Part of the conference series
Breakthrough science and technologies
Transforming our future

Digital technology and the planet: towards net zero

Held on 10 – 11 December 2020

Conference report

THE ROYAL SOCIETY

Introduction

On 10 – 11 December 2020, the Royal Society held an online international conference. This explored how digital technologies can be harnessed to reduce carbon emissions towards Net Zero – from computer hardware to digital twins that create a 'control loop' for the entire planet.

Bringing together leading experts from industry, academia, policymaking and the wider scientific community, the event followed the launch of the Royal Society's *Digital technology and the planet* policy report on 3 December.

The programme was shaped by Dame Julia Slingo DBE FRS (Natural Environment Research Council, former Met Office), Professor Andy Hopper CBE FREng FRS (University of Cambridge), and Alex van Someren (Amadeus Capital Partners). The first day focused on two broad themes: the underlying data and technology for climate change mitigation; and the economic and policy incentives to ensure a 'good deal for nature' in a data-enabled Net Zero economy and society. The second day explored the vision for future cities, while the positioning of the UK, challenges for industry and post-COVID recovery were discussed by a panel.

This conference is part of a series organised by the Royal Society entitled Breakthrough science and technologies: transforming our future, which addresses the major scientific and technical challenges of the next decade. Each conference covers key issues including the current state of the UK industry sector, the future direction of research and the wider social and economic implications.

The conference series is organised through the Royal Society's Science and Industry programme which demonstrates the Society's commitment to integrate science and industry across its activities, promote science and its value, build relationships and foster translation.

This report is not a verbatim record, but a summary of the discussions that took place during the day and the key points raised. Comments and recommendations reflect the views and opinions of the speakers and not necessarily those of the Royal Society.

Executive summary

Observations have shown a 50% increase in atmospheric CO_2 since 1850. This, and increases in other greenhouse gases such as nitrous oxide, has led to a global average surface temperature rise of 1°C above pre-industrial levels. If emissions continue to increase at their present rate, temperatures could rise by more than 4°C by 2100. However, limiting global warming to 1.5°C may still be feasible. To achieve a 1.5°C target, the net emissions of long-lived greenhouse gases, principally CO_2, would have to reach 'Net Zero' level by around 2050.

Tackling climate change and achieving the UK's commitment to Net Zero emissions by 2050 will require transformative changes across the economy and society. Digital technology can be an enabler of this change. Conference speakers explored a range of digital technologies showing genuine promise towards net zero carbon emissions.

Key themes:

1. **Green computing**
   Computing must be energy proportionate and ideally should be used in conjunction with use of renewable energy sources.
2. **Computing for green**
   Opportunities are emerging for the use of computing tools such as digital twins to determine the lowest carbon real-world scenarios, combining environmental, social and economic factors in a system of systems.
3. **Trust for green**
   The above themes should be combined with public inspection of the core building blocks of digital technology, in a public forum, to build trust in the system.
4. **Innovation**
   Solving the climate problem will require widespread implementation of both innovative and existing technologies. Rapid innovation around one central problem, as seen during the COVID-19 pandemic, will help develop the solutions needed.

"Digital technologies offer a glittering prize of nearly a third of the 50% carbon emissions reductions the UK needs in the next ten years to reach Net Zero."

Professor Andy Hopper CBE FREng FRS, Treasurer and Vice President, Royal Society and Professor of Computer Technology, University of Cambridge

"Most of us will live in cities in the coming decades, and in the race to Net Zero we must also be in a race to sustain the biodiversity and natural ecosystems on which we depend."

Dame Julia Slingo DBE FRS, Natural Environment Research Council, former Met Office

"There must be a change of mission statement in the Energy sector, from the goal of being the lowest cost option to the goal of being the lowest emissions option."

Alex van Someren, Managing Partner, Amadeus Capital Partners

KEYNOTE

The state of the planet: a blueprint for a green future

Dr Emily Shuckburgh OBE, Director of Cambridge Zero and Reader in Environmental Data Science at the Department of Computer Science and Technology, University of Cambridge, outlined the climate issue and potential solutions – from new policies to emerging technologies – and Cambridge Zero's report 'Green Recovery: A Blueprint for a Green Future'[1].

> "The UK's territorial greenhouse gas emissions for the energy sector are decreasing as we reduce coal use and increase energy efficiency, but emissions are roughly constant for other sectors. Digital technologies will help build efficiency of these systems – from transport to buildings."
>
> Dr Emily Shuckburgh OBE, Cambridge Zero and Department of Computer Science and Technology, University of Cambridge

Recovery from the COVID-19 pandemic offers the opportunity to build both more resilient economies and societies. The following leading threats currently face our planet:

- Social inequality, where the richest 1% of the population (around 78 million people) have twice the wealth of 6.9 billion people.
- Biodiversity loss, with one million species at risk of extinction.
- Climate change, including repeated episodes of extreme weather.

Digital technologies offer a solution to these threats via two routes: assessing and monitoring risks and contributing to sustainable solutions.

Assessment and monitoring

Vast datasets from observation, simulation and crowd-sourced data offer the opportunity to better understand and track the environment. Satellite monitoring, including from the European Space Agency and private companies, provides tens of terabytes of data per day from space. Meanwhile, 4000 ocean floats provide data from the sea's surface to up to 6 km depth. Combining datasets enables understanding of risk, applying machine learning to combine climate simulations with historic observations to understand the likelihood of disruptive weather events.

Sustainable solutions

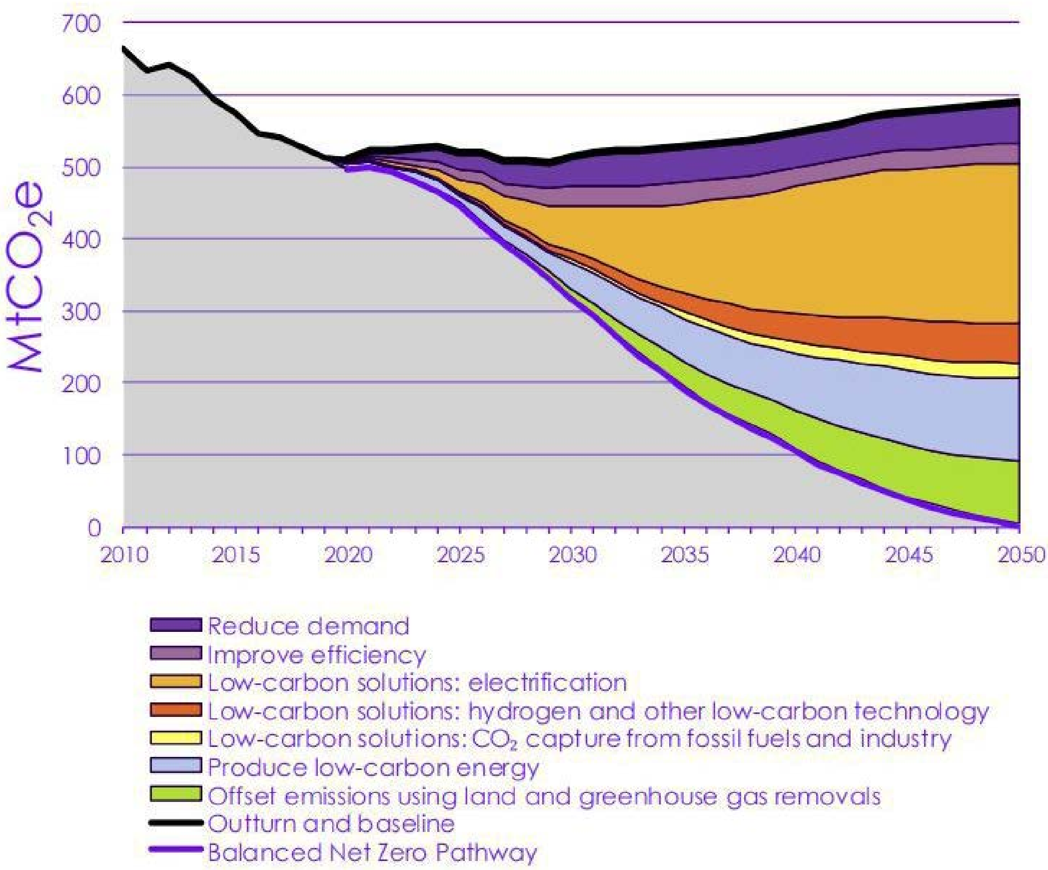
Although carbon emissions dropped around 7% in 2020 compared to 2019 due to global lockdowns, this scale of decrease is needed year-on-year for the next decade to maintain the target emissions pathway. The UK's territorial greenhouse gas emissions have decreased in the last decade due to reduced coal consumption and increased energy efficiency of technology. However, emissions for other sectors – transport, industry and construction – remain broadly constant. Digital technologies can build efficiency in these systems, while democratising progress to Net Zero 2050 in a just and fair transition.

