THE D^2S AGENDA

Research, Innovation, Action

Digital Disruptions for Sustainability [D^2S]

Sustainability in the Digital Age

ACKNOWLEDGEMENTS

** Affiliations are listed for identification purposes only.*

The Digital Disruptions for Sustainability Agenda (D^2S Agenda) was shaped through discussions with and contributions from an Expert Advisory Committee as well as through a series of online and in-person consultations.

The views presented in any given section of this report do not necessarily reflect those of all the contributors or their affiliated institutions.

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PREFACE

"If solutions within this system are so impossible to find, then maybe we should change the system itself." This is the message of Greta Thunberg and the youth activists around the world demanding climate action. It is simple and powerful. Yet few global efforts are dedicated to making it happen – to changing the systems that are inhibiting transformative climate actions.

Most climate mitigation strategies approach the climate crisis principally as a carbon management problem, focusing on reducing emissions by sector (e.g. energy, transport, or food). Sector-based emissions reduction work is critical, but it is not sufficient. This is because, while research indicates that deep decarbonization is technically possible, we have not yet figured out how to steer society onto a decarbonization path. More research and innovation on this issue are urgently needed.

In this report, the Digital Disruptions for Sustainability Agenda (D^2S Agenda), we explore this issue – how to steer society onto an inclusive deep decarbonization path. Our approach considers the climate crisis principally as a social challenge, where the formal and informal rules, power structures and dynamics, and mindsets embedded in our social systems are constraining climate actions. We explore the opportunities and challenges of leveraging the capabilities of the digital age to disrupt these rules, power structures, and mindsets and break the constraints to action.

The premise of this effort is that the digital revolution is already driving transformations in our underlying social systems at an unprecedented scale and pace. With a conscious and coordinated effort, we could steer these societal transformations toward the systems changes needed to unleash rapid, deep, and inclusive climate action.

The initial outlook for the digital revolution promised the democratization of information, the strengthening of governance through broader citizen engagement, a more equitable and greener sharing economy, and an improved ability to measure and manage previously intractable global environmental challenges. While some of these visions of positive systems change have emerged, many have not because we, as a society, failed to anticipate how the digital revolution would unfold. We did not foresee the scale of systems changes that would result from digitalization nor the new types of challenges posed by such large-scale changes. As a result, today we live in a digital age that threatens privacy, human dignity, social justice, the future of democracy, and environmental sustainability.

> Tackling the climate crisis and working towards a just and equitable digital future are inherently interconnected agendas.

But it is not too late. The potential to leverage the digital age to benefit society and the planet is massive. And there is now a growing urgency to do so because society is interconnected through and dependent on both the natural and digital worlds – and our current trajectory poses global systemic risks emerging from both worlds. To seize the potential and minimize the risks, we must recognize that tackling the climate crisis and working towards a just and equitable digital future are inherently interconnected agendas. With this in mind, we must look ahead together – anticipate the systems changes that are unfolding as a result of the digital revolution, imagine the potential for new systems changes that could be realized from digitalization, and identify what actions we must take now to steer these powerful levers of change to help build the world we want.

The D^2S Agenda provides an initial framework for these ambitious tasks. It was developed with input from over 250 people around the globe. We are thankful to everyone who has engaged in this effort. We need to now expand the circle and deepen the collaborations so that together we can realize the potential of the digital age to drive systems changes toward a climate-safe and equitable world.

Amy Luers,
Executive Director,
Future Earth

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REFLECTIONS

Having led innovation and development efforts at Google.org, the World Bank, and the Aga Khan Foundation, I have learned that the challenges of stewarding a sustainable planet and building a more inclusive and equitable digital future are intimately connected. Digital technologies such as AI and others can move us closer to the UN Sustainable Development Goals while also being drivers of economic, social, and political inclusion rather than exclusion. But this requires a more systemic view of solving these problems. What kind of economic, social, and political system do we need to build to ensure that people and planet can both thrive in a sustained way? Where are citizen voices in this conversation? Public-private partnerships cannot ignore civil society. Equitable gains to multiple segments of society in the digital economy will not happen automatically. The bottom 25% of society will not reap a digital dividend unless their voices are included early in this process and by design. That will require soul-searching and culture changes in the way we behave, govern, innovate, and plan for the future. The D^2S Agenda outlines a powerful framework to focus us on these tough issues."

Aleem Walji
Former CEO,
Aga Khan Foundation

At ClimateWorks, we've been exploring how alternative futures might impact climate strategies. One critical disruptive force is the digital revolution, which is creating new challenges but may also offer huge opportunities to drive systems change and accelerate climate action. The D^2S Agenda sets out a valuable framework for leveraging the digital revolution to achieve positive change."

Charlotte Pera
President & CEO,
ClimateWorks Foundation

Data is not the new oil – it's the new plutonium. Amazingly powerful, dangerous when it spreads, difficult to clean up and with serious consequences when improperly used. Data governance is therefore more urgent as a policy challenge than climate change because abuse of data compromises the very democratic processes on which we rely to intelligently and effectively address challenges like climate change. The Digital Disruptions for Sustainability Agenda provides a helpful framework for understanding the powerful connection between the data governance and the climate agendas, and highlights important work needed to move forward on both."

Jim Balsillie
Canadian Council of Innovators

Sustainability transformations will not be possible without the transition to digitalization. Artificial intelligence, machine learning, and virtual realities are vital tools for securing the welfare of what will soon be 10 billion people on Earth within planetary boundaries. But digitalization will not automatically enable sustainability. We will only achieve our sustainability goals if digitalization is consciously geared towards them – so far, this has not been the case. If we fail to steer the digital revolution, it may perpetuate or even accelerate unsustainable growth patterns. Sustainability in the digital age is thus a tremendous governance challenge. Future Earth's D^2S Agenda outlines important research, innovation, and near-term actions needed to begin to steer digitalization to empower the sustainability transformations we seek."

Dr. Dirk Messner
President,
German Environment Agency; Governing Council Co-Chair,
Future Earth

The D^2S Agenda highlights the potential of four digitally empowered capabilities to drive the world towards carbon neutrality. However, by definition almost, these digitally empowered capabilities could lead to a much more iniquitous world than ever. And this is the direction they are driving the world today. Basic capabilities have to precede the digitally empowered capabilities. These basic capabilities can themselves be accelerated through digitalization, but they are not geared to do so today. We need to direct our research, innovation, and actions to ensure that we have the policies, business models, and public-private partnerships to steer the digital transformations away from the iniquitous path we are on toward a climate-safe and equitable world. Sustainability calls for digital empowerment of the poor; not digital empowerment for the poor."

Dr. Leena Srivastava
Deputy Director General for Science,
International Institute for Applied Systems Analysis (IIASA);
Advisory Committee Co-Chair, *Future Earth*

Technology can help us monitor the health of our planet and measure the full value of its ecosystems. By accelerating investment and deployment of AI solutions, we have the potential not only to mitigate climate-related risk for our businesses, but to fundamentally transform how we manage Earth's natural resources for a more prosperous and climate-stable future. The D^2S Agenda presents a valuable framework for beginning to identify priority areas for research and innovation to advance on these critical issues. However, this will only be possible with swift and concerted action from the digital sector to reduce emissions and help scale advanced energy solutions. Microsoft is already showing that this can be done."

Dr. Lucas Joppa
Chief Environmental Officer,
Microsoft

Digital Disruptions for Sustainability identifies important opportunities to leverage technologies to help solve climate change and other key 21st century challenges. The report makes a compelling case for additional research to explore capabilities such as unprecedented levels of transparency related to supply chains and carbon emissions."

Tom Kalil
Chief Innovation Officer,
Schmidt Futures

1 | EXECUTIVE SUMMARY

THE GOAL

Young shepherds walk through the KenGen wind power station in the Ngong Hills, Nairobi, Kenya in 2017.

NET-ZERO EMISSIONS BY 2050, WHILE INCREASING EQUITY AND CONSERVING NATURE

In 2015, world leaders adopted two international agreements – the 2030 Agenda for Sustainable Development and the Paris Agreement on climate change – that committed to pursuing widespread and rapid societal transformation to achieve a common goal of building a climate-safe future that is more sustainable, resilient, and prosperous for all. Digital disruptions are already driving societal transformations at a scale and pace unparalleled in history. It is unclear where these digital disruptions will lead; risks and uncertainties lie ahead. Yet opportunities exist for these disruptions to steer us towards a net-zero carbon emissions society.

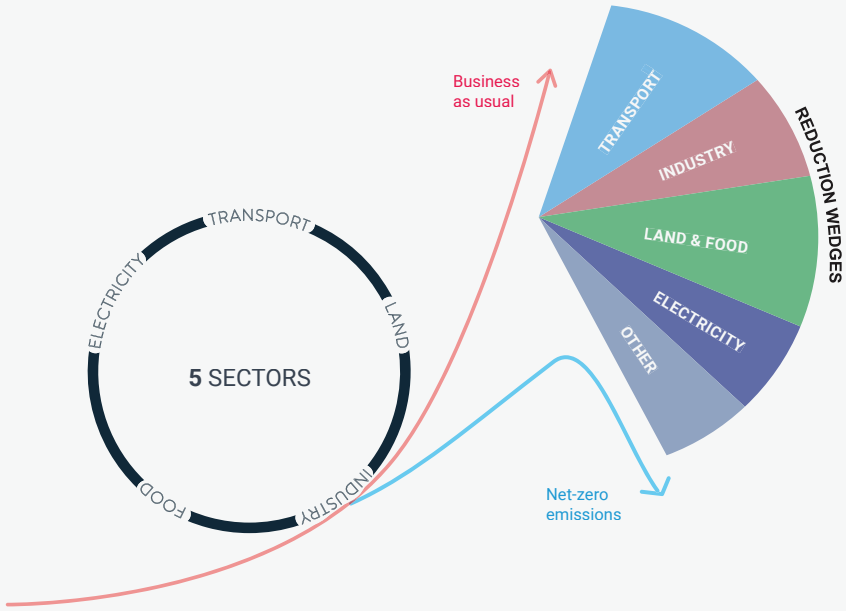
In this report, we explore the opportunities and challenges of leveraging the digital age to disrupt the facets of existing economic, governance, and cognitive systems that are maintaining society on a carbon-intensive and increasingly inequitable path. We identify research and innovation opportunities and near-term actions needed to enable society to steer these disruptions towards a climate-safe and equitable world.

SECTOR-BASED STRATEGIES ARE NOT ENOUGH

Keeping global average temperature rise to well below two degrees Celsius will require cutting greenhouse gas (GHG) emissions in half by 2030 and reaching net-zero emissions by 2050 [1,2]. This will require completely decarbonizing our global society over the coming 30 years – the fastest energy transition in human history [3]. Yet GHG emissions continue to rise by ~2% per year [4].

Five sectors account for 80% of GHG emissions.

- Climate change is often approached as a technical carbon management problem.
- Most strategies focus on emission reduction “wedges” [5] or decarbonization pathways [6,7] by sector.
- Significant progress has been made in each of these sectors to reduce emissions and increase energy efficiency. But emissions are still going up. More rapid and widespread changes are needed.

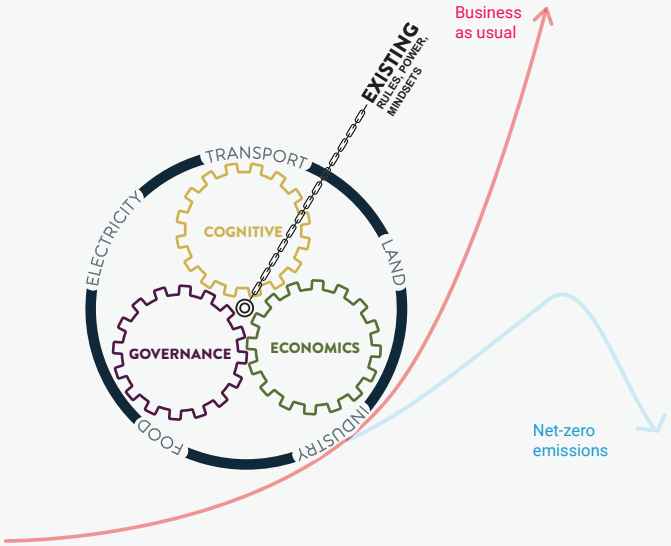


THE CONSTRAINT

RULES, POWER STRUCTURES, AND MINDSETS EMBEDDED IN EXISTING SOCIAL SYSTEMS

While research shows that deep decarbonization pathways are technically feasible, rapidly steering society onto those pathways has proven to be a monumental task. This is because the rules, power structures, and mindsets embedded in existing economic, governance, and cognitive systems constrain society from making the rapid transformations needed.

[Figure below: The gears inside the circle below represent the social systems cutting across all emitting sectors. The black chain that is connected to the centre of the gears represents that these social systems are constrained by the rules, power structures, and mindsets embedded in them.]



We need to disrupt and change the systems constraining rapid, deep, and inclusive climate actions.

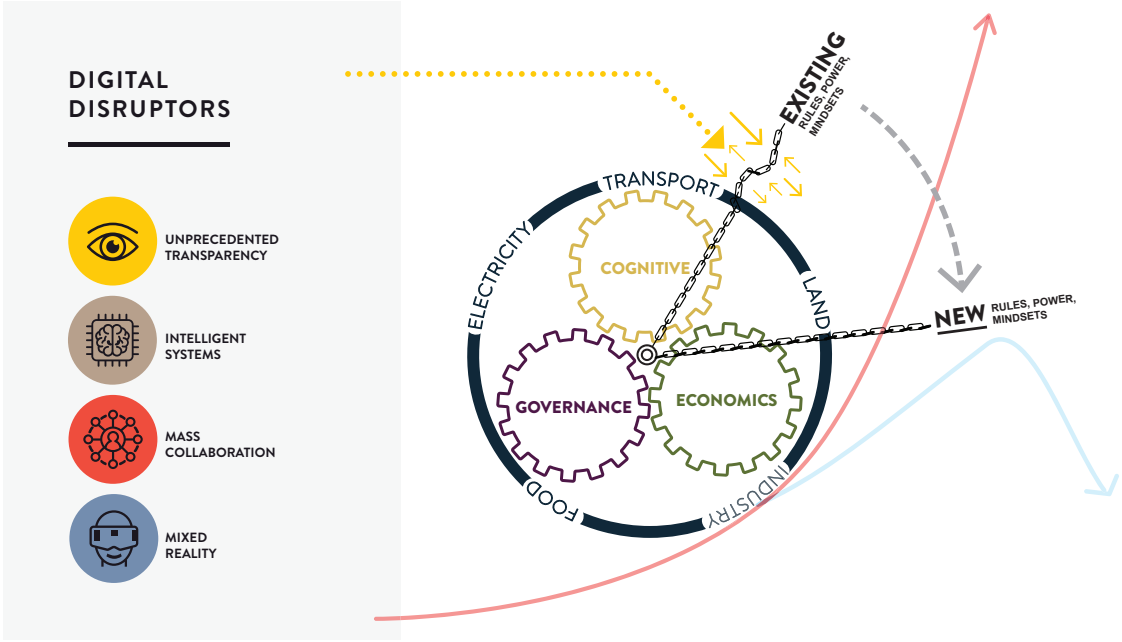
- Donella Meadows, the pioneering leader of systems change, highlighted the need to focus on “leverage points” – places within a complex system where a small shift in one thing can produce big changes in everything [8].
- Meadows found that the biggest leverage points in social system centre around shifting the rules, power structures, and mindsets that define the functioning of the system.

THE OPPORTUNITY

DIGITAL DISRUPTIONS FOR SYSTEMS CHANGE

Our social, cultural, economic, and political interactions are increasingly mediated by machines, powered by our data and artificial intelligence (AI) [9]. This emerging reality is already influencing societal rules, power structures, and mindsets. Over the last year, Future Earth engaged more than 250 diverse experts from over 30 countries to develop this agenda on Digital Disruptions for Sustainability (D^2S Agenda), which explores how to leverage the digital age to drive systems change and enable societal transformations towards a climate-safe and equitable world.

We identified four digitally empowered capabilities that are already disrupting economic, governance, and cognitive systems at a global scale: unprecedented levels of transparency, intelligent systems, mass collaboration, and mixed reality.



Could these digital disruptors help steer global society towards a net-zero carbon future that is equitable and just?

We believe they could, but only if there is a conscious effort to navigate in that direction. If that effort is not made deliberately, we risk rapid, deleterious impact on the environment, the economy, and society at large.

THE RISKS

IT IS NOT CLEAR WHERE THESE DIGITAL DISRUPTIONS WILL LEAD HUMANITY

Without guidance, they may steer us down a path that threatens privacy, human dignity, social justice, the future of democracy, and environmental sustainability.

OUR STRATEGY

DISRUPT. Disrupt the rules, power structures, and mindsets constraining transformative actions

by

STEER. steering digital disruptors to drive changes in existing economic, governance, and cognitive systems

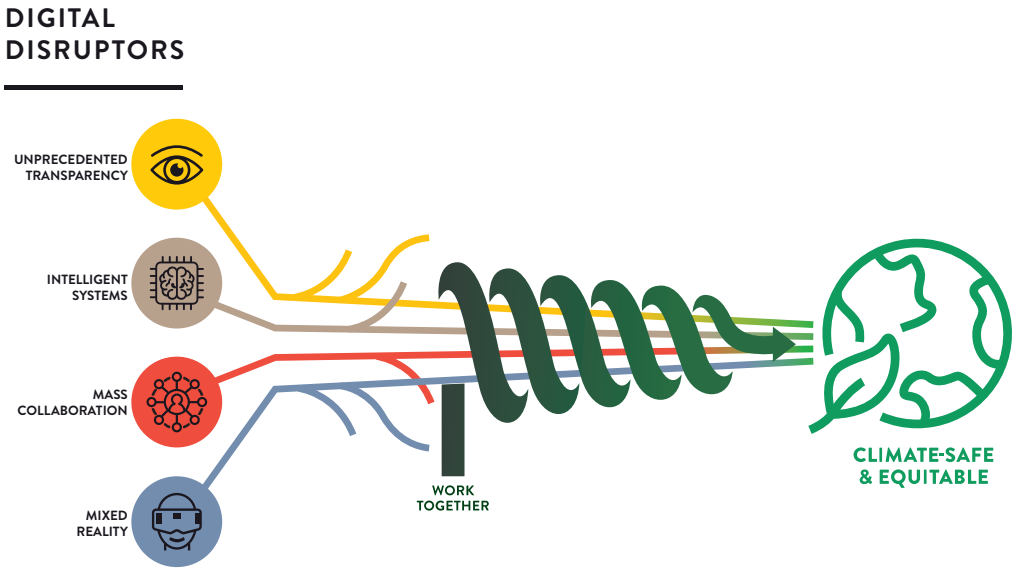
and

SCALE. scaling these systems changes to unleash transformations needed for climate-safe and equitable outcomes.

OUR APPROACH

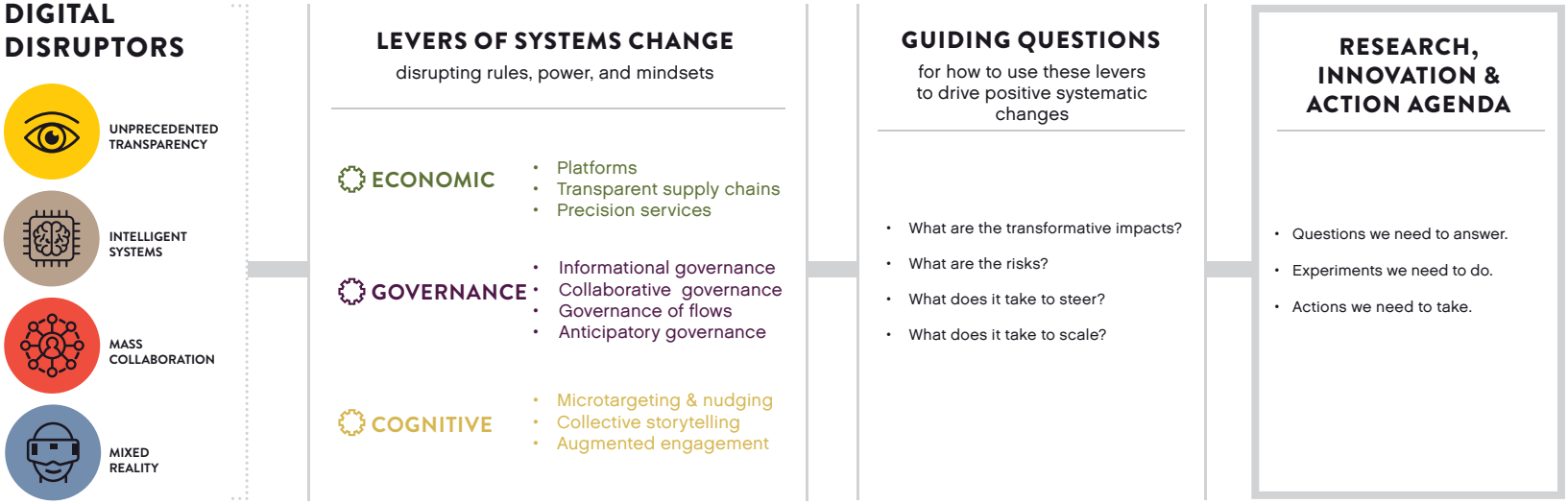
COLLABORATE TO LEVERAGE THE DIGITAL AGE TO HELP DRIVE SOCIETAL TRANSFORMATIONS TO A CLIMATE-SAFE AND EQUITABLE WORLD

The four digital disruptors identified in this report are already driving transformations in social and economic systems. It is unclear where these transformations will lead society. They pose many risks for humanity and the planet. One of the key risks is leaving behind a large portion of the global population who are not yet sufficiently engaged in shaping and benefitting from the digital age. But these digital disruptors may also hold the power to help society achieve a sustainable and equitable path to net-zero emissions. But this can only happen if researchers, tech innovators, policy and business leaders, civil society, and citizens collaborate together to consciously steer these digital disruptions to drive transformations to a sustainable, climate-safe, and equitable world.



THE D^2S AGENDA

BUILDING THE D^2S AGENDA



The diagram above outlines the analysis process for developing the D^2S Agenda. Our research started by asking "what are the systems that are sustaining our unsustainabilty" through an international engagement process. Then we identified how the digital age was already, or had the potential to disrupt the systems constraints to climate action. We focused on four digital disruptors and explored how these four disruptors are already shifting the dominant economic, governance, and cognitive systems. We identified levers of systems change that have been developed by these digital capabilities. For each lever of systems change, we explored the potential transformative impacts, the risks, and what it would take to steer and scale. Finally, we identified key questions, innovations, and actions needed to enable the levers of systems change to drive positive, transformative change.

D^2S AGENDA: RESEARCH, INNOVATION, AND ACTION

Examples of questions that need to be answered, experiments that need to be done, and actions that need to be taken.

