REGULATORY HORIZONS COUNCIL

The Future of Technological Innovations and the role of Regulation

The Regulatory Horizons Council (RHC)

July 2021

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Introduction

Background

The [Regulatory Horizons Council](#) (RHC) is an independent expert committee, supported and administered by a team of civil servants, established by the Department for Business, Energy, and Industrial Strategy. A commitment from the [White Paper on Regulation for the Fourth Industrial Revolution](#), it provides the government with impartial, expert advice on regulatory reform to support the rapid and safe introduction of *technological innovations* with high potential benefit for the UK economy and society.

The Oxford English Dictionary defines an *innovation* as the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations[1]. The RHC is largely focused on where this has been achieved by technological change, or *technological innovation.* We are interested in innovations that have a high potential economic, social, and/or environmental impact. These impacts can be positive or negative. We seek to understand such technological innovations, to understand what needs to happen for them to achieve take up and therefore to deliver benefits and we are primarily interested in how regulation can act as an enabler to ensure that the UK extracts the best value from these innovations.

The Paper

Between June and September 2020, we conducted one-to-one interviews with 31 experts (see Annex D). We sought to achieve a balanced mix of expertise across five broadly defined areas: health and life sciences; digital, data and cyber; engineering and energy; innovative business models; and citizens and the environment. The purpose of the interviews was to <u>capture opinions on the future socio-economic and environmental context within which technological innovations will be delivered from now to c. 2030</u>; how innovations might shape that context; what could be done to bring about a preferred future and how regulation can act as an enabler. The <u>opinions have not been fact-checked and do not represent the views of the Council or government.</u> Instead, the quotes are meant to 'speak for themselves' – as are the 'Council's comments'. This paper sought to acknowledge that there are a range of views on these issues. These can be firmly and sincerely held even where they may not be based on fact. <u>This report contains no recommendations made by the RHC for government and a government response is therefore not expected. The content of this report is entirely that of the RHC.</u>

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[1][https://www.oecd.org/site/innovationstrategy/defininginnovation.htm#:~:text=Product%20innovation%3A%20A%20good%20or,friendliness%20or%20other%20functional%20characteristics](https://www.oecd.org/site/innovationstrategy/defininginnovation.htm).

We used the 7 Questions technique, pioneered by Shell in its scenario-planning process[2]. The questions were adapted to suit the purpose of the exercise and are a combination of hindsight and foresight questions. <u>Responses are based on interviewees' intuition</u> (what they believe) rather than an organisation's policy or view. Interviews were conducted under the Chatham House rule[3].

The output was used to guide the RHC's understanding of topics, supplementing our horizon scanning by helping us collect highly uncertain but high impact events and ultimately informed the RHC's prioritisation of possible priority areas.

The paper is broken down into two parts:

Part one highlights strategic issues that were raised by interviewees. At the beginning of each section, the Council offers its reflections on the issues identified. This is then accompanied by quotes from interviews which include a range of opinions. Although Council members were interviewed and therefore some quotes are from individual Council members, the quotes are <u>not</u> necessarily the view of the Council.

Part two provides commentary and reflections from interviewees on specific technologies that commonly came up. There are some overlaps with some of the themes emerging from Part 1 and, for completeness, some quotes consciously appear more than once.

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[2] https://foresightprojects.blog.gov.uk/2018/05/01/7-questions-futures-technique/
[3] https://www.chathamhouse.org/about-us/chatham-house-rule

The Council's reflections

The RHC is new and small, but we have a big remit and huge ambitions. We are very grateful for the willingness of everyone who participated in this exercise to give their time and intellectual energy to help develop our thinking and priorities.

The thoughts and opinions we have collected in this exercise make clear the potential for technological innovation to change the way we live and work. They allude to the potential for such innovation to help us deal with some of the major challenges of our time, such as climate change, social inclusion, and productivity. It is also clear that, to achieve this potential, it will be important for technological innovation to be applied and taken up in ways that maintain public trust and confidence – not only in respect of physical safety, but also in respect of issues like privacy. It is also apparent that some potentially highly beneficial technological innovations have economic properties (such as network externalities and tipping effects) that create potential competition issues, and indeed where common standards and inter-operability could help smaller innovative players gain access to markets. Such issues may give rise to the need for regulation. Indeed, regulation could help to create an environment that is encouraging of innovation, for example by levelling the playing field through standards, or giving clarity that enables investment cases to be produced, or by providing the public with the confidence they need to use the new products and services that it enables.

The comments we have received give us some ideas as to how this balance might best be achieved. Regulation and regulators need to develop tools and techniques for dealing with uncertainty, for example using futures or scenario planning to enable decision making that is robust to different states of the world. The best may well be the enemy of the good, and it seems clear that regulatory design and decision-making needs to reflect a nuanced view of risk and proportionate responses to that risk, rather than a one-size-fits all approach. It would also be helpful if regulators evaluated possible interventions not only with a view to mitigating downside risk, but also factoring in the potential impact of their interventions on benefits from innovation, which could be stymied. All those involved in regulation should see their work as part of a learning process, which is valuable, and which means that regulation will, and should, evolve over time. While the pandemic has had a devastating impact, it is very heartening to see that it is possible to speed up regulatory processes without losing necessary rigour and fairness.

Our interviewees have often spoken of the way in which technologies will interact with people or change the way in which our society and our economy works. The interaction between technological innovations and the way in which they are used will be critically important. It will be important for regulatory design and implementation to take account of the role that technological innovations will play when they become part of wider systems – interacting with individuals, with societies and with the natural world. This may have implications both for the risks those innovations bring but also the benefits; too much focus on regulating *technologies* risks overlooking both.

The value of regulation in enabling people to trust new technologies may also be critical in enabling their take up. But the drivers of trust are dynamic, context changes and experience matters. In an age of social media, ideas travel quickly, concerns are easily amplified, and debates can tip. So, it will be important for regulators to understand how people feel about technological innovations. They will need to acknowledge views that are firmly and sincerely held, even where they may not be based on fact. And regulators may need to engage in the debate themselves, in part to provide trusted, independent analysis, and in part to maintain the legitimacy of their process and their authority.

The potential of these technological innovations to disrupt the status quo shines through from the interviews. The technologies themselves will bring new and better ways of doing things, but they will disrupt the systems around them and spark other new ideas and opportunities. But every change brings winners and losers. And it may well be those who are comfortable with current regulatory regimes who will feel most threatened by these innovations. It is therefore critically important for regulators to seek out the challengers and the disrupters, and to develop their regulatory thinking and take account of diverse viewpoints, including those from people who may not know how to talk to regulators or even that they exist. In a similar vein, part of the innovation behind many of these new technologies and the value they will bring lies in their cross-cutting nature. But when cross-cutting new approaches meet regulatory frameworks that were designed around previous approaches, they will find those frameworks extremely complex, costly and time consuming to understand. And so, it will be important to find ways to cut through complexity, or at least provide help to those who must navigate it.

These are the Council's reflections on some of the themes from a rich set of interviews. We will consider how best to take them forward as we progress our work. And we may well return to the interviews in future to ensure we have fully mined them for the thoughts they provoke.

Issues

The nature of the regulatory challenge

Key issues raised by interviewees

- What is the preferred timing of regulation?

- What are the preferred types of regulation?

- At what level should regulation exist or be defined?

- Does regulation enable innovation and commercialisation or stifle it?

- What difference does the prevalence of a technology make to how it is regulated?

- How is public trust maintained or lost?

Council's comment

Many of the issues above and statements below are starkly simplistic. None of them can be true across the board. As a Council we are aware of the major differences across sectors and subsectors. Even within e.g., genetic technologies, the regulatory issues and freedom of regulatory action will be different for microbes and industrial biology, plants and gene editing, plants and other genetic technologies, animals, and genetic technologies, etc.

Regarding timing, though a change of government can bring a revision to regulation, not all regulation works in c. 5-year government cycles. We think the broader point is regulation will necessarily need to decide some things in advance, taking account of the facts at the time to inform choices, but does so best when it builds in sufficient adaptability to take account of change. There is also a point about regulation tending to be backwards looking rather than anticipatory.

The rollout of first generation smart meters is an example of the trade-offs of regulation. On the positive side, regulation prevented the widespread installation of smart meters that could never be made compatible across suppliers in the future. However, the result of switching supplier for a majority of first generation (SMETS1) smart meters was that they went 'dumb'. The intention was for this to be rectified in the future, as has started to happen, but it has impacted public confidence. Generalising, the learning from this is that regulators and policymakers must, with regular review, consider how public confidence could be affected by incentives they create around the roll-out of technological innovations, especially where public acceptance is a pre-requisite of the success of such a roll-out.

On engagement by regulators, this is vital, and should include a broad range of stakeholders including industry, customers, government, and civil society groups as well as others. This is tied to the necessity for regulators to not only anticipate new tech and its applications but also consider where the public concerns might be. Along with transparency, these are all fundamental requirements for successful regulation. In the case of controversial technology, this may include how to successfully incorporate consenting and dissenting voices into the development of regulation.

Regarding the quote below on the need to be in the control of the development of technologies, the Council is of the view that this is not possible or desirable. The key concern is far more nuanced - we need to be alive to the risks and watch what happens so we can see where the risk factors are crystalising and give ourselves the ability to act quickly if we need to – trying not to hamper innovation along the way. Some express a desire for new tech to 'align' with 'broader societal values' but it seems very hard to imagine how this would be achieved and how we might avoid some sort of Soviet-style centralisation of innovation trajectories.