There are substantial opportunities across sectors for digital technologies to reduce greenhouse gas emissions. For example, digital twins can find ways to build energy efficiencies in the real world. Meanwhile, Cambridge University researchers are seeking to produce synthetic fuels through artificial photosynthesis. In transport, digital technologies could facilitate transformation into a service-for-mobility business model, while Net Zero aviation is exploring sustainable fuels and electrification of aviation. Precision farming in agriculture could be enabled by digital technologies, using less fertiliser to farm more efficiently. Waste reduction could be facilitated by building a more circular economy, for example to simulate when a battery will come to the end of its useful life in order to reuse rare elements such as Lithium and Cobalt. Finally, more efficient running of buildings using digital technologies and development of alternative construction materials to cement and steel would reduce carbon emissions.

1 Green recovery: a blueprint for a green future. See https://www.zero.cam.ac.uk/green-recovery-report (accessed 13/1/21)

FIGURE 1

Illustration of the reduction of effective CO_2 emissions brought about by implementing different approaches to reach Net Zero by 2050 – many of which can be supported by use of digital technologies.



Credit: Climate Change Committee, The Sixth Carbon Budget: The UK's path to Net Zero (2020).

Green recovery: a blueprint for a green future

This recent report by Cambridge Zero looks at the technological structures to accelerate progress towards Net Zero, as well as the wider context to transform the economy and society towards a greener future. This includes ensuring that technological solutions are rolled out equally across society.

A cross-governmental task force could address how technologies can approach Net Zero, along with a Net Zero delivery board that convenes government, the private sector, NGOs and civil society. Nature-based solutions, such as afforestation and restoring peatlands will additionally help to restore biodiversity and mitigate climate change. As the UK hosts COP26[2] in 2021, much will ride on the scale of ambition developed internationally ahead of this event. The conference offers a reset moment in the wake of the pandemic in order to develop a more sustainable world.

2 The 26th United Nations Climate Change Conference of the Parties.

KEYNOTE

The UK and global climate ambition

Professor Jim Skea CBE, Professor of Sustainable Energy at Imperial College London and Co-Chair of IPCC[3] Working Group III, outlined recent work of the IPCC, the recent work of the UK Committee on Climate Change, as well as how digitalisation may fit into the UK policy agenda.

> "IPCC reports have so far not picked up on digitalisation: the sixth assessment in 2021 will do so."
>
> Professor Jim Skea CBE, Imperial College London and Co-chair IPCC Working Group III

Recent reports from the IPCC have demonstrated that "rapid, far-reaching and unprecedented changes" would be required across all sectors to limit global warming to 1.5°C. This would require measures that go beyond traditional policy instruments. Digitalisation would play an intrinsic part in these transformations.

International context

The IPCC Special Report on Global Warming of 1.5°C (2018) identified around 100 published emissions pathways compatible with limiting warming to 1.5°C. CO_2 emissions would need to fall by 45% globally by 2030 compared to 2020. The Framework Convention on Climate Change and the UK's Net Zero target meanwhile refer to total greenhouse gas emissions. Net Zero CO_2 would need to be reached several years before Net Zero total greenhouse gas emissions.

The IPCC Special Report showed that limiting global warming to 1.5°C could be achieved by either early emission reductions, or by the large scale use of carbon dioxide removal (CDR) methods later in the 21st century. The latter could include afforestation and the use of bioenergy with carbon capture and storage (BECCS) (figure 2). CDR which involves large scale land use changes could have negative implications for food security and biodiversity.

The rapid, far-reaching changes in all systems would include:

- Scaling up annual investment in low carbon energy and energy efficiency by a factor of five by 2050 – and reductions in fossil fuel investments.
- Renewables supplying 70-85% of electricity in 2050, with coal use for electricity generation being essentially eliminated.
- Deep emissions cuts in transport and buildings and changes in land use and urban planning.

To date, IPCC reports have not discussed digitalisation, but the IPCC Working Group III report (scheduled for 2022) will do so in the context of a chapter on innovation and technology transfer. Digitalisation is a sweeping trend relevant for climate change mitigation across a wide range of sectors and systems.

The UK

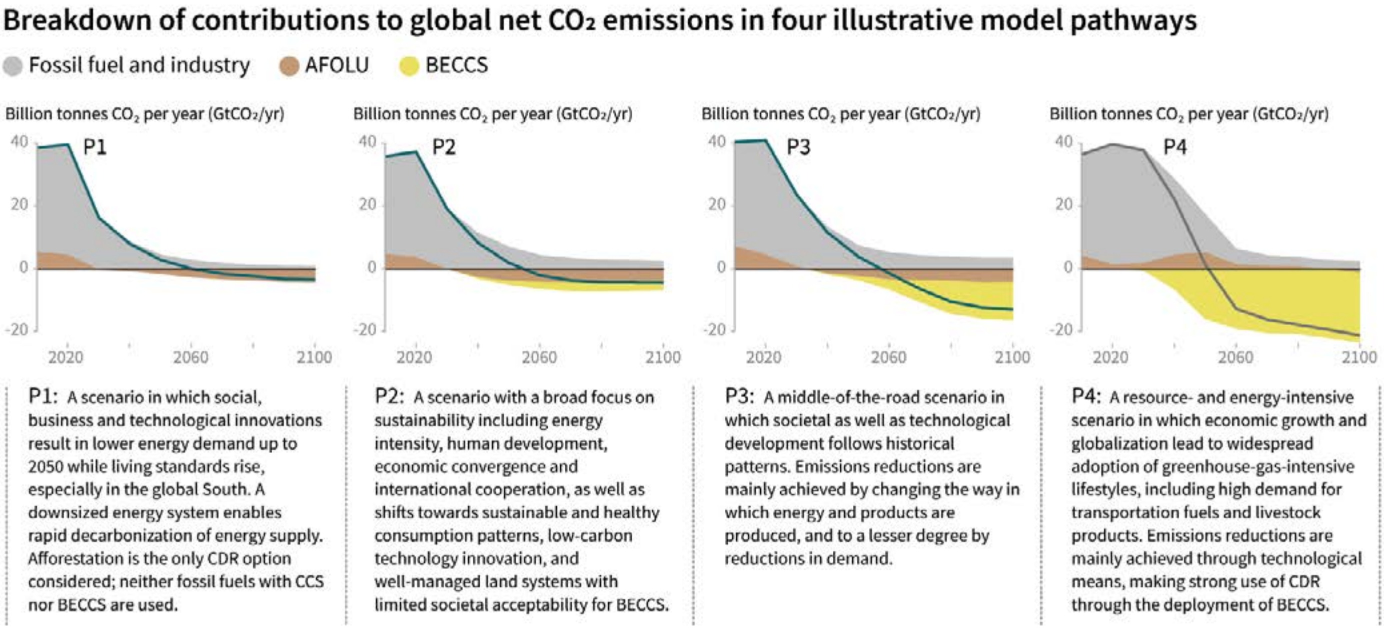
The UK's 10 point-plan, with its focus on greener buildings, offshore wind, and the transport sector, could bolster the climate leadership needed towards COP26. Meanwhile the UK's Climate Change Act provides a robust framework towards Net Zero 2050. The Climate Change Committee's (CCC) Sixth Carbon Budget[4], supports this ambition. Since 2008, all CCC Carbon Budgets have been legislated for and adhered to. The Budget recommends an emissions pathway requiring a 78% reduction in the UK's 1990 territorial emissions in the period 2033-2037 - effectively bringing the previous 80% target forward by 15 years. Electrification and system integration across demand and supply form a key part of this ambition, representing a large convergence with the digital economy. Digital technologies are needed to integrate all energy sources, balance supply and demand and reduce the cost of doing so.

3 The Intergovernmental Panel on Climate Change is the United Nations body for assessing the science related to climate change. Source: www.ipcc.ch (accessed 12/4/21).

