4IR and the Environment

How the Fourth Industrial Revolution can curb air pollution and decarbonise the economy

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SMF Social Market Foundation

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Scott Corfe joined the SMF as Chief Economist in 2017. Before joining, he was Head of Macroeconomics and a Director at the economics consultancy Cebr, where he led much of the consultancy's thought leadership and public policy research. His expert insights are frequently sought after in publications including the Financial Times, the Sunday Times, the Guardian and the Daily Telegraph. Scott has appeared on BBC News, Sky News, Radio 4 and a range of other broadcast media.

Scott was voted one of the top three forecasters of UK GDP by Focus Economics in 2016.

FOREWORD FROM THE SPONSOR

2019 saw a palpable shift in people's attitudes to the environment, here in the UK and across the globe. Now more than ever, there is an understanding both of the impact of the personal decisions we make on the environment, and of the effect of the declining health of the environment on us. Whether by reducing our use of single-use plastics, changing our diets or finding new modes of transport, we are engaging with environmental issues more than ever.

Businesses are making changes too. At Vodafone, I'm proud to say that we have set ourselves ambitious targets to reduce our own impact on the environment. At the same time we are supporting our customers to do the same through our technology. Globally, we are aiming to reduce our greenhouse gas emissions by 50%, and to purchase 100% of our energy from renewable sources by 2025. Other initiatives, including the move toward a company fleet of electric vehicles, the use of plastics in road surfaces at our sites and our partnership with Fairphone are all indicative of our desire for change. It's what we want as a business, is important to our employees and is vital for our customers. Many other businesses are on a similar path of change.

Even so, there remains a great deal to be done to reduce CO2 emissions, clean up the air we breathe and slow the warming of our planet. Businesses, governments and individuals all have a part to play. Technology will continue to play a crucial role in deepening our understanding of the environment. It is helping us to identify the most effective steps to improve our behaviours, and there are already examples of this in action. The Internet of Things is helping to run buildings more efficiently and to monitor air quality. Reliable connectivity is reducing the need for travel. In-vehicle telematics is altering the model of car and bicycle ownership and encouraging more sustainable choices. The dawn of 5G will accelerate this progress as businesses digitise their processes, public services become increasingly efficient and people's behaviour continues to change.

I welcome the Social Market Foundation's important research into the impact of technology on air quality and decarbonisation. The next few years – coinciding with some of the most exciting technological developments – will be crucial in changing the way we live and work. Vodafone is excited to be part of this and I hope that this research will help to continue the conversation.

Scott Petty, Chief Technology Officer, Vodafone UK

EXECUTIVE SUMMARY

This report focuses on the role that Fourth Industrial Revolution (4IR) technologies can play in improving the environment. In particular, it explores the role of 4IR in reducing air pollution and decarbonising the economy. It is the fourth in a series of SMF reports on 4IR, following our 2018 reports on the use of 4IR in the home and the workplace, and our report earlier in 2019 on 4IR in local government.

Terms

4IR refers to the latest technologies which are building on the digital revolution that commenced in the second half of the 20th Century. This includes internet connected appliances ("the internet of things"), driverless cars, big data, robotics and artificial intelligence.

Context

The environment has surged up the political agenda in the UK, and voters now report it as among the top issues facing the country. The YouGov Top Issues Tracker shows the environment now more likely to be reported as a top issue than education, housing and pensions. In part, this reflects mounting evidence on the consequences of climate change and environmental degradation:

- **Data from NASA show that, in 2018, global temperatures were on average 0.8 degrees Celsius higher relative to 1951-1980.**
- **Climate change is already having a number of effects on human lives and the wider ecosystem.** The world has seen an increase in both the frequency and severity of heatwaves in recent years
- **Rising average temperatures are changing the nature of our planet. Since 1870, sea levels have risen by 20cm, with about 8cm of this rise occurring since 1995.**[1]

In addition to climate change and global warming, air pollution is also a growing concern. Particulates, and other emissions from vehicles and industrial activity, are now known to be detrimental to health:

- **Air pollution is the single largest environmental risk factor to human health.** According to the World Health Organisation (WHO), nine out of ten people worldwide breathe polluted air. It is responsible for around 7 million deaths per year.[2]
- **A recent study published in the European Heart Journal estimated that emissions are responsible for 64,000 annual deaths in the UK**, just 18% less than the 78,000 deaths caused by tobacco.[3]
- **An increasing body of research has shown that air pollution—even in relatively low doses—has a negative impact on educational outcomes**.

How 4IR can help

This report identifies a number of channels through which 4IR technologies can tackle the environmental challenges associated with air pollution and global warming. These include:

- **Better monitoring of air quality,** using affordable low power wide area networks (LPWANs) to track air quality.

- **More personalised advice on air pollution.**
- **Using technologies to remove pollution and carbon from the air.** Emerging technologies include:
    - **Robotic trees.**
    - **Parasitic drones.**
    - **Air-cleaning buses**
    - **Air separation plants.** Industrial plants focused on removing carbon from the atmosphere.
- **Cleaning up transportation** through:
    - **A shift to autonomous vehicles.** Automated vehicles (AVs) are designed to be more fuel and energy efficient than their diesel, petrol, and electric counterparts.
    - **Creating fleets of autonomous vehicles and improved public transport,** reducing the need for private car ownership;
    - **Sophisticated road pricing,** which smooths traffic throughout the day and relieves congestion in urban areas.
- **Using big data and blockchain-based solutions to encourage environmentally-friendly decision-making by consumers and businesses.** This can allow customers in stores to see the carbon emissions of their purchases at the point of sale.
- **Decarbonising industry** through:
    - **Green commercial vehicle fleets.**
    - **Reducing computer energy-usage through wider uptake of cloud-based solutions.**
    - **Usage of virtual and augmented reality** to replace meetings/site visits.
    - **3D printing** – to enable local production of global designs and reduce final product transportation.

- To ensure that the benefits of 4IR are realised in practice we set out a number of recommendations to policymakers:
    1. Ensure that fairness is a key component of environmental tax design. A new road pricing system should include a free allowance of road usage each year, to help reduce the burden of taxation on lower income households.
    2. Require large companies to collect and provide information on the environmental impact of their operations. Building on mandatory carbon reporting, this information should include effects on air quality, use of plastics and primary materials. Such data should be publicly available.
    3. National government to commit to installing air pollution monitors in every postcode area of the UK, as requested in The Times' "Clean Air for All" campaign.
    4. Ensure that air pollution data gathered from these monitors is open source and accessible through an application programming interface (API), to support the development of apps providing personalised advice on air pollution.
    5. Develop a planning strategy to ensure that homes being built today are suitable for a carbon "net zero" world of lower rates of private car ownership. This includes ensuring that new homes are well-served by public transport, electric vehicle charging facilities and access to car sharing clubs. The creation of "smart", internet and data-driven towns and cities, with the supporting broadband and mobile infrastructure, needs to be central in the planning process.
    6. In addition to banning new sales of petrol & diesel vehicles beyond a certain point, set a target for reducing rates of car ownership, and increasing the proportion of

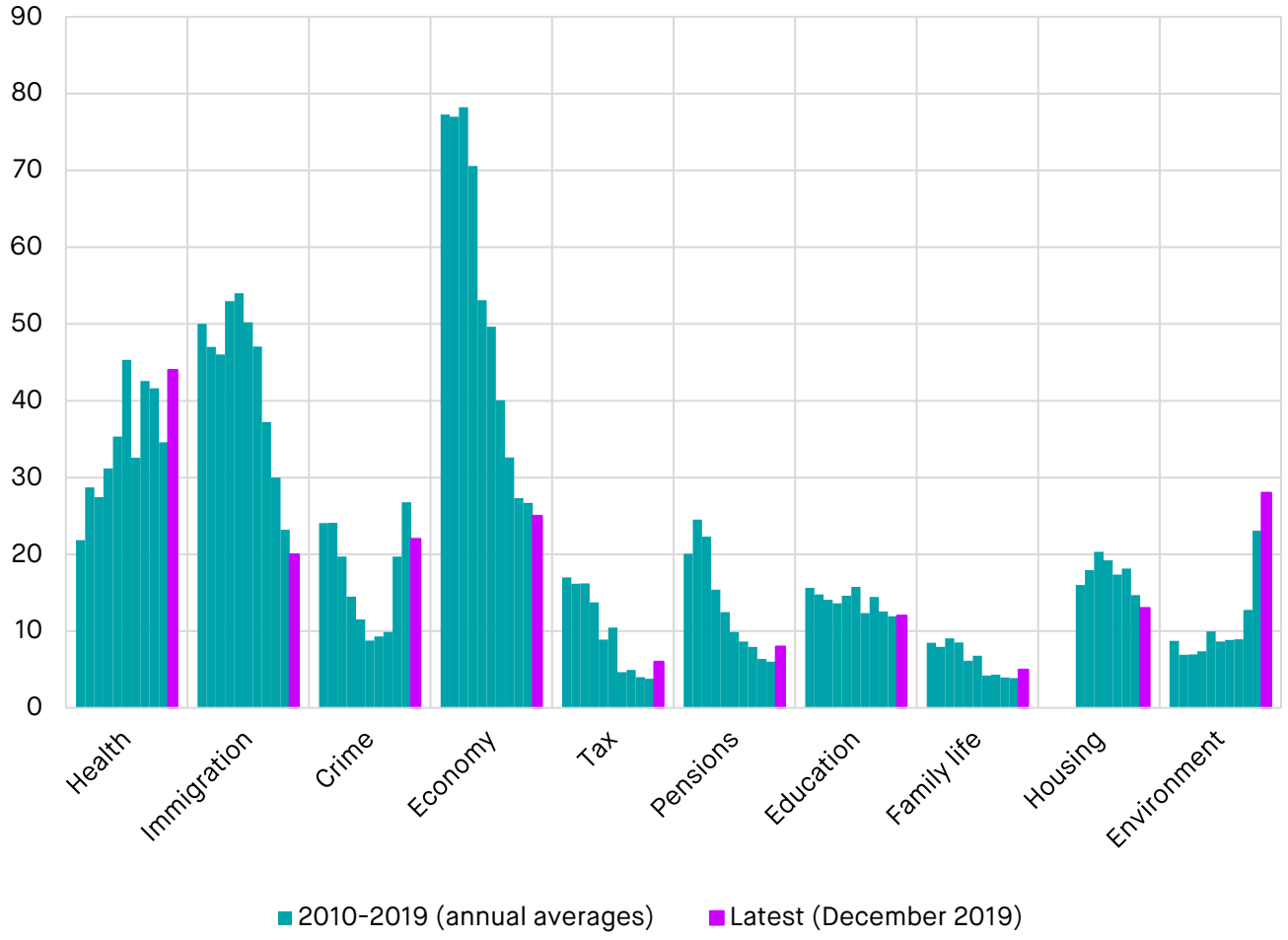
journeys made on foot, by bike and by public transport. Cities and large towns should aim for a quarter of journeys to be made by bicycle – a similar proportion to the Netherlands.