On the potential for government picking winners, the Council is of the view that the track record is mixed and it is preferable instead for government to create the conditions for success. Within this, there is a role for government to think about which technological innovations have real potential to be taken up and to be impactful, then to be clear about the risks and consciously make decisions about regulation at an appropriate time. There is an important role for regulation to address market failure, but it is equally important to be aware of the potential for 'regulatory failure' as well, i.e., the potential that regulation will make things worse. This might happen e.g., if standards are set by a limited group of stakeholders and they favour incumbents.

On the timeliness of regulatory approaches and decisions, the big lesson from the UK's approach to vaccine development decisions with respect to Covid-19 has been that very fast regulatory decisions can be done and do make a difference. The Medicines and Healthcare products Regulatory Agency's (MHRA) decision to act fast, and work in parallel, vs the European Medicines Agency's slow and less agile approach is possibly the single biggest regulatory lesson of the crisis. The problem for innovation is not that regulators say "no" so much as take a long time to say "yes". Of course, there are implications of speeding up decision making, not least resource. A related approach that has had success in the UK is that of Adaptive Licensing.

In terms of the purpose of regulation, the Council is of the view it is not always about preventing outcomes. Regulation can be about creating a framework that aligns the interests of those with power with those who have less power.

On standards, interoperability and access to data are just as important as direct regulations. Standards do play a role in delivering company and national competitive advantage. They can also help unlock investment, by clarifying what is required of a technology or application and creating greater certainty. That said, although the process of standard development can be more supportive of innovation than formal regulation, once a standard is in place, it can be just as difficult to change as a regulatory system.

Regarding state aid, the Council would suggest caution in the consideration of relaxing state aid limits for large incumbents such as in aerospace and nuclear power for R&D. Providing certainty of a long-term market might be a more useful incentive to these large companies. One challenge we would offer is, 'is there evidence that additional R&D state aid to UK large companies leads to better economic and business outcomes'? It may well be the case that disruptive innovations are developed by SMEs and then acquired and scaled by incumbents. Clearly government procurement should take account of any impact on the UK economy, including on competitiveness in emerging technologies.

On the operation of regulation, where we can amend regulation to reduce transaction costs this is probably a good thing. That means being as simple as possible, and creating rules that enable markets to work (e.g. standards, weights and measures etc). It also means being slow to regulate in ways that create transactions costs.

On public trust, the quotes below are useful at highlighting what work needs to be done in this area. Key questions are raised about, e.g., what good constructive engagement with dissenting voices (and multiple disagreeing voices) really looks like i.e., how do we move beyond simplistic surveys that have a 'tick box' feel to them? Issues around trust in those conducting work or the motives of those challenging work are raised. There are strong forces prepared to fan the flames of fear (rival firms, pressure groups etc), and the growth of social media can make it easier to spread disinformation. But the public can ignore them when it sees a practical benefit in an innovation. For example, it proved difficult to get the public to worry about mobile phones causing brain cancer, despite strenuous attempts, because mobiles were too useful.

Interview quotes - Timing

'We need regulation to stop working in 5-year cycles where we try to decide everything in advance.'

'We need to get to a place where we can create or amend regulation, very quickly.'

'Decisions are needed at pace in a context of complexity and deep uncertainty and where societal views may be contradictory but equally valid.'

'We need our regulators to be very intelligent customers and engage with their industries, with government intervening early enough to ensure favourable conditions exist for the successful implementation of new technologies. For example, regulation of smart meters went wrong. The mandate from government requiring their installation was well intentioned but poorly implemented, due to a lack of timely supporting standards and conflicting regulatory objectives.'

'The opportunity is not so much about the specific technology, it's about the process of when and how we sort the good and bad technology and create regulatory structures to constrain or enable these to develop.'

'There is a risk of negative consequences 'if we just let innovation happen'. For example, **AI is an exciting and scary prospect, so we need to be in control of its development.'**

'The Government needs to be able to pick winners and move at pace when there is sufficient evidence or possibility of market failure, to take forwards specific applications. Regulation gives the parameters of how to work going forwards and gives the industry comfort. For example, if you leave the regulation alone in hydrogen you will see lots of different solutions for non-standardised production and distribution of hydrogen and this won't benefit anybody as it will be much slower to develop.'

'Regulation for innovative products via product standards is possible early on and can still deliver public value under uncertainty. For example, the vaping industry did better in UK because we went with the argument that they might not be 100% safe, but still much better than smoking. This can be compared with the US where it was essentially prohibited and then went to black market - which caused much bigger issues.'

'Sometimes regulation can be used to encourage innovation such as carbon emissions trading, although this often still fundamentally relates to a protection from a societal harm **– creating incentives around preventing pollution of the environment with the resulting innovation being a by-product.'**

'We are operating across one of today's major societal divides – between nature-based solutions and technology-based solutions to societal challenges. The best overall societal outcome in many cases will come from an integrated balance between the two, but each individual or group will probably see a different ideal balance and we should not be naïve about the possibility of achieving a consensus.'

'Regulation almost always follows innovation; it is a response. It makes sense generally that governments would not try and spend money stopping something before it has materialised.'

'A lack of regulation helps things to get things off the ground – companies ask for forgiveness, not permission. Excessive caution in regulation curtails innovation.'

'As a result of Covid-19, we have seen that when government really wants things to happen regulation can be relaxed to enable rapid development. We may want to take our lead from the Food and Drug Administration in the US about creating a structure where certain medicines have an accelerated path from idea to delivery.'

'Regulation influences return on investment, due to compliance costs. This therefore alters where investment is allocated and highlights the value of regulatory arbitrage.'

Interview quotes - experimentation enabling

'A great future regulatory option for **UK regulators to run big experiments** and see what works, A-B comparative testing from an 'apolitical' standpoint.'

'**Sandbox methods are great** for getting innovators to the field demonstrator stage in a safe way that is not hampered by the burden of regulations e.g., allowing preferential access for a field demonstrator to the national grid to prove a technology.'

Interview quotes - standards

'**Where there isn't one set of standards, it is more difficult to scale as entities aren't speaking the same language.** The whole basis for establishing the World Wide Web was communication standards, which have a much wider application in digital in general.'

'**The BSI should work more with other countries to set standards to get critical mass so our manufacturers can foster more of a global mindset and compete more effectively.** National standard bodies with globally recognised standards provide local manufacturers an export advantage.'

'**Prominence of standards will get bigger - used to be EU and USA but now Australia has a big voice in setting of standards through the realisation that it is easier to determine the terms of trade if you get in there early with standard setting.** Europe turbo charged the development of mobile connectivity with the GSM mobile standard. Manufacturers knew what they had to develop for which developed certainty and gave European manufacturers the scale to commercialise. USA was late to this; they are now keen to learn lessons from 2G - how they got it wrong and how to be better for 5G.'

Interview quotes - state aid

'**EU regulations have had positive and negative effects on innovation. On the positive side,** in civil aviation the clean sky programme has been great at convening EU aerospace companies towards the common goal of keeping the EU No1 in civil aerospace**.'**

'**If the UK wants to stay 'number one' in jet engines we need to tread our way through state aid regulations, some of which are bizarre artifacts of history based on competitive landscape of other EU countries rather than the US or China.** For example, the block exemption limit of £20m makes no sense given it

doesn't prevent unfair competitive advantage in digital companies but is a blunt inhibitor to companies like aerospace or nuclear industries where £20m is small change.'

'Competition law and state aid regulations need to be looked at and use of government procurement needs to be skewed towards the UK. We need to invest heavily behind moon-shot opportunities. A specific example of innovation being inhibited by EU state aid regulations is small modular reactors. Our own prime minister wants to progress with it and its key to decarbonising the grid and relevelling the grid but is blocked by EU state aid regulations despite government support.'

Interview quotes - level

'We should have strong regulation at a framework level to ensure the market works effectively (such as the Weights and Measures Act which effectively framed how a market operated). **Small amounts of heavy regulation are more effective than endless details.'**

'We don't want regulation to be so tightly defined that it unnecessarily restricts things. It should be more focused - more about guard rails, protecting the vulnerable, the poor, the hurting.'

Interview quotes - prevalence

'It's difficult to regulate technology that is very prevalent, such as the internet, but a lack of regulation means there is a *dark side to freedom*.'

'Genome sequencing is an example of where regulating will be complicated – it can be done with minimal kit and almost everywhere, it doesn't need mega labs. **Where the opportunity for possible development to happen very easily and locally it becomes much harder to regulate outcomes.'**

Interview quotes - public trust

'The hype of new technologies and the failure to respect values or have effective governance will lead to mistakes with consequential loss of public trust in innovations.'

'Are we going to learn the public trust lessons from past genetic modification (GM) endeavours when we are exploring future GM? The answer seems to be no at the moment.'

'Genetic Modification: public understanding would need to be worked on – the words both wrongly have bad connotations.'

'We are operating across one of today's major societal divides – between nature-based solutions and technology-based solutions to societal challenges. The best overall societal outcome in many cases will come from an integrated balance between the two, but each individual or group will probably see a different ideal balance and we shouldn't be naïve about the possibility of achieving a consensus.'

'It will go wrong! Not if, it's when! It will be because of a values clash between the needs of innovation and the needs of people.'

'The perspective that the economy trumps everything is one of the biggest causes of distrust in governance and tech.'

'You need to be realistic in accepting that you will never convince absolutely everyone with a new innovation, particularly those that are very ideologically opposed.'

'Scientists can be criticised when they talk about 'educating the public'. This is a challenge when what is in the public interest is not necessarily what the public are interested in. This is difficult also because it can sound quite paternalistic. We need a balance between education and listening – **a conversation is required in non-technical language that addresses scientific and ethical concerns.'**

'Often, conversations about safety are placeholders for ethical conversations. Even when you conclude that something's safe people might still say they don't want to go ahead for ethical reasons.'