4 https://www.theccc.org.uk/publication/sixth-carbon-budget/ (accessed 13/01/21)

FIGURE 2

Characteristics of four illustrative model pathways compatible with 1.5°C warming. While the pathways are very different in terms of action, the timing of Net Zero is relatively insensitive. Pathway 1 shows rapid decarbonisation of industries from 2020, requiring a 7% reduction in emissions year-on-year until 2050. In Pathway 4, substantial action is delayed until 2030, at which point CO_2 is captured with technologies such as BECCS or via increased afforestation (Agriculture, Forestry and Other Land Use, AFOLU).



Credit: IPCC Special Report on Global Warming of 1.5°C (2018).

Data and technology for climate change mitigation

Monitoring, simulation and prediction of climate change and progress to Net Zero

Nick Rayner, Head of Climate Monitoring, and Nic Bellingham, Supercomputing Technology Lead, UK Met Office discussed the Met Office's work on monitoring, simulation and prediction of climate change.

The UK is a leader in climate and environmental science and high performance computing. For over 30 years the Met Office has been monitoring, simulating and predicting the climate system. Over time, the needs for information about climate variability and change have diversified and become more local helping to inform practical decision making. Simultaneously, the explosion of data from observation sources such as satellites, together with increases in model resolution and complexity, have challenged traditional approaches.

Data storage and sharing

The UK has outgrown its data centres: the Met Office receives over 200 billion observations per day, crucial to the quality of Weather and Climate models. Current systems for receiving and processing these observations are reaching their capacity limits, so cloud-hosted solutions are being introduced to process land observations, storing 10TB of data per day.

Data is of greatest value when used in combination with other datasets, but giving others access to data in a useful way remains a major challenge. The Open Geospatial Consortium (OGC) seeks to make data easier to find, accessible, interoperable and reusable. Met Office experts have worked with the OGC to develop and agree an Environmental Data Retrieval application programming interface (API) - a new international standard to make it simpler for non-experts to identify environmental data within 'big data' stores and retrieve subsets.

Sustainable simulation

Previously, modellers could rely on computer chips becoming ever more powerful to handle increasingly high-resolution models (figure 3). Greater model resolution and the need to represent more detailed processes necessitates larger supercomputers. The Met Office's High Performance Computing (HPC) facilities enable the UK to take a world-leading position in weather, climate and environmental science.

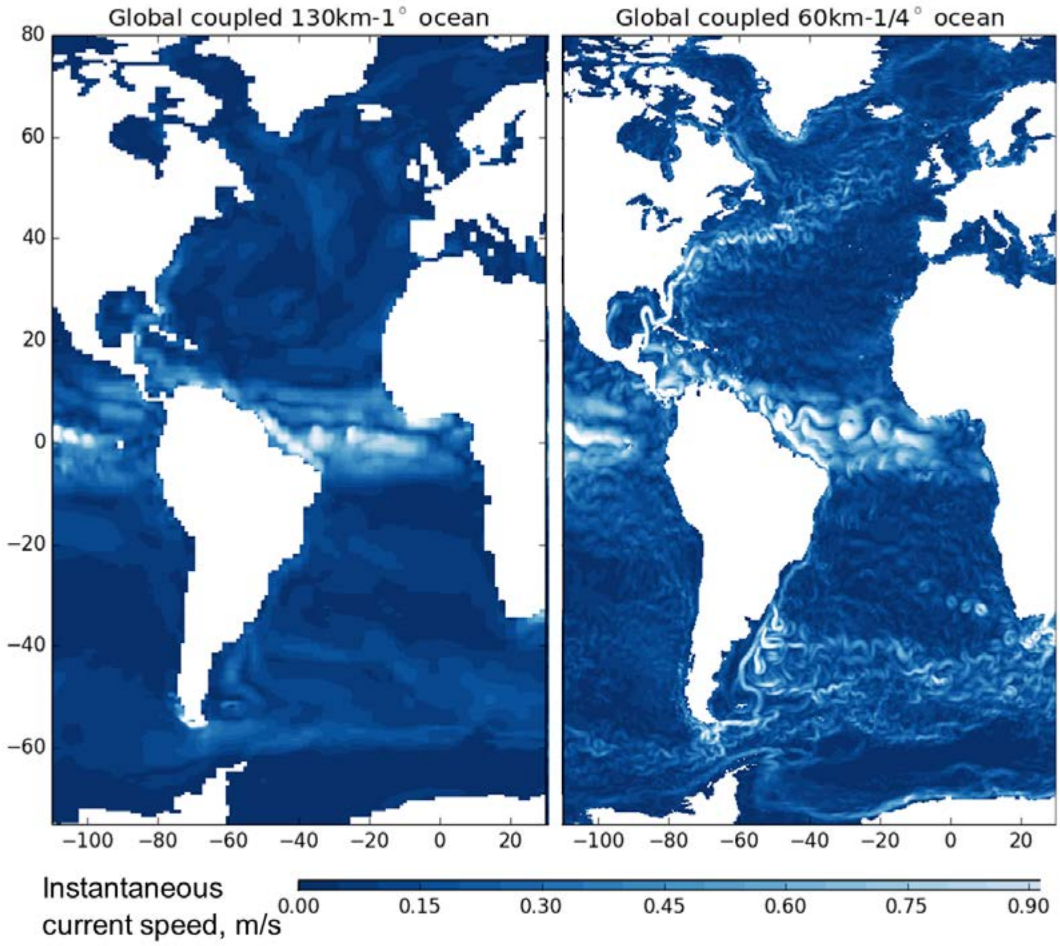
There is a need to simulate the climate system and to increase resolution and complexity while striving for sustainability. This will require improvements in the efficiency of the underlying technology. Steps are being taken to reduce the machines' energy consumption and maximise efficiency by using DC rather than AC power, free air cooling, and solar panels on data centre rooves. However, supercomputers are currently the Met Office's most significant source of emissions. A new supercomputer will offer six times the current compute capability by 2023. Improvements in power efficiency mean that it will only use a little over twice as much power, and techniques such as the embedding of machine learning into our models may deliver equivalent results with less computation power.

> "Our current supercomputer performs over 12,500 trillion arithmetic operations per second – that's more than 1.6 million calculations per second for every man, woman and child on the planet. And it does this 24 hours a day, 365 days of the year."
>
> Nic Bellingham, Supercomputing Technology Lead, UK Met Office

> "Our latest set of climate projections for the UK have been run at the resolution of a typical weather forecast model. This allows us to better represent future extreme events such as the frequency of hot spells, which directly affect people's health and ability to grow crops."
>
> Nick Rayner, Head of Climate Monitoring, UK Met Office

FIGURE 3

The improvement in the simulation of the ocean from using a model grid spacing that is a quarter of a degree in latitude and longitude, rather than one degree produces much more realistic representation of ocean currents and eddies (right). This allows better simulation of how heat is distributed around the ocean, exchange of energy and gases between the ocean and the atmosphere, and therefore the way that carbon is taken up by the ocean.



Credit: Malcolm Roberts, Met Office (after Coward).

What role for digital twins in Net Zero?

Professor Paul Monks, Chief Scientific Officer, Department for Business, Energy and Industrial Strategy, gave an overview of BEIS' outlook on Net Zero. Digital twins – detailed computer simulations twinned with real-life examples – will be essential on the path to Net Zero to better understand the 'system of systems' that forms the economic, social and natural environment.

"Digital has a key role in managing our built environment as both a key enabler and as a key tool to manage the Net Zero transition. Merging physical and digital is critical to delivery of Net Zero, and if a week goes by when somebody doesn't mention the word 'digital twin' then you probably haven't won."

Professor Paul Monks, Chief Scientific Officer, Department for Business, Energy and Industrial Strategy

Digital twins for the built environment

The built environment is responsible for 25% of the UK's greenhouse gas emissions and 40% of UK energy demand. An estimated ~£100 billion of investment in buildings is required in the next decade to decarbonise the sector by 2050.

Digital twins can play a role to deliver dynamic 3D models that reflect real-time performance while delivering energy resilience, cost savings, and decarbonisation of buildings, communities and cities. They are defined as:

- Representing assets in the physical world with a digital model;
- Looking and feeling like the real environment;
- Simulating models forward with varying degrees of fidelity;
- Connecting with relevant time data to ensure the model mirrors reality; and
- Are not just data models, but must include relational interaction.

Digital twins will also enable trialling of sustainable materials and technologies *in silico.* As use of digital twins expands, this will facilitate modelling of a complex 'system of systems', integrating economic, social and natural factors to enable smart cities that are data-driven, sustainable, resilient and prosperous. Effective use of digital twins will require structured, sharable data for decision making. Data for the public good[5][1] recommended creation of the following:

1. A National Digital Twin: an ecosystem of connected digital twins to enable better outcomes from our built environment.
2. An Information Management Framework: to enable secure resilient data sharing and effective information management.
3. A Digital Framework Task Group: to provide coordination and alignment among key players.