CHAPTER 1: INTRODUCTION

The environment has rocketed up the political agenda in recent months. Extinction Rebellion protests, reports highlighting the dangers of air pollution and mounting scientific evidence on the consequences of global warming have contributed to the environment shifting from a relatively fringe issue to a central concern of voters.

As the chart below shows, the environment is increasingly seen as among the most important issues facing the country. Data from December 2019 show a greater proportion describing the environment as one of the most important issues facing the country, than the proportion citing the economy and crime as most important. The environment has recently overtaken immigration as a top issue facing the country.

Figure 1: Which of the following do you think are the most important issues facing the country at this time?



Source: YouGov Top Issues Tracker. Survey respondents can choose up to three top issues.

Despite the growing political salience of the environment, and the prospect of severe natural disaster if global warming and environmental degradation are not addressed, policymakers continue to drag their heels. Infrastructure to support electric vehicle usage en masse remains limited. Politicians continue to shy away from difficult conversations with the electorate about the behavioural changes that might be needed to avert environmental catastrophe.

While the UK economy has made significant headway in reducing direct carbon dioxide and pollutant emissions, less progress has been made in reducing pollution associated with the goods and services that we import from overseas. In many respects, as a country, we have outsourced our pollution to other parts of the world – flattering the picture of progress made to date on our carbon footprint. That needs to change going forward. Political rhetoric in 2019 showed some movement in the right direction, with all major political parties signalling a commitment to transitioning the UK to a carbon net-zero economy. The Conservative Party stated an intention for the UK to reach net zero by 2050 through "investment in clean energy solutions and green infrastructure to reduce carbon emissions and pollution".

Political momentum on green matters is often fleeting, capricious and inconsistent. The recent abolition of the Department for Energy and Climate Change, with responsibilities folded into the Department for Business, Energy and Industrial Strategy, was seen by some as the downgrading of climate change in the list of government priorities[4] - though there are murmurs that a separate climate change department will be revived.[5] Boris Johnson's 2019 general election campaign commitment to maintaining the road fuel duty freeze raises questions around the Conservative Party's prioritisation of "green issues" over traditional party interests such as low taxes. On the other hand, in the 2019 general election the Conservatives committed to shifting the UK to a carbon net zero economy.

Prior to the Conservatives being the party of government, New Labour shelved plans to introduce road pricing, as a way of reducing congestion and pollution, amid widespread public opposition.[6] Addressing environmental degradation will require a significant change in the mindset of our political class – away from a focus on the short term and election cycles, towards a cross-party consensus to address long-term issues related to the environment.

Now is the time for policymakers to act. Technological change is paving the way for policy solutions that can be both effective and palatable for the electorate. The Fourth Industrial Revolution (4IR) – the rise of artificial intelligence, data analytics, the internet of things and robotics – could usher in a new era of greener transportation, data-driven solutions for reducing pollution along supply chains and robotics capable of removing carbon dioxide and pollutants from the atmosphere.

It is these technological solutions to the environmental crisis that we focus on in this report

The structure of this report is as follows:

- **Chapter 2** provides an overview of some of the environmental challenges facing the UK at present.
- **Chapter 3** discusses the opportunities created by 4IR to improve the environment. We focus particularly on the role these technologies can play in reducing air pollution and decarbonising the economy.
- **Chapter 4** outlines some of the barriers to realising these benefits.
- **Chapter 5** sets out recommendations to policymakers.

"The environment" is an enormous topic area and we make no claim to cover all aspects of environmental degradation within the pages of this report. We pay particular attention to role that 4IR can play in reducing carbon emissions and air pollution.

What do we mean by 4IR?

The Fourth Industrial Revolution (4IR) is a term that is gaining mainstream use as the technology that underpins it is becoming more and more relevant in our day-to-day lives. Yet many of us do not know what the Fourth Industrial Revolution is, or are confused by the terms used to describe the technologies that comprise 4IR – the internet of things, big data and machine learning, for example. This report seeks to address this issue.

A simple way to consider progress is that:

- The First Industrial Revolution saw water and steam used to power and mechanize production.
- The Second used electric power to create mass production.
- The Third used electronics and information technology to automate production.
- The Fourth Industrial Revolution is building on the Third, the digital revolution that has been occurring since the middle of the last century.

4IR is characterized by a fusion of technologies that is blurring the lines between the physical, digital, and biological spheres – artificial intelligence, big data, machine learning and "the internet of things" which is seeing an increasing proportion of household and business appliances connected to the internet.

According to the World Economic Forum, there are three reasons why today's transformations represent more than a prolongation of the Third Industrial Revolution but rather the arrival of a Fourth and distinct one: speed, scope, and systems impact. On speed, when compared with previous industrial revolutions, the Fourth is evolving at an exponential rather than a linear pace. In scope, it is disrupting almost every industry in every country, with robotics and artificial intelligence potentially changing the types of jobs available in our economy dramatically – and the skills needed to perform them. The breadth and depth of these changes could transform the entire system of production, management, and governance.

Definitions of the types of technologies comprising the Fourth Industrial Revolution vary from source to source, though in this research our focus lies on:

- The internet of things –appliances and devices that are connected to the internet, enabling them to send and receive data. Examples include "smart" washing machines and thermostats which can be controlled remotely, for example via a smartphone.
- Big data – the use of large datasets (e.g. of consumer behaviours) created and analysed using new technologies.
- Artificial intelligence – complex algorithms capable of decision-making and learning over time.
- Robotics – the use of machines to automate tasks.
- Connected and autonomous vehicles such as "driverless cars".

CHAPTER 2: SETTING THE SCENE – AN ENVIRONMENTAL CRISIS?

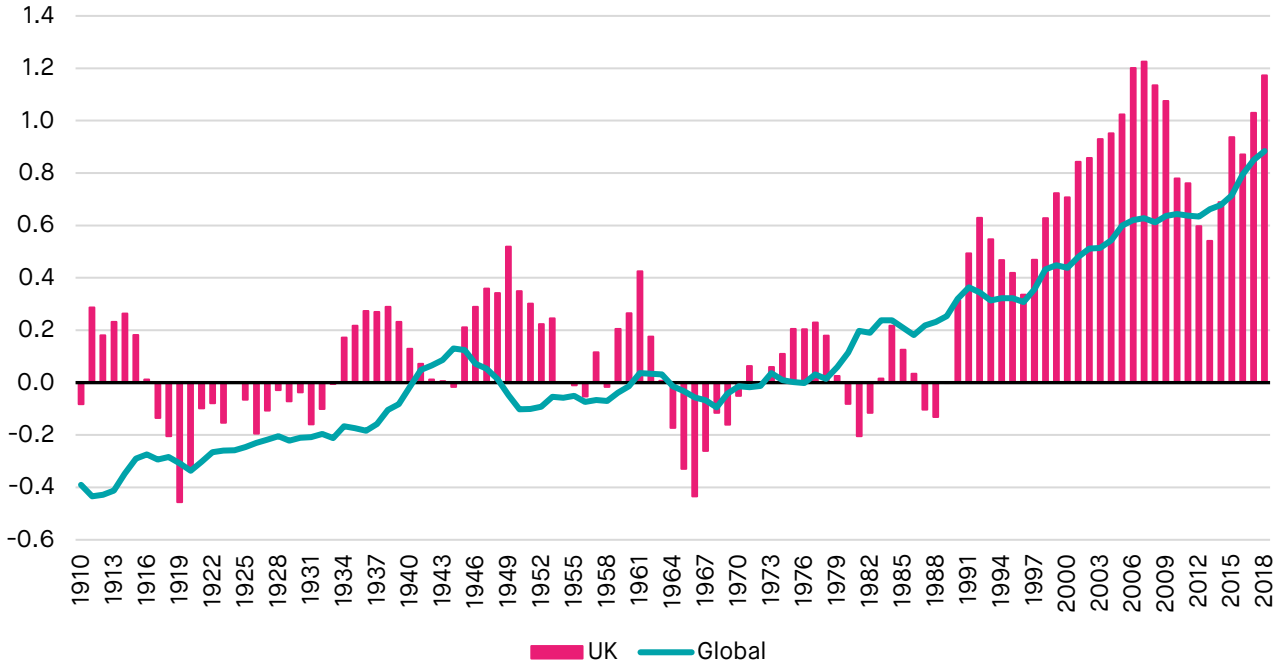
Human activity is having an adverse impact on many aspects of the Earth's environment. Climate change, loss of wildlife and ecosystems, and pollution are all resulting from economic activity and population growth. This chapter provides a brief overview of these challenges – and their implications. In particular, it provides an overview of the challenges around air pollution and global warming.