Data

Key issues raised by interviewees

- Where and by whom should data be stored?

- Who should control access to data?

- What are the appropriate responses to data breaches?

- How can public trust be built and maintained?

Council's comment

There is no doubt that the ability to collect, analyse and draw insight from vast quantities of data and data from new sources is already unlocking huge value, and that this will increase in the future. But the interview quotes highlight the issues that will need to be navigated through if this value is to be unlocked in a sustainable way, which has real legitimacy. It is clear that, while issues such as privacy and security remain critical, ideas around 'data equity', who benefits from data, are increasingly being surfaced. The question of data ownership, and with it control, is key. Is data owned by the collector of the data, or by the individual or entity that created it? If the person who creates value is the person who analyses the data, how much of that value should they share with the owner of the data?

If we are to realise the potential value from data, we need to exist in a virtuous circle, where people allow data about them and how they live their lives to be collected, where that data is properly protected, where it is used to create value, and where the people whose data was used to create that value see and appreciate it, and therefore remain content to give the data.

The comments also highlight a need for greater understanding of the economics of sectors in which value is created through data collection and analytics. Such markets can exhibit increasing returns to scale, as the insight created by data increases as the size of the dataset increases, which creates barriers to new entry and can lead to the acquisition of market power, especially when coupled with, for example, proprietary techniques for data analytics. The extent to which, and circumstances within which, this matters are not currently well understood, although the recent Furman review and the CMA's digital advertising market study are important contributions to the thinking. As we move forward in regulating this area, we must also understand the longer term dynamics of highly innovative markets, and indeed markets that are characterised by relative low capital costs but place a high value on intellectual property. It may be more important to regulate dynamically, in ways that enable cycles of 'creative destruction' and the replacement of current technologies with new ones, than it is to regulate statically, seeing today's technologies as if their current pre-eminence were set in stone.

Interview quotes - data ownership and public trust

'In the future, data should be held by newly created trusted legal institutions – data banks. These would be charged with responsibly holding information and create a structure where there is a high degree of confidence about how that data is being used and what value is being extracted from it.'

'The thing society is not talking about is data equity – my data becomes a massive source of value when coupled with an algorithm. What do I get in return? Usually not a lot. This has huge implications; we could end up in a situation where people's wealth isn't just their assets but how much their data is worth. Who is

rich and poor in society depending on their data equity, social inclusion issues especially if someone values privacy over sharing data, are they then excluded from a value creation opportunity?'

'Data privacy and data access are growing concerns. What is the appropriate place and level for data to be retained? Greater local resilience can help, where instead of data all going to one central place you allow certain parts of the UK to have the resource they need.'

'We should open up the data sets, it doesn't cost money. **The crucial thing is reassuring people that data will be safe and showing them the benefits** of doing so. **We also need to improve the quality of data.'**

'If you open up the data, you have to be very careful with who gets access **to it** and what the rules are otherwise failings in handling will mean it will revert back to an extremely regulated system**. You definitely need red lines and severe consequences. If you take a relaxed approach to who gets access, e.g. giving data to Cambridge Analytica, the consequences should be going to jail, people autoregulate if consequences are severe!'**

'How we manage public trust with regard to our data is going to be crucial. **Banks are playing a big role in brokering our data – they have an oasis of trust for our salaries protecting from fraud etc but now they need to expand that trust for our data as well. '**

'There is no point trying to engage the 5% of the population who hold the most extreme views and scepticism of handling of data as their views are set but you need to win over the rest of the population.'

'Clear, prompt responses to mistakes – i.e. data breaches – and decisive next steps to rectify them, is the model needed to win trust.'

'The development of automated decision-making requires data – key questions around where that comes from, how well protected it is and who owns that data.'

'With Covid-19, the value of tech companies collecting location data has been game-changing, helping us to understand individual behaviour during the pandemic. However, there are also concerns that come with this, particularly around privacy.'

'Covid-19 has accelerated the accessibility of data, reducing or stopping regulation on data use, a massive step forward, enabling a big push in epidemiology in health. We will be hitting second wave in September so these easements shouldn't go away.'

'Our short-term priority probably needs to be digital in all its guises. Even gene editing is digital tech when emailing the genetic codes.'

Automated systems

Key issues raised by interviewees

- How is liability dealt with when it comes to autonomous systems?
- What issues does automation raise?
- How are potential biases mitigated?

Council's comment

This strikes us as a particularly difficult area. Two things make it so. The first is the need to appreciate the system, which raises the need to understand the interaction between different elements within it. It may be possible for the algorithm governing machine A to be reasonable, and the algorithm governing machine B also to be reasonable, but does that mean we will be content with the result that is generated when machine A and machine B interact? And who is responsible for that result? The second is the potential that now exists for these systems to learn over time. We may be happy with the algorithms as they exist today, but if they are set up to learn and 'improve' over time, will we be happy with their future iterations? And how will we know? These two factors together create a complex dynamic that must place a premium on creating a process of oversight and 'checking in' (the 'human in the loop') and a set of principles that can guide developments, without precluding innovation. Such a process and principles will themselves need to evolve over time, as our interaction with these systems is in its infancy, and what society views as beneficial, acceptable or concerning will change as our experience grows.

There is no doubt that these autonomous systems will cause us to examine our own nature as human beings and societies. Questions around the extent to which we want algorithms to replicate human decision-making, with all its imperfections and biases, or make 'better' decisions and who decides what 'better' looks like, are already being examined by organisations such as the Centre for Data Ethics and Innovation and the Law Commission . It will be important not to box regulatory issues off from these wider ethical discussions and pretend that they are susceptible to more 'objective' and 'analytical' approaches. We need to find a way of facing into the inevitable ethical challenges regulation of these systems will raise, creating a meaningful public debate, and reflecting the resulting views in regulation.

Interview quotes – liability

'The liability question is key. The machine per se isn't liable, we need to impose requirements on the machine maker around transparency, or via standards. Opaque processes erode trust. People will try to give away responsibility to a machine – need to remind people that they are working with machines with limitations.'

'Many challenges around liability for autonomous vehicles, who does it lie with – the designer, the operator?'

Interview quotes - algorithmic or artificial intelligence based decision making

'Biases can quite easily develop in systems and must be guarded against. At the moment this is done by 'case failure analysis'.'

'Artificial intelligence should have 'human in the loop' so decisions aren't fully autonomous. It should be a companion/support, not a replacement of humans.'

'There is very real potential for discriminatory effects via algorithm or artificial intelligence based decision making, which could be hard to identify. **For high risk examples, such as potential biases around facial recognition, if these lead to unequal effects across the population we will end up with people being mistreated – this must be guarded against.'**

'For medical diagnostic technology, e.g. breast-cancer screening, **without explicability, we could end up with all sorts of problems.'**

Research, development and commercialisation

Key issues raised by interviewees

- Which technologies should we pursue?

- How could regulation around healthcare be reformed to support innovation?

- How might transport and energy funding and regulation be changed?

- How can government procurement support commercialisation?

Council's comment

Much innovation happens precisely at the point of translating ideas that arise in the context of 'pure' research and development into something that is commercially viable, i.e., that can be applied in ways that will create value. The interviewees have identified healthcare and transport/mobility as areas that are ripe for such innovation and we agree. Coincidentally, it is often at the point of commercialisation that new ideas meet regulation. Regulation can be helpful, for example, where the existence of standards makes it clear what safeguards must be in place before a technology can be brought into widespread use. But it is important to guard against the fact that existing regulatory frameworks will probably have been developed on the basis of pre-existing technologies and even by precisely those existing players who would be most disrupted by new approaches. If the UK is to get best value from the cutting-edge R&D that is being undertaken, it must focus on fostering the right mindset, principles, and approach to design and implementation decisions across all aspects of regulation. The quotes highlight the risk that, if we do not achieve this, ideas will be commercialised elsewhere in the world, where regulatory approaches are more conducive.

Interview Quotes - technological priorities

'**Leading on AI will allow the UK to be competitive on the global stage,** it's a huge strategic area.'

'**There is an opportunity for the UK to be at the cutting edge for quantum technologies (QT), which does not actually need a huge amount of money, but we need to change our operating model.** We have a lot of assets, there is a lot we can do to enable getting to real applications. **The UK needs something new, a series of enterprises maybe to fund the innovation and commercialisation.** We want to decouple the funding from the technical progress.'

'**AI – in all of its different forms – is a massively strategic area. We have some fundamental AI research done in universities or private companies including**

pharmacology – it has huge potential in a range of industries e.g. drug discovery, optimising logistics networks, diagnosing diseases – broad applications. The UK isn't investing as much money as other countries such as China – I really think this is area that we want to maintain global leadership.'

Interview quotes - healthcare

'If the UK reforms health care data by making it more open, then we'd have a massive competitive advantage internationally. We have a reasonably good coherent data system from having the NHS and a big population. If you could access all national healthcare data, then you would be able to discern patterns far more easily. Estonia have done pretty well – but tiny. USA haven't done it well. Germany has more restricted access to data so not so good. Rwanda have done well – open public data.'

'Regulation of the healthcare industry now starting to act against people's interests. The tight controls over diagnostic devices are stifling and counterproductive.'

'Currently it takes three years to recruit participants for drug trials but if you have open data sets and a set criterion you can find those people almost instantly. This will greatly reduce the time required of clinical trials.'

Interview quotes - transport & energy

'For trains, rather than spend £100bn on HS2, I would look at how we could spend one percent of that on R&D, asking how we could make a fundamentally different model of transport. For example, all the possibilities around maglev trains.'

