

# Green Shoots

*How to drive innovation to meet net zero*



Ted Christie-Miller | Alex Luke

ONWARD >

# About Onward

Onward is a campaigning thinktank whose mission is to develop new ideas for the next generation of centre right thinkers and leaders. We exist to make Britain fairer, more prosperous and more united, by generating a new wave of modernising ideas and a fresh kind of politics that reaches out to new groups of people. We believe in a mainstream conservatism – one that recognises the value of markets and supports the good that government can do, is unapologetic about standing up to vested interests, and assiduous in supporting the hardworking, aspirational and those left behind.

Our goal is to address the needs of the whole country: young as well as old; urban as well as rural; and for all parts of the UK – particularly places that feel neglected or ignored in Westminster. We will achieve this by developing practical policies that work. Our team has worked both at a high level in government and for successful thinktanks. We know how to produce big ideas that resonate with policymakers, the media and the public. We will engage ordinary people across the country and work with them to make our ideas a reality.

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## About the programme

This year-long programme of work, culminating at COP26 in November 2021, will explore the practical challenges to net zero and set out a series of bold, deliverable and politically possible policies to achieve it. It will be framed around how the green transition can be aligned to the economic recovery, turbocharging green growth and levelling up productivity rates and employment levels across the whole of the UK. It will focus on three core components: a large-scale analysis of key incumbent industries; research on the green skills and jobs opportunity; and an exploration of the possibility for future innovation to materially drive down or capture emissions at the pace required.

The programme follows on from Onward's 2019 report, *Costing the Earth*, which set out the case for decarbonisation through innovation and greater government accountability. This, combined with Onward's work on levelling up and political strategy ahead of the 2019 election, puts Onward in an ideal position to be a bold voice for practical and politically possible decarbonisation policy.

## About the authors

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# Summary of the argument



Getting to net zero requires us to transition, at pace, from an economy dependent on fossil fuels to an economy fuelled by renewables and low-carbon alternatives. If we do not want to accept lower growth, much higher borrowing or declining living standards, the only way to achieve this is to develop, scale and diffuse technologies that are either in their infancy or are not yet viable. In short, net zero - much like the pandemic - is an innovation problem as much as it is an economic or political challenge.

This is particularly acute given the historically low levels of research and development (R&D) intensity and capital investment in low-carbon and net zero technologies to date. In two of the UK's most carbon-intensive industries - Land Transport and Construction - companies spend as little as 0.01% and 0.09% of turnover respectively on R&D annually. In the last six years, investment in clean technologies has averaged just £7.3 billion per year; one seventh (14%) of the investment needed to meet the trajectory set by the Climate Change Committee's Sixth Carbon Budget.

It is not just investment and early-stage development that we should worry about. Even when low-carbon products exist, we have proved slow to diffuse them across the economy. Heat pumps and electric vehicles have existed for some years, but have struggled to become mass market products. To achieve official targets - such as the adoption of 600,000 heat pumps by 2028 and all new car sales to be electric or hybrid by 2030 - there needs to be a step change in levels of production and demand. On current trajectories, heat pump installations will not achieve nationwide rollout until 2187 - a century and a half too late.

Unless we do something about it, this innovation deficit will severely inhibit our ability to innovate our way to net zero - driving up costs, heightening disruption and locking the UK into a higher emission pathway. At present innovation is made harder by a number of market distortions that prevent efficient incentives for investors and entrepreneurs. The UK suffers from both static price failures, whereby prices do not reflect carbon costs to society - which Stern and Stiglitz estimate as a \$100/tonne - and dynamic failures where people make choices that appear economically sensible in the short-run but leave society worse off in the long-run.<sup>1</sup> This strengthens the case for the government to take a more active role in supporting net zero innovation and diffusion, and ensuring effective regulation of key technologies.

- First, strong incentives need to be put in place to encourage the early-stage development of net zero-aligned technologies, including green hydrogen, carbon capture and battery technology. This can be done by ensuring carbon prices accurately reflect carbon costs. It could also be done by embracing mission-orientated funding, boosting high value human capital, and ensuring intellectual property frameworks are fit for purpose.

- Second, we need clean technologies - once developed - to be able to be deployed at scale across the whole economy in a rapid timeframe. While market forces will do much of the heavy lifting, the tight timescale will likely require the Government to tighten consumer and business incentives for certain technologies to ensure their rollouts are fast enough to reach net zero.
- Third, policymakers should ensure that any regulation sector supports, rather than prohibits, scientific innovation. This could be done by creating a Green Innovation Sandbox Service to reduce barriers to net zero innovation and introducing a Regulated Asset Base model for capital-intensive strategic energy projects, such as nuclear.

The innovations of recent decades, and the rapid diffusion of digital communications technologies, should give policymakers confidence that market-led technological innovation can help to achieve net zero. But it is also true that the innovations such as the smartphone, internet and GPS were developed using government-initiated research, stewarded by sensible regulation and diffused with the help of public infrastructure, like spectrum and satellite technology.

It is time for the Government to embrace its role in creating the frameworks and incentives through which the innovation needed to get to net zero will flourish, and provide a foundation for a more dynamic and sustainable economy. This report sets out how to do just that.

# Summary of recommendations

Problem	Solution
<p>Historic government interventions have distorted the price of carbon, meaning market signals do not effectively incentivise consumers or firms towards sustainable behaviour</p>	<ol style="list-style-type: none"> <li>1. Establish a gold standard for carbon offsets, by establishing a new Carbon Accounting Regulator.</li> <li>2. Rebalance carbon prices through the VAT system, to ensure incentives encourage the uptake of low-carbon products.</li> <li>3. Introduce a Conservation Tax Relief, to encourage donations of land which could act as a natural carbon sink.</li> <li>4. Commission the Office for Tax Simplification to review the options for a carbon tax.</li> </ol>
<p>More support is needed to mobilise people and institutions to develop innovations and solve key net zero challenges.</p>	<ol style="list-style-type: none"> <li>5. Establish a National Energy Laboratory, to research net zero technologies and overcome energy system challenges.</li> <li>6. Actively recruit top global scientists and researchers in key net zero technologies.</li> <li>7. Create a Net Zero Genius Grant, to attract the best scientists and inventors to conduct cutting-edge net zero research in the UK.</li> </ol>
<p>The cost of Carbon Capture, Uptake and Storage (CCUS) is currently not commercially viable.</p>	<ol style="list-style-type: none"> <li>8. Expand the Contracts for Difference model to include CCUS, to reduce the cost of carbon capture.</li> </ol>
<p>The current heat pump rollout trajectory is not even close to being on track for the 2050 net zero target.</p>	<ol style="list-style-type: none"> <li>9. Incentivise low-carbon heat installation             <ul style="list-style-type: none"> <li>• Make a proportion of the cost of installing a low-carbon heating system deductible from personal tax.</li> <li>• Create a boiler breakdown scheme.</li> <li>• Introduce a community finance model for heat networks.</li> </ul> </li> </ol>
<p>Regulatory barriers and high capital costs can present difficulties in bringing innovations to market.</p>	<ol style="list-style-type: none"> <li>10. Create a ‘Green Innovation Sandbox Service’, to allow innovators to demonstrate the commercialisation of their products under a derogation from regulation.</li> <li>11. Introduce a Regulated Asset Base model for capital intensive strategic energy projects.</li> <li>12. Introduce a Carbon Credit Tax Relief for negative emissions technologies such as Direct Air Capture</li> </ol>

# The challenge

*Innovating our way to net zero*



In amending the Climate Change Act in 2019, Parliament legislated not only to set a pathway to net zero emissions by 2050 but to deliver the majority of that reduction - 78% - within a much shorter timescale, by 2035 in order to meet the Paris Agreement target of keeping global CO2 emissions below 1.5-2 degrees Celsius. This gives the lie to the idea that the UK can postpone difficult decisions on climate. The timescales are too short and the risk too great for anything other than wholesale action now.

But while net zero will inevitably lead to considerable changes in how we live, travel, heat our homes or manufacture products, it does not have to lead to lower living standards or slower growth. If progress on emissions is driven primarily by rapid scientific innovation, rather than regulation, net zero should lead to higher welfare, lower costs and a more resilient economy. But to achieve that, we need to develop, scale and diffuse low-carbon technologies at a much faster pace than the UK has done to date. We need a green innovation revolution to undo the climate legacy of the industrial revolution.

Several promising net zero technologies are currently held back from deployment because they are expensive and sub-scale, rendering them barely commercially viable. For instance, a tonne of carbon dioxide abatement using Direct Air Capture can cost anywhere between £200 per tonne to £800 per tonne. This makes it too expensive to be market competitive. We have a short window of time to accelerate the development of these and other technologies to reduce the costs and disruption of net zero. It will take concerted action from both the public sector and private enterprise - driven by strong incentives and institutions - to be successful.

And it is only by acting now that ministers can create viable pathways to reach net zero and cut costs to consumers and businesses along the way. The rapid innovation in offshore wind that occurred in the last decade was achieved only with deep government subsidies through Contracts for Difference and strong institutional support from the Green Investment Bank. Offshore wind farms reduced their costs by 72% in the period 2013-2021. Achieving a similar decrease in cost over a similar timeframe will be crucial if we are to ensure the commercialisation of key technologies like carbon capture, hydrogen and battery technology. If this does not happen, the costs from both climate disasters and adaptation are likely to rise considerably.

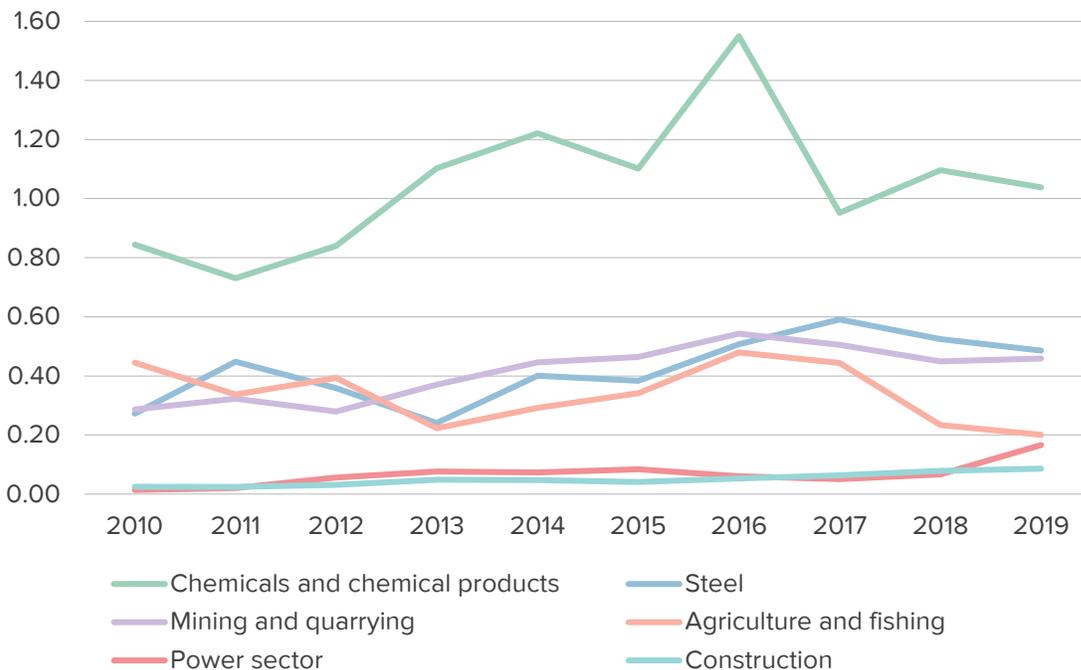
## Carbon-intensive industries

R&D intensity - spending on research and development as a share of total turnover - has historically been low in some of the most carbon-intensive industries. For instance, Land Transport and Construction industries currently spend 0.01% and 0.09% of turnover respectively on research and development - despite buildings and transport being the two most emitting sectors in the UK economy. This is in stark contrast to other sectors: the Chemicals industry has an R&D intensity 12 times as high (1.04%) as Construction.

Low R&D intensity has contributed to limited innovation in some carbon-intensive sectors, reflected in their poor levels of decarbonisation over the last three decades. As Figure 1 shows, many carbon-intensive sectors have had rising R&D intensity since 2010 but have flatlined since the middle of the decade. The three least R&D intensive industries - Transport, Construction and Agriculture have decarbonised slower than almost any other sector. The transport industry has cut emissions by just 1% since 1990, the Agriculture sector by 33% and the Construction sector has increased emissions by 46% since 1990. R&D intensity in carbon-intensive sectors is especially low compared to some of the UK's most innovative industries. R&D intensity in Computer, Electronic and Optical products and Pharmaceuticals is 5.35% and 2.68% of turnover respectively.<sup>2</sup>

**Figure 1: R&D intensity of selected carbon-intensive industries, 2014-2019**

Source: ONS, Onward Analysis



This gap in R&D intensity has been reflected in the levels of progress these sectors have had. Decarbonising to net zero within the next three decades will require significant and rapid changes across many parts of the economy, but particularly so for carbon-intensive industries. In order to achieve these changes within the tight timeframes required, high levels of productivity will be required within these industries.

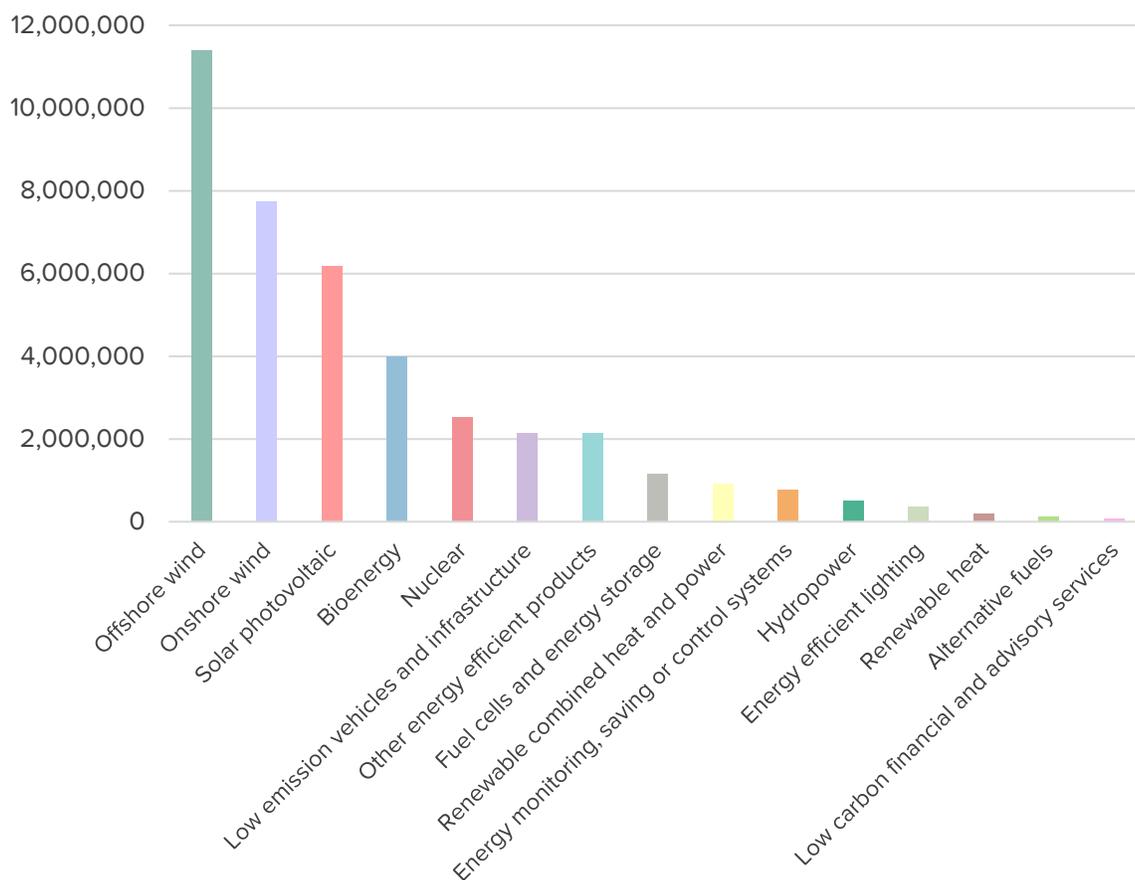
As the works of Wakelin (1997) and Guellac & van Pottelsberghe de la Potterie (2003) have shown, along with many others, there is a clear correlation between R&D intensity by a business or industry and productivity.<sup>3 4</sup> Kancs & Siliverstovs (2016) found that this relationship is nonlinear, and in fact higher levels of R&D intensity resulted in greater productivity elasticity.<sup>5</sup> While a minority of carbon-intensive sectors are by their very nature low in R&D intensity, such as construction, increasing R&D spending is a clear route to boosting productivity across many others. Doing so will bolster innovation in these industries and put them closer to being on the right track to reach net zero by 2050.

### Lack of investment in net zero industries

Total capital investment in Low Carbon and Renewable Energy Economy (LCREE) sectors (as defined by the Office for National Statistics) totalled £44 billion since 2014, equivalent to around £7.3 billion a year to 2019.<sup>6</sup> Nearly half of this investment since 2014 (£19.1 billion) has been directed towards offshore and onshore wind.

**Figure 2: Total capital investment in net zero sectors since 2014 (£ thousands)**

*Source: ONS LCREE, Onward Analysis. Note that the 'Carbon capture and storage' and 'Other renewable energy' sectors are excluded here as their investment figures were not disclosed as part of the LCREE release*



This total investment is considerably lower than the sum likely to be needed. The Climate Change Committee has argued that “low carbon investment must scale up to £50 billion each year to deliver net zero”.<sup>7</sup> It is also disproportionately lower than other infrastructure transitions. For example, the first major investment in the UK railways between 1836 and 1837 cost £35 million, equivalent to £3.6 billion today.<sup>8</sup> Considering an investment of this scale was made on railways alone, the economy-wide investment needed to deliver net zero will be much larger.

Investment as a percentage of total turnover varies significantly between different sectors, reflecting their different stages of development. In technologies such as fuel cells, 77.2% of turnover has been directed towards investment since 2014. This level of R&D intensity is significantly higher than other crucial net zero industries such as low emission vehicles and infrastructure (8.4%), renewable heat (4.2%), low carbon financial and advisory services (1.6%) and Carbon Capture and Storage (0%, due to zero current turnover).<sup>9</sup>

Low emission vehicles and renewable heat alone are forecast to provide up to 1.5 million jobs by 2030, if the UK meets the pathway set out in the CCC’s Sixth Carbon Budget, but may struggle to do so if innovation does not lead to the lower costs and higher performance necessary to increase consumer demand. This suggests that a key priority for the Government should be to encourage much higher levels of R&D intensity in key net zero industries, well in advance of 2050.