TO **DISRUPT, STEER, AND SCALE** **ECONOMIC** SYSTEMS	TO **DISRUPT, STEER, AND SCALE** **GOVERNANCE** SYSTEMS	TO **DISRUPT, STEER, AND SCALE** **COGNITIVE** SYSTEMS
RESEARCH • How can we facilitate the embedding of democratically determined public values (e.g. keeping temperature rise well below two degrees) into digital platforms? • Will an unprecedented increase in transparency of the social and environmental externalities of supply chains lead to transformative shifts in business practices and consumption norms? • What are the social and environmental outcomes of existing digital nudging of consumers? Is digital nudging a powerful lever for shifting production and consumption behaviours and norms at a global scale? • How can vulnerable populations leverage precision service capabilities to develop customized climate mitigation and adaptation solutions?	• How can trust and accountability be effectively created in a world where decisions are based on collective and artificial intelligence? • Under what social and political conditions do the expansion of informational and anticipatory governance systems lead to inclusive sustainability outcomes? How can we leverage the digital age to enable and scale these and overcome constraints such as algorithmic bias and unequal quality and coverage of data? • Under what conditions does Measurement, Reporting, and Verification (MRV) lead to inclusive sustainability outcomes? What technical, institutional, and political constraints must be addressed for MRV to be effective in different governance systems? How can these be enabled and scaled in the digital age?	• Why do some concepts and narratives become embedded in societal discourse while others do not? How do they shape societal change? How has the emergence and reach of new concepts and narratives changed in the digital age and how does this vary with social and cultural context? • How can we minimize and mitigate the risks of using digital technologies and platforms to manipulate cognitive biases and amplify specific worldviews? Can these mechanisms be used ethically to foster a new shared narrative centred on net-zero carbon emissions and global equity? • What are the interconnections between changes in individual and collective mindsets, and how do these translate to collective action? How have these links shifted in the digital age? Do these provide an opportunity to steer and scale inclusive collective action on climate change?
INNOVATION Develop analytic and legal systems and institutions that credibly use new data streams from satellite imagery, other sensors, and crowdsourcing to quantify and expose the cost of environmental and social externalities.	Develop a new tool box for climate governance that leverages the four digital disruptors to better tap into the capacity and expertise of people across networks of states, businesses, local governments, and civil society.	Build a network of targeted engagement strategies that leverage mixed reality tools and intelligent systems to co-create new meta-narratives across populations and geographies.

CROSS-CUTTING ACTIONS
(for enabling conditions)

- Establish a social contract for the digital age.
- Promote inclusion as a touchstone of the digital age.
- Expand open access to high-public-value data.
- Establish foundational standards for the digital sector.
- Expand public–private partnerships to build our digital future.
- Reduce environmental impacts of the digital age.
- Foster cross-sectoral collaboration and innovation.
- Invest in targeted communication, engagement, and education.

2 | INTRODUCTION

INTRODUCTION

Two powerful forces are shaping human destiny: global climate change and the digital revolution. Both are human creations that pose systemic risks to society. The changing climate is driving systemic shifts that threaten to destabilize the health and wellbeing of humankind. Big data, digital platforms, and artificial intelligence are rapidly transforming society in ways that pose systemic risks to the global social fabric. But fortunately, the digital age also presents systemic opportunities for driving the large-scale societal transformations needed to build a climate-safe and equitable world.

Keeping global average temperature rise to well below two degrees Celsius will require cutting greenhouse gas (GHG) emissions in half by 2030 and reaching net zero emissions by 2050 [1]. In other words, we must completely decarbonize our global society over the coming 30 years. This challenge is often approached as a technical carbon management problem. Climate action strategies typically centre on emissions reduction opportunities, broken down by sector, “wedges” of activity [5], specific categories of actions [6], or pathways [7,10].

While research shows that deep decarbonization pathways are technically feasible, rapidly steering society on to those pathways has proven to be a monumental challenge. This is because the dominant formal and informal rules, power structures, and mindsets embedded in our existing social and economic systems reinforce the current carbon-intensive and inequitable development path.

Investors and strategists working on the climate crisis are increasingly turning to digital innovations to improve efficiencies and reduce emissions from high-emitting sectors such as electricity, transport, food, land, and industry [11]. However, little attention to date has focused on how the digital age is driving transformations in underlying social systems that are keeping society on a carbon-intensive and vulnerable path and how these could be leveraged to disrupt the distribution of power, the norms, rules and mindsets that are keeping society on a carbon-intensive path. This is the focus of this report – the D^2S Agenda.

Driven by the digital revolution, society is experiencing massive disruptions that are leading to societal transformations at a scale and pace unparalleled in history. With over 4.1 billion people currently online [12], the digital revolution is reshaping almost every aspect of human lives. Machines, powered by our data, and artificial intelligence (AI) increasingly mediate our social, cultural, economic, and political interactions [9]. As a result, global society is increasingly interconnected through and dependant on both the natural and digital worlds.

Society is increasingly interconnected through and dependant on both the natural and digital worlds.

THE BUIDLING OF THE D^2S AGENDA

This report highlights opportunities and challenges for leveraging the digital revolution to drive systems changes by disrupting the systems currently maintaining our unsustainable development trajectory. *The D^2S Agenda is not a roadmap for how technology can solve the climate crisis*. Rather, it is an exploration of how we can leverage the digital age to disrupt the rules, power structures, and mindsets that are currently constraining climate action and steer society towards a climate-safe and equitable world.

The D^2S Agenda was developed over the course of a year through a combination of workshops, interviews, and desk-top research, as part of Future Earth's Sustainability in the Digital Age initiative. With in-person and online dialogues, Future Earth engaged more than 250 diverse experts from over 30 countries to develop the Agenda.

Initial framing of the D^2S Agenda was established through an online exercise conducted in the spring of 2019 with Futures CoLab, a collaboration between Future Earth and the MIT Center for Collective Intelligence. This online exercise engaged approximately 150 subject-matter experts from around the world in facilitated discussions to explore the question "what are the systems sustaining society's unsustainable – carbon-intensive and biosphere-degrading – lifestyles?" This resulted in the identification of digitally empowered systems changes that are already disrupting or that have the potential to disrupt the systems that are sustaining our unsustainability (see Appendix for details).

Another key contributor to this effort was a workshop on AI & Society held in Montreal, Canada, in September 2019, sponsored by the Canadian Institute for Advanced Research (CIFAR), the French National Centre for Scientific Research (CNRS), and UK Research and Innovation (UKRI). This workshop gathered 30 experts from academia, policy, the private sector, and civil society working in the areas of climate change, AI and digital technologies, and social change. The focus of this workshop was on the near-term actions needed to create the enabling conditions to leverage the digital age to unleash and steer societal transformations towards a sustainable, climate-safe, and equitable world.

> The D^2S Agenda is an exploration of how we can leverage the digital age to disrupt the rules, power dynamics and structures, and mindsets that are currently constraining climate action and steer society towards a climate-safe and equitable world.

These multiple lines of inquiry identified four digital disruptors – unprecedented transparency, mass collaboration, intelligent systems, and mixed reality – that are supporting the strengthening and scaling of key levers of systems change across three societal systems – economic, governance, and cognitive. For each lever, we explored the positive potentials, the risks, and what it would take to steer and scale in order to shed light on how to use the levers to drive positive, systemic changes. This resulted in the Research, Innovation, and Action Agenda, identifying key questions we need to answer, experiments we need to do, and actions we need to take in order to leverage digital disruptors to foster societal transformations to a climate-safe and equitable world.

BUILDING THE D^2S AGENDA

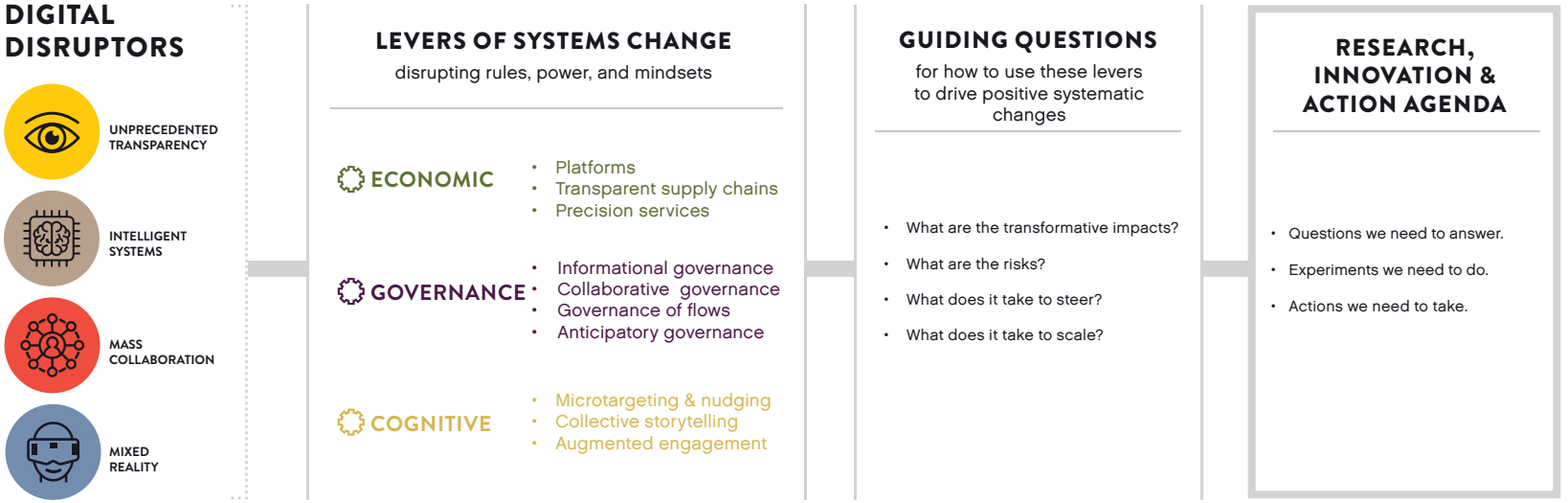


Figure 1. Building the D^2S Agenda. The diagram above outlines the analysis process for developing the D^2S Agenda. Our research started by asking "what are the systems that are sustaining our unsustainabilty" through an international engagement process. Then we identified how the digital age was already, or had the potential to disrupt the systems constraints to climate action. We focused on four digital disruptors and explored how these four disruptors are already shifting the dominant economic, governance, and cognitive systems. We identified levers of systems change that have been developed by these digital capabilities. For each lever of systems change, we explored the potential transformative impacts, the risks, and what it would take to steer and scale. Finally, we identified key questions, innovations, and actions needed to enable the levers of systems change to drive positive, transformative change.

3 | SOCIETAL TRANSFORMATIONS

“

Achieving a sustainable future requires, as well articulated in the IPCC Special Report of 1.5°C global warming, rapid and unprecedented societal transformation. This transformation must be inclusive, involving far-reaching transitions in all sectors and fundamental behavioral change.”

Dr. Youba Sokona
Vice-Chair, Intergovernmental Panel on Climate Change;
Senior Advisor for Sustainable Development, South Centre

SOCIETAL TRANSFORMATIONS & SYSTEMS CHANGE

A collage of images from societal transformations that have occurred throughout history, including the Green Revolution, the fall of the Soviet Union, and the end of Apartheid.

WHAT IS MEANT BY TRANSFORMATIONS

The increasing urgency and complexity of global sustainability challenges such as the changing climate, biodiversity loss, and water insecurity, has led to the emergence of the concept of transformation. It is used in contrast to words such as adjustment, adaptation, or transition which imply incremental changes. Societal transformations refers to fundamental changes in structural, functional, relational, and cognitive aspects of societal systems that lead to new patterns of interactions and outcomes [13]. Given the pace and magnitude of global environmental changes underway, there is a growing consensus that such fundamental changes – transformations – are needed to achieve the goals of the Paris Agreement on climate change and the Sustainable Development Goals in the next decade [14–19]. The need for systems changes now runs deep across the globe. The 2020 Edelman Global Trust Barometer Report found only 18% of the global population surveyed say that the system is working for them – a 2% decrease in just one year since the 2019 report was released [20].

SOCIETAL TRANSFORMATIONS HAVE HAPPENED BEFORE

History shows that rapid societal transformations are possible and not uncommon. The Industrial Revolution, women gaining the right to vote, the Green Revolution, the collapse of the Soviet Union, the end of apartheid in South Africa – all of these societal transformations were spurred by disruptions resulting from a combination of technology, social movements, market signals, and/or government policy. In the past, rapid transformations have taken several decades. More recent societal transformations are measured in years not decades. For example, over just a few years, Microsoft and Apple brought computing to the masses, Google transformed how society accessed information, Facebook transformed how we connect with each other, and eBay and Amazon transformed how we do business.

> Only 18% of the global population surveyed say that “the system is working for them”.

HOW TRANSFORMATIONS HAPPEN

Deliberate societal transformations are often initiated by small groups of committed individuals expressing values not shared by larger groups at a given point in time. These small groups often operate in informal networks that work both outside and within a dominant existing social system, to develop alternatives that disrupt and potentially replace the dominant regime if and when the right opportunity occurs [21,14,22].

Research on transformations is growing in multiple sectors, including energy [23], food [24,25], and urban systems [26,27]. Multiple perspectives have analysed how societal transformations could be conceptualized for sustainability [14,21,28], including socio-technical transitions [29], transformative pathways [30,31], focusing on equity and eliminating poverty [19,32], and personal to planetary actions [33,34]. The digital sector has been a transformative force changing business and governance models for key sustainability sectors such as energy, transport, land, and cities. While there is still limited research in this area and multiple risks to consider, the potential for the digital age to foster societal transformations for sustainability is huge [14,35,36].

However, in order to truly capitalize on the opportunity presented by the digital age, we must move beyond thinking of transformation exclusively in the physical sense – that is, building more efficient or less polluting infrastructure. Investments and policies in the physical structures are 'shallower leverage points' not having as big an influence on systems change [37]. More effective leverage points are those that focus on changing deeply embedded characteristics of how the system functions. These are defined by flows of information, the rules of the systems, and the mental models and power dynamics that control them [37]. These deep leverage points are more difficult to influence but the impacts are much greater. For example, a deep leverage point can be reached by accelerating transformations in the "personal sphere" by fostering change to "individual and collective beliefs, values, and worldviews" [28]. This could include changing the relationship between humans and nature, which many point to as a critical step in transitioning to a sustainable and equitable path [38].

Learning from history and experimenting with new approaches to drive rapid societal transformations for sustainability has become a global priority. In 2015, the nations of the world signed the 2030 Agenda and in doing so agreed "to take the bold and transformative steps … to shift the world onto a sustainable and resilient path" via the 17 Sustainable Development Goals [39].

HOW DIGITAL & TECH INNOVATORS CAN HELP

The digital age has led to societal transformations at a scale and pace unprecedented in human history. While not all the changes have been positive, most have been rapid and widespread. Many started with a simple disruption to the status quo way of doing business, telling stories, or communicating with friends. Then, changes emerged from those disruptions and some began to grow exponentially. We must study how and why certain disruptions led to exponential changes while others did not. We must also quickly establish the institutional and technical conditions to be able to steer digital disruptions to support a low-carbon world. This will take experimentation, collaboration, and adjustments along the way.

The digital sector and the digital innovator are critical to driving the societal transformations needed to achieve a world with net-zero emissions. But they cannot do it alone. Digital innovators, systems scientists, and policy and civil society need to come together to rethink global systemic opportunities and challenges and collectively build a path to global sustainability in the digital age. Each group brings their unique assets to the collaboration. Earth and social systems scientists understand the feedbacks and connections that define systems but are often constrained in their conceptualization of the potential for change. Policy and civil society leaders understand the cross-cutting lever within and outside of government that can drive change. Meanwhile, tech innovators are driven to reconceptualize and rebuild the world beyond perceived constraints (see Figure 2). This mindset of not just thinking outside the box but of breaking the box and thinking exponentially is powerful. But if not put into a full systems perspective this mindset can lead to solving problems not worth solving or worse – to unintended detrimental consequences for the planet and society.

The mindset of digital tech innovators is often to not just think outside the box, but to break the box and think exponentially. This is powerful. Yet, without a full systems perspective, this can lead to unintended detrimental consequences for the planet and society.

LEVERS OF SYSTEMS CHANGE

To rapidly and fundamentally change a system, we must identify what systems scientists call “leverage points”. These are places within a complex system (an economy, an ecosystem, a technology) where a small shift in one thing can produce big changes in everything.

Over 20 years ago, Donella Meadows wrote a seminal article about Places to Intervene in a System, where she proposed a hierarchical list of possible leverage points for transformative systems change. This is represented in a simplified, adapted version in Figure 2.

Meadows established that the strongest leverage points for driving systems changes are altering the rules of the system, the power structures and dynamics that uphold them, and the mindsets that define them. Her work has shaped much of the research on societal transformations over the last decades. Yet, in practice, most climate strategies still focus on the realm of physical and institutional parameters and structures (the left-hand side of the spectrum in Figure 2). According to Meadows and other systems scientists [8, see also 37,38], these types of interventions have the lowest potential for driving deep systems changes. Information flows and control, with a slightly higher potential as a lever of systems change, refers to who has access to information, who controls flows, and how this influences feedback loops. In the time since Meadows’ work on this subject, the digital revolution has radically altered information flows and controls, which has driven massive systems changes throughout society. We now live in a new societal system, where the currency is data and attention, and human and social identities are increasingly defined more by the virtual than the physical world. This new societal system has opened up tremendous opportunities to move further to the right on Meadows’ classic figure (Figure 2) – and to start to push the most influential levers of changing rules, power structures, and mindsets.

By rules, we refer to both informal and formal rules, including informal social and cultural norms as well as formal incentives, punishments, and constraints. Power focuses in particular on the balance of power – who holds power and how it is distributed – and also references the structures underlying power balance. Mindsets are comprised of the value systems, worldviews, and beliefs which underly our opinions. These are often the most difficult to shift but, at a large enough scale, present the most powerful potential leverage point for transformational systems change.

In the new societal system created by the digital age, it is easier than ever before to push those big levers of rules, power structures, and mindsets. Indeed, they are already being pushed and driving even more extensive systems changes in society as a result of the digital age. But many of these changes are intensifying unsustainable production and consumption systems, threatening democracy, and driving deep inequalities. The D^2S Agenda aims to identify opportunities to steer the forces pushing these powerful levers to shift rules, power structures, and mindsets towards a climate-safe and equitable world.

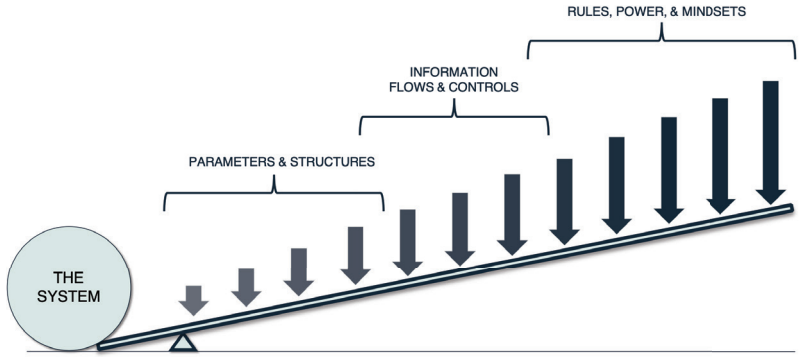


Figure 2. Levers of systems change. In 1999, Donella Meadows identified 12 leverage points to bring about change in a complex system [adapted from 8]. We have grouped these into three main categories: (1) physical and institutional parameters and structures; (2) information flows and controls; and (3) rules, power structures and dynamics, and mindsets.

The digital revolution radically altered information flows and controls [a key lever], which drove massive systems changes throughout society in just a few years.

Climate change protest led by Spanish students in Las Palmas, Gran Canaria, Canary Islands, Spain on March 15, 2019.

4 | DIGITAL DISRUPTORS

“

We shape our tools,
and thereafter our tools shape us.

Often attributed to Marshall McLuhan

DIGITAL DISRUPTORS

The digital age has emerged as a result of widespread access to new information and technologies including big data, cloud computing, the Internet of Things (IoT), blockchain, and rapid advances in machine learning and AI. These digital technologies, in and of themselves, have no disruptive power. Power lies in the ability to combine these technologies to change how companies, governments, and civil societies create value, shape social norms, and communicate with, govern, and perceive the world. The digital age is also characterized by a continuous connectivity among people, driving systemic social–economic changes at a scale and pace unprecedented in human history.

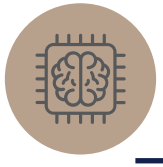
Below we highlight four digital disruptors that have the potential to unleash societal transformations towards a climate-safe world. Yet without a concerted effort, these digital capabilities also hold the power to increase inequality, compromise democracy and privacy, and further degrade climate and the environment [42,43].

UNPRECEDENTED TRANSPARENCY

Satellites and other remote sensors, coupled with digitalization more broadly, are making information more open and accessible. Increasingly, transparency is becoming the norm and privacy is harder to find. Open digital surveillance platforms coupled with involuntary disclosure programmes are redesigning the meaning of transparency and accountability and creating new ways to shape, communicate, and govern sustainability [44].

MASS COLLABORATION

The social web, the ubiquity of smartphones, and the emergence of decentralized digital ledgers are enabling people to connect and collaborate like never before. Massive collaboration enabled by digital technology has given rise to new forms of business around co-production and shared resources, new forms of social movements driven by online communities, and new forms of governance.



INTELLIGENT SYSTEMS

Machine learning and collective intelligence have created new forms of intelligent systems. Computers now have the capacity to gather and analyse data, perform complex activities, perceive and respond to the world around them, adapt based on experience, and communicate with other systems. Machines are also enabling new forms of human interaction. Machines and humans together are now solving bigger problems than either could address alone. Intelligent systems are revolutionizing a variety of sectors from energy to governance.

MIXED REALITY

Technologies are increasingly enabling the merging of real and virtual worlds. This has created the opportunity to build immersive experiences superimposed on the real world, which have been shown to elicit emotional and behavioural responses distinct from traditional engagement methods.

THE DIGITAL DIVIDE

Over half of the global population is online, with over 4.1 billion internet users in 2019 [12]. But access varies widely by region and population (see Figure 3). For example, Africa and Asia have a 28% and 48% internet penetration rate respectively, compared to Europe with a rate of 82.5% [12]. There is also a growing divide in internet access between urban and rural communities [45].

Two main drivers of the digital divide are the educational and economic disparities between countries [46]. The highest growth in internet users comes from mobile broadband access, which requires less investment in hardware as opposed to fixed broadband [47]. To ensure sustainability and equity in the digital age for all, it will be important to disseminate low-cost solutions to close this digital divide.

The economic impacts of the accelerating rate of technology uptake also varies by region. Projections indicate that the economies of some regions (e.g. North America or China) stand to gain more than others from the AI boom due to the rates of adoption and access and how different regions trade with each other through their supply chains [45]. Because the regulation of the digital world is not keeping pace with the changes, the digital divide may be poised to expand. As the commercialization of AI, blockchain, and derivative technologies rapidly expands, the disparity between those who benefit and those who do not will likely to grow unless, as a society, we can proactively tackle the divide as a global priority for sustainable and equitable growth.

