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UNLEASHING SCIENCE

Delivering Missions for Sustainability

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TABLE OF CONTENTS

LIST OF FIGURES

We need to urgently redouble efforts to achieve the Sustainable Development Goals

Business-as-usual approaches – to science and science funding – are no longer appropriate to this massively complex and urgent challenge

Effective action will require broad and bold engagement, and commitment, from science funders, but also from the decision-makers and influencers in governments, in the private sector and in civil society

The international funding community is ready for the challenge and has requested the International Science Council to lead on the development of a process to convene the necessary voices, jointly designing the way forward

This report is an input into that process

It is intended as a strawman, to disrupt our thinking and to inspire ambitious and achievable outcomes

Let’s begin

PREFACE

In today's highly uncertain world, the 2030 Agenda and the Sustainable Development Goals (SDGs) offer an invaluable framework to guide governments and societies in shaping a transformative and resilient recovery from COVID-19, creating a more sustainable society in the long run.

Achieving the transformative vision of the SDGs by 2030 requires an urgent realignment of most countries' and actors' priorities and resources towards longer-term, more collaborative, and drastically accelerated action. It also requires game-changing collective action within science systems and funding globally.

While science has been recognised as a critical lever in achieving the SDGs, the current capacity of the international science system is not necessarily up to the task to effectively contribute to the transformative, systemic changes needed for human wellbeing to thrive in the 21st century. By contrast, the exceptional role science played in the collective response to the COVID-19 pandemic shows what science can achieve if political leaders and science funders set their minds to it. This includes inter alia the unprecedented speed of vaccine development, data sharing, international research collaboration, fast-tracking of support for research, and scientists' collaboration with the private sector. Thus, the COVID-19 experience demonstrates that science can play a vital role in solving global crises, however, it is not currently the norm in how science is positioned, organized and incentivized to contribute to addressing global existential threats.

Unleashing the full potential of science is a massively complex and urgent challenge requiring bold, strategic, and collaborative action from governments, science policy makers, science funders, scientists, the private sector and civil society. A qualitative and quantitative step change is needed in science to support critical societal transformations towards a more sustainable, equitable and resilient future. There is an urgent need to step up the pace of progress and redouble efforts of all actors to achieve the SDGs. Relying on business-as-usual approaches is not an option.

The science funding community is ready. Science funders at the 2019 Global Forum of Funders (GFF) recognized the urgent need to scale up game-changing collective action within funding and science systems throughout the world in order to maximize the impact of science towards the implementation of the SDGs. They have requested the International Science Council to lead on the development of a process to convene the insights and ideas of the global scientific community on the critical priorities for science and to jointly design the way forward.

This report is an input into that process. It presents a framework of ideas on how science, along with science funders, policy-makers, civil society and the private sector, could rise to the occasion of acting effectively in the face of urgent and existential risks to humanity. The report offers a Framework to Unleash Mission-Oriented Science, highlighting the need to focus on a limited number of Sustainability Science Missions – in the critical areas of food, energy and climate, health and wellbeing, water, and urban areas – and outlining a potential way forward for the delivery of such missions. It is intended to challenge and, where necessary, disrupt our thinking and inspire ambitious and achievable outcomes.

The International Science Council developed this report based on the input collected from an ISC-led global call in 2020 to shape a priority action agenda for science. In addition to the call, the ISC undertook extensive reviews of international research agenda-setting reports and the relevant scientific literature published since the adoption of the SDGs.

The report was developed under the valuable guidance provided by the members of the Scientific Advisory Group who helped to define the scope, analyse the multiple inputs, develop a framework for mission-oriented science, identify an exploratory set of research questions for such missions and review the report. The development of the report would also not have been possible without strategic advice provided by the members of the Steering Committee, representing the partners of the GFF. Its findings were represented at the 2nd Global Forum of Funders, the 2021 Annual Meeting of the Global Research Council and the 2021 United Nations High-level Political Forum on Sustainable Development, and further inputs were integrated in the report.

Recognizing the complexity and the urgency of the challenge to maximize science impact towards the Agenda 2030, the International Science Council is establishing a high-level coalition of political leaders, science funders, both national and philanthropic, development aid agencies and scientific strategists to identify practical steps, appropriate institutional arrangements and funding mechanisms, building on the insights provided by the report.

As a science community, we must collectively take a much more holistic approach to empowering science for sustainable societal transformations in the 21st century. It is time to be disruptive and do things differently and with imagination and collaboration!

Sir Peter Gluckman
President-elect, International Science Council

Partners of the Global Forum of Funders

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EXECUTIVE SUMMARY

The imperative of a new approach

The scope, scale and speed of human pressure on Earth is unprecedented. Taken together, human actions are undermining and challenging the fundamental processes that underpin a habitable biosphere and Earth system resilience. Advancing human development while respecting planetary boundaries is now the most important challenge for humanity, and for science.

'Unleashing Science' is a roadmap for science and research, in the broadest sense, along with science funders, policy-makers and the private sector, to advance this transformative agenda. The report argues for a major step change in the approach to science and science funding by delivering specific missions for science as they relate to the critical areas of food, energy and climate, health and wellbeing, water and urban areas.

The inability of the existing global science system to effectively support the sustainability agenda

Despite achievements and concerted efforts, there is a fundamental misalignment between the scale of global challenges and the structures of science funding. This misalignment is particularly manifest in the unequal capacity to produce scientific knowledge in the Global South, with respect to the Global North. Furthermore, support for global multilateral scientific cooperation on sustainable development is insufficient and fragmented. International science funding is particularly inadequate for international scientific and science-policy collaborations that have the potential to synthesize knowledge and data in innovative ways that can advance the capacity for global action.

The establishment of the Intergovernmental Panel on Climate Change (IPCC), the Intergovernmental Science-Policy Platform on Biodiversity (IPBES), the Millennium Ecosystem Assessment, Belmont Forum and Future Earth are examples of major global collaborative research undertakings. But the scale of the challenges faced is much larger than the current capacity of the research community to meet societal needs. As it is currently organized, the international science system produces significant but narrowly-focused, fragmented and compartmentalized knowledge that is often disconnected from society's most immediate needs. In short, much of science funding supports research that is limited in its ability to contribute to the transformative, systemic changes needed for human wellbeing to thrive in the 21st century and beyond.

Long-term systemic reforms of existing science systems need to take place at the national and international level. But the pace of this reform, although necessary, will be incommensurable with the timeline for achieving the Sustainable Development Goals (SDGs) or that of addressing our current planetary crises. Time is of the essence.

Envisioning an international mission-oriented science

To meet the challenges of the 21st century, and in particular the immediate science needs associated with Agenda 2030, the report offers an ambitious approach – a concerted effort to produce actionable knowledge through co-designed mission-oriented research in support of key social transformations to sustainability.

What is needed are support structures, processes and funding mechanisms that orient science towards the following attributes:

- Solutions-focused and driven by the common good
- Transformative
- Interdisciplinary, with a step change in the role and support given to the social sciences
- Embracing transdisciplinarity
- Systems-focused
- Networked and flexible
- Globally and regionally connected and capacitated
- Collaborative and inclusive
- Open and accessible to all
- Critical, innovative and reflective
- Societally accountable.

One goal – Five sustainability science missions

The scientific advances most needed in the near term are those that help stabilize the Earth system within a safe-operating space within 10–20 years. This requires halting and directing societal systems away from unsustainable practices towards restoration, repair, resilience and long-term sustainability. The guiding vision – for the near-term – is Agenda 2030 and the SDGs. Beyond that date are the ecological, economic and social pillars of sustainability, i.e. a dignified existence for all within planetary boundaries.

Drawing on responses to a call led by the International Science Council (ISC), and extensive reviews of research agenda-setting reports and the scientific literature, the report identifies five areas requiring immediate and transformative changes: food, water, health and wellbeing, urban areas and energy/climate. The rationale for selecting these five thematic areas is as follows:

- Each of these areas, if unaddressed, pose existential risks to humanity, and none can be effectively dealt with unilaterally.
- They are major drivers of unsustainability and environmental degradation, as well as social deprivation and inequality.
- These areas are most at risk from the environmental changes already underway.
- They have been recognized as critical across various transformative frameworks and there is a strong consensus across scientific communities in favour of these five areas.

To stabilize the Earth system within a safe-operating space within 10–20 years, the report argues that mission-oriented work needs to focus on these five broad areas to urgently make them more sustainable, equitable and resilient. The report identifies five missions that allow integrating the SDGs:

- Food: eating adequate, healthy diets without consuming nature's bounty
- Water: replenishing nature's reservoirs to provide enough clean water for all
- Health and Wellbeing: being whole and well in body, mind and nature
- Urban areas: thriving in places while stewarding the natural environment
- Climate and energy: shifting to clean energy while restoring a safe climate.

These missions represent larger, inclusive areas and the next step will be to define with key stakeholders more granular, specific science missions within each area. Based on this understanding and for ease of reading we refer to these areas as 'science missions' throughout the rest of the report.

Learn more: council.science/science-missions

All missions must be realized in culturally sensitive and geographically appropriate ways, and owned and co-created with affected societal partners. Each mission must be delivered in a way that is galvanizing: it must ignite the imagination, not just for scientists, but for all those directly impacted and for society at large. Furthermore, they will have to be delivered in a way that ensures social equity and justice, minimizes environmental degradation and builds resilience, promotes nature-based solutions and does not undermine the delivery of other missions.

An initial set of research questions was distilled for each mission (Annex 1). However, the final list of game-changing priorities that each mission will address, will be identified through a process of co-design, involving key stakeholders and relevant disciplines, and prioritizing topics that require the most pressing global collaboration.

To bring about the needed transformational changes through these missions requires not only technological innovation, but more importantly, fundamental changes in the political, economic, structural and behavioural aspects of each system. It is critical to understand the key obstacles and barriers that exist and identify effective ways of overcoming these. Examining existing mindsets, belief systems, cultural values and norms, power dynamics, vested interests, governance systems, resource flows and practices will be key in addressing the root causes that maintain unsustainable practices within each mission's remit.

Implementing mission science

The report offers one possible solution – the creation of 'Sustainability Mission Stations' that will bring together the best of global science to work with policy-makers, the private sector and civil society actors to deliver jointly on the co-designed missions. This would require the full-time dedication of a core group of carefully selected scientists, policy experts and science implementers from across the word, adequate financial support and institutional shielding so they can remain focused and deliver not just knowledge outcomes, but also action outcomes.

It is essential to build on the existing science infrastructure – physical, virtual and intellectual. This means drawing strongly on existing human capital, institutions and networks of relevant researchers and practitioners, and also creating unique spaces for them to come together, immerse themselves in the mission goals and collaborate on the co-defined research questions without distractions or constraints.

Next steps

The ambition is to make Mission Stations operational within the next 3 years and to mobilize US$20–40 million per science mission station per annum for at least five years. In this context, the ISC will establish a high-level coalition of political leaders, science funders, both national and philanthropic, and development aid agencies over the next 15 months, tasked with identifying the most appropriate institutional arrangements and funding mechanisms required to co-construct and deliver on the missions identified.