Digital twins for circular economy

Digital twins can facilitate the circular economy - an industrial system that is restorative by design. Circular use of batteries will be increasingly important as economies move towards electrification. Digital twinning of batteries will help monitor them as they reach the end of their useful life, to track and reuse rare materials. Meanwhile, a collaboration between EPSRC and the Ellen MacArthur Foundation explored how the circular economy could create an industrial economy that is sustainable by design. Moving forwards, we will seek to embed circular material flows in progress towards Net Zero.

5 National Infrastructure Commission, 2017.

Zero and everyone: insights from lowRISC's business model for logical infrastructure

Dr Gavin Ferris, Co-Founder and CEO of the UK non-profit lowRISC CIC, described the challenge and benefits of making open source silicon a reality and how lowRISC's business model could have a direct relationship to Net Zero digitalisation.

> "Governments can leverage non-profit CICs (such as lowRISC) to efficiently deliver digital solutions for Net Zero, and by so doing create not only ecological benefits for the planet, but also economic and developmental benefits for participating commercial companies, universities and, through the facilitation of start-ups, the economy at large — truly a scenario in which everyone wins."
>
> Dr Gavin Ferris, Co-Founder and CEO, lowRISC CIC

Advanced digital technologies are central to many proposed solutions for adverse climate change. However, these kinds of systems are highly complex, inherently requiring challenging levels of cooperation across multiple sectors and jurisdictions during build-out. While innovation has a part to play here, a more important element is the widespread, low-cost availability of foundational intellectual property (IP): the hardware, software and data building blocks that can typically form over 90% of a typical design.

This leaves a question of how best to create and support such a 'digital commons' of permissively licensed IP, to avoid both the opportunity costs of reinvention, and the financial and frictional costs of commercial licensing.

The answer is not to try to replicate open source software. This is because software engineering is atypical, since most other real-world disciplines (such as chip design) must deal with challenges not found in the software world (such as relative lack of qualified engineers, high up-front funding costs, multi-year design cycles, physical end product, and higher quality bar).

By contrast, lowRISC's 'Newlabs' business model and governance structure was created specifically to address these difficult issues with OpenTitan[6] — the world's first open source silicon root of trust, built in collaboration with Google, Seagate, Western Digital, and others — developing rapidly into a high profile proof point[7].

Under the 'Newlabs' approach, a non-profit engineering company (such as lowRISC CIC) serves as the unconflicted steward for complete products, acting as the trusted intermediary between participating for-profits, academia, and the broader open source community. Companies pay the CIC partnership fees and also contribute developers during the initial phase of work. They do this because later, once the project moves into the maintenance phase, their in-house engineers can be freed up to work on other, more profitable lines.

This 'upstreaming' of products into the open source domain allows companies to reduce overall opportunity cost, while still delivering end products that they can trust. The component elements of the underlying design — all of which have very high quality testing, documentation and support — are released into open source repositories, from where they can be re-used by others as foundational IP.

Further, by leveraging targeted government funding in place of direct company contributions, this business model may be reworked to create digital solutions to adverse climate change — facilitating knowledge sharing, preventing costly 'reinvention of wheels', and creating adjacency benefits for the economy as new start-ups leverage the created component IP.

6 See https://opentitan.org/

7 See https://security.googleblog.com/2020/12/opentitan-at-one-year-open-source.html

FIGURE 4

The benefits of logical infrastructure for Net Zero digitalization (NZD).

Credit: lowRISC CIC 2020.

AI for industrial energy efficiency

Optimised energy efficiency will remain key to emissions reduction until there is a zero-carbon energy mix on the grid. Sims Witherspoon, Programme Manager, DeepMind, discussed the use of Artificial Intelligence (AI) for industrial energy efficiency, including in data centres.

> "Optimised energy efficiency will remain key to emissions reduction until we have a zero-carbon energy mix on the grid. Large industrial systems constitute more than half of global energy consumption, so a scalable solution for a problem that size could mean significant progress on global emissions reduction."
>
> Sims Witherspoon, Programme Manager, DeepMind

The problems behind climate change require solutions that scale – something that technology does well. AI in particular is a powerful tool for complex problems, especially ones rich in data with a defined action space (levers to adjust a system) and clear goals to achieve. Industrial facilities offer all three, and they account for more than 50% of global energy consumption, so optimising their energy consumption offers a promising target for global emissions reduction[8].

DeepMind explores AI as a science of its own, as well as in the application of AI to scientific problems. One of these applications is an autonomous system that optimises industrial energy efficiency. While humans cannot consider all permutations and combinations of operating setups to fully optimise complex mechanical systems, reinforcement learning (RL) systems can help. RL systems can understand the state of the system (via thousands of sensors), make recommendations on how to improve a facility's energy efficiency, understand the impact of particular actions, and iteratively improve recommendations towards a goal or reward.

Specifically, DeepMind has applied RL using deep neural networks to improve the energy efficiency of data centre cooling systems. By teaching the RL network which parts of systems could be adjusted along with the system's operational constraints (temperature, pressure), it could optimise for future energy consumption while ensuring the system continued to operate safely and effectively. When DeepMind's system delivered hourly recommendations for the facility managers to implement, it reduced energy consumption in the data centre by 40%. After the facility managers asked for an autonomous system (meaning they did not have to manually implement the recommendations), DeepMind built a system with additional safety mechanisms that directly implemented the changes through the data centre control system. Even with the robust safety constraints (which make the system more conservative), DeepMind saw 30% energy savings using its autonomous system.

However, real-world AI implementation brings challenges:

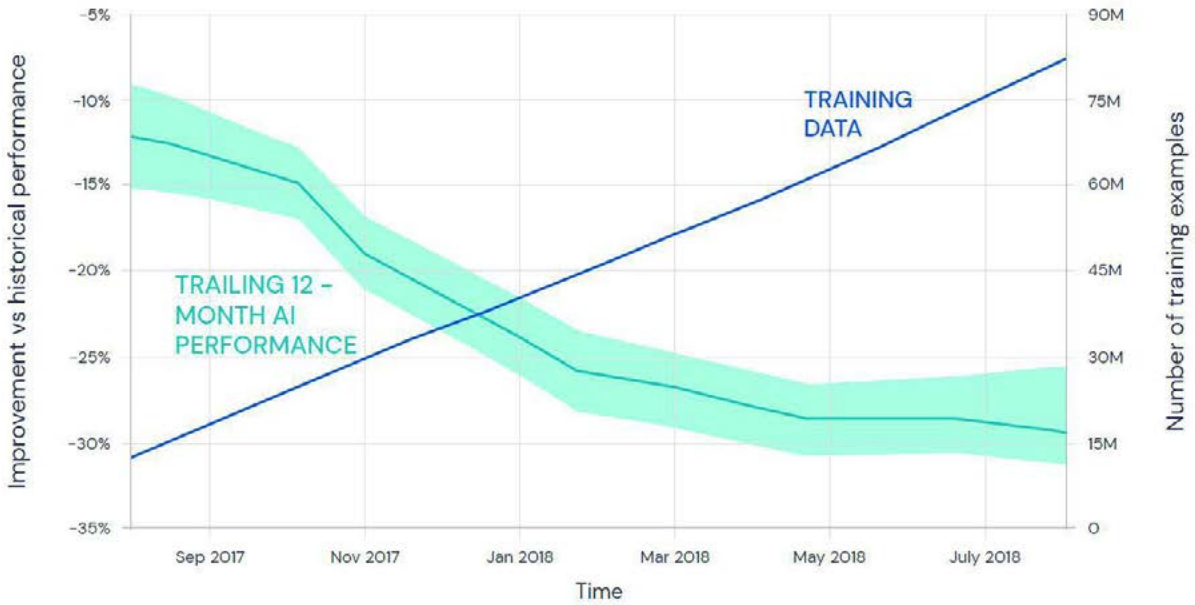
- Generalisability: many AI systems must be custom-tuned for each use case, taking time and expertise.
- Data quality: messy, missing, biased or latent data is problematic, but data quality overall is being improved systemically by policymakers, such as the UK Energy Data Taskforce.
- Deep integration: deep domain knowledge is required to apply AI to the real-world, and so partnerships between AI experts and domain experts are key. Deeper partnerships facilitated by cross-functional events will facilitate faster solutions towards Net Zero.