'In the context of trains, the regulatory approach I would take to do this is to amend planning regulation. I would allow regional governments to bid as a consortium with research institutes and companies to propose how they can work together on planning major projects. Perhaps in the UK the Northern Powerhouse or regional forums could play this role. However, the UK is limited by the lack of major players like General Electric or Siemens.'

'From a market perspective, **offshore-wind has totally transformed the UK market for electricity generation, as well as our carbon footprint. However, from a supply chain perspective there has been a massive, missed opportunity for wealth creation by UK businesses** given the UK's natural endowment for wind power.'

'With real ambition and integrated steps we could create players in the wind space – we need large oil and gas or aerospace company's involvement with investing in this innovation. **We already have great research institutes and innovative start-**

ups in the UK but not players of scale. The UK does not have any Original Equipment Manufacturer (OEMs), if I had enough money, I would give £200m and challenge UK industry to come up with 2 different methodologies for coming up with new technology solutions for renewable energy.'

'Carbon-capture and storage is an exciting potential opportunity for the UK. Best place is North Sea, but government will use pilot projects rather than saying we don't care how when or where you do it**, but we want all CO2 emitting businesses to put a portion of their emissions in carbon capture and then ratchet up percentages each year: i.e., create market discovery process.**'

Interview quotes - commercialisation and wealth creation

'The use of government procurement has not been deployed optimally to stimulate UK innovation and wealth.'

'The UK lacks the ability to quickly scale and our academia have a tradition of holding on to things.'

'The UK should think about the advantages of being a second-mover in certain areas and avoid the costs of being first.'

'Buying foreign technology is not the way to foster a self-sustaining economy but we are moving in the right direction now that we've started sponsoring our own design of nuclear power plants and building it ourselves in the north of England and it's not just a Westminster bubble exercise anymore.'

Interview quotes – general & misc

'The nation needs to treat research and development (R&D) as a precious thing to improve – for example forcing pension fund to invest in R&D with massive tax benefits (e.g. massive capital gains tax relief if there are longer term R&D pay offs).'

'The USA's restrictions on the operation of foreign defence primes via its International Traffic in Arms Regulation (ITAR) results in UK companies struggling to operate in these markets. The focus becomes about meeting these regulatory requirements, preventing collaboration.'

'Weak regulation is benefiting founders and owners – the market concentration in the U.S. has become huge. You can see it in tech, airlines etc, huge power. There is an argument around how new ideas are swallowed up by large players. Things are

never brought to market, to an initial public offering, because they are bought up privately and subsumed into dominant companies.'

'Considering GM and other advanced biotechnology techniques (e.g. gene editing) as applied to crops, **European regulatory decisions since the 1990s have resulted in the movement of markets mainly to North and South America.**'

Regulation for achieving net zero

Key issues raised by interviewees

- What are the key challenges for getting to zero carbon emissions?
- What are the possible consequences?

Council's comment

Addressing climate change, and in particular achieving net zero carbon emissions, requires massive systemic change across our economy and society, not just in the UK but globally. The scale and complexity of the challenge requires radical thinking across multiple systems. New ideas, inventions and innovations will be needed if we are to succeed, and pro-innovation approaches to regulation will be imperative. All of the features of pro-innovation we have highlighted above will be relevant. Given the sheer number of firms that will be affected by this – not just in the energy sector but in transport, manufacturing, communications and other areas – and their economic power, the need to guard against vested interests will be particularly important. The long term nature of the objective and the potential for any transition to affect different groups in society differently make it important for government to be clear about the policy aims and what it sees as acceptable and unacceptable in terms of trade-offs, to provide the policy context in which regulators can act. Government may also need to step in to ensure adequate coordination, exchange of information, and learning between regulators in pursuit of net zero.

Interview quotes - timing

'Regulating 'for getting to zero carbon emissions' will be the biggest challenge for regulation in the near future.'

'The discussion in future will be how to meet that net zero target, the big question for me will be around decarbonising heat. It's going to be a difficult challenge, in many ways more tricky than decarbonising electricity generation.'

'Another key aspect is looking at decarbonisation of infrastructure, for example replacing concrete or steel with other decarbonised materials or making them in a much more environmentally friendly way. There are some regulatory barriers around this where I know companies have been stopped from using alternatives to concrete because the regulator says you cannot use other materials despite them having been proved to be effective.'

'In addition to looking more broadly at the scope of regulation, looking increasingly at the global impact of regulations is vital. For example, climate change regulations achieve nothing if the consequence is that greenhouse gas emissions are offshored rather than reduced. There is also the question of how UK regulations can create the right environment so that UK technology can compete and realise full impact globally.'

'More sustainable materials – alternatives to plastic for packaging – huge amount of interest in this space. Covid-19 has driven shift to online shopping and some shift will endure. I don't think things will bounce back as they were before – will cause people to eyeball it or think more carefully about potential impact on the environment.'

'We need to develop boiler technology – hydrogen boilers that do not pollute – if we are serious about net zero. We are going to have to replace every boiler by 2040 with something that is clean. This will be universally beneficial.'

Interview quotes - consequences

'There is no way to achieve sustainability with just marginal decarbonisation - it does not cut it - **we have to completely change how we live, we have to travel less, have to find a different way of doing what we are doing now. The virtual world is therefore fundamental in changing the way of how these things work.'**

'Who knew we would create new problems when we banned plastic bags - with the resulting rise in the use of woven bags with a higher emissions footprint. There are always unintended consequences.'

'The safety regulatory environment has to be completely rethought in light of new nuclear power and electrification of aviation. Regulatory bodies need to be deconstructed and rebuilt to serve the new economy**.'**

Drivers of innovation

Key issues raised by interviewees

- Consumer demand

- Disrupters

- Human desire to communicate

- Competitive forces

- Cultural factors

- Skilled workforce/education

- Infrastructure

- Access to finance

- Regulation

- Technological advances

- Novel applications of technologies

Council's comment

The drivers of innovation are many and various, which is precisely the point. What strikes us from these quotes is the importance of creating fertile ground for innovation in general, as something that is valued by our society wherever and however it might occur. It is clear from our interviewees that an approach that attempts to foster innovation in specific cases, while it may be partially successful, will inevitably miss many of the instances in which the coincidence of an idea and a use case could lead to something amazing. To date, as a Council, we have focussed on some specific areas of technological innovation – fusion energy, unmanned aircraft, genetic technologies and medical devices – where it is clear that the answers to some big regulatory questions will have a real impact on whether and how they are taken up. These quotes prompt us to consider a more general piece of work aimed at encouraging all those who work in regulation, to do their work in a way that creates a climate that would foster innovation.

Interview quotes

'**With the internet and smartphones,** consumer demand has been the most important factor**, making it affordable for most of the population is key to its early success. As platform technologies they have been very successful in enabling wider society to participate in the innovation.**'

'**The user-experience. Are people willing to give it a go? Does it make people's lives easier? Flexibility, customisation etc.**'

'Most innovation is driven by human need – there are not many innovations where you would say this is entirely new. **Normally innovation builds from existing tech and grabs market attention due to unique application to solve a problem i.e. 3D printing and application to producing PPE during Covid-19. A lot of innovation doesn't originate from sudden blue sky thinking but from bringing together different technologies you already see around you.**'

'**Disruptors push a lot of innovation. Permission-less innovation is often dynamic. Innovators don't ask for permission they just go and do it** e.g., Uber and Deliveroo. Big existing players will try and oppose but sometimes the favourability of market dynamics will outweigh that.'

'**One of the key shapers of recent innovation is the** human desire to communicate and interact with others. **Trying to create dialogue and get people to genuinely communicate with each other has been a core aim. Constant communication now dominates technology.**'

'**Spotify has reinvigorated the music industry. The old industry was addicted to over-charging for a piece of plastic for £15 when you wanted to listen to one track every now and then.** It took destruction and even illegal things (e.g., illegal streaming) to pave the way for better outcomes for consumers in the music sector.**'**

'**When Amazon moved to the UK, it changed everyone's views on how quickly you can deliver. Other companies started to move towards the same day delivery model after saying it was impossible to do.** You need to unleash this rapid change by embracing the forces of competition.**'**

'**The Silicon Valley ecosystem allowed companies to do their own thing and there was not regulation because the industry hadn't existed previously.** There were nearby high-quality universities providing graduates and venture capital funding.'

'A culture where you can innovate, fail and move forward **but where it doesn't have prohibitive consequences.**'

'UK had a lead in Telecoms development because of skills in producing the base technologies, this allowed the UK to build platforms for internet and mobile.'

'Future driver of innovation will be venture capital - given its increasing importance - where is the funding going?'

'For the Internet, a key driver of innovation was industry and not government.'

'Regulation blocking GM in the UK has influenced people to innovate in different ways – look harder in mutations or other species – gene editing technique to replace random mutation with a more targeted approach – big question right now is whether it will be classed as GM.**'**

'Technological advancements have driven these innovations – markets that we didn't know existed until you have an iPhone you realise the market. Technology has driven the uptake.'

'Drivers of innovation are not necessarily technology itself but the question, **can clever entrepreneurs find the applications of these technologies that will build billion-dollar businesses?'**

'Need acquirers and exit systems to create the ecosystem of companies buying start-ups, then those founders becoming angel investors and investing in new start-ups etc.'

'One driver of innovation should be **meaningful collaborations between government, academia, big corporates and start-ups.** This will avoid siloes and disconnects that have a chilling effect on possibilities.'

'AI has been enabled by the sudden explosion of data facilitated by the internet, academic excellence being rewarded and funded and a lack of regulation.'

'Future drivers of AI innovation would include: education, including in schools; funding – taxing tech giants properly; regulation – recommend a ban on *general AI* and a focus on *narrow solution AI* - point the tech at the right thing; and the creation of standard labels for AI, similar to food standards labels.'