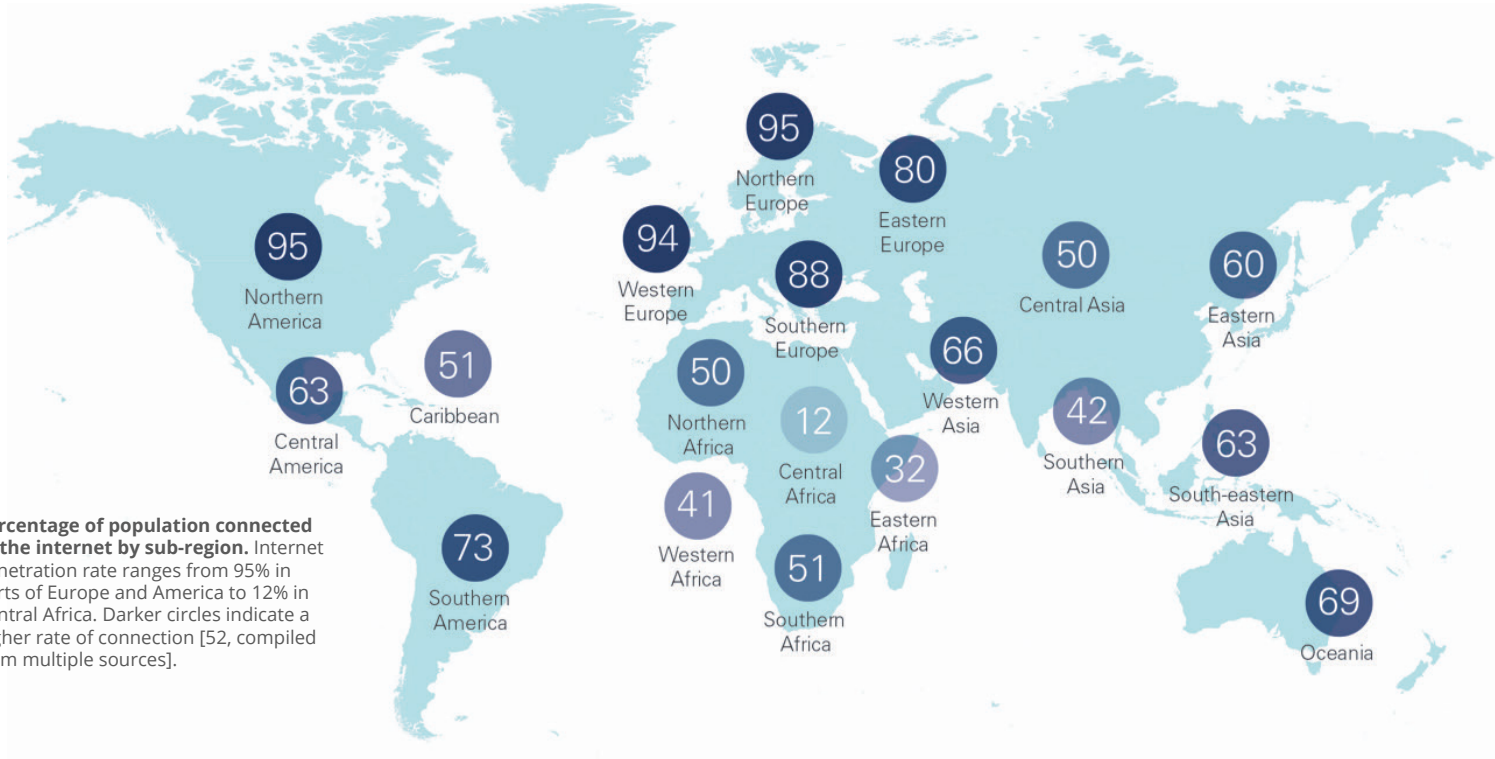


Figure 3. Percentage of population connected to the internet by sub-region. Internet penetration rate ranges from 95% in parts of Europe and America to 12% in Central Africa. Darker circles indicate a higher rate of connection [52, compiled from multiple sources].

DIGITAL TECHNOLOGIES TODAY HAVE LARGE CARBON FOOTPRINTS

Progress is being made. Continuing to shift the digital sector to renewables is critical.

ARTIFICIAL INTELLIGENCE

AI has incredible potential for increasing efficiency. A recent report by PwC and Microsoft showed that strategically employing AI could lead to a 4% reduction in global GHG emissions by 2030 [45]. This can help to reduce GHG emissions [49] but can also improve many other factors related to human impact on the environment, including, for example, enhancing conservation efforts [50] and better management of water resources [51].

Given the great potential of AI, better understanding the climate impact of developing AI and training machine learning models is critical. One analysis found that training a single AI model can emit nearly five times as much carbon as the lifetime emissions of a single car [52]. Other studies, however, have cautioned that the assumptions underlying this finding are not representative of common practice, making generalizations to all AI and machine learning activities inaccurate [53]. Despite this divergence, there is agreement that more can and must be done to reduce the carbon footprint of AI and machine learning. This includes ensuring that cloud providers and data centres used in training models rely on renewable energy sources and enhancing transparency with regard to emissions [53,54]. The development of an openly accessible Machine Learning Emissions Calculator (https://mlco2.github.io/impact/) may help, as it will enable the AI and machine learning community to track emissions and share data and to include them with published code and papers.

AI could be a critical component of the digital game changers for climate through its potential to drive systems-level change. But to scale, it must be powered by renewable energy.

Smart home service device is displayed at CES 2017 at the Sands Expo and Convention Center on January 5, 2017 in Las Vegas, Nevada. The use of AI-powered devices in homes and business is becoming mainstream.

BITCOIN

Energy consumption estimates for bitcoin vary significantly, but comparisons are presented in the order of the annual energy use of whole nations (e.g. Jordan or Sri Lanka) [55] or almost twice that used by Google as a company (5.7 TWh) [56].

To track this, the University of Cambridge recently released the Cambridge Bitcoin Electricity Index, which is an online tool that provides real-time estimation of the energy requirements of the bitcoin network. Their estimates range between 21 and 146 TWh [57].

Bitcoin is built on blockchain, which is a distributed and immutable electronic ledger of every transaction that takes place in a network. Not all blockchains are created equal. Some blockchains, including bitcoin, employ proof of work protocols to secure transactions. Others are based on proof of stake – a less energy-intensive protocol for which great strides are being made to overcome trade-offs in terms of security. A wide variety of efforts are working to build climate-smart blockchain options. Shifting to renewable energy sources will eventually overcome many of these issues, but time is of the essence.

The mining rigs of a supercomputer and air filters are pictured inside the bitcoin factory 'Genesis Farming' near Reykjavík, Iceland on March 16, 2018. At the heart of Iceland's breathtaking lava fields stands one of the world's largest bitcoin factories at a location rich in renewable energy, which runs the computers creating the virtual currency.

SYSTEMIC OPPORTUNITIES

In this report, we explore the potential of the four digital disruptors to disrupt the existing rules, power structures, and mindsets that are maintaining society's carbon-intensive path and constraining climate action. We focus on the constraints embedded in three social systems: economic, governance, and cognitive. These three systems are represented below as gears that are driving society along the current high-emissions pathway. The premise of the D^2S Agenda is that the four digital disruptors are already disrupting the rules, power structures, and mindsets embedded in each of these social systems, and driving societal transformations. An opportunity exists now to steer these transformations to build a climate-safe and equitable world.

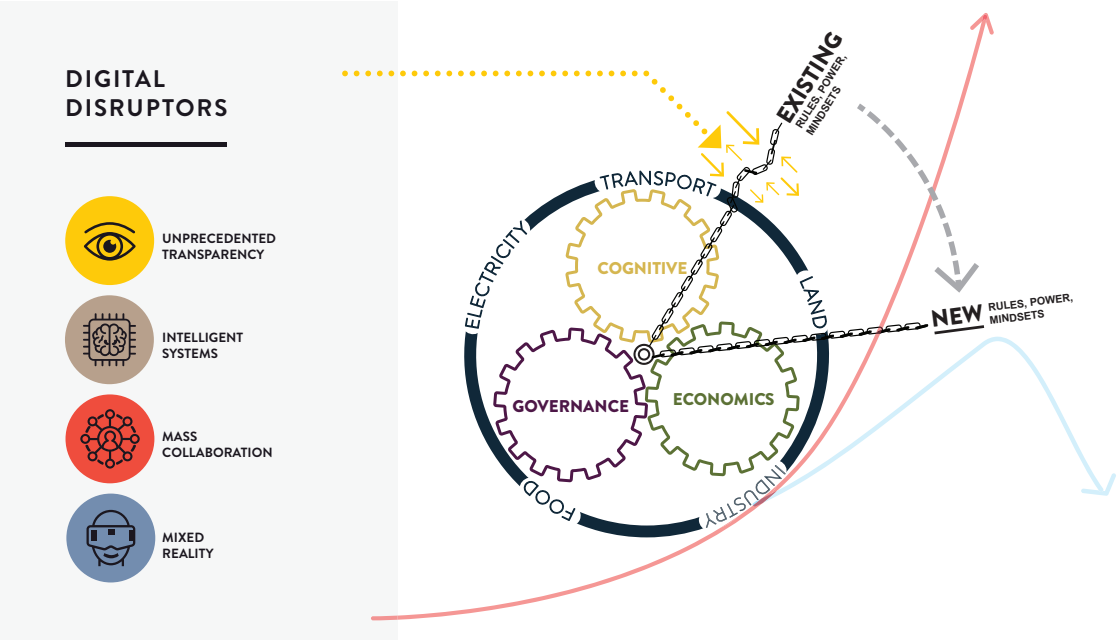


Figure 4. Digital disruptors' systemic potential. The outer circle represents the proximate sources of GHG emissions that are contributing to the high emissions pathway. The gears inside this circle represent the social systems cutting across all emitting sectors. The black chain that is connected to the centre of the gears represents that these social systems are constrained by the rules, power structures, and mindsets embedded in them. The premise of this report is that the digital disruptors are disrupting the rules, power structures, and mindsets, and open up the potential to steer us to a lower GHG emissions path – represented by the blue arrow.

SYSTEMIC RISKS

While the societal transformations resulting from the digital age create opportunities, they also pose a series of systemic risks related to both intentional and unintentional harm, as listed below. This list is not intended to be comprehensive, but rather to be illustrative of challenges associated with the power of the digital age, providing context for the urgent need for research, innovation, and action. The risks highlight the need to focus research and innovation not only on the digital sector as a source of tools to increase efficiencies, but also as a force of systems changes.

1. If we continue on our current path, the digital age could accelerate and intensify resource- and emissions-intensive development and risk exceeding planetary boundaries [36,58].
2. Digital technologies can enable increasingly authoritarian actions by governments around the world, undermining the agency of citizens – for example, through rigid control of information [59,60].
3. Irresponsible use of digitally empowered decision-making and the increasing impact of social media and echo chambers leading to political polarization may erode democracy and deliberation [36], potentially contributing to the rise of digital dictatorship [60].
4. The global economy is increasingly dominated by digital companies that can at times circumvent government regulations and fair contributions to public funds [61,62].
5. Massive upheaval in current labour markets may occur as a result of increasing automation in the workforce, leading to loss of human dignity as opportunities for “meaningful work” are reduced [36,63].
6. Inequality at the global scale may worsen due to an inability to overcome digital divides or address information asymmetries, resulting in unequal access to and benefits from digital capabilities [36,58].
7. Many companies now derive value from data – oftentimes collected for free from citizens – leading to serious privacy concerns [58,64] and worries that this might intensify with the expansion of surveillance capitalism [65,66].
8. Advances in cyberspace – enabling communication across computer networks – have opened up a world of opportunities but have also led to incredibly complex systems difficult for human minds to comprehend. As a result, cybersecurity and safety present increasingly significant risks [67,68].
9. Without adequate and transparent integration of ethical and environmental considerations into their development, there is a risk that various applications of algorithms could perpetuate and intensify biases and lead to inequitable and environmentally detrimental outputs [69,70].

CROSS-SECTOR COLLABORATION IS NEEDED TO STEER DIGITAL DISRUPTORS

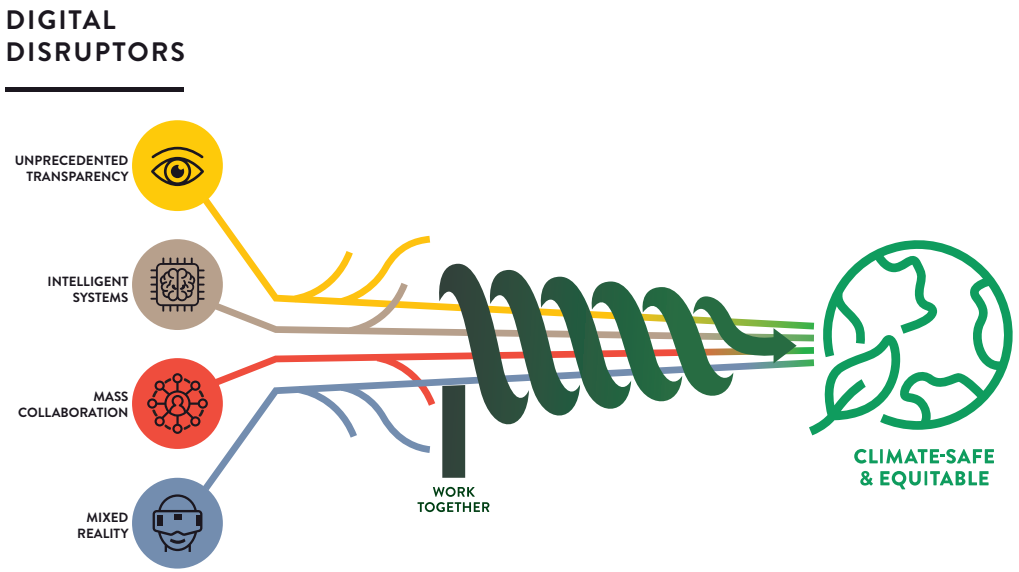
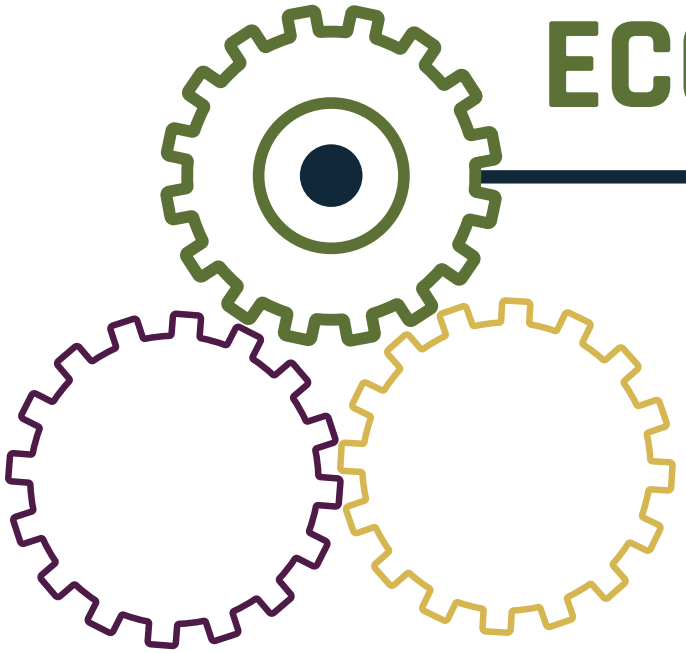


Figure 5. Working together. It is unclear where the digital disruptors will lead society. Individually and together, they are driving widespread societal transformations. Through focused collaboration among researchers, tech innovators, policy and business leaders, civil society, and citizens, we believe we can steer them towards the climate-safe and equitable world we want.

5 | RESEARCH & INNOVATION AGENDA



ECONOMICS

“

He is led by an ~~invisible~~ digital hand to promote an end which was no part of his intention.

Adam Smith

ECONOMIC SYSTEMS

GOAL

Disrupt the rules, power structures, and mindsets that constrain climate action by steering digital disruptors to drive changes in existing economic systems. Scale these systems changes to unleash the transformations needed for climate-safe and equitable outcomes.

WHAT WE ASKED

How are digital disruptions to economic systems shifting the formal and informal rules, the distribution of power, and the individual and collective mindsets that are currently sustaining our unsustainability?

Can these digital disruptions be leveraged to unleash equitable societal transformations to a net-zero carbon emissions world? If so, how?

WHAT WE FOUND

We identified the following digitally empowered levers of change as having the potential to positively disrupt existing rules, power structures, and mindsets of economic systems.

- Digital **Platforms** are increasingly powered by intelligent systems and the mass collaboration of people around the globe. They have also empowered the development of new business models with the potential to decentralize economic power and change the rules and mindsets of economic systems. But limited governance of these digital platforms, and of the data and algorithms embedded in them, has led to a greater centralization of power in the private sector – who own the data – as opposed to the people served by the platforms.

- Increasingly accessible data – from satellites and many other remote sensors – are making it easier than ever to track products from cradle to grave. The possibility of having truly **Transparent Supply Chains**, with environmental and social externalities made publicly visible, could be on the horizon. While many critical pieces to the puzzle are still missing, targeted research and innovation could fill these gaps. Ultimately, though, the sustainability and equity outcomes of such enhanced transparency in supply chains will depend on key issues connected to who owns and controls the information and the political and normative context in which it is deployed.

- Enhanced transparency and intelligent systems are enabling more valuable services targeted to specific contexts, for example in agriculture, disaster risk management, and medicine, that have the potential to improve outcomes at less cost. These new, lower-cost **Precision Services** open up novel opportunities to vulnerable communities for climate risk management services that were previously unavailable to them. However, whether these services ultimately empower vulnerable communities will depend on what data is available, who owns and controls access to the data, and the process of deriving information and knowledge from it.

RESEARCH & INNOVATION

Each of the levers of change listed above are already in place at different scales and in different sectors. The research and innovation needs outlined below were developed to help steer and scale these levers to drive societal transformations towards a climate-safe and equitable world.

RESEARCH: Questions we need to answer.

- How can we facilitate the embedding of democratically determined public values (e.g. keeping temperature rise well below two degrees) into digital platforms? What are the public values that should be incorporated into the design of the "platform society"; how do we do that, and who is responsible for doing so?
- How can we effectively manage and regulate an economy dominated by digital platforms for inclusive and positive sustainability outcomes? Who is responsible and accountable for the outcomes resulting from the "platform society," such as the circulation of misinformation and the implications of choice architecture?
- Will a massive increase in public visibility of the social and environmental externalities of supply chains lead to transformative shifts in business practices and consumption norms? Can big data, data analytics, and machine learning provide salient, credible, legitimate information – that is ethically derived – to effectively steer development, planning, and business decisions towards a sustainable and equitable world?
- What are the social and environmental outcomes of existing digital nudging of consumers? Is digital nudging a powerful lever for shifting production and consumption behaviors and norms at a global scale?
- How can vulnerable societies leverage precision service capabilities to develop customized climate mitigation and adaptation solutions?

INNOVATION: Where we need to experiment and learn by doing.

1. Develop analytic and legal systems and institutions that credibly use new data streams from satellite imagery, other sensors, and crowdsourcing to quantify and expose the cost of environmental and social externalities.
2. Improve the ability to track and monitor carbon and other environmental goods and services from big data and remote sensors.
3. Develop new business models that ethically and legally leverage individual and social data to steer society towards sustainable consumption patterns, while strengthening human agency.
4. Develop new models that support co-developed knowledge-intensive precision services for vulnerable populations currently disconnected from the digital world.

ECONOMIC SYSTEMS

Recent research suggests that over the next decade, climate action could deliver US$26 trillion to the global economy [71]. The private sector must be part of the climate solution. Capturing the trillions of dollars will require more than simply reducing the impact of existing business models; it will require building new models that drive and thrive on low-carbon, biosphere-positive, and equitable growth. “Business model” is used here to refer to the way a company seeks to create, capture, and share value. Traditional business models are based on linear models of economic growth driven by mass production and mass consumption, tightly coupled to fossil fuels and massive amounts of waste. This economic system is fuelled by neoliberal policies of free-market capitalism that shift power towards the private sector and away from government spending and public ownership. Many are calling for the need to rethink the neoliberal frame – which is increasing inequalities, and in turn hurting economic growth, perpetuating vulnerabilities, and increasing environmental degradation [72,73] – and shift towards a circular economy based on use, sharing, reusing, and recycling. Recently, a Business Roundtable statement was released, signed by 181 CEOs who committed to run their corporations not just for the benefit of shareholders but for the broad diversity of stakeholders – consumers, suppliers, communities, and employees [74]. Unfortunately, the statement did not explicitly call out environmental sustainability.

While the growth in production of electronic devices and the digitalization of society is an industry that is itself built on the linear production and consumption model, it also provides opportunities to disrupt the linear economic model and the neoliberal capitalist system. This disruption is beginning, not only through the rumblings at institutions such as the Organisation for Economic Co-operation and Development (OECD), the World Economic Forum (WEF), and the International Monetary Fund (IMF), as well as work done by UNEP on the Digital Ecosystem [58], but also by new business models that are powered by the digital age through collaboration, intelligent systems, and increased transparency.

New business models and processes are enabling shifts in production and consumption practices – giving rise to “prosumers”, customers who both produce and consume a product or service – and challenging the intellectual underpinning of neoliberal policies. Adam Smith’s “invisible hand”, the unobservable force that helps to balance the supply and demand of the market, has disappeared and been replaced by the “digital hand” [75]. In the digital economy, transactions and even intentions are computer mediated. It is still unclear what the implications of the digital hand will be for people and planet. But what is clear is that it is incumbent on society to take an active role in helping guide the digital hand towards a sustainable and equitable path.

Here we explore three digitally empowered levers to disrupt economic systems to accelerate and expand sustainable actions: (1) platforms, (2) transparent supply chains, and (3) precision services.

Society must take an active role in helping steer the digital hand towards a more sustainable and equitable path.

People's behaviour, connections, beliefs, and sentiments provide core data that fuels the economy today.

PLATFORMS

The digital age has given rise to new business models centred around digital platforms [76], big data, networks, and algorithms, which have enabled the rise of a new economy based on sharing, giving, or obtaining access to goods and services [71,72]. Platforms work through the interplay of technologies (data, algorithms, interfaces), business (operators of the platforms), and users – where users here include individuals, corporations, governments, and civil society [77].

Platforms enable users to market personal assets, experiences, or skills at a scale previously inaccessible to individuals or small enterprises (e.g. Airbnb, Uber, Huffington Post). From this perspective, platforms can shift economic power from traditional institutions, such as hotels, taxis, and newspapers, to individuals. On the other hand, platforms lead to a concentration of power in the hands of the few platform operators, who are able to position themselves as the gatekeepers and mediators of data, content, and value [78].

Digital platforms do not simply connect social and economic actors but fundamentally steer how they connect with each other. These digital platforms are not neutral. Platforms inscribe norms and values in their choice architecture [76]. Furthermore, they can rapidly shift social norms at scale through simple changes in their interfaces and selection options. For example, when Google added walking, biking, and public transportation as part of their standard travel time calculations, they were helping to shift social norms. When Facebook added an “other” option to gender classification, it influenced social norms beyond what were then the conventional binary options [76].

Currently the dominant platform architecture reinforces the rules, power structures, and mindsets of our high-carbon society. But these could be reshaped to deliberately steer society towards a climate-safe and equitable world. How to govern platforms, and the data and AI that power them, is a growing topic of discussion and debate [79]. Data flows and algorithms across a variety of platforms conceal social and economic information, increasingly making societies opaquer and creating what has been referred to as a “black box society” [80].