DeepMind is developing an industrial adaptive controls platform in collaboration with Google Cloud. This will make the AI system more widely available, including to building management providers and data centre operators. Such widespread adoption and collaboration to scale digital technologies will help tackle climate change.

8 U.S. Energy Information Administration Office of Energy Analysis, U.S. Department of Energy. International Energy Outlook 2019 with projections to 2050 (2019). See www.eia.gov/ieo.

FIGURE 5

A graph showing continuous performance improvement in AI, without additional programming. This is important, as while rules and heuristics do not improve over time, AI does.



Credit: 2020 DeepMind.

PANEL DISCUSSION

A good deal for nature – incentives for the data-enabled Net Zero economy and society

The discussion, chaired by Alex van Someren, Amadeus Capital Partners, considered the economic, policy and regulatory levers with potential to incentivise companies, governments and individuals to find a 'good deal for nature'. The panel comprised Dr Rhian-Mari Thomas OBE, The Green Finance Institute; Dimitri Zenghelis, Bennett Institute Cambridge University and Grantham Research Institute LSE; Alexandra Bolton, Centre for Digital Built Britain at the University of Cambridge; and Peter Bingham, Ofgem.

Policy levers to incentivise financial activity towards Net Zero

- Achieving the Net Zero target requires investment in early-stage technologies: public funding can help to create and shape markets.
- Investment at scale is the most effective way to bring the cost of new technologies down, while generating their innovation and implementation in a positive feedback loop. Support is needed for early-stage R&D and deployment to account for the fact that innovation has positive public spill-overs but will be underprovided by the public sector.
- Internally consistent policies on a cross-party basis, plus regulations and standards, are needed to facilitate substantial behavioural and institutional innovation. Meanwhile, policy to support investment must be credible enough to build confidence so businesses invest at scale.
- Historically, institutional reforms have been effective policy mechanisms for change, such as the UK's Climate Change Act. Combined with an investment bank, this would support private investors to leverage and scale-up finance in sectors with potential market failures.
- The former Green Investment Bank is an excellent case study of private-public collaboration: public funding successfully initiated UK offshore wind which is now entirely privately financed. This provides a blueprint for how public finance can overcome early-stage risk, and the new National Investment Bank can mitigate risk for technologies that require more investment such as green hydrogen; Carbon Capture, Utilisation and Storage (CCUS); and nature-based solutions.
- Other sustainable finance mechanisms, including first loss guarantees (where public finance reduces risk) and contracts for differences (offering a guaranteed minimum price for industry) create investor confidence in risky technologies.
- There is a significant appetite for sustainable finance. ESG funds received $87 billion net inflow globally in the first three quarters of 2020.
- The UK Government issuing a Green Sovereign Bond sends a strong message ahead of COP26. Such bonds have been effective in catalysing domestic green bond markets.
- Ofgem has devoted £40 billion of energy investment into a greener, fairer energy system for Britain including £30 billion of upfront funding for networks and £132 million to support vulnerable consumers. The high return of equity offered for network companies makes it an attractive package to incentivise investors.
- Work such as Data for the Public Good (2017[9]) represents good use of public funds to ensure that commercial interest produces the best outcome for the country and planet.

> "There is no magic green bullet for this sector, but the example of offshore wind does show how public finance can help to crowd in private capital."
>
> Dr Rhian-Mari Thomas OBE, CEO, The Green Finance Institute

9 See https://nic.org.uk/app/uploads/Data-for-the-Public-Good-NIC-Report.pdf

Barriers and risks to progress

- Keeping costs low is essential for industry to compete. Consumers ultimately fund green energy infrastructure, but many are struggling to pay their bills. Consumers must feel like the technology is excellent, otherwise uptake will be poor as with smart meters.
- The inertia of the current, historical system is a barrier. The benefit of moving onto a new system is a function of the number of people who move: the first mover will take on most of the risk and none of the market. Policy is vital to guide expectations and encourage change, such as towards Electric Vehicles.
- Energy, transport and buildings are the highest regulated and policy-driven sectors; the associated policy risks can deter investors. The private sector will often find courage to invest after an entrepreneurial state has invested public funding, as with the internet and voice activation technology. The green revolution similarly needs public funding in the first instance.
- Data is currently structured in a way that is siloed rather than shareable. Changing this, including via holistic policies, will ensure a well-functioning system of systems that connects financial aspects with data itself.
- The pandemic presents a major barrier: analysis from Vivid Economics shows that 16 of the G20 rescue packages encourage environmentally negative outcomes, such as by providing finance for industries that are large employers but need to pivot. By financially supporting the status quo, these packages are investing in stranded assets where fiscal stimulus with a green focus is needed.

> "In early-stage technology experimentation there should, and will, be failures, but there may be lack of acceptance by those who hold public funds that failure is part of scientific method. Some money may appear to be wasted, but in fact that is part of refining the quality of the solutions that really do work."
>
> Alex van Someren, Managing Partner, Amadeus Capital Partners

> "It is essential to structure data to be sharable rather than siloed, with initiatives and policy that are not siloed but holistic. Better data use will ensure that we don't get pockets of excellence and pockets of desert, but a well-functioning system of systems."
>
> Alexandra Bolton, CEO, Centre for Digital Built Britain, University of Cambridge

Future steps for the UK

- The green shoots of sustainable investment in engineering infrastructure are appearing following the pandemic, including in new nuclear, CCUS, hydrogen and 40 GW of offshore wind.
- In the pandemic, society found new digital ways of working and how to use data and digital technologies more effectively. Developing a data architecture that is better connected and more readily shared will improve evidential decision making for Net Zero and the response to future emergencies.
- Learning from the pandemic, there is an opportunity to restructure our data-enabled economy and society to be more resilient – with data more readily accessed by those who need it - in the instance of another shock.
- There is a need for systems-of-systems thinking, secure and resilient information management and sharing, and Government policy that takes advantage of both.
- Widespread behavioural change is essential – in the past, the energy system provided consumers as they needed it and supply adjusted to meet demand: the future renewable energy system will be governed by the supply, in turn driven by the weather. Renewable energy may never achieve the inter-seasonal storage of fossil fuels, so consumer behaviour around energy use will have to change. This will be enabled by better information and technology.
- Future UK investment in spatial and digital data will help to support disclosure processes to reallocate capital towards greener outcomes. Digital systems (from satellites to ground sensors) can accurately measure emissions from specific assets or businesses, meaning that disclosure does not have to be voluntary.
- The UK is showing real leadership on financing for nature, beyond climate and carbon to focus on biodiversity, soils, air and water. This is challenging from a financial perspective but great progress has been made, such as the Taskforce for Nature-Related Financial Disclosure and the Dasgupta Review[10].

"Already we are seeing the green shoots of sustainable investment following the pandemic, including in Carbon Capture, Utilisation and Storage (CCUS), hydrogen and electrification of heat."

Peter Bingham, Chief Engineer, Ofgem

"We cannot wait for innovations to happen in a vacuum. They will happen if we steer and design them, and the earlier we start designing this transition the lower the future cost will be and the bigger the opportunities."

Dimitri Zenghelis, Special Advisor, Bennett Institute Cambridge University and Senior Visiting Fellow Grantham Research Institute LSE

10 The Economics of Biodiversity: The Dasgupta Review (HM Treasury, 2021).

A good deal for nature: output and vision for future cities

Getting to Net Zero: is it time to get smart?

Many of the technologies needed to deliver Net Zero heating – heat pumps, district heating, solid wall insulation – have existed since the 1970s, yet uptake remains low. Dr Matthew Lipson, Business Leader: Consumer Insight, Energy Systems Catapult (ESC), discussed how the emergence of smart home technologies and Heat-as-a-Service (HaaS) could help to accelerate uptake of low carbon heat while ensuring it is affordable to all in society.

Decarbonising heat is one of the greatest challenges to meet Net Zero. Although low carbon heating solutions have existed since the 1970s, only ~4% of people use it at home. However, rapid consumer change is possible – demonstrated by the uptake of PCs and mobile phones. For this to change at the pace we need it will help if low carbon options are at least as good as the status quo, competitively priced, personalised, and readily installed.

Smart controls

The energy sector, like automotive, can innovate by using data to understand consumers. The ESC found that giving people room-by-room control of their heating, plus information about the cost of heating their whole house versus some rooms, transformed people from passive bill-payers with little interest in energy into discerning, engaged customers.

HaaS, in which households pay for warm hours instead of kilowatt hours, is a new business model that could accelerate uptake of low carbon heat. App-based heating could track users' energy consumption habits and advise on packages to best suit their needs (figure 6). Data from smart heating could be used to create tailored retrofit packages for homes and to plan low carbon heating for the area.