It's getting hot in here – global warming and its potential consequences

One of the most widely-discussed environmental impacts of human activity is global warming. Carbon dioxide and other greenhouse gas emissions such as methane are believed to be contributing to rising temperatures across the globe – something on which there is currently a widespread scientific consensus.[7]

Data from NASA show that, in 2018, global temperatures were on average 0.8 degrees Celsius higher relative to 1951-1980. Met Office data for the UK also show that average temperatures in Britain have also crept up in recent decades; the ten hottest years of the past century in Britain have all occurred since the year 2000.

Figure 2: Annual temperature anomaly, relative to 1951-1980, degrees Celsius (5 year rolling averages)



Source: NASA global temperature data, Met Office data on average UK temperatures

Climate change is already having a number of effects on human lives and the wider ecosystem. The world has seen an increase in both the frequency and severity of heatwaves in recent years. The 2003 heatwave caused more than 70,000 additional deaths across Europe.[8] The July 2019 heatwave in Europe caused almost 400 deaths in the Netherlands.[9]

Rising average temperatures are changing the nature of our planet. Since 1870, sea levels have risen by 20cm, with about 8cm of this rise occurring since 1995.[10] With rising sea levels, saltwater can intrude into freshwater systems, resulting in the relocation or death of species. Flooding also

poses a risk to human lives. Research by Alfieri, Burek, Feyen and Forziei (2015), for example, suggests that global warming increases the frequency of river floods in Europe, with modelling suggesting that the South of England in particular will see an increase in precipitation over the years to 2080. Schaller et al (2016) found that human-induced climate change increased the risk of severe storms like those that hit the south of England in the winter of 2013/14.[11]

Carbon Brief has published an analysis of 138 different papers that have looked at extreme weather events over the last 20 years, and shown that from these events, 63% of them were more likely to occur or more severe due to human influence through climate change. Two examples of their findings were that the Korean heatwave of 2013 was 10 times more likely to occur due to climate change, and 85% of the reports on heatwaves in general concluded that climate change had caused heatwaves to be more frequent or more severe.[12]

If average temperatures continue to rise, even by a seemingly modest amount, there could be substantial negative impacts. In 2018, a special report by the United Nations Intergovernmental Panel on Climate Change set out the potential impacts of global warming of 1.5 degrees Celsius above pre-industrial levels. The report warned there is only a dozen years left for global warming to be kept to a maximum of 1.5 degrees Celsius, beyond which even half a degree of further heating will significantly worsen the risks of drought, floods, extreme heat and poverty for hundreds of millions of people.[13]

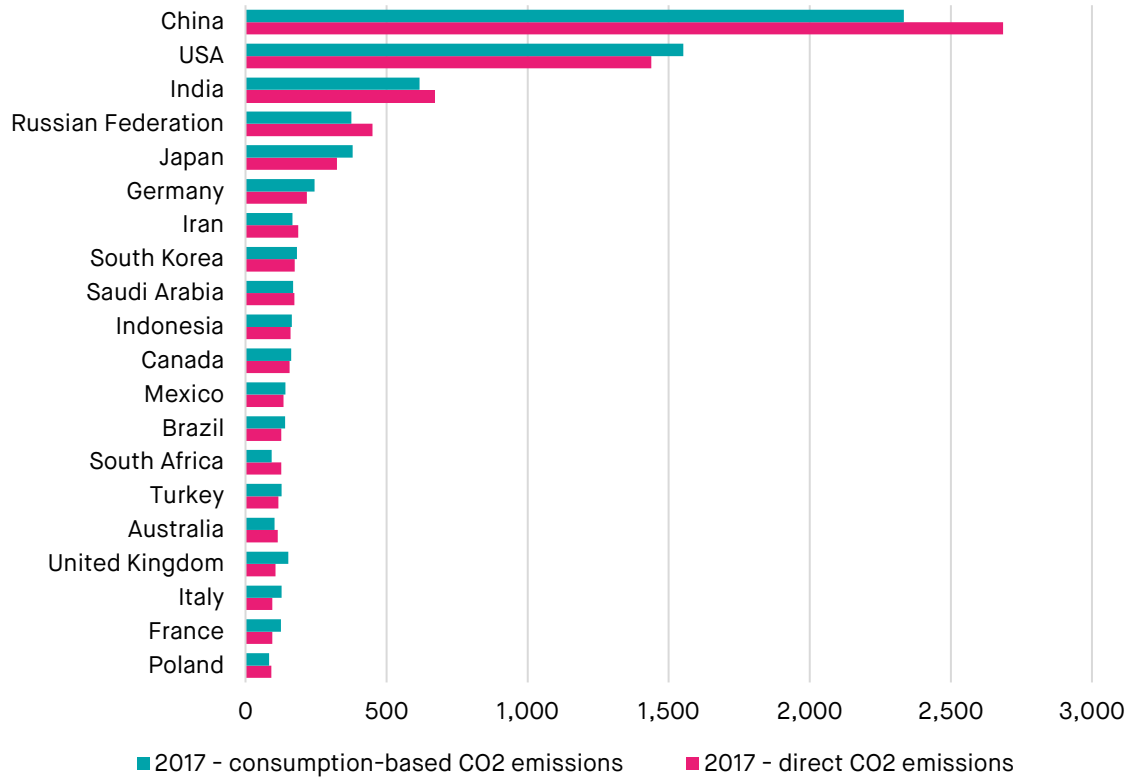
Critically, global warming is, as the name implies, a problem without borders. The actions of one country in emitting greenhouse gases increases temperatures not just locally, but across the globe – highlighting the need for international coordination on the matter.

While UK carbon dioxide (CO_2) emissions peaked in 1972, once we consider imported emissions – such as when the UK imports products that are manufactured abroad – UK emissions peaked in 2007.[14] Through the importation of goods produced elsewhere in the world, the UK has become the biggest importer of CO_2 emissions per capita in the G7 group of wealthy nations.[15] Decarbonising the UK's economy, therefore, must not just be about reducing polluting activities at home – but drastically changing the types of goods and services that we are purchasing from other parts of the world.

As the chart below shows, the UK remains among the biggest emitters of CO_2 in the world. The UK is the 17th largest emitter of CO_2, between Australia in 16th place and Italy in 18th place. When you look at the amount of CO_2 associated with the UK's consumption of goods & services, including those imported from elsewhere, the country ranks 12th globally.

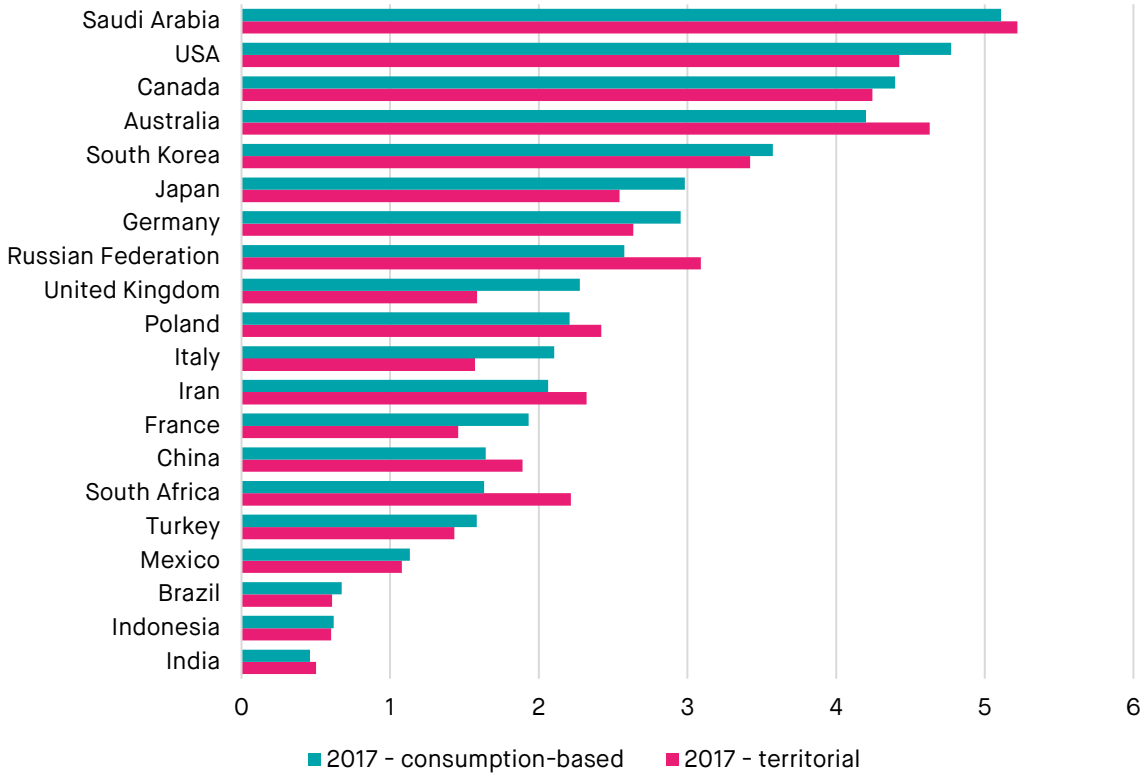
Chapter 3 of the report sets out the potential for 4IR to help decarbonise the economy and curtail global warming. This includes through better monitoring of carbon emissions, "carbon capture technologies" and through an improved transport network which utilises cleaner private transportation (autonomous & electric vehicles) as well as a more compelling public transport offer.