Towards business-unusual: courage and commitment

Current trends in Earth's life-support systems and in society have coalesced to create a critical moment in human history. If science wants to play a relevant part in addressing these intersecting crises, the system that supports it internationally must change. To do so requires society to break with business-as-usual and rise to the occasion of the human predicament.

'Unleashing Science' argues for stepping out of business-as-usual approaches to funding research and institutional arrangements. This calls for courage, and it calls for commitment.

1 A PLANET ON 'RED ALERT': SOCIETY FAR OFF-TRACK TO DELIVER ON THE SDGS

The scope, scale and speed of human pressures on Earth are unprecedented. Humanity has become the dominant force in shaping the future of all planetary systems. The most serious and immediate risks are human made and unfold at planetary scales, from climate change to the COVID-19 pandemic, to biodiversity loss and rising inequalities (UNDP, 2020).

Taken together, human actions are undermining and challenging the fundamental processes that underpin a habitable biosphere and Earth system resilience. It can no longer be taken for granted that the planet will be able to continue to support human wellbeing and development. The consequences of this profound human imprint are evident in a convergence of crises: worsening disaster losses, widening gaps in wealth, destabilization of nations, rising discontent and authoritarianism, and cascading systemic risks endangering economies, human welfare and governability. The threat is existential.

Advancing human development within planetary boundaries is now the most important frontier for human exploration (UNDP, 2020), and the most pressing challenge for science.

> *'The 2030 Agenda and its 17 SDGs represent the most ambitious and significant attempt since World War II to rethink what development means. We cannot afford to miss this opportunity to protect the planet and build the society we want to live in'.*
>
> - GFF (2019)

The adoption of the Sustainable Development Goals (SDGs) in 2015 by the United Nations is a global response seeking to reconcile human development with planetary boundaries. The current COVID-19 pandemic has significantly set back efforts towards SDG achievement. There is an urgent need to step up the pace of progress and to take substantial additional actions to strengthen needed transformations beyond 2030.

'Unleashing Science' is a roadmap for how science and research, in the broadest sense, along with science funders and policy-makers can help advance this urgent, transformative agenda. A major step change in approach is needed.

2 SCIENCE FOR SOCIETAL TRANSFORMATIONS

The State of International Scientific Efforts and Organization

Since its adoption, the 2030 Agenda has galvanized the efforts and contributions of the global scientific community. A plethora of new knowledge, synthesis processes and transformative global research agendas have been developed[1]. While diverse in scope and focus, these efforts all identify critical entry points for science to contribute to addressing the SDGs in an integrated fashion. There is a crucial need to focus the scientific community on the SDGs as, to date, only 10% of global research output relates directly to the SDGs (Digital Science, 2020). In addition, much science is being produced, which while highly relevant to the necessary societal transformations to sustainability is not being brought into sustainability and transformations discussions and action agendas, e.g. on governance, behaviour change, communication and circular economies. Far from being at the core of concerted efforts of science systems worldwide, sustainability science remains a limited field in the broader scientific landscape, and other relevant science is not effectively used in policy debates (UN GSDR, 2019).

> *'Only an urgent, more ambitious and well-resourced global plan of action will ensure that the goals [of Agenda 2030] are met.'*
>
> \- GFF (2019)

In part, this insufficient research focus on the SDGs is the result of the constraints of available research funding. Clearly, no single country can achieve a sustainable society alone, but current science efforts (and the underlying science funding support) are primarily national in scope and as a result fragmented. Research funding prioritizes national scientific efforts that generate national benefits (particularly economic benefits) over international collaboration to achieve global societal and environmental benefits for the common good: about 80% of research projects involve only domestic collaboration, with the remaining involving bilateral (15%) and multilateral (5%) collaboration (Digital Science, 2020) (Textbox 1).

There is also huge inequality in the capacity to produce relevant knowledge between the Global North and the Global South. This imbalance threatens the achievement of the SDGs. There is a need for redistribution of global funding to low-income countries to build up their capacities to produce knowledge required for dealing with regionally-specific, but globally-interlinked challenges.

[1] Some examples include Randers et al. (2018), TWI2050 (2018), Sachs et al. (2019), UN GSDR (2019) and WEF (2020).societal and environmental benefits

Textbox 1: A Snapshot of Human Deprivation

Environment	Wealth	Health	Happiness
Nine out of ten people breathe air with high levels of pollutants	71% of adults own less than US$10,000 in wealth	Life expectancy has doubled in a century	More die by suicide than war and violence
One in nine people use water from unsafe sources		One billion are obese; 800 million go hungry	Happiness inequality is rising
2.3 billion people lack access to a toilet		100 million suffered acute hunger in 2018	
One billion people have no access to electricity		COVID-19 pandemic, with at least 3.8 million deaths as of June 2021	
Three billion people suffer from land degradation, desertification and have missed out on the great acceleration			

Source: TWI2050, 2018

Institutional fragmentation and the resulting complex funding landscape undermine the effectiveness of different research efforts and make it more challenging for science to contribute effectively to the attainment of the SDGs. The persistent inequality in global vaccination against COVID is a stark reminder of what may emerge around the SDGs if research and implementation of sustainability solutions continue to remain fragmented. There is a need for significantly improved coordination and strategic prioritization in the research and underlying research funding contexts (Figure 1).

Funding Priorities

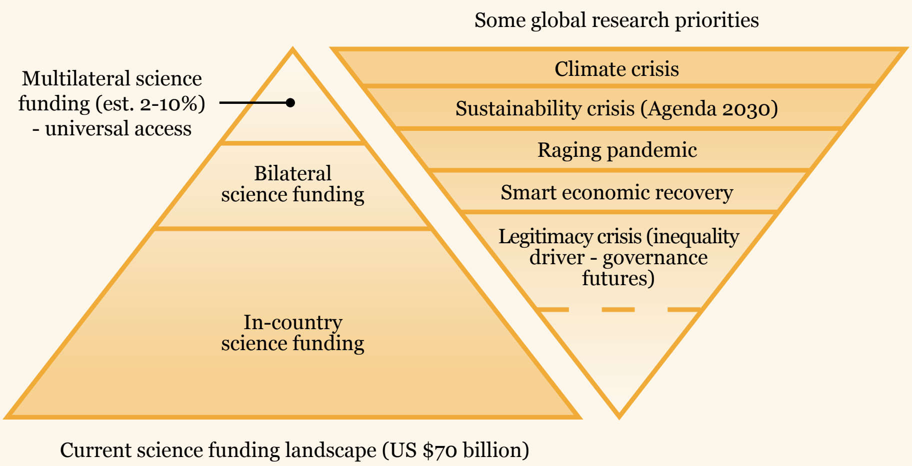

Figure 1: The Mismatch Between Science Funding vs Global Research Priorities. Investments in research are not aligned with global priority concerns but determined largely by national competitive interests. Support for global multilateral scientific cooperation on pressing global challenges (at scale and in a timely manner) is insufficient.

The global science funding and international research situation on sustainable development can be summarized as follows:

- Misalignment between the scale of the global challenges that must be urgently addressed and that of the science funding available;
- Misalignment is particularly clear in the unequal capacity to produce scientific knowledge in the Global South vs Global North;
- Investments in research are determined largely by national competitive interests;
- Science funding is particularly insufficient for international scientific and science-policy collaborations;
- Global multilateral scientific cooperation (at scale and in a timely manner) is almost non-existent;
- International scientific effort is highly fragmented; and
- Intense competition for limited science funding undermines any effort for researchers to come together to bring a unified focus to the common cause of sustainability and humanity thriving within safe planetary boundaries.

Limits of the Current Science System to Support Societal Transformations

The science system is not currently organized and incentivized in ways that enable scientists to contribute effectively to finding and implementing responses to global existential threats. By contrast, the exceptional role science played in the collective response to the COVID-19 pandemic shows what can be achieved if society, political leaders and science funders set their minds to it. This includes inter alia the unprecedented speed of vaccine development, data sharing, fast tracking of support for research and scientists' collaboration with the private sector. The point of this juxtaposition is two-fold: science can play a vital role in solving global crises and the exception of the COVID-19 experience shows that this is not currently the norm in how science is positioned to contribute to addressing existential threats.

Of course, in the past 300 years, the contemporary science system has generated knowledge, resulting in many benefits that transformed the human condition. But this science system, particularly as enacted in contemporary universities, has only a limited capacity to effectively address today's societal challenges. Moreover, while producing many human benefits, the dominant scientific knowledge system has also side-lined other knowledge systems (Textbox 2), an epistemological injustice now criticized by many inside and outside of science. Some contemporary challenges such as climate change, resource extraction, destruction of biodiversity, obesity and premature deaths from toxic air and water pollution have been exacerbated by scientific and technological advances.

Textbox 2: Key Definitions

Knowledge systems – in the broadest sense – are the interconnected ways in which societies organize what is known, how it is known and how that knowledge is related to the material basis of existence. Differently put, knowledge systems relate knowledge contents to epistemologies (the ways in which people come to know that content) and ontologies (the nature of what is). Knowledge systems are closely intertwined with society, economies and cultures and are integral to shaping the way societies develop, function and mobilize resources (Fazey et al., 2020). Examples of different types of knowledge systems include (but are not limited to) scientific knowledge, indigenous and traditional ecological knowledge, practical and tacit knowledge. All knowledge systems can be described through the institutions, practices, routines, structures, mindsets, values and cultures that shape what and how knowledge is produced and used, and by whom.

Scientific knowledge is produced in an effort to understand the phenomena, processes and fundamental nature of things, iteratively using systematic approaches to refine understanding through empirical observation, measurement, experimentation, hypothesis testing, theory building and rational explanation. While this does not make science entirely unique, the resulting knowledge has proven remarkably robust and enabled extraordinary human advances (Bunge, 1998a, 1998b; Popper, 2002).

Science systems – as a particular subset of knowledge systems more generally – include the institutions, practices, routines, structures, mindsets, values and cultures affecting what and how scientific knowledge is produced and used, and by whom. Such systems are constituted by elements (institutions, structures, assumptions, values and standards) that are functionally interrelated (via the funding, generation, validation, evaluation, communication and application of knowledge) in particular contexts (organizational, operational and political). Science systems include the elements, functions and contexts associated with universities, research institutes and non-governmental and governmental organizations, as well as related funding systems, structures and incentives. Science systems are traditionally organized in, and produce knowledge and technology through, the natural sciences, social sciences, applied sciences, humanities and the arts, sometimes in collaboration with industry and commerce (Parinov and Neylon, 2011; Hessels, 2013).

Mission-oriented science – as used in this report – is singularly goal-oriented and solutions-focused, science conducted for a limited period of time until a substantial challenge has been successfully addressed. Missions are of significant size, scope and ambition; and while focused on a clearly defined topic, question or goal, require interdisciplinary and transdisciplinary approaches: the input from a wide range of knowledge-holders and stakeholders, integration across disciplines and knowledge spheres, the development of applied as well as fundamental knowledge and direct engagement with those who will enact policy and practical changes in response to the generated knowledge. Mission-oriented science and mission science is used interchangeably in this report.