'Problems in managing tech can include perverse incentives, e.g., legal constructs that preclude engagement or behavioural mindset issues – '*group think'* and '*not our problem*' responses.'

'Microsoft have said healthcare businesses have demonstrated 2 years of innovation in two months due to Covid-19.'

'Innovation mostly down to technological push rather than demand or regulatory hindrance.'

Interviewees commentary on specific technologies

In conducting our interviews and assessing what was said, we found that interviewees often gravitated towards certain technologies. There is some duplication from Part 1 of the report, intended for completeness.

Quantum Technology

Council's comment

It is evident from the quotes on this topic that a consensus exists concerning the ongoing importance of quantum technology: this is a technology, or suite of related technologies, that, if nurtured appropriately, has the potential to radically transform so many activities that are vital to the UK. From quantum imaging in medicine, quantum sensing in communication technology, to quantum cryptography in information security: there appears to be a near endless stream of applications at various stages of development. Indeed, it is perhaps best to see quantum computing, as a facilitating technology that will drive revolutionary advances in any sector with a significant need for data storage or processing. In recognition of this potential, over the last ten years the UK has committed more than £1bn[4] to a coordinated programme in developing quantum technology. This enthusiasm is matched by other countries[5].

Themes that emerged from the interviews include (but are not limited to):

Timeframe for development and market applications: Quantum technology needs investment over the medium to long term to realise its potential: 'more than 10 years will be needed to get to a place where there are good commercial applications', 'The barriers to making a quantum device are pretty high. It's unlikely to quickly go to scale' and 'many other applications that we don't yet know about. It may not deliver tangible benefits now but between 10 and 30 years it could!'

Financial: The regulatory environment in this sector for quantum communications needs examining; in the context of the global financial system, for example, quantum technology will 'improve connectivity, reduce transaction costs on analysing information and therefore make things quicker, better, cheaper faster'. There is a sense of urgency here, however, and some concerns were expressed concerning a 'quantum apocalypse' that could cause catastrophic failure of the system.

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[4] https://iopscience.iop.org/article/10.1088/2058-9565/ab4346

[5] https://iopscience.iop.org/journal/2058-9565/page/Focus_on_quantum_science_and_technology_initiatives_around_the_world

Interview quotes

'Scale of computational progress QT offers is such that every area of technology that has been built in the last fifty years, is going to be changed. **Things that are too complex to model will now be modellable. QT will eliminate the hardware barriers to approaching very difficult problems. Even Digital is not as exponential as QT.'**

'We need a proper regulatory environment for quantum communications. At present, the global financial system would fall over if there were rapid breakthroughs, and the potential of quantum was realised!'

'Quantum has 'potential for serious impact, but over a longer timeframe of 5-10 years.'

'There will be a 'global quantum arms race' and we don't want the UK to be left behind.'

'Quantum technologies will facilitate things being more connected, faster, and better. It will improve connectivity, reduce transaction costs on analysing information and therefore make things quicker, better, cheaper and faster.'

'If you have a quantum layer on products/services like autonomous vehicles, drone deliveries then it will turbo charge everything else.'

'Quantum computing – UK has interesting start-up companies in this space along with strong academics – but more than 10 years will be needed to get to a place where there are good commercial applications.'

'The barriers to making a Quantum device are pretty high. It's unlikely to quickly go to scale. Once the problem is cracked though, it won't be that difficult.'

'Interestingly, it doesn't actually need a huge amount of money. The opportunity is for the UK to be at the cutting edge for QT. **We need to change our operating model. We have a lot of assets, there is a lot we can do to enable [us] to get to real applications, a series of work that allows us to tackle some of these better. These disruptive things, need something a bit different, a series of enterprises maybe?'**

'The capability QT offers in terms of sensing, measurement and many other things. A quantum sensor potentially has the ability to do quite detailed mapping of sub-surface structures.'

'The possibilities of exploiting quantum phenomena are potentially as revolutionary as solid state electronics. QTs look like solid-state electronics but they exploit effects we don't yet fully understand. **Can potentially develop untappable comms**. In sensing, we are already seeing the effects of QT + meta materials to see around corners, to make devices invisible (radar not optical so far). **Many other applications that we don't yet know about. It may not deliver tangible benefits now but between 10 and 30 years it could!'**

Data, Artificial Intelligence and Distributed Ledger Technologies

Council's comment

The responses here highlight the wide range of current and future applications of these technological sectors. They reflect both optimism regarding the power of data, AI and to a lesser extent DLTs, but also concerns regarding potential harms.

Data is seen as of value in its own right, but also increasingly as the critical foundation for data-driven technologies, notably artificial intelligence systems. There is recognition of the tension between the opportunities that arise from personal data being acquired from an ever-increasing range of devices which is set against concerns around privacy. This is particularly evident in health applications where the opportunity to improve care, is contrasted with the risk of the misuse of sensitive data.

In terms of AI, some responses point to a relative lack of regulation of AI, and that this may have facilitated the rapid innovation in this space. Others note the concerns about bias, concerns around privacy (eg facial recognition). It is evident that the risks and levels of concern varies according to the application of AI, and this is highlighted as being a challenge for regulation since this may vary significantly across areas. Highlighted applications include drug discovery, diagnosis, optimisation of systems such as logistics networks and energy production (supporting a net zero carbon approach).

There is also concern about generalised artificial intelligence, and its potential to overtake human intelligence. The replacement of human roles is reflected both positively (doing the 'dull parts of what we do'; doctors can spend more time on communication) and negatively (lack of jobs for lower skilled people).

Responses regarding DLTs noted applications in areas such as finance, data integrity, and tackling fraud, but had variable confidence in their value and uncertainty as to when this might be realised. Cryptocurrencies were highlighted as exemplifying the challenges that DLTs may bring. Whilst suggesting that the technology was still relatively immature, it was also suggested that introducing regulation early might be of value and might help ensure systems were harmonised.

In its initial tranche of priority areas, the RHC is considering medical devices, which includes an emerging number of AI applications (considered as Software as a Medical Device, SaMD). The RHC will consider current changes in the regulatory environment (such as the UK's exit from the EU, and the transition of the EU to a new regulatory framework (the 'Regulations') from the existing 'Directives' system, that has been operational in the UK. The RHC will consider a number of specific challenges in the regulation of medical devices, but also look to lessons learned from the COVID-19 pandemic, and how the UK's regulators (such as the MHRA) responded to accelerate innovations through to patients.

In the second tranche of priority areas the RHC may specifically look at AI in a particular context, to better understand any areas of risk (such as bias and exclusion), whilst also looking to create an environment that supports innovation and can unlock the potential benefits of this technology. DLT will be considered for evaluation in further tranches.

Throughout its work, the RHC will consult widely, recognising both the opportunities in this area but also the risks that the use of data, and of powerful data-driven technologies may bring. Consideration will include both the technology but also the actual application, recognising that these are wide-ranging and may have widely different risk profiles and associated concerns.

Interview quotes - data

'There is a need to store and use healthcare data – watches, healthcare records, images. This can be integrated and used for people to manage their own health. Big push to move healthcare upstream in its natural history – **paradigm for healthcare to be sustainable identifying people much earlier on that they have health issue – wellness agenda. Need to get beater at understanding how molecular pieces interact with each other – changing molecular here how does that change an outcome over there – big piece of analytical work needs to be done, we need to be able to measure it and put it in a model.'**

'Nudging, incentive tools - how do you persuade people if it is in their interest to do something they don't want to do? Might be the way in healthcare. We can then allow computers to analyse this data and find opportunities within it. **We are moving into an era where the biologist has a 'machine-led recommender system' to help them. The machine could be telling us things like 'did you know that this molecule can cure X disease'.'**

'The advances in communication technology mean we deliver services differently – in transport you see disruptors like Uber. We know more about what's happening in transport now, in the post Covid-19 environment we've collected a lot more data on how it's used. **We had to borrow that data from transport operators themselves at first but in future we will have more direct access.'**

'Concern over privacy issues and data control may have contributed to missed opportunities to help patients – during Covid-19 limitations on the use of health data were relaxed to enable rapid responses to improve health outcomes. I think we can learn lessons here to reflect ongoing risks and the cost of not sharing health data.'

Interview quotes - UK as pioneers of AI

'There is an exciting opportunity for the UK to be a pioneer for responsible AI - AI that can explain how it takes decisions and isn't a *black box.'*

'Leading in AI will allow the UK to be competitive on the global stage.'

'Competitive advantage - **UK doesn't have as much money being invested [in AI] as China and really think this is area that we want to maintain a global leadership on** – massively strategic area.'

Interview quotes - risks of AI

'The question I'd like to ask if I could see the future is what has happened with machine learning, **did we fall into the cognitive biases traps that could lead us to bad unintended consequences like discrimination and bad outcomes ie people deprived of access to mortgages etc. What can we allow machines to do without understanding why we do it – how do we protect against the worst outcomes?'**

'All the major players have pulled back from facial recognition tech until inherent bias issues are resolved.'

'There will be a substantive change in what kinds of activity people are involved in. **A substantial part of the population will find they are no longer required. Lower-tier technician jobs no longer required.'**

'Machine learning will be biggest priority in the short term as it can help us save costs in a time of financial strain and deliver better content to our audience. Rather than it taking jobs that's not what it's about – it's more transactional and dull parts of what we do that can be done via machine learning ie recruitment. There are risks but if we could apply ethically that should be manageable.'

Interview quotes - regulation and standards

'AI's ability to disrupt society will be extreme. We will need protective regulations in this area. Most countries have strong regulations on firearms. As AI becomes more

powerful we will need to think about it in a similar way, or like a virus or a bacteria that can be dangerous if it spreads in the wrong directions.'