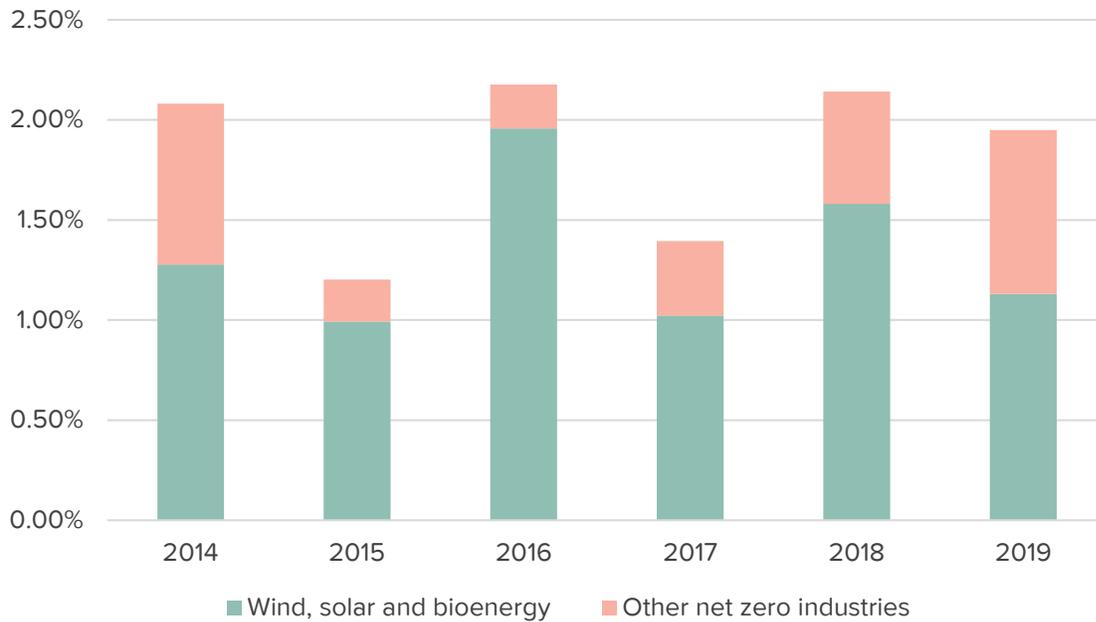
On top of this, as Figure 2 shows, the amount of investment in each sector is heavily weighted towards the power sector. This is despite the fact that more investment is needed in sectors which are likely to contribute much more towards decarbonisation in future than they currently do, such as renewable heat, carbon capture and hydrogen.

Investment by industry can also be expressed as a proportion of total national Gross Fixed Capital Formation (GFCF). GFCF represents an estimation of the total net capital spend by both the public and private sectors on everything from new machinery and software to infrastructure, and so encapsulates all capital investment in the LCREE sectors. For example, there has been more than twice the proportion (1.3%) of total investment in select industries within the power sector - offshore wind, onshore wind, solar and bioenergy - as in all other net zero sectors combined (0.5%), as shown in Figure 3.

While the UK’s record on decarbonising power is impressive, partly as a result, the relative lack of investment in greening construction, transport or manufacturing, for example, has held back progress in other carbon-intensive parts of the economy.

**Figure 3: Capital investment in net zero sectors as a proportion of total national capital investment (GFCF)**

Source: ONS LCREE, ONS, Onward Analysis



### Current public innovation funding for the transition is insufficient

The Government supports innovation for net zero technologies through two main mechanisms: funding delivered by UK Research and Investment (UKRI), such as the Industrial Strategy Challenge Fund (ISCF), and funding delivered by BEIS through the Net Zero Innovation Portfolio (NZIP).

Following the establishment of UKRI in 2018, the primary body funding low-carbon and net zero innovation is Innovate UK (formerly the Technology Strategy Board). The ISCF, which began in 2017 and will run until 2025, is delivered through Innovate UK, and provides funding to meet 23 challenge areas. Of these, just over half (13) are aimed at the net zero transition, aiming to promote clean growth and the development of greener transport. The total funding is around £1.4 billion over the duration of the fund, or £173m per year - a relatively small figure given the scale of the challenge.

There is an argument that Innovate UK and UKRI have historically underfunded net zero technologies. Since the establishment of Innovate UK in 2004, just £1.7 billion of funding has been awarded to projects within the ‘Clean Growth & Innovation’ sector (c. £2.0 billion in 2021 prices), averaging around £100 million per year.<sup>10</sup> This represents around a seventh, 14.6%, of total Innovate UK funding over this period. By comparison, the ‘Ageing Society, Health & Nutrition’ sector received a 17.1% share of Innovate UK funding, equivalent to £2.3 billion in 2021. It should be noted that Innovate UK funding for EVs is primarily distributed under the ‘Manufacturing, Materials and Mobility’ (MMM) sector, for which funding has totalled £5.5 billion since 2004 (£6.5 billion at 2021 prices).

However, it is difficult to determine the proportion of this funding which is net-zero aligned and hence it has been excluded from this analysis. Even if the MMM sector funding was entirely net-zero aligned, funding would average just £360m per year. A lack of available funding has manifested itself in the number of business-led applications to Innovate UK which are approved and awarded finance, which currently stands at just 15%<sup>11</sup>. This means that up to 85% of businesses developing new net zero technologies who apply for such funding are rejected and are forced to seek support elsewhere, likely from the private sector which comes with the expectations of financial returns.

Innovate UK also funds and oversees a network of nine Catapults, independent technology and innovation centres which aim to assist private and public research bodies to bridge the gap between innovation and commercialisation of new technologies. Catapults are designed to be funded in 'thirds', with a core third of funding from government, one third from the private sector, and one third from collaborative research and development.

However, while this arrangement creates skin in the game for all partners, short-termism and relative lack of funds can militate against long-term and full-scale strategic partnerships. First, the Catapults are funded in 5-year periods, meaning they have only short-term funding certainty. Second, they receive relatively little funding compared to broader R&D spend: in the current period - for 2018-2023 - Innovate UK allocated just £780m to the Catapults network, including £180 million for the Renewable Energy Catapult, equivalent to just £36m per year.<sup>12</sup> This is far smaller than the R&D budget of many private-sector firms - the world's 10 largest wind turbine manufacturers spent around £1.4 billion on R&D in 2018 - therefore limiting the scope for private-public sector joint development.<sup>13</sup>

The £1 billion Net Zero Innovation Portfolio was announced as part of the Ten Point Plan. It aims to provide funding to companies within 10 specific net-zero priority areas in order to commercialise innovative new technologies, such as CCUS, Nuclear, Hydrogen and Energy Storage & Flexibility. This funding is welcome and is delivered through funding competitions targeted at bringing technologies forward to the demonstration stage. While funds have steadily been released, funding competitions remain small in comparison to the scale of the challenge. For example, a competition for floating offshore wind is worth just £17.5 million.<sup>14</sup>

## The UK has a poor past record at commercialising key technologies

The Climate Change Committee's Net Zero Balanced Pathway is heavily reliant on widespread commercialisation and deployment of key technologies. For a number of nascent technologies such as CCUS, Direct Air Capture and Battery Technology, the Committee assumes a certain degree of "commercialisation" and "cost-reduction" as a result of innovation.<sup>15</sup>

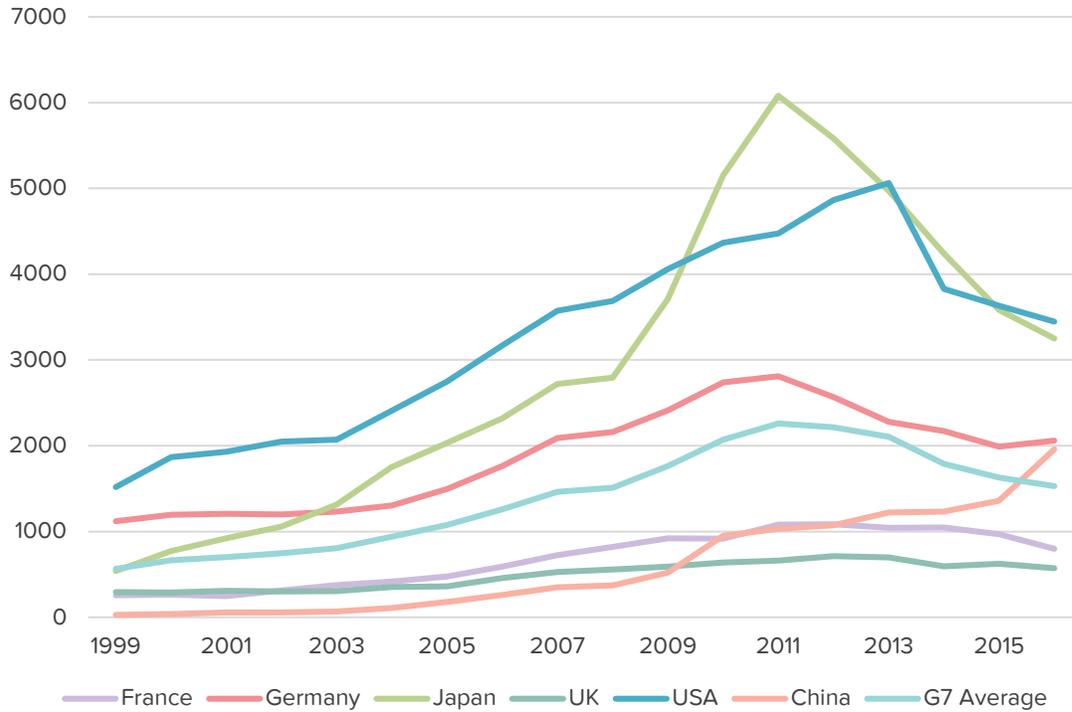
On one level, this assumption is well-placed: the UK has some of the best science and research capability in the world. But it is also true that the UK has in the past often failed to leverage our basic science expertise for commercial gain. For example, only around 5-7% of UK businesses report cooperation activities with universities, Higher Education Institutions or public sector research organisations.<sup>16</sup> Similarly, when businesses have been asked to indicate how much they use universities as a source of knowledge for innovation, and how important they see universities as such a source of knowledge, only around 20% of businesses value universities in this way - and neither measure shows a clear upward trend in recent decades, as Haskel et al have found.<sup>17</sup>

This problem is particularly true in environment-related technologies. Up until 2012, the UK had a consistent - if modest - upward trajectory in environment-related patents, but since then there has been a drop off of 20% up to 2016. The UK underperforms in comparison to our main European competitors. Germany, for example, filed 246% more patents in environmentally-related technologies than the UK between 2012 and 2016, the most recent 5-year period for which data is available. France's output over the same period was 54% higher than that of the UK. This is despite the fact that these nations have also seen a drop-off in annual patents filed over this period. Meanwhile, other economic competitors such as China have increased their level of patents over this period by 82%.<sup>18</sup> This is indicative of a growing trend of China overtaking G7 countries in terms of environment-related patents, as shown in Figure 4.

In practice, China has positioned itself as a world leader in environment-related technologies, exporting technologies to Western countries with strict climate targets to enormous economic benefit. Today, China manufactures 73% of the global supply of electric vehicle batteries, 80% of solar panels and more than half of newly installed wind power capacity.<sup>19 20 21</sup> This dominance is a product of the Government's forward planning for the long-term and state-led investment, but it has also benefited from far higher levels of patenting and superior commercialisation.

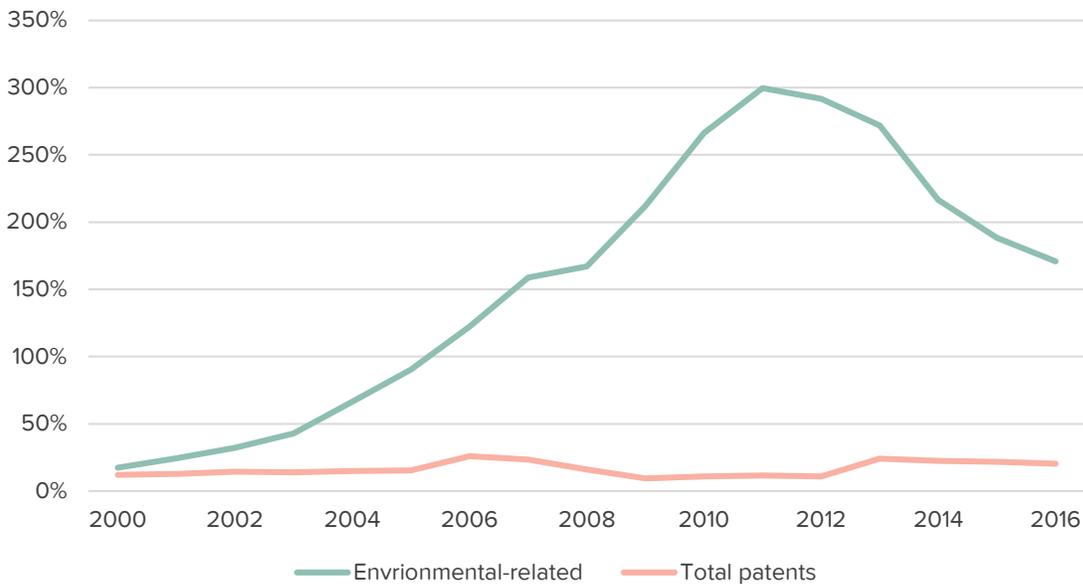
**Figure 4: Total patents applications in environment-related technologies filed under the Patent Cooperation Treaty, across selected countries and the G7**

Source: OECD, Onward Analysis



**Figure 5: Percentage increase above 1999 levels in patents filed each year in the UK under the Patent Cooperation Treaty**

Source: OECD, Onward Analysis



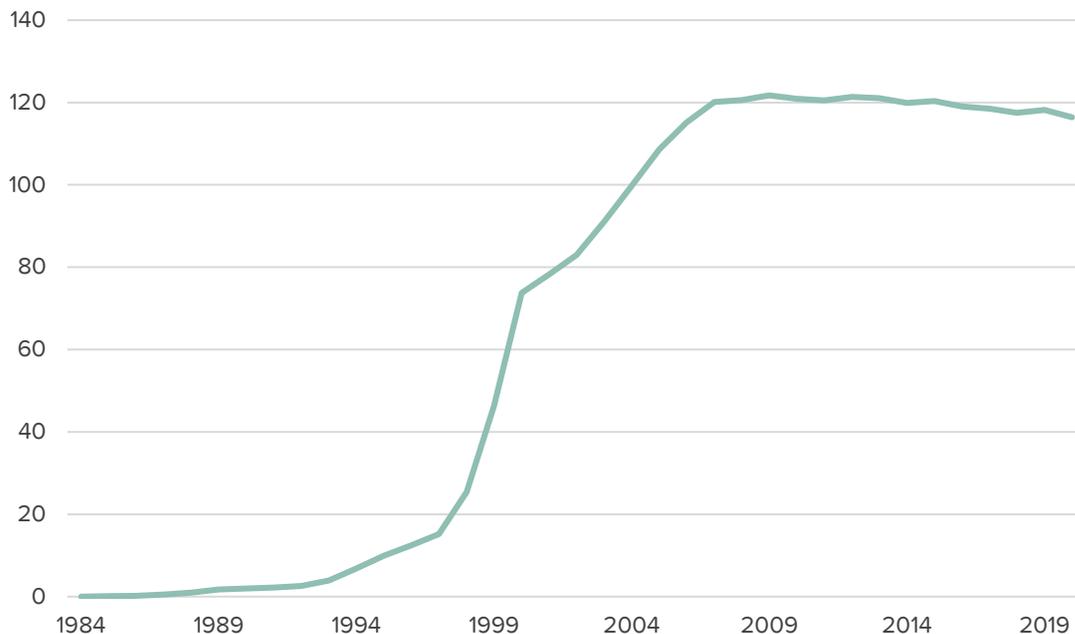
**In addition to fostering the scientific innovation necessary to deliver net zero, diffusing new technologies across the real economy in time will be an additional challenge**

The recent history of innovation demonstrates that even when new technologies are priced for mass consumer markets and offer transformational welfare benefits, they still take time to diffuse across entire populations. For example:

The roll-out of mobile phones took roughly two decades to be fully diffused across the UK economy, as shown by Figure 6. In 1985, there were 0.09 mobile cellular subscriptions per 100 people. It took 20 years for there to be as many mobile phones as people (109 per 100 people) in 2005.<sup>22</sup> This is despite overwhelming demand and a steep fall in the average price from more than \$3,000 per unit in the 1980s, to less than \$1000 in 1997.<sup>23</sup>

**Figure 6: Number of mobile cellular subscriptions per 100 people in the UK**

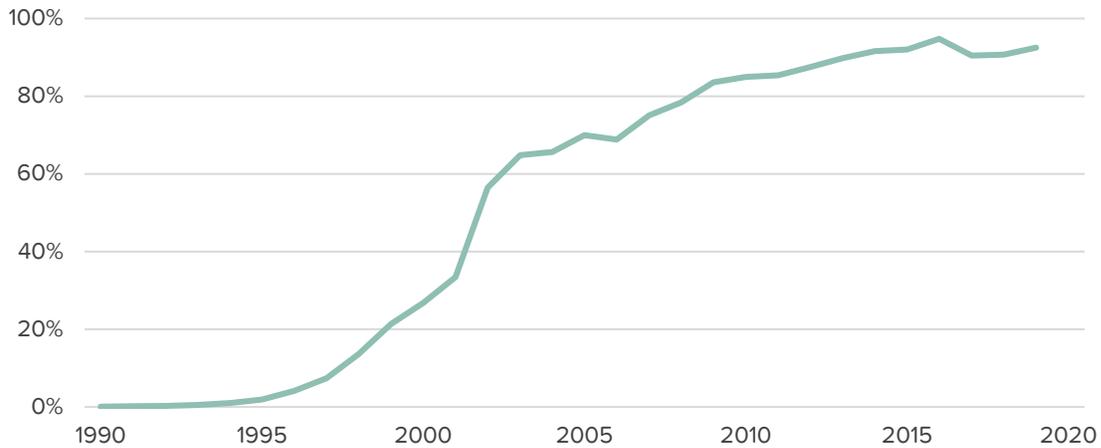
*Source: World Bank, Onward Analysis*



The roll-out of the internet was slower, as shown by Figure 7. In the space of ten years, from 1990 to 2000, the share of people using the internet went from 0% to two thirds (65%), but by 2010 only 85% of people were internet users, despite it being free and accessible. It took thirty years for full society-wide diffusion.<sup>24</sup>

**Figure 7: Percentage of the UK population using the internet (defined as accessing the internet on any device within the past three months)**

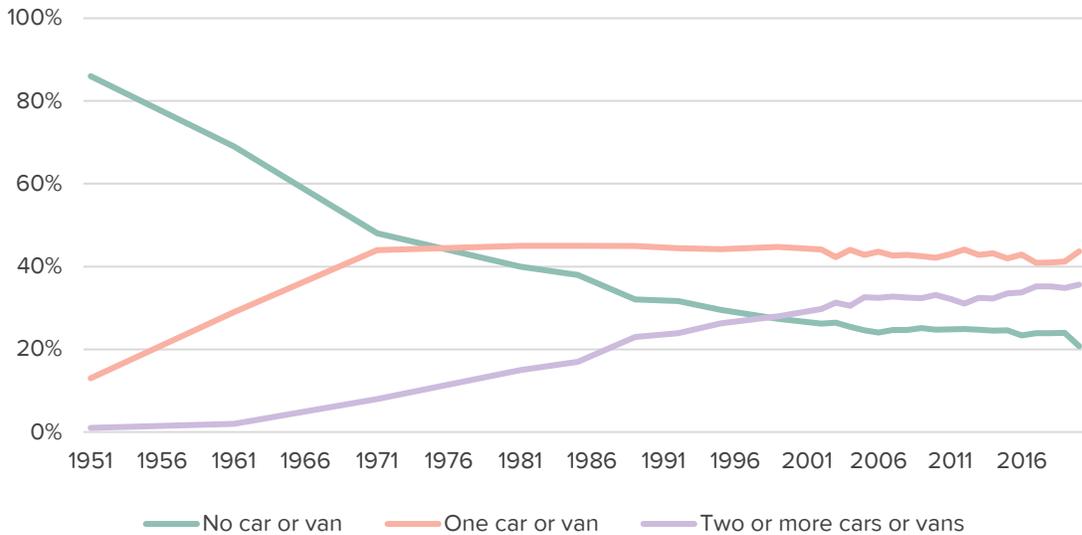
Source: *Our World In Data, Onward Analysis*



Levels of car ownership, a much more capital-intensive product, took much longer. In 1951 just 13% of people had at least one car or van in Britain. By 1976 the amount of people with a car surpassed those without, levelling off at about 40% of the public and maintaining at that level until today.<sup>25</sup>

**Figure 8: Levels of car ownership in Great Britain over time**

Source: *Transport Statistics Great Britain, Onward Analysis*



These products - cars, phones and the internet - represent products with enormous welfare benefits for consumers and still took decades to reach full diffusion. This suggests that the diffusion of net zero products such as heat pumps and electric cars, which are currently much more expensive than equivalent carbon-intensive technologies and offer lower levels of benefit for consumers, may struggle to diffuse rapidly across the economy without considerable help from government subsidies. Examples of these products are shown in Table 1.