Figure 3: CO2 emissions, measures in million tons, 2017



Source: Lund University ICOS Carbon Portal

Figure 4: Per capita CO2 emissions, tons, 2017



Source: ICOS Carbon Portal, UN population estimates

Hard to breathe – growing concerns about air pollution

Air pollution is the single largest environmental risk factor to human health. According to the World Health Organisation (WHO), nine out of ten people worldwide breathe polluted air. It is responsible for around 7 million deaths per year.[16] Worldwide ambient air pollution accounts for:

- 29% of all deaths and disease from lung cancer;
- 17% of all deaths and disease from acute lower respiratory infection;
- 24% of all deaths from stroke;
- 25% of all deaths and disease from ischaemic heart disease;
- 43% of all deaths and disease from chronic obstructive pulmonary disease.[17]

A recent study published in the European Heart Journal found that emissions are responsible for 64,000 annual deaths in the UK, just 18% less than the 78,000 deaths caused by tobacco.[18]

An increasing body of research has shown that air pollution—even in relatively low doses—also affects educational outcomes across several distinct age groups and varying lengths of exposure. This implies that a narrow focus on traditional health outcomes, such as morbidity and mortality, may understate the true benefit of reducing pollution, as air pollution also affects educational attainment.[19]

Growing awareness of the negative health consequences of air pollution has led to increased media interest and campaigns to improve air quality across the UK. For example, the Times newspaper recently launched a "Clean Air for All" campaign to tackle air pollution in Britain and demand the Government take urgent action to update the Clean Air Act to confer a legal right to clean air for everyone in the UK. The Times campaign also calls for a ban on the sales of new diesel and petrol cars from 2030, traffic bans outside schools and pollution monitors in every postcode.[20]

Critically, "air quality" is a multidimensional issue – with pollution generated from a range of sources, and also different types of pollutant. Concerns include:

- **Particulate matter (PM)** – a mix of solid and liquid droplets in the air. $PM_{2.5}$ ("fine particulate matter") and PM_{10} are common measures of such air pollution. Human activities, such as the burning of fossil fuels in vehicles, power plants, road dust and various industrial processes generate significant amounts of particulates.

- **Nitrogen dioxide** – resulting from road traffic and indoor gas cooking.

- **Sulphur dioxide** – resulting from burning fossil fuels

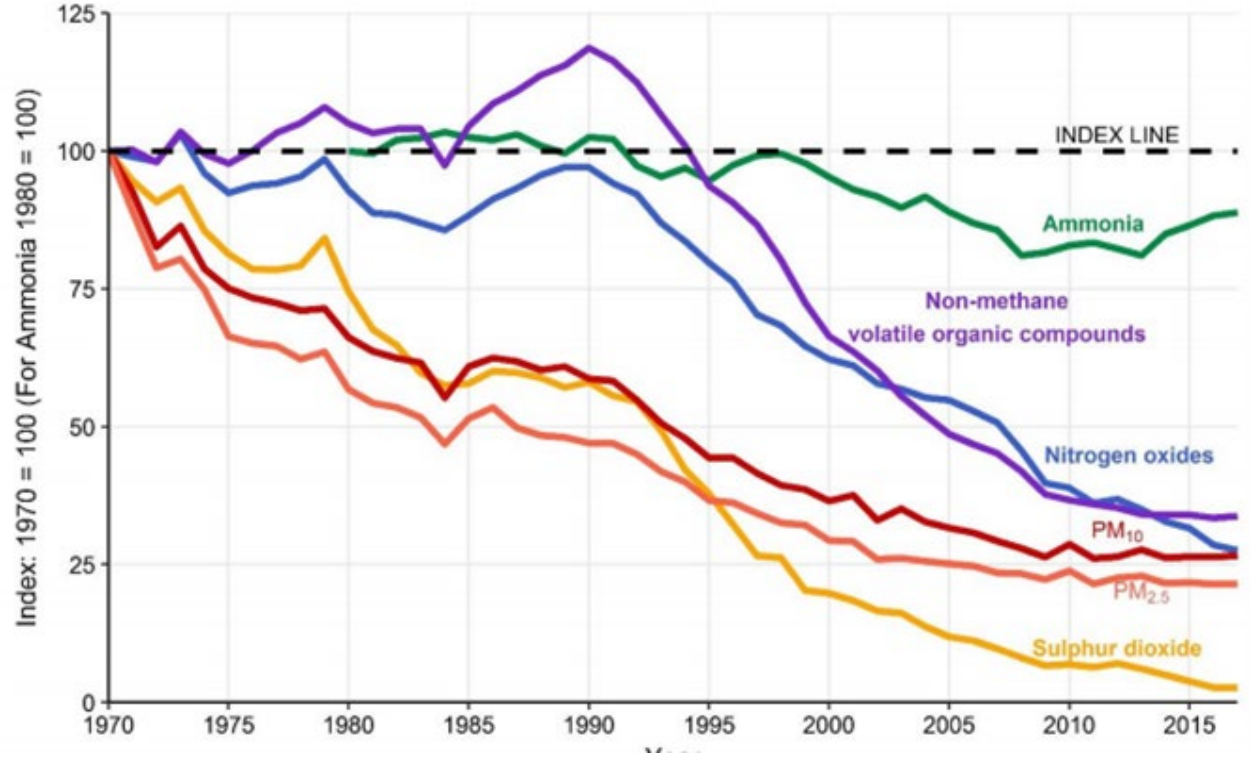
- **Ground level ozone** – resulting from chemical reactions from vehicle emissions.

- **Ammonia** and **non-methane volatile organic compounds (NMVOCs)**. NMVOCs are emitted into the atmosphere from a large number of sources including combustion activities, solvent use and production processes. Certain species such as benzene and 1.3 butadiene are directly hazardous to human health.

While air pollution has risen up the political and media agenda in recent years, pollution in the UK as a whole has actually declined over the past 50 years, as the chart below shows. Nevertheless, continued deaths from air pollution and the growing evidence base around its negative impacts

on public health highlight the need to do more on this issue. As we discuss in the next chapter, there is scope to use 4IR technologies to both better monitor air pollution and reduce emissions of particulates and other pollutants from sources such as transportation.

Figure 5: Trends in annual emissions of sulphur dioxide, nitrogen oxides, NMVOCs, ammonia and particulate matter in the UK



Source: Ricardo Energy & Environment

CHAPTER 3: CAN 4IR IMPROVE THE ENVIRONMENT?

Although the UK has made strides to address these issues in recent years, there is still much more that could be done to get us on a greener economic growth path. Critically, the UK needs to act as a global leader and a role model country on the environment – addressing the cross-border nature of global warming means that one country acting in isolation is not enough. We need to lead by example – and get as many other countries to follow as possible.

One way that the UK can become an environmental leader is through innovative use of new and emerging technologies to radically decarbonise the economy and clean our air. As we discuss here, the Fourth Industrial Revolution offers a range of innovative solutions to the environment. This includes through dramatically curtailing car usage with autonomous electric vehicles and using robotics to "clean" air we breathe. Usage of big data and blockchain-based solutions can also change consumer behaviour and nudge individuals into making more environmentally-friendly lifestyle choices.

This chapter provides an overview of some of the ways that 4IR can improve the environment – and gives examples of how it is already doing so.

Better monitoring of the environment

The internet of things offers the opportunity for government, individuals and businesses to gain a better understanding of the state of the environment – such as levels of air pollution.

For example, in Brazil, Sao Paulo authorities are using mobile network data to monitor air pollution. Algorithms use machine learning and anonymised data from the mobile network. Combined with existing weather, traffic and pollution data, they can monitor pollution and predict pollution levels up to 48 hours in advance.

Authorities in Chicago are using an Array of Things (AoT) – a series of connected devices - as an urban sensing network of programmable, modular nodes installed around the city to collect real-time data on Chicago's environment, infrastructure, and activity for research and public use. Described as a "fitness tracker" for the city, AoT measures factors that impact liveability such as climate, air quality and noise. Besides monitoring these, there is potential to monitor temperature, detect urban flooding and provide block-by-block weather/climate information.

Information can be made freely available via application program interfaces (APIs), allowing for further innovation such as apps that help individuals determine the cleanest or safest route to a destination.

Critically, better monitoring of the environment does not need to come with a huge price tag attached. Low power wide area networks (LPWANs) use small, portable, low cost and always connected sensors. These can be attached to parts of the urban environment such as street lighting. Government and business can then apply data analytics and machine learning to understand, analyse, predict and mitigate environmental issues. In London, the GSMA (the trade association of mobile operators) is working with the Royal Borough of Greenwich on a proof of concept project to trial a range of sensor and data types to measure air quality and gain further insights into the levels and causes of pollution.[21]

Narrowband Internet of Things (NB-IoT) technology is likely to play a growing role in environmental monitoring. NB-IoT provides strong coverage over wide areas, even when devices are underground or deep within buildings. It also offers great power efficiency, so devices can run on batteries for years without the need for charge. As such, NB-IoT can be useful for long-term monitoring of air, water and other forms of pollution.

Personalised advice on pollution

The Fourth Industrial Revolution is already unveiling new technologies to tackle air pollution and improve air quality, but it is also important for government and businesses to develop the means to communicate these efforts, and their underlying implications, to people in a meaningful way. The Internet of Things (IoT) has an important role to play in translating personalised data into personalised advice on issues such as air pollution.

Currently, UK Air, run by Defra, tracks air pollution across the UK into a Daily Air Quality Index (DAQI), categorised on a scale of 1 (low) to 10 (very high).[22] This index is then used to provide health advice to the public and recommend actions for short-term exposure to air pollution. Air quality forecasts are issued on a national scale, but the UK Air website allows individuals to search for their preferred location or postcode. The figure below provides a quick summary of the advice given.

Figure 6: Daily Air Quality Index and accompanying advice

Air Pollution Banding	Value	Accompanying health messages for at-risk individuals*	Accompanying health messages for the general population
Low	1-3	**Enjoy** your usual outdoor activities.	**Enjoy** your usual outdoor activities.
Moderate	4-6	Adults and children with lung problems, and adults with heart problems, **who experience symptoms**, should **consider reducing** strenuous physical activity, particularly outdoors.	**Enjoy** your usual outdoor activities.
High	7-9	Adults and children with lung problems, and adults with heart problems, should **reduce** strenuous physical exertion, particularly outdoors, and particularly if they experience symptoms. People with asthma may find they need to use their reliever inhaler more often. Older people should also **reduce** physical exertion.	Anyone experiencing discomfort such as sore eyes, cough or sore throat should **consider reducing** activity, particularly outdoors.
Very High	10	Adults and children with lung problems, adults with heart problems, and older people, should **avoid** strenuous physical activity. People with asthma may find they need to use their reliever inhaler more often.	**Reduce** physical exertion, particularly outdoors, especially if you experience symptoms such as cough or sore throat.

