THE ROYAL SOCIETY

Digital technologies and the planet

Note of discussions at a Royal Society workshop, 26 November 2019

Background

The Royal Society is the UK's national academy of sciences. The Society's fundamental purpose, reflected in its founding Charters of the 1660s, is to recognise, promote, and support excellence in science and to encourage the development and use of science for the benefit of humanity.

Reflecting this mission, the Society's policy activities on data and digital technologies seek to advance these areas of science and technology for the benefit of society. In pursuit of this ambition, the Society will shortly begin a new policy project investigating the ways in which digital technologies can contribute to reducing carbon emissions. To help define the scope of this project, a workshop on 26 November 2019 explored visions for the future application of digital technologies to tackle sustainability challenges, and the technology and policy developments that might help bring those visions into being. This note summarises discussions at the workshop. It is not intended as a verbatim record and does not reflect an agreed position by participants or the Royal Society.[1]

The potential of digital technologies to support sustainable living

Human activity has increased atmospheric carbon dioxide (CO_2) concentration by more than 40% since pre-industrial times. This, and increases in other greenhouse gases, such as nitrous oxide, has led so far to a global average 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. As global temperatures increase, the negative impacts of climate change on people and the environment become more severe and adaptation becomes harder, costlier, and in some cases, impossible.

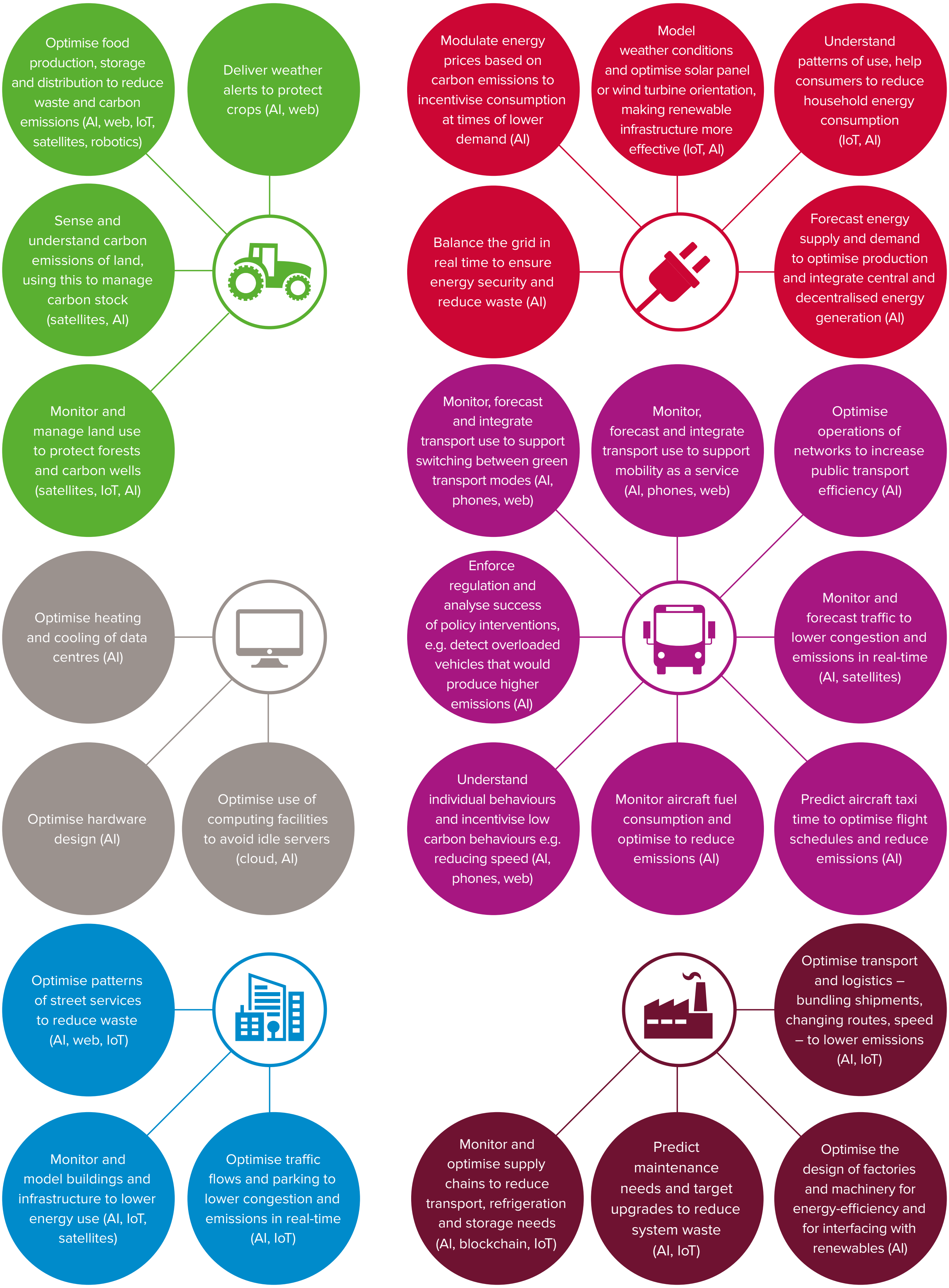
Limiting global warming to 1.5°C may still be feasible. To achieve a 1.5°C target, the net emissions of long-lived greenhouse gases, principally CO_2, would have to reach 'net-zero' level by around 2050. In the next decade urgent, ambitious and concerted action is required across all countries and sectors to deliver rapid emissions reductions. This transition will require major emissions reductions from all sectors of the economy. Rapid and unprecedented changes in energy, land use, urban development, transport, infrastructure and industrial systems are needed, with implications for how individuals live and work.