Given the unprecedented influence that digital platforms, such as Google, Facebook, and Twitter, have on democracy and the global economy, many are looking toward establishing a framework for regulating or governing platforms as we do public utilities [81]. While many national and regional efforts are emerging to govern data and AI [82], at a global stage there is no clear path to developing an effective governance mechanism. But given the influence of platforms on informal rules, power structures, and mindsets, it is clear that developing effective governance mechanisms for digital platforms is vital for securing equitable strategies for steering societal transformations to a net-zero emissions future.

Digital platforms are not neutral. Platforms inscribe norms and values in their choice architecture. Furthermore, they can rapidly shift social norms at scale through simple changes in their interfaces and selection options.

CAN THE DIGITAL HAND STEER SOCIETY TOWARDS A LOW-CARBON LIFESTYLE?

Digital platforms have become a ubiquitous part of our society, influencing what we purchase, who we listen to, and how we interact with each other and the environment. Influencing the decisions of billions of users every day, are these valuable levers for societal change?

To explore these as viable levers, many questions remain, including the following:

- *Who is responsible and accountable for the outcomes resulting from the platform society such as the circulation of misinformation, the prioritization of products, and ideas?*
- *Should digital platforms be required to nudge to low-carbon options? What are the ethical and legal constraints to digital platforms nudging?*
- *What would be the carbon impact of digital platforms nudging at a global scale?*

SHARING ECONOMY AND SURVEILLANCE CAPITALISM

New business models based on platforms, data, artificial intelligence, and co-development have shown great promise for moving society away from the linear model of mass production, consumption, and waste, towards more of a use-based economy, disrupting the neoliberal systems by decentralizing power and ownership. Yet the veil of extractive industry and inequitable growth still weighs heavy, even on those models that appear to be the most disruptive. The platform-based companies Google, Apple, Facebook, and Amazon have aggregated power at unprecedented speed and scale: their combined market capitalization grew from US$430 billion in 2010 to more than US$2,300 billion in 2017 [83]. The platform economy is based largely on the extraction and accumulation of data collected through user surveillance (what is often referred to as "surveillance capitalism"). As Harvard's Shoshana Zuboff defines it, surveillance capitalism "aims to predict and modify human behavior as a means to produce revenue and market control" [84]. The result is a centralization of power and concerns over privacy, ethics, and the backlash against labour practices [85].

Despite these growing concerns, the platform business model continues to power the sharing economy. It is estimated that 70% of Europeans [86] and 72% of Americans [87] are involved in sharing economy activities. Sharing has become big business with the rise of companies such as Uber and Airbnb, which are criticized as centralizing power and monopolizing markets [88]. The sharing economy is expected to grow to a US$335 billion industry by 2025 [89]. There are currently 17 billion-dollar companies built on sharing or collaborative economy models [90].

Meanwhile, traditional companies are adapting their business models to fit with more collaborative cultures [91,92]. As the sharing economy takes off, some see it as having great potential to disrupt the neoliberal model and promote needed shifts in consumption behaviours [93], but better governance models are urgently needed [93]. Meanwhile, others argue that the sharing economy continues to bolster the resource-intensive consumption and production of free-market capitalism [94–96]. In fact, some have called the sharing economy "neoliberalism on steroids" [97], commoditizing aspects of people's daily lives that were previously outside the reach of markets [98].

At the centre of these concerns are top-down "sharing" models, where data is the currency that defines power. Big data enabled the growth of the sharing economy, which is rapidly becoming a core part of the global economy. The governance of the data that fuels the sharing economy and the regulation of the platforms that manage them will likely define how this trend shapes the rules, power structures, and mindsets of economic models moving forward – and their sustainability outcomes. Governing the access to and use of data in the sharing economy can help to set the foundation for sharing power and sharing resources in a more equitable manner. New forms of platform cooperatives are building new business models to share data and power among workers. For example, co-ops such as Juno and People's Ride are emerging as alternatives to Uber. Experimenting with new ways of sharing and using data within platform or hybrid business models could prove to be powerful means for breaking out of the ties of neoliberal policies and building new norms of collective consumption.

The governance of the data that fuels the sharing economy and the regulation of the platforms that manage them will likely define how this trend shapes the rules, power structures, and mindsets of economic models moving forward – and their sustainability outcomes.

STEERING DIGITAL DISRUPTORS FOR ECONOMIC SYSTEMS CHANGE

To build a climate-safe and equitable world, we must overcome the exploitative and ecologically destructive biases of neoclassical and neoliberal economic systems. Momentum is already building around alternative models such as:

Circular economy: The new economic model that entails gradually decoupling economic activity from the consumption of finite resources, and designing waste out of the system [99].

Stakeholder capitalism: The proposed reorientation of capitalism that calls for corporations to redirect their focus from shareholders to stakeholders including customers, employees, and society as a whole [100,101].

Doughnut economics: The new economic framework that orients growth and progress within both social and environmental boundaries, which together define a safe and just operating space for humanity [102].

How these, and related, models for reimagining economic systems will evolve is still uncertain. The four digital disruptors identified in this report create the opportunity to help strengthen and scale each of them, but they also could undermine them. Intelligent systems can help to accelerate a transition to a circular economy by improving operating systems and opening opportunities for new business models [103]. Blockchain and other mass collaboration techniques can help to strengthen stakeholder capitalism by shifting power dynamics through new forms of co-production and ownership. Similar systems could be used to guide and incentivize society towards socially just and environmentally sustainable consumption patterns.

However, each requires collecting and processing huge amounts of data and exploring new approaches to governing the digital sector, which confronts privacy and ethical concerns. Research, innovation, and near-term actions are urgently needed to address these issues to be able to effectively leverage digital disruptors to help strengthen and scale these alternative economics systems. For example:

- *Analysts need to explore the ethical and legal approaches to direct digital nudges to support a transition to a climate-safe and equitable world.*
- *Civil society, governments, and the private sector must collaborate to ensure that information security, data privacy, ethics, and the threat of disinformation are managed to catalyse positive transformation.*
- *Public-private collaborations are needed to develop verifiable and enforceable rules regarding consent, data ownership, aggregation, protection, storage, and disposal*

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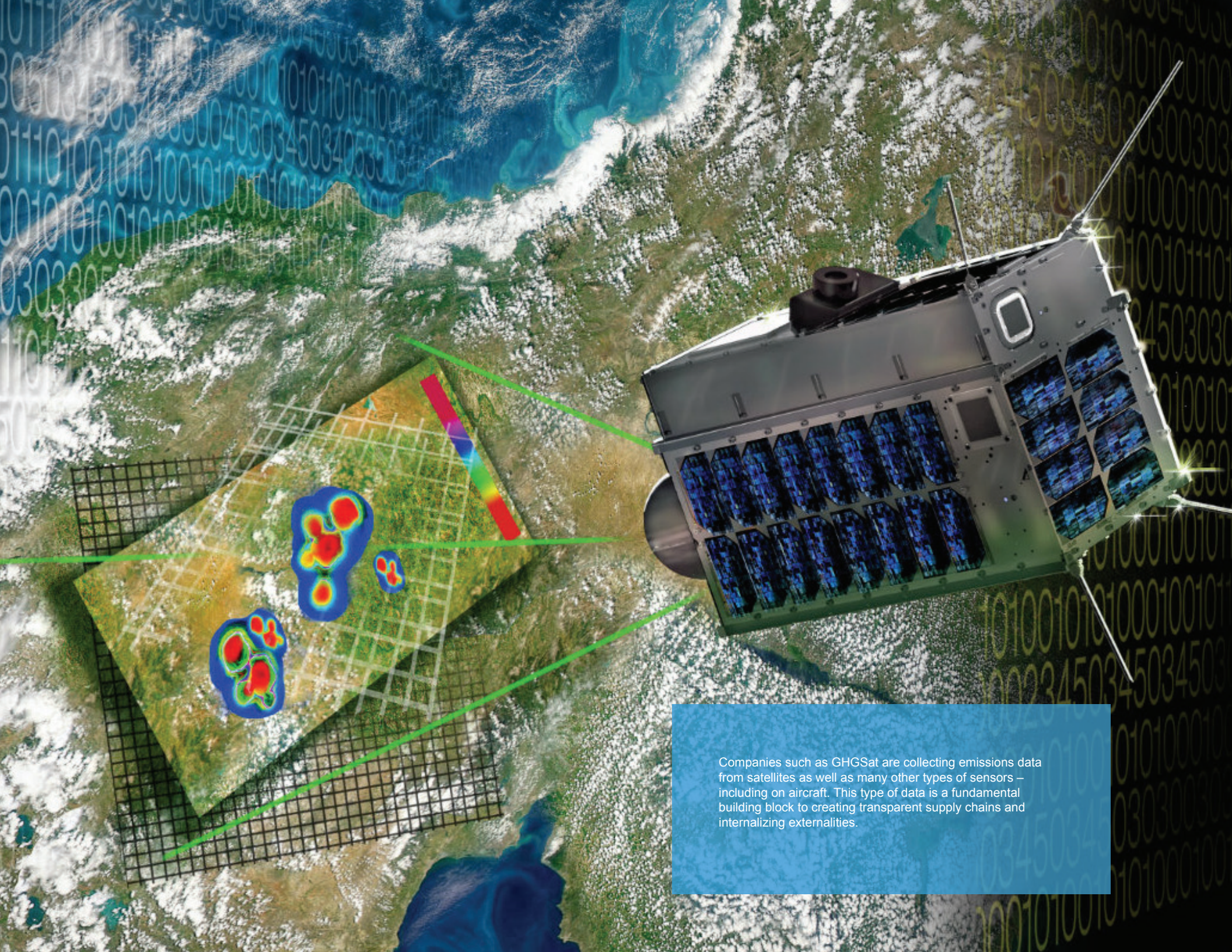


Companies such as GHGSat are collecting emissions data from satellites as well as many other types of sensors – including on aircraft. This type of data is a fundamental building block to creating transparent supply chains and internalizing externalities.

TRANSPARENT SUPPLY CHAINS

Global supply chains cross multiple regulatory borders and involve the exchange of goods and services from a wide diversity of places and actors. The diversity of attributes and actors shaping supply chains influences how sustainability norms are expressed and reinforced [104]. The complex exchange of material, informational, and financial resources can lead to a range of unintended effects that stretch across the globe [105], with social and environmental externalities that have traditionally been difficult to regulate [106]. But that is changing.

Aerial view of deforestation to clear land for palm oil and rubber plantations in Thailand in 2018. This is a powerful example of the types of environmental externalities which were often hidden behind complex, global supply chains but are increasingly visible in the digital age.

MONITORING AND QUANTIFYING EXTERNALITIES

Externalized costs (or externalities) are among the great unknowns of economic activities. They make it difficult to disincentivize extractive and unsustainable activities and to level the playing field for circular and sustainable business models. But greater access to data and the analytical capacity to process them is making this increasingly feasible.

There is increasing demand worldwide from regulators and consumers for greater transparency in reporting and accounting for social and environmental externalities, including GHG emissions, deforestation, and labour conditions. Meanwhile, big data, earth observations, IoT, and AI are increasing public visibility of social and environmental externalities [106] and forcing companies to internalize these costs into their business models [107]. Some companies are now building their brands around transparency [108] and even developing business around increasing transparency. For example, Optel's Geotraceability and other similar digital technologies now enable companies to monitor the social and environmental impacts of production. Non-profits are also emerging in this space. For example, new non-profit WattTime, which recently won the Google AI Impact Challenge grant [109], uses digital tools to let customers know how clean energy is in real time. Systems such as these could not only empower consumers but also expand corporate adoption of "shadow carbon pricing", the voluntary implementation of an internal carbon price [for a detailed definition, see 94]. Meanwhile, traceability can facilitate programmes to enable reuse and repurposing of products and thus can provide pressure to move towards a circular economy.

While there has been growing interest in supply chain transparency for sustainability management and a proliferation of supply chain transparency initiatives [111,112], there has been limited assessment of how these different transparency systems are influencing governance regimes and how they can be best designed and implemented to be positive catalysts for potentially transformative change [106]. Key factors have been identified for linking increased transparency to improved sustainability outcomes. For example, one is trust; research suggests that transparency can build trust, but if transparency is used to replace trust, results can be counterproductive [113]. More targeted and coordinated research, innovation, and actions are needed to effectively use this lever for large-scale systems change.

ENABLING CONDITIONS TO SCALE DEMAND FOR LOW-CARBON GOODS

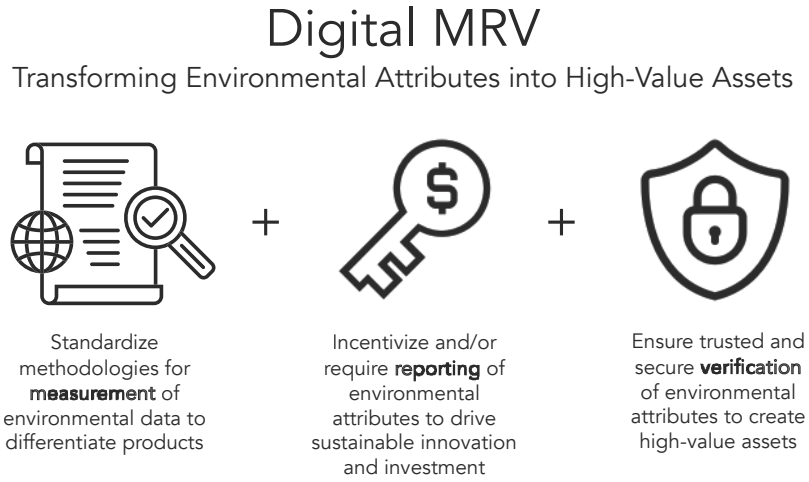
For most goods and services, consumers are unable to differentiate low-carbon options from higher-polluting alternatives in the market. In the power sector, renewable energy certificates have become a standardized, trusted way to overcome this constraint; as a result, energy investors and customers are able to monetize clean energy demand.

Imagine if there were a similar "certificate" for other low-carbon goods. Historically, it was difficult or impossible to measure, report, and verify the environmental attributes needed to accurately assess the emissions impact of various industrial processes and products. However, exponential growth in sensors, data, and analytics capabilities – as well as emerging AI and blockchain technologies – are changing that by enabling more transparent supply chains.

To develop low-carbon "certificates" for a broader diversity of goods we must strengthen and expand digital MRV systems that leverage data to enable markets to value environmental attributes [114]. To do this, two major actions are needed:

1. Establish standard methodologies for defining product categories and measuring environmental attributes of industrial commodities.

2. Co-develop incentives and/or regulatory requirements for reporting and verification through dialogues among industrial companies, institutional investors, and policy-makers.



REVERSE SUPPLY CHAINS

A reverse supply chain is the movement of goods from customer to vendor, a veritable flip of the regular supply chain. A major reason for the failure to valorise the waste created in a linear economy is the lack of information about it. Information transparency, when applied to materials and products, has the potential to radically change how reverse supply chains work. It enables tracking, collection, sorting, transporting, and refining of waste into new resources and products, to the point where the concept of "waste" is rendered less relevant. Making such information transparent is challenging because it entails an element of standardization and a number of data ownership and privacy issues. Yet it is possible. For example, Swachhcoin leverages AI and blockchain to enable transforming waste into new goods; when a consumer contributes to the raw materials by throwing their own waste into Swachhcoin bins (which is automatically detected by Swachhcoin), the consumer gets a rebate on future purchases.

ENABLING AND CONSTRAINING TECHNOLOGY

Blockchain could be a powerful tool to enable the above transformations by building interoperable layers that facilitate the ability of different value-chain players (who may be partly working in competition) to read from the same script. Many questions remain, however, on how to govern, fund, and run such protocols. The biggest blockchain protocols, in particular bitcoin, consume massive amounts of energy, orders of magnitude more energy per transaction than a typical credit card [55,56]. These impacts will need to be addressed before this can be an effective part of the solution.

Traditionally, supply chains have involved the transfer of goods and services from producers to consumer. A small but growing proportion of the global supply chain is reversing this trend, with goods flowing from consumers back to producer and valorizing waste.

> "Digital technologies are enabling unprecedented transparency of lifecycle impact data of raw materials, products, and supply chains and present new platforms to channel consumer behavior into market signals to activate demand for sustainable products. In order to steer towards this opportunity, it is imperative to advance dialogues around the role of government and other actors in the digital economy.

Tom Hassenboehler, Partner, *The Coefficient Group;* Executive Director and Founder, *EC-MAP*

PRECISION SERVICES

The digital age has enabled the scaling of customized knowledge-intensive services, which we refer to here as “precision services”. Precision agriculture, precision disaster risk management, precision medicine, and precision insurance are all examples of leveraging big data, IoT, machine learning, research, and co-production of knowledge to provide targeted services that traditionally had to be provided more generally. For example, precision medicine refers to the tailoring of medical treatment to the individual characteristics of each patient. It recognizes that people respond to medical ailments and treatments in different ways based on characteristics of the individual. Precision medicine uses genomic data, vast amounts of patient healthcare data, and machine learning to target treatments that the individual patient needs [115].

Climate change is another sector where precision services are beginning to emerge. Climate-related risks have typically been difficult for government, investors, and businesses to plan for and manage [116,117]. However, advances in climate and data science are making customizable information about climate risks an increasingly accessible service. Big data and AI are increasingly being used to improve climate projections (e.g. CLIMA), map vulnerabilities, and build resilience [49,118]. Companies such as Jupiter Intelligence, One Concern, and non-profits such as the Climate Impact Lab, are turning scientific information into customizable platforms that governments and investors are beginning to use to manage risks and direct finance [117].

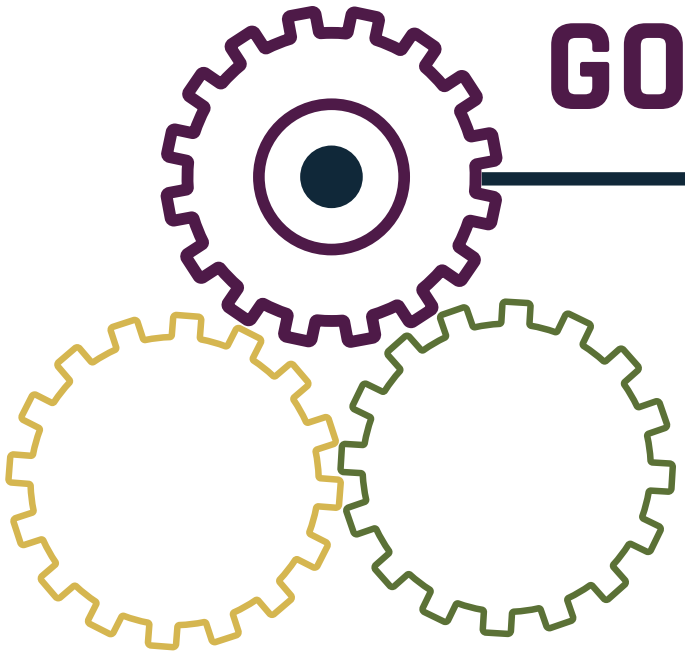
This trend of increasing access to customized climate services may help to mainstream, or normalize, the consideration of climate risks in government, business, and investments. However, for these new developments to help drive societal transformations to build climate-resilient communities, they must evolve from generic tools for prediction and scenarios to tools for empowerment and co-development rooted in specific political and normative contexts.

Research shows that inequality and power relations are critical factors generating and perpetuating vulnerability to climate change [119–124]. One example of this dynamic is the inability of the most vulnerable to insure themselves against climate-related risks. In 2016, only about 100 million people in Africa, Asia, and Latin America were covered by insurance schemes against climate risks [125]. Fortunately, there is a growing focus on exploring new insurance schemes to support climate risk management in low-income communities (e.g. resilience bonds, microinsurance, index insurance). Big data and intelligent systems are opening up new business models for insuring these communities from climate-related risks [126]. Meanwhile the disaster management community has demonstrated how mass collaboration, intelligent systems, and unprecedented transparency are helping to build networks and empower vulnerable communities to work together to provide targeted disaster response [127].

There is an urgent need to connect precision climate services to help expand insurance for low-income communities. It is also critical to learn from the digital humanitarian and disaster risk management communities about the opportunities and challenges for co-developing precision climate risk management services that empower vulnerable communities confronting the increasing intensity and frequency of climate risks around the world.

Can precision climate services help build new business models that would shift the power dynamics that drive economic development pathways? What are the data, technology, and policy issues that need to be addressed to rapidly and effectively scale precision services that empower the poor and build equality?

Two girls must step precisely as they cross a narrow bridge in Bangladesh. Precision services can be immensely helpful in areas at risk of flooding or other hazards and have the potential to more evenly distribute the benefits of the digital revolution to more marginalized or vulnerable populations.



GOVERNANCE

“

Bureaucrats sometimes do not have the correct information, while citizens and users of resources do.

Elinor Ostrom
Nobel Laureate

GOVERNANCE SYSTEMS

GOAL

Disrupt the rules, power structures, and mindsets that constrain climate action by steering digital disruptors to drive changes in existing governance systems. Scale these systems changes to unleash the transformations needed for climate-safe and equitable outcomes.

WHAT WE ASKED

How are digital disruptions to governance systems shifting the formal and informal rules, the distribution of power, and the individual and collective mindsets that are currently sustaining our unsustainability?

Can these digital disruptions be leveraged to unleash equitable societal transformations to a net-zero carbon emissions world? If so, how?

WHAT WE FOUND

We identified the following **digitally empowered levers of change** as having the potential to positively disrupt existing rules, power structures, and mindsets of governance systems.

- Increasing access to open data from satellite imagery and other remote sensors (e.g. for forests) as well as big data on individual and social behaviour (e.g. urban emissions) is disrupting traditional power structures, which is creating new levers for accountability and enabling broader citizen engagement in governance processes. The rise of this **Informational Governance** has the potential to accelerate action, but evidence from existing efforts is mixed in terms of both sustainability outcomes and equity and social justice.

- The increasing flows of goods, services, and capital across the globe has climate and equity implications which traditionally had little to no governance. However, the rise of intelligent systems and enhanced transparency is opening up opportunities for the **Governance of Flows** in ways that could disrupt current power dynamics and pave the way for more innovative climate mitigation strategies.

- Digitally enabled collaboration among large, dispersed groups has facilitated the growth of voluntary climate governance systems with increasing power to influence both formal and informal rules. If enabled and scaled effectively, **Collaborative Governance** systems could help to accelerate climate action.

- Given the high risk and uncertainty related to the changing climate, decision-makers are increasingly turning to foresight tools to anticipate alternative futures. Digitally empowered intelligent systems create new opportunities for **Anticipatory Governance**, which enable staying ahead of crises but risk undermining democracy if not implemented effectively.

RESEARCH & INNOVATION

Each of the levers of change listed above are already in place at different scales and in different sectors. The research and innovation needs outlined below were developed to help guide and scale these levers to drive societal transformations towards a climate-safe and equitable world.

RESEARCH: Questions we need to answer.

- Under what social and political conditions do the expansion of informational and anticipatory governance systems lead to inclusive sustainability outcomes? How can we leverage the digital age to enable and scale these and overcome constraints such as algorithmic bias and unequal quality and coverage of data?
- How can trust and accountability be effectively created in a world where decisions are based on collective and artificial intelligence?
- How can transparency in climate governance be enhanced by emerging technologies? Will enhanced transparency in GHG emissions and reduction compliance deliver environmental benefits and citizen empowerment?
- Where is the line between unprecedented transparency for accountability and surveillance for control? What standards, policies, and norms are needed to avoid crossing that line?
- Under what conditions does Measurement, Reporting, and Verification (MRV) lead to inclusive sustainability outcomes? What institutional and political constraints must be addressed for MRV to be effective in different governance systems? How can these be enabled and scaled in the digital age?

