International Science Council

The global voice for science

A SYNTHESIS OF RESEARCH GAPS

for science to enable societies to accomplish the Sustainable Development Goals by 2030

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Connect with us at:

www.council.science
secretariat@council.science

International Science Council
5 rue Auguste Vacquerie
75116 Paris, France

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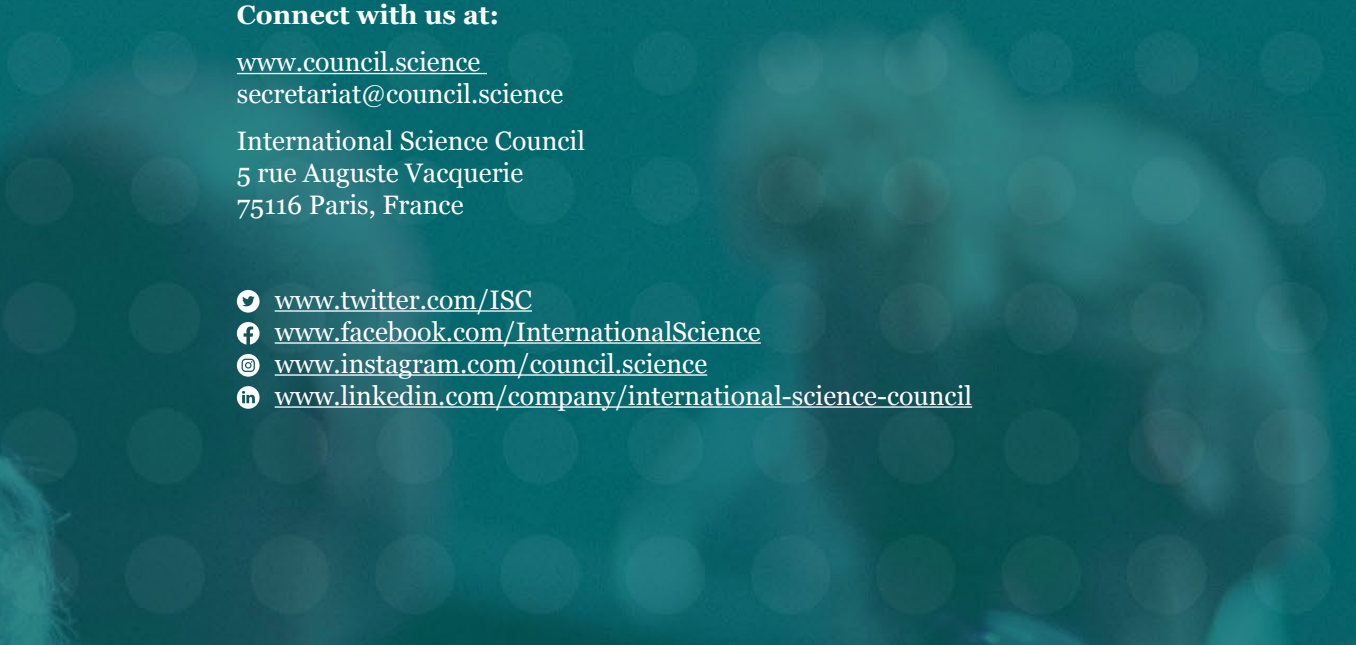

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INTRODUCTION

In 2019, the Global Forum of Funders asked the International Science Council (ISC) to convene the insights and ideas of the global scientific community on the critical priorities for science that will support and enable societies to accomplish the Sustainable Development Goals (SDGs) by 2030. To this end, the ISC launched a global call for inputs in October 2020 to shape a priority action agenda for science. The ISC also undertook the review of international agenda-setting reports and transformative frameworks and commissioned the review of the relevant academic literature (see *Sources of Input and List of reports and articles reviewed*).

The collected inputs informed directly the development of the report *Unleashing Science: Delivering Missions for Sustainability*. This report highlights the need to focus our collective wisdom and research efforts on the delivery of five Sustainability Science Missions – pertaining to food systems, energy and climate, health and wellbeing, water and urban areas – if we are to stabilize the Earth system within a safe-operating space within 10–20 years. *Unleashing Science* identifies possible areas for scientific inquiry for each mission.

The inputs collected through the global call and the literature reviews provided in addition valuable insights on research gaps and priorities which, if pursued, could support the impact that the Sustainability Science Missions seek to accomplish. The present document introduces these research gaps and possible priorities. They have been distilled into five topical areas.