Digital technologies could support this transformation (see figure 1)[2]. These technologies have already reshaped many daily activities – from online retail to on-demand transport services – with individuals using data-enabled systems to bring physical activities into the digital realm, reducing carbon emissions in the process. As technologies develop and systems for data use evolve, there will be further opportunities to find new ways of carrying out everyday tasks, with digital technologies bolstering a low-carbon revolution.

1. This workshop was conducted under the Chatham House Rule. The Society would like to express its thanks to all those who participated in discussions.
2. Digital technologies include, for example, mobile phones, the internet, cloud computing, artifical intelligence (AI), the internet of things (IoT), blockchain technology, robotics and analysis of satellite data.

FIGURE 1

A summary of some of the potential applications of digital technologies to reduce carbon emissions.



Thinking about the future

Changes and pathways

Harnessing the power of digital technology for improved sustainability requires action to:

- Reduce the environmental cost of computing, by encouraging wider uptake of existing best practice and increasing the utility of the systems that are already available.
- Create pathways to increased use of digital technology to tackle climate change, by identifying both local and systemic changes that can reduce carbon emissions across sectors.

By speculating about desirable futures across different sectors, it is possible to create ideas and insights that can inform the development of digital technologies and their applications for climate goals. The table below contemplates these potential futures, and their implications for technology development today.

This table draws from deliberately speculative workshop discussions that set out to generate ideas about alternative potential futures.

TABLE 1

The potential of digital technologies to support sustainable futures.

Domain	Opportunities and challenges
Energy	Sustaining human activities – and enabling human flourishing – requires an energy system that can meet the needs of a growing population, without relying on carbon-intensive sources. Digital technologies offer the opportunity of creating flexible energy systems, which allow electricity generation to meet demand in a sustainable way. Optimisation and balancing of the energy system through these technologies could both reduce overall energy needs and better-manage energy storage. At the same time, shifting patterns in production and distribution of renewable energy could create opportunities to reduce fuel poverty – providing cheap or free energy at particular times of day. Such a system would require: • More effective mechanisms to store energy and carbon, utilising improved battery technologies and carbon capture and storage technologies; • Monitoring and management systems that enable optimisation of energy production and use, supported by organisational ecosystems that allow relevant stakeholders to collaborate on this challenge; and • Infrastructure changes to develop smart grids and charging systems that enable widespread use of electric vehicles, local power generation systems, and other emerging forms of technology to be applied to reduce carbon emissions. Policy frameworks could help incentivise the development and deployment of these systems. In a sector that already has an established regulatory system, measures to prompt further action could include: mandating the retrofit of existing assets for generation, supply and distribution of energy to enable deployment of digital systems; legislation to manage different types of fuel use or reduce carbon emissions; or standards to enable system deployment.