INNOVATION: Where we need to experiment and learn by doing.

1. Develop a new tool box for climate governance that leverages the four digital disruptors to better tap into the capacity and expertise of people across networks of states, businesses, local governments, and civil society.
2. Foster polycentric governance systems, leveraging unprecedented transparency, mass collaboration, and intelligent systems, to build complementary top-down and bottom-up approaches that can effectively reinforce – and not counteract – each other at different scales.
3. Improve the ability to track and monitor carbon and other environmental goods and services from big data and remote sensors.
4. Explore methods to integrate new digital data streams – from satellite imagery, other sensors, and crowdsourcing sites – to enable more credible and legitimate measurement, reporting, and verification (MRV) systems that support inclusive sustainability outcomes.

GOVERNANCE SYSTEMS

Here we use the term “governance” to refer to the structures, processes, rules, and traditions that determine how people in societies make decisions and share power, exercise responsibility, and ensure accountability [128]. Our understanding of how different governance systems might support or suppress societal transformations, and the feedback loop between transformations in governance and transformations in society, is still incomplete [128].

We have not yet developed effective governance mechanisms to steer the world to climate safety. The dominant focus for many years had been around establishing one global deal that would be state-centric and top-down, defined through the UNFCCC. But it is increasingly recognized that to drive the deep societal transformations needed to keep global temperature rise well below two degrees, we need a combination of both top-down steering and bottom-up self-organization [14,129,130].

We need to shift the focus from governments to governance. This is beginning as the power to drive action becomes more distributed among non-state actors, including large corporations and national and global financial institutions and actors. Many see these non-state actors as critical to fostering transformations to sustainability and equity [131–133]. The Paris Agreement has begun to formalize this shift by establishing a more decentralized framework and recognizing a greater diversity of actors [134,135].

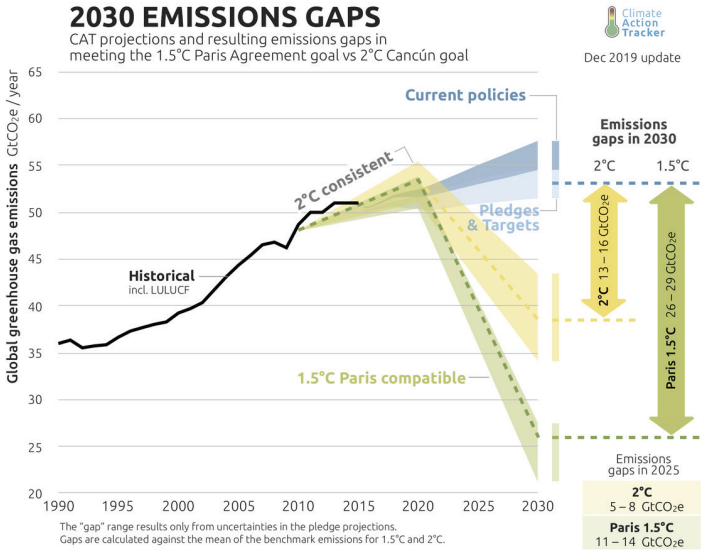


Figure 6. 2030 Emissions Gaps. Carbon Action Tracker projections and resulting emissions gaps in meeting the 1.5°C and 2°C climate goals.

Existing climate governance mechanisms are not sufficient. We need to expand and revise our tool box. The digital disruptors identified in this report open up new ways to leverage the capacity, expertise, and intelligence of people that can help to transform climate governance.

POLYCENTRIC GOVERNANCE & COLLECTIVE ACTION

The climate governance landscape today has evolved to be increasingly distributed and what some have called fragmented [136]. Elinor Ostrom reflected positively on this shift to what she called a polycentric governance structure [137]. Polycentric systems have multiple centres of authority at various scales rather than a monocentric unit. Each unit within a polycentric system exercises considerable independence to make their own norms and rules. Ostrom found in her research that, under the right conditions, polycentric governance systems create opportunities to overcome the challenge of collective action characterized by Hardin's "Tragedy of the Commons" [138].

If one approaches climate mitigation as a challenge of managing a commons – where the atmosphere that provides the service of sinks for GHGs is the commons – then mitigation requires addressing two key challenges: (1) constraining the use of the atmosphere as a sink so as to prevent its destruction, and (2) distributing the sustainable sink capacity among competing users [139].

Traditionally, these two tasks have been orchestrated by the UNFCCC and nation states – so far with little success. One reason for the limited success to date is that the climate crisis is so complex, with so many actors involved, that there is no 'optimal' solution that can be used to make the necessary substantial reductions in GHG emissions [140]. Collective action is typically unsuccessful in situations where the incentive to free ride is large [141].

The digital age is accelerating the development and growth of networks around the world, opening up opportunities for polycentric governance systems.

The challenge of free riders can be lessened by mobilizing at smaller scales – with fewer and more diverse sets of actors. Smaller collective actions can emerge to form a broader polycentric system. Polycentric governance systems are attractive when addressing these complex problems because they allow for more policy innovation and provide more opportunities for broader, more inclusive representation of diverse actors [142] than top-down policy approaches.

Empirical and theoretical research shows that more decentralized approaches, which incorporate both bottom-up and top-down efforts, with multiple institutions rather than one global one, are likely to lead to more cooperation in addressing climate change [137,143,144].

A few key factors contribute to the success of polycentric approaches to managing a commons: trust, reciprocity, and reputation, which can be facilitated through a diversity of actors and by increasing the visibility of behaviors [142,144,145]. But polycentric governance is not a panacea; a number of concerns have been raised in systems where certain conditions have not led to desirable outcomes [142].

Governing the commons without top-down regulation

Elinor Ostrom demonstrated that groups are capable of avoiding the tragedy of the commons without requiring top-down regulation if the following conditions are met [137,146]:

1. clearly defined boundaries;
2. proportional equivalence between benefits and costs;
3. collective choice arrangements;
4. monitoring;
5. graduated sanctions;
6. fast and fair conflict resolution;
7. local autonomy; and
8. appropriate relations with other tiers of rule-making authority (polycentric governance).

WE ARE TACKLING 21ST CENTURY CHALLENGES WITH 20TH CENTURY GOVERNANCE STRATEGIES.

There is an urgent need to ask tough questions and experiment with redesigning global governing practices to solve the complex policy challenges of the 21st century.

Is it time to move beyond the closed doors of the UN Conference of the Parties (COP)?

Do we need a “Conference of the Peoples” – the people’s COP?

The digital disruptors explored in this Agenda open up new ways to empower the growing networks of non-state actors and strengthen polycentric governance systems [147,148].

INNOVATING IN HOW WE GOVERN

Faced with increasingly complex global challenges and declining trust in the public institutions responsible for addressing them [20,149], many are looking toward innovative approaches to governance [148,150,151]. Many of these are focused on expanding participation among different sectors of society beyond formal government bodies. This may be an important trend as the 2020 Edelman Global Trust Barometer Report found that government officials are among the least trusted individuals, while company experts, academics, and peers are among the most trusted [20]. If trust is the basis of effective governance, as Ostrom indicated, then these results suggest we need innovation in governance that moves beyond traditional government bodies.

Innovations in technology, practice, and advances in social science offer opportunities for increasing the effectiveness and legitimacy of new strategies and hybrid models of governance. For example, the Governance Lab [147] and the National Endowment for Science Technology and the Arts (NESTA) have researched, experimented with, and catalogued a range of innovations in governance and decision-making models. The MacArthur Foundation supports a global research network on opening up governance to improve lives [148]. The Earth Systems Governance Project [152] is a global alliance of leading researchers collaborating to understand what works best in the context of governing challenges associated with global environmental changes and to explore novel governance mechanisms for sustainable development.

Innovation in governance is not just happening in the lab, it is being carried out in real time across the globe. Communities around the world are experimenting with how to leverage the increased availability of data, the expanded ability to engage a greater diversity of people in problem-solving, and new advances in technologies to transform governance [81,153]. For example, in Madrid a public platform – Decide Madrid [154] – for citizen engagement in decision making was launched. Looking beyond governments, the global public health community has explored new approaches to strengthen network-based approaches to governance [155,156]. For example, the Global Outbreak Alert and Response Network (GOARN) is a network of technical and public health institutions, laboratories, non-governmental organizations, and others that work to observe and respond to threatening epidemics [157]. GOARN works closely with and under the World Health Organization (WHO) but is directed by a steering committee of 20 representatives from the core partners [158].

DIGITALLY ENABLED LEVERS

The early outlook for the internet was that it would usher in a new era of accountability and political empowerment, expanding citizens' participation in policy-making. While some of these hopes have been realized, many have not because we, as a society, failed to anticipate how the digital age would unfold. The digital age has disrupted the rules and power structures of traditional governance systems, but the outcomes have not always led to a net benefit to society. This is in part because the digital revolution expanded so rapidly that the societal tools of the analogue world have not been able to anticipate and steer the transformations underway.

Challenges remain, but the prospect of the positive potential of the changes unfolding are significant. Much of the recent reshaping of the global environmental governance landscape has been enabled and/or influenced by the digital age [159–162]. Specifically, it has begun to disrupt traditional multilateral governance structures by: (1) enabling an unprecedented shift in transparency that has empowered the growth of informational governance approaches, and increasing focus on governing flows of goods and services rather than simply places or organizations; (2) increasing the connectedness of different actors across the globe, which has enabled a rise of more collaborative governance models; and (3) creating intelligent systems that are supporting the development of smart governance of cities, electric grids, land systems, and more.

Do these disruptions to traditional governance structures hold the power to spur the deep societal transformations needed to build a climate-safe and equitable world? Perhaps, but as with most big opportunities there are risks. Here we explore four digitally empowered levers to disrupt governance systems to accelerate and expand sustainable actions: (1) informational governance, (2) governance of flows, (3) collaborative governance, and (4) anticipatory governance.

Innovation in governance is critical, but it needs to be collaborative, transdisciplinary, and grounded in social science.

DIGITAL LEVERS

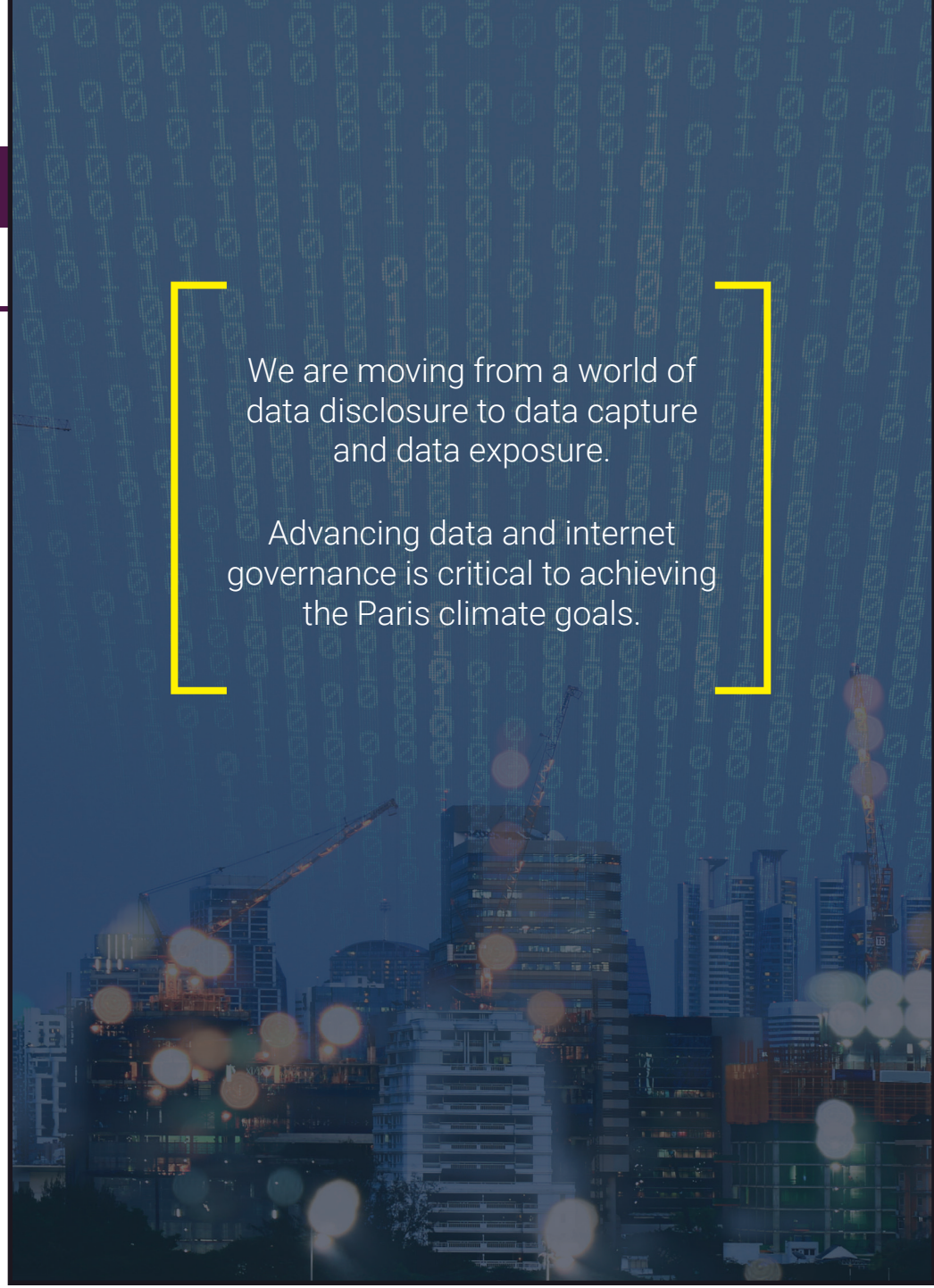
INFORMATIONAL GOVERNANCE

Unprecedented transparency, mass collaboration, and intelligent systems are rapidly shifting how information is used and by whom in environmental governance regimes. These trends are giving rise to what some call “informational governance” [163,164].

The UN Paris Agreement on climate change is built around a bottom-up “pledge and review” system, with an “enhanced transparency framework” that relies on a voluntary disclosure system to hold nations accountable to their pledges. The effectiveness of this approach is yet to be shown [165]. But this arena is changing rapidly, and it is still unclear what role unprecedented transparency – through public exposure via open data platforms – will and should play in the future in steering action on climate and related issues, though it is likely to increase. For example, programmes like Global Forest Watch are creating the possibility for involuntary disclosure of emissions from forests, enabling anyone in the world to see the carbon implications of deforestation in near real time. As new satellites are launched – such as NASA’s Geostationary Carbon Cycle Observatory, which can measure the daily total concentrations of carbon dioxide and methane at a horizontal ground resolution of 5-10 km [166], and MethaneSAT, which can pinpoint the location and magnitude of methane leaking from oil and gas production sites worldwide – transparency may increasingly be less of a choice than the rule.

The development of digital MRV systems [167], which leverage big data and satellite imagery to track emissions [168], and digital ledgering technologies, such as blockchain [169], show promise for strengthening the power of a pledge and review approach.

The rise of informational governance may contribute to disrupting existing governance regimes by encouraging closer collaboration amongst new constellations of actors and, in doing so, potentially overcoming power imbalances and pre-existing biases [164]. Yet questions still remain around its effectiveness in different settings and scales.



We have moved from a world of data disclosure to data exposure. We could leverage this opportunity to foster trust and reciprocity among and across communities around the world. But this will require focusing on data and internet governance as a central part of our climate strategies.

There are many concerns for ethics, equity, and privacy in making certain data and information public [161–163]. Innovations such as data trusts, legal instruments to manage data and data rights, have emerged to address these concerns. Questions also arise and need to be addressed regarding the effectiveness of relying on transparency for governance and accountability [173], as many barriers to transparency and accountability are not technical but rather social and political [106]. Are these issues that can be tackled? What are the trade-offs among the ethical, equitable, and climate protection issues and is it even possible to address these issues simultaneously [174]? What is clear is that the impact of increased transparency on governance systems depends on what information is being made transparent, how it is being made transparent, and for what purpose.

"Many are optimistic about the role of unprecedented levels of transparency in securing more accountable and effective global sustainability governance. Yet, research suggests that transparency may not be all that it promises to be. For example, transparency is often assumed to be essential to trust, however, the opposite might well hold: there might need to be trust first, in order to have meaningful transparency. And thus it is critical to research not only the design of transparency systems, but also the normative and political contexts within which such systems are deployed, as these shape whether and under what conditions transparency may realize its transformative potential in global sustainability governance."

Prof. Aarti Gupta
Professor,
Wageningen University

THE PROMISES AND PERILS OF UNPRECEDENTED TRANSPARENCY

Transparency has been an axis of hope in the complex web of climate strategies among business, civil society and government.

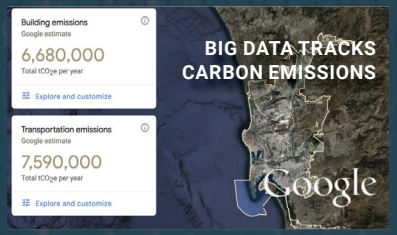
Efforts led by the Carbon Disclosure Project (CDP) and the Task Force on Climate-related Financial Disclosures have started to shift norms in reporting in ways that are promising. But, unfortunately, these efforts alone will not provide the coverage or accuracy needed to support the development of an effective tool for transforming governance systems.

The unfolding of the age of unprecedented transparency, fueled by big data, remote sensors, and machine learning, has brought great hopes that these tools could accelerate improvements in the accuracy of transparency programs, leading to greater accountability and ultimately stronger sustainability outcomes. Today, satellites can take pictures of every inch of the world every day. These remotely sensed data sets, combined with the now constant data trails generated by tracking human's activities and emotions second-by-second, enable the generation of insights into the behaviour of people, companies, and governments.

The increasing ability to make visible what is happening at any time or any place in the world is raising concerns around the fine line between the benefits of transparency and threats of surveillance [175]. Who is being watched by whom defines the power structures and ultimately frames the mindsets that shape the social fabric of society. There are valid and pressing concerns that these digital tools are already being used to control the rights and privileges of citizens [176]. The power of surveillance is increasing with new technologies, such as facial recognition, which are expanding the power of public and private sector actors to surveil citizens. Many tech leaders understand the risks of these powerful tools and are actively calling for the need for public regulation [177,178]. Yet, regulation has proven challenging. As with so much of the digital world, this represents a new category of societal risk that is not bound by political borders and thus not tied to a clear governance body.

While these fears are valid, the digital age is not going away any time soon. Thus, there is an urgent need to explore how to steer these big data and machine learning capabilities to enable the emergence of more trustworthy processes for collecting, analyzing, and using data. Currently, there is a growing community working on these issue, but very few are approaching this through the lens of building a climate-safe and equitable world.

To date, much investment has been made into technical tools such as Global Forest Watch and Google Environment Insights, which allow open access to carbon emissions of activities around the world in near real time. These tools have demonstrated huge potential. But to scale up these efforts to effectively drive the change we want, we must look beyond the tools themselves. It will be necessary to recognize that if transparency and traceability are to be seen as levers of change, they must be viewed not just as technical or administrative issues but as social and political issues as well [175].



Furthermore, to realize the potential of these new technologies, the international climate community must begin to reimagine climate governance in the digital age, including the full complexity of the challenges it may bring. Huge potential exists to strengthen and scale more polycentric governance systems. But considerable research, innovation, and near-term actions are needed to move this forward in a productive manner. For example, we need to:

- Assess the conditions under which enhanced transparency leads to inclusive and positive sustainability outcomes.
- Explore new opportunities and challenges for reimagining how to integrate enhanced transparency into formal and informal climate governance systems.
- Strengthen transparency of the provenance and quality of data and algorithms and support the development of mechanisms to equitably govern their use.
- Enhance international cooperation to support ongoing processes to develop a universal declaration of digital rights as an extension of the human rights laid out by the United Nations.

Making transparency work for climate requires understanding the institutional conditions under which it can build both the trust and accountability needed for inclusive and positive sustainability outcomes.

GOVERNANCE OF FLOWS

Global society is a system of nodes (nations, corporations, communities) and flows (of goods, services, information, power). Traditional governance structures are designed to govern the nodes of society and not the flows among them. We must shift the focus onto flows if we are to seek systems change in our hyperconnected world. Material flows are governed through agreements such as the World Trade Organization. Yet virtual flows of goods, services, and information are often lost in traditional governance structures. Virtual flows include both the flow of embedded goods (and "bads") and services/disservices [113,179,180] and the process of "teleconnections" or "telecoupling" – the flows of information in one location that influence production and consumption decisions in another region of the world [181–183].

Virtual flows and teleconnections create challenges for traditional governance structures. As explained by Hallie Eakin and colleagues, the interaction among telecoupled systems "emerges essentially as an 'ungoverned' process, such that the indirect outcomes of the interaction often appear unexpected or 'surprising' because they lie outside the dominion of the existing governance arrangements" [184]. The implication for climate change can be significant. Consider, for example, forests. Reducing Emissions from Deforestation and forest Degradation (REDD) has been identified as one of the least expensive means for tackling climate change [185]. While REDD is included in the Paris Agreement, implementing it has proven difficult in practice [186,187], in large part because of the issue of leakage. Leakage refers to the challenge inherent in reducing emissions from deforestation and forest degradation in one location often simply displaces the carbon impact to another place on the globe [186,188].

Traditional land governance has a territorially based focus on tracking and regulating land use and management in a given place an¬d is thus unable to tackle the leakage alone. There are signs that land governance is shifting from "territorial" to "flow-centred" arrangements [189] through certification programmes or voluntary reporting [190,191]. Yet these are still a long way from solving the leakage challenge. Research suggests that, globally, over 50% of reforestation can be directly connected to increased deforestation in another part of the world [192]. Increasingly, a combination of AI, mass collaboration, and unprecedented transparency is opening up new possibilities for tracking the flows and connections among forest use and management around the world (e.g. Global Forest Watch, Forest+). Given the significant developments in this space, the potential to address environmental degradation and displaced emissions associated with telecoupling and leakage through digital mechanisms is proving to be quite high.

Another example is flows of "embedded carbon": carbon emitted in the production of goods and services, analysed in a full life-cycle assessment. The UN Paris Agreement and most other policy frameworks are based on reporting of end-point emissions, yet science tells us that what matters for the climate is the total cumulative emissions in the atmosphere [193,194]. New digital technologies such as blockchain could play a key role in enabling systems for tracking the cumulative flow of carbon into and out of countries, thus enabling new distributed governance systems. But creating governance systems for the climate and equity outcomes we seek will require working beyond technology, to understand and shape governance systems within specific social and political contexts.

RESOURCE FLOWS ARE A GROWING GOVERNANCE GAP

The complexity of the global exchange of goods, services, and capital makes governing flows an increasing challenge. Even international mechanisms such the World Trade Organization (WTO), which have the mandate to govern flows, have limited effectiveness with regard to sustainability issues [195,196]. Civil society groups have begun to try to fill this governance gap by promoting transparency through supply chains and certification and standards programs [175,197].

