and how. Perhaps the adoption of the SDGs in 2015 can pave the way from a common framework on what matters, but a substantial journey lies ahead of the economists and social scientists to get there.

Using the law as a weapon

Until now, the law has been a tool in the hands of governments and corporations. But recently, it has become a way for nature's defenders to fight back, and climate activism has entered the courtrooms. Over the last years, a number of natural sites around the world have been granted legal rights, among them the Ganges river in India, as well as several forests and rivers in New Zealand, the United States, Ecuador, and Colombia. And with allies on their side, such as the environmental NGO ClientEarth, these new 'legal citizens' have a way of defending them-

selves. Among ClientEarth's victories are wins against the UK government itself, in cases related to violations of its own policy on air pollution. Similarly, legal action by ClientEarth meant the abandonment of a EUR 1.2bn project to build a coal-fired power plant in Poland. The lawsuit was brought by ClientEarth as a shareholder, with argument that the construction would harm the future economic interests of the company and pose an indefensible financial risk to investors in the face of the energy transition away from fossil fuels.

One, often overlooked, development is the Chinese dedication to similarly address the country's environmental challenges. China has passed a range of environmental protection laws and is providing its citizens with ways to engage in climate activism via the law, allowing for them to sue polluting companies. Environmental NGOs are hence also playing a more important role, with 252 environmental public interest litigation cases brought by Chinese NGOs from 2013 to 2017.

Using the law as a weapon can help hold polluters accountable. What are the arguments for and against this approach?

Proponents say: Although new bills and laws amendments are made by governments, it is wrong to assume that the creator of the system does not have to comply with its own rules. Following the attitude 'equality before the law', every member of society – whether the individual, an enterprise or the government itself – has to fulfil the outlined legal requirements. Thus, we must use the full potential of our legal framework to ensure that climate sinners do not escape their legal responsibilities.

Critics say: Assuming everyone makes use of their rights, by using the law as a weapon against others, the very process of law enforcement can turn out counterproductive. The aspiration for legal justice on all levels has the potential to create a monster of bureaucracy that slows down actual change. If everyone sues everyone, who then has the capacity to make meaningful changes for a better, more sustainable future? Additionally, the legal system is often sticky, and any laws implemented will stay for a long time, it is therefore crucial to ensure that the laws are sensible and enforceable. Overregulation carries the risk of hampering business, and lack of proper enforcement skews the competitive landscape.

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PART 2

MYTHS AND CHALLENGES

While there is no shortage of potential climate solutions, myths surrounding climate change still permeate the public discourse. Such myths may delay action against or shift the focus to solutions that are inefficient, too slow, or too expensive. In this part of the report, we examine and respond to these myths. We also look at the practical challenges related to implementing effective climate solutions.

MYTHS SURROUNDING CLIMATE CHANGE AND CLIMATE SOLUTIONS

There are quite a number of myths and false claims surrounding the reality of climate change, the reasons behind climate change, the severity of climate change, and what solutions should be used to limit or reverse climate change. We have selected some important and opinion-distorting myths below, which we will examine and respond to.

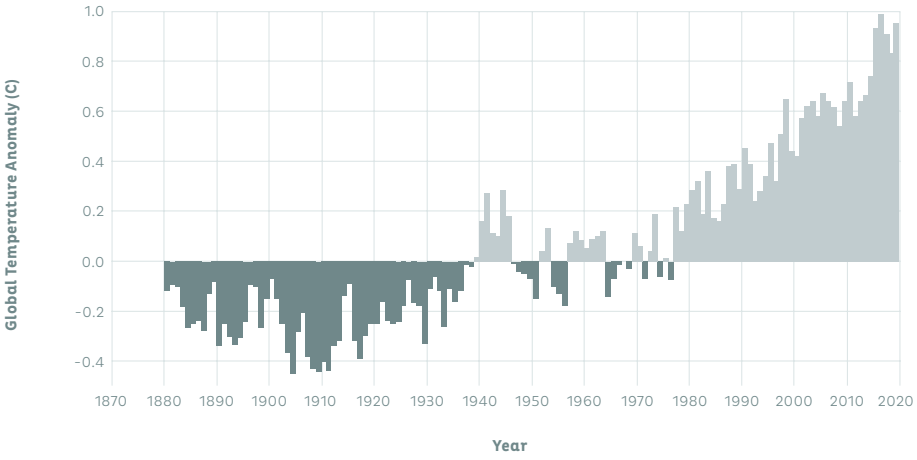
If global warming is real, how come we still set cold records?

New cold records are set all the time. In January 2020, a cold record was set for Greenland, Bangladesh recorded the coldest temperatures ever in 2018, and many other countries have set cold records within the last decade. If the globe is really getting warmer, we shouldn't be setting all these cold records, should we?

Response: Far more heat records than cold records are set every year. In 2019 alone, Belgium, Germany, France, the United Kingdom, Luxembourg, the Netherlands, Vietnam, and Cuba all set heat records. In February 2020, a new heat record was set for the Antarctic. Overall, global temperatures are rising rapidly, with every year since 1987 being warmer than the global maximum of the previous 100 years. According to the National Oceanic and Atmospheric Administration (NOAA) 2019 Global Climate Summary, the combined land and ocean temperature has increased at an average rate of 0.07°C per decade since 1880, and the average rate of increase since 1981 (0.18°C) is more than twice as great.[1]

In addition, global warming has always been assumed to imply more extreme weather, which includes cold spells as well as heat waves. The North Atlantic Current, which transports warm water from the Gulf of Mexico towards Europe, providing much of north-western Europe with a relatively mild climate, may be temporarily stopped by global warming, making it very cold in Europe.[2]

FIGURE 2.1: **HISTORY OF GLOBAL SURFACE TEMPERATURE SINCE 1880**



Source: Climate.gov, 2020.