> "If we start with the consumer rather than the technology, we can build low carbon energy systems that are as good or better than those we currently have so we can enjoy experiences we love within a fairer, zero carbon energy system."
>
> Dr Matthew Lipson, Business Leader: Consumer Insight, ESC

The future

Policies that are technology and business-model agnostic are vital to support the low carbon transition, with industry and Government working together to facilitate innovation. The 'Carbon MOT' model, proposed by the ESC, would assess the current carbon footprint of a consumer's home and offer a decarbonisation target and timescale, that could be hit with any technology as long as it was zero carbon. In Denmark, industry is selling Government-backed low carbon heat pumps with HaaS; the Scottish Government is exploring how to do the same. England requires a similarly ambitious model to increase uptake of low carbon energy. To make low carbon heating price competitive with fossil fuels, climate costs should be factored in. HaaS could also help societies care for the vulnerable, by identifying homes that were difficult to heat and directing support to those struggling to afford their heating. GPs could even prescribe a 'warm home' to patients with health conditions where a cold home could do harm.

FIGURE 6

Illustration of how HaaS could be controlled via a mobile app.

Credit: 2020 ESC.

Funding the energy and transport infrastructure to achieve Net Zero

Simon Daniel, Founder and CEO, Moixa, explored how communal infrastructure, such as connected battery storage within households, could enable a greener future. Green Pensions could help fund the transition to low carbon infrastructure, generating new 'as a service' rights for those who receive pensions in future.

Connected battery storage

Around a third of the UK's energy comes from renewable sources today, forming a projected two thirds of the energy mix by 2030. The UK gets 95% of its electricity locally, creating a challenge when renewables are in short supply. Energy storage is a solution to renewable energy unreliability.

Moixa's software, GridShare, connects batteries in large-scale virtual powerplants to help manage batteries and the energy transition. Creating a communal energy infrastructure this way could enable households to use energy from each other's home batteries. This has been implemented in Japan, where 25,000 batteries have been connected in the world's largest managed fleet of household batteries (0.25 GWh of storage, doubling every 6 months). Soon this will be controlled digitally, including resharing excess energy back onto the grid.

Creating large fleets of connected batteries and electric vehicles (EVs) will facilitate their management to help cities achieve Net Zero. However, electricity demand needs to be distributed, otherwise the UK's electricity provision would have to grow 3-4-fold to meet the projected needs. Linking electricity costs to time-of-use pricing could help to flatten demand, while reducing the cost of building new infrastructure, such as for EV charging. Data will facilitate understanding of electricity demand to optimise when batteries charge and discharge, to provide better services, reduce waste, and manage the overall renewables demand across the National Grid.

Net Zero pensions

Net Zero pensions are a potential means to help fund the Net Zero transition, as an alternative to increased taxation. It costs an average of £35,000 to pay an energy bill over retirement, meaning that the UK Government spends £12 billion per year to support pensioners heating their homes. New Zero pensions could involve instead spending the £35,000 on energy efficiency, home insulation, EVs, or R&D towards solar batteries as an upfront investment in low carbon infrastructure, as part of pensions savings. This low carbon infrastructure, including services such as heating, would become a new pension right along with any savings.

The UK can exploit its leadership position in technologies such as batteries, the grid and AI, plus financial services, to invest in these fields today and create jobs now for a low carbon future. New technologies and sharing economy models could enable "as-a-service" energy, mobility and heat as a new pension right for low carbon universal basic services. This would balance climate, social inequality and financial debts. Future cities could therefore fund investment in renewable generation, battery storage, low carbon transportation, smart grids and building energy efficiency, secured against existing private, public and state pension obligations.

> "2050 is not so much a money economy: it is a service and digital economy in a cashless, as-a-service future."
>
> Simon Daniel, Founder and CEO, Moixa

Decarbonising the built stock: a digital twin of London and smart meters

Professor Tadj Oreszczyn, Professor of Energy and Environment, UCL, discussed ways to tackle climate change at the building, city and national level using data to better plan for a rapid transition for Net Zero carbon.

The building sector represents >50% of energy consumption in the winter quarter. Decarbonising the UK's 29 million buildings will require billions of pounds of investment to meet their diverse requirements, including insulating houses and installing heat pumps. To facilitate the smoothest transition, it is important to use existing data, alongside new data from smart meters and the Internet of Things and smart analytics.

To tackle the building problem, UCL has combined a range of datasets to build 3DStock[11] - a digital twin of the built environment – to help understand the current built environment and plan its decarbonisation. Datasets include:

- Buildings' footprints and addresses;
- Building height based on LIDAR, from the Environment Agency;
- Floorspace and building use, from the Valuation Office Agency;
- Technology within buildings, based on Energy Performance Certificates and Display Energy Certificates; and
- Other datasets, such as conservation zones from the Land Registry and energy usage from BEIS.

The London Building Stock Model

Most of the UK building stock is multipurpose and can be difficult to define. The London Building Stock Model [12] combines data sources to create a detailed digital twin of London, modelling 3.78 million premises to resolution of 0.5 m^2 including information on the use for each storey and roof orientation (figure 7). It has helped to establish that EPCs overestimate energy use in older properties but underestimate in new homes, also that high-rise buildings (>20 storeys) emit more than double the emissions of low rise (<6 storeys) even accounting for floor area. The model is used to recommend fabric and heating system energy improvements for London boroughs (figure 8).

This detailed three-dimensional representation of London can find the best locations for solar panels using the London Solar Opportunities Map[13]. This is probably the world's most sophisticated model at the city scale to look at solar potential in an urban area because it works at a resolution of 0.5 m^2, knows angle of incidence on each surface, and accounts for obstructions such as trees. It can demonstrate where London has 2 GW of potential for solar energy provision. The research group at UCL is in discussion with the Government to roll out the models across the whole of Great Britain, with Sheffield as the next city to be modelled.

"Buildings are challenging and unlike cars are not mass produced and regularly turned over. Updating millions of diverse buildings to achieve zero carbon represents a massive sociotechnical challenge for next 30 years."

Professor Tadj Oreszczyn, UCL

11 Steadman, P., et al. (2020). Building stock energy modelling in the UK: the 3DStock method and the London Building Stock Model. Buildings and Cities, 1(1), pp. 100–119. DOI: https://doi.org/10.5334/bc.52

12 For the public version see: https://www.london.gov.uk/what-we-do/environment/energy/energy-buildings/london-building-stock-model.

13 See public version at https://maps.london.gov.uk/lsom/

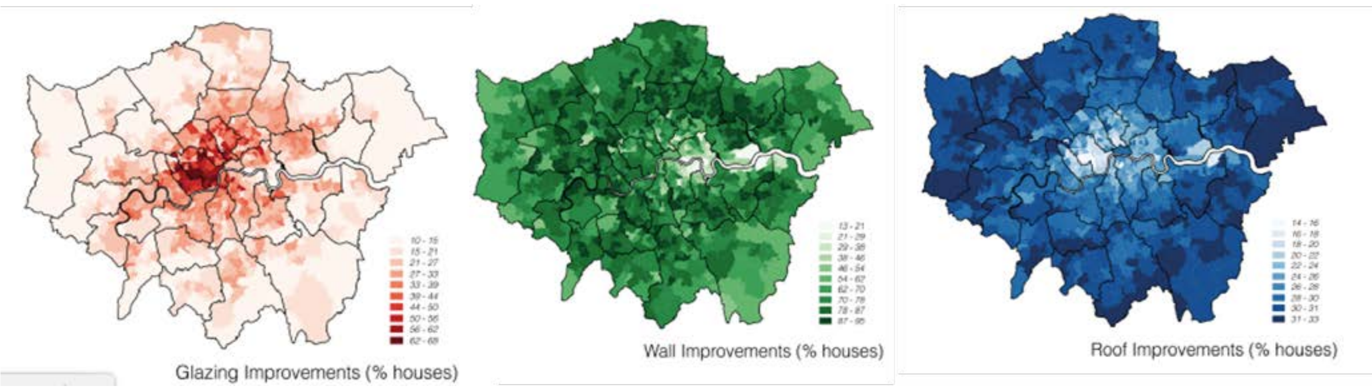
FIGURE 7

The London Building Stock Model can be used to identify fuel poverty, minimum energy efficiency standards, poorly performing non-domestic buildings, and to plan energy improvements.

Credit: UCL Energy Institute Building Stock Laboratory.