Transformative science – as used in this report – is science that helps change the current trajectories of unsustainability (e.g. in the climate, biosphere and oceans as well as in human conditions such as wealth disparities, hunger, discrimination and oppression) towards a thriving, resilient and sustainable coexistence of humans with nature. To be truly transformative, science must be:

- *Comprehensive and solutions-oriented*, i.e. closing geographic and sectoral gaps and gaps in the interrelationships and dynamics of interdependent spheres of life, and focused not just on deepening problem understanding but on developing effective responses to those problems.
- *Co-designed and transdisciplinary*, i.e. framing the question and research across knowledge disciplines (physical, natural, social and humanistic sciences), sectors of society, genders, generations, geographies and different knowledge systems, by working closely from the outset with knowledge users in identifying problems, defining research questions, as well as in generating and integrating that knowledge for application.
- *Accessible and used*, i.e. remedying inequities and inadequacies in data availability and access, effectively reaching relevant decision-makers and stakeholders, and the use of knowledge by decision-makers by making science discoverable, accessible, user-friendly and efficacious (UNESCO-IOC, 2021).

A recent review (Fazey et al., 2020) outlines some of the key properties of the current science system that inhibit its ability to inform and support global transformations towards sustainability. They can be organized into three categories:

Self-organization and Foci

- *Narrowly focused*: science commonly pursues only incremental advances in knowledge, which is typically disconnected from the embodied, practical context in which it is used and from which it is derived; has a narrow understanding and interpretation of what counts as legitimate knowledge and as credible ways of knowing;
- *Fragmented*, distant and abstract: knowledge production and use often lack systemic thinking and are dominated by linear and fragmented understandings of reality. Much of the emphasis traditionally has been on intellectual and problem-oriented (e.g. theory generation) rather than pragmatic, solution-oriented advances;
- *Compartmentalized*: knowledge production is often organized in disconnected disciplines, and conforms to explicit and implicit norms of academic cultures. The compartmentalized structure leads to strong path dependencies that constrain emergence of new ways of knowing and acting. The focus is on producing generalizable knowledge rather than knowledge relevant to local issues and contexts.

Attitude

- *Exclusionary and disconnected from society's needs*: science is conducted by a research population not representative of the broader society; in addition, it is still predominantly discovery-driven, resulting in limited relevance to the concerns, realities and scale of the challenges facing people and the planet;
- *Elitist*: science pays very limited attention to indigenous, tacit, practical or other forms of knowledge, and typically regards other ways of knowing as inferior to science.

Normative Orientation

- *Uncritical*: while nominally interested in innovation, all too often science supports the reproduction of existing systems and ways of doing things, reinforcing existing social, economic and political forms of power, and thus limiting the emergence of more creative, equitable or holistic ways of working with global challenges.
- *Captured by a growth-mindset:* scientific knowledge is frequently viewed as a commodity, emphasizing speed over quality and competition over collaboration.

All of these traits are created and reinforced by current norms and incentives within the existing science system, including science funding practices, and provide limited opportunities for creativity, questioning underlying assumptions and developing more innovative and holistic responses to contemporary challenges.

As a result, the existing science system tends to generate small-scale, narrowly-focused, incremental and abstract insights. In short, it supports research that is limited in its ability to contribute to the transformative, systemic changes needed to thrive in the 21st century and beyond. There needs to be substantial increase in efforts of science that have the capacity to move beyond a narrow focus, and which contribute to solving pressing global challenges and their root causes in an integrated, systemic and useful way. Going beyond business-as-usual approaches to science, science funding and science–policy–practice interactions is imperative given the urgency of the matter.

> *The existing science system supports research that is fundamentally limited in its ability to contribute to the transformative, changes needed to thrive in the 21st century and beyond. It is simply not fit for purpose.*

3 THE VISION: AN INTERNATIONAL MISSION-ORIENTED SCIENCE

To meet 21st century challenges, and in particular the immediate science needs associated with Agenda 2030, the report offers an ambitious approach – a concerted effort to produce actionable knowledge through co-designed mission-oriented research. This must be supported, in addition, by continuing reforms of the existing science system, which will occur on a slower, but still relevant time scale.

As it has been argued above, a rapidly realized, qualitative and quantitative step change is needed in science to support the urgent societal transformations towards a more sustainable, equitable and resilient future. This will require bold and strategic action from a 'collaboration of the willing' (GFF, 2019) – governments, science policy-makers, science funders, scientists, the private sector and civil society.

Given the speed of degradation of societal and environmental/life-support systems, and the urgent timeline on which society must meet the Paris Accord, the SDGs and related global agreements, we cannot only gradually adapt the prevailing science system to 21st century realities. This simply will take too long. While persistent, incremental reform of the entire science and related educational systems must continue (as described in the penultimate section of this report), the Earth and humanity simply cannot wait.

We therefore must rapidly implement a targeted, mission-oriented set of scientific initiatives and associated support structures that harness the best of what science can do, but do so in a different (albeit largely proven) way. We have to design and swiftly build up the capability to support and enable dedicated scientists in delivering clearly focused mission-oriented science advances that connect seamlessly with other parts of society that can help implement necessary policies, practices and behavioural changes.

Textbox 3 lays out the ways in which mission-oriented science can be useful to the necessary societal and policy changes.

Textbox 3: What Mission-driven Science Can Do to Inform Actions that will Realize the SDGs

While realizing the SDGs is ultimately a political and societal matter – a choice humanity makes or fails to make – mission-driven science in support of the common good can do much to support the right choice. There are several key categories of scientific contributions needed (adapted from GFF, 2019; Keener et al. in preparation):

- Being ***responsive*** to identified decision-making needs
  - Draw on, organize and curate existing knowledge in accessible ways
  - Harness and synthesize existing knowledge to address specific strategic questions
  - Co-identify knowledge gaps with societal partners
  - Provide evidence for decision-making
  - Fill in data gaps
  - Convene stake-, rights- and knowledge-holders
- Being ***supportive*** to identified policy and action interventions
  - Mobilize national-level science on specific use-inspired challenges
  - Negotiate framings for problems and potential solutions that resonate
  - Communicate problems, solutions and relevant science effectively
  - Educate the public and key stakeholders
  - Characterize and narrow uncertainties
  - Help build capacity for science-informed action
  - Provide decision-coaching support
- Being ***generative*** to identify new solutions
  - Co-produce new, use-inspired knowledge
  - Inform the development of more sustainable solutions
  - Identify critical leverage points to rapidly pilot and scale beneficial actions
  - Develop priorities for integrative, synergistic cross-sector actions
  - Identify possible interventions with multiple beneficial outcomes
- Being constructively ***critical*** of inadequate policy approaches
  - Monitor social and environmental trends
  - Track progress and evaluate outcomes of actions, thus accelerating learning
  - Scan for emergent or novel societal risks
  - Highlight shortfalls and propose alternative models of economic activity and governance that centre the public value and the common good of human endeavours
  - Help identify and address trade-offs faced by policy-making and action around SDGs
  - Accelerate transformative change by identifying the most significant interactions within the SDG framework, thus helping to prioritize actions and avoid maladaptive ones.

Generating these urgently needed mission-driven scientific advances in support of social transformations to sustainability is a design problem.

What is needed are support structures, processes and funding mechanisms that produce the intended outcomes – science for achievement of Agenda 2030 and a thriving society within planetary boundaries beyond that decadal set of goals. The features of a support structure that can deliver on sustainability science missions outlined below has the following traits (Cornell et al., 2013; Fazey et al., 2020):

Self-organization and Foci

- *Integrative*: be focused on co-producing societally relevant, integrative approaches that address global sustainability challenges and the common good;
- *Transformative*: be oriented towards learning how to achieve transformative and systemic outcomes;
- *Interdisciplinary*: understand and frame current global challenges as intertwined natural and social problems, and therefore give prominent leadership roles to the social sciences, arts and humanities, without negating the important contributions from physical, natural, engineering, medical and other applied sciences;
- *Systems-focused*: be capable of working beyond silos, and with complexity, trade-offs, synergies, feedbacks, values, ethics and systemic issues;
- *Networked and flexible*: be organized in connected, adaptable structures for social impact that incentivize development and application of context-specific insights as well as produce more generalizable knowledge;
- *Globally and regionally connected:* actively seek and enable within- and cross-continental collaborations so as to be relevant to and address key matters of concern across different regions of the world; and
- *Strength-based and capacitating*: start from high-capacity expertise in transdisciplinary knowledge generation and ways of working, but also invest in mentoring and building transdisciplinary capacity in the next generation.

Attitude

- *Collaborative and inclusive*: be open, inclusive and connected with key societal partners, policy-making audiences and especially those most affected;
- *Embracing transdisciplinarity*: integrate diverse sources of knowledge across disciplines and ways of knowing, and engage diverse, pluralistic, egalitarian and creative modes of knowledge production and learning, connecting and integrating silos of expertise and practice; and
- *Open and accessible to all:* contribute to the global knowledge commons, producing open and accessible knowledge in service of societal needs, not protecting private ownership when it is done at the expense of the public good.

Normative Orientation

- *Driven by the common good:* explicitly integrate and address the normative agenda of sustainable, equitable human development within planetary boundaries, i.e. for the benefit of humans and nature;
- *Critical, innovative and reflective:* insist on deep questioning of existing structures, values and practices, and create a culture of risk taking, innovation, reflectivity and (experiential) learning;
- *Solutions-focused:* whether the science undertaken is fundamental or applied, it must be use-inspired, action-oriented and always strategically planned for the wise and ethical use and application of knowledge; and
- Societally accountable: be focused on advancing science for the common good, implying an accountability to society, and not only disciplines, professional societies, institutions or personal career advancement.

4 THEMATIC FOCI: ONE GOAL – FIVE SUSTAINABILITY SCIENCE MISSIONS

> *For an accelerated implementation of the SDGs, it is critical to build and harness scientific knowledge and capacities […] and create a 'moon-shot' mission for Sustainability Science.*
>
> - GFF (2019)

Scientific advances most needed must help stabilize the Earth system in a safe-operating space within 10–20 years (Sachs et al., 2019), i.e. halt and redirect societal systems away from unsustainable practices and help bring about a turn towards restoration, repair, resilience and the coexistence of humans with each other and with nature. The report emphasises here where science should focus within one to two decades.

On behalf of the Global Funders Forum (GFF), the ISC conducted an extensive review of current research agendas, drawing principally on three sources (for more detail, see council.science/SDGs-science-agenda):

- Inputs received from an ISC-led call (239 valid responses, 61 countries);
- Agenda-setting reports (21 reports, including Randers et al., 2018; TWI2050, 2018; UN GSDR, 2019; UN, 2020); and
- Scientific literature (95 articles).

Based on this input, the Scientific Advisory Group identified the most critical consensus areas that require transformative changes and where mission-oriented work needs to focus. Five mission areas were identified: food, water, health, urban areas and energy/climate. Of course, these five thematic foci are deeply interrelated. The transformative challenges in one cannot be met in isolation from the other.

The rationale for selecting these five thematic areas is as follows:

- Each one, if unaddressed, poses existential risks to humanity;
- None can be effectively dealt with unilaterally;
- They are major drivers of unsustainability and environmental degradation (climate change, air and water pollution, deforestation and loss of biodiversity) and social deprivation and inequality;
- They are most at risk from the environmental changes already underway; and
- They have been recognized as critical across various transformative frameworks, and have the force of strong consensus among relevant scientific communities behind them.