Climate change is just natural variations

It is claimed by some that climate change is not primarily man-made, but rather due to natural variations. The evidence is that there have been warm periods on the planet before. As an example, the Middle Ages witnessed a period of warmth which made it possible for Europeans to settle on Greenland. Even the name Greenland suggests a time with a very different climate. On an even larger scale, the

variation in temperature is also evident from the many ice ages that the planet has gone through, with associated changes in sea levels far greater than the few meters predicted by climate models. The change in temperature is largely due to natural cycles of sunspot activity.

Response: It is true that the climate has been warmer in the past, but these warmer periods have also been associated with higher concentrations of greenhouse gasses. The difference is that life generally had time to evolve to handle the changed conditions. When rare, abrupt warming periods have taken place, they have caused mass extinction. This was the case with the Permian Mass Extinction 252 million years ago, also known as 'The Great Dying'. This period is the closest the Earth has come to extinguishing all complex life. Some 90% of all species died out, more than those lost in the Cretaceous extinction, when a comet or asteroid impact ended the age of dinosaurs.

The Permian Mass Extinction was caused by massive volcanic eruptions unleashing CO_2 and noxious gasses, which led to ocean acidification and global warming, which made it much more difficult for complex life to survive. It took the Earth ten million years to recover. If we were to go back in time to visit that Earth, it would be like visiting another planet altogether. Mankind would not be able to survive under those conditions. Hence, it is true that global warming has taken place before, but this is hardly an argument against mitigating climate change – rather the reverse.

It is also true that solar activity influences Earth's temperature. The Medieval Warm Period lasting from ca. 950 CE to ca. 1250 CE was an unusually warm period in the North Atlantic and attributed to increased solar output. However, when measuring the impact of the sun, volcanoes, and other aspects that do in fact impact temperatures on the planet, there is still a substantial component left – the main one being CO_2. Since 1970, the global average temperature has risen at a rate about 170 times the background rate over the past 7,000 years. If the sun was the primary driver, temperatures should in fact have fallen.

Climate models are inaccurate and can't be trusted

In September 2019, a global network of 500 scientists and professionals signed an open letter to the UN stating that there, in fact, is no climate emergency at all. "The general-circulation models of climate on which international policy is at present founded", they wrote, "are unfit for their purpose". Therefore, it is "cruel as well as imprudent" to squander trillions of dollars based on results from such immature models.[3]

This is far from the only criticism of climate models. Similar criticism points out that computer simulations conducted decades ago didn't accurately predict current warming, so we should be wary of the predictive power of newer models.

Response: It is true that older climate models often predicted temperatures for today that were different, often higher, than they proved to be. However, recently, a group of researchers from UC Berkeley ran 17 older climate models – as much as 50 years old – again with new data that represent actual carbon emissions in the intervening time rather than the emissions that were predicted when the models were originally made. With these more accurate data, most of the models accurately predicted recent global surface temperatures. For ten forecasts, there was no statistically significant difference between their output and historic observations.[4] Modern climate models are more sophisticated and include more dynamic effects and hence should predict future climate change with even greater accuracy.

Unfortunately, there are sometimes hidden motives driving attempts to downplay the severity of the climate crisis. While open scientific discourse should always be encouraged, it is important to call out exterior motives where they exist. For example, signatories of the above-mentioned open letter have been shown to have high-level links to conservative politics, industry, and mining. Critics say that it repeats "well-worn and long-debunked talking points on climate change that are contradicted by scientific institutions and academies around the world, as well as the assessments of the Intergovernmental Panel on Climate Change".[5]

Reducing carbon levels is too expensive

It is often claimed that reducing atmospheric CO_2 will be so expensive that it will seriously harm the economy. Those investments could be used better to curb poverty and cure illness, and we will have less expensive means to tackle climate change in the future.

Response: In the Fifth IPCC Assessment Report (AR5),[6] the cost-benefit analysis of different climate mitigation policies has been estimated. The conclusion is that the more emissions are reduced, the greater this contributes to long-term economic performance. For some policies, the technologies they make use of are already making profit and will have immediate benefit; for others, the benefit comes in the longer term. Perhaps not surprisingly, doing nothing has the worst impact on the economy. In the long run, money saved by protecting existing industry and habits are dwarfed by the costs of damage done in the longer term. Economists have calculated that cutting carbon emissions so that carbon dioxide peaks in the

range of 450-550 parts per million would cost 1% of the GDP annually. While climate scientists have since adjusted their assessments of which range is acceptable (below 450 parts per million), some have expressed doubts about whether this is doable considering our current trajectory.[7] That being said, if we ignore climate change, it could end up being far more expensive (estimates go as high as 20% of global GDP).[8]

We should give up flying

One climate solution that draws a lot of media attention, especially on social media, is pledging not to fly, or at least limit flying to one trip a year. Flying is far less climate-friendly than most other means of transportation, and we have become far too accustomed to spending our vacations flying across the globe.