**Table 1: Examination of consumer-facing net zero technologies**

Source: Department of Energy and Climate Change, BEIS, Green Business Watch, IMS Heat Pumps, Direct Line Group

Technology	Current capital cost	Current running cost or savings per annum	Usability
Heat Pumps	Air Source Heat Pump (ASHP) c. £10,000	£520, based on average heat demand of 12,000 kWh per year, average electricity price of £0.13/kWh and an ASHP with an efficiency of 300%.	Lower output temperatures than gas boiler alternatives, but similar running costs. Some ASHPs may struggle in colder weather, and they can take a day or two to get up to temperature if turned off completely. GSHPs work better in these temperatures as there is more residual heat in the ground.
	Ground Source Heat Pump (GSHP) c. £15,000	£445, based on average heat demand of 12,000 kWh per year, average electricity price of £0.13/kWh and a GSHP with an efficiency of 350%. <sup>26</sup>	
Electric car	c. £30,000 for a brand-new low-end model such as the Nissan Leaf, Renault Zoe or Volkswagen ID3.	£343 for annual charging costs and no tax. This compares to average annual petrol costs of £824 and £166 tax for petrol cars, providing an average yearly saving of £647. However, it may have higher insurance costs. <sup>27</sup>	The average range of an EV in the UK is around 200 miles on a full charge. Charging times and access to chargers are the main constraints on usability at present.
Window glazing	Between £3,000 and £7,000 depending on size of the property.	Between £35 and £155 in savings per year for a gas heated home, depending on type of structure and energy rating of property. <sup>28</sup>	'Hassle cost' to the consumer as works take place, but minimal other impacts. Consumers benefit from a significant reduction in noise.
Smart meter	£0, no upfront cost to consumer (as with existing meters, the cost is paid for via electricity bills)	Average savings of £36 per annum expected by 2034. <sup>29</sup>	Removes need to send meter readings and provides accurate bills and information on energy usage, incentivising good energy habits.
Building insulation	Cavity wall insulation: c. £720	£180 - £275	'Hassle cost' to the consumer as works take place, but minimal other impacts. However, solid wall insulation may decrease living space and require redecorating, or significantly change the appearance of the exterior of home.
	Solid wall insulation: c. £5,000 - £18,000	£180 - £455	
	Loft insulation: c. £395	£200 - £240	
	Solid floor insulation: c. £950-£2,200 <sup>30</sup>	£30 - £90	

It is also worth noting that the market capacity to scale adoption of some of these key technologies may also be limited. For example:

- Reviewing the electric vehicle market, it has taken 10 years to develop an EV charging network capable of charging 600,000 of UK vehicles. To put this in perspective, in the next thirty years we need to create a charging network to supply 37 million EVs, 62 times as many as are currently on the roads.<sup>31</sup> While the trajectory is positive, the current level of uptake has been nowhere near fast enough to meet the scale of the challenge.
- Looking at the heat pump market, there are currently only 1,200 plumbers capable of installing heat pumps in the whole of the UK, according to EY.<sup>32</sup> The training for heat pump installers is relatively time- and cost-efficient, with some providers offering courses for £595 which take only three days. However, there were 1.67 million of gas boilers sold in the UK in 2019, which are much quicker to install than heat pumps.<sup>33</sup> If this number was replaced with an equivalent number of heat pumps and potentially hydrogen boilers, at current staffing levels, each plumber would need to be installing four heat pumps a day, 365 days a year to achieve net zero by 2050. The Heat Pump Association says that the number of installers needs to increase by 58-fold by 2035 to 69,500 to have the right capacity for the Government's trajectory.<sup>34</sup>
- The same is true of the retrofit market. 15 million homes need to be retrofitted by 2030 to meet 2050 targets.<sup>35</sup> At present, just 108,000 thousand people work in energy efficiency improvements and just 324,200 Energy Company Obligation (ECO) improvements were made in 2020. In practice, this means capacity of providers would need to rise five-fold (514%) to have sufficient capacity to deliver retrofit improvements at the scale necessary to meet government targets.

## The rollout of key net zero technologies is currently below the trajectory required

There are two major consumer-facing challenges that will need to be overcome in order to reach net zero emissions. The rollout of electric vehicles (EVs) is one - road transport accounts for around a quarter of UK emissions - while the deployment of heat pumps is the other, in order to eliminate the 17% of UK emissions which arise from heating buildings. If these technologies do not reach full deployment within the required timeframes, then the net zero emissions target will be at risk. Comparing the current trajectories for EVs and heat pump uptake with the targets for these technologies helps to show whether current policy support is sufficient.

### Electric vehicle rollout

Looking first at the diffusion of EVs in Figure 9 below, we see that the number of battery electric vehicles (BEVs) on the road in the UK has increased 28-fold in the last eleven years, with around 250,000 registered as of 2021. Other low-emission vehicles, such as

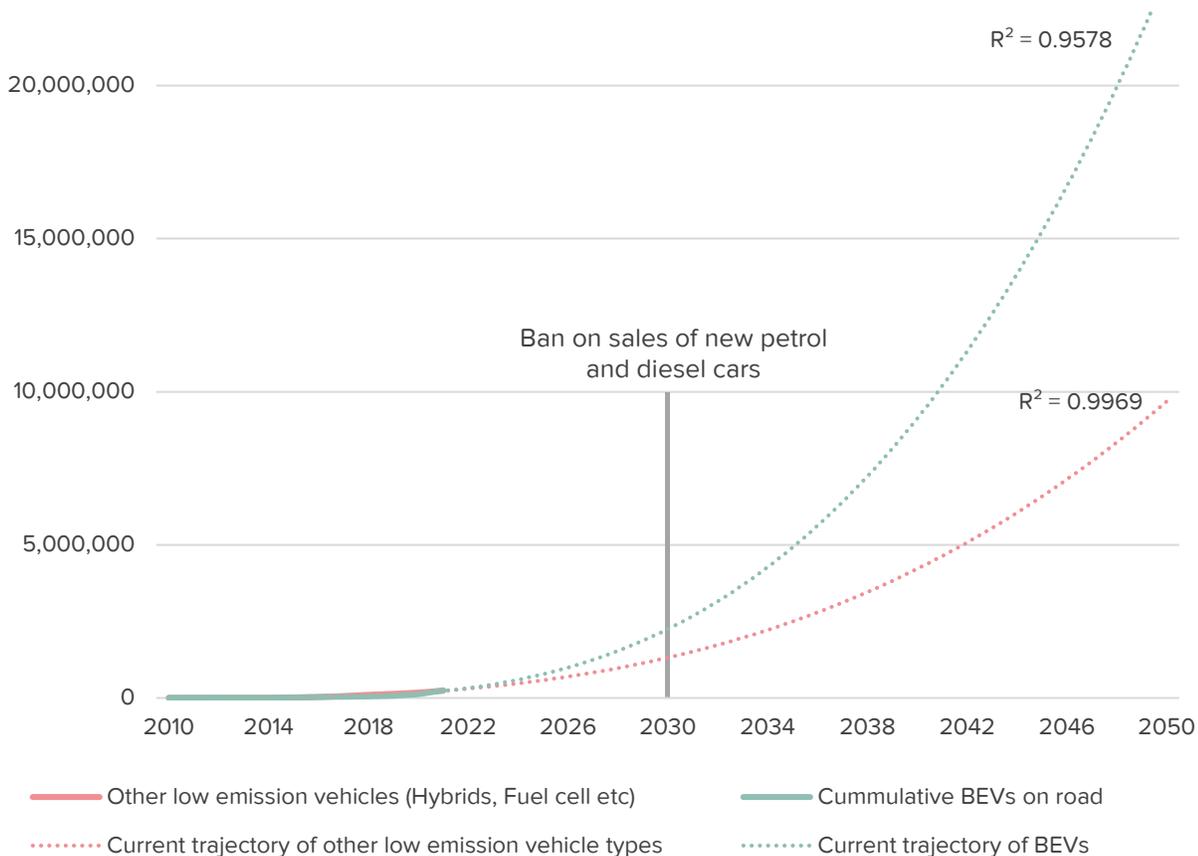
plug-in hybrid electric vehicles (PHEVs) or fuel cell vehicles have also seen a significant increase in uptake. These were almost non-existent on British roads a decade ago but there are now close to 240,000 in circulation. It should be noted that these other low-emission vehicles will likely need to be phased out eventually to reach net zero emissions by 2050 - meaning it is the rollout of BEVs which remains most crucial.

The data shows that this rollout of BEVs is progressing well, with continued growth in the rate of adoption. As Figure 9 shows, on the current trajectory approximately 23.6 million Battery Electric Vehicles (BEVs) are likely to be licensed by 2050. In addition, the adoption rate is likely to increase further in the run up to 2030 and the following years as the ban on the sale of new petrol or diesel cars and the 2035 ban on plug-in hybrid vehicles each come into force.

Based on the current estimate of 31.7 million licensed cars on the road in the UK, the current trajectory for EV uptake leaves an 8.1 million shortfall. However, the Department for Transport predicts that this will rise to 37 million cars by 2050 - meaning this shortfall could grow to 13.4 million. Overall, the rollout of EVs has been encouraging to date and the current trajectory will bring us close to achieving the net zero target.

**Figure 9: Current trajectory of low emission vehicle uptake**

*Source: Onward Analysis, Department for Transport*



## Heat pumps

The relative success of the EV rollout lies in stark contrast to the rollout of heat pumps. Heat pumps are not the only option for decarbonising domestic heat. But they are the most realistic option for widespread use and are most advanced in terms of their commercial development. Alternatives such as hydrogen boilers are still in their infancy and would rely on a reliable source of 'green' hydrogen, which is not yet available and could itself place heavy demands on renewable energy sources. Other alternatives, such as heat batteries, remain in the early stages of commercialisation and may only serve a niche market. As a result, heat pumps will likely need to become widespread in order to decarbonise the way we heat our homes by 2050.

The Government has targeted 600,000 heat pump sales per year by 2028. But as of 2019 annual sales were just 33,589, and on the current trajectory the 600,000 target will not be hit until 2057, as shown by Figure 10, which is almost three decades too late. Under the CCC's balanced pathway, part of the Sixth Carbon Budget, the outlook looks even worse. The CCC expects heat pump sales will reach 1 million a year by 2030, with over 27 million homes installing a heat pump by 2050. As Figure 11 shows, on the current trajectory, only around 1.8 million will be installed by this date. In fact, it will take until 2187 - an entire 137 years after the deadline for reaching net zero - to install heat pumps in 27 million homes based on the current uptake trajectory.

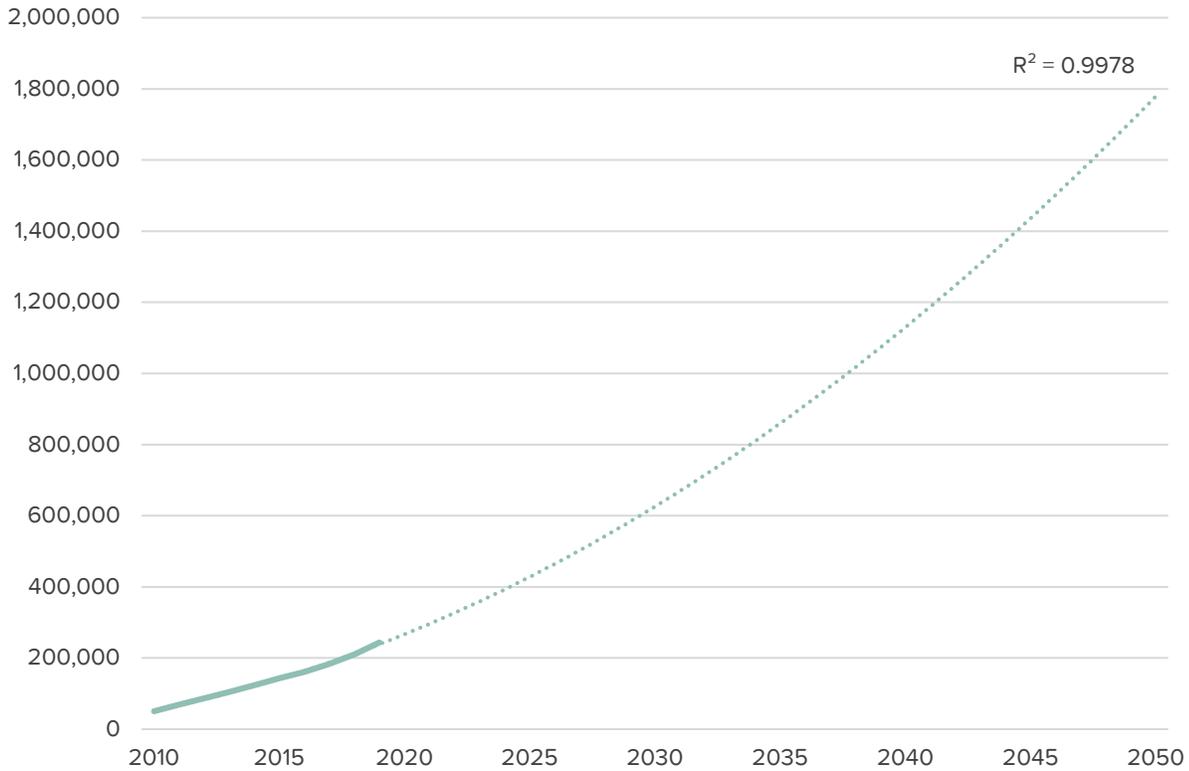
**Figure 10: Current trajectory of heat pump sales, vs CCC's Balanced Pathway**

*Source: European Heat Pump Association, BEIS, BSRIA, CCC Sixth Carbon Budget, Onward Analysis*



**Figure 11: Current trajectory of heat pump uptake**

*Source: European Heat Pump Association, BEIS, BSRIA, Onward Analysis*



Urgent action will be required to correct this trajectory and bring it in line with the Government's target and the CCC's balanced pathway. This may require the use of incentives provided to consumers to encourage them to purchase and install a heat pump or to help them with the cost, which is currently prohibitively expensive for many. However, innovation in design and production will also likely be required to bring down the unit price, while innovations in their installation could help to bring down the labour costs. It is also crucial that the development of alternatives to heat pumps is not suppressed, in order to provide the greatest chance of reaching the net zero target for the decarbonisation of heating.

# Innovation pathways

*How different net zero technologies compare*

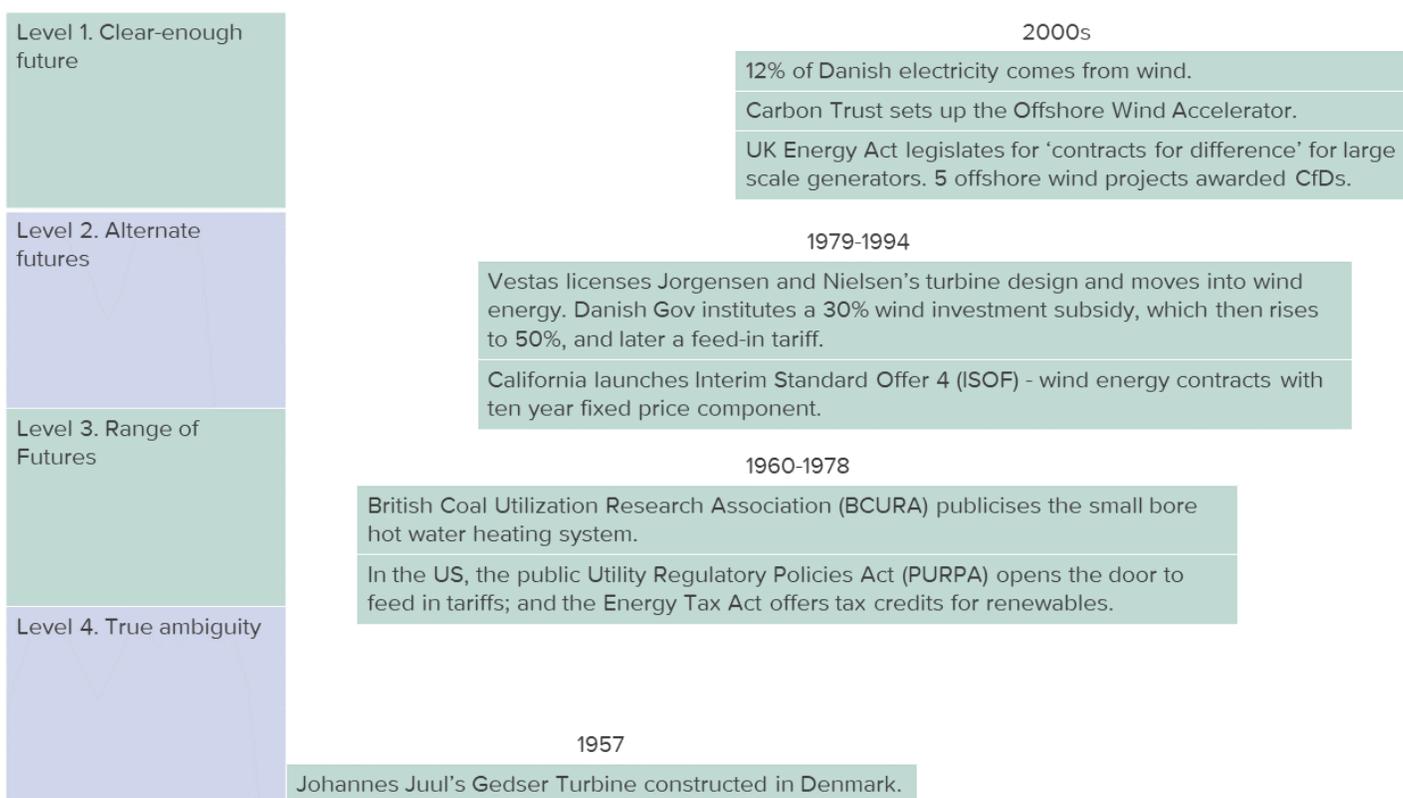


## Wind power

### Innovation and technological development

- Global policy support for wind in the past two decades has grown global capacity 43-fold, from 17.4 GW in 2000 to 743 GW as of 2020. This has established wind as the world's largest source of renewable energy. 95.4% of this capacity is onshore, 4.6% is offshore.<sup>36</sup>
- The technology is well established, so the largest opportunities are now likely to exist in efficiency improvements, decommissioning and replacement of ageing parts to extend lifespans, services, and improvements to energy transmission infrastructure.
- Many current and future European offshore wind sites are, or will be, located in the North Sea - and so are most accessible from UK ports, so there is significant opportunity for the UK to build a strong operations & maintenance services industry.