Enhanced transparency, intelligent systems, and mass collaboration have led to rapid escalation in building transparency in supply chains. Yet, more still needs to be done to ensure that these schemes lead to positive sustainability outcomes.

COLLABORATIVE GOVERNANCE

Collaborative governance refers to “the processes and structures of public policy decision-making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private, and civic spheres” [198]. Governments, international organizations, and local communities are increasingly turning to collaborative governance solutions to address sustainability challenges involving multiple stakeholders [199–201]. However, collaborative approaches have proven difficult to scale due to significant coordination and verification requirements. Mass collaboration, enhanced transparency, and intelligent systems could help to overcome some these constraints. For example, some have suggested the creation of a big data-driven “transnational sustainability agency” [202] or digital “global participatory platforms” [203,204]. Meanwhile, blockchain and AI provide opportunities to strengthen and scale existing frameworks and principles of deliberate design in governance [146] and socio-technical systems [205]. Critical to the successful advancement of collaborative governance is the strengthening of institutional structures around information-sharing and the creation and management of the knowledge commons [206,207].

Sidewalk Labs, in Toronto, Ontario taken October 31, 2019. Sidewalk Labs, a project of a subsidiary of Google parent-company Alphabet to create a sustainable and futuristic neighborhood on a former industrial site on the city's waterfront.

Governments and citizens are already experimenting with putting some of these concepts into practice. For example, BitNation is an organization that is building a decentralized voluntary “nation,” with the goal of explicitly striving to “disrupt the nation-state oligopoly through offering more convenient, secure, and cost-efficient government services” [208], including services such as World Citizenship ID and a Refugee Emergency Response project [209]. While many challenges exist to realizing this vision, aspects of it could unlock new strategies for governing the climate commons. At this stage, the model is so novel that the rules and regulations surrounding its use are poorly understood or lacking altogether [210]. Defining the rules of the emerging “virtual states” could be an avenue that helps to steer the trajectory of society toward a more inclusive, lower emissions growth pathway.

The potential to scale collaborative governance is interconnected with data and internet governance. Big Tech companies provide the platforms that can enable scaling, but the implications for empowering people and sustainability outcomes is still unclear. Steering these efforts towards positive outcomes will require coming to terms with how to regulate new technologies while working with and confronting the private sector companies that created them. Consider, for example, Sidewalk Labs. The vision of Sidewalk Labs, a Google affiliate, was to build a model smart sustainable community by collecting data on everything within it, from water use to human movements. The potential for such a model is powerful. But privacy and data governance issues prevent the realization of the vision. Furthermore, while smart communities may rely on technological connections, intelligent and resilient communities require people connections. With stronger data governance and public-private-people partnerships, the trend of Big Tech companies building “smart communities” could be steered towards the co-creation of “collectively intelligent community networks” with more inclusive and positive sustainability outcomes.

With stronger data governance and public-private-people partnerships, the trend of Big Tech companies building “smart communities” could be steered towards the co-creation of “collectively intelligent community networks” with more inclusive and positive sustainability outcomes.

MAPPING TO EMPOWER

Maps are powerful visual tools and have long been employed for a wide range of governance purposes. But maps are not neutral. They are a reflection of the data, perspectives, and methods which go into creating them and have the potential to open up – or close down – governance options [211]. In the interest of enhancing governance for both sustainability and equity, it is critical to explore opportunities to diversify data collection and open up access to high-quality data in support of more participatory approaches to mapping. This requires technical capacity, equitable data governance, and public-private partnerships that facilitate collaborative issue resolutions.

The Nairobi City-wide Open Public Spaces: Inventory and Assessments initiative, coordinated by Nairobi City County and UN Habitat (as part of their Public Space Programme), used a range of techniques – from traditional, quantitative GPS data collection to photography and informal discussions – to collect data to feed into the production of a diversity of maps. This process empowered local populations to create more holistic narratives around city planning, where addressing social and environmental concerns were understood as complementary goals, and enhanced understanding of the value of public spaces [211]. This is particularly relevant in informal settlements such as Kibera, Nairobi, where community-led public space projects continue to grow [212,213].

Building off this success and others in the Public Space Programme, UN Habitat has joined forces with the popular video game Minecraft (through a public-private partnership with Microsoft) to create even easier ways to engage citizens in participatory mapping [214]. Crowdsourcing data in this way has enabled the integration of multiple perspectives and worldviews into mapping processes that provide direct input to governance, leveraging opportunities for mass collaboration and intelligent systems to push for more collaborative approaches to governance.

So far, much of the work done to diversify approaches to mapping has taken place at local or sub-national scales. Further research, innovation, and near-term action needs include:

- *Opening up access to spatial data and analytical software to build capacity and foster communication amongst community-led initiatives.*
- *Developing mechanisms to standardize data collected in participatory mapping exercises and co-develop strategies to address issues of consent and ownership.*
- *Creating platforms that integrate arts-based practices with traditional, quantitative mapping and other qualitative approaches.*

A playground developed collaboratively with local Kibera communities and Kounkuey Design Initiative using both land and materials repurposed after a clean-up of the site and revitalization as a public space.

ANTICIPATORY GOVERNANCE

Futures analysis, alternatively referred to as foresight, entails the identification of and reflection on alternative potential futures using a range of available methods [215]. Given the high degree of uncertainty and high risk associated with climate change, there is a proliferation of the use of both qualitative and quantitative futures analysis methods for climate change mitigation and adaptation [216,217]. However, a deeper understanding of the implications of this proliferation – including the effect of the degree to which processes are participatory, the specific goals of a foresight process, and the degree to which underlying assumptions are made transparent – is still lacking [216].

While the use of futures analysis as an input to decision-making is certainly not new, it has taken on new meaning in the digital age. In today's world, everything is becoming "smart". We have smartphones, smart homes, and smart cities. This begs the question: Should we be building smart governance systems to tackle the climate crisis?

As digital technologies enable more accurate prediction and analysis of more comprehensive datasets, the use of algorithms to conduct futures analysis for governance is increasing across a diversity of applications. This has given rise to anticipatory governance – whereby current governance mechanisms are used to steer society based on an assumed enhanced understanding of the future [216]. Anticipatory governance has taken on a new power in the digital age, enabling the development of mechanisms that respond ex-ante to highly uncertain societal challenges. In the case of climate change mitigation and adaptation, societal objectives are often value-laden and disputed, requiring a more pluralistic approach to science-policy interactions [218] and a more democratic design of anticipatory governance systems [216].

Some say the world today is governed by intelligent machines, which are concentrating power in the hands of those controlling the algorithms [219]. Algorithms shape what we buy, what we read, and even who lives or dies [220]. This trend is going to continue and thus urgently requires the establishment of standards and frameworks to ensure that algorithms governing society are transparent, ethical, and equitable.

Algorithms are increasingly used by governments at both the local [221] and national levels [222]. Consider, for example, policing, which has seen a paradigmatic shift from "focusing on what happened to focusing on what will happen", calculating statistical likelihood as a mechanism to foster effective preventive action [223]. Predictive policing is a method that uses "computer programs and new mathematical algorithms … helping law enforcement agencies better predict when and where crimes will occur" [224], and may increase effectiveness of law enforcement by increasing efficiency regardless of available resources [204].

Risks or critiques associated with anticipatory governance include that this form of governance may perpetuate biases, that it could diminish the accountability in governance regimes, and that assumptions underlying the algorithms could be insufficiently transparent [69,226,227]. This is at least in part because regulatory frameworks too often overlook the relevance of the complex relationship between different stakeholders – including developers, users, regulators, and the individuals who are ultimately profiled – to evaluations of predictive policing [228].

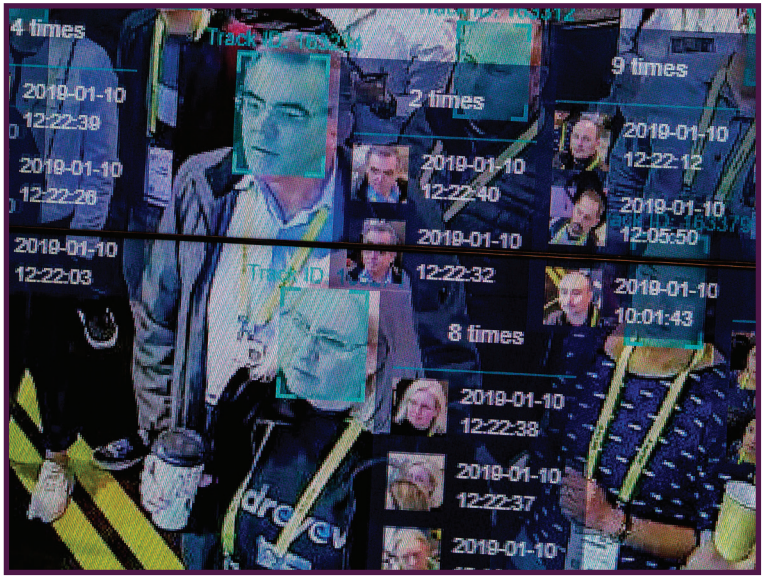
The use of predictive algorithms has been observed across a variety of sectors, including homeland security [229] and business intelligence (data mining [229], habit formation [230], and consumer behaviour [225,231]). The use of predictive algorithms for governance requires the input of vast quantities of data – something humans are producing at an exponential rate in the era of big data [232] – as well as advanced analytical capabilities to process these data.

Could anticipatory governance be used to build sustainability and equity? Some have proposed and are beginning to explore such applications. The approaches fall on a spectrum ranging from top-down authoritarian – which Peter Seele [202] has called the "Digital Sustainability Panopticon" – to more open and participatory, with a diversity of stakeholders working together to collect, manage, and analyse big data [233,234].

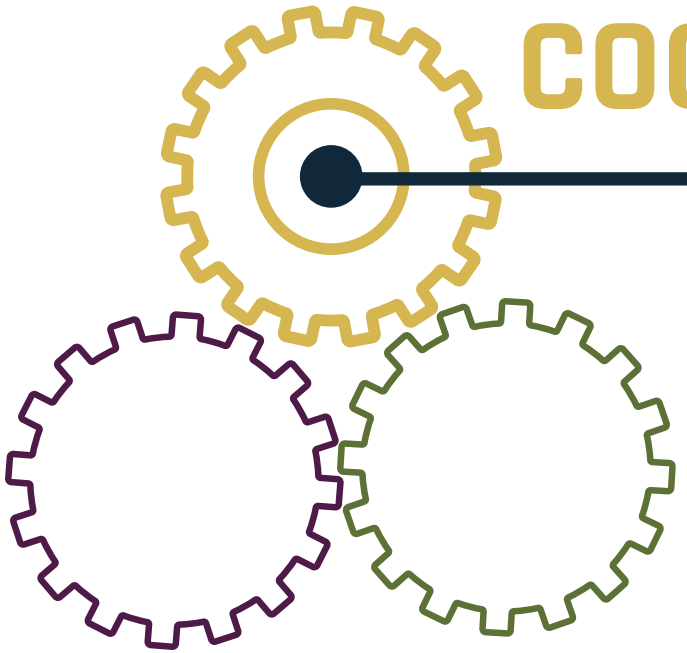
There are signals that this method of governance could be highly efficient – for example, in predicting emissions and behaviours – but many questions remain about how, if, and when anticipatory governance is appropriate. Singapore and China are rapidly moving towards a governance system that is using citizen data and predictive models to govern society [235]. The Chinese government has partnered with private companies to use big data and AI to build a digitally powered "Social Credit System", which will be fully operational by 2020. The system, which the government argues will be used to measure and enhance trust, has been criticized as a form of "mass surveillance" [236]. Increasingly, it is clear that mass surveillance by governments and companies is becoming widespread. In 2013, Edward Snowden, a contractor to the US National Security Agency, revealed to the world that mass digital surveillance has become common practice in the US. The questions we need to ask are: How do we place guardrails on this new reality? What regulations can be established to prevent malicious use of these tools? Are there models for ethically using these digital powers to track and reach the masses to address global challenges? It is urgent that we unpack the risks associated with anticipatory governance now – especially since it is already being tested and implemented.

But research suggests that anticipation and foresight should not just be left to machines. Combining collective intelligence (CI), enabled by the mass collaboration of people, with AI might be what is needed to make us more intelligent and effective in tackling the complex problems of today [237].

Anticipation should not just be left to machines. Combining collective intelligence (CI), enabled by the mass collaboration of people, with AI might be what is needed to make society more effective in tackling the complex problems of today.



A live demonstration uses artificial intelligence and facial recognition in a dense crowd at the Las Vegas Convention Center during CES 2019 in Las Vegas on January 10, 2019.



COGNITIVE

“

The confidence people have in their beliefs is not a measure of the quality of evidence but of the coherence of the story the mind has managed to construct.

Daniel Kahneman,
Nobel Laureate

COGNITIVE SYSTEMS

GOAL

Disrupt the rules, power structures, and mindsets that constrain climate action by steering digital disruptors to drive changes in existing cognitive systems. Scale these systems changes to unleash the transformations needed for climate-safe and equitable outcomes.

WHAT WE ASKED

How are digital disruptions to cognitive systems shifting the formal and informal rules, the distribution of power, and the individual and collective mindsets that are currently sustaining our unsustainability?

Can these digital disruptions be leveraged to unleash equitable societal transformations to a net-zero carbon emissions world? If so, how?

WHAT WE FOUND

We identified the following **digitally empowered levers of change** as having the potential to positively disrupt existing rules, power structures, and mindsets of cognitive systems.

- Targeting content and nudging individuals towards specific decisions have long been used in any number of types of political, commercial and public campaigns. Digital capabilities have amplified these techniques, enabling the **Microtargeting and Nudging** that can personalize influence at scale. While much concern has been raised around how these can be manipulated, they have also been shown to be means of influencing behaviours and social norms. As microtargeting and nudging are now embedded in the digital social and economic world, it is incumbent on society to explore how to regulate this power to avoid malicious outcomes and advance.

- Stories unite us and give us purpose. In the digital age the building and sharing of stories is rapidly changing. Powerful **Collective Stories**, which used to take decades and even centuries to have global impact, can now emerge in months. These can be malicious and manipulative, or co-created and generative. A critical challenge for the climate movement is how to steer these digital transformations to empower and accelerate the growth of collective narratives that are both fact-based and values based, without encroaching on basic human rights.

- Stories engage people more than simple facts. But experiences can build empathy and connection to what might otherwise be distant issues. The use of mixed reality tools has given rise to a new type of **Augmented Engagement** that can create experiences through the merging of virtual and physical worlds. These can be powerful public engagement tools and have been shown to influence behaviour. But they have not yet been explored as a means for scaling engagement strategies.

RESEARCH & INNOVATION

Each of the levers of change listed above are already in place at different scales and in different sectors. The research and innovation needs outlined below were developed to help guide and scale these levers to drive societal transformations towards a climate-safe and equitable world.

RESEARCH: Questions we need to answer.

- What are the interconnections between changes in individual and collective mindsets, and how do these translate to collective action? How have these links shifted in the digital age? Do these provide an opportunity to steer and scale inclusive collective action on climate change?
- How effective and efficient is digital nudging for influencing behaviour and mindsets at scale? What are the implications for sustainability outcomes? Can nudging be legally and ethically mandated at a global scale? If so, how could the mandated nudges be determined?
- Why do some concepts and narratives become embedded in societal discourse while others do not? How do they shape societal change? How has the emergence and reach of new concepts and narratives changed in the digital age and how does this vary with social and cultural context?
- What is the relative importance of social movements in shifting individual beliefs and cultural and social norms and in shaping policies? How have these changed in the digital age and how do they vary with social and cultural context?
- How can we minimize and mitigate the risks of using digital technologies and platforms to manipulate cognitive biases and amplify specific worldviews? Can these mechanisms be used ethically to foster a new shared narrative centred around net-zero carbon emissions and global equity?
- Can augmented experience change human mindsets and norms at scale?

INNOVATION: Where we need to experiment and learn by doing.

1. Build a network of targeted engagement strategies that leverage mixed reality tools and intelligent systems to co-create new meta-narratives across populations and geographies.
2. Explore methods that leverage unprecedented transparency, mass collaboration, intelligent systems, and mixed reality to help build collective narratives that draw on emotions and create a credible and legitimate shared view of reality.
3. Develop automated programs to monitor the sources, spread, and uptake of fake news. In parallel, developing transdisciplinary initiatives to empower individuals to evaluate the veracity of news.

COGNITIVE SYSTEMS

Cognitive systems refer to systems (human or otherwise) connected with the acquisition and processing of information and knowledge. Psychologists and economists have shown that human cognitive systems influence and are influenced by social and cultural norms, which collectively influence behaviour [238,239]. Today, human and social cognitive systems are embedded in machine systems (Figure 7). Data from individual and social behaviour are used by machines to influence both machine and human behaviour. Machines learn from other machines and humans. The result is that machine behaviour at times surprises even the people who developed them [9].

NORMS

Social and cultural norms – widely accepted and practised modes of conduct – are both a consequence and facilitator of human behaviour and social interactions [239,240]. What other people do and think influences individual and collective behaviours and cognitive processes, with important implications for societal outcomes [241–243] In particular, social and cultural norms have been shown to have a strong influence on human behaviours related to climate change [240,244,245] and therefore play an important role in determining emissions pathways.

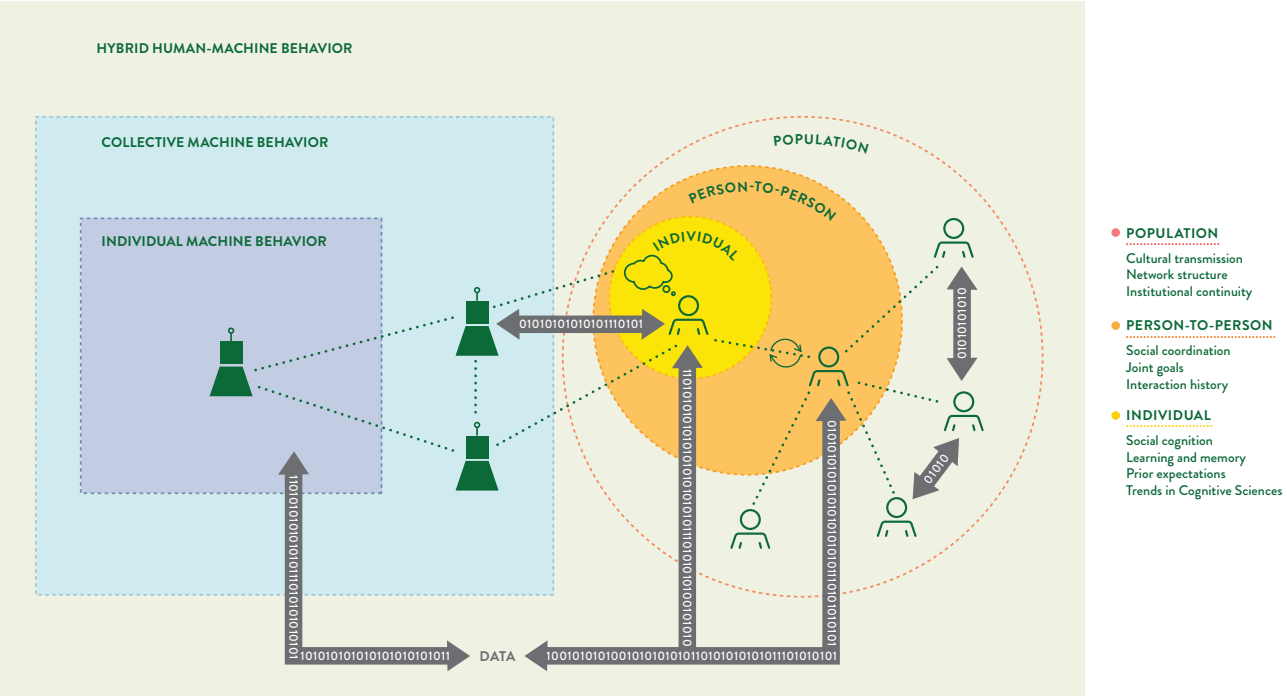


Figure 7. Human-machine cognitive systems are intertwined. They interact across three levels – individual, person-to-person, and population. Together, these different levels of human-machine interactions form, perpetuate, and reshape social norms (adapted from [9,239]).

Human, social, and machine collective behaviour is driving societal transformations.

In-person interactions have formed the backbone of cognitive engagement for millennia. In the digital age, people are becoming increasingly focused on virtual interactions, with many implications for cognitive engagement strategies to address issues such as climate change.

As Erik Assadourian of the World Watch Institute [246] argues, our "norms, stories, rituals, values, symbols, and traditions" are codified in public and private institutions and thus influence nearly all of our life choices. In fact, research suggests that these cognitive factors are potentially more important for securing broad and long-term behavioural changes than the conventional wisdom of economic self-interest [247]. But norms can change and have changed rapidly in the past, for example, rapid shifts in smoking patterns [248], acceptance of same-sex marriage [249], and shifts in childbearing patterns [241]. As a result, system changes towards sustainable consumption and production will likely co-evolve with shifts in social and cultural norms [250].

COGNITIVE BIASES

Human cognitive systems are constrained by a range of biases. For example, we are biased towards maintaining the status quo, considering the present over the future, pre-existing beliefs over new ideas, and avoiding losses over securing equivalent gains [251–253]. These cognitive biases result from the fact that human brains rely on two different systems for processing information and making decisions [254]. System 1, often described as the fast processing mode, is intuitive, automatic, and emotional. System 2, the slow processing mode, is deliberate, analytical, laborious, and rational [254]. Both these systems continually operate to guide human judgement and decision-making [255]; however, because human brains are "cognitive misers" [256], they often default to System 1. As a result, social, emotional, and cultural factors often exert a greater influence in guiding human decision-making than rational thinking [254].

Cognitive biases facilitate fast learning by short circuiting deliberative processing. Research indicates that these cognitive biases also inhibit rational deliberation on complex issues such as climate change, and may contribute to the gap between recognition of a crisis and the failure to take actions to address it [257]. Understanding these cognitive biases has opened up new strategies for addressing sustainability challenges, by either leveraging these biases for shaping behaviour – for example, through nudging behaviours – or overriding them through, for example, automated systems.

The digital age has enabled new opportunities to expand and scale engagement and intervention strategies that leverage or override human cognitive biases, but many bring their own social, ethical, and legal challenges.

Extensive and continuous interaction with digital technologies has altered individual and social cognitive processes... and can shape social norms.

MACHINES AND HUMAN COGNITION

Throughout history, human cognition has been shaped by tools such as language [258], writing, and mathematics [259]. It is therefore no surprise that the internet has profoundly changed human cognitive behaviours and processing [260]. Extensive and continuous interaction with digital technologies has altered individual cognition as well as social cognitive processes. Over the last two decades digital interactions have shifted human cognitive processing towards more shallow modes of learning, increased distractibility, and increased tendencies to addictive behaviours [260]. But they have also created opportunities to expand human and social cognitive processes.

For example, even when people rationally understand what climate change is, they often don't have the cognitive processing capacity to analyse all the relevant information, and thus they default to cognitive System 1, which reinforces intuitive behaviours embedded in social and cultural norms that tend towards the status quo [261,262]. According to AI pioneer Yoshua Bengio, current technology can replicate System 1 with increasing success, although it is still far from achieving the performance and rationality of System 2, which is one of the main avenues of research in current AI and one of its biggest disruptive potentials [263]. Thus, the digital world is extending society's System 1 processing and the existing biases embedded within them.