Response: There is nothing wrong with changing consumption patterns to reduce your personal climate impact, but far more drastic changes are needed than flying less: It makes a difference, but not much of a difference in the larger picture. Assuming that we have done all we need to do for the climate by each of us flying less is a dangerous misconception.

Refraining from flying, or limiting flight to a single yearly trip, does reduce greenhouse gas emissions, but not by very much. Aviation's share of global carbon emissions is estimated to be around 2.4% or roughly 1 billion tonnes of CO_2 annually out of estimated total global emissions of 42 billion tonnes in 2019. Flying does produce other greenhouse gases, including nitrous oxide, black carbon, and water vapour, which according to Stefan Gössling, a professor at Sweden's Lund and Linnaeus universities, "makes a contribution to global warming that is at least twice the effect of CO_2 alone".[9] CO_2 accounts for 76% of global greenhouse gas (GHG) emissions, so this double effect corresponds to around 4% of GHG emissions. Passenger traffic is responsible for about 80% of commercial aviation, making the GHG emission contribution from passenger flight about 3%. Hence, even if all passenger flights were to stop tomorrow, this would only reduce global GHG emissions by 3% – far too little to prevent global warming.

For comparison, in 2017, 27% of total EU-28 greenhouse gas emissions came from the transport sector, with road transport being responsible for 71.7% of this,[10] or 19% of EU greenhouse gas emissions, with cars being the greatest contributor. Refraining from driving will thus have six to seven times the effect of refraining from flying. Carpooling, using public transport, or bicycling as an alternative to driving alone make far more of a difference. Buildings are responsible for nearly

40% of global GHG emissions,[11] and a Siemens study from 2014 shows that 95% of building-related energy use in Europe comes from buildings constructed before 1980.[12] Hence, renovating houses and adding better insulation and low-energy, smart-metered solutions for light, heating, hot water, ventilation, and climate control – and possibly installing solar panels or wind turbines – also makes far more sense than giving up flying.

Flying less may be a small step in the right direction, especially in terms of sentiment – but it will not make any real difference for climate change, and it will hurt the economies of many developing countries that are heavily reliant on their tourist industries. Innovation can also reduce the climate impact of flying dramatically. A recent study has shown that climate warming related to contrails resulting from black carbon emissions can be reduced by 59% with only a 0.014% increase in fuel use, simply by changing the flight altitude of selected flights.[13] If far more people from the growing middle classes in countries like China and India choose to fly in the future, it could become a real climate issue – but no more than any other growth in consumption among the global middle class, unless the growth in flying is disproportionally higher than the general growth in consumption.

We should all go vegan

Meat and dairy products are generally thought to have higher climate footprints than vegetable food products. Hence, it is often argued that if we all adopt vegan diets, we can dramatically reduce climate change.

Response: As we briefly touched upon in Part 1, calculating the climate footprint of food is far from simple. In 2015, a study from Carnegie Mellon University found that eating lettuce has three times the carbon footprint of eating bacon, for the same caloric content. The study examined how growing, processing and transporting food, food sales and service, and household storage and use take a toll on resources in the form of energy use, water use, and greenhouse gas (GHG) emissions. It found that a recommended healthy diet of fruits, vegetables, dairy, and seafood increased the environmental impact in all three categories, compared to the current average diet.[14]

This study was based on resource use in the US for the various types of food, which implies heavy use of irrigation in fruit farming, and the results may be different when studying food production elsewhere. In fact, other studies in Europe and Croatia have demonstrated that reduced meat consumption would indeed lead to reductions in energy use, water use, and GHG emissions. In addition, overall

calorie intake is not the only important part of a diet; vitamin, protein, and mineral intake are also important. Even so, the study did show that a vegetarian or vegan diet may not necessarily be better for the climate – a lot depends on which plants and animals are farmed and how, for example how crops are fertilised, and which crops are grown where.

Food crops are very often fertilised by natural fertilisers like slurry and manure. If we were to reduce the production of meat and dairy, the supply of natural fertiliser would drop, and farmers would be forced to use more artificial fertiliser – which has a very high emissions footprint, an environmental impact on water, and doesn't replenish the dirt as well as natural fertiliser. In 2019, a study from Cornell University found that methane emissions from artificial fertiliser plants in the US were 100 times greater than previously reported and 3 times higher than the Environmental Protection Agency (EPA) estimate for *all* industrial processes in the United States.[15] This significantly worsens the GHG emissions footprint for farming that uses artificial fertiliser compared to farming that uses natural fertiliser. Dispensing with animal farming in favour of agriculture may end up harming the climate rather than helping it. Improving animal farming through selective feeding and breeding, genetic engineering, managed grazing, and other innovations is likely to make a far greater difference.

With that said, reducing the amount of meat we eat, and being more selective with the meat we eat, is probably good for the climate, but entirely dispensing with meat and dairy is almost certainly a very bad idea unless we can develop artificial fertiliser with a smaller climate footprint or find ways to reduce the need for fertiliser, for example through genetic engineering,[16] or through *regenerative agriculture*, a holistic farming method that it is claimed to enhance carbon sequestration in farmland with no use of artificial fertiliser, instead relying on techniques like managed grazing, composting, animal integration, and crop rotation.[17]

Selected other climate myths

"Climate scientists do not agree".

Response: 97% agree that climate change is happening and is man-made; only 1% disagree.[18]

"CO_2 is plant food – plants will thrive and absorb more CO_2 as levels rise".