These five themes also allow researchers to address, speak to and integrate all of the SDGs (Figure 2).

Recognizing that each of the science missions must be co-designed with relevant societal partners, the report only describes them below in rough outline. Furthermore, given that these missions represent larger, inclusive areas, the next step will be to define with key stakeholders more granular, specific science missions within each area. Based on this understanding and for ease of reading we refer to these areas as "science missions" throughout the rest of the report.

Learn more: council.science/science-missions

Five missions integrating the 17 SDGs

“an indivisible agenda” (GFF 2019)

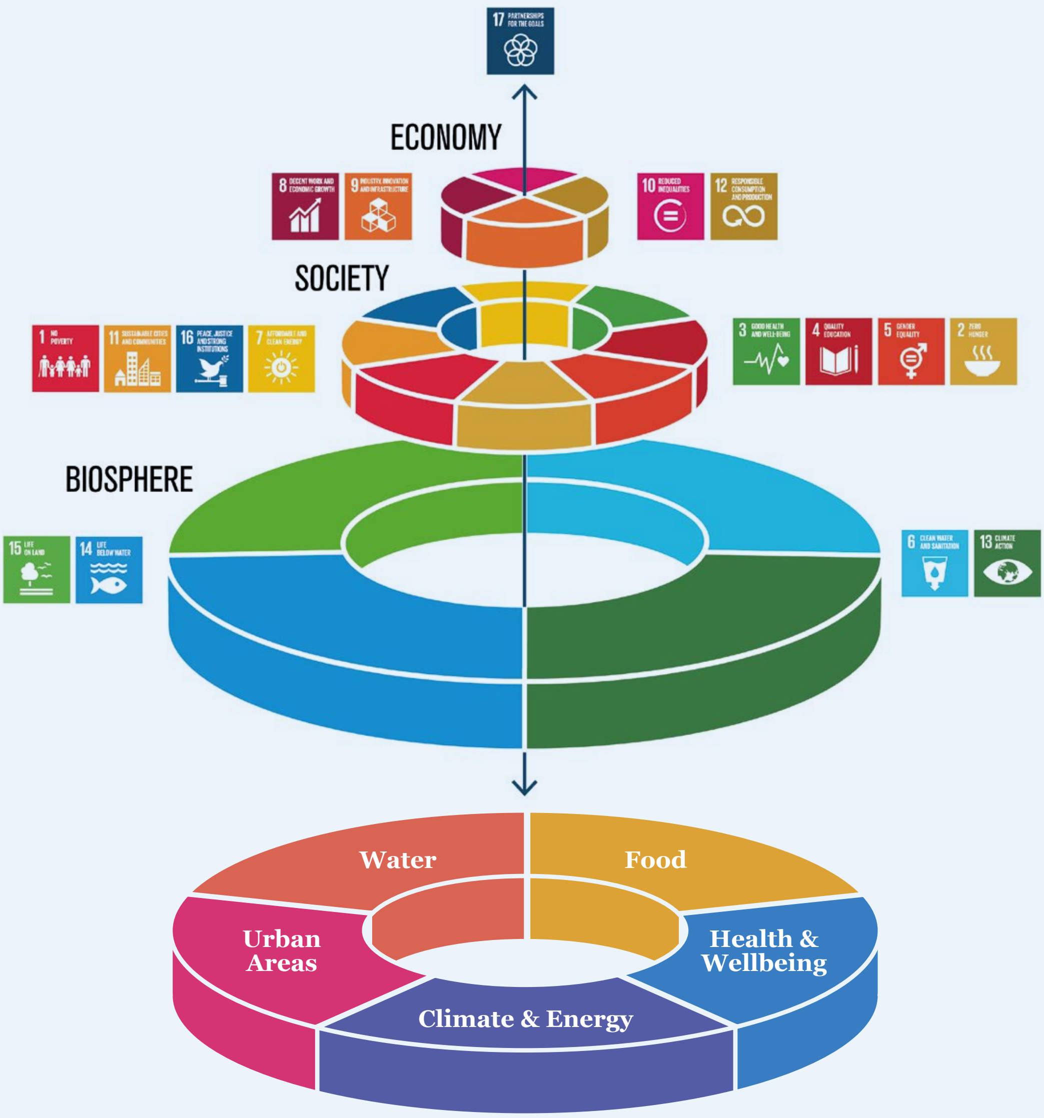

Figure 2: The Five Missions Integrate the 17 SDGs.
They must be implemented within ecological and physical planetary boundaries, in societally context-sensitive ways and provide for meaningful and sustainable economic livelihoods.
Source: Adapted from Stockholm Resilience Center

Food: Eating Adequate, Healthy Diets Without Consuming Nature's Bounty

The overarching objective under the food theme echoes multiple SDGs and aims to secure universal access to affordable, reliable healthy diets without undermining the sustainability of other resources or the wellbeing of food sector workers. The mission must address food security issues along the entire spectrum from hunger/malnutrition to overconsumption/obesity.

Water: Replenishing Nature's Reservoirs to Provide Enough Clean Water for All

The objective of the water theme is to provide global, equitable and affordable access to clean water and effective sanitation without posing unsustainable pressures on ecosystems, other resources or people. This mission must address water issues along a spectrum of extremes: from not enough water and persistent water insecurity to too much water, with water quality being an issue across the entire spectrum of conditions.

Health and Wellbeing: Being Whole and Well in Body, Mind and Nature

The health theme's overarching objective is to ensure global, equitable access to all necessary services, networks, resources and supportive conditions for human health and wellbeing. Although, in some societies, the disease burden and associated healthcare costs are driven by an ageing population with a growing incidence of chronic illnesses, in others, a prevailing focus will be on prenatal and paediatric care to raise healthy children. In an increasingly volatile world, trauma prevention and treatment are increasingly important. More attention to mental health and wellbeing will be central to this mission.

Urban Areas: Thriving in Places While Stewarding the Natural Environment

The overarching objective under the urban and infrastructure theme is to build and transform cities into just, thriving and low-resource throughput sites of human habitation in mutually beneficial relationships with their surrounding rural areas. The challenges are staggered across the spectrum of building entirely new cities to remaking existing, and often ageing infrastructure; from reshaping hard structures to managing informal settlements; and from designing safe spaces for highly concentrated, yet mobile populations to connecting isolated settlements to essential services and opportunities.

Climate and Energy: Shifting to Clean Energy While Restoring a Safe Climate

The climate and energy objective seeks to provide universal access to affordable, sustainable and carbon-free energy to enable human development and interaction without damaging other Earth and life-support systems. This transition is now underway but many obstacles remain and the transition must progress more rapidly to avoid crossing critical tipping points.

Although scientists have proposed a myriad of intriguing research questions for these missions (Annex 1), they should not be seen as a priority list. Such a list must emerge from the co-design process. Topics listed in Annex 1 should only be seen as seeds, as possible starting points, for the co-design process.

> *Each of the science missions must be co-designed with relevant societal partners. The report deliberately does not narrow down a priority list of research questions.*

Each mission must be delivered in a way that is galvanizing: it must ignite the imagination, not just for scientists, but for all actors directly involved and for society at large. During the co-design phase of each mission, it is worth asking what would inspire society to pursue an urgent and existentially rewarding task. Each mission must stay cognizant of, and be implemented in a way consistent with the SDGs and other international agreements, and must be owned and co-created with affected societal partners. Thus, each mission must:

- Be explicitly and clearly defined;
- Be policy, action and outcome driven;
- Ensure social equity and justice;
- Minimize environmental degradation and build resilience;
- Promote nature-based solutions;
- Aim to solve multiple problems at once;
- Be culturally appropriate and context-sensitive to the particularities at regional, national and subnational levels; and
- Not undermine the delivery of other missions.

5 SCIENCE IN ACTION: A THEORY OF CHANGE THAT DELIVERS

How can this transformative, mission-oriented science make a difference in policy and practice? How will this 'unleash' science and enable it to be impactful and influential in the world of action?

A 'theory of change' is used here to describe this 'how'. At their best, theories of change are learning models that provide clarity amidst an often difficult to see, much less to predict, change process. They delineate why a set of interventions is thought to contribute to a desired outcome. Transformative changes are multi-directional, multi-scalar, adaptive and sometimes non-linear change processes that are never fully controlled, directed or understood, especially not ex ante. The theory of change offered here – articulated through the common elements in an 'action logic' (Figure 3) – is thus an informed starting point that will require constant updating as the work progresses.

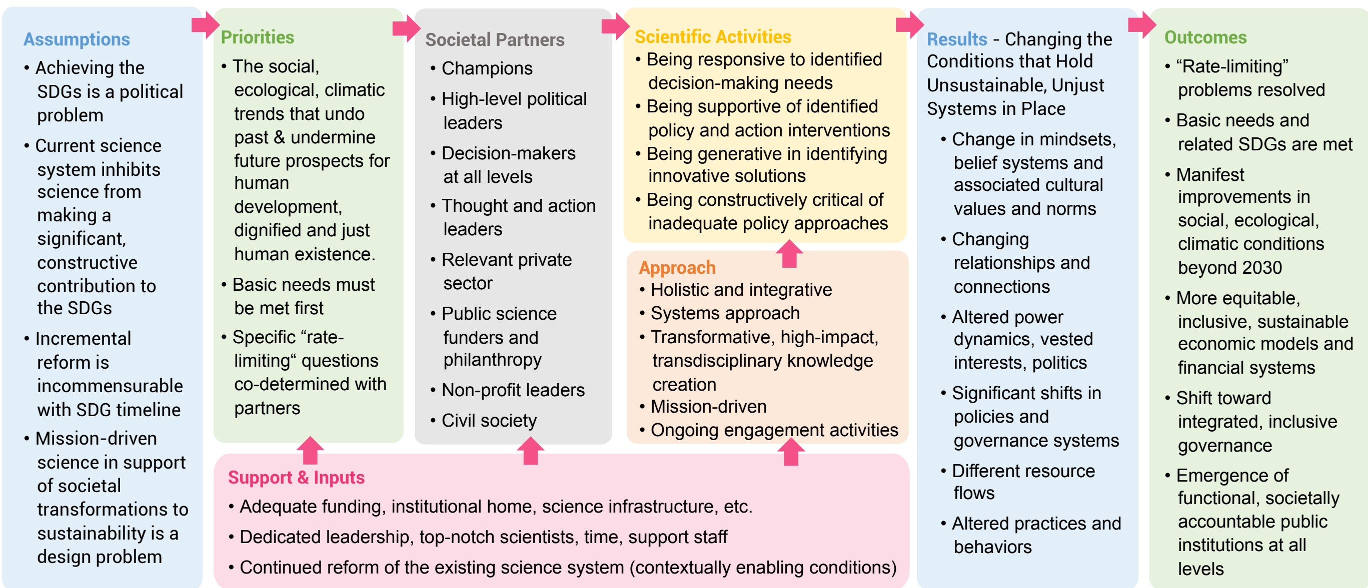

Figure 3: 'Action Logic' for Delivering Mission Science and Action.

Below, the report discusses each of the elements of this action logic and where relevant, offers more ideas on what actionable pathways may entail.