Source: Department for Environment, Food, and Rural Affairs

Going forward, we expect more sophisticated advice to develop, particularly as monitoring of air pollution at a local level continues to improve. Tools such as Google Maps could, in the future, provide personalised routes for individuals looking to minimise their exposure to air pollution –

encouraging them to cycle or walk down less congested roads. Wearables and smartphones might also increasingly be able to monitor local levels of air pollution – and provide advice to individuals.

Case study: airTEXT

Operated by Cambridge Environmental Research Consultants (CERC) Ltd and supported by the Greater London Authority, the Environment Agency, and Public Health England, airTEXT is a service which provides personalised air quality alerts via text message, email or voicemail.

So far, pollution forecasts and alerts for NO_2, O_3, $PM_{2.5}$ and PM_{10} using the DAQI scale are issued for Greater London (by Borough), Slough, Chelmsford, Colchester, and the Three Rivers District. The main purpose of the service is to alert at-risk individuals (those with heart and/or lung problems) about the level of air pollution so that they can reduce their outdoor activities.

Using robotics to tackle global warming and air pollution

Robotic trees and "parasitic" drones

Robotic, internet-connected technologies are increasingly likely to be used as a means of reducing air pollution.

A number of countries and businesses are already innovating in this space. In the Mexican city of Puebla, a start-up has installed "robotic trees" that suck up as much air pollution as 368 real trees, using microalgae in their towering metal structure. The microalgae clean CO2 and other contaminants from the air, returning pure oxygen to the environment.[23]

Figure 7: Robotic trees in Mexico

In Hong Kong, a group of designers has been exploring the use of signs and drones to suck CO_2 out of the city air. During the day, the drones (or, as the designers call them, "parasitic robots") would perch on billboards. Coated in a polymer known for its carbon-sucking powers, the robots

spread their wings and collect pollution as long as the sun is up. At night, when the billboards light up, the robots would attach to them, using the heat from the neon in the next step of the process. Heating up the polymer to a certain temperature releases the CO_2, which can be collected and used in energy production.[24]

Figure 8: Sketch of a parasitic carbon-absorbing drone attached to a billboard

Source: https://www.fastcompany.com/3037893/these-parasitic-robots-are-designed-to-suck-pollution-from-city-air

Air-clearing buses

The UK's first bus that can filter pollution from the air was unveiled in Southampton in 2018. The Bluestar bus has a filter system on its roof.[25] This removes particulate air pollution and blows out pure air behind it. The trial has recently been extended, with a greater number of buses fitted with the filter system.[26]

Figure 9: Bluestar air-cleaning bus

There is scope for such air-cleaning technologies to be rolled out across the UK, and elsewhere, including on other forms of transportation such as trains and cars.

Air separation plants – a way of decarbonising the economy?

On a larger scale than robotic trees, buses and parasitic drones, there is increasing discussion around the role that "air separation plants" could play in decarbonising the economy and reducing air pollution. Such plants might be able to deliver decarbonisation benefits on a much greater scale, and more efficiently, than robotic trees and other such technologies.

The process of air separation is physically possible and does not represent a new technology, as air separation units have long been deployed in industries such as electronics, chemical processing, and petroleum refining.[27] However, recent innovations have repurposed the process to focus solely on removing carbon dioxide (CO_2) directly from the air in order to reduce its amount in the environment. 4IR offers the prospect of more efficient and sophisticated air separation solutions – through more advanced robotics, better monitoring of the atmosphere (driven by internet-of-things technologies) and artificial intelligence. Domestically, the UK Carbon Capture and Storage Research Centre has been recently established in order to promote innovation and adoption of carbon capture and storage technologies.[28]

Currently, the market has a small number of providers, but there is appetite for development of new ways to extract CO_2 directly from the air. EY estimates that, by 2030, the value of the carbon capture and utilisation industry would be worth between $80bn and $1.1tn.[29]

However, these technologies come with a number of disadvantages at present. Firstly, due to the relative newness of this market, the cost of a tonne of CO_2 captured directly from the air is

much higher than the cost of capturing CO_2 at the emission source. In this sense, prevention is better than the cure as far as global warming is concerned – it is best to prevent CO_2 entering the atmosphere in the first place. Moreover, aiming such technology at large industries or governments for central provision may dissuade individuals from trying to reduce their carbon footprint.[30] If that were to occur, air separation plans (and indeed technologies such as robotic trees) might prove counterproductive and ultimately detrimental to the environment. As such, it is important for policymakers to ensure that carbon capture technologies do not lead to complacence over reducing carbon emissions.

Another issue with air separation is that carbon storage is likely to lead to additional costs for households and businesses as, by definition, the process can remove captured carbon from the environment indefinitely. Once sucked out of the environment, CO_2 will have to be stored elsewhere, in a place where it will not contribute to global warming – with associated storage costs. Research suggests that, if CO_2 is buried in order to offset emissions from vehicles, then a price of $100 per tonne of CO_2 captured would lead to an increase in the price of a litre of fuel by $0.22.[31]

Below, we summarise and evaluate the main services offered by the three current largest companies in the field of air separation.

Case study: Carbon Engineering[32]

Origin: British Columbia

Main offer: Remove CO_2 from the atmosphere via direct air capture technology, then purify it for use or storage
Cost: under $100 per tonne of CO_2[33]

Main customer base: Industries

Uses for CO_2, once captured:

- Stored underground;
- Used to produce ultra-low carbon intensity transportation fuels in order to lift dependency on fossil fuels
- Used to produce materials which typically require a large amount of CO_2 such as steel or concrete or chemicals, such as plastics, fertilisers, carbonates, and industrial chemicals;
- Used during oil recovery to reduce the net addition of CO_2 from oil production and fuel use.

This technology is the most popular carbon removal and storage initiative so far. However, the company has attracted some criticism. For example, using these air separation plants during oil recovery goes against the company's self-reported purpose to reduce the reliance on fossil fuels. Climate campaigners are worried that this technology will have the opposite effect as it could be used to extract more oil.[34]

Case study: Climeworks[35]

Origin: Switzerland

Main offer: Capture CO_2 from low-grade/waste heat with a filter, which is reused and should last for several thousand cycles.[36]

Cost: $600 per tonne of CO_2 [37]

Main customer base: Businesses and individuals

Captured CO2 is then sold to customers in the following industries:

- food and beverages: to produce carrier gas in bars and restaurants for draft beer and soft drinks; inert gas for packing fresh meat and vegetables; dry ice [38]
- agriculture: to use in greenhouses; generated on site to cut transport costs (and emissions) [39]
- energy, fuels, and materials production [40]

This technology has the potential to reduce the reliance on carbon as a material used in the production of goods as it ensures that new CO_2 is not created during the production process. However, the current price of $600 per tonne may act as a barrier to many businesses.

Case study: Global Thermostat [41]

Origin: USA

Main offer: Air capture technology can be retrofitted into an existing facility, rather than needing to redesign an existing plant; air separation plants also generate their own heat and power, so can be located anywhere

Cost: $120 per tonne of CO_2 [42]

Main customer base: Industries
Three types of plants: [43]

- 'pure air embodiment': capture CO_2 directly from the atmosphere at low concentrations, and can be carbon negative; co-locate with industrial facilities (or solar farms) to utilise their residual process heat to run the carbon capture operations.
- 'carbureted embodiment': co-locate with industrial facilities to utilize their residual heat, and capture concentrated CO_2 from those facilities' smoke stacks. Global Thermostat (GT) blends that CO_2 with atmospheric air, and can capture significantly more CO_2 than is being emitted. By capturing this additional atmospheric CO_2, the system can be carbon negative. This model produces the lowest cost CO_2 per tonne.
- 'self-carbureted embodiment': stand-alone; burn fuel in GT's own gas turbines, generating the heat and electricity needed to capture their own emissions while also capturing CO_2 from the atmosphere, remaining carbon negative.

These carbon capture plants have been designed to work alongside already existing industry processes, which may be a significant advantage to businesses which wish to be more carbon neutral but may be unable to commit to redesign their facilities. However, it is unclear if the plants will ultimately be carbon negative.

The role for 4IR in improving air separation technologies

We identify the following channels through which innovations associated with the Fourth Industrial Revolution could make further improvements in the carbon capture and utilisation market:

- As new technologies such as more sophisticated and efficient robotics emerge, the cost of capturing, storing, or selling a tonne of CO_2 should decline, which would open up the market to new customers.
- New innovation could enable the creation of a larger-scale air purification plants or could link initiatives together to monitor global levels of CO_2 in the air and strategically capture CO_2 in areas where it is in greater abundance. Global monitoring, driven by internet-of-things technology, can therefore help focus air separation efforts where they are likely to be most effective.
- In the longer term, new storage facilities could be developed in order to store CO_2 which is not to be reused more efficiently.