### Innovation timeline for wind power



### Market overview

- China (38.5%) and the US (16.1%) have the largest current shares of global wind (offshore and onshore combined) capacity. The UK has the largest market and capacity for offshore wind, and added 1,680 MW of capacity in 2017, representing 39% of all capacity added globally in 2017.
- The UK market is well developed with strengths in: blade manufacture, operations and maintenance services, offshore engineering skills. Direct competitors are Germany and Denmark, key producers of components. The UK's EU market share for offshore wind is only 2%, vs 18% for Germany and 7% for Denmark.<sup>37</sup>

### Barriers to innovation

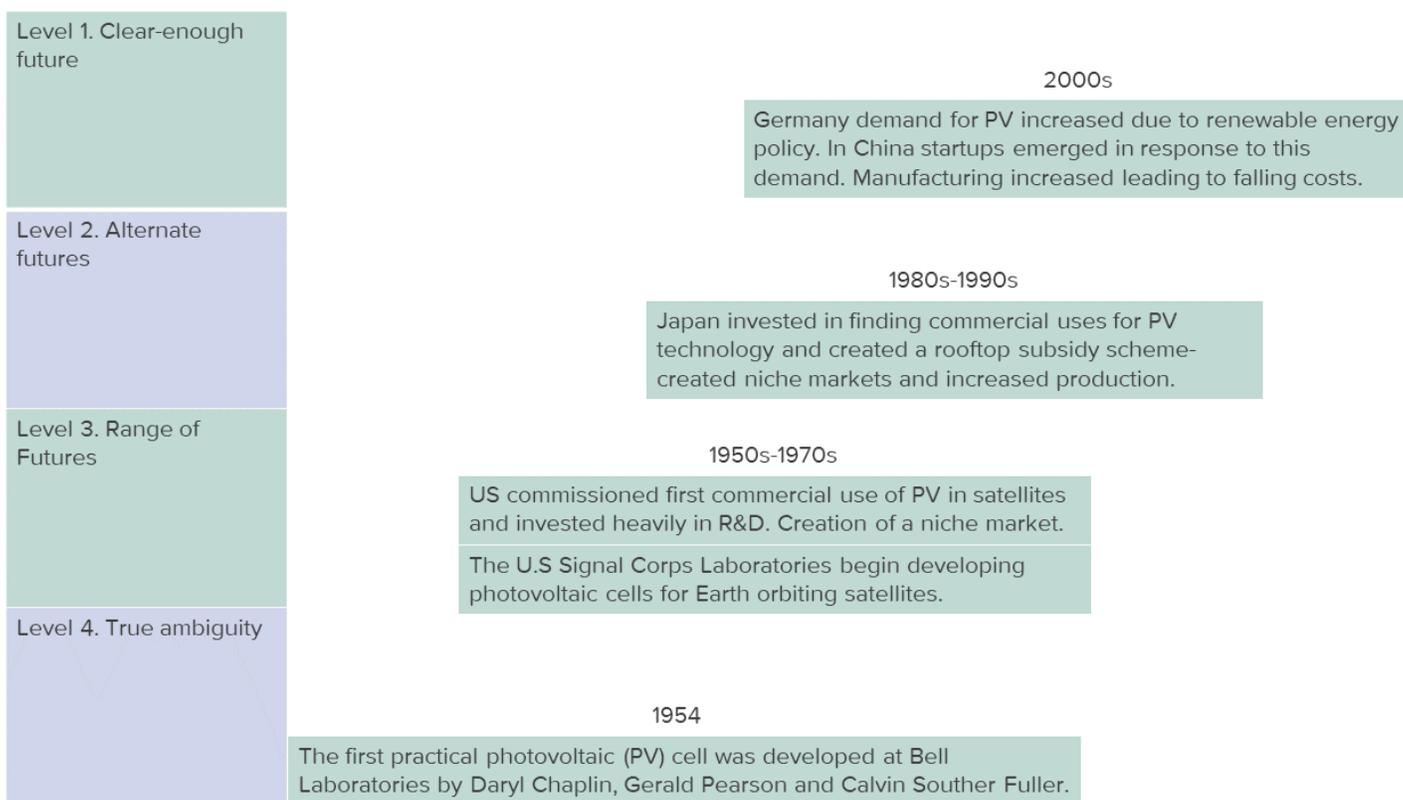
- Skills deficiencies in advanced engineering, logistics and infrastructure; high CAPEX costs; lack of test sites for prototypes (again due to high capital costs); CfDs can deter new entrants to the market as current players have established economies of scale.

## Solar power

### Innovation and technological development

- Policy support for wind in the past decades has grown global capacity ten-fold, from 73.7 GW in 2011 to 714 GW as of 2020. This has established solar as the world's second largest renewable energy source. The UK's solar capacity reached 14 GW in June 2021, the 11th highest capacity globally, however it only contributed 4% of the UK's energy consumption in 2020.<sup>38</sup>
- As the technology has developed, long-term policy support for solar as a power source has increased. As shown in the innovation timeline, this increased demand has led to widespread innovation within solar power, contributing to a rapid decline in the cost of the technology.
- Solar PV has also continued to decline in price, especially for competitive contracts offered for large scale industrial installations. In some parts of the world, prices have reached as low as \$14/MWh, ensuring solar is one of the cheapest forms of energy available.

### Innovation timeline for solar power



### Market overview

- The global market for new solar grew to 113 GW in 2020, however new installations in the UK made up less than 1% of this. The global market is dominated by China, in which more than a third of global capacity (36%) is installed, along with the United States (11%), Japan (9%), and Germany (8%).
- China dominates the global production market, producing far more solar panels than any other country with Chinese Solar PV manufacturers accounting for a share of 71% of the global market in 2019 alone.

### Barriers to innovation

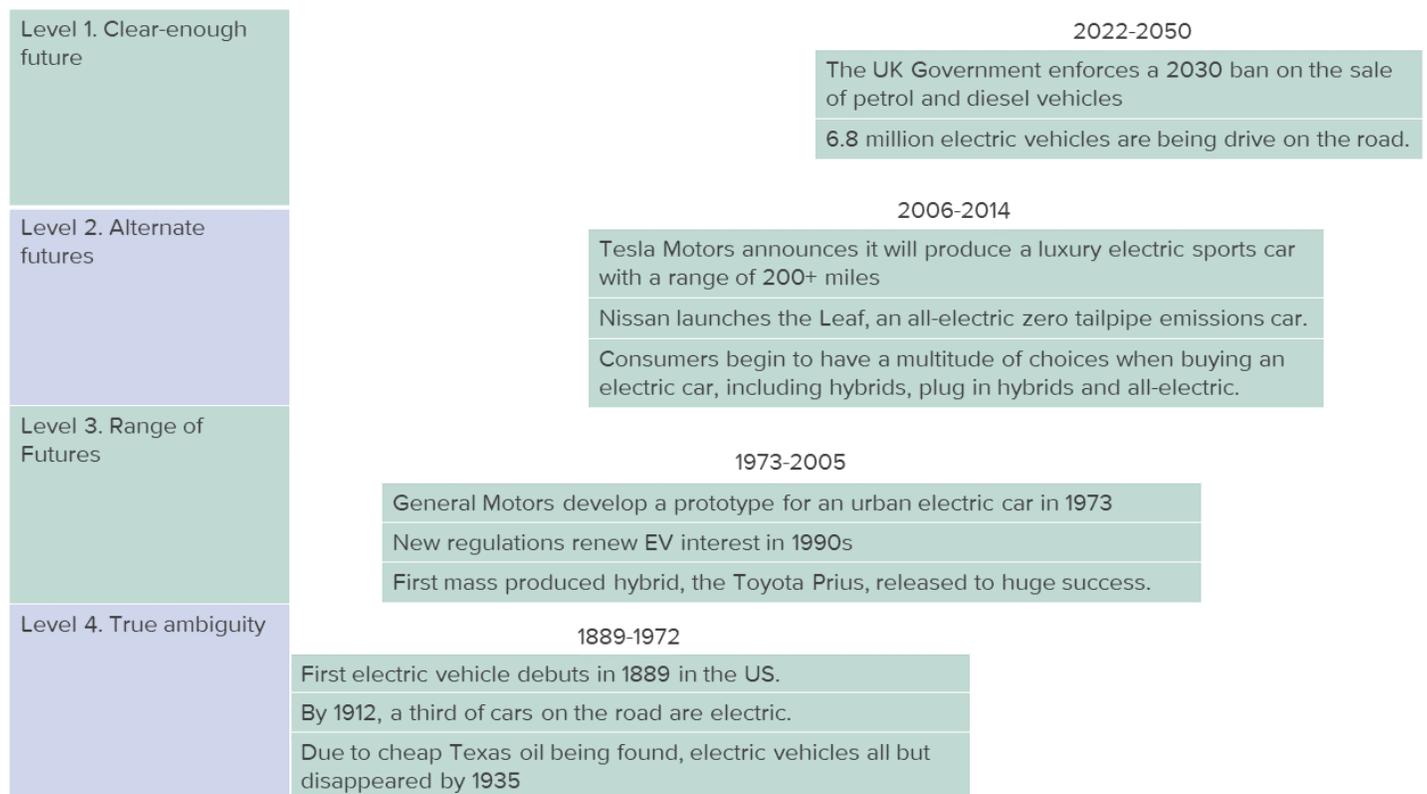
- Lack of inclusion within CfD schemes (historically); extreme market dominance of Chinese firms with large economies of scale; lack of UK content requirements.<sup>39</sup>

## Electric Vehicles

### Innovation and technological development

- The development and rollout of electric vehicles has rapidly accelerated in the past two decades and the number of EVs on the road globally is increasing by around 40% year on year. As of 2020, the 10 million EVs on the road represented around 1% of global car stock.
- China has the largest stock, with 4.5 million EVs, compared to 3.2 million in Europe.
- EVs are set to dominate the automotive industry and replace Internal Combustion Engine (ICE) cars, since alternatives such as fuel cell vehicles are not close to the same level of development. There are now more than 370 different models of electric cars available for consumers to purchase, with most major car manufacturers offering at least one.
- Improvements to efficiency and battery technology, along with EV chargers, have seen rapid increases in range, and significant falls in charging time and cost.
- The average range of a BEV on the road in the UK is now 200 miles. The average range of BEVs on the market is even greater, at 350km, up 75% in the past 5 years.
- The UK has more than 20 Research and Development plants across the UK focusing on developing new EV technologies.<sup>40</sup>

### Innovation timeline for EVs



## Electric Vehicles

### Market overview

- The automotive industry is one of the UK's largest, employing 186,000 people and accounting for 12.8% of exports. Eight plants produce 93% of vehicles. In total, there are 30 manufacturers and 2,500 component providers in the domestic supply chain that produce 70+ vehicle models (as of 2017).
- The UK has the 2nd highest European car exports by value. The UK also manufactures the Nissan Leaf which captured 20% of the European BEV market in 2016. The UK is currently the 10th largest exporter of EVs globally but is far behind the US, Germany and China. China alone manufactures 73% of batteries used in EVs, driven by the dominance of Chinese firms in the extraction of rare-earth elements needed for EV batteries.
- The early dominance of these competitors, and others which are now emerging within the EV market mean that the UK's market share across the automotive industry is likely to decline, unless further major assembly plants for EVs are opened.
- One issue with the current market is that EVs can prove more expensive to insure than conventional vehicles. This is because insurers have a lack of data on typical repair costs from accidents involving EVs due to their relative rarity to date.

### Barriers to innovation

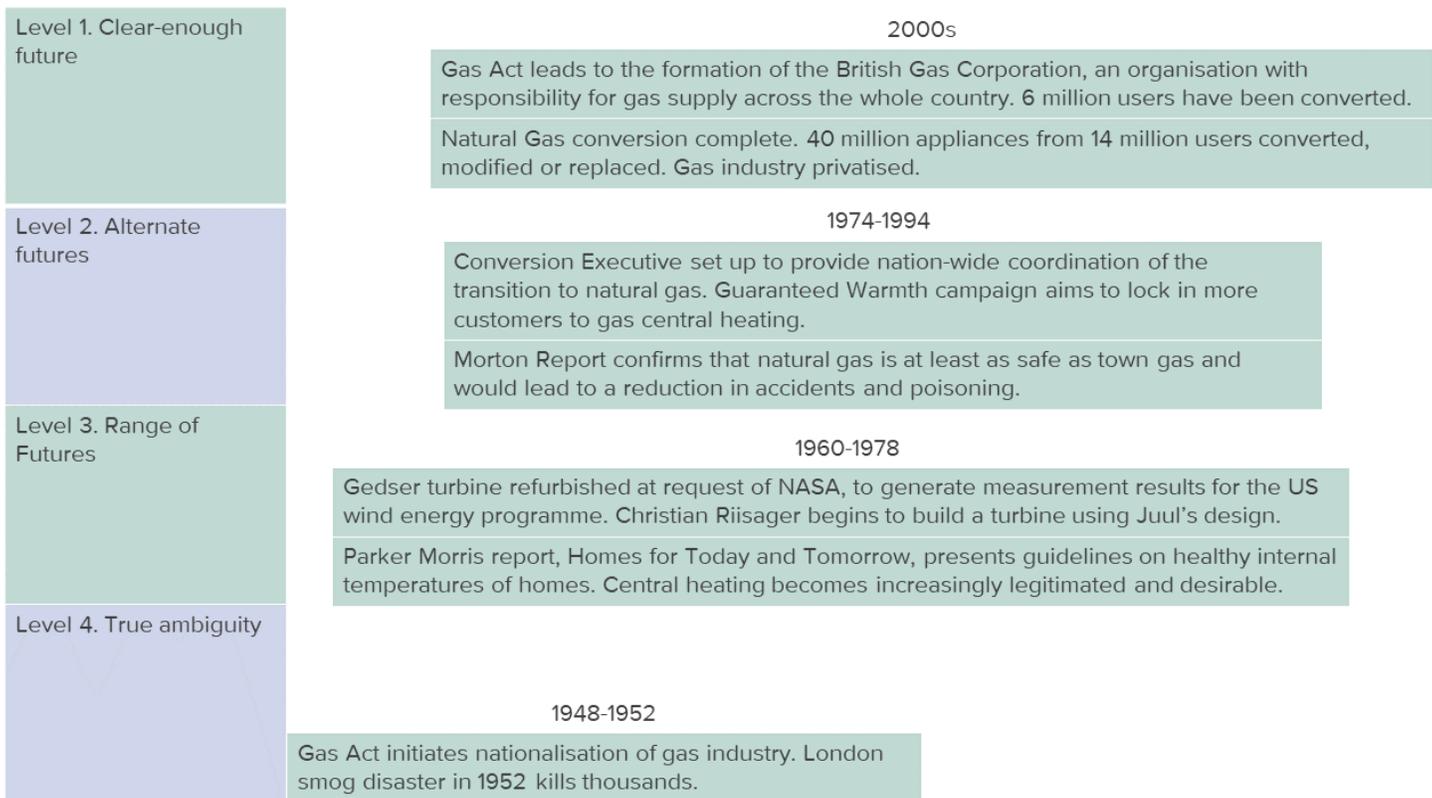
- High cost and technical risk of innovation for novel vehicles incentivises a 'wait and see' approach.
- Regulation for autonomous vehicles is required before they can be placed on the market.
- High upfront costs and uncertainty in future demand make it difficult to justify investment in innovation to achieve the necessary economies of scale.
- A skills gap exists for manufacturing and servicing of EVs compared to conventional ICE vehicles.
- Electricity distribution and generation capacity is currently too low for the levels of demand forecasted in 2050 due to the rollout of EVs.
- A lack of data on vehicle positioning and utilisation hinders the development of charging stations.

## Heat pumps and heat networks

### Innovation and technological development

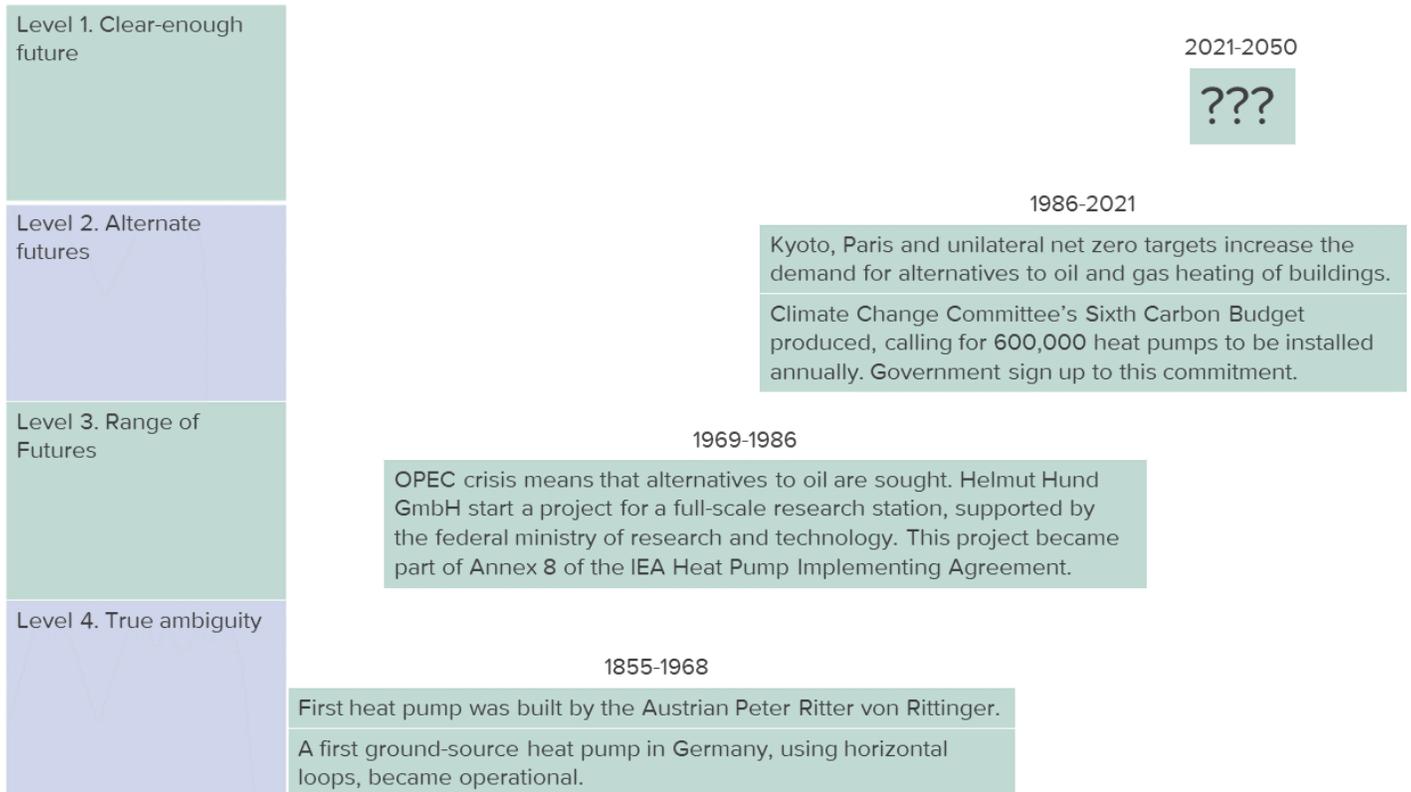
- Heating, including for industrial processes, accounts for the greatest proportion of UK emissions (37%) of any sector, while the heating of buildings alone accounts for around 17% of UK emissions. Gas and central heating systems became widely adopted in the UK in the late 20th century, and today just 15% of properties in the UK remain off the gas grid. Cheap prices for gas for domestic heating and ease of use if connected to the gas grid have continued their dominance.
- Gas boilers remain the heating system of choice for most households in the UK: sales hit a record high of 1.7 million units in 2019, and 22 million households across the country now rely on gas for their central heating. By comparison, there are only around 239,000 heat pumps in operation in the UK as of 2019 - fewer than 1% of all heating systems.
- As of 2015, around 14,000 heat networks were in operation across the UK, providing heat to around 460,000 customers, serving 2% of UK heat demand. The majority of these networks (85%) are communal, serving one building only - such as a block of flats - while the remaining 15% are district networks serving multiple buildings.
- Heat pumps are well established, but require innovations in technology (to reduce cost) and regulation to speed up deployment.