FIGURE 8

The London Building Stock Model can also be used to recommend fabric improvements for London as a percentage of houses in each borough.



Credit: UCL Energy Institute Building Stock Laboratory.

Building back better: BT's support for a green recovery

Andy Wales, Chief Digital Impact and Sustainability Officer, BT Group, introduced BT's pledge to become a Net Zero carbon emissions business by 2045. This roadmap includes two new initiatives announced in 2020 to support a green recovery: the UK Electric Fleets Coalition and the Green Tech Innovation Platform.

BT set its first science-based target in 2008 to reduce the carbon emissions intensity of its operations by 80% by 2020. This target was achieved in 2016, when BT set a new goal to further reduce the carbon emissions intensity of its operations by 87% by 2030/31. This science-based target was one of the first in the world to be aligned to a 1.5°C pathway. BT purchases 100% renewable electricity worldwide (figure 9) and is the joint largest private buyer of renewables in the UK, demonstrating that investing in renewables can be done at scale within a major industry.

Seeking to decarbonise its estate, BT has invested £45.3m in energy management projects in 2019 which reduced energy consumption by 2.3%. This has also been good for business, with these projects saving £343m since 2009/10. Through working with suppliers on various initiatives, BT has reduced its Scope 3[14] supply chain emissions by 8% to 3 million tonnes CO2e. Meanwhile, customers saved 13m tonnes CO2e through services like broadband, cloud computing and video and teleconferencing solutions in 2019/20.

The UK Electric Fleets Coalition

In June 2020, BT launched the UK Electric Fleets Coalition with the Climate Group, calling on the UK Government to target 100% electric car and van sales by 2030 and to introduce supportive policy measures to unlock infrastructure investment. BT and Openreach have the second largest commercial fleet in the UK with 33,000 vehicles and fleet emissions account for approximately 66% of the company's direct emissions. To help meet their carbon goals, Openreach aims to convert one third of its commercial fleet to electric vehicles by the mid-2020s. Meanwhile, collaboration with industry leaders will bring together vehicle manufacturers, buyers and charging infrastructure suppliers.

> "If we look back two years on the climate agenda, the change has been really significant. I'm excited about the pace and momentum from countries, companies, cities and investors around Net Zero right now."
>
> Andy Wales, Chief Digital Impact and Sustainability Officer, BT Group

14 Greenhouse gas emissions are categorised into three groups, or scopes, by the Greenhouse Gas Protocol. Scope 1 accounts for all direct emissions of an organisation or under their control. Scope 2 covers indirect emissions including from generation of purchased electricity, heating and cooling. Scope 3 incorporates all other indirect emissions across a company's value chain. Source: https://www.carbontrust.com/resources/briefing-what-are-scope-3-emissions (accessed 12/4/21)

The Green Tech Innovation Platform

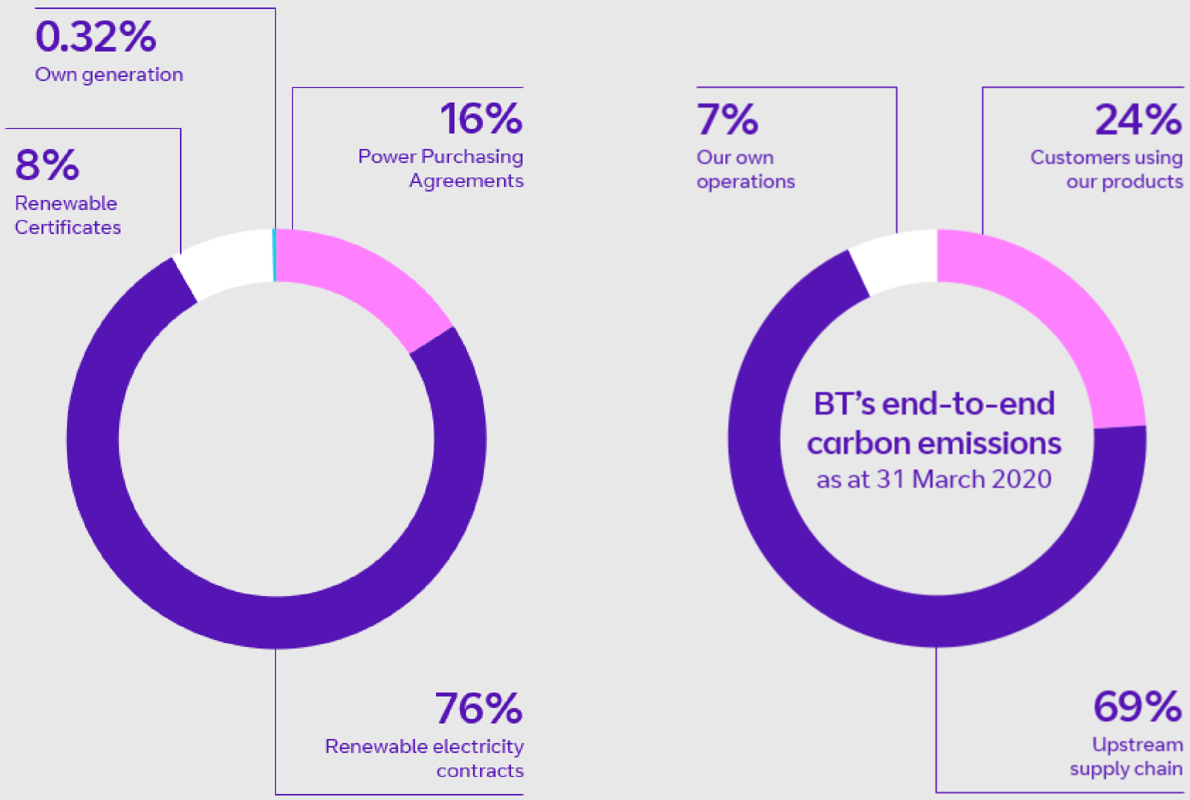
Launched in June 2020 by BT's CEO Philip Jansen, this platform aims to uncover new partnerships and new technology from scale-ups that can support public sector customers towards Net Zero. Focussing on Internet of Things solutions for social housing, air quality monitoring, CO2e measurement and on remote diagnostic solutions, BT aims to deliver proof of concepts with new partners in 2021.

By investing in new technologies, as well as increased data availability, the technology itself can reduce energy use. A 5G network could, as the technology matures, use as little as a tenth of the power used by 4G[15]. This will be enabled by more efficient use of spectrum, greater capacity of 5G radio systems for the same power usage, and better management of 'idle' mode. The reduction in energy use is clear when used across a network that is renewably sourced.

The SMARTER2030 report[16] from the Global e-Sustainability Initiative (GeSI) demonstrates that computing has the potential to reduce global emissions 20% by 2030. BT seeks to seize the opportunity by innovating and working with others to help realise this potential.

FIGURE 9

Left: BT uses 100% renewable electricity, with the below breakdown of renewables.
Right: Breakdown of emissions (total 4.2 MT CO2) across the whole supply chain.



Source: BT Digital Impact and Sustainability Report 2019/20.

15 *Ericsson Sustainability and Corporate Responsibility Report* (2017). See www.ericsson.com.
16 See https://smarter2030.gesi.org. Accessed April 2021.

PANEL DISCUSSION

Positioning of the UK and challenges for industry – research, implementation and post-COVID recovery

This panel discussion, chaired by Professor Andy Hopper CBE FREng FRS, featured Dr Robin North, Immense Simulations; Dr Ruchi Choudhary, University of Cambridge; and Dr Matthew Lipson, Energy Systems Catapult. Participants from the computing, transport, built environment, and energy sectors discussed learnings from the pandemic, including improving data access and maintaining the momentum to translate research.