Response: This is true, but only to an extent. There are limits to how much CO_2

plants can absorb, and even now, they only absorb about a quarter of anthropogenic CO_2, leaving the rest to accumulate in the atmosphere.

"Animals and plants will adapt".

Response: Earlier instances with rapid climate change have all been associated with mass extinction.

"Climate scientists change their mind all the time – in the 1970s, they predicted a new ice age; now they predict global warming".

Response: A comprehensive study of climate science in the 1970s, when the field was much smaller and less developed than it is today, found that predictions of global warming (not cooling) was the consensus even then.[19]

"China is mainly to blame – they should cut down on carbon emissions, not us".

Response: While it is true that China is the world's largest emitter of CO_2, the per-capita emissions of China are only half of that of the United States and around the level of European countries like Germany.[20] At any rate, the whole world must go carbon zero by 2050 to minimise the effects of climate change, so we all need to act.

CHALLENGES TO IMPLEMENTING EFFECTIVE CLIMATE SOLUTIONS

There is a consensus that climate change is real, man-made, and a serious threat to our future, with massive costs in terms of material destruction, food safety, and the loss of low-lying land areas. As discussed in Part 1, we also have a wide range of possible solutions for the climate crisis; solutions that, together, have the potential to mitigate or even reverse climate change. This, however, does not mean that these solutions will be implemented to anywhere near the degree necessary to tackle climate change. Below, we will look at some of the most serious challenges and barriers against applying existing or future solutions to sufficiently mitigate the threat of climate change.

Economic challenges

There are significant short-term costs associated with combating climate change: Fossil-fuel energy plants need to be replaced with renewable energy sources, buildings need to be renovated to reduce energy use, transport needs to be made climate-friendlier, deforestation needs to stop and new forests planted, and significant research needs to be done in clean energy production, energy-storage

technology, climate-friendly food production, carbon sequestration and storage (CSS), and more. These costs must be paid while societies already struggle with rising healthcare costs, growing populations and/or dependency ratios, rising security costs, and other costly challenges such as those formulated in the UN's 17 sustainable development goals for 2030.[21]

As mentioned above, economists have calculated that the price of cutting emissions to more sustainable levels will likely be less than the long-term costs connected to maintaining the status quo in terms of emissions. However, the expenses must still be paid, and countries need to agree on who should pay how much. Government decision-makers fear that comprehensive regulation might hurt their countries' competitiveness and hence their economic growth, and the increased prices may just mean consumers will buy from companies situated in less regulated countries – a phenomenon known as carbon leakage. In general, states and nations are more suited to incremental rather than radical change, so climate measures tend to be too little, too late to make much of a difference. Some governments fear that introducing climate taxes may be socially imbalanced, with the less wealthy ending up paying more than their fair share, accentuating the rise in inequality we see over most of the globe. Yet, there is a more fundamental economic challenge to fighting climate change that has to do with the very way we measure wealth and growth.

The standard way to measure national wealth is gross domestic product or GDP. The success of a nation is measured, by its voters as well as international economists, by how much its GDP is growing. The GDP measure, however, does not include sustainability and can promote unsustainable behaviour. GDP is defined as the total monetary or market value of all the finished goods and services produced within a country's borders in a specific time period. The resources used to make these goods and services do not count against GDP, nor does the longevity of products or services. In fact, it is better for the GDP if products wear out quickly, so we need to purchase them again, than if we make durable products (a phenomenon known as *planned obsolescence*). During the Great Depression, planned obsolescence was even suggested as a means to stimulate the economy, since people buying more products and services would create more jobs for employees making these things, and these employees would then pay more taxes and themselves consume more. Never mind that this would lead to higher resource use, more waste, and no real growth in wealth, since people would have to buy the same (or nearly the same) products/goods over and over rather than buying new products and goods that last.

Therein lies an even deeper economic barrier to fixing climate change: Our economy is based on growing consumption. If consumption for whatever reason stagnates, we will need fewer workers making products and goods and providing services, especially as automation takes over more work tasks currently done by humans. If fewer people work, or all people work less, their income and consumption decreases, meaning that even less work is needed, and people earn even less, creating a negative spiral. With less work being done, the national tax income suffers, and with it, public welfare and public infrastructure. Business owners will also earn less, and more businesses will have to close. Only if people keep choosing to consume more or are forced to consume more (e.g. through more planned obsolescence), can our economy – the way it is designed today – continue to thrive. This is obviously not sustainable, and something must change.

Lacking transparency

Even when we are ready to do something for the climate, it may be difficult to find the right thing to do. Sometimes simple, but ineffective measures get more attention in the media than complex, but effective measures, and consumers and politicians both are more likely to react on whatever sends the strongest signal, regardless of its effectiveness. We see feel-good campaigns like pledging not to fly this year, refraining from using plastic straws (which has no measurable effect), or choosing to buy local rather than imported goods (even though buying local in itself is not necessarily better for the climate).[22]

To illustrate the point, consider the example of the reusable cotton shopping bag. It may intuitively seem like a more climate-friendly choice than single-use plastic shopping bags, but producing cotton bags has a far higher climate cost than producing plastic bags, and according to a Danish government study, you have to reuse your cotton bag 7,100 times before it is a better climate choice than a single-use plastic bag – and 21,000 times if the bag is made from organic cotton (and presumably more if you ever wash your cotton bag).[23] This, however, assumes that used plastic bags are disposed of correctly and ultimately, are incinerated in power plants as an alternative to fossil fuels. If plastic bags end up in landfills or in nature, the account is different, and a similar British study from 2011 found that a cotton bag only needs to be reused 131 times to be the more climate-friendly choice.[24] Two such different results add confusion and detract from the transparency of what is the correct choice.