Digital disruptors are altering our cognitive systems and can shape social norms [75]. But developing effective strategies to do so that are ethically, legally, and ecologically sound requires much research, innovation, and near-term actions.

A number of proposals have been made for shifting cognitive patterns, including consciously nudging people towards low-carbon and climate-resilient choices [251,264], building new narratives [265,266], and social movements [267,268].

Here we explore three digitally empowered levers to disrupt cognitive systems to accelerate and expand sustainable actions: (1) microtargeting and nudging, (2) collective stories, and (3) augmented engagement.

MICROTARGETING AND NUDGING

Personalized recommendations and content are now a standard part of digital interactions. Driven by big data and machine learning, corporations, political campaigns, health promoters, and educational programmes all turn to microtargeting tools to pierce through the information overload and cognitive biases and make it personal. These methods are increasingly being used by advocacy groups to target climate advocacy efforts. For example, the Climate Advocacy Lab works with social scientists, data scientists, and climate advocacy groups to connect knowledge to action on how to best build social movements around the climate crisis in the United States. In Canada, the Mila AI institute is developing a tool that aims to generate images that depict accurate, vivid, and personalized outcomes of climate change using machine learning tools to help people visualize climate change on a personal level [269,270].

People tend to be more susceptible to nudges than attempts to persuade using rational arguments or facts.

The digital age has transformed daily life with the increasing omnipresence of connected devices that suggest what to buy, what to read, what to eat, when to exercise, who to connect with, and who to vote for. These suggestions are made in the form of “nudges”. In behavioural economics, nudges refer to a method of influencing behaviour changes through small changes in how choices are presented to an individual, without actually altering the choices. Nudges are based on the understanding that the person’s decision environment, or “choice architecture”, may be constructed in such a way that it enables them to make “better choices” [264]. Richard H. Thaler, who won the Nobel Prize for his work on nudging, argues that what constitutes “better” is defined by the individual making the choices. For example, a common way that choice architecture is used to nudge healthy eating behaviour is to strategically position healthy food items in the supermarket or a restaurant [271].

Nudge theory emerges from cognitive and social psychology research demonstrating that people’s decision-making is usually not rational but shaped by cognitive biases and heuristics [272]. As Nobel laureate Daniel Kahneman has shown, the vast majority of human decisions are made by System 1 (the fast thinking mental system) rather than System 2 (the rational mental system) [252]. As a result, people tend to be more susceptible to nudges than attempts to persuade using rational arguments or facts [272].

Nudging did not emerge from the digital age, but the rapid pace of innovation has amplified the impact of nudges. In the digital age we live with multiple overlapping and competing nudges that increasingly influence our decisions. Digital nudging blends cognitive and behavioural sciences, big data, and machine learning to microtarget nudging at a massive scale. Machine learning develops and refines messages and images that are most likely to persuade an individual to take a certain action based on that person’s data. Nudge engines can now be purchased as a service from companies such as Humu or scaled through the use of bots, which are automated software applications that run repetitive programs.

Microtargeted nudges can be powerful forces of good. For example, imagine if everyone was nudged to choose healthier food, be more physically active, and save for retirement. However, nudging can also be used to unethically manipulate people for political power, financial benefit, or malicious intent. Machine learning has enabled bots to become an increasingly sophisticated means of mass nudging – as famously deployed by foreign hackers to influence the 2016 United States (US) election [273]. The classic example of unethical use of microtargeting nudges was the case of the political consulting firm Cambridge Analytica, which combined data mining, data analytics, and strategic communications to influence political outcomes. In 2016, Cambridge Analytica unethically and illegally collected and manipulated personal data from millions of Facebook users to drive support for the Trump presidential election. The power of digital nudging is only likely to increase as companies invest in the design of AI-powered bots, capable of both socializing with users and generating predictive models of their behaviour [274].

While microtargeting and nudging are frequently applied for political and commercial purposes, in recent years the use of nudge techniques has increasingly been explored to achieve policy goals [58,275]. This is an emerging field in policy broadly and in sustainability specifically. Much work is still needed to understand the potential scale of the impact, the ethical and privacy implications, what it would take, and how it would be implemented to effectively nudge society for global climate policy goals.

> "Climate change is humanity's biggest crisis. A critical obstacle to addressing this crisis is that, despite the growing intensity of extreme weather events, to many people climate impacts still often seem distant and abstract. Machine Learning and interactive technologies could help make climate risks more concrete and more personal. Our hope is that these technologies will enable the scaling of more targeted and personalized public engagement strategies that could ultimately strengthen collective action."

Prof. Yoshua Bengio
A.M. Turing Award, 2018;
Scientific Director,
Mila; Full professor,
University of Montreal;
Co-Founder*, Element AI*

STORIES CONVEY THE VALUES, HISTORY, AND CULTURE THAT UNITE PEOPLE.

The ultimate symbol of unity is the joining together of hands. This picture depicts the joining of hands on the eve of the Hindu festival of Janmashtami, in Mumbai on August 18, 2014. On this day, people come together to celebrate the birth of the Hindu deity Lord Krishna. They are guided by a common narrative embedded in the legend that Lord Krishna is the 'destroyer of evil'. The narrative goes that the destruction of evil will lead to the prevalence of goodwill, which will bring unity.

Narratives are the storylines that define us. They reflect our values and are articulated within and across social and cultural networks. They unite us and give us purpose. A classic example from the US is the story of President John F. Kennedy's first visit to NASA after proclaiming to the US Congress that the country "should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth" [276]. During his tour of the NASA facility, President Kennedy and was introduced to the janitor of the facility and asked him what he did for NASA. The janitor responded: "I am helping to put a man on the moon" [277]. The janitor identified himself with the NASA mission and its narrative gave him purpose.

A more universal example is the role of narratives in religion. Across the full range of religious groups, narrative plays a key role in conveying meaning and making principles accessible. Whether it is Hinduism, Christianity, or Islam, narratives play a key role in uniting culture and giving purpose [278].

As van der Leeuw recently articulated, narratives "are at the root of the "imagined futures" that […] drive our societies' economies" [279]. He went on to conclude that "changing narratives and thus changing imagined futures can transform ideas, attitudes, and institutions and are thus essential to effectuate societal change" [279].

In the digital age, narratives can change and spread at unprecedented rates. What's more, these narratives have proven to be powerful avenues for rapid social change. #MeToo emerged and drove real change on the ground in less than a year. #FridaysforFuture expanded from one person to a global movement within a matter of months. The power to change narratives at scale today is unparalleled in human history. But how that can in turn scale deep societal transformations is still an experiment in the making. With targeted research, innovation, and adaptation, the potential for change in this space is unprecedented.

#FridaysforFuture expanded from one person to a global movement within a matter of months. The power to change narratives at scale today is unparalleled in human history.

Swedish climate activist Greta Thunberg, 16, started a school strike for climate in front of the Swedish Parliament in August 2018. A year later she traveled across the Atlantic by boat to speak at the climate summit in New York as a leader of the global youth movement.

WHO DEFINES REALITY?

Arguably the biggest challenge to sustainability from the digital revolution is not the IoT, biotech, or big data, but rather the ability to distinguish fact from fiction. In the last decade, winning political narratives have suggested that globalization is to blame for job insecurity, wage stagnation, and waves of migrants. On the other hand, winning techno-optimistic narratives have focused on connecting people around the world, organizing their information, and creating unparalleled efficiencies leading to greater personal freedom. In contrast to both, narratives on transformations to sustainability are often low profile in major economies. Those that are breaking through are strongly contested along political tribal lines.

One study has shown that "fake news" – which often triggers strong reactions of surprise, disgust, or fear – travels six times faster and can reach up to 100 times more people than accurate information [280]. Another study estimates about half of all parents with young children are exposed to anti-vaccine messages on social media [281]. Given how pervasive this issue has become, more research is needed to understand the sources, spread, and uptake of fake news, including the creation of a comprehensive data-collection system [282]. Around 9%–15% of Twitter accounts – approximately 48 million accounts – are bots. That number rises to 60 million accounts on Facebook. Low-credibility information is heavily supported by bots, so curbing them may be an effective strategy for mitigating the spread of online misinformation [283]. But don't blame the bots for everything: real people are the ones most likely to share fake news on social media [48].

People are more likely to believe the information that is repeated regularly. And we tend to evaluate information more favourably if it comes from people within our tribe or matches our current beliefs. Algorithms exploit these biases to influence and predict behaviour and keep us clicking. A recent report found that algorithms used on YouTube are escalating the spread of climate misinformation videos on their platform. One key finding of the report was that at least 16 of the first 100 videos suggested on YouTube.com based on a search for "global warming" featured false information about climate change [284]. The fact that the editorial team at Nature Communications pointed to the spread of misinformation and 'fake news' as a major barrier to climate literacy and, ultimately, to climate action emphasizes the significance of this worrying trend [285]. Further, social media ecosystems are predisposed to spreading emotionally charged messages over fact-based content. In the UK, the highly successful media and social media campaign to leave the European Union focused on an emotionally charged message of fear of immigration, while the campaign to stay in the EU was based on the logic of economic cooperation. It stood little chance. As the last US presidential election reached its conclusion, about one in four Americans visited a fake news website, and about half of these people believed the stories, particularly if the stories favoured their preferred candidate [286,287].

THE SHIFTING ROLE OF THE MEDIA

Since the Enlightenment of the 18th century, the principles of reliable, unbiased information and a widely shared, defensible description of reality have been regarded as essential to functional and fair governments, complex societies, and thriving economies. The news media has an important role to challenge propaganda, but the media's influence may be eroding under twin pressures: the erosion of the media's business model in a digital world and the dominance of social media platforms in access to news and other information. Media companies have lost revenues to search engines that provide content for free and are thus losing their gatekeeping role in defining reality. Similarly, while academia builds knowledge and understanding of our world, only 0.5% of academic articles make it to the mass media – academics are largely speaking to themselves.

In the digital world, new gatekeepers have replaced the old guard and the floodgates have opened. Checks and balances are bypassed, ignored, or destroyed. The bar to access mass audiences has dropped because anyone can broadcast with few or no financial or editorial constraints.

A NEW KIND OF POWER

Rasmus Nielson, Director of Research at the Reuters Institute for the Study of Journalism, argues that digital media platforms hold three types of power. The first two, hard and soft power, are held by any wealthy corporation or media operation. But the third is "platform power" [288]. Platform power includes the power to set standards, to automate action at scale, to make and break connections, and to operate secretly. But it is also the power to define reality. How can these platforms evolve to support collective storytelling around societal goals and fact-based worldviews?

> Fake news travels six times faster and can reach up to 100 times more people than accurate information.

Man stands in the woods, experiencing nature physically in the forest and virtually through VR, which provides personal experiences defined by mixed realities.

AUGMENTED ENGAGEMENT

Stories and experiences that draw on emotions, values, and worldviews tend to be more effective in engaging people than simply reporting facts [289]. Storytelling is rapidly changing [290]; through virtual immersion in data and imagery, stories are increasingly becoming more powerful means of emotional engagement. The next rapidly emerging means of public engagement is leveraging virtual and augmented reality to blend stories and experiences together to build empathy and connect emotionally.

Virtual reality (VR) and augmented reality (AR) have been characterized as the ultimate “empathy machine” [291] through immersive story experiences. While many question the true impact VR and AR can have on building empathy and shifting behaviour [292], they are increasingly being explored in a range of sectors from education to public health [293,294]. In fact, some have referred to these forms of immersive engagement tools as the next frontier in behavioural health [295]. Promising exploratory work has been conducted that demonstrates positive connection between immersive storytelling and increased public engagement around climate change [296].

Immersive virtual engagement offers fundamentally new ways to communicate the causes and consequences of climate change. Much research and experimenting are needed to explore the potential of VR and AR in public engagement efforts around climate change. However, early research [296] suggests that immersive virtual engagement can help to (1) build understanding of complex issues such as climate change [293]; (2) engage emotional response to simulated changes through visual, auditory, and haptic stimuli [292]; and (3) elicit action [294].

Apple CEO Tim Cook captured the challenge and opportunity of augmented engagement when he said “AR is the future, but fake news is ruining everything” [297].

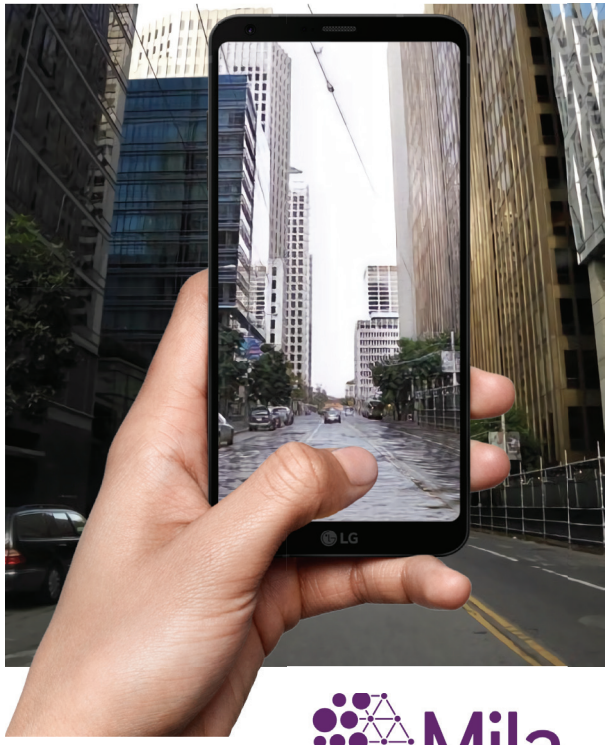
> People who experience stories through immersive VR tend to think “I was there; therefore, it is real, and it matters.”

LEVERAGING MACHINE LEARNING TO MAKE CLIMATE PERSONAL AND PRESENT TO OVERCOME COGNITIVE BIASES

Public concern and awareness of climate change does not match the magnitude of its threat to humans and our environment. One reason for this mismatch is that it is difficult for people to mentally simulate the complex and probabilistic effects of climate change. People also have trouble visualizing the impact that our actions will have on our future, especially if the consequences are long term, abstract, and at odds with current behaviour and identity.

To overcome these challenges, a team at Mila AI institute, led by Professor Yoshua Bengio, is working to develop an interactive personalized visualization tool powered by AI to enable a user to see what a location of their choice (e.g. their house) will look like in 2050 or 2100 according to various climate scenarios. These scenarios would include the case of insufficient global action, as well as cases where individual action (like buying electric vehicles) and collective action (like meeting the Paris Agreement goals) can influence our current trajectory

- *Can personalized stories shift individual worldviews, mindsets, and behaviours?*
- *If so, how can we effectively bring this approach to scale to drive societal transformations?*
- *How do we compare and contrast the environmental costs of AI (training neural networks, travelling to conferences, etc.) and its benefits?*
- *How will society at large react to such AI-generated imagery? What are the preventive measures to take to make sure that it is not perceived as manipulation and paternalism?*



Mila

IMMERSIVE PLATFORMS

There is a growing interest in using virtual and augmented reality in platforms, even among leading media outlets such as The New York Times and the BBC. With new 360º VR technologies, storytelling can be immersive and personalized, which can make stories feel more real and potentially foster more emotional connection to them. Research suggests [299,300] that people who experience a story through immersive journalism tend to think, consciously or not, "I was there; therefore, it is real, and it matters" [298]. While research continues to explore this issue, where "a core question is whether virtual reality can provide similar feelings of empathy and compassion to real-life experiences" [301], the technologies and applications are rapidly expanding.

Immersive VR technologies may prove to be powerful means for augmenting traditional storytelling and public engagement strategies around complex challenges such as climate change. But they can also be weaponized through manipulative tools such as "deepfakes", which are a form of disinformation that uses machine learning algorithms to create audio and video of real people saying and doing things they never actually said or did. These are rapidly becoming indistinguishable from reality [302] and much more widely accessible. It is now possible to make a fake video of a person speaking in just a few minutes from just a few images of the person's face. New user-friendly tools, such as FaceApp, allow people to develop deepfakes without any programming or coding experience [303].

The rapid rise of mixed reality tools offers fundamentally new ways to engage people with the climate crisis, build empathy for distant populations, and shape norms. But this shift also poses severe threats to our democracy as disinformation campaigns can lead to more extensive manipulations of human perceptions and social interactions. Urgent actions are needed to address misinformation while research and experimenting are needed to explore the potential of VR and AR in enhancing public engagement efforts around climate change.

Pokémon GO is a location-based augmented reality game that combines the use of smart mobile technology with physical exploration in the real world. It quickly became a global phenomenon in 2016. Its innovation in engaging people of all ages was to superimpose computer-generated information over physical surroundings – putting virtual creatures in real-world locations.

Artist and activist, **Glenn Cantave** uses mixed reality to amplify the narratives of marginalized communities. Inspired by the power of Pokémon Go to engage people, he wants to leverage these same tools to reorient social activism. The Monuments project tags historical monuments that document historical injustices and replaces them with digitally created monuments that represent the voices of marginalized communities.

6 | CROSS-CUTTING ACTIONS AGENDA

ACTIONS

GOAL

Establish a set of enabling conditions that will facilitate steering digital disruptors to shift rules, power structures, and mindsets that constrain climate action by driving changes across economic, governance, and cognitive systems.

WHAT WE ASKED

What set of conditions are necessary to enable and steer the transformative potential of digital levers towards:

- disrupting the rules, power structures, and mindsets constraining transformative actions;
- steering digital disruptors to drive transformations in economic, governance, and cognitive systems; and
- scaling transformations to unleash climate-safe and equitable outcomes?

What near- and medium-term cross-cutting actions must be prioritized in order to leverage the digital age to accelerate societal transformations towards a climate-safe and equitable world?

WHAT WE FOUND

Certain actions have a high potential to foster the emergence of enabling conditions for positive transformational change. These actions were identified and refined through a series of consultations with experts from around the world. While this list is by no means comprehensive, it points to near- to medium-term actions which, if realized, have the potential to catalyse the enabling conditions for broader systems change and build global momentum to leverage digital capabilities for advancing sustainability and equity. Priority actions include the following:

- Establish a social contract for the digital age.
- Promote inclusion as a touchstone of the digital age.
- Expand open access to high-public-value data.
- Establish foundational standards for the digital sector.
- Expand public-private partnerships to build our digital future.
- Reduce environmental impacts of the digital age.
- Foster cross-sectoral collaboration and innovation.
- Invest in targeted communication, engagement, and education.

ACTIONS - ENABLING CONDITIONS

A critical next step will be identifying and supporting the emergence of enabling conditions that have the potential to strengthen and scale our collective ability to leverage digital capabilities. This is important in order to minimize the risks associated with these capabilities and to build up public trust in new digital infrastructure [36,170]. Understanding these enabling mechanisms is essential in catalysing and steering digital disruptions towards positive societal transformations and requires thinking about the broader context in which transformative, systemic changes will occur. Actions emerged through a series of discussions and consultations with a broad range of experts focused on what needs to be done to establish the necessary enabling conditions.

ESTABLISH A SOCIAL CONTRACT FOR THE DIGITAL AGE

Many of the societal changes unfolding as a result of the digital age are threatening individual rights, social justice, and environmental sustainability. However, the potential exists to steer these digital transformations to benefit society and the planet. To seize on this potential, we urgently need a social contract for the digital age that recognizes individual rights, social justice, and protection of the Earth's life-support systems. The foundation of such a contract must include the following:

- *Enhanced international cooperation to support ongoing processes to develop a universal declaration of digital rights as an extension of the human rights laid out by the United Nations.*
- *Expanded societal dialogues on positive and negative trade-offs (including environmental impacts) of digital transformations as levers of societal transformations, leveraging models such as change labs, social innovation labs, living labs, and transformation labs (or T-labs).*
- *Enhanced transparency with regard to the algorithms used and data provided publicly to help overcome biases and build a foundation for equitable systems.*
- *Improved internet access around the world as part of a targeted effort to close the digital divide and improve equity.*

PROMOTE INCLUSION AS A TOUCHSTONE OF THE DIGITAL AGE

Digitally enabled capabilities have enormous potential for increasing equity and inclusion around the world, but so far this has not come to pass [46,64]. Priority actions to promote inclusion will require the following:

- *Build capacity to foster equitable participation in public deliberation platforms, financial markets, and other opportunities enabled by the digital age.*
- *Work to bridge the digital divide, opening up access to the transformative power of the digital age for all.*
- *Create incentives to equalize the quality and quantity of data available around the world.*
- *Work towards a global commitment to ensure that innovations critical to advancing global sustainability and equity are shared openly.*

EXPAND OPEN ACCESS TO HIGH-PUBLIC-VALUE DATA

Vast quantities of data are being created every day. However, much of the data needed to advance environmental and equity agendas are either not being made publicly available or are not being collected at all [64]. The actions that must be taken to overcome these barriers include the following:

- *Establish a multi-stakeholder process for identifying data necessary for research, governments, and business. These data must be made public (e.g. sharing protocols, data standards) within acceptable privacy, trust, and ethical boundaries.*
- *Explore innovative revenue models to incentivize public data provision.*

> "As we work to implement decarbonization strategies, we are proactively working with partners to leverage the power of data and artificial intelligence to be part of the broader solution of building a climate-safe world."

Dr. Ravi Jain
VP Search Science & AI,
Amazon

ESTABLISH FOUNDATIONAL STANDARDS FOR THE DIGITAL SECTOR

Critical societal systems rely on the digital sector, yet few formal standards exist to provide guidance on the handling of both personal data and data generated by sensors, mechanical devices, images, and live camera feeds [64,304]. Priority actions to establish standards include the following:

- *Establish verifiable and enforceable rules regarding consent, data ownership, aggregation, protection, storage, and disposal.*
- *Strengthen transparency of the provenance and quality of data and algorithms and support the development of mechanisms to equitably govern their use.*
- *Develop hybrid (public and private) governance mechanisms to regulate and license equitable open access to data and to reduce or avoid biases in public data used as inputs to algorithms.*

"We are at a pivotal moment in environmental history. Our choices over the coming decade on how to deploy disruptive technologies present an unprecedented opportunity to protect our environment – a feat that we have failed to accomplish over the past forty years. We need to bet big on digital technologies precisely because nothing else has the potential to achieve the kind of transformation our planet needs. This will require public-private collaborations to figure out how to do this in a fair and equitable way. As a foundation, there are critical actions we need to set us on the right path focused on data, standards, and governance of the digital sector."