Approaches to achieve Net Zero

- Anonymised, protected data giving activity patterns for household energy use and EV transport would help provide the supportive infrastructure needed, such as charging points, while identifying how emissions-generating activities occur and which interventions would be most powerful. Data is currently expensive, goes out of date rapidly, and there are concerns about privacy.
- One ongoing short-term challenge faced is the fragmentation of digital industry, especially in the energy sector across the pipeline from generation to data creation, curation and use. This is a political, social, management and technical challenge that must be addressed.
- There is a lack of trust or consensus on what a gold standard digital system entails. Trustworthy digital systems are needed that are reproducible, curatable, and comply with security and ethics.
- Good decision-making by individuals, corporations and government can be made easier by increasing the accessibility of digital technologies and data, as well as making testing infrastructure more widespread and durable.
- Data is an output of a digital system but not an outcome. There is a need to stress the importance of translating data into meaningful information.
- After the pandemic, there is a substantial opportunity to change how humans occupy the built environment and consume energy. Data can be used to understand how reorganisation can form a path to Net Zero.
- It will be a challenge to make sure that all of society can enjoy Net Zero, when some people will struggle to afford to live in a Net Zero world, for example if they are unable to charge their electric vehicle without off-street parking. Expertise should be focussed to make sure everyone can enjoy Net Zero.
- Previous energy transitions were driven by improvement rather than energy efficiency or cost reduction. For widespread adoption, the low carbon option needs to be as good, or better, than high carbon and this will require collaboration across disciplines to consider the definition of ‘good’.
- Good low carbon services present a mass customisation challenge, as requirements vary between individuals. Complex supply chains must be mastered to deliver diverse, excellent experiences.
- The legal commitment to Net Zero is very powerful but must also be supported by effective policy. Technology-neutral policies can provide clarity, driving innovative behaviour.
- The Companies House definition of a business may need to evolve: the current definition places pressure on businesses to make profit, but in reality they must also build towards a planet that works for many types of stakeholder.

> “Every previous energy transition, from horse to car or coal to gas fires, has been driven by improvement to people’s lives, not by energy efficiency or reduction in cost. If the low carbon option is as good or better than high carbon, the transition will be far simpler.”
>
> Dr Matthew Lipson, Business Leader: Consumer Insight, ESC

Data access

- Following substantial private and public work, it is easier to access data at scale now than five years ago. Obtaining a licence for access presents a barrier, despite using reusable standard templates. Greater use of standard templates would help increase the speed of data access.
- Useful datasets are often collated and controlled by private organisations: even with willingness from both sides, it can take a year of negotiation to secure access. Future business models could help make secondary datasets available on sensible terms, increasing investor confidence in overcoming data-based business challenges within a set timeframe.
- There is an important role for Government to set a framework for long-term stewardship of enabling assets. Widely available datatypes and 'infostructure' will be valuable for cross-sectoral challenges, requiring structural support by government over the next decade.
- The Global System for Mobile Communications (GSM) in telecoms is a good example of how a sector was brought together for rapid collaboration to accelerate interoperability. This needs to be replicated for heat and transport towards Net Zero.
- Data must be translated into meaningful information. Heat-as-a-service shows stakeholders the importance of translating data into something that they can benefit from.
- Data is perceived as both scarce and too abundant. Post-pandemic will be a good moment to integrate across data models for future use.
- Digital technology is now available everywhere. In future, a free app could offer a personal carbon meter for everyone on the planet in a way that is trustworthy, accurate and informs lifestyle decisions.

"Data is certainly an output of a digital system, but it is not an outcome."

Dr Ruchi Choudhary, Reader of Architectural Engineering, University of Cambridge

Scenario-based simulation

- The pandemic has galvanised simulation for transport infrastructure decision making, with openness around the need for scenario-based alternative futures. The Department for Transport sees simulation as a necessity to create resilience, and more work is needed to embed this around all routine decisions.
- Simulation for the energy sector has been in place for some time, supported by research councils and industry to support potential future scenarios. 1 in 100-year events, such as the financial crash and COVID, are big shocks to the system on top of incremental changes. One issue is the reproducibility of data or physics models which are static in time.
- Simulation-as-a-service offers a business model that reduces the cost and time in decision making for stakeholders, as used by Immense.
- Blanket rollout does not work for digital infrastructure. Constant monitoring and digitally-enabled feedback loops would allow continuous learning and improvement.

"During COVID-19, the whole world has adapted very rapidly, enabled by a few organisations, to very big changes. Our challenge is to harness that to lock in beneficial changes towards Net Zero."

Dr Robin North, CEO and Co-Founder, Immense Simulations

Harnessing the urgency of the pandemic response for climate

- Widespread understanding of the scale of the pandemic emergency led to rapid acceleration and scaling by industry and not-for-profit organisations, for example to develop vaccines. This urgency must be retained for efforts towards Net Zero due to the time taken to build infrastructure.
- The pandemic has highlighted a need to make a ‘refresh cycle’ in companies’ strategies part of structural change towards Net Zero for the benefit of all.
- Use of pathfinder cities could help accelerate low carbon infrastructure development in these key areas, driving change and learning to leverage in other areas. Examples of best practice already exist across niches in the system and must also be acknowledged.
- Creation of shared infrastructure would allow reuse of laboratories, releasing funding for use on learning.
- The enthusiasm of the younger generation could be readily harnessed towards Net Zero by both Government and by private and public sectors.
- The younger generation has high awareness of climate change but little influence. Views of younger generations could be embedded in decision making through membership of corporate boards.

> “Digital is now a toolset available everywhere – whether in terminal devices such as phones or cloud-based options. This is a real difference to 10 years ago.”
>
> Professor Andy Hopper CBE FREng FRS, Treasurer and Vice President, Royal Society and Professor of Computer Technology, University of Cambridge

KEYNOTE

The role of smart technologies in changing behaviours and cutting emissions

The Climate Change Committee has estimated that over 60% of the measures to reach Net Zero emissions will involve behavioural or societal change, meaning that consumers will play a central role in the shift to a zero-carbon economy. Juliet Davenport OBE, CEO and Founder, Good Energy, discussed the potential for smart technologies to transform consumer's energy usage.

Digital transformation could create $1.3 trillion for the electricity sector, while global investment in digital energy infrastructure is estimated to reach $64 billion by 2025. In this way, digital technologies could enable a wider part of the marketplace to be part of Net Zero. Achieving zero carbon in the energy sector will require change under four pillars.

Research and innovation

To establish the right investment into early-stage technologies and enablers, as well as the business models.

The UK currently spends significantly less on R&D in energy than on pharmaceutical, aerospace and automotive R&D. Increasing investment in innovative energy technologies now will facilitate a smart future. The UK needs to engage with universities and research centres to ensure this research is happening.

Regulation

To create a new regulatory framework to replace that which was written for a world with only 40 power stations when today there are over 1 million.

Regulation is currently a barrier to innovation. Vehicle-to-grid technology is one future business model which applies variable pricing based on the time of charging and the option to return energy back to the grid. Good Energy's research with Salford University into vehicle-to-grid technology found households could save £300 per annum, with their vehicle additionally providing an income stream, but regulation does not currently allow this business model. The Energy Data Taskforce is exploring how digital futures can be facilitated through supporting new regulation to facilitate early stage technologies.

Infrastructure

To build low-carbon, distributed energy infrastructure to replace today's high-carbon, centralised model.

The UK's energy infrastructure was built for high-carbon, centralised technologies. The future vision is for a data-led energy infrastructure that is self-regulating and supports flow of multiple power inputs. Management and measurement of the grid will become crucial as different technologies are used, along with improved data sharing and openness. Small scale pilots will allow innovative technologies to be trialled before integration into larger companies. As electric vehicle (EV) numbers increase, so does potential for smart charging on the network. In 2010 there were ~1,000 electric vehicles on UK roads; by 2030, 10 million are anticipated. EVs represent a large mobile battery, and EVs and the grid could support each other with electricity flows.

Consumers

Awareness has risen that consumers are an intrinsic part of the energy system and that their profiles change over time. Transformation is needed to include the consumer in the system.

The digital world is key to empowering consumers to change behaviours, such as increasing awareness of time-variable pricing, while using smart digital systems will require high levels of consumer engagement and trust. The next generation of smart meters will help to understand where there is consumer appetite towards building a Net Zero home, reducing pressure on the grid. It is also essential to involve the younger generation in consumer decisions: Good Energy's Good Future Board recruits children from years 7 to 12 to better understand their needs and concerns, with the intention to give the next generation practical tools to empower them in regulatory decisions.

FIGURE 10

As electric vehicle (EV) numbers increase on UK roads, so does potential for smart charging on the network.

Credit: Good Energy 2019.

"The UK currently spends 1.7% of its GDP on R&D, but only £0.2 billion on energy. We can't reach a smart new world with old world spending."

Juliet Davenport OBE, CEO and Founder, Good Energy

"What is abundantly clear is that digital connectivity is going to be so vital. We have seen windows onto a future world that from my climate scientist's view is deeply encouraging that we will win this battle against climate change and get to Net Zero."

Dame Julia Slingo DBE FRS, Natural Environment Research Council, former Met Office

Acknowledgements

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Professor Andy Hopper CBE FREng FRS
University of Cambridge

Dame Sue Ion DBE FREng FRS
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