Even companies and governments struggle with a lack of transparency. It is common for companies and governments to purchase carbon offset as an alternative

to reducing carbon emissions on their own. However, a lot of carbon-offset schemes have turned out to be fraudulent, late, ineffective, or something that would have been done anyway. As much as 73% of non-fraudulent carbon credits offer little or no environmental gain.[25] There are indeed watchdog organisations that evaluate and ensure the integrity of various offset processes, but this is difficult work, requiring proper auditing and, if not done correctly, it could be a gold mine for fraud and corruption. This is a problem, as legitimate carbon offset projects can be quite good for the climate because it is often cheaper to reduce carbon emissions in developing countries than in developed countries, like Denmark, that already have strict emission rules. It is possible that blockchain technology can be used to improve value chain traceability in the future and hence increase the transparency of carbon offset solutions.

Climate taxes are often mentioned as a partial solution for climate change, but the effectiveness of such taxes could be hurt by a lack of transparency in what the climate impact is for various products and services. What, for instance, is the climate impact of a leather jacket compared to, say, a jacket made from a plant-based leather substitute such as 'vegan leather'? Leather comes from cattle, and cattle are generally considered bad for the climate (though this question is complex, as discussed on page 38). Leather may thus be labelled as having a high climate impact for tax purposes, but if meat cattle are slaughtered anyway, is it not better for the climate if we use their leather rather than a substitute that has a climate footprint of its own? Even if leather is taxed higher, should that depend on how and where the source animal has been farmed? Emissions from biogas are currently not counted towards carbon emissions in the EU, but the production and transport of wood pellets for burning in European power plants has a carbon footprint that perhaps ought to count against the carbon neutrality of biomass.

Nor is it at all clear if organic farming is better or worse for the climate than industrial farming. A study of farming in England and Wales found that, though organic farming may reduce the climate footprint per unit of production of livestock by 5% and of crops by 20%, organic farming has an estimated 40% lower yield, requiring Britons to import more food from overseas – and if half of that extra food comes from farmland converted from wild grassland, overall emissions would increase 22%.[26] However, there are a lot of uncertainties in this math. For one, the yield from organic farming need not be as low as in the estimate above. A 2014 study found that the yield from organic farming was just 19.2% lower than conventional fields, and for legumes and perennial crops: no difference in yields were found.[27] Yield gaps also depend a lot on where the crops are

grown, with organic yields in developing countries often being higher than conventional yields, especially for small-scale farming.[28] Given that organic farming may benefit the environment in other ways, it may in fact be better overall for the climate – or not. In the end, the issue may have to be decided on a case-by-case basis, which certainly does not make things easier.

This overall lack of transparency makes it very difficult for decision-makers, whether governments, business leaders, or consumers, to make the right decisions that will benefit the climate the most. When in doubt, we tend to go with our gut feeling, but when it comes to complex issues like climate change, our gut is rarely a very good guide, and we often end up with feel-good solutions rather than solutions that actually do good.

Resistance to genetic engineering

Perhaps paradoxically, climate activists are often also opponents of genetic engineering, especially GM food. In fact, genetic engineering can greatly benefit the climate. Earlier in this report, we discussed the prospects of genetically modified livestock and crops genetically engineered to increase yields, need less water, or better absorb fertiliser. We could also mention genetically modified algae for biofuel production,[29] bioengineered grass with longer roots that allow them to store more carbon in the soil,[30] and crops that are more resilient to climate change.[31]

However, such beneficial uses of biotechnology are often resisted by both consumers and organisations. Nineteen out of the 28 member countries of the European Union have voted to either partially or fully ban GMOs, which will make it harder for African farmers to sell climate-resilient or climate-friendly GM crops to the European market. A field test of GM biofuel algae has been met with outrage by organisations like Friends of the Earth. Organic farming could be made more climate-friendly by using GM crops that require less fertiliser, no pesticides, or that have increased yields, but organic farmers as well as consumers of organic food are opposed to this idea, with IFOAM, the International Federation of Organic Agriculture Movements, even saying that organic agriculture and GMOs are 'two opposing concepts'.

There may be some wisdom in having a cautious approach to genetically modified organisms, but with climate change looming, it may be prudent to weigh this caution against all the good that GMOs could do for the climate. Denying climate solutions just because they involve GMOs may limit efforts to combat climate change and may endanger global food security.