Domain	Opportunities and challenges
Food	Aligning individual and planetary health could both improve societal wellbeing and support a low-carbon food production system. In such a system, individuals would enjoy improved health, with a diet of lower meat consumption and nutrient-dense foods. These individual behaviours would support a wider system of careful land stewardship, with a circular economy that better manages use of fertilisers, water, transport networks, and the location of food production to support low-carbon behaviours. Such stewardship requires careful alignment of incentives, with stakeholders working together to manage the full system of food production, and to find ways of accounting for shifting patterns of costs and benefits. This alignment and optimisation could be supported by better sharing of data to enable supply chain management across food producers and distributors.
Transport	A green transport system would make use of a diverse range of mobility options, each made accessible and comfortable for users. These could include: fully autonomous personal vehicles, powered by low carbon sources of electricity; alternative air-travel options, such as airships, which reduce the reliance on road networks or carbon-heavy fuel sources; and forms of system optimisation to reduce energy requirements and congestion – for example, running convoys of autonomous freight vehicles on motorways overnight. Technology developments required to support such a system include: • Further progress in creating trustworthy and robust AI technologies, to support the development of autonomous vehicles; • Advances in battery technologies, increasing their capacity; • Digital systems to support and coordinate local power generation systems; • Sophisticated cybersecurity systems, to protect autonomous vehicle fleets from hacking, or protect individuals using personal autonomous vehicles from harm. In addition to these technology developments, wider social changes would also contribute to realising this vision. These would include different attitudes towards personal vehicle ownership, or a greater desire to engage with autonomous driving systems. Such changes would need to be supported by a policy framework that ensured trustworthy technology development and deployment, and that managed the distributional implications of changing patterns of technology use. For example, removing traditional energy sources from the economy would have implications for taxation and the regulation of carbon emissions; regulation might be required to set standards in the development of autonomous systems; and infrastructure changes would need to be enacted in ways that supported both rural and urban communities, which might have different needs.

Domain	Opportunities and challenges
Supply chains and optimisation	A key cross-cutting challenge to enabling the sustainable use of resources, and reducing carbon emissions, is the ability to coordinate supply and demand of goods, services, or resources. Different ways of managing supply, processing and shipping materials, or storing resources exist, and optimising these could support more efficient and effective systems – across transport, food and agriculture, energy, and more. Core to such optimisation would be an interactive infrastructure – an information infrastructure that complements physical systems, allowing users to interrogate how that system is working and identify areas where alternative approaches to managing the system could increase efficiency. Such systems could interface with digital twins of physical infrastructure, or draw from data combined from different organisation or actors in the system.
Economics and finance	Signals today point to at least two routes by which financial systems could play a role in enabling a transition to a low-carbon economy, in some ways building on existing models of carbon accounting or environmental impact analysis. One approach is to have pervasive accounting of the monetary cost of carbon, through changes to the mechanisms that determine the price of goods and services. This would be implemented through a global carbon tax. Creating such a system would require global consensus on the development and implementation of such a tax, as well as institutional innovations to implement such an initiative on the global scale. Such changes could only be secured through significant and sustained public demand and political will. A second approach would be to implement pervasive physical accounting of the energy, materials, and resources required to deliver services such as heating or cooling, or mobility. This would, in the first instance, make clear to consumers the environmental consequences of their use of different services, though information provision alone would be unlikely to prompt significant behavioural changes across the population. This approach does, however, create opportunities for policymakers to put in place provisions to regulate market access on the basis of the carbon-intensity of services provided by different operators (for example, the number of kilometres of mobility provided per unit carbon by different transport providers). Achieving such a system would require technical solutions that allow tracking of emissions productions throughout the lifecycle – from production to use – and at the point at which a good or service is used. These solutions would draw from dynamic approaches to lifecycle analysis, and a data architecture in which all potential sources of carbon emissions are trackable and known.