### Innovation timeline for gas and central heating



## Heat pumps and heat networks

### Innovation timeline for heat pumps



### Market overview

- Heat pump sales in the UK annually were just 37,000 in 2020 - equivalent to around 1 in 800 households. Average costs are high - between £8,000 and £15,000.
- Globally, the market is much larger with more than 4 million units sold annually and a 30% year-on-year growth rate. 1.3 million units were sold in Europe, with some countries such as Sweden, Finland and Norway averaging a sale every 40 households each year.
- The UK's market strengths within the heating sector include a strong commercial HVAC industry, refrigeration expertise, and a strong domestic gas boiler industry.
- However, the UK's share of the European heat market is only around 0.5%. This is in contrast to competitors such as France and Germany, which have 38.5% and 12.6% shares of the European market respectively and are recognised first movers.<sup>41 42</sup>

### Barriers to innovation

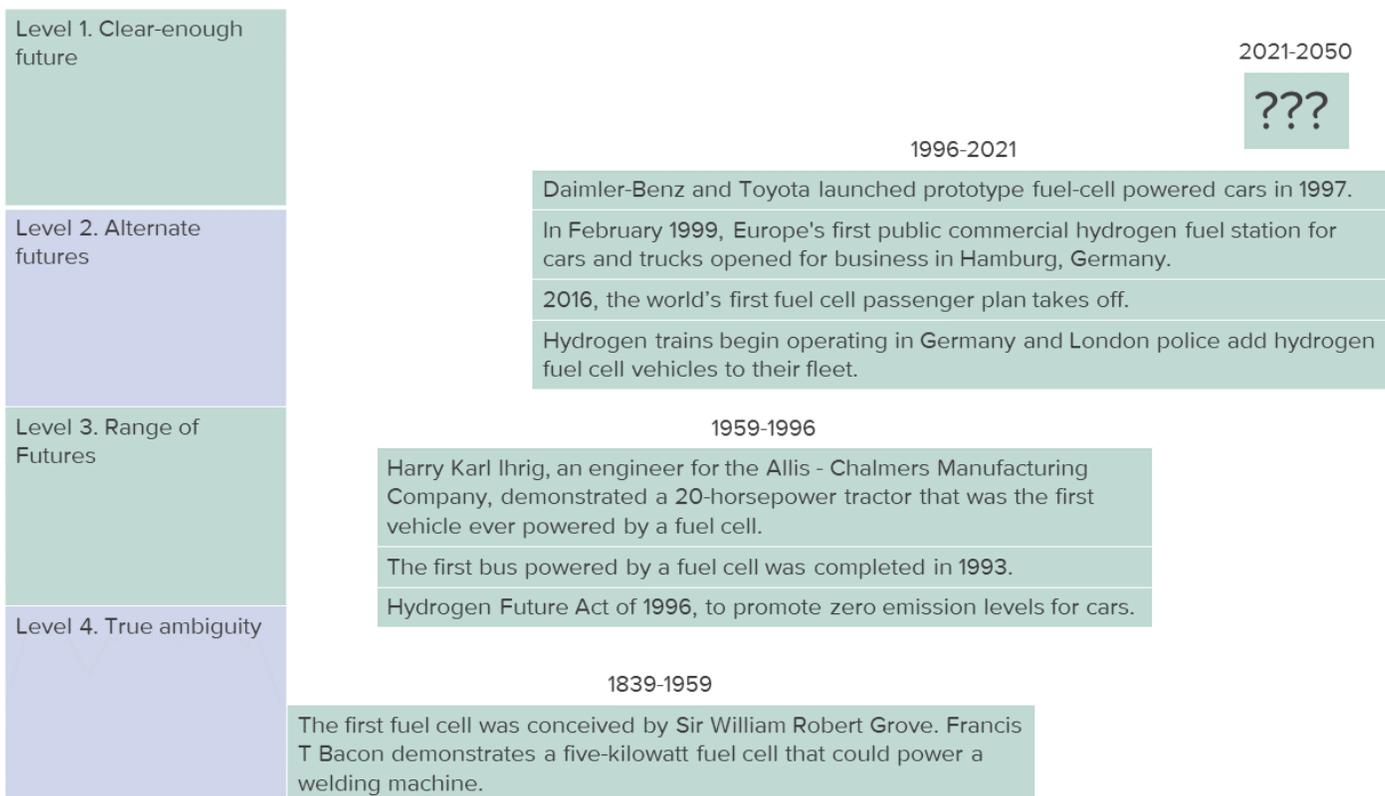
- The renewable heat industry in the UK is small, and the first-mover advantage enjoyed by France, Germany and China which has established their market dominance which may limit innovation in heat pump development by UK firms.
- Gas boilers can be up to ten times cheaper than a heat pump to install, and around 80% of boiler replacements take place due to emergencies, in which there are few opportunities to switch consumers to a heat pump, since they currently take days to install.
- These are barriers to the establishment of a strong supply chain within the UK, which would provide the necessary environment for innovations within the heat pump market.
- Barriers to heat networks include a limited policy framework, uncertainty around future demand, and high capital costs due to construction and infrastructure, for which there is limited opportunity for innovation to reduce costs.

# Hydrogen

## Innovation and technological development

- The hydrogen sector is wide (with many potential applications across multiple sectors), so we focus here just on production, infrastructure and the development of fuel cells. Production methods consist of natural gas reforming, coal gasification and electrolysis. Infrastructure consists of transport (pipelines, tube trailers etc), storage, and refuelling stations.
- Production capacity is currently very low, but the Government has committed to reaching 5 GW by 2030.
- Fuel cell vehicle development and infrastructure remains in its infancy, with just 283 fuel cell electric vehicles on the UK's roads today and just 11 refuelling stations available.

## Innovation timeline for hydrogen fuel cells



## Market overview

- Just three fuel cell vehicles are available to purchase in the UK market. The global rollout has been slow - the US is the world's largest market with just 11,000 vehicles on the road. China, South Korea and Japan dominate fuel cell vehicle development and production, while key competitors for the UK across the sector are likely to be Germany and the US within the electrolysis and gasification technology markets respectively.
- Current hydrogen production in the UK is very small, ranging from 10-27 TWh per year and is produced primarily for use in the petrochemicals sector. The majority of this production is not low-carbon.

## Barriers to innovation

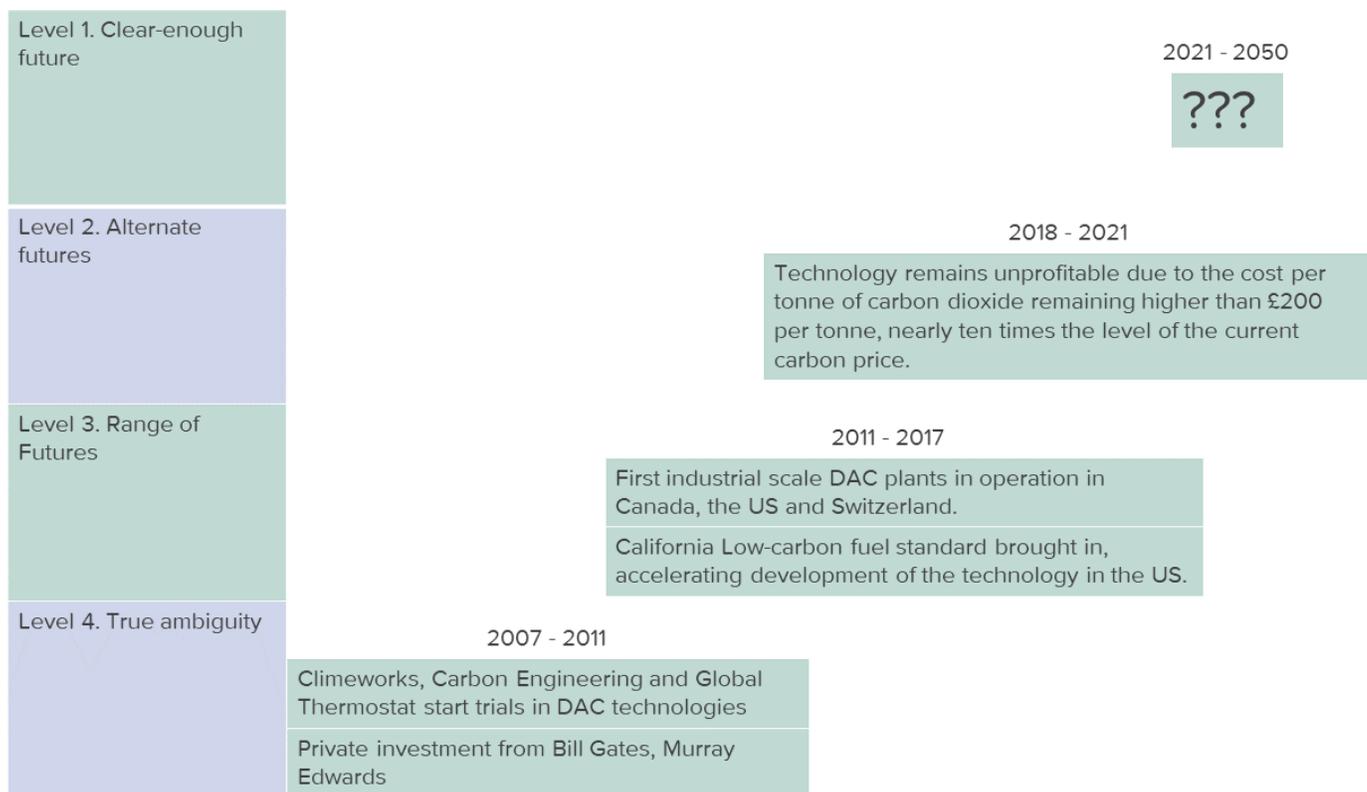
- Major uncertainty over future demand and use across sectors; lack of clear price signals, incentives and regulations; uncertainty over viability of using CCUS to produce blue hydrogen; renewable energy demand for green hydrogen; hydrogen infrastructure unable to react quickly to changing demand; high capital costs for production and infrastructure; lack of a clear route to market; EVs much more developed than fuel cell vehicles; consumer demand for hydrogen uncertain and hampered by safety concerns.<sup>43</sup>

## Carbon Capture, Uptake and Storage

### Innovation and technological development

- Just 41 commercial plants for CCUS are in operation or advanced development globally as of 2021. Three types of CCUS are deployed at sites of fossil fuel combustion, such as power stations or industrial sites: pre-combustion, post-combustion and oxyfuel combustion. Costs range from \$15-\$120 t/CO<sub>2</sub>, depending on the CO<sub>2</sub> concentration of the gas produced by burning.
- CCUS can also be deployed away from industrial sites in order to capture carbon from the atmosphere using Direct Air Capture (DAC). However, DAC is much more expensive than conventional CCUS and still in its infancy and yet to reach commercial scale.

### Innovation timeline for Direct Air Capture



### Market overview

- The global market remains embryonic and so there are likely to be first-mover advantages for those countries which can demonstrate successful commercial-scale CCUS projects at a competitive price. The UK has a comparative advantage to deploy CCUS at industrial clusters, as captured carbon can be stored easily in existing North Sea wells.
- The market for CCUS components, design, engineering and services is likely to mirror the Oil and Gas components and services markets, which the UK excels in, capturing 11.8% of global share despite only accounting for 1.1% of world oil production. The UK's main competitors are the US, Germany, Japan and China for high-value components and the provision of services.<sup>44 45</sup>

### Barriers to innovation

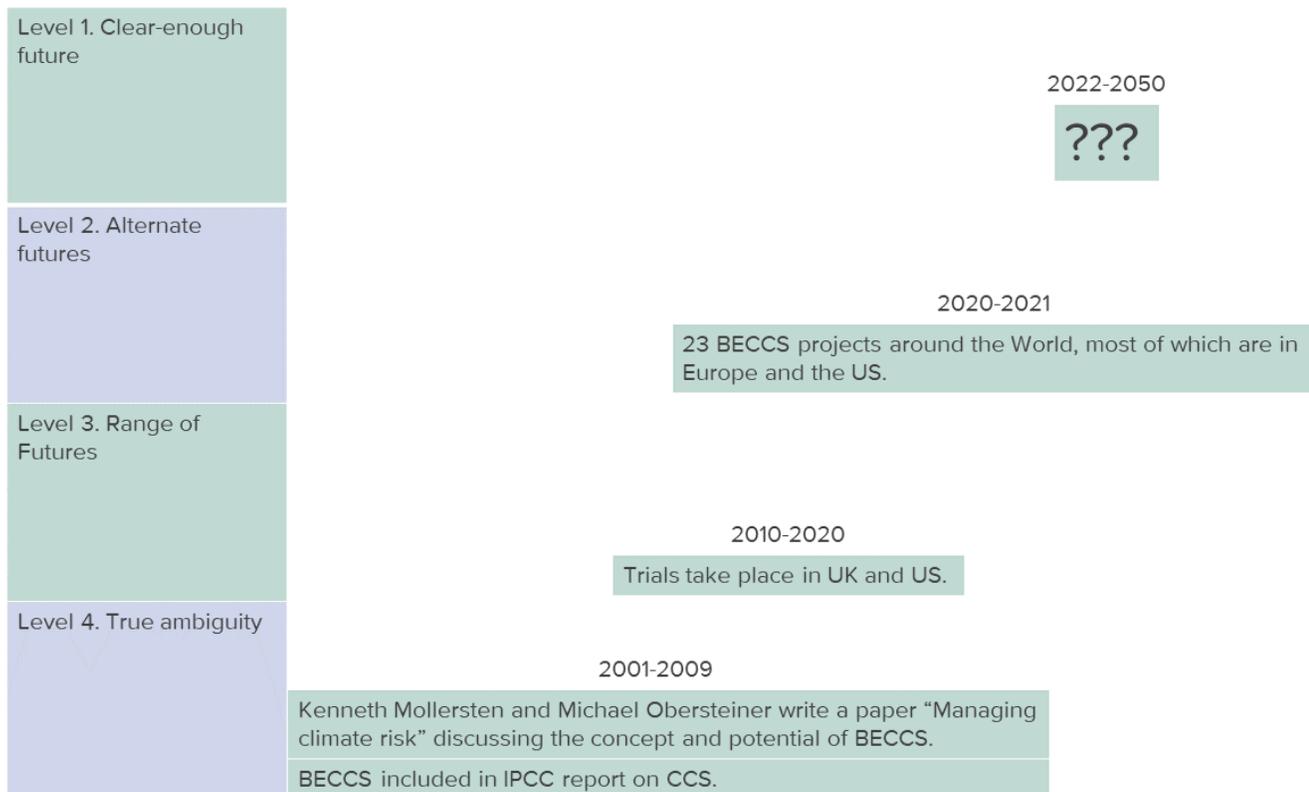
- High CapEx costs (estimated £0.8 - £2.2 billion per plant), which deters private sector investment due to high risk. Commercial scale projects in the UK not in development yet.
- Policy demand and uncertain policy support plus lack of clear carbon price inhibits innovation from development to full deployment; long-term liabilities difficult to insure (such as against leakage from storage); unclear regulations regarding storage sites.

## Bioenergy

### Innovation and technological development

- The bioenergy industry is well established in the UK, with all forms of bioenergy providing 11% of the UK's primary energy in 2019 (10% globally) - along with 37% of all renewable energy, overtaking nuclear (35%) for the first time. Bioenergy has advantages over other renewables since it is not weather-dependent, and thus is uniquely flexible for a renewable source. It can be scaled up or down with demand.
- The rollout of bioenergy with CCUS is still in its infancy however will provide the greatest value to the energy system, as it will be a negative emissions technology. Currently, only 23 BECCS projects exist globally. Developments within CCUS will increase deployment.
- Biomass gasification is also used to produce syngas which has a range of applications, including as the hydrogen fuel source in fuel cells. Anaerobic digestion can also be used to produce a methane rich gas from biomass which can then be burned to produce electricity.

### Innovation timeline for bioenergy with CCUS



### Market overview

- The UK is the world's largest importer of wood pellets and is 5th globally for biomass and waste electricity generation as of 2016. As the UK has limited feedstock, it will likely always be a net importer of biomass and biofuels.
- The UK has strengths in anaerobic digestion (with more than 450 operational plants), academic research into biofuel development, and gasification technologies.
- Key competitors are China, the US and Germany, who all have existing strong manufacturing bases for similar technologies including gas generation.<sup>46</sup>

### Barriers to innovation

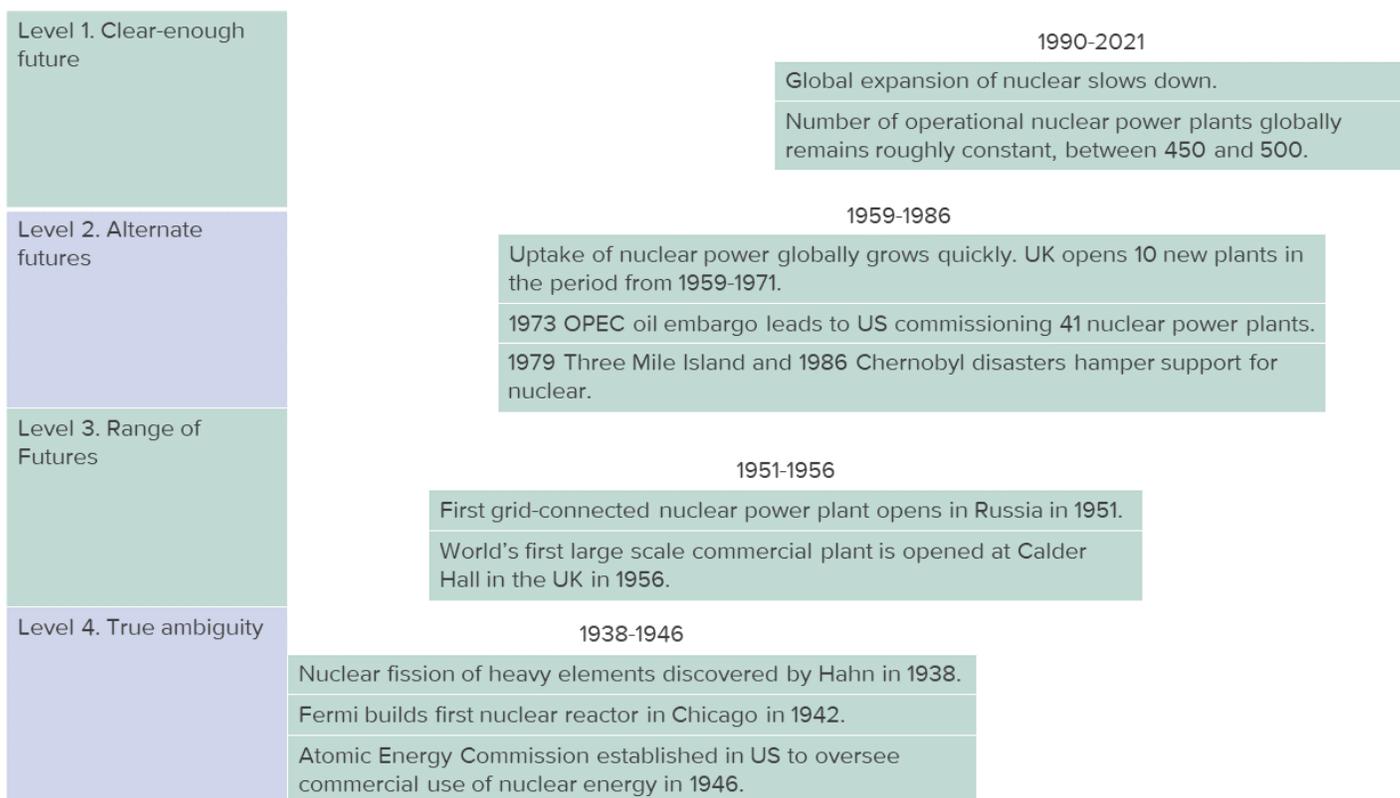
- Policy-dependent demand; high perceived risk and returns in the far future reduces access to private finance; costly feedstock classification processes make it difficult to determine the eligibility of waste feedstocks; limited land to produce feedstock.