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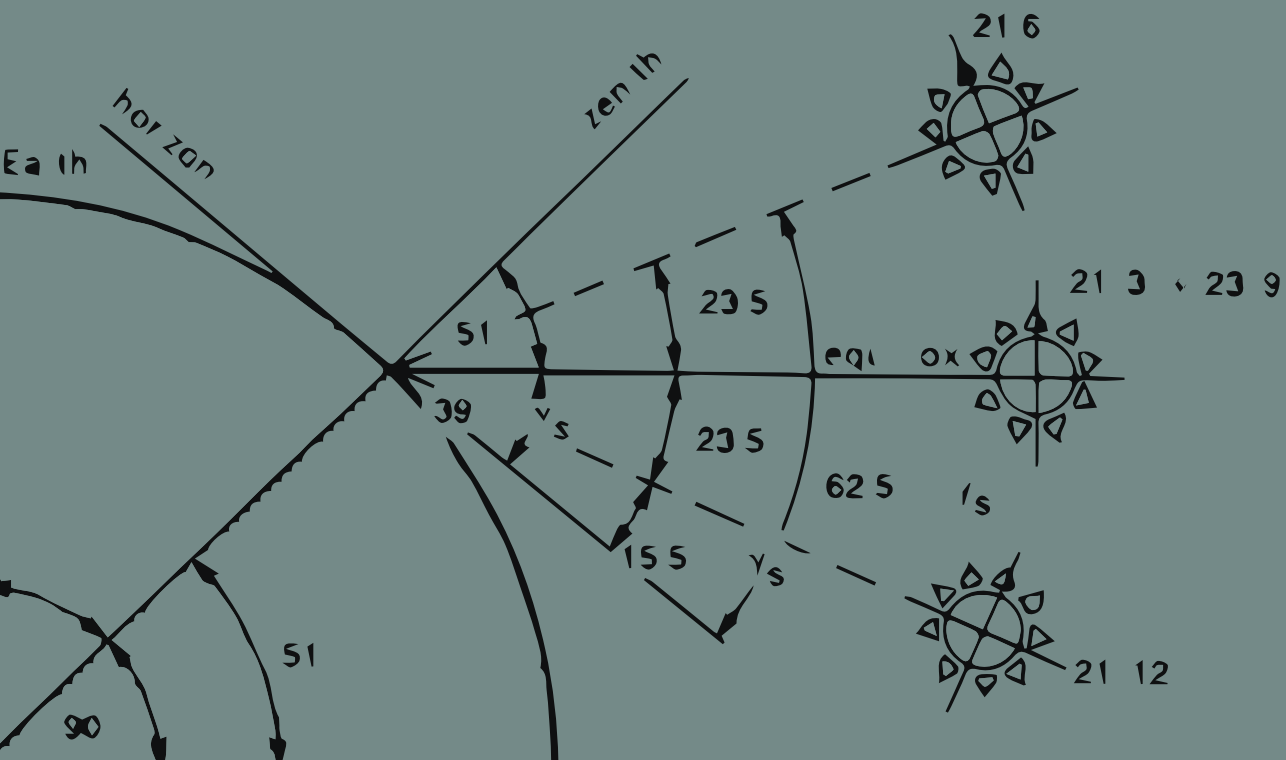
CONCLUSION:

VISIONS OF A GREENER WORLD



This report rests on our conviction that 97% of climate scientists cannot be wrong. At the Institute, we live and breathe the notion of multiple futures and the fact that nothing but time of day and the seasons change automatically. We firmly believe that the future is in the hands of those who are here in the present; they create it, one decision at a time. Such devotion to our discipline prevents us from being normative and taking a stand. But in the question of climate change, we are making a conscious exception. We believe that the threat to our climate, biodiversity, and ecosystem is real. We believe that the existing modus operandi of growth and prosperity has come at the expense of something we failed to notice, measure, and value, before it started yelling back at us – we forgot nature. The extreme weather, the disappearance of species, the retraction of centenarian glaciers, and the increases in global temperatures and sea levels are all nature's way of telling us enough is enough. And while we acutely recognise the fact that the resources we have taken for granted, especially the living and breathing ones above ground, are finite, then there is one resource which seems even more scarce, and that is time. Time to act and react.

The comforting thought is that we also believe we still have time to change things. In '2040: How we saved the world', we provided a peek into a world in which we have succeeded. It is possible! And it is in our hands. It will take a lot of action, and more than anything, it will take agreement and coordination. When reading Yuval Noah Harari's *Sapiens*, we learn that what truly sets humans apart from other species is our ability to create and convey stories which unite people in a joint cause. If there was ever a cause worth uniting for, then the preservation of our own habitat is a worthy candidate. A step in the right direction is to imagine how this can be done. We do not mean that we should ignore the obstacles along the way, but no ambitious goals have been achieved without a vision of what success could look like. Sometimes one has to imagine the goal and work backwards, and this is where futures studies is an invaluable tool.