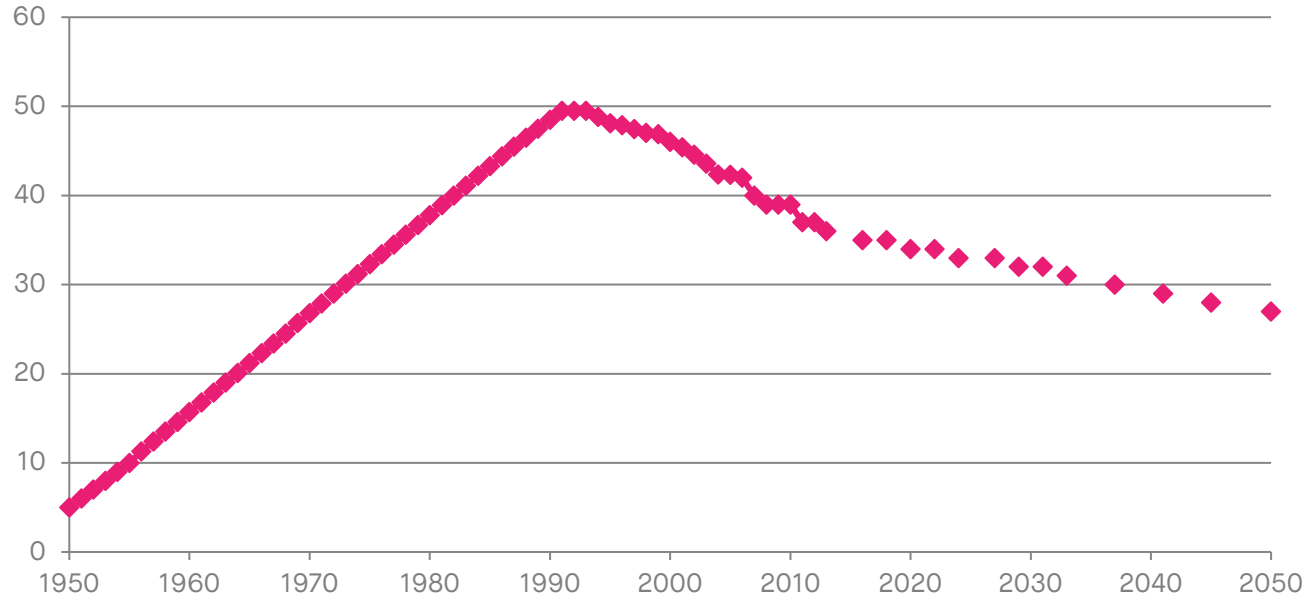
Reducing carbon emissions and pollution from transportation

Motor vehicles are a large source of air pollution in addition to carbon dioxide emissions. The World Health Organisation estimates that road transport, mainly due to the use of diesel, is responsible for up to 30% of particulate emissions (PM) in European cities; in OECD countries, vehicles account for up to 50% of such emissions.[44] Domestically, 22% of total UK emissions of carbon dioxide is due to road transport.[45]

The rate of car in cities such as London has been on the decline, despite population growth and income growth. Urban planning has constrained the reliance on cars by providing alternatives of travel and controlling the expansion of road capacity. In London, car use peaked in 1990, when 50% of all journeys were made in this manner. By 2015, cars accounted for 37% of trips, with academic research suggesting that this trend is likely to continue as the proportion of journeys undertaken by car is estimated to fall to 27% by 2050.[46] There is evidence that car use is also declining in Birmingham and Manchester city centres.[47]

Although the share of journeys made by car in the UK's capital has been declining, an estimated 5.8m such journeys are made every day, making road traffic the single biggest source of air pollution in London.[48] Moreover, outside of major cities in the UK, car dependency remains a major issue. Many parts of the country are poorly served by public transport, leaving car ownership an essential for most households. Where public transport is available, it is often slow, expensive and irregular.

Figure 10 Share of journeys by car in London, 1950 - 2050



Source: Metz, D. Peak Car in the Big City: Reducing London's greenhouse gas emissions (2015)

Over-reliance on individual motor vehicles as a main mode of transportation has negative impacts on both car users and third-parties through two main channels: decreasing a person's 'active time' (exercise) and exposure to air pollution. As discussed earlier, academic research has shown that air pollution contributes to tens of thousands of deaths each year in the UK.

Moving away from diesel (and other fuel) could lead to several benefits. In urban areas, it is estimated that swapping one in four car journeys for walking or cycling could save over £1.1bn in health damage costs per year.[49] Research from the charity Sustrans shows that 40% of short car journeys are undertaken to go under two miles away, which is an easily cycled distance.[50] Encouraging greater use of cycling and walking could lead to health benefits as the population gets more daily exercise.

4IR and the end of private car ownership

4IR has the ability to change the way individuals travel, with the rise of car clubs, telematics and electric & autonomous vehicles. This has the potential to bring with it a wide range of environmental benefits.

Autonomous vehicles and the environment

Automated vehicles (AVs) are designed to be more fuel and energy efficient than their diesel, petrol, and electric counterparts. Estimates suggest that AVs alone could lead to a 2%-4% reduction in oil consumption and related greenhouse gas emissions annually over the next 10 years.[51]

A government-commissioned report estimated that Level 4/5 autonomous vehicles will account for 10% of the market for new vehicles by 2035 under a central scenario.[52] Level 4 autonomous vehicles are capable of driverless valet parking, in addition to urban, rural & highway automated driving. Level 5 autonomous vehicles offer autonomy in all environments.

Autonomous vehicles could play a key role in reducing air pollution, given the ability of connected autonomous vehicles to coordinate and drive more smoothly, with fewer stop-start cycles. Forecasts estimate that, at market penetration rate of 5%, the smooth traffic under automated vehicles will be able to reduce some emissions by between 15% (for carbon dioxide) and 73% (for nitrogen oxides) when stop-and-go waves are reduced or eliminated by the dampening action of the autonomous vehicle in the flow of human drivers.[53] As such, autonomous vehicles offer significant opportunities to improve the environment, even if they are powered by petrol or diesel.

At full automation, the behavioural response of drivers is uncertain. AVs may lead to either more people owning a private vehicle, or they may enable cars to become a shared commodity. The latter scenario is likely to facilitate a further decline in car ownership; the first outcome is likely to result both in an increase of car trips and an increase in the duration of car trips as travel time could be used more productively.[54] As AVs become more affordable in the future, demand for mass (and public) transportation could also decline in favour of individually owned automated vehicles. Pollution and congestion could rise if the absolute number of AV combustion-engine vehicle kilometres increases. [55] Such a scenario would be undesirable even in a world of only electric vehicles – given associated congestion as well as the environmental impact of manufacturing cars. Ultimately, the aim of policymakers should be to reduce rates of car ownership, rather than merely encourage a shift from diesel/petrol to electric vehicles.

Car as a service

The car industry is evolving from one providing goods (vehicles) to households to one providing services; for example, the past decade has seen a sharp increase in the proportion of individuals leasing rather than owning their cars. At the same time as the rise of leasing, car-sharing services such as Zipcar have enabled people living in urban areas to minimise the costs associated with car usage – hiring a car when they need to use one, rather than owning a car that is rarely used. Zipcar recently announced that more than 250,000 UK residents have now signed up to use its service, with one third of members having joined since January 2018.[56] Uber has changed the taxi landscape dramatically, bringing in a new era of convenience for individuals who can now summon a taxi using their smartphone.

Autonomous vehicles could significantly increase the efficiency with which cars are used. At present, individual cars spend the overwhelming majority of their time idle – research by the RAC Foundation found that the average car is parked at home for 80% of the time, parked elsewhere for 16% for the time and only on the move for 4% of the time.[57] We could imagine, instead, a world with fleets of autonomous vehicles which can be hired using a mobile phone app. Once an individual has been dropped off, the autonomous vehicle would then proceed to pick up its next passenger – a "driverless Uber" service. This approach to motoring could cut congestion and pollution by reducing the number of cars on the road. A fleet of driverless taxis could be nearly constantly in use (at least during the day), taking individuals to and from destinations and spending relatively little time parked. Reduced levels of on-street parking could also contribute to reduced congestion and improved traffic flows in some areas.

Smart road pricing

One implication of a shift towards electric vehicles is that the government is set to lose a substantial pool of tax revenues currently associated with car ownership and usage. As petrol

and diesel vehicles are phased out, fuel duty revenue is set to disappear – highlighting the need for new forms of tax revenue from motorists.

One option is for the government to increase vehicle excise duty ("road tax"), including for electric vehicles, to ensure a continued flow of revenues from motorists. But this would be an inefficient way of raising revenue. Critically, as vehicle excise duty does not vary according to how much an individual uses the road network, both heavy and light users of the roads would face equal levels of taxation.

A new system of road pricing seems, from an economic perspective, by far the best long-term form of motoring taxation. Road pricing is also a good way of reducing the environmental costs of car ownership and encouraging individuals to use alternative means of transportation.

Under road pricing, an individual pays a fee to use a stretch of road – potentially a per-mile charge. The level of road pricing would vary depending on the time of day and the location. City and town centres may face higher road prices, for example, to reflect greater levels of demand to use roads in these areas. Similarly, road pricing would be higher in the "rush hour" to reflect greater levels of demand. Road prices could also be set at a higher level in areas suffering from relatively high rates of air pollution.

By varying road prices according to the time of day, individuals would be encouraged to (if they can) use the road network when prices are cheapest and the roads are less congested. This should in turn lead to a greater spread of traffic throughout the day, reducing the bunching of traffic around rush hours. Reducing the numbers of cars idling in traffic in urban areas can help curb air pollution.

Already, basic forms of road pricing exist in the UK – such as toll roads and the London Congestion Charge. What we envision is a much more widespread form of road pricing with more dynamic pricing. For example, the pricing structure of the London Congestion Charge is relatively crude, with times where motorists must pay the charge, and times when motorists are exempt from the charge (such as at night and at the weekend). We expect big data analysis of traffic flows and road demand to bring in road pricing which varies throughout the day and depending on prevailing circumstances on a given day – for example, road user charges may be reduced on a day where traffic is unusually quiet.

London has recently introduced the Ultra Low Emission Zone (ULEZ) in an effort to improve air quality in the capital. Unlike the Congestion Charge, ULEZ operates 24 hours a day, 7 days a week, every day of the year within the same area of central London as the Congestion Charge. Most vehicles, including cars and vans, need to meet the ULEZ emissions standards or their drivers must pay a daily charge to drive within the zone, currently set at:

- £12.50 for most vehicle types, including cars, motorcycles and vans (up to and including 3.5 tonnes);
- £100 for heavier vehicles, including lorries (over 3.5 tonnes) and buses/coaches (over 5 tonnes).