Assumptions

The theory of change underlying 'Unleashing Science' commences from several key premises, as previously argued:

- Achieving the SDGs is first and foremost a *political* problem, in which science can play an important role;
- The current science system is structurally *inhibiting* science from making a significant contribution to achieving the SDGs;
- Incremental *reform* of the current science system, although necessary and supportive, will be *insufficient within the timeline* for achieving the SDGs or that of addressing our current planetary crises in a humane, dignified and equitable manner; and
- Generating the needed mission-driven scientific advances in support of societal transformations to sustainability is a *design* problem. Changing the design will produce different outcomes.

Starting Conditions and Priorities

The theory of change's starting point is the serious situation of humanity and the planet. Nearly all SDGs are out of reach by 2030, society is vastly overshooting the temperature goals of the Paris Agreement, continuing to break the web of life and failing to meet the targets of the Sendai Framework for Disaster Risk Reduction. Together, these trends and undermine future prospects for intact life-support systems, human development and a dignified and just human existence. The priority areas for future science missions are not a separate agenda, but emerge from and must deeply integrate all of the SDGs.

Societal Partners

To identify and refine the specific critical knowledge needs, mission-oriented science must work with relevant societal partners. The key societal partners to engage will need to be identified and prioritized for each of the science missions, but they must be drawn from all relevant sectors. This will include a range of influential players, including elected/appointed policy-makers and decision-makers at all levels, relevant thought and action leaders from industry, the financial sector, philanthropy, the non-profit world and civil society (for guidance on how to identify them, see Table 6 in the Implementing Mission Science section).

> *The research agenda is not driven by scientists or science funders alone, but co-created with societal partners. Key societal partners for the co-design process will vary by mission but will include policy-makers and decision-makers at all levels and relevant thought and action leaders from industry, philanthropy, the non-profit world and civil society.*

Understanding the transformative challenge not primarily as a scientific or technical problem but as a political and social one means that the mobilization for action from all relevant sectors must take place on the same timeline as advancing scientific understanding. Advancing scientific understanding and mobilization for transformative action – rather than being sequential activities – must be simultaneous and interactive, with increasingly well-established channels of exchange and learning. Science funders are one critical societal partner for mission-driven science in that they are called on to put their resources and trust in a novel way of working, namely for scientists:

- To conduct risky but potentially high-return-on-investment science; and
- To engage in non-traditional ways across disciplines, world regions and with societal actors.

As previously recognized, 'To unleash the full potential of science, more strategic and collaborative approaches to science funding are required, moving away from individual to collective action', i.e. from nationally-focused to globally-focused funding strategies (GFF, 2019).

Scientific Approaches, Activities and Starting Places

The practice and scholarship of transdisciplinary and transformative science has established how science can be an active, influential and contributing player in societal affairs. It rests on direct engagement between scientists across disciplinary boundaries on the one hand, and decision-makers and affected stakeholders on the other. The trust-building process and the need to build mutual understanding and shared agreements for power sharing, roles and responsibilities is rewarded by more efficient collaboration and decision-making for more effective responses. It is thus imperative that the mission-driven science envisioned here – if it is to be relevant to the needed societal transformations – is approached in this transdisciplinary, transformative manner.

Importantly, while each scientific discipline can bring *depth* in analysis to the sustainability challenges, some of the most important contributions in the near-term will come from synthesizing the *breadth* of knowledge into a more comprehensive, multi-faceted and usable understanding of problems and solutions. Both analysis and synthesis must be solutions- and action-oriented, which implies that they are relevant to societal partners. A substantial part of the science agenda needs to be co-designed (UNESCO-IOC, 2021). Differently put, the research agenda should not be driven by scientists or science funders alone, but co-created with all relevant societal partners.

> *Mission-oriented science is not an isolated scientific activity, but one constantly engaged in the necessary extra-scientific, societal mobilization to act on co-produced scientific advances.*

However, taking seriously what has been learned over four decades of global-change science funding, the biggest levers of change in making a difference on any of these sustainability issues lie in society, not (merely) in better understanding the physical aspects of these challenges.

To bring about the needed transformational changes at every scale not only requires technological innovation but most importantly fundamental changes in political, economic, structural and behavioural aspects of the sectors involved in each theme (TWI2050, 2018; UN GSDR, 2019). Addressing the root causes that maintain societies in unsustainable practices thus requires examining and changing existing social and human–environment relations, resources flows, rules of the systems, vested interests, power dynamics that control them, as well as the individual and collective beliefs, values and mindsets underlying them (Meadows, 1999; O'Brien, 2016; Berzonsky and Moser, 2017).

Social science scholarship has developed a large, multi-disciplinary body of knowledge about when and how societal changes happen – from the personal to the political, the economic to the technological and the behavioural and institutional to the cultural. All of these insights must be harnessed to guide the development of interventions designed to achieve the SDGs. While contextually specific, social change involves the following elements:

- A compelling motivation to change (e.g. values, understanding, needs, interests and social pressures);
- Structures and processes supporting the emergence of the new interventions;
- Capabilities and resources (e.g. human, political and financial – both for producing scientific advances and for the implementation of identified policies and actions);
- Dedicated attention to the dynamics and structures that must end and that inhibit the new, i.e. to the barriers to change (e.g. lack of leadership and political will, vested interests, habits, governance structures, institutional, economic and social hurdles); and
- Mechanisms for scaling up and making change 'stick' while addressing the needs of those affected.

Many forces and assets besides scientific knowledge are needed to mobilize all these elements, including communication, science diplomacy, advocacy, education, political and legal systems, market forces, financial systems and various technologies. For missions to get started, it will be strategically useful to coalesce the existing knowledge about engaged science and societal change into an interdisciplinary and transdisciplinary synthesis.

To unfold its full potential, mission-oriented science should not be an isolated scientific activity, but one constantly engaged in the necessary extra-scientific, societal mobilization to act on co-produced knowledge advances. This requires new ways of behaving within science and among societal actors. However, if science and society take the transformative challenges before humanity seriously, courage – in science as in politics – is the currency of the day: to work with what we have, to risk novel approaches and deviations from existing patterns and to let what we know fuel and inform rather than stall action, including the constant need for vigilance and learning.

Missions can provide a common language to streamline ideas and solutions. However, such a shared orientation must result in actions (and ultimately outcomes, see below). These actions will not only incentivize and otherwise elevate the motivation for transformative solutions, but squarely address the barriers to implementation. Often, those barriers will be political, interest-driven and deeply embedded in the values, identities and worldviews of relevant actors. This is why missions must examine the social aspects of transformative change.

Results: Affecting the Conditions for Systems Change

In typical depictions of action logics, results and outcomes of knowledge generation are often depicted over the near- to medium- and long-term, whereby the ultimate, desired changes in environmental and social conditions result from political and social actions which, in turn, follow from the activities conducted by scientists: near-term knowledge generation and evidence of learning.

Such action logics typically remain vague on how critical systemic changes come about. Although this report cannot be specific to each mission for each region/location where change needs to occur, the report focuses here on the action logic underlying systems change.

Given the lack of time, political mobilization must start immediately and involve political and societal leaders at every level and in every sector relevant to the specific missions. The focus and intended outcome of these interactions will be – first and foremost – changing the fundamental conditions that hold systems in place or that can be mobilized to affect change. Scholarship on collective impact has established six conditions as critical for transformative change: policies, practices, resource flows, relationships/connections, power dynamics, and mindsets (Figure 4). They are as applicable to changing the science system as they are to changing other societal systems.

The six conditions of systems change, i.e. the levers that must be pushed to shift unsustainable systems towards more sustainable systems, are described in more detail in Textbox 4.

Interrogating and moving these six conditions in context-sensitive ways will help overcome the barriers that currently prevent societal actors from implementing decisive interventions in specific societal systems. While the language of system change is general and does not indicate any direction in which a system ought to change, the major global agreements – such as Agenda 2030 with its specific SDGs and the Paris Agreement – provide the globally agreed direction of change.

Textbox 4: Shifting the Conditions that Hold Systems in Place

Mindsets, belief systems and associated cultural values and norms – People's ways of thinking, their attitudes, beliefs, values and norms are often the most difficult to shift but present the most powerful potential leverage point for transformational systems change. Such shifts can happen at the interpersonal all the way to the societal level. Shifting mindsets affects the deepest drivers – the intent and ways of thinking – that design and steer systems in certain ways. While science itself can help understand how to change minds, it is critical to mobilize communication, advocacy, public awareness campaigns, education and the power of social influence and of technology in order to affect this condition of systems change.

Relationships and connections – The way people think about themselves and others affects the relationships they form and the connections they initiate and maintain over time. It colours the relationships within and across families, genders, races, professional groups, disciplines, nations, generations and so on. It also determines who is considered equal/unequal or in/out, who they respect or disrespect and who they meet and maybe never encounter. Thus, social relations profoundly shape our experience and knowledge of the world. Creating forums in which different disciplines, professional groups, knowledge-holders, stakeholders, representatives of different segments or sectors of society can convene inevitably changes understanding, insights, levels of trust and willingness to cooperate.

Power dynamics, vested interests, politics – Mindsets also shape prevailing attitudes towards others, revealing power dynamics, as well as subtle and not so subtle hierarchies in any social unit. These typically play out in politics and strategic efforts to defend vested interests. Dominant actor groups will hold undue influence over decision-making procedures and outcomes. Thus, if scientific outputs are to have an influence on decisions, deliberate efforts must be made to change mechanisms that uphold current hierarchies and distributions of power. Working with allies with sufficient political will and coalitions of interests willing to push for fundamental shifts in power dynamics will be an essential element of political mobilization for change.

Policies and governance systems – On the basis of changed power dynamics, it becomes possible to change the steering mechanisms of policies and governance systems. Science cannot only help identify policy mechanisms and suggest ways to align them in a systemic fashion, but must engage in the political process. Thus, mission-oriented science does not engage in sustainability politics for its own interest or as a more influential interest group than others, but represents science as a common good, and is normatively aligned with sustainability goals as articulated in Agenda 2030. Its task is to help policy-makers understand and discern the implications of different policy choices for the urgent task at hand, namely to address humanity's existential risks.

Resource flows – As minds are changed, new relationships are formed and power dynamics are shifted, the door also opens to changing how resources get distributed. Who or what is enabled, rewarded, supported or subsidized constitutes a crucial influence on the direction in which change can go. Science can help inform prioritization and distribution, assess needs and requirements, and help identify the types and levels of resources and assets required to destabilize incumbent systems and initiate, build and scale up emergent systems.

Practices and behaviours – What actually gets done, what actions are taken and which behaviours become prevalent in a given system also flow from the underlying ways of thinking, valuing, relating and decision-making. Practices and behaviours are often the most visible expressions of the other five conditions of system change. Science can help identify practices and behaviours consistent with the SDGs, build capacity for novel/alternative practices, inform behaviour change campaigns in collaboration with others and help monitor and evaluate their impact.