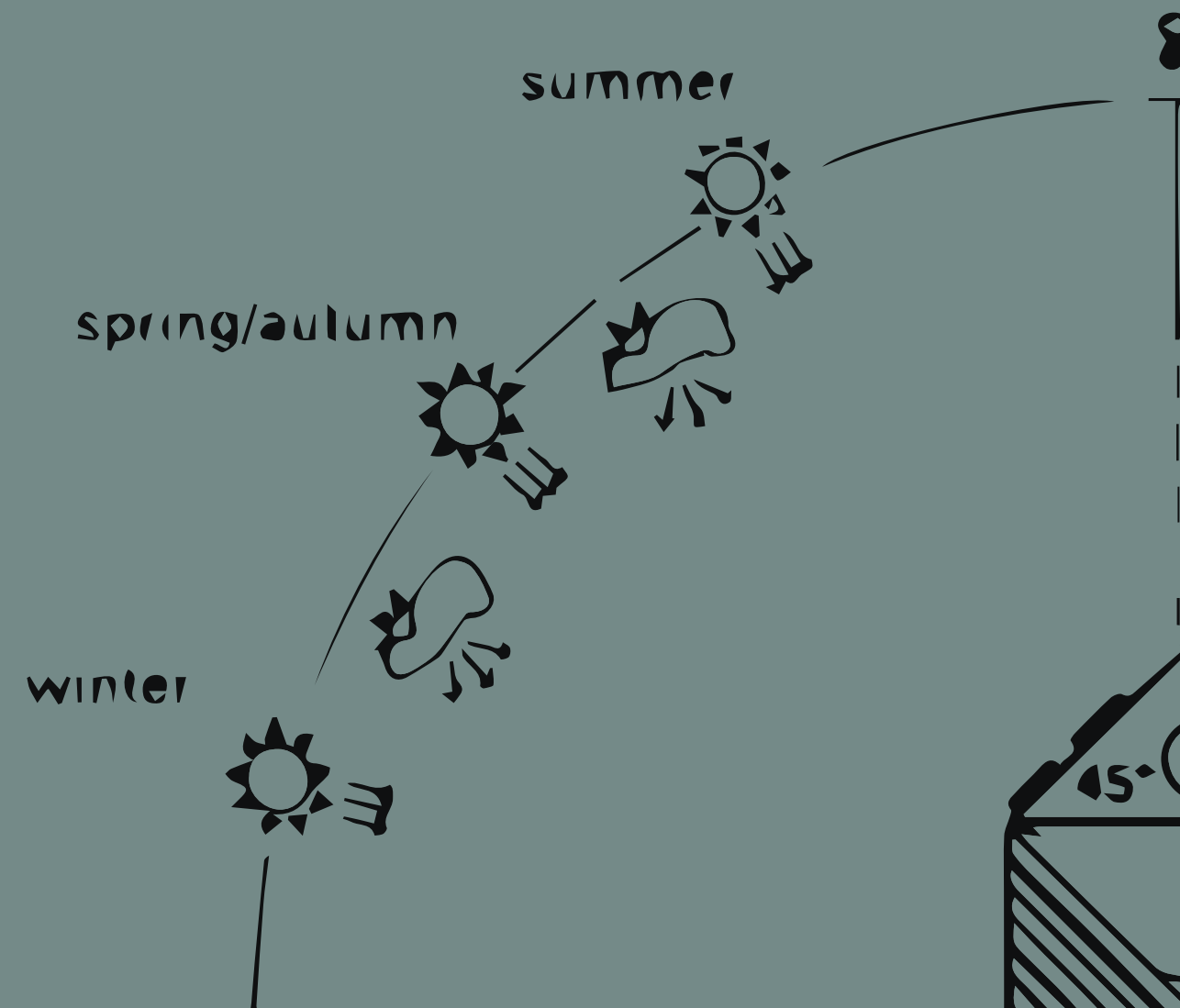
Speaking of tools, the report has also provided an overview of some of the best solutions at our disposal. Some are technological and innovation driven – others are a matter doing things differently or doing different things entirely. For example, the hard sciences provide us with one set of solutions, including better and cleaner energy sources, while the social sciences put other levers at our disposal. A number of economic mechanisms, such as an aggressive GDP growth focus and rent-seeking, have to take their fair share of responsibility for the depleted ecologic capital. But at the same time, the discipline of economics also offers a variety of mechanisms to try and restore the balances. Be it carbon taxes, subsidy control, green investments, or redefining GDP to capture the externalities it has created, all of these instruments can offer a helping hand. A related field within the social sciences is law. We often talk about democratisation as a trend which, among other things, has provided fair access to information and a voice to those who previously struggled to be heard. Now it appears that the law is also being put in the hands of the people. Legal activism is on the rise and not only is nature beginning to gain legal rights of its own, but several organisations are paving the way for citizens to use law as a vehicle to protect their environment. The courtrooms are no longer a safe space for the big corporates or even governments, in which they ultimately prevail or settle. No, they are now a place where a small shareholder, using the law as a vehicle, can derail investment plans of EUR 1.2bn if they are not environmentally and hence financially future-proof.

One of the innovative solutions we described in Part 1 is the use of genetic modification for crops and livestock to increase their yield, resilience, and reduce their climate impact. Ever since the 1973 breakthrough in GMO lab technology, when Boyer and Cohen developed a method to carve out a gene from one organism to place it in another, the GMO debate has been a heated one. Somewhere in that heat of discussion, we forgot that what we have come to know as traditional agriculture has been genetically modifying nature for over 30.000 years by simply selecting species to breed. Overlooked examples include fruits and vegetables that we have enjoyed for years which have resulted from such practice and have often mutated beyond recognition from the original wild ancestor crop. Carrots were not always orange – they were scrawny and white; peaches resembled cherries and were salty; aubergines used to look like white eggs; bananas had more and bigger seeds; and dogs were wolves. But nonetheless, GMOs have been accused of everything from having a negative effect on butterflies to farmer suicides in India. The debate continues, and it is one with a lot of emotions. This leads us to another, perhaps more crucial question: the role of emotion and ethics in the context of climate change. Are ethical and moral considerations on GMOs, or which coun-

tries should bear the main responsibility and costs of cutting back emissions, a necessity or a luxury? Do we have time to ponder in the North while people suffer from famine and crop yield failures due to drought in the South? And how do we compare what has been coined 'survival emissions' in the least developed countries to 'luxury emissions' in the developed world? A big part of the disagreement preventing concrete action is exactly that: who should take the lead.