ULEZ effectively creates a higher road price for particularly polluting vehicles, and we would expect such schemes to become increasingly prevalent going forward.

The long term need for a sophisticated road pricing system across the UK is likely to increase the extent to which vehicles are connected – for example, vehicles may need to be fitted with telematic "black box" devices which report on the road prices prevalent in a particular area, so motorists can make informed decisions about where to drive. Mobile phones could also provide such information. Such devices, which would be receiving dynamic pricing data on the road network, could provide guidance for motorists on routes they can take to reduce road charges.

Increasing the attractiveness of public transport

As discussed earlier, improving the environment requires a decreased dependency on car ownership in the UK. Encouraging more widespread use of buses, trains, trams and other forms of public transport would reduce emissions from petrol and diesel vehicles, and curb the environmental damage associated with road building and manufacture of cars.

To do this, public transport needs to become a much more appealing and cost-effective proposition from where it currently stands – and here 4IR technologies create some opportunities.

One way 4IR can improve public transport is through the rollout of "smart city" and "smart town" monitoring devices, such as internet-connected traffic lights – something the SMF discussed in its recent "Tech in the Town" report. In Barcelona, smart traffic lights and traffic control cameras are being used to ensure buses encounter as many green lights as possible when travelling – improving the quality of the public transport service. In addition, the use of smart traffic lights has allowed Barcelona to provide "green light routes" for emergency services responding to incidences, allowing them to provide assistance more rapidly.[58]

Autonomous public transport, which does not require a driver, could also improve the reliability of the public transport network - for example by minimising downtime due to staff shortages or industrial action. Indeed, this is already a reality; the Docklands Light Railway in London operates driverless trains.

In Singapore, there are plans to introduce driverless buses on its public roads by 2022.[59] Nanyang Technological University in the country already uses driverless shuttles at its campus.

The environment on the blockchain

Historically, carbon markets have been highly centralised, opaque and in many instances illiquid, resulting in very restricted market participation. Big data and blockchain technologies offer opportunities to open up the market for carbon, and also increase transparency around the pollution driven by our day-to-day purchases.

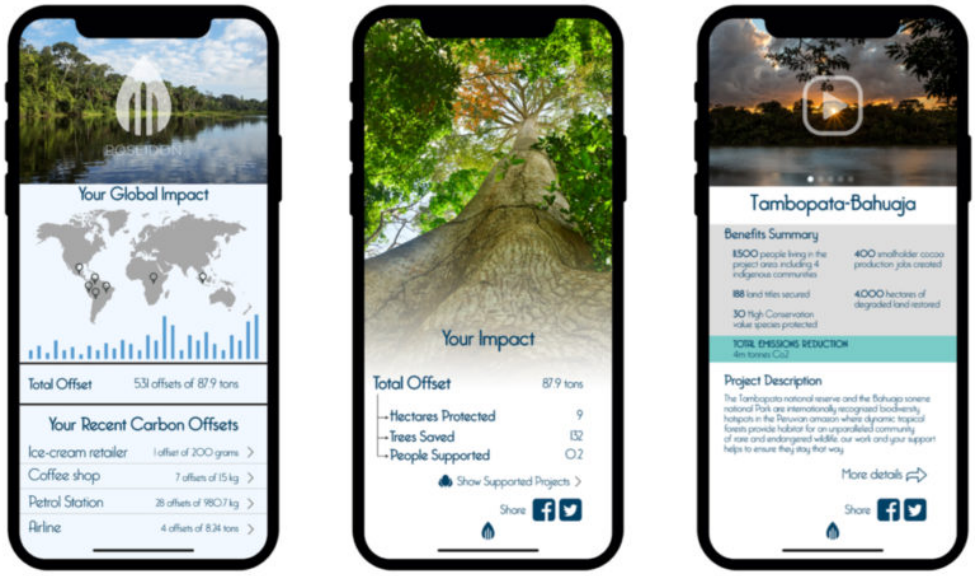
The technology behind blockchain has the potential to open up existing and create new carbon markets for a wider range of players, including smaller businesses and individuals. The distributed ledger technology can add more integrity to the system, remove the need for middlemen and allow more direct and simple channels for purchasing and trading carbon. This ultimately makes it easier for everybody to participate in carbon markets and for new peer-to-peer and business-to-consumer marketplaces to emerge.

A company called Poseidon recently partnered with US ice cream giant Ben & Jerry's to break down carbon credits into microtransactions that can be attached to every scoop of ice cream in

their London Soho store, allowing Ben & Jerry's and their customers to see the carbon emissions of purchases at point-of-sale and the opportunity to offset their impact in real time. The project has, to date, already protected over 4,000 trees.[60]

Furnishing consumers with information about the environmental impacts of their behaviours could change spending patterns significantly – encouraging more environmentally sustainable purchases. Requiring supermarkets to show the carbon emissions associated with products imported from afar could encourage consumers to purchase more locally produced food. A smartphone app infrastructure could develop which makes it easier to understand the environmental cost of our actions – and encourage us to carbon offset, donating money to things such as the planting of trees.

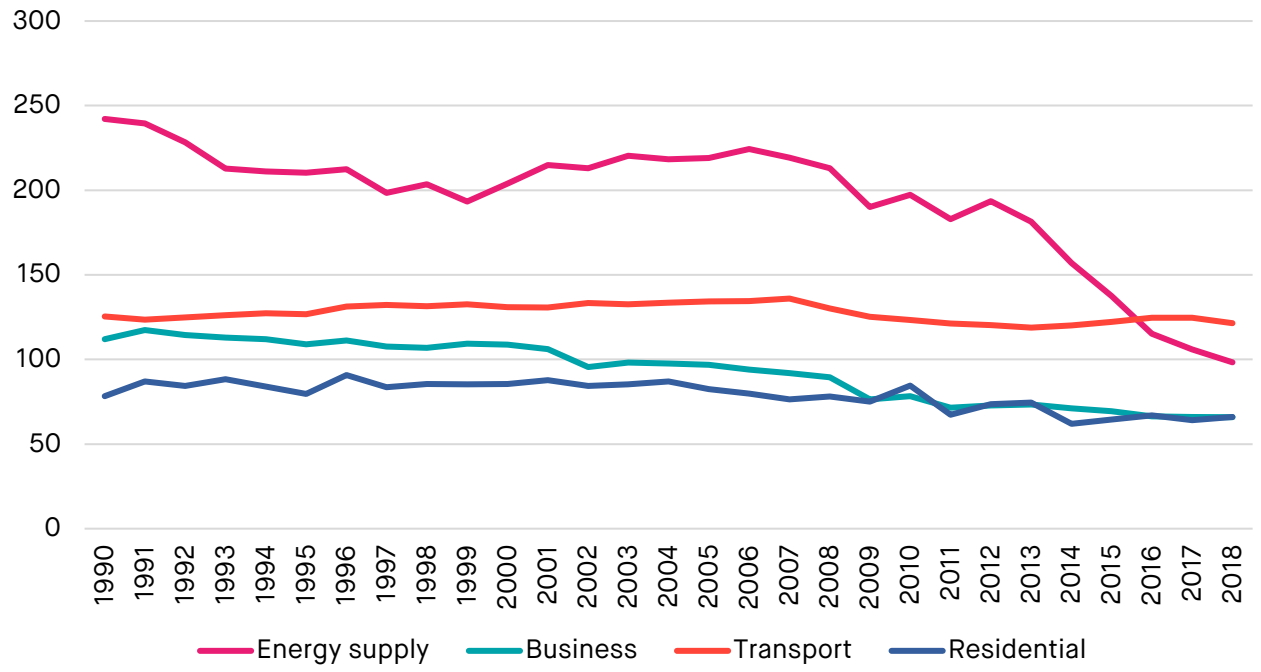
Figure 11: Your environmental impact on an app



Decarbonising industry

As the figure below shows, carbon emissions from UK business have fallen sharply in recent years, and are now broadly in line with residential emissions. In part, this reflects the UK economy increasingly revolving around services rather than manufacturing, mining and other more polluting industries.

Figure 12: Carbon dioxide emissions by source, million ton



Source: "Provisional UK greenhouse gas emissions national statistics 2018", Department for Business, Energy & Industrial Strategy

However, there is still scope for business to go further in reducing its carbon footprint in the UK. In addition to the adoption of autonomous and electric transportation, for example in company car fleets, 4IR opens up additional avenues for industry to decarbonise. This includes:

- **Wider usage or cloud technology.** Delivering business computer applications and services over the internet reduces storage and computer power needs within companies. Big data can also help optimise company computing resource and power usage. A study by Accenture for Microsoft[61] found that cloud-based operations reduced carbon emissions by an average of:
    - 90% or more for small operations (~100 users)
    - 60% to 90% for medium-sized operations (~1,000 users)
    - 30% to 60% for large operations (~10,000 users)
- **Usage of virtual and augmented reality.** Increased usage of "virtual meetings" (e.g. video conferences) to reduce business-related travel.
- **Taking advantage of AI.** AI-optimised energy system modelling and forecasting can help businesses become more energy efficient.
- **3D printing machines.** 3D printing can enable local production of global designs, reducing final product transportation and associated carbon emissions[62].
- **Internet of things technologies.** This includes smart heating systems and appliances in offices which are more energy efficient. Internet connected factory equipment can also help improve industrial lifecycle tracking – optimising machinery maintenance, energy efficiency and recycling[63].

CHAPTER 4: CHALLENGES IN REALISING THE BENEFITS OF 4IR

Although 4IR offers a number of opportunities to improve the environment – from blockchain-based carbon trading to air separation plants – there are a number of challenges to realising these benefits, which we discuss below.