Creating a pathway

Greening computing

The link between digital technology use and sustainability is not always a simple one, and policies to support their deployment need to take into account unexpected interactions or consequences of their use. The manufacture and use of digital devices can be resource-intensive, for example, and there can be rebound effects from their use: as devices become more accessible and they make different types of activity easier, individuals potentially consume more and increase their carbon footprint as a result.

Recent years have seen significant advances in the deployment of 'green computing' approaches, which seek to reduce the carbon emissions that come from the management and use of computing systems. Industry best practice has now significantly reduced energy consumption by data centres, and many technology companies have in place policies to encourage the use of renewable energy. While digital technologies do have a carbon footprint, toolkits – including guidance and technology tools – that promote existing best practice could help reduce this during their deployment.

Enabling decision-making

Digital technologies could become powerful decision-support tools. By integrating data from across different sources or organisations, and identifying points of intervention to increase the carbon-efficiency of a system, these tools could enable more effective human management of complex systems – whether transport, land use, or energy networks. Achieving this requires digital systems that work well for people, allowing human users to bring additional contextual understanding or judgment to bear on the operation of the system. Human users may need to understand how a digital system has reached a decision, or require information to be provided in ways that are useful in supporting decision-making. This requires careful design of the interfaces between people and technology, with implications for the underlying technical architecture – including the ability of that architecture to track the provenance of data and resources through a system.

Centralisation and decentralisation

Many of the technology applications that could enable a system-level change in activity – with resulting carbon efficiencies – require data sharing or collaborations across organisations or stakeholders. This implies a centralisation of efforts to analyse data. Such centralisation requires incentives that encourage organisations to collaborate, investing time and energy in:

- Bridging divides between domain experts, developing shared vocabularies and frameworks to effective research collaborations;
- Enabling data sharing and analysis efforts, ensuring high-quality data is available for use by digital technologies in decision-making; and
- Aligning the objectives and efforts of different stakeholders working within a system, through governance approaches that encourage collaboration while managing a tension between the ability of decentralised collaborations to drive change quickly at a local level and the scale of impact enabled by centralised direction.

Efforts to scale such collaborations between organisations (or groups of organisations) to achieve system-level change can benefit from decentralised approaches to technology development. By ensuring technology and software is widely available, organisations can lower the barriers to creating and deploying new applications or developing further collaborations. Open development approaches are already common in fields such as machine learning, and widespread adoption of these norms could spur further action.

Institutions, governance and behaviour

The incentives that shape whether individuals, organisations, and societies do or do not engage with large-scale initiatives to tackle climate issues are complex. To date, policymakers have pursued a combination of legislative and policy frameworks, research and development activities, and behaviour change initiatives as part of efforts to tackle climate change. While these efforts have brought some success, further action is needed, and at pace. Such action will require committed leadership and strong policy frameworks that create the conditions for a systemic shift – using a combination of shifting social norms, institutional incentives, and technology deployment to create a tipping point at which new systems can emerge.

In pursuing these approaches, care is needed to ensure that policy frameworks do not have unintended negative distributional implications – that those already at most risk of being adversely affected by climate change are not further marginalised or negatively affected by policies to address it.

Policy and research efforts need to engage effectively with these communities to ensure their priorities and concerns are reflected in any action, and to provide a voice in decisions about them.

Where is further action needed?

To create a future in which the power of digital technologies is harnessed to support planetary wellbeing and human flourishing, further work is needed to:

- Create an amenable data environment, in which datasets to support new applications are well-governed and appropriately available;
- Share best practice and practical advice on how to implement digital technology-enabled solutions;
- Integrate data and digital technologies into decision-making processes to better manage systems, developing trustworthy technologies to support decision-making and guidance on their implementation;
- Identify ways in which digital technologies can support carbon tracking, using this information to support policymaking in relevant domains;
- Enable digital-enabled solutions to reduce carbon emissions to be created and deployed at scale and to a timeline that reflects the urgency of the need;
- Develop stakeholder-led solutions to key challenges, highlight areas of opportunity and direct funding to them;
- Facilitate working across research domains and collaborations across sectors to develop and deploy creative technology solutions; and
- Bridge discussions across technology and policy communities, so each can better understand the actions needed to facilitate further action.