Transformation: Shifting the Conditions That Hold Systems in Place

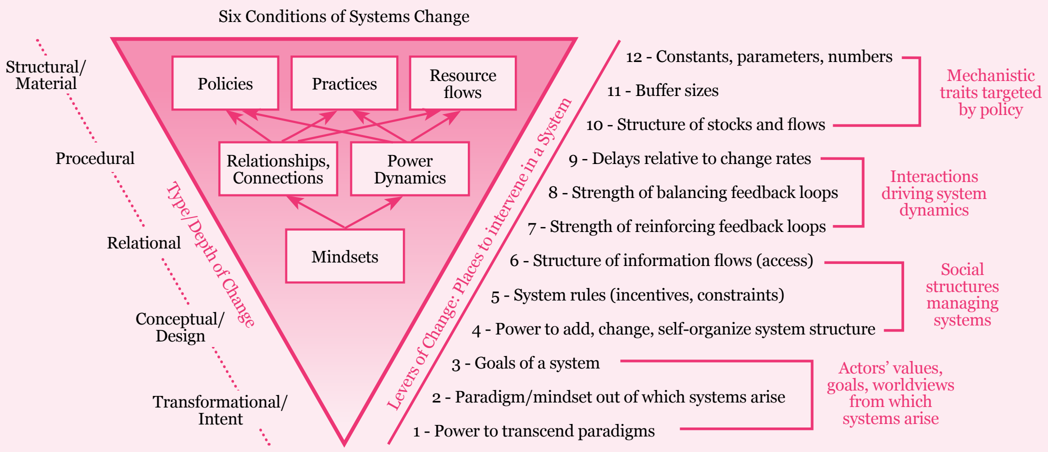

Figure 4: To Contribute to Transformative Change, Mission-oriented Science Must Change the Conditions that Hold Systems in Place.
Source: Moser et al., 2019 based on Meadows, 1999, and Fischer and Reicher, 2019

Outcomes

Working deliberately towards change in the six conditions for transformative change in any of the systems involved in the science missions will disrupt, challenge, mobilize proponents and opponents, and cause unforeseen effects, some positive, others negative. The chances of transformative change can be increased, and the direction enabled through bottom-up and top-down interventions (e.g. policy, funding, civic pressure, narratives and leadership).

Mission-oriented science does not end at proposing or even informing the implementation of transformative action, but must be actively engaged in the tracking, analysing, understanding and course-correcting of changes set in motion, so that the dynamics of change can be nudged in overall desirable directions.

The guiding vision – for the near-term – is Agenda 2030 and the SDGs, and beyond that are the ecological, economic and social pillars of sustainability, i.e. a dignified, thriving existence for all within planetary boundaries. Delivery of science missions may also contribute to the long-term transformation of economic models and financial systems towards being fairer, more inclusive and ecologically sustainable, and stimulate shift towards integrated and inclusive governance and the emergence of functional, societally accountable public institutions at all levels.

Each of these outcomes will look differently across different regions of the world, because the underlying regional expression of drivers of unsustainability vary. The co-design process will bring out these differences and set out traceable regional goals and interventions.

> *Mission-oriented science does not end at proposing the implementation of transformative action, but must be actively engaged in the tracking, analysing, understanding and course-correcting of changes set in motion, so that the dynamics of change can be nudged in overall desirable directions.*

6 IMPLEMENTING MISSION SCIENCE

To deliver on the five missions outlined above, it is essential to build on the existing science infrastructure – physical, virtual and intellectual – while not falling into the trap of incremental change and science-business as usual approaches. This means drawing strongly on existing human capital, institutions and networks of relevant researchers and practitioners, but creating unique spaces for them to come together, immerse themselves in the mission themes without the distractions and constraints typically associated with the existing science system and to collaborate on the co-defined research questions.

Mission science needs focus, full-time dedication of human capital, adequate financial and political support and institutional shielding to allow it to stay firmly concentrated on the mission goal and deliver not just knowledge outcomes but action outcomes, i.e. real changes in hearts and minds, social relations and power dynamics, policies, resource flows and practices, to effect change.

An ambitious mission science agenda is not to distract from existing national or international science programmes and research networks. Rather, these should be considered crucial intellectual and networking partners, allowing missions to harness the best expertise, knowledge, influence and action from wherever it is available.

One Way Forward: Sustainability Mission Station(s)

There are various models for how mission science could be delivered. A more comprehensive rapid comparative analysis of different institutional arrangements and operational mechanisms would need to be undertaken as part of a structured co-design process with all key partners, drawing on relevant organizational design knowledge and experience to ensure the best possible outcomes.

This report offers one possible way forward - the creation of one or more 'Sustainability Mission Stations' that would bring together the best scientists to collaborate with policy-makers, the private sector, civil society actors and science implementers to explore, inform and foster the needed transformational changes at every scale. Potential institutional models of how the Mission Stations could be organized are outlined in Textbox 5.

The pros and cons of these models, and any others to be determined, would need to be subject to rigorous assessment. The feasibility of establishing and mobilizing required resources for Mission Stations, whether these are virtual or physical or a hybrid combination of both, would need to be tested, and appropriate, agile governance arrangements would need to be explored.

Regardless of the selected model, the Mission Stations should be capable of efficiently mobilizing existing scientific infrastructure and knowledge, as well as researchers from elsewhere to contribute to the missions' implementation. Furthermore, Mission Stations should put in place an online platform to ensure accessible knowledge storage and to facilitate open global exchange.

Other elements which need to be considered during the comparative analysis of models include: the ability to deliver key functions, the process of launching the Mission Stations, ways of working and needed funding mechanisms, as described in sections below.

Textbox 5: Potential Institutional Models of how the Mission Stations could be organized

1. **One Global 'Sustainability Mission Station'.** Similar to CERN[1], but for global sustainability research, this station would bring together in one place the best scientists across the world to implement all missions and their interrelated dynamics. It would reinforce the unifying notion of addressing existential risks and make for the easiest, quickest, cost efficient cross-mission interaction. It would require a global network and could include satellite institutions to adapt and apply identified actions to the regional and political peculiarities around the world.

2. **Five Global Thematic Sustainability Mission Stations**. This model would place one Mission Station with a single mission theme on a particular continent. Each thematic mission would bring together the best scientists from across the globe and would be responsible for driving its delivery. A global mechanism for coordination and learning across missions would be needed to ensure that the delivery of one mission does not undermine the delivery of others. Satellite stations and networks on other continents may also help ensure that proposed solutions can be applied in culturally sensitive and appropriate ways in regions other than the host continent.

3. **Five Integrated Regional Sustainability Mission Stations.** This model would place one station on each continent and bring together the best scientists from across the continent/region to implement all the missions in each region. This model would allow for the delivery of all missions in an integrated manner (the primary advantage of the first model), exploring interlinkages across missions, but also considering the specificities of each region. A global mechanism for coordination and learning across regions would however also be required. Satellite (national) missions and networks in other countries on the same continent could further ensure that proposed solutions can be applied in culturally sensitive and appropriate ways in other places, also giving individual nations a larger stake in investing in missions.[3] Collectively establishing and supporting Mission Stations and any satellites particularly in the Global South, would help rectify years of global science funding inequalities.

Functions of the Mission Station(s)

Regardless of how the Mission Station(s) will be set up, they must act as generative knowledge hubs as well as backbone structures for creating collective social impact. They must:

- Start with identifying the most pressing problems and actions for solutions, as well as identifying actors with whom to collaborate on detailed research-and-action agendas that require global scale and collaboration and critical interventions and that can help shift the six conditions for systems change described above (see Textbox 4).
- Focus on fundamental changes in political, economic, structural and behavioural aspects of each mission. It will be critical to understand key obstacles and barriers currently preventing the necessary transformations and identifying effective ways of overcoming them. Therefore, prominent roles must be given to the social sciences, arts and humanities.
- Co-design and co-refine research and implementation agendas and focus throughout on putting knowledge into use through strong engagement with policy and practice and civil society.

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[2] The European Council for Nuclear Research

[3] While reminiscent of the structural organization of Future Earth and other large regional research funding programs, the distinct difference is having an ambitious mission focused on the common good, physical places for interaction on an ongoing basis, freedom from the common institutional and professional constraints experienced in the existing science system, a supportive funding mechanism and political backing.

- Apply a synthetic and systems approach to each mission and harness all relevant types of research, from basic to applied, in all relevant disciplines.
- Establish standing, but flexible, mechanisms from the start for regular exchange between science, practice/policy and implementation science.
- Produce global and regional knowledge syntheses with concrete options for intervention, early on, to quickly make existing knowledge accessible to policy-makers for near-term concrete actions, including the integration of knowledge produced by existing global and regional research initiatives.

Ways of Working

Regardless of the implementation model developed, each would need to address organizational, leadership and functional issues and enabling conditions. These include:

Leadership and capabilities:

- Consider different leadership models (e.g. central, top-down leadership and more distributed/bottom-up approaches). The leadership must be diversely populated with both representation of and accountability to society at large, and scientists that have the capacity to lead transdisciplinary teams.
- Using incentives (e.g. job and promotional security, sufficient science funding, freedom from teaching or institutional service obligations), attract the best transdisciplinary scientists from across diverse disciplines with strong collaborative skills and commitment to the common good; core mission teams should include futurists, science-policy expertise, science brokers, strategy and communication experts and science implementers.
- Stimulate innovation through collaboration across disciplines and ongoing focus on and engagement with real-life challenges and practitioners.
- Throughout the mission teams, build strong science and management oversight capabilities, as well as skills in communication, science diplomacy, science brokerage etc. These capabilities need to be strategically aligned and complementary so that there is a seamless translation from 'the lab to the boardroom' and other high-level decision-making bodies.

Organization:

- Quickly develop a flexible, but transparent and accountable collaborative structure and approach.
- Put international equitable collaboration (North–South and South–South) at the heart of the research process, with strong emphasis placed on support of mission science in the Global South.
- Incentivize scientists and institutions to work towards solutions-oriented, transdisciplinary, transformative outcomes, rather than career or personal gains, and enable them to succeed through leadership development, capacity building and other relief from common constraints and career-related insecurity for the duration of their engagement in the mission.
- Embed practitioners within research projects from relevant sectors. Similarly, scientists could be seconded to work on missions from their home institutions for a flexible period of time, up to 5 years, parts of which could be spent in practitioner institutions.
- Set up a rigorous process of evaluation to track mission progress, to ensure continuing relevance and commitment, and to foster adaptive management and rapid learning. Each mission would need to set up an 'Accountability Board' made up of people from all relevant sectors of society. The performance of each mission should be externally reviewed every 5 years.
- Ensure access to all necessary capacities and tools (e.g. data libraries and models for systems integration).

Textbox 6: Identifying Mission-specific Societal Partners and Experts

Bringing the right people into the room begins with having support from the highest political level, and thus the convening power and mandate to co-design a mission with the most powerful leaders in a relevant mission area.

Identifying the 'right' people to bring together is a function of agency, *influence* and *interests*. Some partners may be critical to engage throughout the mission; others may be crucial to engage actively at key moments while they can be kept informed at other times. The guiding questions in the matrix below can help to identify the 'right' people.