'Regulation is going to be tricky in AI – because of its broad nature of applications you can use it for – machine learning, facial recognition technologies, there are technologies creating huge controversies around what is acceptable/not acceptable – **Office for AI, CDEI – lots of people thinking about this already.'**

'Regulation – one idea is standards labels for AI, similar to food standards labels.'

'The big fear at the moment has been from those involved with machine learning, concerned that when more regulation is brought in may be too bluntly applied.'

'AI's ability to disrupt society will be extreme. We will need protective regulations in this area. Most countries have strong regulations on firearms. As AI becomes more powerful, we will need to think about it in a similar way, or like a virus or a bacteria that can be dangerous if it spreads in the wrong directions.'

'Regulation may have got in the way of developing AI because of difficulty of accessing data.'

'The lack of regulation has so far helped AI to develop. Lots of concern about privacy today in this forum, but AI is still largely unregulated. In general, companies ask for forgiveness not permission.'

'AI requires some sort of bias testing. There tends not to be racial diversity in the leading organisations to begin with.'

Interview quotes – broad applications

'AI has huge potential in a range of industries i.e. drug discovery, optimising logistics networks, diagnosing diseases – broad applications.'

'AI can help with technologies that move us towards zero carbon emissions – electricity generation and storage but most importantly intelligent management of the energy grid.'

'Also being used to analyse sentiment on social media to e.g. identify criminal activity.'

'Alexa will now be suggesting what our shopping should be rather than noting it for us.'

Interview quotes - healthcare applications

'AI would be able to create more efficient logistics in hospitals, as well as discover new drugs, diagnose diseases.'

'**AI and autonomous systems will have a much wider role in diagnostics and diagnostic support – we will increasingly get to a point where patient data is automatically analysed via algorithms increasing efficiency and accuracy** – in this context the role of a doctor is more in communication of conditions and exploring different risk pathways for treating conditions with the patient.'

'**Immunology treatments and gene editing work have a lot of potential.** One of the benefits of machine learning is being able to deal with huge volumes of data to provide health solutions that were previously impossible for humans to manage.'

'**A lot of healthcare is information processing, if we can do this more efficiently it will provide more time for people to provide care, 'something a robot can't do'.**'

'**As soon as you have big data then you can apply AI to it.** In the medical world it helps with imaging, radiology, diagnosis and helps to improve judgements. The question is, 'what is the diagnostic test that will give you the best yield?' AI will streamline the efficiency and more cost effectiveness.'

Interview quotes - distributed ledger technologies (DLTs)

'**If not regulated now, potential that DLTs could bifurcate and split.** Means different systems won't be able to connect to each other which would be sub-optimal.'

'The key question for the future of DLTs is, **have they brought us greater safety and efficiency?**'

'**Blockchain is a no-brainer for use in entire finance system,** can eliminate large amounts of financial fraud**'**

'**Blockchain can modernise systems and keep data safe**, allowing government to save money and time e.g. electronic IDs/passports, land registries, NHS patient data.'

'Faith in blockchain/DLTs and our existing systems being safe could be disrupted completely. Some experts think it will be 20 years until these technologies have their full effect. That said, I don't think we can properly comprehend how far reaching the changes could potentially be.'

'Blockchain/DLTs has a bad reputation because of cryptocurrencies. One solution is to ban public blockchain/DLTs.'

'Need a legitimate type of blockchain/DLTs where 'data is accounted for and has an owner.'

'One use case for DLTs is that they can be used to mitigate the proliferation of counterfeit pharmaceuticals online.'

Genetic technologies

Council's comment

The responses here cover a range of issues relevant to the future capabilities of products developed using modern genetic technologies: they can contribute to sustainable, healthy future diets; to meeting the Government's Net Zero policy commitments and the UN Sustainable Development Goals; to large-scale production of chemicals using fermentation processes rather than the energy intensive processes of the petrochemicals industry; to significant reductions in the carbon footprint of agriculture and aquaculture; to diagnostic and vaccine production; and to personalised cell therapies.

The responses below also point to the failure of today's regulatory systems to be proportionate and adaptive to the benefits and risks of many of these types of products and to permit the development of those that are safe, effective and meet major societal needs. This regulatory question is most urgent for novel developments in plants, animals and some aspects of industrial biotechnology, and the RHC is focusing first on these areas.

The RHC has been considering how future regulatory systems for these technologies can be adapted to deliver safety, quality and efficacy while also meeting the needs of different types of product and different industry sectors, i.e., smarter regulation rather than less regulation.

We are also aware of the societal context for innovation in this area. It is important to take account of the full range of stakeholders and opinions so that their views can be incorporated into the design of future governance of the technologies. Among other things, we contributed suggestions to DEFRA on their genetic technologies regulation consultation. We also held a series of workshops with industry, scientists, policy makers/regulators and advocacy groups representing the interests of specific stakeholders. The responses below raise some of the complexities that we encountered: the new contributions made by genome editing technology; differences in attitudes to animal and plant applications; the European and global political context.

Health-related applications of these technologies raise different challenges and will require different solutions. For example, human genomic databases will require very different types of curation compared to plant, animal or microbial databases. Some of the regulatory systems in place will need adaptation to deliver a more supportive innovation environment and citizen engagement in the health context raises different kinds of question compared to agri-food. We will also progress consideration of these issues, but on a more extended time-scale.

Interview quotes - timing

'There's a 15% minority that are very against GM but most people do not care very much. **Policy and government actors are not sufficiently aware of this change in the public mood.'**

'Large companies in this area are thinking that it does not matter which regulatory system you use as long as it's not the same as the European system.'

'You will need crop proteins that will deliver a balanced diet if many more people become vegan/ vegetarian. [With GM Crops] **You could have a revolutionised food economy which is much less damaging to the environment.'**

'GM crops is the obvious example of where regulation has held back innovation. There's a question about what is the point of spending large amounts of tax payer's money on scientific research if this is not converted into positive change for society.'

'GM crops are part of everyday life elsewhere in the world – no evidence that any harm is caused by GMO crops – highly publicised and politicised. **GMOs can't get through the system in the EU and are always blocked. This has supressed innovation in the UK.** For example, genetically modified cereals can eliminate nitrogen fertiliser, the biggest cause of carbon emission. However because of the regulatory system this cannot be done in the UK. The Gates Foundation looking at its use in sub-Saharan Africa instead.'

'Definitely prioritise reforming regulation of gene editing to free it up. The UK would be at the forefront of this technology and attract investment as they wouldn't be able to do it in Europe. **I believe the bridge between basic research and industry which is innovation is not addressed very well.** When a new plant variety is placed on the

market anyone can take it and apply research to it – you can take those characteristics into another plant – IP doesn't then have great value.'

'Genome sequencing is an example of where regulating will be complicated – it can be done with minimal kit and almost everywhere, it doesn't need mega labs. The opportunity for development then becomes possible locally and much harder to regulate for outcomes.'

'We've already talked about using machine learning to look at our datasets and discover things that wouldn't occur to the human brain (patterns/ rules). **Similar vast datasets will arise from sequencing human and non-human genomes.'**

'The HFEA act is struggling to cope with the pace of innovation in genetics, embryology and reproductive medicine.'

'There is potential to sequence someone at birth and predict quite accurately what health issues they may face in their life – but this will require more fundamental understanding of genome sequence variation and its consequences.'

'Synthetic biology and engineering biology are creating new materials or using existing materials in novel ways. How do you regulate for the definition or classification of such materials? It really needs expertise. It's not just for policy professionals it will require experts.'

'Gene-editing – not as bullish about impacting other industries economically than medicine and agriculture. So using bugs to produce industrial chemicals hasn't been as big as expected in the 1980s, for example. Healthcare will loom large in our thoughts after the pandemic. So cancer and other cures could have very big economic impact.'

'Shocking case of killing off the industry with the EU policies on GMOs. **If we had gone down the route of encouraging this industry we would be less reliant on chemicals and have a range of other benefits.'**

Networking and Internet of Things (IOT)

Council's comment

The internet of things clearly has great potential to deliver productivity and environmental benefits. Regulation needs to ensure that innovation in technology and use cases is encouraged, but – especially given the potential use of IoT alongside humans in the workplace, and in people's homes – it will be important for regulation to ensure a degree of safety and security that fosters confidence, as this will be critical for wider take-up. Those responsible for regulation in this space will need to develop a nuanced assessment of the risk according to the use of the technology in different applications, and will need to regulate in ways that are proportionate to that risk, avoiding a 'one size fits all' regulation of the technology that would kill potentially useful, low-risk applications.

Although not explicit in the comments from the interviews, it is clear that there are linkages between IoT and platforms. Connected devices may need to 'plug in' to platforms that connect them with each other, with end-users and potentially also system-controllers. One of the comments refers to the role IoT will play in smart cities, for example, which would require some platform layer or layers to enable communication and coordination between, say, traffic lights and autonomous vehicles. This suggests that regulation will need to consider economic issues. The economics of two sided markets such as platforms has been much written about, for example in the recent report from Jason Furman and his team on regulation of digital markets and in the CMA's digital advertising study. In considering the regulation of IoT it will be important to consider not only how to enable new technologies to develop today but how to ensure today's winners do not foreclose the market from future challengers who will bring the next generation of innovation.

A final challenge that is evident from the comments is that, right now, to succeed anyone in the IoT space is likely to have to navigate multiple regulatory landscapes. The comments allude to 'factories of the future' which are subject to health and safety regulation by the Health and Safety Executive, smart cities which will bring in surface transport by local government and aviation regulation by the Civil Aviation Authority, 5G which is subject to regulation by Ofcom, smart meters which are subject to regulation by Ofgem. If we are not careful, the sheer complexity of that regulatory landscape could act to favour bigger players over potentially more innovative smaller ones.