## Nuclear fission

### Innovation and technological development

- Nuclear fission is a mature technology which has been deployed at a commercial scale since the 1960s. Continued innovation has led to improvements to reactor design and increased safety and efficiency. The majority of reactors currently in use around the world are Generation II or Generation III reactors. These are efficient, but very costly to build and operate.
- New reactors in development will be built using modular components and technology, which will reduce planning and construction costs and time. These will take the form of Small Modular Reactors (300 MW of capacity or less) or Advanced Modular Reactors. New reactors will also improve energy yield, reduce waste, increase opportunities for spent fuel reuse, and increase digitisation and automation.

### Innovation timeline for nuclear fission



### Market overview

- Nuclear is more reliable than weather-dependent renewables, but significantly more expensive. For example, electricity from Hinkley Point C will cost £92.50 /MWh for 35 years.
- Nuclear technologies are not highly traded worldwide due to security concerns, however the UK is likely to be reliant on overseas firms for the development and manufacture of new nuclear capacity beyond Hinkley Point C. Within the domestic market, firms operating have strengths in developing instrumentation and control plants, uranium enrichment, and decommissioning.<sup>47</sup>

### Barriers to innovation

- Security concerns prohibit global trade; policy uncertainty and regulatory barriers to Small Modular Reactors; certification and regulatory requirements are complex and site-specific; high capital costs and long time frames deter private sector investment; skilled workforce takes a long time to reach maturity and is vulnerable to turnover and obsolescence.

## Building fabric

Operational emissions from buildings currently account for 19% of UK emissions, and 40% of global emissions. Building fabric included the components and materials that make up both domestic and commercial buildings through their design, construction and operation.<sup>48</sup>

- The building stock across the UK varies significantly, with many older buildings likely to require retrofit in the coming years, particularly to ready them for heat pumps. There is also often a significant gap between the expected emissions performance of a building when estimated as part of the design process, and the real-life performance of these buildings once built.
- Innovation opportunity areas include: decreasing the embodied carbon of building materials; developing new building materials; innovations to modelling, testing, construction and installation processes; improvements to training to reduce installation errors.
- Barriers to innovation include building standards designed for minimum requirements rather than maximum performance (leading to a focus on meeting lowest criteria at minimal cost); lack of modern construction skills; inertia and unpredictability of homeowners; limited demand due to high up-front costs.
- New PAS2035 standards introduce additional skills requirements to try and ensure higher standards are achieved. Another barrier is the “hassle cost” to consumers, exacerbated by negative experiences of previous installations.

## Smart Systems

Smart systems encapsulate a range of new technologies, and enable the integration of low-carbon technologies at lower costs compared to conventional systems. They include energy pricing based on time and location, flexible energy demand management, technologies which allow conversion between different forms of energy (for example electricity to hydrogen), and energy storage technologies.<sup>49</sup>

- In 2017, electricity networks alone received more than \$303 billion of investment, of which around a tenth (\$33 billion) was invested into smart grid technologies.
- Innovation opportunity areas: Demand Side Response technologies to manage consumer demand; use of networks and data to create a ‘smart’ grid; software, AI and machine learning to automate grid management, heat batteries.
- Barriers to innovation: data on electricity consumption is currently not sufficiently collected or shared; highly regulated market means demand is partly dependent on policy; long payback periods for storage technologies; regulatory separation between gas & electricity hinders development of power-to-gas.

- Another barrier is that consumers do not optimise their energy usage because energy prices do not accurately reflect benefits to the energy system of using energy at off-peak times.

## Heavy Industry

Heavy industries include chemicals, iron & steel, cement and ceramics; industries that were all covered as “carbon giants” in Onward’s previous Greening the Giants report. These industries add around £16 billion to the UK economy each year.<sup>50 51</sup>

- Innovation in these industries is likely to revolve around developments which allow these sectors to meet their decarbonisation targets in increasingly cost-effective manners while protecting the industries themselves.
- Major innovation opportunities may include the deployment of CCUS at heavy industrial sites, or fuel-switching to alternative low-carbon fuel sources including renewable electricity, biomass and hydrogen.
- Other innovation opportunity areas include: adapting industrial processes to produce less emissions; improving the efficiency of existing processes; substituting materials for low-carbon alternatives; and improvements to specialist equipment such as kilns, furnaces or refrigerators.
- Barriers to innovation include: Capex payback periods are often longer than the private sector is willing to accommodate; early movers are not usually compensated for technical and reputational risks they take; retrofitting new technologies requires production downtime; skills gaps; first mover disadvantage disincentives SMEs who usually drive a large share of innovation.
- Additionally, industries are insufficiently incentivised to commercialise new technologies and innovations; and regulation is often poorly aligned (for example, utilising waste as an input requires a complex set of licensing and other criteria due to the many players involved in designing the regulation);

## Nuclear Fusion

Nuclear fusion has been in development for more than eighty years. The primary challenges to nuclear fusion relate to superheating plasma to more than 100 million degrees Celsius, and confining it long enough for the atoms to fuse together. However, the energy breakeven point ( $Q = 1$ ), at which a fusion reactor releases more energy than it uses when heating the plasma, has not yet been reached. The current record ratio, as of August 2021, is  $Q = 0.7$ .

The UK is a leader in fusion research. The Culham Centre in Oxfordshire is the UK’s national fusion research laboratory, and is home to the Joint European Torus project, which achieved the world’s first controlled release of fusion power in 1991. Private sector investment is now flooding the surrounding area, with firms such as Tokamak, First Light

Fusion and General Fusion all either headquartered or building facilities in the surrounding region. Two primary forms of fusion reactor are in development, which use different methods to heat and confine the plasma. These are Magnetic Confinement (MCF) and Inertial Confinement Fusion (ICF).<sup>52</sup>

The new ITER MCF project in France, which is a collaboration between the UK and six other countries, is designed to produce ten times as much energy as it uses ( $Q = 10$ ). However, ITER has been under construction since 2007, will not be completed until 2025, and is not expected to achieve a  $Q$  value of 10 before 2035.<sup>53</sup>  $Q$  values of greater than 10 will be required before fusion can become commercially viable. Due to the long lead times in constructing reactors, fusion is therefore highly unlikely to play a part in reaching net zero by 2050.<sup>54</sup>

### **Common barriers to innovation**

A major barrier to innovation for many technologies is the high perceived risk of investing in their development, which reduces access to private finance. This is most common for those technologies in which returns are only likely far in the future, and so there is a long payback time on any investment.

This is especially prohibitive for those technologies with uncertain long-term policy support, such as Bioenergy and Nuclear. In addition, first-movers within consumer-facing industries, such as EV manufacturers, may not be well compensated for the technical and reputational risks they take developing and bringing new products to market, which can lead to them prioritising a 'wait-and-see' approach. This delays the development of new products until it is clear what is popular, stifling innovation.

High Capex costs for testing and deployment also deter private investment in new green technologies. This is especially true for capital-intensive industries such as offshore wind, which lacks test sites for onshore prototype testing and offshore demonstration facilities. The CCUS industry is also highly capital-intensive, with an estimated £0.8 - £2.2 billion cost per DAC plant and returns that will likely depend on a permit or credits market which is not yet operational. The nuclear industry has long suffered from high capital costs preventing the development of new reactors, hence the stagnation of the industry in recent decades.

Another common barrier to innovation across green industries are the skills shortfalls which exist in advanced engineering, logistics, and infrastructure management in the UK. These deficiencies hinder R&D and limit opportunities for the deployment of technologies which are dependent on a mature, highly-skilled workforce, such as Nuclear, Wind and EVs. The growth of these industries may be limited if they cannot access the workforce required.

Regulatory barriers, where regulation inhibits innovation, makes deployment or commercialisation difficult or does not adapt to the changing technological landscape, are also common across various green technologies. For example, while heat networks can provide low-carbon heating solutions to entire districts, their diffusion is limited by the current lack of policy framework and regulation. In addition, in some heavy

industries opportunities to use waste as an input for industrial processes are restricted by the complex set of licensing requirements and other criteria that must currently be met, due to the many parties involved in designing the regulation. Other examples include new nuclear sites, which require very complex and site-specific licensing and regulation due to safety concerns, and Power to Gas development, which is limited by a regulatory separation between gas and electricity.

Final barriers to innovation exist in the form of consumer-led barriers, which inhibit demand for new technologies and slow their diffusion. These barriers can take a number of forms. For example, consumer understanding of hydrogen and confidence in its safety is low, which may hinder demand for fuel cell vehicles or for hydrogen as a fuel source to heat homes. The rollout of heat pumps and insulation measures in homes is obstructed by consumer inertia, whereby there are limited opportunities to replace heating systems in homes as consumers wait until significant repairs are needed. Consumers are also influenced by previous negative experiences, and the ‘hassle cost’ of having work done to their homes. Changing consumer perceptions and behaviour will be crucial to overcoming these barriers to diffusion.

# Solutions



As this report has set out, reaching net zero will require rapid innovation and a step change in how technologies are adopted across the economy. While market forces are the only way to deliver such a transformation in such a short space of time, they will not do so alone. There is a compelling case for government intervention to stimulate and boost the innovation process - as governments did for space travel, the development of the internet and numerous other technological leaps - to help the UK get to net zero in time.

In particular, government interventions could provide the necessary policy certainty to reduce long-term investment risk for the private sector, and provide greater encouragement for innovation from development right through to full demonstration. This would have the effect of increasing access to private finance for innovation within each technology and speeding up the process of development. In addition, interventions may also be able to help overcome other commonly identified barriers to innovation, such as regulatory barriers, skills shortages, and prohibitively-high capital expenditure costs.

There are also significant market failures at play, which further build the case for policy intervention. First, there are static price failures, whereby the market prices for goods and services do not reflect their full cost - or benefit - to society. As an example, a flight to Edinburgh from London is on average 57% cheaper than taking the train, but 530% more carbon-intensive - partly because the climate cost is not reflected in the price.<sup>55 56</sup> Second, there are dynamic failures where people make choices that appear economically sensible in the short-run, but leave society - and themselves - worse off in the long-run. This is a particular feature in the development of new technologies.

Government intervention in innovation policy would build on earlier examples of Government backed R&D such as: the development of jet engines, radar, nuclear power, the Global Positioning System, and the internet.<sup>57</sup> While this will be vital in reducing carbon emissions, it will also deliver a near-certain economic benefit. Given the rapid adoption of net zero targets globally, those countries that achieve these goals fastest will also benefit from a 'first mover' advantage, and be in prime position to realise domestic industrial benefits. This appears to be one reason why China is rapidly embracing renewable technology for export, despite continuing to rely on carbon-intensive sources at home.

Some of the necessary technologies are known but not widely adopted. The innovation challenge for this group is to dramatically increase diffusion (such as electric vehicles and zero carbon heating). For others, both the design and the route to market are unknown (such as carbon capture). To raise discovery and encourage widespread adoption to the levels needed, we set out our recommendations for ministers into two different categories: development and diffusion. The former is the stage of innovation which involves the research, development and market formulation of a product or service. The latter is the process whereby a product or service is spread across the economy and applied to the intended recipients.

**Table 2: Price and carbon intensity of different products**

Sources: Annual domestic energy price statistics, Greenhouse gas reporting conversion factors 2019, Transform Scotland 2017 'A Green Journey to Growth', Poore & Nemecek 2018 'Reducing food's environmental impacts through producers and consumers', prices taken from Sainsburys, Onward Analysis

Product	Average cost	Average carbon intensity
Flight from London to Edinburgh	£54	177kg of CO2 per passenger
Train from London to Edinburgh	£126.50	28kg of CO2 per passenger
Monthly gas bill	£46 <sup>58</sup>	2502kg of CO2 per household <sup>59</sup>
Monthly electricity bill	£59	838.8 kg of CO2 per household
Fruit and vegetables	Tomatoes: £1.75/kg	1.4 kg CO2 per kg
	Peas: £1.10/kg	0.9 kg CO2 per kg
	Bananas: £0.73/kg	0.7 kg CO2 per kg
	Apples: £1.35/kg	0.4 kg CO2 per kg
Meat and fish	Beef: £7.50 (for a 1kg joint)	60 kg CO2 per kg
	Lamb/Mutton: £11.00 (for a 1kg leg)	24 kg CO2 per kg
	Poultry: £4.99 (for 1kg of chicken breasts)	6 kg CO2 per kg
	Fish: £13.44 (for 1kg of salmon fillets)	5 kg CO2 per kg <sup>60</sup>

## Development

### **A framework for the market: accounting for the real carbon cost**

A key challenge in increasing demand for low-carbon technologies and solutions is the relative ease and low cost of existing technologies and solutions. In some cases the existing costs do not account for the real cost of carbon, acting as a perverse incentive to delay action in tackling climate change. Realising the true cost also frames the urgent need to act. However, the challenge for policy makers is to do so in a manner so as to prevent significant additional costs being placed on taxpayers at or below average income. Building the cost of tackling climate change on the household bills of average income households could damage public support for realising net zero.

As we argued in *Costing the Earth*, there are perverse incentives favouring carbon-intensive activity which causes stagnant levels of innovation in prospective net zero sectors. For example, residential gas use, which equates to 10–11% of total emissions, has a negative effective carbon price since its use is supported by a 5% VAT rate which is below the prevailing rate for other goods and services. At the other extreme, rail transport is subject to an effective carbon price of up to £568/tCO<sub>2</sub>. To spur net zero innovation, there is an urgent need to bring carbon prices down to parity.

While negotiations continue at the multilateral level about the introduction of a carbon border tax, there are a series of steps available to ministers that – depending on levels of ministerial ambition – could be taken unilaterally.

#### **1. Establish a gold standard for carbon offset standards**

Carbon accounting is steadily becoming one of the crucial hurdles of the net zero transition. From heavy industry to agriculture, a significant push to monitor and account for carbon emissions is vital. Once achieved, it will accelerate the development of the voluntary and compliance carbon markets, which should lead to innovation in carbon reduction and removal technologies.

However, carbon offsets – while likely to play a critical part in tackling net zero – have been criticised in some quarters for fraud and green washing, with some studies estimating that three-quarters fail to provide any meaningful environmental benefit. Offsets have previously been criticised by campaigners and activists, with offset schemes being branded as part of the “wild west” due to insufficient enforcement and different standards between providers.<sup>61</sup>

Two ways in which ministers could increase the value of, and confidence in, offsets would be through pull-through public procurement and market regulation.

First, the Government should establish a new Carbon Accounting regulator to oversee the monitoring, reporting and verification of greenhouse gas emissions, reductions and removals across the UK economy. This new regulation would tackle what the Energy Systems Catapult has called the “proliferation of standards, protocols and other

programmes” in the market, which undermine investor confidence and distort incentives.<sup>62</sup>

A new regulator should have the ability to levy financial penalties against organisations that do not comply with the approved standard. New accounting standards would also prevent the ‘double counting’ of offset credits against the carbon budgets of two or more parties. The regulator could also dictate the inclusion of Scope 3, or ‘value chain’, emissions within carbon accounts. At present, carbon accounts often involve the setting of voluntary Scope 3 emissions boundaries by companies, despite the fact that Scope 3 emissions represent around 80% of emissions from companies. Such a regulator would boost investor confidence in the UK by introducing greater transparency to carbon offsets. The prize for doing so is high: McKinsey estimates that the global market for carbon credits could be worth upward of US\$50 billion by 2030.

It could also pursue alignment with other regulators internationally, such as those in Canada, as well as with the International Financial Institutions to establish a global benchmark for offsets. As highlighted by the United Nations Framework Convention on Climate Change (UNFCCC), differential standards are a barrier to investment and therefore action: “a plethora of standards currently available creates confusion among climate actors”.<sup>63</sup> International cooperation between regulators could help to ensure that offsets are genuinely producing real and ‘additional’ reductions in emissions, which are not over-estimated. A study into the effectiveness of the UN Clean Development Mechanism (CDM) found that an estimated 85% of offset projects examined had a low likelihood of being additional - essentially, their emissions reductions would likely have occurred anyway in the absence of an offset scheme.<sup>64</sup>

New accounting standards should also examine the permanence of carbon removals and offsets on the market. At present, the offset market is largely compared solely on price, with investors given little information as to whether the offsets they purchase are permanent, or on the risk of a project failing. As the CDM review found, the non-permanence of carbon removals is one of the key issues with offsets markets at present, with no distinction made between removals such as Direct Air Capture combined with geological storage under the sea, which is essentially permanent, and nature-based solutions, such as forestry, which may be temporary or include natural risks, like forest fires.

Second, the Government should commit to offsetting the carbon emissions from the UK Government’s carbon footprint from projects in the UK. This would do two things: it would ensure that the nature-based or technological removal of carbon is based in the UK, ensuring efforts meet the UK’s standards, and secondly it would use government procurement to support carbon removal innovation in the UK. There would be a cost implication to such a policy initially: the global average for carbon removal around £2.38/tonne<sup>65</sup> while for UK-based offset projects, the price can be as high as £15/tonne. But doing so would increase investment in the UK while also reducing concerns about the validity and efficacy of carbon offsetting.

There are a number of secondary benefits to consciously building the carbon offsetting market in the UK. It would allow greater oversight and monitoring of projects, so offset

providers can be held accountable for the quality of their credits. It will also increase the pace of regeneration of UK woodlands and peatlands therefore increasing the Government's chances of hitting its target of 30,000 hectares a year by 2030 - last year (2019-20) just 13,660 hectares of new forest were planted across the UK.

## **2. Rebalance VAT to incentivise lower-carbon products**

As mentioned earlier in this chapter, innovation in net zero sectors is held back by perverse incentives that encourage carbon intensity activity at the expense of greener alternatives. For example, no VAT or carbon taxes are currently charged on flights (although they are subject to Airline Passenger Duty), but rail transport is subject to an effective carbon price of up to £568/tCO<sub>2</sub>.<sup>66</sup> VAT on energy-saving materials and products, such as heat pumps, solar panels and insulation, was originally taxed at a reduced 5% rate. However, this was raised to 20% in 2019, adding significant costs to the price of decarbonising buildings. For example, the cost of a recent refurbishment of a former Ministry of Defence accommodation site in Hampshire, which was turned into an eco-tourism site, increased by around £200k in VAT alone.<sup>67</sup>

These VAT imbalances need to be addressed in order to at least create a level playing field for low-carbon alternatives, and in some cases to make low-carbon products more attractive than carbon-intensive products. In the first instance, VAT on heat pumps and heat batteries should be reduced to the pre-existing 5% rate for all consumers. In 2020, assuming all sales were at the higher 20% rate rather than the reduced 5% rate, VAT receipts from heat pumps would have totalled around £70 million. This is a small price to pay to provide consumers with what is effectively a 15% discount on the cost of installing a heat pump, whose prohibitive price puts off consumers and dampens demand that would spur greater price competition and product innovation. This should also be extended to other low-carbon heating solutions, such as heat batteries.

Reducing VAT on low-carbon heating systems is also unlikely to cost the Exchequer in the long term. Assuming the rollout of heat pumps goes to plan, by the mid-2030s the vast majority of gas boiler sales each year will be replaced with heat pump sales. Heat pumps are, on average, at least four to six times more expensive than gas boilers. Therefore, if heat pumps were charged a reduced rate of 5% VAT, which is one quarter of the rate charged on gas boilers, the average gross VAT paid on one boiler sale or one heat pump sale would be roughly equal, even once accounting for falls in the cost of a heat pump in the future. Therefore, in the long term, this should not significantly reduce the Exchequer's VAT receipts.