Guiding Questions to Identify Societal Partners to Engage in the Mission-oriented Work		
	Obligatory/Necessary/ Responsible (higher degree of positive/negative influence, power or authority)	**Discretionary/Optional/ Affected (lower degree of positive/negative influence, power or authority)**
High interest/ concern	• Who makes the ultimate decision? • Who is in a position to implement a decision? • Whose support and engagement are essential to success? • Who has the relevant expertise or information? • Who has control over/ responsibility for key resources?	• Whose work, lives, wellbeing and/or properties are affected? • Who is ready and/or most motivated to participate? • Who has influence on those in power? • Who are the champions, opinion leaders and influential communicators? • Who can help you identify the right stakeholders?
Low interest/ concern	• Whose work, lives, wellbeing and/or properties are affected (even if they do not know it yet or do not exhibit interest)? • Who has indirect influence? • Who can block a decision? • Are there gatekeepers who can motivate others to engage?	• Who would gain an advantage from participation? • Who has relevant experience? • Who has qualities helpful to ensure a successful process and good team work? • Who has influence on those in power? • Who do you want to learn from and connect to for the purpose at hand?

Source: Resilience Metrics, Getting the Right People in the Room, available at https://resiliencemetrics.org/sites/default/files/files/Resilience-Metrics-Job-Aid-Getting-the-Right-People-in-the-Room.pdf

The above matrix can assist in an initial mapping exercise of relevant experts and societal partners. As high-priority groups and individuals are contacted, they can help identify – and bring in – others that are not yet on the radar, thus helping to refine the stakeholder map over time. Individuals who fall into the top left quadrant may differ significantly in societal power and political leanings or interests. Thus, professional and knowledgeable facilitation and – at various times in the process – meetings in cohorts may be essential.

Funding Levels and Model to Support Mission Science

Given the scale of the global challenge that each mission is seeking to address, the Mission Stations will require ambitious and sustained multilateral, international funding for the entire period of the mission. Current multilateral funding systems are fragmented, narrow in focus and insufficient to meet the pressing global challenges before society. Thus, science funders' ambition must significantly increase. Moreover, mission scientists and leaders must not be held back and delayed by variable, unpredictable and insecure funding levels, nor by complex funding management.

This, too, is a political challenge, requiring the engagement of political leaders at the highest levels. The proposed global funding model to be put in place is a common pool, quickly established, that allows individual national science funders to put funding towards each mission. Emerging experience with multilateral funding models (e.g. Belmont Forum) suggests that complex funding models are notoriously difficult to implement, thus a simpler common-pool model, with dedicated fund management expertise and oversight to meet national contributor needs, should be established.

In light of the challenges with multilateral funding, the funding pool needs to be open to contributions from private and philanthropic sources. This, too, is notoriously difficult, and a concerted effort from high-level champions is required to advocate for mission funding, create enthusiasm and buy-in for supporting these life-critical science and action missions.

An estimated annual budget of at least US$100–200 million for five mission areas should be assumed (US$20–40 million per science mission station per annum, including governance and institutional support). Regional knowledge and capacity needs must be taken into account in stations' resourcing. Given the long neglect and urgent challenges particularly faced in the Global South, fundamental support from the North is particularly important.

This funding would support both practice-relevant syntheses of existing knowledge and fundamental and applied research – as needed (and identified through the co-design process). It would also support 'last-mile' work in bringing knowledge to users (extensive outreach, communication, training and addressing other application hurdles). Depending on the co-designed research agenda, annual support may fluctuate, increase or decline over time. A simple but effective auditing system needs to be in place to responsibly manage funds – a task that should be handled by financial-management experts rather than be a burden on scientists.

Funding for implementation would be additional but equally necessary to achieving the ultimate changes on the ground. This is important to emphasize, because science funding alone will not accomplish the SDGs. Seamless funding streams need to be created through close interaction with policy-makers, philanthropy and the private sector to realize suggested policies and actions on the ground. Importantly, funding for collective planning and agenda development, much less for implementation of selected solutions is typically far more difficult to obtain than for knowledge creation. Funders and policy-makers – like scientists – must be encouraged to think in systems: putting in place the scientific, planning, governance, finance, human skill/capacity, socio-political and implementation components of systems change.

It is important to remember that going to the Moon was a political decision, not a scientific imperative, and it garnered funding support accordingly. The US invested 2–3% of GDP/annum (US$283 billion in inflation-adjusted dollars during 1960–1973 or ca. US$20 billion/year) into achieving that ambitious goal. The opportunity of crafting a safe and dignified future for humanity should be morally worthy of a similar commitment. If the G20 nations each committed to that level of funding (resulting in US$400 billion, with matching funding levels for implementation from all interested nations and industry), one could begin to see the level of transformative ambition.

Time Horizon

The Mission Stations should be ready to launch and achieve basic functionality within 3 years. This is highly ambitious but time is of the essence. This implies a nimble, well-resourced, high-capacity but relatively small-scale planning effort to get started.

This is the time for ambition and action, for courage and risk taking for our collective good. Public science and private-sector funders have enormous experience – both of what does and does not work – that can be used in developing a support structure for mission-oriented science.

The immediate time horizon for delivery (Phase I) would remain anchored to Agenda 2030, and the implemented model(s) and accomplishments should be evaluated after the first decade. Based on the outcome of that evaluation, the successful aspects should be replicated in a subsequent Phase II over the decades following, as long as mission-driven science is deemed essential.

7 SUPPORTIVE REFORMS OF EXISTING SCIENCE SYSTEMS

This report makes a strong case for why an ambitious mission-oriented approach to science is needed. At the same time, incremental progress in reforming the prevailing science system is helpful in its own right and is depicted here as a contextual enabling condition. The existing system educates and trains the necessary human capital, and advances researchers' capacities. The steady reform efforts of existing science system need to continue, as it will provide some of the institutional capabilities and much of the staff required for the mission-oriented work[4]. As a result, this report does not argue against such reform nor for competing with other science funding programmes. It does argue emphatically, however, that investment in reform will not be sufficient to ensure that science contributes in constructive, useful and timely ways to achieving Agenda 2030 and a sustainable future for humanity.

[4] Building on the inputs received from the ISC-led global call and the literature review, five broad areas for reforming the existing science systems have been identified for science to become more effective in supporting societal transformations towards sustainability (for more details see https://council.science/sdgs-science-agenda/)

8 NEXT STEPS

The ambition is for Mission Stations to be operational within the next 3 years and to mobilize US$20–40 million per science mission station per annum for at least five years. In the next 15 months, the ISC will be hosting a high-level coalition of political leaders, science funders, both national and philanthropic, and development aid agencies along with science leaders to identify the most appropriate institutional arrangements and funding mechanisms required to co-construct and deliver on the science missions identified.

9 CONCLUSION

Current trends in Earth's life-support systems and in society have coalesced to create a critical moment in human history. The tragic losses of life from the COVID-19 pandemic, as well as the severe economic impacts it created, put a laser focus on humanity's vulnerability to the systemic and cascading risks we have set in motion.

Until the pandemic, the policy opportunities and action imperatives embedded in hard-won global agreements such as Agenda 2030 and the Paris Agreement have not been sufficient to mobilize global action addressing the existential risks humanity now faces. Perhaps COVID-19 has held up the necessary mirror to recognize the consequences of inaction.

The long-term transformation of national science systems towards a more open, inclusive and collaborative global science system is necessary and must be pursued. But this form and pace of incremental progress, this report argues, will be too slow to respond to this *kairos* – this urgent moment in human existence on planet Earth. If sustainability science wants to play any relevant part in addressing these intersecting crises, the system that supports it internationally must change. To do so requires society to break with business-as-usual and rise to the occasion of the human predicament. Scaling up science investment to strongly and sustainably support a small number of focused science missions, united around a common sustainability agenda as described above, provides a real opportunity for mobilizing and putting to use the best transdisciplinary science for societal transformations in an outcome-driven, coordinated and integrated manner.

> *"Kairos (καιρός) is an Ancient Greek word meaning the right, critical, or opportune moment for action."*

This report thus argues for a strong shift towards mission-driven science *in addition and in parallel* to continued efforts to reform science more broadly – to provide it with a spearhead. It calls for a transdisciplinary, transformative approach to international science, supported by a common pool of science funding and a support system that largely shields researchers from the distractions and disincentives inherent in the existing science system to produce urgent societally relevant and usable knowledge to achieve real policy outcomes.

It argues for stepping out of business-as-usual approaches to funding science, doing research and creating supportive institutional arrangements for science implementation. This calls for courage. And commitment.

ANNEX 1

Examples of critical areas for scientific inquiry that Mission Stations could focus on

Below the report provides examples of critical research areas that each Mission Station could consider as starting places to 'seed' the co-design conversations about defining its scope of work. These areas have been identified through an ISC-led global call and extensive literature review (see council.science/SDGs-science-agenda). However, the final list of game-changing research questions that each Mission Station will have to address would need to be identified through a co-design process, involving key stakeholders and relevant disciplines, and giving priorities to topics that require global collaboration.

Food Mission: Eating adequate, healthy diets without consuming nature's bounty

Current food production methods are major contributors to human-caused climate change, unsustainable water use, ocean acidification and eutrophication, air and water pollution, deforestation and biodiversity loss. Current food consumption patterns are also driving inequalities in health outcomes through inadequate nutrition, leading to both food insecurity and hunger among some groups, and overweight and obesity in others. At the same time, food systems are vulnerable to the environmental changes now underway, e.g. through the increasing severity of droughts, floods, extreme heat events, diseases and land degradation caused, in part, by climate change, biodiversity loss and the way we manage food production itself. Earth's capacity to sustain current and growing needs for nutritious food will continue to weaken with ongoing environmental declines. For example, food security is threatened by the loss of pollinators and fertile soil. Loss of pollinators threatens annual global crop output worth between US$235 billion and US$577 billion (UNEP, 2021). Furthermore, access to sufficient and healthy food is very unequally distributed across the globe. Current food systems fail to deliver healthy diets to all, with some 800 million people undernourished and nearly two billion overweight (TWI2050, 2018). The COVID-19 pandemic has put the spotlight on food systems, which is thought to be one of the main drivers of the pandemic itself. The pandemic has also highlighted some of the main systemic risks of our hyperconnected global food system – trade disruptions, export bans and restrictions to migrant seasonal work – that have exacerbated food insecurity in already vulnerable areas. The transformation of the food system is thus imperative to limit the emergence of other similar threats in the future. This will require tackling human and environmental health as joint goals for the future development of food systems (Sperling et al., 2020). This implies that in transitioning towards sustainable food systems, the focus must be on enabling more equitable global access to nutritious foods and maximizing the nutritional value of produce while also minimizing the impacts on climate, land, water, biodiversity and oceans.

To support the transition to sustainable food systems that support healthy people and a resilient biosphere, science needs to:

- Provide better guidance on technological and social innovations, effective economic incentives and regulations, and forms of governance that will be required.
- Identify ways of overcoming existing impediments that slow down the transition towards more sustainable food systems, including regulatory barriers, market mechanisms, destructive subsidies and social and cultural factors.
- Improve understanding of interactions across food, water, energy and land use systems and their impacts on climate change, biodiversity loss, emergence of zoonotic diseases and impacts on public health (nutrition and through air and water quality) as well as how to build resilience to these impacts as they will inevitably increase in the future even with substantial mitigation efforts.