Interview quotes

'Really interested in looking into IoT – think the UK has a massive productivity problem to solve, so we've got to do something that generates economic growth and IoT would help with this. Post Brexit - **if we want companies to create manufacturing jobs here in the UK, to have 'factories of the future' here, we need to think what is the production technique of the future? Better connections between people and productive capacity to produce things and that is IoT.'**

'Worry about IoT - will it enable people to hack into these networks i.e., my smart fridges or other devices in people's homes? **Consumer trust is a fragile thing,** so setbacks may hamper efforts to deliver benefits.'

'Going forwards I think we're going to have more data connectivity and more IOT. **IOT will evolve more within the 5G bubble – the challenge there is making sure that is a secure environment.** In 10 years' time almost all of society could rely on 5G and you are much more at risk. There's a lot to look at in cyber security around this as if hacked becomes a huge vulnerability.'

'**IOT will bring real challenges in terms of creating a system we can no longer comprehend or control. The likelihood of a failure or a malicious attempt to exploit a system. Regulation will become increasingly important.'**

'**IOT will support very many of our environmental monitoring objectives** and be used for a lot of our smart cities. **IOT is the technology that will bring about the quickest changes.** Regulation important – a lot of industrial organisations seeking to take advantage. There needs to be **some way of ensuring compatible operation. Not just standards.** Many have the potential to cause significant disruption to lives.

'On the IOT tech side, there is a real need for collaboration. **The system level integration requires deeper thinking.** Mobile phones are an IOT in some respect. **We haven't developed our thinking about where intervention for the public good is required.** A prerequisite of knowing what to do is an understanding of what such a systems would look like AND then thinking about malicious or accidental errors being introduced. A red-team exercise. We're building a machine that we won't fully understand.'

Transport and Energy

Council's comment

There are a few comments that relate to private sector vs state ownership. Part 1 also raised the issue of state-aid. There are clearly different views on whether the state should provide more or less funding. The RHC focus is on the adoption of disruptive technology. A useful question is to what extent has regulation and industry structure enabled the adoption of new technology to: 1) provide improved energy supply (according to the energy trilemma) to UK consumers; and 2) enable UK derived goods and services to compete in global markets and secure value for the UK.

In terms of generation technologies (gas, nuclear, wind, solar) and grid technology (smart grid), there may be more that the UK can do to capture supply chain value or a higher share of export markets. It would be useful to understand this better. The decarbonization of heating is an opportunity to think through regulations that improve the UK's chance of success. Hydrogen and carbon capture and storage are noted as opportunities.

The comment about ensuring a long-term market for a technology, in this case carbon capture and storage, is interesting. Doing this in a technology neutral way is also important. Certainty of large and long terms market could prove a powerful incentive to technology development. To some extent this is already done in various countries via feed-in tariffs, contracts for difference etc to build nuclear, wind, and solar plants. Hinkley in the UK is such an example.

Technical standards and definitions are important in facilitating take-up of green transport. Achieving a common understanding of what is green and common standards for interoperability is important.

Strong central co-coordinating and driving action is needed and the Centre for Connected and Autonomous Vehicles is an example of this happening in a sector. Working across stakeholders and internationally to set standards and move the industry forwards. It is worth considering if this approach is something that would help with other technologies and transport sectors?

Interview Quotes - Timing

'There are clear lessons from the energy reform of the 1980s. Then, we moved away from an unreliable and expensive state-directed energy system to a vastly improved market based system (under the Lawson reforms). Unfortunately, we've now reversed that.'

'Gorbachev noted when touring London that there were no queues and asked who planned it. The answer was that we don't plan it, we just have price signals. If you can't centrally plan a bread distribution system in the USSR, then how can you centrally plan an energy network? **We trust the private sector with food and petrol, so why can we not with energy.'**

'The role of hydrogen in transport will increase a lot, the key question will be how can we supply large quantities of green hydrogen through electrolysis, small modular reactors or carbon capture. **Getting hydrogen right is the key to the future – if we can develop it effectively,** I think you'll see a real move towards decarbonisation in heavy industries and how we use energy in the home.'

'I worry we have turned energy into wholly a client for government rather than using trial and error to see what works best. Subsidies for existing tech means we are disguising what the best new tech is.'

'**Subsidising wind power doesn't find out what's best** – isn't so much of a success story, not coming down as quickly in price. **I'm very critical as too expensive, causes too many problems (e.g.**, **kills wildlife), not reliable enough and doesn't last very long.**'

'**With the iPhone the integration of innovations suddenly compounded and changed the world. This type of compounding could happen in the energy sector when different innovations come together.**'

'**Nuclear power – lack of advance since 70s due to over-regulation making innovation impossible.** Not set up to embrace new tech – licensing too difficult and expensive. Similarly both fracking and GMOs didn't happen in Europe because regulation took too long (even if it didn't say no).'

'**Carbon-capture and storage is an exciting potential opportunity for the UK.** Best place is North Sea, but government will use pilot projects rather than saying we don't care how when or where you do it, but we want all CO_2 emitting businesses to put a portion of their emissions in carbon capture and then ratchet up percentages each year: i.e. create market discovery process.'

'**Transport is a big player for getting hydrogen technology right - often this is where people want to start applying the technology.** There are key regulatory issues holding up the development of the industry. Firstly, the definition of what is green hydrogen is an immediate issue – from a perception point of view this is important. Storage pressures for hydrogen are another area – we need to adjust this as it's based on hydrogen stored in cars many years ago and modern buses and trains can store it at a lower BAR measurement. **These kind of issues need a regulatory push to point the industry in the right direction.**'

'**Automation of vehicles is a priority** – a unit called CCAV was set up for this purpose. BEIS is looking at the industrial opportunity and DfT is looking at how to make it work on the roads. **There is a lot of regulation around this area i.e. how you build the curvature of roads, safety and insurance issues. The UK has been at the forefront of developing standards and regulation internationally here but there are still a lot of unanswered questions that need further work and to deconstruct the barriers to innovation. The UK still has the opportunity to be a leader here where companies want to inward invest and locate their tech innovations.**'

'**The real challenge with decarbonisation for transport is long distance aviation** – a moonshot project on a large aircraft that can travel on synthetic fuels or hydrogen could solve a massive problem that is the elephant in the room. I**t would be a big challenge and require a lot of investment but I think we have lots of skills to deliver that in the UK.**'

'**There is an opportunity to explore high speed underground travel but the technical challenges are massive. There is a massive amount of regulation here because the scale of what can go wrong.**'

Other quotes

Council's comment

Two of the quotes remind us of the importance of humility about forecasting technology and innovation. Although a lot of innovation looks obvious in retrospect, it is often not predicted. The emergence of the search engine in the early 1990s was inevitable, whether Google was founded or not, and so probably was it becoming the main means of monetising the internet. But almost nobody foresaw its importance. Some very clever people said some very inaccurate things about the future of technology, as the quotes from Ken Olsen and Ernest Rutherford remind us. Two quotes that demonstrate this ae: 1) the Nobel-prize-winning economist Paul Krugman's remark in 1998 that "By 2005 or so, it will become clear that the Internet's impact on the economy will have been no greater than the fax machine's" and 2) Microsoft's CEO Steve Ballmer's remark in 2007 that "There's no chance the iPhone is going to get significant market share. No chance." Forecasting the future of complex non-linear systems is all but impossible, and the RHC should be careful not to fall into the trap of thinking we can solve that problem. We should always consider multiple alternative scenarios.

Vertical farming is an important trend we should be acutely aware of. Cheap, efficient LED lighting has made all the difference to growing food indoors. Lettuce factories already produce tens of thousands of lettuces per day each in Japan and have several major benefits: no need for pesticides because the space is biosecure; far less water used; closer to market; recycled nutrients; massive land sparing (roughly 1:300). In theory, the world could already be fed from an indoor farm the size of Wales – though for many crops this dream is still a long way off. However, this is a relatively "permissionless technology" that will not encounter special regulation, so may not attract the attention of the Council.

Digital identity is another area bound to require attention in the coming years. Securing your data and privacy online is an increasing concern for many people. This is a rapidly evolving area, as the issue progresses from computer viruses 20 years ago to phishing ten years ago to deep fakes today. It is effectively an arms race between criminals and a well-motivated IT and financial services industry.

Automation's threat to employment has generally been exaggerated. The serious worries of the 1960s that computers in factories would lead to mass unemployment echoed similar concerns going back to the Luddites and has been echoed since in debates on artificial intelligence. There are good reasons to think that automation augments rather than replaces human action so technology does not cause unemployment in the long term and AI will be no different. Nonetheless, in practice work has indeed been evolving to allow shorter working weeks, longer education, longer retirement and even more time for social media and retail therapy while at work. A person who lives to the age of 80 and works a 40-hour week from the age of 25 to 65 with normal holidays, lunch breaks and so on, will spend less than 10% of their life at work .

The measurement of CO2 in the atmosphere is efficiently and easily done these days, following Ralph Keeling's pioneering work in Hawaii. Stations all over the world record CO2 levels, showing significant seasonal rises and falls, steady year on year increases in the peaks and troughs, but also increases in the amplitude of the seasonal changes – the latter indicating a global greening trend that has been widely analysed.

Innovation should be distinguished from invention. Repeatedly throughout history, the process of coming up with a novel device has been distinct from the process of making a new device affordable, available and reliable. The latter is indeed a hard slog, less glamorous but in the end often more important. Britain has been especially marked by a better record at discovery and invention than at application and innovation. Our policies should be aimed at remedying the lack of Jeff Bezoses, rather than (or as well as) creating even more Francis Cricks.