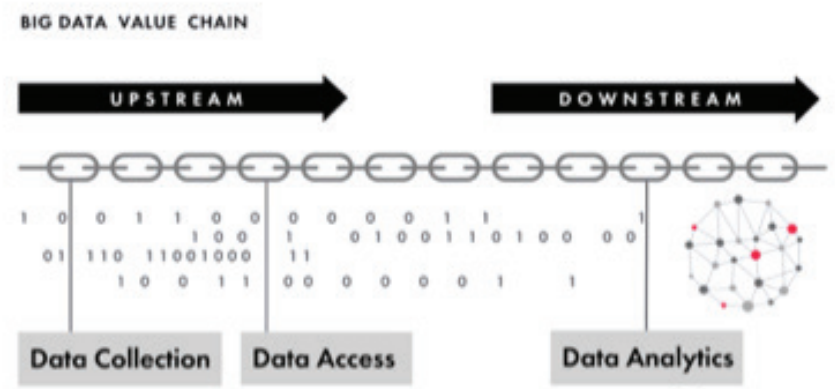
Dr. David Jensen
Head of Policy & Innovation in the Crisis Management, *UNEP*

STANDARDS NEEDED FOR DIGITAL COOPERATION AND SUSTAINABILITY

As vast amounts of data are created, and as data flows increase and the cost of data storage continues to drop, the international community has an enormous opportunity to leverage big data analytics to address climate change by generating new insights that could be used to transform existing industries, create new ones, and more. New data value chains – comprising thousands of participating organizations that support data collection, data access and storage mechanisms, and the production of insights from data to address public good issues – can be created. However, global standards are needed to make this goal a reality.

Organizations of all sizes, whether public, private, or not-for-profit, need a full suite of data governance standards to manage issues such as data ownership and use, security, residency, privacy, and the protection of fundamental rights. Additionally, interoperability standards are required for data collection and grading to take place and for data access platforms to operate across sectors and regions [305].

The challenge is that no international organization is currently mandated to coordinate the development, maintenance, and use of technical standards covering data value chains and policy-oriented standards focusing on data governance. Standard-setting activities in this field are fragmented between hundreds of organizations. As no data standards registry is maintained, stakeholders and experts alike are struggling to determine what data standards have been published, who is working on new documents, and whether there are gaps that need to be addressed. Although there is growing recognition that a new mechanism to coordinate the development of global data standards is needed, little progress has been made in recent years towards the adoption of an international convention on data governance. A new approach is needed. Alternative pathways, such as the creation of a "data free trade zone" to foster the creation of international data collaboratives are being explored [305].



International digital cooperation can help address pressing issues like climate change. Global standards are needed to create data value chains linking data collection and grading to data analytics and solutions through appropriate data access platforms. Graphic: CIGI

In order to foster digital cooperation through standards, it will be imperative to:

- *establish a mechanism to coordinate the development of global data standards similar in scope to bodies such as the Internet Engineering Task Force, which contributed to the development of technical standards that helped lay the foundation upon which web applications operate today;*
- *explore how standards can help foster the creation of "data free trade zones" that support the emergence of international data collaboratives; and*
- *enhance understanding on how international data collaboratives can and should be structured.*

Digital technologies have led to exponential increases in revenue for many private sector actors, enabling new business models which often depend on extracting value from public and private data. This extraction is frequently done without public consent and to the benefit of the few. We need to focus on harnessing the potential of digital sector for global public benefit. This will require public-private partnerships to both support the development of public benefit data and services, and to build the institutional and regulatory context needed to steer the digital transformations underway to both empower business and support the wellbeing of people and the planet.

Dr. Asunción Lera St. Clair
Senior Principal Scientist, *DNV GL;*
Advisory Committee, *Future Earth*

EXPAND PUBLIC-PRIVATE PARTNERSHIPS TO BUILD OUR DIGITAL FUTURE

Engaging the private sector – in particular, major platforms – and government and civil society actors will be critical to combine resources, knowledge, and expertise to work towards a common goal. Priority actions include the following:

- *Build public–private partnerships that include major platforms in support of societal goals and digital rights, including, for example, the rights to privacy and to be forgotten, and ensuring that algorithms steer behaviour in a positive direction without perpetuating pre-existing biases.*
- *Develop funding mechanisms to deploy purpose-oriented responsible research and innovation projects to direct public and private efforts and investments towards digitalization for sustainability and equity, diversifying sources of funding to enhance outcomes along the entire innovation spectrum.*
- *Co-develop regulations and guidelines for the ethical and sustainable management of the platform economy.*
- *Create incentives for businesses at different scales to leverage digital tools to work towards increasingly sustainable, circular business models.*
- *Continue to develop mechanisms to institutionalize innovative ownership models, including, for example, data trusts and mission-focused incubators.*

FOSTER CROSS-SECTORAL COLLABORATION AND INNOVATION

Tackling the challenge of decarbonizing society by 2050 will require unprecedented collaboration and innovation involving the active participation of individuals and groups across scales and sectors. Doing so, however, presents its own set of challenges. We must work together to overcome obstacles to cross-sectoral efforts by fostering stronger communication, building spaces for innovation, and creating opportunities for different communities to come together. Priority actions for fostering collaboration and innovation include the following:

- *Create open and accessible collaborative arenas such as change labs, social innovation labs, living labs, and T-labs.*
- *Build capacity and skills in an equitable manner around the world, prioritizing areas lacking in engagement and education.*
- *Promote innovation and experimentation through enhanced support for cross-sectoral activities – including workshops, initiatives, and projects – focused on leveraging the digital age to address the climate crisis.*
- *Adapt, test, and scale concrete methods for enhancing transdisciplinary collaboration and innovation. Scenario co-development can help enhance cross-sectoral communication and improve understanding of one another's worldviews and mindsets. Innovation sprints are a powerful way to bring together a group around a common goal with a solution- or action-oriented mindset. Scaling these efforts – for example, through the use of bespoke virtual platforms – has great potential to enhance cross-sectoral collaboration and innovation around the world.*

INVEST IN TARGETED COMMUNICATION, ENGAGEMENT, AND EDUCATION

As the movement behind Sustainability in the Digital Age grows, communication, engagement, and education to enhance knowledge transfer and knowledge co-production will become critical components of scaling and maintaining momentum. Priority actions to realize this include the following:

- *Encourage basic research into the implications of transitioning to the digital age on within- and between-country equity (including, for example, research into particular digital phenomena such as the platform economy and blockchain).*
- *Create opportunities for stronger interdisciplinary training (e.g. ethics courses for computer scientists, digital technologies courses for social scientists) to enhance cross-fertilization of ideas and innovation.*
- *Employ targeted communication and engagement channels to build public awareness of the opportunities and challenges of leveraging the digital age to drive societal transformations towards a more climate-safe and equitable world.*

REDUCE ENVIRONMENTAL IMPACTS OF THE DIGITAL AGE

The carbon footprint of the digital sector has been estimated to account for around 2% of global GHG emissions between 2010 and 2015 [306]. But the digital sector has many other types of environmental impact. Mining, in particular for rare earth materials, and the growing problem of e-waste are leading to environmental degradation around the world, with many impacts accruing to lower-income communities and developing nations [307,308]. Priority actions include the following:

- *Scale up cross-sectoral collaborations to increase reliance on renewable energy sources.*
- *Support efforts to further investigate environmental impacts of the digital age, including indirect impacts and impacts on equity worldwide.*
- *Encourage both public and private sector engagement in innovative partnerships to reduce environmental impacts linked to energy consumption, supply chain sourcing, e-waste, and use of rare earth materials.*

In order to realize the positive potential of the digital age, it is imperative that the digital sector transitions to renewable energy sources.

GREENING THE DIGITAL SECTOR

Overview

The combined carbon footprint of the digital industry – including information and communications technology, entertainment and media, and associated paper usage – amounted to approximately 2.6% of total global GHG emissions, or 1,370 million tonnes of carbon dioxide equivalent, in 2018 [54].

Digital industry emissions are declining. Many companies are imposing their own internal carbon fee to fund decarbonization efforts. Current estimates suggest we must further reduce annual emissions by 55% by 2030 to stay on track to limit global warming to well under 2 degrees Celsius [54]. Figure 7 shows how this is possible through reduced emissions in different sectors. The most effective strategy will be the digital industry transitioning to renewable energy [54].

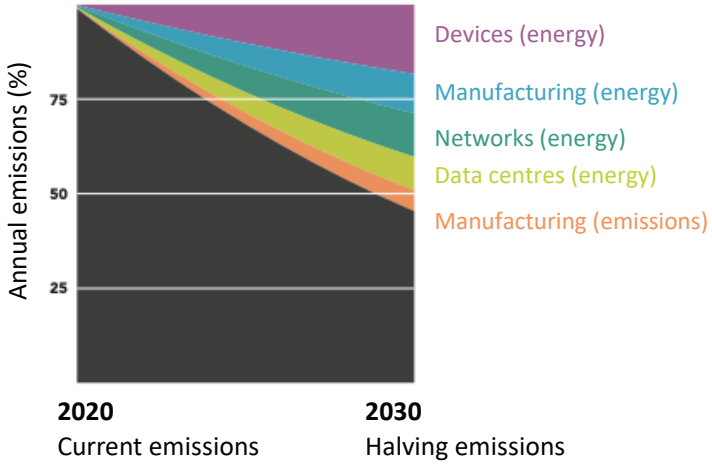
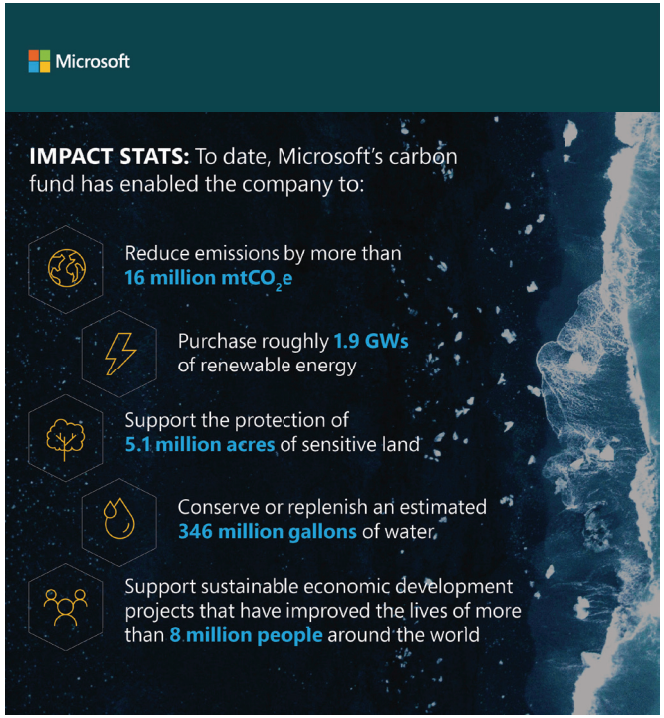


Figure 8. A trajectory to halve digital industry emissions by 2030 [54].

The digital sector is already working to address this challenge. For example, Microsoft has committed to going carbon negative by 2030 and to removing all their historical emissions from the atmosphere by 2050. A major mechanism to achieve these goals is through an internal carbon fee to make all divisions of the company financially responsible for reducing their own emissions. Microsoft will also increase transparency along all supply chains to become accountable for all emissions, setting an important precedent for companies in the digital industry [309].



7 | APPENDIX

GLOSSARY

LIST OF TERMS

Algorithm: A process or set of instructions to be followed in calculations, data processing, automated reasoning, or other problem-solving operations performed by a computer.

Anticipatory governance: A form of data-driven decision-making that employs predictive algorithms and other prediction and foresight mechanisms to anticipate possible outcomes as a means of decreasing risk in decision-making and governing more efficiently by addressing events early or before they even occur.

Artificial intelligence: The simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using information), reasoning (using rules to reach approximate or definite conclusions), and problem solving.

Augmented Engagement: The use of mixed reality tools to develop an interactive experience that enables connection to otherwise remote concepts or experiences.

Augmented reality: A technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view and an interactive experience of a real-world environment enhanced by computer-generated perceptual information.

Blockchain: A digital ledger or database in which transactions are recorded chronologically, creating a permanent record that is transparent to anyone connected to the network.

Bot: Automated software applications that run repetitive programs

Business model: A plan or strategy for the way a company seeks to create, capture, and share value.

Choice architecture: The design of different ways in which choices can be presented to consumers and the impact that this presentation ultimately has on consumer decision-making, derived from behavioural science.

Circular economy: An economic system aimed at eliminating waste and the continual use of new, finite resources by employing recycling, reuse, re-manufacturing, and refurbishment to create a closed-loop system.

Cognitive systems: Systems connected with the acquisition and processing of information and knowledge, making decisions, and forming judgements.

Collaborative governance: Also known as participatory governance. The "processes and structures of public policy decision making and management that engage people constructively across the boundaries of public agencies, levels of government, and/or the public, private, and civic spheres" [198].

Collective storytelling: The social and cultural activities of sharing stories and narratives scaled up to larger groups and situating their components (including questions, problems, and overarching themes) in relation to a broader context.

Crowdsourcing: The practice of obtaining input or funding for a question or project by enlisting the services of a large number of people (either paid or unpaid), typically over the internet.

Digitalization: The process of using digital technologies and digitized data to change how a system functions.

Digitization: The process of converting from analogue to digital format.

Digital age: Often cited as beginning in the 1970s, the digital age refers to a period during which the use of digital technology became prevalent and common throughout the world. The digital age is characterized by a rapid shift towards an economy based on information technology and has also led to changes in social relationships, science, politics, and many other facets of societies around the world. Also referred to as the information age.

Digital disruptors: Capabilities brought about by digital-age technologies and innovations with the potential to drive systems change at a scale and pace unprecedented in human history.

Digital MRV (measurement, reporting, and verification): Tools for generating data (such as energy attributes) that quantify, communicate, and authenticate outcomes. Digital MRV can improve the speed and accuracy of regulatory reporting, lower reporting and verification costs, and increase the scalability and security of transactions.

Digital nudge: A set of carefully developed rules, hints, tips, and suggestions that encourage people to change behaviour in small but meaningful ways, where "nudges" are designed based on desired outcomes in terms of behavioural change.

Governance of Flows: Governance of the embedded flows of goods, services, capital, and information, including both material and virtual flows.

Informational governance: A new form of governance in which information is the crucial resource used to govern and which has been characterized by transformative changes across governance institutions due to new information flows [163].

Intelligent systems: Machines with embedded, internet-connected computers with the capacity to gather and analyse data, perform complex activities, perceive and respond to the world around them, learn from experience and adapt, and communicate with other systems.

Internet of Things: A network of appliances, electronics, mobile devices, and sensors that can communicate and exchange data without requiring human intervention.

Machine learning: Sometimes referred to as a subset of AI, machine learning is the study of algorithms and statistical models that computer systems use to perform specific tasks without receiving instructions, relying on patterns and inference derived from "training data" instead.

Microtargeting: Transmitting a tailored message to a subgroup of a broader population on the basis of unique information about the subgroup. This technique is most commonly associated with election campaigns and includes direct marketing, data mining, and predictive market segmentation techniques.

Mixed reality: The merging of real and virtual worlds to produce new environments and visualizations where physical and digital objects coexist and interact in real time, enabling users to view and manipulate these objects. Sometimes referred to as a combination of augmented and virtual reality.

Neoliberalism: An economic paradigm often associated with "laissez-faire" economic liberalism and free-market capitalism.

Platforms: Online frameworks for facilitating transactions, innovation, and collaborations, which have enabled new strategies for how businesses create, deliver, and capture value.

Precision services: Scalable customized knowledge-intensive services.

Prosumer: A customer that both produces and consumes a product or service, such as electricity or energy storage.

Resilience: Most famously, resilience is "a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables" [232]. Resilience has also been referred to as the ability of a system to adapt to change, to recognize or anticipate risks and defend against them before adverse consequences occur, or as a paradigm for safety management [311].

Sharing economy: An economic model where peer-to-peer online platforms enable community-based acquisition, sales, and/or sharing of goods and services.

Societal systems: The many anthropogenic systems that together compose and underpin global human society, including, notably, our economic, governance, and cognitive systems.

Societal transformation: Fundamental changes in structural, functional, relational, and cognitive aspects of societal systems that lead to new patterns of interactions and outcomes.

Surveillance capitalism: A term popularized by Shoshana Zuboff and based on the premise that capitalism has become focused on collecting and processing data relating to a significantly expanded portion of society's activities and people's behaviour. Surveillance capitalism refers to the act of accruing a profit from free digital services by tracking and monitoring behaviour and selling this information (often without the explicit consent of users).

Systems approach: A change that influences the interactions and interlinkages between different components of one or multiple systems.

Transparent Supply Chains: Disclosure about social and environmental conditions of the supply chain and open information about buyers' purchasing practices allow traceability.

Unprecedented transparency: A phrase used to describe actions and approaches that radically increase the openness of organizational processes and data, making information publicly available and accessible.

Virtual reality: A simulated experience that enables users to view and move around in an artificial world (though this can mirror the real world) and interact with virtual features.

APPENDIX 1

FUTURES COLAB EXERCISE

To kick off the development of the D^2S Agenda, the team sought inputs from a broad diversity of experts on the systems keeping us on an unsustainable and inequitable development path and potential levers to disrupt these systems. This was done through a virtual deliberation exercise. Futures CoLab is a network of diverse international experts, a platform for online collaboration, and a process for asynchronous and facilitated dialogue. The goal of Futures CoLab is to enable experts from around the world to collectively explore solutions to global systemic challenges. Futures CoLab is a collaboration between Future Earth and the MIT Center for Collective Intelligence.

PROCESS AND PARTICIPANTS

The Disrupting Systems for Global Sustainability exercise took place from March 4 to 24, 2019. 178 participants from 31 countries and a diversity of backgrounds were involved (see Figure A1). The two primary goals of the exercise were: (1) to characterize key systems that are sustaining our unsustainability; and (2) to identify disruptions to these systems and mechanisms through which new technologies and associated practices of the digital age could be leveraged to foster these disruptions.

In the first week, participants were asked to broadly identify systems that are preventing society from shifting to a more sustainable and equitable path. After these submissions were received, the Futures CoLab team used a natural language processing tool to suggest ways of grouping the identified systems. In the second week, participants shared ideas about potential disruptions that could lead to the unraveling of today's unsustainable systems and enable the transformations necessary to steer the world toward sustainability. In the third and final week, participants voted on the disruptions they believed could have the most significant impact on enabling transformations towards sustainability. Throughout the exercise, participants were encouraged to engage in discussions by commenting on each others' submissions. This deliberative process helpeds both to clarify and expand upon individual contributions while also contextualizing participants' inputs.

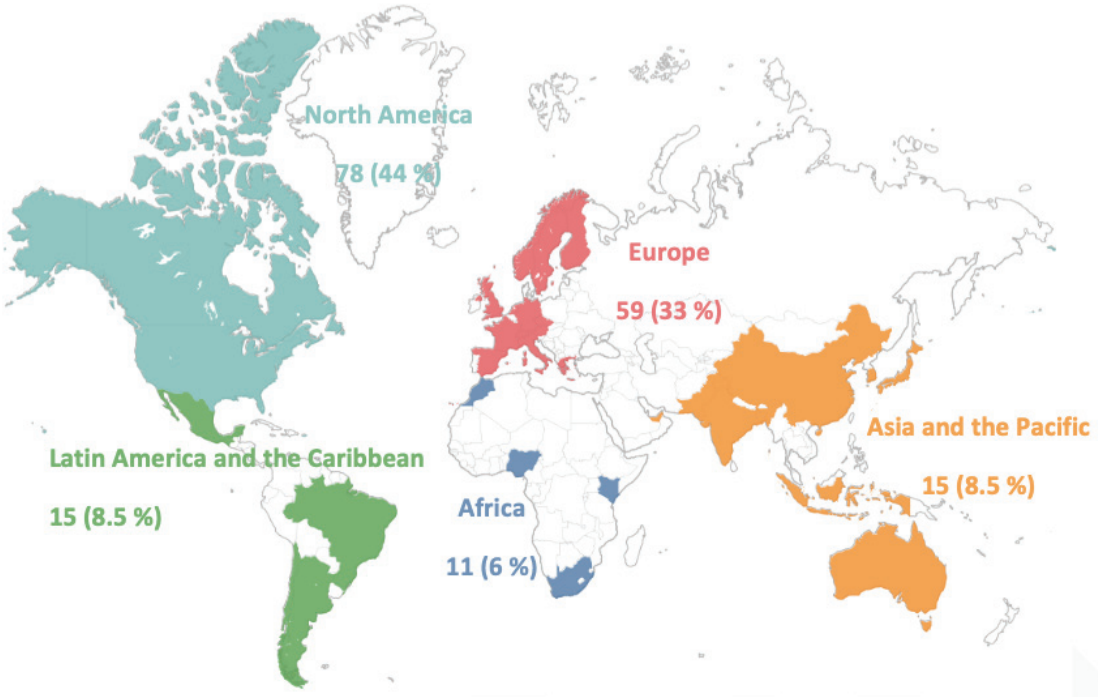


Figure A1. Futures CoLab participants. Regional balance of participants in Futures CoLab: Disrupting systems for global sustainability.

OUTCOMES

Many of the issues highlighted in the Futures CoLab dialogues were linked broadly to systems of production and consumption, including emissions in urban and food systems, land use changes and trade, as well as issues with consumer behaviour. These were relatively unsurprising and align closely with the findings of the IPCC – for example, with the categories used in the IPCC Working Group III contribution to the Fifth Assessment Report to explain dominant sources of emissions [312].

A main message of the online dialogues was that underlying these systems of production and consumption, and maintaining unsustainable behaviour, were key social systems which need to be disrupted. Three systems emerged as responsible for reinforcing the rules, power structures, and mindsets that are keeping society on a carbon-intensive, biosphere-degrading, and vulnerable path: economic, governance, and cognitive systems. It became clear over the course of the exercise that finding levers to disrupt these three systems – not those physically contributing to GHG emissions but those underlying societal structures that drive emissions and reinforce unsustainability – will be critical in order to steer society onto a more equitable and sustainable path. This message formed a starting point for the development of the D^2S Agenda.

While the online dialogues did not delve into the technological aspects deeply, there were still indications of different types of digitally enabled capabilities with the potential to unleash transformative systems change. These discussions led to the development of the four digital disruptors identified in the D^2S Agenda.

More information can be found in the synthesis report Disrupting Systems for Global Sustainability, available online at futureearth.org/initiatives/other-initiatives/futures-colab/.

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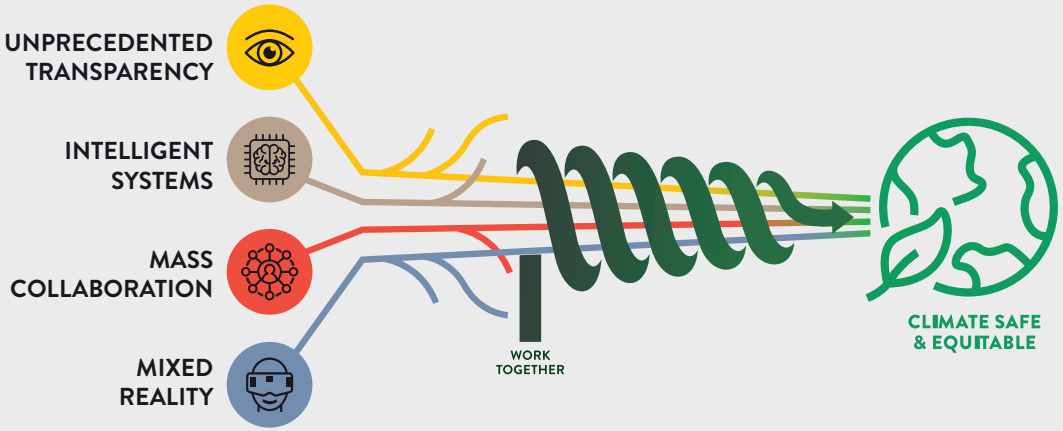

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