Critical areas for scientific inquiry:

- Identifying sustainable agricultural, aquacultural and fishing practices that minimize environmental damage and maximize resilience of food systems in the face of multiple shocks;
- Strengthening the biological diversity of crops, animal species and production systems, suited to diverse environmental conditions;
- Developing new and alternative food sources that improve food and nutritious health, while reducing environmental impacts;
- Enabling the shift towards affordable, healthy and environmentally sustainable diets;
- Identifying ways of reducing food waste and enabling the shift to circular food systems;
- Analysing current and future food crises (e.g. in the context of climate change, severe hunger or conflicts);
- Identifying mechanisms of governance, types of institutions and capacities required for transitioning towards more sustainable food systems;
- Understanding the distribution of power in food systems and identifying mechanisms for minimizing negative influence and control of large food corporations;
- Identifying the incentives for environmental stewardship in the food and land use system sectors;
- Identifying regulations, economic mechanisms and incentives that will advance the transition, but also identifying ways of removing regulatory barriers and inappropriate subsidies that undermine it;
- Identifying ways of protecting the food system workforce;
- Understanding interactions across and within systems (e.g. food–water–energy, land use–climate change–emergence of zoonotic diseases, food insecurity–climate change–conflicts and food systems–trade–risks), identifying synergies and trade-offs; and
- Assessing the roll-out of digital technology for the food systems, including through an equity lens.

Water Mission: Replenishing nature's reservoirs to provide enough clean water for all with minimal pressure on ecosystems

Adequate access to good-quality water is a uniquely fundamental requirement for life, both for humans and other organisms. As well as being a SDG itself (SDG6), it cuts across all of the other SDGs. At present, about one-fifth of the global population lives under conditions of water insecurity. Water insecurity affects particularly those in the dry tropics, subtropics, the Middle East and Central Asia, typically the world's poorest who are also at great risk of displacement. The number of people affected is projected to rise in the future, as a result of climate change, intensification of land and water use and a growing and urbanizing population, particularly in the most affected areas. The increasing demand on freshwater resources, along with the return-flows of polluted water, are placing unsustainable pressure on water-dependent ecosystems, threatening not only their biodiversity and their capacity to continue to yield steady flows of good-quality water for human use, but also fisheries (riverine, lacustrine and coastal), recreation and cultural uses.

Critical areas for scientific inquiry:

- Improving water-use efficiency (i.e. getting more product per unit water used), especially in irrigated agriculture, which currently consumes two-thirds of global freshwater;
- Advancing circular use in human water systems: recycling, repurposing and minimizing polluting waste in the water stream;
- Identifying ways to sustainably use unconventional water sources: energy-efficient desalination, grey water, cloud and atmospheric vapour harvesting, and groundwater, its recharge and use as a store;
- Improving understanding of the water needs of ecosystems: how much water, and in what pattern and quality, do water-dependent ecosystems need to remain functional?
- Undertaking integrated catchment studies: managing the whole resource at the scale at which it functions, climate land- and water-use projections, impacts of storage structures and engineered solutions, nature-based solutions to water quality, storage and flooding;
- Identifying equitable and functional water governance for access and supply protection, particularly between headwater regions that generate the bulk of the resource, the middle-river consumers where most is used and the coastal communities and ecosystems that need to survive on what is left;
- Assessing future social, economic and environmental value of water in the context of climate change, particularly in societies with current and future water stress;
- Analysing the social, economic, political and environmental cost of failure to find solutions to water stress in affected societies;
- Assessing competition for water among different water uses and water users in different geographical and temporal scales, considering its underlying causes and its social, economic, political and environmental consequences; and
- Identifying financial options to assist low- and middle-income countries finding alternatives to address their water stress problems.

Health and Wellbeing Mission: Being whole and well in body, mind and nature

The challenge of achieving universal human wellbeing means overcoming stark inequalities that characterize prevailing human conditions. These inequalities reflect evident disparities of income, education, demographic trends (e.g. fertility, life expectancy and ageing), population health outcomes and healthcare access across maternal, child and adolescent health, infectious diseases, non-communicable diseases and mental health (TWI2050, 2018). Human wellbeing should become a central tenet of economic progress and is not simply interpreted as a means to an end – to service shareholder or state benefits. Indeed, human health and wellbeing should be understood as preconditions for, and outcomes of, sustainable development (Dora et al., 2015). This means that health outcomes are useful indicators of progress in sustainable development.

The core research activities pursued under this mission should address the achievement of health equity for current and future generations. In recent decades, there has rightly been increased attention to the social determinants of health and health inequalities; however, less attention has been paid to the ecological determinants of health and intergenerational health equity. The focus needs to be on preventing and achieving solutions through cross-sectoral collaborations, promoting community participation and empowerment, and through integrating social science knowledge, laboratory science, medicine, public health interventions, development studies, medical anthropology, etc. There is a pressing need to bring human ecology into epidemiology in understanding, and responding to, patterns of health.

Critical areas for scientific inquiry:

- Developing pathways to universal access to quality healthcare and equitable health insurance systems;
- Improving global health governance (i.e. leadership, coordination, programme effectiveness and priority setting);
- Improving understanding of, and identifying equitable prevention and treatment pathways for specific health threats (e.g. mental health, microbial resistance, non-communicable diseases, neglected tropical diseases, malaria, tuberculosis, HIV/AIDS and vector-borne disease);
- Improving future pandemic preparedness and the resilience of health systems to disasters and emergencies;
- Expanding understanding of the socio-economic, cultural and environmental drivers of emerging infectious diseases (such as COVID-19, Ebola and SARS);
- Developing advanced therapies, precision medicine, digital health and tele-medicine, and indigenous medicines;
- Improving understanding of public health and its environmental connections (e.g. health effects of air pollution and climate change);
- Advancing a 'One Health' approach to protect the health of people, animals and the environment;
- Advancing critical understanding of prevailing and emergent demographic trends and their socio-economic consequences and implications (including reducing maternal and infant mortality);
- Systematically measuring and monitoring global human health and wellbeing; and
- Understanding the implications of the mismatch between humans and their contemporary environments, and what this means for disease prevention and health promotion.

Urban Mission: Thriving in places while stewarding the natural environment

The scale and speed of current urbanization are unprecedented in human history. More than half of the world population lives in urban areas. Seventy percent of the world population will live in urban areas in 2050. Most of the yet-to-be built urban areas will be in low- and low-to-middle-income countries, mainly in Asia and Africa and to some extent in Latin America (TW2050, 2018). Urbanization in many of these countries is characterized by informality. While megacities receive significant attention, they only concentrate approximately 13% of the world's urban population. More than half of the urban population is concentrated in cities with fewer than one million inhabitants (UN, 2019). Small- and middle-sized urban areas have significantly less resources to manage urban growth than megacities. Urban areas are responsible for a large proportion of direct and indirect carbon emissions and the construction of new urban infrastructure will result in significant increases in greenhouse gas emissions. The growth of urban areas will necessitate the construction of buildings and roads, water and sanitation facilities, transport and energy systems that will be energy and emission intensive in their construction and operation. Current urban growth paths will lock in patterns of energy consumption and behaviour, aggravating inequalities and path dependencies that are difficult and costly to change once in place. Current urbanization patterns will also lock in patterns of vulnerability to climate change. Transformative changes to create positive lock-in and avoid path dependence in fossil fuels to create just, liveable, resilient, sustainable and low-carbon cities are essential in light of the rapid pace of urbanization, particularly in the case of small- and middle-sized cities and urban areas yet to be built.

Critical areas for scientific inquiry:

- Building an improved understanding of cities as a complex of socio-technical and socio-ecological systems;
- Improving systems understanding of urban-rural interactions;
- Identifying ways of empowering urban social innovation;
- Developing diverse urban growth pathways in better harmony with nature, particularly through the use of nature-based solutions in different social, economic, geographical and cultural contexts;
- Assessing the costs of inaction at the national, regional and global level, as well as the economic, social and environmental benefits of transformational changes in current and future cities now and in coming decades;
- Assessing and minimizing social urban vulnerability to climate change and cascading impacts of climate change;
- Identifying ways of building multiscale climate response capabilities of cities;
- Assessing and identifying ways of reducing the global footprint of cities, including through circular and distributive urban economies, sustainable urban design, services and lifestyles;
- Developing new urban theories and analytical approaches in the Global South;
- Building an improved understanding of urban informality and identifying ways of upgrading informal settlements;
- Identifying inclusive, participatory mechanisms of urban governance and institutions; and
- Identifying novel financing mechanisms in cities, particularly in low- and middle-income countries, from funding options for informal neighbourhoods to investing in nature-based urban infrastructure.

Climate and Energy Mission: Shifting to clean energy while restoring a safe climate

The global energy system based on fossil fuels accounts for close to 80% of primary energy today. Transforming this system to reach net-zero carbon emissions by 2050 and at the same time to provide universal energy access without increasing the use of fossil fuels is one of the major challenges in the 21st century. Transforming to a net-zero carbon global energy system is essential to limit global warming to 2°C in this century and reduce negative impacts of climate change threatening nature and societies.

Achieving net-zero by 2050 would require decarbonization of the energy systems, accompanied by a transformation of land use and food systems (detailed in another mission). To decarbonize the world's energy system by mid-century, transformative actions would need to be built on four pillars:

- Reduced energy demand and improved energy efficiency in all sectors;
- Shift of electricity generation from fossil fuels to renewable sources;
- Electrification and fuel switching, the conversion of current uses of fossil fuels outside of power generation (such as the internal combustion engine, boiler and heaters in buildings and various industrial processes such as steel production) to zero-carbon electricity; and
- Reduced energy poverty and universal access to low-carbon, clean cooking and electricity for all, especially those excluded today (TWI2050, 2018).

Although the energy transformation is considered feasible and affordable for the world, there are a number of barriers (e.g. institutional constraints, current energy systems design, market control by incumbents and policies that favour fossil fuel technologies and business models) that slow the transformation process. To increase the world's chances of achieving the 2°C goal, ways of overcoming these barriers must be urgently identified.

Critical areas for scientific inquiry:

- Integrating the social, behavioural, and economic factors in energy and climate models;
- Developing robust transformative pathways to energy system decarbonization while achieving universal energy access, taking into account differences in energy use across countries;
- Understanding of barriers to just energy transformation and identifying ways of overcoming them;
- Assessing the potential of distributed energy generation in different contexts, facilitated by the digital technologies;
- Identifying options for reducing energy demand and improving energy efficiency in all sectors;
- Developing sustainable and smart mobility solutions;
- Developing battery-life extension and improved energy storage solutions;
- Developing pathways of achieving universal energy access in low- and middle-income countries, while avoiding path dependence in fossil fuels;
- Building multidimensional knowledge on the costs of inaction, delay or limited action to achieve net-zero energy systems and universal energy access;

- Advancing understanding of transformative climate mitigation and adaptation strategies and pathways, assessing the effectiveness of these strategies, and translating results into actionable information;
- Transforming the capability of global and regional climate models through coordinated efforts;
- Downscaling of climate data and making the data accessible and usable to impact researchers and planners/decision-makers;
- Improving understanding of the solar influence on climate change;
- Improving understanding of the synergistic impacts of air pollution and climate change on human and ecosystems health and development;
- Building a better understanding of carbon storage in soils and plants;
- Improving understanding of the effects of climate change on the distribution of non-native and native species at different geographic scales; and
- Transdisciplinary interventions and scenarios to manage the global climate system.

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