Resistance to road pricing and carbon taxes

The previous chapter of the report highlighted sophisticated road pricing as a way of reducing congestion and the environmental costs of car ownership. But the introduction of such road pricing could be met with significant opposition. Increased use of road tolls was much discussed by the New Labour government in the 1990s and early 2000s, yet implementation was curtailed by public concerns. In 2007, 1.8 million people signed an online petition opposed to toll roads on the Downing Street website. A BBC-commissioned survey in that year showed 74% of respondents opposed to road pricing, where motorists would be charged by the mile during busy periods.[64]

Similarly, while the public has become more concerned about the environment in recent years, it is unclear whether voters are willing to put their money where their mouths are. Blockchain and data analytics offer the potential to better understand the pollution associated with our actions – which could allow government to do more to tax the most polluting activities. How would consumers respond to higher prices in the shop as more goods are affected by carbon and other environmental taxes? Significant public opposition remains a distinct possibility.

The need for a shift in consumer thinking about private car ownership

As discussed, decarbonising the economy requires a significant change in our approach to mobility – away from petrol and diesel vehicles and towards electronic and autonomous ones. However, that is not enough – we also need to reduce our dependency on private vehicle ownership altogether. That means encouraging a shift towards public transport, taxis and car clubs.

This will require a significant change in consumer mindsets. Firstly, households requiring a car need to be sold on the idea that electric vehicles are fit for purpose. “Range anxiety” – concern about not having enough battery for a journey – is currently a major barrier to uptake of electric vehicles, alongside cost. This is despite the fact that electric vehicles currently have more than enough battery power for typical car journeys – a normal commute to work, a visit to the supermarket and so on.

Range anxiety concerns should resolve themselves in the long-term as technological progress improves the range of electric vehicles and the number of rapid charging points expands. Consumers also need to consider new options – such as owning an electric vehicle and perhaps hiring a petrol or diesel vehicle on the rare occasions when a longer commute needs to be made.

Perhaps the harder consumer shift will be encouraging greater use of public transport. Private cars are, for many, a status symbol that will be hard to let go of. They also provide unrivalled convenience in many instances – for example when transporting large items or making journeys

to places that are poorly served by public transport. Government has a long way to go before public transport can rival such levels of convenience.

The need for forward thinking from government

Government needs to become more forward looking when it comes to technological change. This means ensuring that the infrastructure being built today is suitable for future needs.

With respect to electronic and autonomous vehicles, there are numerous infrastructure requirements that need to be put in place before these become a widespread technology. Charging infrastructure for electric vehicles needs to expand significantly. Depending on the level of sophistication and intelligence of autonomous vehicles, there may be a need for roads to be redesigned into a format that is easier for an autonomous vehicle to navigate. Much of the UK's road network is relatively old, and complicated road layouts may prove difficult for autonomous vehicles to navigate.

If government is to reduce car ownership, thought also needs to be given to town/city planning and the location of new homes. Homes need to be built close to public transport connections, jobs and other amenities if we are to curb car dependency, yet this is not happening. Alternatively, public transport needs to expand to serve homes that are currently poorly served by bus and rail connections. A recent report by the RAC Foundation argued that many new build homes are being produced next to bypasses and link roads which are too far out of town to walk or cycle, and which lack good local buses.[65]

Critically, 4IR needs to be supported by the right digital infrastructure network. This includes sufficiently fast broadband and mobile coverage to support the take-off of 4IR solutions.

Uncertainties around the pace of change required

While there is broad agreement on where we need to go on the environment – decarbonising industry, moving away from petrol/diesel vehicles and so on – there is uncertainty and disagreement on what is a sensible timetable for getting there. In part this reflects uncertainty around how catastrophic climate change could be, as well as how long we have left to be able to limit or reverse global warming.

This uncertainty creates some real challenges for policymakers. A rapid and difficult-to-achieve timetable risks spooking the electorate. Widespread social unrest could follow the introduction of measures which increase living costs (through for example higher taxes on cars) or lead to job losses in industries deemed to be too polluting.

On the other hand, an unambitious timetable risks environmental disaster due to excessive global warming. If rapid change is required, this might be very difficult to achieve in a democratic society – where politicians are primarily concerned with winning the next election, undermining incentives to make unpopular choices which might not yields benefits until many years later.

As discussed earlier, the Conservatives have set a target of being net-zero on greenhouse gas emissions by 2050. However, others such as Friends of the Earth believe this is an unambitious pace of decarbonisation.[66]

Whether the 2050 target is retained, or a more ambitious target is brought in following pressure to do more, more rapidly, it is crucial that policymakers publish details on how they intend to meet their targets, and to ensure that the electorate buys into these policy measures.

Costs of technological solutions

While some technological solutions, such as low power wide area networks for monitoring the environment, can bring benefits for modest cost, other technologies come with a high initial price. This includes air separation plants which could help decarbonise the atmosphere.

Evaluating policies related to the environment is particularly challenging for government – given uncertainties around the pace of change required and the consequences of inaction. These uncertainties mean that appraising technological solutions – through a cost-benefit analysis – is not without its challenges. Another issue is the cross-border nature of climate change. The benefits of the UK's investment in decarbonising technologies are spread across the globe, even if the UK bears all the costs of the technologies. As such, technologies such as air separation plants might suffer from what is known as the "free rider problem" – other countries might fall into inaction on climate change, as the issue is being dealt with by "others". This could be resolved through the creation of a complete global carbon market, where countries and businesses engaged in decarbonising activity are paid a fair price for such initiatives. However, there are substantial challenges to creating such a global carbon market, particularly given likely unwillingness of some countries to participate in the market.

CHAPTER 5: WHAT NEXT FOR POLICYMAKERS?

Below we set out a series of practical policy recommendations that we believe could encourage more widespread use of 4IR technologies for addressing environmental issues such as climate change and air pollution.

Fair green taxation

In the previous chapter, we discussed the challenges associated with the likely unpopularity of taxes aimed at discouraging pollution and improving the environment – such as road pricing.

To gain support for green taxes, it is important that they are seen as fair and not as just a cash cow for government. This includes ensuring that low income households are not overly-penalised by these new taxes.

Fairness can be built into the design of measures such as road pricing. For example, road pricing could be made progressive by giving households a free allowance of road usage each year. This would help protect lower income households, who tend to travel less than higher income households – ensuring that the burden of motoring taxation falls more heavily on the richest individuals.

Recommendation 1:

Ensure that fairness is a key component of environmental tax design. A new road system pricing should include a free allowance of road usage each year, to help reduce the burden of taxation on lower-income households.

Harnessing the power of big data for the environment

The smart and intelligent use of data has the potential to improve the environment. Better monitoring, through internet-connected devices, can raise awareness of air pollution and carbon emissions. It can also help provide personalised advice to individuals – especially those suffering from respiratory illnesses such as asthma. Making it easier for consumers to measure their carbon footprint, and the environmental impact of their purchases, could cause a step change in behaviour for the good of the environment.

There is much that policymakers can do to facilitate this data revolution. The first is through the installation of low-cost air pollution monitors – such as on streetlights and public buildings. At present, there are not enough of these monitors installed across the UK. Requiring pollution monitors in every postcode area of the UK would be a welcome measure – as requested in the Times Clean Air for All campaign. Policymakers should also consider the role that smartphone data could play in providing insights into air pollution. Smartphone data can identify congestion and weather in areas, and therefore estimate likely levels of air pollution.

Critically, a national, comprehensive set of air quality data should be made available to the public, including through an application programming interface (API) to support the development of smartphone apps and online tools – such as those providing personalised advice (e.g. travel

routes) related to air quality. Air pollution levels should become a regular feature of weather forecasts going forward.

Government should also demand more from big business on environmental data. Requiring large firms to collect and share more information on the environmental footprint of the products they sell can help consumers and businesses to make more environmentally-friendly choices. It can also create new opportunities for consumers to engage in activities such as carbon-offsetting, and the creation of an app infrastructure increasing the ease of carbon offsetting.

Recommendation 2:

Require large companies to collect and provide information on the environmental impact of their operations. Building on mandatory carbon reporting, this information should include effects on air quality, use of plastics and primary materials. Such data should be publicly available.

Recommendation 3:

National government to commit to installing air pollution monitors in every postcode area of the UK, as requested in the Times "Clean Air for All" campaign.

Recommendation 4:

Ensure that air pollution data gathered from these monitors is open source and accessible through an application programming interface (API), to support the development of apps providing personalised advice on air pollution.

Forward planning

Policymakers need to ensure that the homes we are building today, and the transport decisions being made, are the right ones for a future in which we are aiming to decarbonise the economy. At present, such forward thinking is lacking.

To meet our environmental goals, urban planners need to be thinking increasingly about:

- Requiring large housing developments to have car sharing facilities.
- Introducing new requirements for electric car charging points in new developments.
- Ensuring road layouts in new developments are "autonomous vehicle friendly"
- Ensuring homes are located near public transport, or that bus and rail networks are expanded to serve new developments
- Planning on the assumption that car ownership must diminish in the future.
- Fitting environmental monitors in the urban environment.

- Ensuring that the broadband and mobile infrastructure is in place to allow the creation of "smart" towns and cities which can use data to tackle environmental issues, reduce congestion and improve the quality of public transport.

On the decarbonisation of transport, government has committed to banning the sale of new petrol & diesel vehicles beyond 2040. But it needs to go further and focus on a modal shift towards public transport usage. Given this, we recommend that, in addition to the petrol & diesel vehicle ban, that government sets a target reduced rate of car ownership in the future, as well as a target for journeys made on foot, by bike and by public transport such as buses and trains.

Recommendation 5:

Develop a planning strategy, to ensure that homes being built today are suitable for a carbon "net zero" world of lower rates of private car ownership. The creation of "smart", internet and data-driven towns and cities, with the supporting broadband and mobile infrastructure, needs to be central in the planning process.

Recommendation 6:

In addition to banning new sales of petrol & diesel vehicles beyond a certain point, set a target for reducing rates of car ownership, and increasing the proportion of journeys made on foot, by bike and by public transport. Cities and large towns should aim for a quarter of journeys to be made by bicycle – a similar proportion to the Netherlands.[67]

ENDNOTES

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