Depending on ministerial ambition, the 5% reduced rate of VAT could also be re-applied to the costs of retrofitting buildings. New builds currently benefit from a 0% rate of VAT on building materials or labour costs. This perversely creates a financial incentive to demolish and rebuild buildings, rather than to retrofit them. Reducing VAT on retrofit to the previous 5% rate - and aligning the rate for new builds at 5% - would eliminate this incentive and significantly reduce the costs of retrofit for many households.

Ministers should also consider introducing VAT on flights. Both rail travel and aviation are zero-rated for VAT, despite aviation being around six times as carbon-intensive.

While Airline Passenger Duty is charged on flights, the cost of flying often remains much cheaper than alternative, lower-carbon methods of transport. This imbalance could be altered by introducing a 5% VAT on flights. This would only result in a small increase in the cost of flying - a flight from London to Glasgow would cost £3 more, and the cost would be borne by the most prolific frequent fliers. However, it would raise nearly £2 billion in VAT receipts each year, which could be spent on domestic train and bus transport or meet the shortfall in fuel duty as EVs replace older models.<sup>68</sup> This may also be preferable politically to a “Frequent Flyer Levy” that some have previously proposed.

**Table 3: Proposed rebalancing of VAT rates**

*Source: Onward Analysis*

Product	Current VAT	Proposed VAT
Heat pumps and heat batteries	20%, however those over sixty or claiming certain benefits are eligible for a reduced rate of 5%.	Move to 0% (c. £2,000 cheaper per unit)
Gas boilers	20%	Keep at 20%
New builds	0% on building materials or labour.	Keep at 0%
Retrofit	20%, however those over sixty or claiming certain benefits are eligible for a reduced rate of 5%.	Remove the eligibility criteria and introduce the reduced 5% rate for all.  Cavity wall insulation - £60 - £83 cheaper Internal wall insulation - £625 - £1300 cheaper Loft insulation - £13 - £55 cheaper Glazing - £600 - £875 cheaper <sup>69</sup>
Rail transport	0%	Keep at 0%
Aviation	0%	Raise to 5%  This would raise nearly £2 billion in additional VAT receipts.

### **3. Introduce a Conservation Tax Relief to encourage the donation of land for carbon sequestration**

The Government should introduce a Conservation Tax Relief to encourage donations of land towards environmental projects such as forestry and peatland.

This would be modelled on the conservation tax relief scheme in Australia, which allows taxpayers to claim back donations of \$5,000 or more to an environment or heritage organisation against their tax returns over a five-year period.<sup>70</sup> A similar scheme exists in the United States through the Federal Conservation Tax deduction, originally introduced in 2006 on a temporary basis and made permanent in 2015. This scheme enables a landowner to contact a local land trust to negotiate terms of future usage, which if they local land trust agrees would then become eligible for tax relief from their federal income tax. Landowners are eligible to deduct 50% of income for the year of the donation and for each of an additional 15 years.<sup>71</sup>

The effect of such a tax relief would be to allow people who contribute land to act as a natural carbon sink, either a forest or peatland, to receive a discount from the income tax bill equivalent to the value of the donation. It would also incentivise the adoption of Conservation Covenants, outlined in the Environment Bill which is currently going through Parliament.<sup>72</sup>

There may be legitimate concerns over the tax reliefs for landowners or the potential for abuse from such a scheme. However, evidence highlighted that the US scheme found that tax incentives have substantial effects on permanent conservation outcomes and that high-income landowners do not disproportionately benefit in comparison to low-income landowners. While there are examples of abuse, these exist for all conservation schemes, and appropriate oversight and enforcement of claims would mitigate the potential for abuse.<sup>73</sup>

Such a policy would allow for a nature-based, and more immediate, solution to remove carbon emissions from the atmosphere. Some evidence estimates four-fifths of the UK peatland has been affected by human activities, with more than four-fifths of Scottish peatland has been degraded. Restoring the peatland in the UK would not be fiscally neutral: the ONS estimates that the cost of the full restoration of the UK's peatland – around 12% of the UK's total landmass - would be between £8 billion and £22 billion over the next 100 years. But the net reduction in carbon emissions would save £109 billion over the same timeframe.<sup>74</sup> Although more analysis on the costs would be required, peatland restoration could be cost neutral in the medium-to-long term.

A UK Conservation Tax Relief could be set at either a fixed value (as per the Australian example) or it could be as a percentage of their annual income (as per the example of the US scheme), but would vary depending on ministerial ambition.

#### **4. Commission the Office for Tax Simplification to review the options for a carbon tax**

Since the introduction of a carbon price on fossil fuels in the energy sector through the EU ETS and the UK's Carbon Price Floor, the use of coal in the UK has been effectively phased out while the deployment of renewables has skyrocketed. Following the UK's departure from the European Union, the UK ETS has been established, which applies to the power sector, aviation, and energy intensive industries.

The UK ETS is an example of a 'cap and trade' scheme, whereby total emissions from sectors covered by the scheme are subject to a cap, which is reduced over time in line with the UK's net zero ambitions. Participants within the scheme then receive free allowances to emit, which can be traded, effectively putting a price on greenhouse gas emissions from these sectors.

This form of cap-and-trade scheme has been effective in reducing emissions within the sectors it applies to. However, the emission of greenhouse gases represents a clear market failure across the entire economy, and not just the sectors covered by the UK ETS. Therefore, there is a good case that ministers should go one step further and examine the options for placing a price on carbon across the entire economy, through the introduction of an economy-wide carbon tax. A tax on goods and services based on their carbon intensity would help to reduce the negative externality of greenhouse gas emissions by accounting for their hidden social costs and ensuring their price reflects these. Some studies, such as Parry et al. (2018), have found that carbon taxes raise more revenue and are more effective at cutting emissions than emissions trading schemes.<sup>75</sup>

Such a tax would be politically challenging. The Government should not commit to any tax before it has explored the options openly and with the input of experts, industry and consumer groups. The best approach would be to commission the Office for Tax Simplification (OTS) to conduct a review into the options for introducing a carbon tax in the UK. The review should begin by examining which goods and services a carbon tax would be applied to and which products or sectors should be exempt. For example, the review could consider whether net zero products such as EVs, wind turbines, heat pumps and retrofit materials should receive an exemption from carbon tax on their embodied or lifecycle emissions.

The review should explicitly consider the options to mitigate the impacts of a carbon tax on low-income households. This is vital because, applied uniformly with no rebates, carbon taxes are regressive, as they will raise the prices of necessities such as heating, petrol and food. Lower income households spend a greater proportion of their income on such necessities, hence the regressive nature of such a tax. The review should therefore examine how to redistribute the revenue raised from a carbon tax to reduce or eliminate the regressive impacts and make it more equitable, through 'carbon dividends' or tax cuts elsewhere.

The review would also need to consider other key questions surrounding the logistics of how the tax would operate. For example, the review should consider whether companies would be permitted to use carbon offsets to reduce the carbon intensity of a

product. In addition, the review would need to investigate the different options for reducing the risk of carbon leakage, which remains one of the major difficulties with pricing carbon.<sup>76</sup>

Options to reduce leakage that should be explored include placing any tax on an escalator starting from a low base, providing firms with the necessary time to adapt their operations and reduce emissions, or by implementing a Border Carbon Adjustment (BCA). A BCA would create an internationally uniform carbon price to level the playing field in competitive markets, by taxing imports based on their carbon intensity. The EU earlier this year adopted a proposal to implement a BCA from 2026.<sup>77</sup>

## Innovating our way to net zero

Aside from the tax and regulatory systems, three other mechanisms will prove critical to mobilising the development of technologies and solutions to getting to net zero: institutions, people and ideas.

### 5. Establish a National Energy Laboratory

While tax policies set the framework of incentives for investment, they do not direct or manage the R&D into specific products, technologies or industries. This is especially true for some aspects of the net zero challenge, in which the development pathway from discovery through to commercialisation is uneven. In analogous areas of science, such as space or digital communications, government grants and mission-oriented policy have proved effective at targeting efforts on specific technologies. We now need to do the same with technologies such as energy storage, green hydrogen, and Direct Air Capture.

The UK's energy system will face many challenges in transitioning to a net zero future, including increased energy demands, grid inertia, energy storage, transmission losses and smart energy management. The new energy technologies needed to solve these issues require development, commercialisation and testing on a large scale before they are ready to be rolled out as part of the grid, which needs to be finely balanced. The commodity nature of electricity, the capital-intensive and long-lived assets required for energy innovation, and a tightly-regulated market reduce R&D spending from industry and the private sector. In order to overcome these obstacles, the Government should fund the creation of a National Energy Laboratory, which would develop new innovations in the energy sector and help to bring the necessary grid infrastructure improvements required for net zero.

While the UK has a number of research institutions aimed at supporting the net zero transition, such as the Faraday Institute or the Culham Centre, these are aimed primarily at developing battery technology or nuclear fusion. Other existing national laboratories within the UK, such as the Science and Technology Facilities Council which is part of UKRI, or the National Physics Laboratory, do not generally conduct research into energy innovations and are generally not commercially focused.

However, what these laboratories do show is that developing institutional capacity for high-risk research and development can attract private sector investment and start-ups, creating innovation hubs around such centres. For example, the Culham Centre, which is the UK's national laboratory for research into nuclear fusion, is located in Oxfordshire. This is now the location for a hub of innovation into nuclear fusion, with private sector ventures such as Tokamak, First Light Fusion and General Fusion all either headquartered or building facilities in the surrounding region, along with new publicly-funded and cross-collaborative ventures such as the Joint European Torus.

A National Energy Laboratory could build on the framework of the Culham Centre and other national laboratories in providing facilities and institutional capacity for high-risk research focused around net zero. It could be awarded the freedom to focus entirely on developing and commercialising energy systems innovations, while working closely with the industry to gather data and to solve the most difficult energy challenges the net zero transition will pose. This would help to bridge the current gap between energy system innovations and commercialisation, and remove some of the main market barriers to innovation within the energy sector and smart systems space. It would also provide facilities which the industry could use to pilot new technologies or innovations.

This would echo the national laboratory systems which work well in other countries, to both develop and commercialise innovations across a range of industries. For example, in the United States, the Department of Energy owns 17 national laboratories, many of which have mission-orientated research objectives. These include the Argonne National Laboratory for energy storage and the Lawrence Berkeley National Laboratory for solar fuels. In addition, there are also national laboratories for renewable energy and energy technology. Similarly, in Germany there are currently 16 Helmholtz Association Research Centers. China, meanwhile, has built up a network of State Key Laboratories, specialising in R&D across all sectors, with an estimated 700 of these as of 2020.

These laboratories have been highly successful at supporting the development of commercial innovations in the past. For example, US national laboratories spent an estimated \$220 million on the research and development of shale gas extraction between 1976 to 1992. Innovations in technologies and methodology arising from this research programme has resulted in an estimated \$100 billion in annual economic activity from shale gas production alone. Another example of a commercialised national laboratory success was the development of cleaner-combusting oil burners, which have provided consumers with fuel savings of more than \$25 billion.<sup>78</sup> These innovations are in return for spending just \$12.3 billion annually on the national laboratories, or an average of less than 0.004% of GDP per laboratory as of 2017.<sup>79</sup> Providing a National Energy Laboratory in the UK with a similar average budget would equate to an annual spend of £522 million, equivalent to around 0.24% of UK GDP.

The UK Government has established a network of catapult centres since 2010, alongside mission orientated research centres such as the Faraday Institute, which separately focus on aspects that will help to tackle climate change such as battery technology, offshore renewable energy and energy systems. These are important elements of the innovation system in the UK, however receive limited core funding which is restricted to five-year periods. Given the urgency required - and the breadth of

the challenge - further bespoke capacity outside of the Innovate UK network could boost the energy transition.

Institutional capacity for high-risk research and development on net zero-aligned technologies is lacking in the UK currently and represents a major barrier to innovation within the Energy sector, and so a National Energy Laboratory would go some way towards addressing this issue. As highlighted earlier, just 14.6% of Innovate UK funding has been towards Clean Growth since 2004, while the Energy Systems and Offshore Renewable Energy Catapults rely on core funding for more than 50% of their total funding - rather than just a third, as designed. A National Energy Laboratory could work with these Catapults to marry their research themes and attract greater levels of private sector investment in achieving the transition. In addition, depending on the level of ministerial ambition, similar national laboratories could be established for other key net zero sectors which face the great commercialisation challenges such as CCUS, nuclear fusion, and hydrogen.

## **6. Actively recruit top global scientists and researchers in key net zero technologies**

In addition to building the UK's institutional apparatus for net zero, the Government should also look to actively recruit world-leading scientists and researchers to the UK to work on these technologies facing the most difficult commercialisation challenges. The new Office for Talent has already been established to make it easier for these top scientists to come to the UK. However, at present this leans towards a 'build it and they will come' approach. The brief of the Office for Talent should be expanded in order to actively seek out, negotiate with, and ultimately recruit scientists and innovators at the forefront of developing these new technologies.

Establishing a system of National Laboratories for these key technologies would provide the institutional framework into which these researchers would be recruited, providing them with the laboratory space, support staff and testing and pilot facilities with which to conduct their research. This would help to establish the UK at the forefront of the development of these new technologies.

This would mirror a number of successful institutions established around the world under the leadership of acclaimed researchers, who act as a lodestar for further funding and talent. For example, the Vector Institute in Toronto gained prominence through its recruitment of Geoffrey Hinton, the leading AI researcher, while Singapore developed its world-leading R&D superpower partly by recruiting top scientists from Caltech, MIT and Imperial to work in collaborative partnership with industry.

## **7. Establish a Net Zero Genius Grant**

Increasing the quantity of innovative activity relies on increasing the supply of workers to carry out high level research, as noted by Romer (2001). This is particularly true in relatively high value labour markets such as advanced science and engineering, where talent is scarce and the frontier of science is being advanced by a small number of individuals globally.

One way to encourage individual research excellence is through permissive research grants, such as the MacArthur Fellows programme. Since inception in 1981, 1,061 MacArthur fellowships have been awarded to individuals in the United States and a further 230 to individuals around the world. Each Fellow has been awarded a \$625,000 of no-strings-attached funding as an investment in future potential, which operates similar to a 'black box' fund. The MacArthur Fellowship programme, supported by the MacArthur philanthropic foundation, is now one of the United States largest independent foundations.

While the UK Government is not a natural philanthropic investor, and genius grants entail a strong appetite for risk, there is a strong case for supporting the development of a similar approach in the UK - to support open-ended scientific discovery in fields that may support the transition to net zero. For example, such genius grants have a strong record of precipitating key inventions and innovation. The MacArthur grant counts amongst its alumni: Stephen J Gould, known for the theory of punctuated equilibrium and Tim Berners-Lee, Founder of the World Wide Web. A similar grant by Peter Thiel counts among its alumni Vitalik Buterin, the founder of the Ethereum cryptocurrency and Ritesh Agarwal who founded Oyo.

The Government should work with existing endowment foundations such as NESTA, Wellcome Trust and private philanthropists to match fund a UK genius grant for scientists in fields related to net zero, worth between £500,000 and £1 million, depending on the level of private contribution. Fellowships could be awarded on the basis of creativity but also on potential future contribution to the climate change debate.

## Diffusion

The second challenge in reaching net zero is to rapidly increase the pace of adoption and commercialisation of some of the technologies already in existence. How can the Government provide the conditions that allow entrepreneurs to find a route to market for their inventions? How can the Government set the frameworks for consumers to switch to low-carbon products at pace and scale? This section will set out a series of recommendations to reform intellectual property, tax and regulation in order to rapidly increase net zero technology diffusion.

### **8. Expand the CfD model to include carbon capture technologies**

Carbon Capture, Usage and Storage (CCUS) are essential if we are to reach net zero. Delaying investment and innovation in the industry will be costly in terms of both emissions and costs to consumers. According to the IEA, a five-year delay in developing and deploying CCUS technologies could reduce the carbon emissions captured worldwide by 2030 by up to half.<sup>80</sup> These types of technologies also represent a faster and, in some ways, the most sustainable form of carbon removal process than other options: nature-based carbon removal techniques (such as tree planting reforestation) are critical but have an upper limit on the removal capacity, while also taking a long time.

Capital cost is a significant barrier to the successful deployment of CCUS infrastructure. According to the IEA, almost all existing carbon capture schemes currently operating have benefitted from government assistance – either through capital support or operating subsidies. Since 2010, 8 out of 15 projects have received grants, ranging from around USD 55 million in Australia to USD 840 million in Canada. The remaining seven projects have had access to operational support in the form of tax credits or subsidies, including projects based in the US. Of the seven projects that have not received a direct capital subsidy, four are owned and operated by a state-owned enterprise.<sup>81</sup>

There is a clear rationale for the Government to support the development and deployment of CCUS. A recent study from Wang et al. (2021) examined the outcomes of 263 CCUS projects, including pilot, demonstration and commercial scale plants. The study found that increasing the sequestration capacity of a CCUS project by 1/MtCO<sub>2</sub> per year increased the risk of project failure by almost 50%. The paper also found that, in order to roll out CCUS projects on a large-scale, the risk associated with such projects will need to be substantially reduced while increasing the reliability of financial returns. The paper notes that greater policy support for CCUS, combined with a stronger market for carbon offsets would be the most effective ways to achieve this reduction in risk while increasing the expectation of returns.

The Government has already acknowledged the importance of CCUS, highlighting potential in the Prime Minister's Ten Point Plan and announcing a £1 billion Carbon capture and Storage Infrastructure Fund.<sup>82</sup> Based on the capital barrier, the Government should also seek to significantly reduce cost barriers to carbon capture infrastructure.

One way to do this is to bring forward a CfD for CCUS. The UK Government, since 2013, has provided certainty in the marketplace for renewable energy sources through the Contracts for Difference auction system. By providing the market with certainty about future demand, the development and deployment – as well as operating costs – of some technologies have fallen significantly. For example, through the CfDs, the cost of offshore wind fell from £140–150/MWh for projects allocated in 2013, to £39–41/MWh for projects allocated in 2019.

Based on this precedent, the CfD model could deliver significant cost reductions for CCUS infrastructure. Although different from the traditional source that CfDs support, i.e., renewable technologies, the 'product' from the auction could instead be tonne captured rather than MWh produced. Under this model, a CfD mechanism could be deployed to reduce the differential between market price and system cost.

Over the five years, CfD payments for renewable electricity generation have totalled around £6.24 billion. Energy suppliers are responsible for paying the costs of CfDs, and so assuming these are passed entirely onto consumers, the average household will have paid an additional £45 per year on their bills to fund this. These CfDs have led to the avoidance of an estimated 20.4 MtCO<sub>2</sub>e in greenhouse gas emissions. Therefore, over this period, avoiding one tonne of CO<sub>2</sub>e emissions has incurred an average of £306 in CfD payments. However, in a divergence from the CfD model, the costs from this scheme would be borne through general taxation rather than consumers to avoid regressive impacts.

There is significant variation in the cost of CCUS technologies. For example, when deployed as point-source carbon capture (for example from flue emissions), costs presently range from £10-15/tCO<sub>2</sub> to £100/tCO<sub>2</sub> depending on the carbon dioxide concentration of the gases involved. However, costs for ambient air carbon removal, through Direct Air Capture, are significantly higher, ranging from £200-£800 t/CO<sub>2</sub>. As a result, different strike prices would be required for different technologies, and as such it is difficult to estimate exactly how much this policy would cost.