The advance of cashless society has been dramatically accelerated by the pandemic. This is a key area for the UK to address, and for all its ramifications, including the use of cryptocurrencies, to be considered. The RHC may well have a role to play.

Interview quotes

'Many famous people have got technological innovations completely wrong. For example, Rutherford (founder of Nuclear Physics) said he was excited about having done some pure science that could not have any military, economic or political application. Of course, a nuclear bomb was used in Japan not that many years after he said this.'

'For agriculture, there are new types of farming, vertical types of farming, very different to conventional, growing produce in climate controlled laboratory environment, set up in urban areas, several in London supplying restaurant and supermarkets – much more efficient than traditional farming, use less water, strict rules on who can go in and out, pests outbreak, sunlight, humidity, temperature all very controlled. Food miles from where food is grown to table will become dramatically decreased. Lab grown meat potentially seen as well. Vertical farming in UK – we have infrastructure to support it and a lot R&D and science is going into it.'

'There is a need for greater innovation around digital identity - a lot of things will come out of that. There's a need to securely authenticate your identity digitally, perhaps government backed. There are a bunch of folks that are working on products to verify your identity using your smartphone – could use this to access products, check into flights, participate in sharing economy, access to digital healthcare serve, make a payment – lots of different applications that feels like something that the UK could be an early leader in as it links closely to payments technology. The UK has been world leader in contactless payments, digital health lots of start-ups in the UK and Covid has really accelerated this, GP consultations over the internet.'

'Automation of tasks is the biggest issue, going to have a huge impact on people doing those administrative tasks – things that turn out to be replaceable. A lot of people have talked about a 'workless society' We need to prepare for it.'

'I would prioritise the **ability to measure and track CO_2 to help deal with the climate emergency.** Would be keen on viewing from space, getting the instruments up to measure the health of the planet. Long lead time. Requires a lot to build and get it up there.'

'There's a distinction between innovation and invention. Likewise between the prototype and the hard slog to turn a new technology into an affordable and available product to everyone. UK is better at invention, not great at innovation. Need to encourage this. It's more about markets and customers are king. We need more Dysons.'

'I expect we'll see an acceleration of a move towards a cashless society. A lot of places saying we'll only take digital. The current financial system is derived from the existing banking structure - I can see that falling apart. It is possible to go totally digital. The implications enable the removal of infrastructure to move cash around. It changes retail banking. It alters the dynamics of crime. You can't necessarily steal people's money. This will change policing of crime. How do we regulate a system with your phone in the middle? We already have data protection. I think we'll need another layer around the financial data.'

'Predicting the future in complex systems is impossible. Experts are slightly worse than lay people in fact. Ken Olsen – builder of mini-computer - said in 1977 that no reason why anyone would want a computer in their own home.'

Annex A - questions about the future

We asked respondents what they wanted to know about the future. Here their responses are organised into the PESTEL framework.

Political

- How does the government track progress – is it still economic indicators like Gross Domestic Product?
- How have we managed our relationships with rival powers?
- What will the government be expected to deliver in terms of services?
- How did governments evolve – did the world become more autocratic? Is government using tech in 'sinister' ways e.g facial recognition, data mining, hacking?
- How did we know what to work on? Was it just organic and you just let people innovate and things just pop out, or was there a concerted approach driven by certain actors (e.g. government)?

Economic

- What is the future of work?
- Are we working more, less or at all?
- What are our working patterns?
- Where are we working?
- How is work and income distributed across society?
- Does capitalism exist in its current form?
- Is the world still governed by money and capital?
- How has globalisation changed?
- Are there different economic models around the world?
- How do we learn to use new tools quickly when they are deployed and scaled so quickly?
- Is there a universal basic income?
- What has happened to house prices and office buildings?

Social

- How open is our society?
- How are national security considerations handled with regard to technology and investment?
- What is the future of family life?
- What is the future of cities?
- How do people get their news?
- How do people access education?
- Do our relationships survive?

- Has the primacy of human face-to-face contact survived?
- Have we prevented the surveillance culture taking over?
- How do we protect the vulnerable?

Technological

- Where has technological transformation occurred?
- Where were we being naïve and should have intervened earlier and more forcefully?
- Has technology enhanced safety, health, efficiency, happiness?
- Has future technology improved people's lives, liberties and our democracy?
- Are humans flouring alongside technology? Has Tech improved a small number of people's lives or allowed a greater number of people to live more fulfilled lives?
- What has happened with machine learning, did we fall into the cognitive biases traps that could lead us to bad unintended consequences like discrimination?
- What have we allowed machines to do without understanding how or why they do it – how do we protect against the worst outcomes?
- What's the most important technological innovation and who 'owns' it?

Technology specific questions

- Has holovision (3D data interfaces) become a reality?
- Do people have direct interfaces with computers using just their thoughts?
- How have bionic eyes progressed?
- Are driverless cars standard?
- What advances have there been in battery technology?
- What happens to genome editing?

Environmental

- Has net-zero been met?
- What contributions have life-sciences made to fighting climate change?
- Has biodiversity improved?
- Which technologies are most important to the climate emergency?

Legal

- What protections are there for the vulnerable?
- How has new technology been regulated?
- What ways have we found to quickly introduce new innovation?

Annex B - the 7Qs in full

1. **Looking back**
   Which technological innovations do you think have had the most impact on UK over the past 20 years?

   Prompts
   [Impacts can be positive or negative].
   What about in <u>your sector</u>?
   <u>Why</u> do you think the innovations you have identified have had an impact?
   What about impacts on <u>society</u>, the <u>environment</u>, and the <u>economy</u>?

2. **Looking back**
   Thinking about what you have just said, what has shaped the development of those innovations over the past 20 years?

   Prompts
   What about <u>regulation</u>?
   Do you see these changes <u>continuing</u>?

3. **Looking forward**
   You are sat in a room with an oracle who can see 10 years into the future. What question(s) would you ask about how technological innovations have affected how we live and work?

   Prompts
   And <u>why</u> these questions?

4. **Looking forward**
   Over the next 10 years which innovations do you think will have the biggest impacts on the UK?

   Possible prompts
   [Impacts can be positive or negative].
   And <u>why</u>?
   What about impacts on <u>society</u>, the <u>environment</u>, and the <u>economy</u>?
   What about innovations in <u>your sector</u>?
   Which innovations do you think will be <u>accelerated or altered by Covid-19</u>? And why?

5. **Short-term priorities**
   Which of these innovations would you prioritise now and why? This could be due to the potential benefits for the UK economy, society, and/or the environment.

   Prompts
   How do you think the <u>regulatory environment might be important for maximising any benefits</u>?

Imagine you are <u>free of institutional constraints</u>, what actions need to be taken <u>now</u> to ensure that this innovation/technology is brought to market in a rapid and safe way?
[Actions can be both regulatory and/or non-regulatory].

6. **What if it all goes wrong**
   If we do not have effective regulation of your chosen innovations/technologies what would be your biggest concerns and why? What might you see go wrong?

   Possible prompts
   What about impacts on <u>society</u>, the <u>environment</u>, and the <u>economy</u>?

7. **Epitaph**
   If we were to give you limitless money and power to develop an emerging innovation which one would you choose, why and how would you do it?

   Prompts
   <u>How</u> would you regulate it?

Annex C - 7Qs wordclouds

The following wordclouds were generated from the collated responses to our seven questions interviews. They help to visualise some of the common themes that emerged.

Q1: Which technological innovations do you think have had the most impact on UK over the past 20 years?

Q2: Thinking about what you have just said, what has shaped the development of those innovations over the past 20 years?
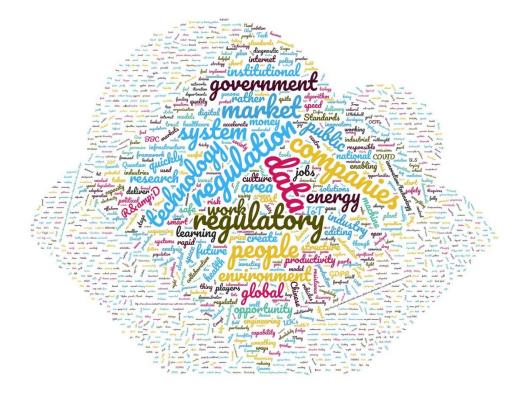

Q3) You are sat in a room with an oracle who can see 10 years into the future. What question(s) would you ask about how technological innovations have affected how we live and work?
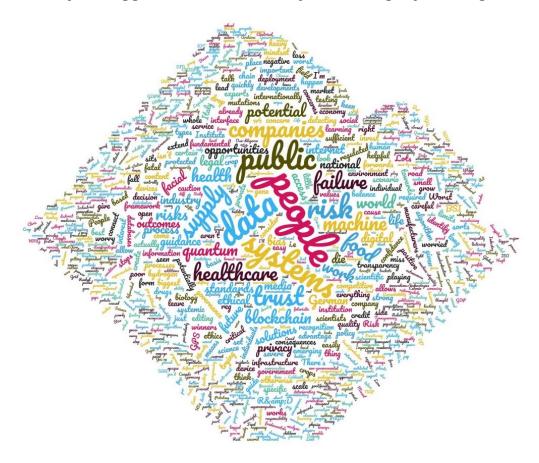
Q4) Over the next 10 years which innovations do you think will have the biggest impacts on the UK?

Q5) Which of these innovations would you prioritise now and why? This could be due to the potential benefits for the UK economy, society, and/or the environment.

Q6) If we do not have effective regulation of your chosen innovations/technologies what would be your biggest concerns and why? What might you see go wrong?

Q7) If we were to give you limitless money and power to develop an emerging innovation which one would you choose, why and how would you do it?

Annex D – list of contributors

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