When the topic of international leadership comes up, we have become used to looking to the developed countries for action. Roughly since the Industrial Revolution, and especially since WWII, the Western world has been at the forefront of not only science and technology, but also at establishing international governing bodies such as the very institutions we look to for guidance and multilateral agreements on the sustainability agenda (UN, WWF, etc.). But perhaps this time, leadership will come from elsewhere. For example, Africa is banning the use of plastic bags, with countries such as Tanzania, Kenya, Rwanda, and others already implementing restrictions. On the topic of climate change, China may well end up in the driver's seat of efforts and actions. Not only is China already the biggest emitter in absolute terms, but it is also home to 18% of the world's population, many of whom are still entering the middle class. It is also the production floor of many global supply chains. Most of the world's apparel emissions are in China, but 72% of those are essentially servicing companies and consumers overseas. Continuing China's growth in an energy-intensive way would eliminate any chance of keeping the global temperature increase at sustainable levels. Consequently, China is making it a question of national self-interest and priority to 'promote global green low-carbon transformation and development path innovation'. It goes without saying that succeeding in this endeavour would also alleviate China's dependency on imported fossil fuels and the critical issue of air pollution. The country is already the world's largest producer of solar cells, wind turbines, and home to five out of the ten biggest producers of electrical vehicles. So perhaps this time, while the yellow vests are in the streets of Paris, and the US is pulling out of international negotiations, the leadership baton of climate change will be picked up by someone else.

Last but not least and closer to home, we can all consider within our own national borders, who should carry the responsibility for change – is it the individual consumers who need to make sustainable choices at the expense of convenience? Is it the citizens collectively who should use their voices to democratically impact policy and research funding? Is it corporates and markets who will lead the way in investments and good corporate citizenships? It is likely all of the above, and the sooner, the better.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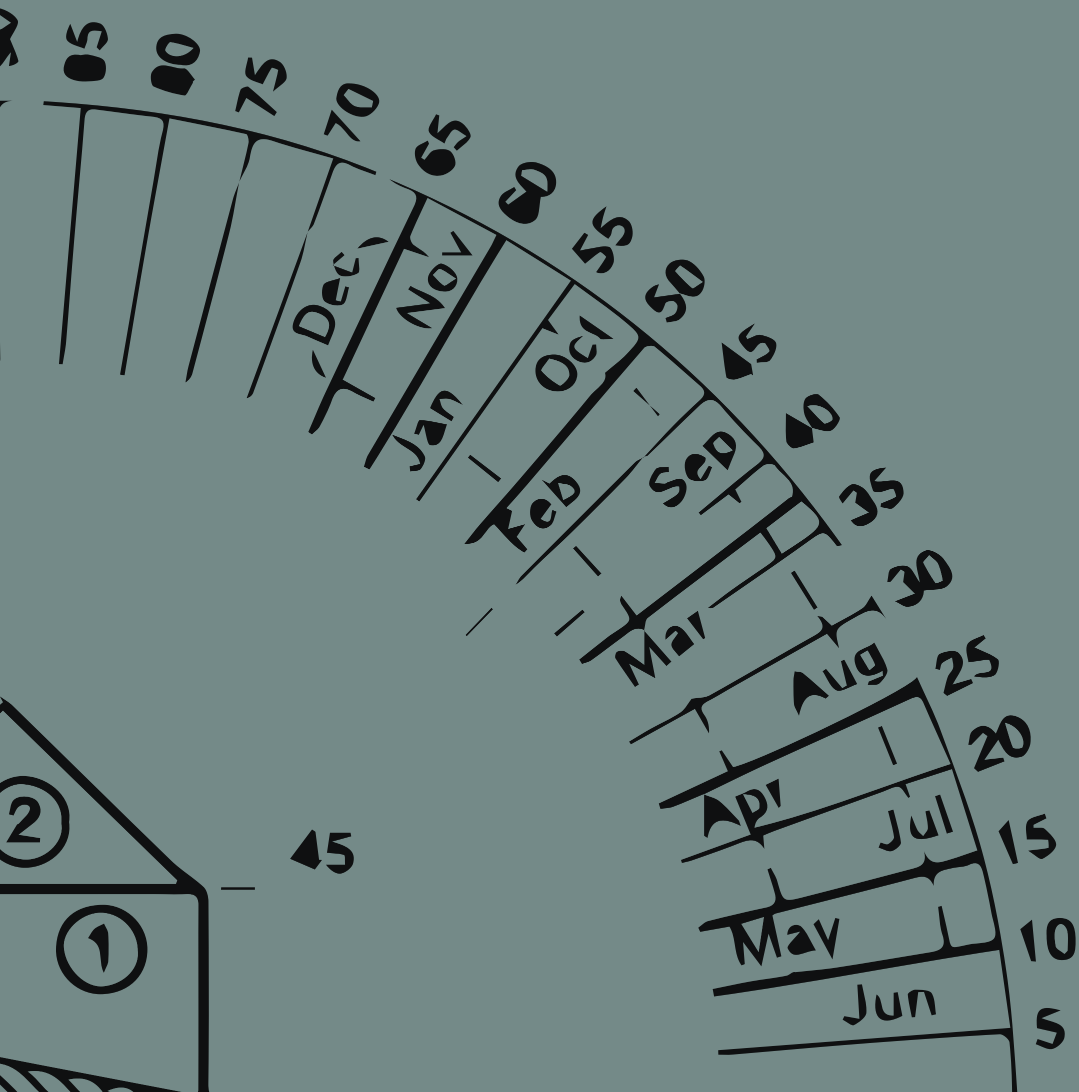

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