However, using Direct Air Capture as an example, forecasts show the expected cost of abatement in 2035 to be £242 t/CO<sub>2</sub>e<sup>83</sup>. If a strike price of £400 t/CO<sub>2</sub>e was agreed, then this would cost the taxpayer £158t/CO<sub>2</sub>e - around half the price of the cost of avoiding one tonne of CO<sub>2</sub>e emissions through CfDs on wind energy. Therefore, a CfD for DAC at this price would incur payments of approximately £158 million to remove 1 MtCO<sub>2</sub>e of greenhouse gas emissions from the atmosphere. Depending on ministerial ambition, contracts could be awarded for greater levels of removals. For example, removing 5 MtCO<sub>2</sub>e would cost £790 million at these prices. This is just one example of how a pricing structure for a CfD for one form of carbon capture could work.

## **9. Incentivise low-carbon heating installation**

Emissions from fossil-based heating systems in homes account for around one sixth (17%) of the annual emissions in the UK.<sup>84</sup> The Government has committed to reducing this, and will imminently publish the Heat and Building Strategy to publish more detail on how it will end the emissions contribution from buildings. A key plank of this strategy is likely to be much greater installation of heat pumps. The Government's current ambition is to install 600,000 a year by 2028, up from 36,000 in 2020. The CCC estimates that by 2025, 400,000 heat pump installations will be needed annually rising to 900,000 a year by 2028.

Not all homes are able to install a heat pump, as their space and insulation requirements exceed what many homes have. In an earlier report, the CCC estimates the number of homes currently suitable for heat pumps at around ten million (although loft top-up will be required in some cases), with a further ten million or more homes which could be made suitable for heat pumps with insulation (solid wall, with some remaining loft and cavities) and heating system upgrades. Therefore, the policy challenge is to dramatically accelerate the installation of heat pumps in two thirds of the UK's housing stock.<sup>85</sup> One solution for homes which are unsuitable for heat pump installation could be a heat battery, another low-carbon heating solution. Heat batteries are particularly suited to large, poorly-insulated and off-grid houses in which they can be installed as a straight swap. While they are less efficient than heat pumps, they would provide a predictable form of flexible energy storage and could help to reduce stress on the grid.

Rapidly increasing the diffusion of low-carbon heat within the UK will be crucial, as set out earlier in this paper. In addition to rebalancing VAT on heat pumps and heat batteries, we outline three further measures to decarbonise the way we heat buildings in the UK. These measures would provide market frameworks to reduce the barriers to

heat pump installation, which the IEA identifies as: high upfront purchase prices, operational costs, and the legacy of the existing building stock”.<sup>86</sup>

### **9.1 Make a proportion of the cost of installing a low-carbon heating system tax deductible**

One of the prohibitive barriers for households wishing to install a heat pump or heat battery is cost. The Energy Saving Trust estimates that an air source heat pump costs between £6,000 and £8,000, while a ground source heat pump can cost between £10,000 and £18,000 and a heat battery around £12,000. Stimulating demand by reducing the cost of installing these systems will be crucial. To achieve this aim, Ministers could allow up to £5,000 of the cost of heat pump or heat battery purchase and installation to be tax deductible from personal taxation.

This scheme would echo a scheme launched in Finland. Under the Finnish scheme, 60% of the installation costs – up to €3,000 – can be deducted from personal taxation. The scheme was extremely successful. In the early 2000s less than 50,000 Finnish households had a heat pump installed. By 2018, this had risen to a million. Finland now has one of the highest sales rates of heat pumps in Europe, due in part to the tax deduction subsidy scheme.<sup>87</sup>

Assuming a high-uptake scenario in which heat pumps are installed in one in forty properties each year - which would see the Government exceed its target of 600,000 installations a year and mirror installation rates in Sweden, Finland and Norway - this policy would equate to amounts of around £3.5 billion annually becoming tax-deductible under the scheme. This would therefore infer a cost to the exchequer in lost tax receipts of approximately £574 million per year, assuming that this £3.5 billion would have otherwise been taxed at the average rate of income tax across all taxpayers (16.5%). This cost would be equivalent to around 0.3% of income tax receipts.<sup>88</sup>

This mechanism would significantly reduce the cost barrier to installations and drive the uptake of low-carbon heating systems over the next decade, prior to the gas boiler ban, helping to establish a strong domestic supply chain.

### **9.2 Introduce a boiler replacement scheme**

In 2009, the Labour Government announced a boiler scrappage scheme. The programme subsidised the replacement of the worst performing boilers (G rated) with the most effective (A rated) or similar systems like a heat pump. Up to 125,000 households were eligible for a grant worth £400, which could be reclaimed after installation. Some private sector providers matched the grant. The total cost of the scheme was £50 million and it was fully subscribed within a few months.

Building on the success of this scheme, Ministers and local government leaders should introduce a boiler replacement scheme to support the adoption of low-carbon heating systems. This scheme would enable a discretionary amount offered to households, as part of a grant, to replace their gas boiler with a heat pump or other system, echoing

many features of the car scrappage schemes operated by councils and private companies.

For example, organisations such as Birmingham City Council and Transport for London operate car scrappage schemes to encourage residents to replace older petrol and diesel models with electric vehicles. While Birmingham City Council offers up to £2,000 depending on eligibility and TfL offers up to £2,000 for cars and up to £15,000 for heavy vehicles, the grant level to encourage households to replace their boiler could vary depending on ambition and levels of available funding.

### **9.3 Introduce community finance models for heat networks**

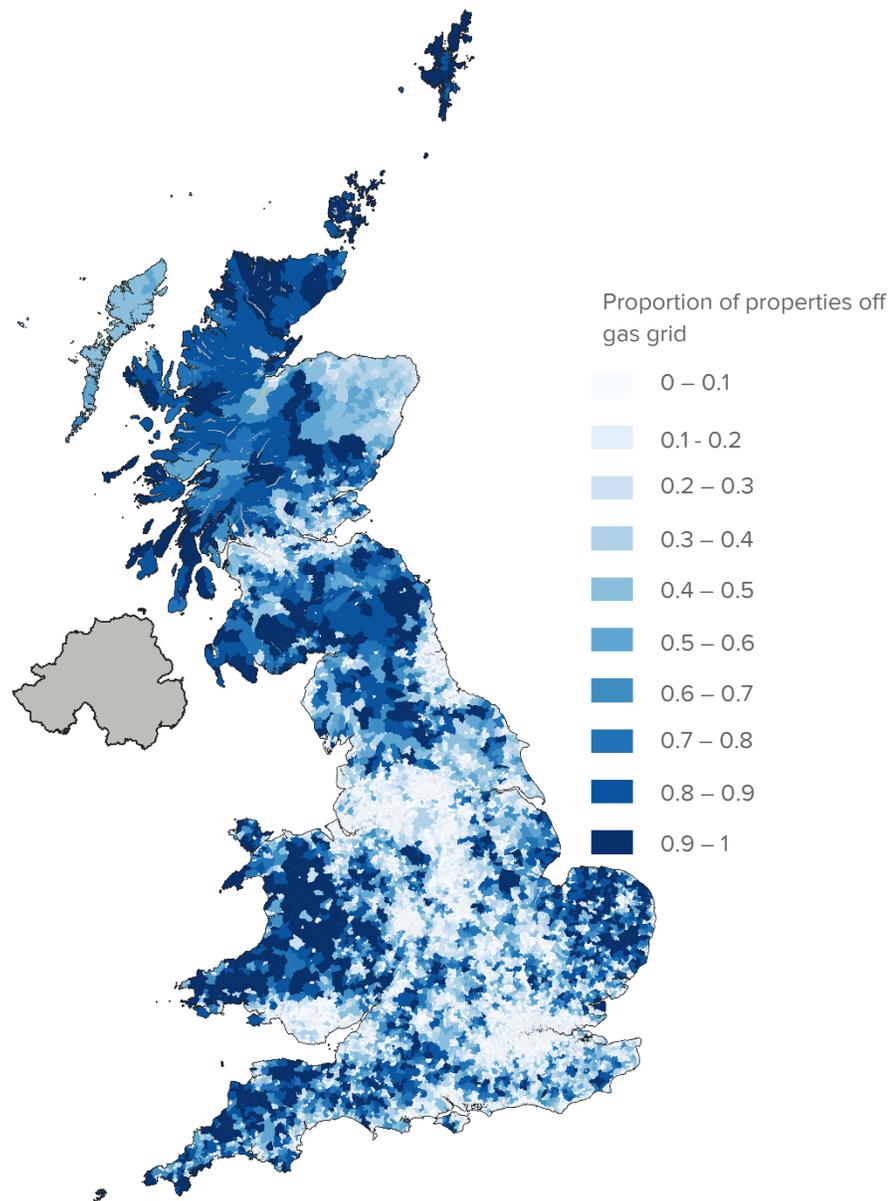
Rural properties – homes and businesses - that are off the gas grid may need additional support to decarbonise. According to some evidence from Cardiff University, 48% of retail building stock in England and Wales were built pre-1919.<sup>89</sup> A bespoke approach for rural properties is likely to be required, especially given they represent a significant element within the UK's carbon emissions. Of the residential buildings in the UK, four million are off-gas grid properties which rely on higher emitting sources of energy for heat (such as oil). As a result, these properties are responsible for a greater share of heating emissions (~23%) than if they were part of the grid.

Given that these properties are not spread evenly throughout the country, as shown below in Figure 12, one option available to Ministers could be to offer support through local authorities. However, finance will be a key barrier. While local authorities have the ability to raise revenue from residents in their area, this already funds services. Therefore, raising the levels of finance required for tackling the number of off gas grid properties through traditional methods would be a challenge without raising council tax further.

Ministers should, therefore, consider introducing a government-backed loan facility where councils could borrow from the Government to be repaid over a number of years through council tax revenue. This loan could then be used to fund the installation of heat pumps and heat batteries, increase levels of insulation and retrofit for these off-gas grid households at scale within that area.

**Figure 12: Postcodes that are off gas grid, 2017**

*Source: Centre for Sustainable Energy, Onward Analysis*



Although this would involve an up-front cost, it would in time be progressively cost neutral as improvements would reduce the cost of the reduced VAT for domestic heating. This subsidy, which costs over £2.2 billion annually, has faced sharp criticisms from campaigners. However, removing the subsidy and increasing the cost of heating would disproportionately impact those facing fuel poverty in rural areas. This approach would instead gradually reduce the cost of the subsidy without dramatically increasing costs on rural households.

## 10. Creation of a 'Green Innovation Sandbox Service'

In 2017, Ofgem launched a 'regulatory sandbox' to reduce barriers to innovation. The sandbox enabled innovators to apply to trial new products or processes without adhering to some or all of the regulations that would cover their business proposition. This followed on from similar regulatory sandboxes launched by the FCA, including Open Banking.

However, the Ofgem sandbox contained eligibility criteria while also being time limited. Ofgem's initial criteria stated that concepts applying for use of the sandbox would have to demonstrate consumer benefit, and that consumers would be protected throughout the trial. The potential for emissions reduction was not mentioned in the criteria. As well as being time limited, the flexibilities offered by Ofgem's sandbox were (understandably) limited to areas that Ofgem had control over. Since the introduction, Ofgem have opened two recruitment windows to innovators in the sector to use the sandbox. In the first window, Ofgem received 30 expressions of interest of which three innovators were put forward. In the second window, Ofgem received 37 expressions of interest of which four innovators were granted sandboxes.<sup>90</sup>

In many cases Ofgem identified that the sandboxes were not actually required and that innovators were free to proceed under existing regulation. In these cases, the service provided reassurance to innovators that they would be operating within existing regulations, allowing them to clarify their position. While sandboxes were not provided in these cases, this clarification still provided a crucial benefit to these innovators and is one of the reasons the scheme has been rendered such a success. In a small number of other cases, it was found that sandbox services would be needed on a longer-term basis than the sandbox was able to provide. The model has been highly successful overall and beneficial to a number of innovators.

Given the challenge that climate change presents, and the need for urgent innovative solutions that can be widely adopted, ministers should establish a net zero innovation sandbox. Innovators would be able to apply for this sandbox, with the main eligibility criteria being emissions reduction, without a time limit, for a derogation from regulation in any policy area. Given the societal change needed to tackle climate change, the ability to flex regulations across government will be crucial.

This sandbox could essentially provide pro-innovation regulatory reforms on a limited basis. One example of how this could boost innovation would be by streamlining the approvals process for new products or trials. This has already been successful in the agricultural space, in which the Government has loosened rules on gene-editing crops and livestock to make it easier to test and commercialise innovations in this space. This has led to the creation of Europe's first gene-edited wheat trial in Hertfordshire. This approach may also be beneficial in the development and rollout of future transport technologies, including autonomous vehicles. The Government has already announced that some autonomous vehicles will become legal on the UK's roads this year, albeit with strict conditions.

A sandbox service could be used to further accelerate the development of autonomous vehicles and address perceptions over their safety by collecting data on a larger scale than current tests can currently achieve. For example, the West Midlands Future Mobility Testbed, a network of 300km of roads which will form an environment for autonomous vehicle testing, could be expanded into a sandbox scheme. In this, the upcoming regulation around autonomous vehicles (which will limit them to 37 km/h amongst other restrictions) could be flexed to enable testing for greater autonomy.<sup>91 92</sup>

For a higher ambition scheme, ministers could also offer the users of the sandbox services a discounted tax rate on profits that are derived from the concept. Similar to the 'Innovation Box' scheme in the Netherlands, which offers an effective 80% tax advantage on profit derived from innovation. Qualifying innovative profits are effectively taxed against 7% instead of the regular 25% corporate income tax.<sup>93</sup>

### **11. Introduce a Regulated Asset Base model for capital intensive strategic energy projects**

Currently around a fifth of the UK's electricity mix (9GW) comes from nuclear sources, and has done consistently for two decades. However, in the 2020s, the majority of the nuclear fleet is due to close, meaning that generating capacity will fall from 9GW per annum to around 1GW.<sup>94</sup> At a time when electricity demand, due to decarbonisation, will be rising, the UK share of the energy mix coming from nuclear will drop from 20% to around 3% - as highlighted by the CCC. Ministers have acknowledged this transition.

In 2016, the Government committed to a new nuclear power station at Hinkley Point C that will provide 3GW by the end of 2026. Three further plants are proposed. The Energy White Paper, published in late 2020, outlined a commitment to bring "at least one largescale nuclear project to the point of Final Investment Decision by the end of this Parliament".

This commitment was based on the need for a clear value for money assessment which underlines one of the major barriers to nuclear new build: cost. Hinkley Point C was supported by a 35-year CfD that priced output at £105/MWh. When contrasted with recent offshore wind generation (priced at £39–41/MWh) and against a high requirement for private capital to fund the construction, new nuclear capacity may struggle to compete against cheaper forms of electricity.

Instead, the Government should use a Regulated Asset Base model, similar to the model introduced to fund the Thames Tideway Tunnel in London. This concept has been called for in a number of academic papers, including by Sir Dieter Helm, the OECD and the Energy Systems Catapult.<sup>95</sup> In practice this model would allow developers to unlock revenue from the end users of the plant as it is built. The project construction would be split into a number of parcels, with payments made after specific targets are met.

As leading experts have highlighted, a Regulated Asset Base model, and decreasing the cost of capital, could have reduced the cost of Hinkley by as much as half.<sup>96</sup> Although the Nuclear Sector Deal published by the Government in 2018 outlined a

commitment to reduce the cost by up to a third, as stated in the Energy White Paper, “raising enough private capital to finance a nuclear power station is challenging”.<sup>97</sup>

While some may question the role of government in supporting the construction of nuclear power plants or the role of nuclear power itself, there is a strong case for both. Firstly, no nuclear power plant has ever been built privately without substantial regulatory guarantees. Secondly, as the CCC have highlighted, nuclear can play an important role in providing predictable low-carbon power. Furthermore, the UK Government estimates that the nuclear sector could support 10,000 jobs during the construction phase.

However, the cost barrier remains. This is why a regulated asset base model has advantages, allowing the developers to access revenue from the eventual users during construction, as stages of the build are completed, rather than once completed and operational - as under the current model. Although some may see this approach as controversial, due in part to funding a project to deliver a good that isn't yet provided, it could tackle the high capital cost of projects and provide cheaper financing, which could provide a better deal for users in the long term.

Some estimates, such as those from Cambridge University, have estimated that a RAB model could reduce the costs of nuclear power to £53/MWh over the lifetime of the plant (if the project were completed on time and on budget).<sup>98</sup> If this price drop were realised, new nuclear builds could be competitive with renewable energy sources and the targets outlined in the pathway could be realised. Moreover, if the RAB model were successful in securing financing for new nuclear build then there follows an a priori case for expanding the use of the model for other high capital intensity projects such as CCUS build.

## **12. Introduce a Carbon Credit Tax Relief for negative emissions technologies such as Direct Air Capture**

The CCC's forecasts estimate that 58 MtCO<sub>2</sub>/year - 14% of today's UK emissions - of carbon removals from negative emissions technologies will be required by 2050 to hit net zero. At present there are no current projects in operation in the UK to directly capture carbon emissions from the air. There is therefore an urgent need to scale up these technologies if they are to fulfil their potential.

The business model surrounding DAC is focused on selling carbon credits within the voluntary carbon market. Large corporations are already buying these credits in bulk. Microsoft, Stripe and Shopify, for instance, have announced their purchase of different types of DAC credits. But the high costs of these credits - between \$250-\$600 per tonne of CO<sub>2</sub> - can act as a major barrier to smaller players entering the market.

To support diffusion and reduce the cost, the Government should introduce a 50% tax relief on DAC carbon credits. So, for a DAC credit worth £400, the Government would subsidise the cost by £200. It should be set at this limit as it would be an equal public-private partnership, sharing the same costs. This would halve the price of the credits, drastically improving their attractiveness to private companies and consumers. This

would incentivise investing in carbon capture schemes, to create a revenue stream to support their operation, in a similar manner to the way that Gift Aid supports UK charities.

The cost of this policy would depend on market demand. But, if there was a reasonable scenario of 1 million tonnes of CO<sub>2</sub> credits given tax relief by 2035, this would cost a total of £200 million, or £14.2 million a year. This is with the assumption of a £200 tax relief on each carbon credit, given that Direct Air Capture credits currently vary in price between £200 and £800 per tonne, so this is an approximate £400 a tonne price point.

Government interventions to support emerging technologies are a tried and tested model for quickly reducing the costs of technologies. As a result of the Contracts for Difference subsidies, the cost of offshore wind fell from £140–150/MWh for projects allocated in 2013, to £39–41/MWh for projects allocated in 2019. The same success can be achieved in negative emissions technologies with a Carbon Credit Tax Relief. This is a consumer-facing and market-driven way to reduce the costs of these technologies and catalyse private investment in the carbon removals industry.

# Conclusion



The transition to net zero will require a step change in the way we generate ideas, and invest in them. As highlighted in this paper, in some areas - such as EVs - the policy framework currently in place should enable the UK to deliver on its climate ambitions. But in other areas - most notably in the installation of heat pumps - we are dramatically off course with the clock ticking away.

In order to deliver on our targets, deep innovation in products and processes will be required from both government and business. In some areas, this will mean greater funding while some solutions are not yet clear. This report sets out recommendations that could stimulate greater levels of funding to increase levels of investment in key technologies while outlining systemic reforms that could set the conditions for the greater levels of innovation needed to reach net zero.

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<sup>84</sup> Climate Change Committee, Sixth Carbon Budget, 2020

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<sup>97</sup> BEIS (2018) Nuclear Sector Deal; BEIS (2020) Energy White Paper: Powering our Net Zero Future

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# Our Steering Group





**Dame Caroline Spelman**

Co-Chair & Former Secretary of State for Environment,  
Food and Rural Affairs



**Rt Hon Caroline Flint**

Co-Chair & Former Shadow Secretary of State for  
Energy and Climate Change



**Guy Newey**

Strategy and Performance Director,  
Energy Systems Catapult



**Melanie Onn**

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**Sam Hall**

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**Will Tanner**

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