Topic A: Sustainable planet for a dignified human future

Topic B: Economies for the People and the Planet

Topic C: Towards integrated and inclusive governance and capable institutions at all levels

Topic D: Digital transformations for humanity and inclusive sustainable development

Topic E: Understanding the processes of societal transformations in different contexts.

In addition to the topical research areas, the input from the global call and the literature review provided valuable insights on how science systems, including science funding, need to evolve to support societal transformations required to achieve the SDGs. These key findings are provided in the second section of this report, *Reforming Science Systems*.

Given the wide scope of the SDGs, any literature review will be selective. The intention of this particular synthesis is to identify, on the basis of a careful analysis of the literature, research areas and themes that can make particularly significant scientific contributions towards implementation of the SDGs in the next decade. We believe that they can help guide future scientific funding action.

Sources of input

- An ISC-led global survey undertaken in 2020 to convene the insights and ideas of the ISC's global network of institutions and experts on the critical priorities for science that will support and enable societies to accomplish the goals by 2030. In total, 239 valid responses were submitted, covering 61 countries from different continents.
- The review of over twenty international agenda-setting reports and transformative frameworks on issues related to sustainable development. This includes Transformation is Feasible: A Report to the Club of Rome, 2018; The World In 2050; IIASA, 2018; UN Global Sustainability Report, 2019; and UN Research Roadmap for the COVID-19 Recovery (see List of reports and articles reviewed).
- The review of scientific literature. In total, 95 scientific articles have been identified and reviewed (see List of reports and articles reviewed) to identify examples of research priorities and needs in fields of sustainable development. Keywords such as research agendas, SDGs, sustainable development, knowledge gaps, research trends and research priorities were used to identify relevant articles in Scopus. A total of 810 documents (articles, reviews, books, chapters and editorial notes) were thus identified. The list was further reduced by prioritising articles published since 2015, which marks the official launch of the SDGs, as well as focusing on reviews and syntheses of current knowledge.

This document was developed by the ISC under the valuable guidance provided by the members of the Scientific Advisory Group – Albert van Jaarsveld, Director General, International Institute for Applied Systems Analysis; Susanne C. Moser, ISC Strategic Advisor on Transformations to Sustainability; Line Gordon, Stockholm Resilience Centre, Sweden; Bob Scholes (sadly passed away on 28 April 2021), University of the Witwatersrand, South Africa; Roberto A. Sánchez-Rodríguez, College of the Northern Border, Mexico; Peter Messerli Associated Senior Research Scientist, Wyss Academy for Nature, Switzerland; Anthony Capon, Monash Sustainable Development Institute Australia; and Melody Brown Burkins, The John Sloan Dickey Center for International Understanding, USA – who helped to analyse and cluster the multiple inputs, and review the document.

Katsia Paulavets, Senior Science Officer, ISC, coordinated the development of the document.

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IDENTIFIED RESEARCH TOPICS

Topic A: Sustainable planet for a dignified human future

Reconciling human development needs and the needs of nature requires a deep understanding of complex interactions between human and natural systems in a constantly changing world, and the capacity to translate this knowledge into action for the wellbeing of all. It also requires a range of options and an understanding of their potentials, limits, application and unintended consequences. There is a need to urgently strengthen the type of science that takes complex and interconnected processes between human and natural systems into account, that deals with multidimensional understanding of existential risks and which considers different geographical, socio-economic and cultural contexts and is globally inclusive and relevant. To build this knowledge, the following research focus areas are proposed:

Improved understanding of the integrated Earth system with human wellbeing

Areas for scientific inquiry include:

- Understanding the dynamic integration of natural and human systems at a planetary scale;
- Revisioning the agenda for human development: identifying ways to enable more just, inclusive and peaceful human development within planetary boundaries;
- Designing coherent visions of potential futures and transition pathways that will allow reducing the risk of a systemic collapse of the natural, human and economic systems;
- Defining and monitoring of planetary boundaries connected to systemic tipping points that may cause irreversible consequences for humanity if exceeded;
- Determining whether humanity is currently on a collapse trajectory and whether or to what extent it is reversible; and
- Engaging and investing in interdisciplinary and transdisciplinary systems science for human and environmental systems health.

Understanding the synergies and trade-offs between the SDGs in different contexts

Areas for scientific inquiry include:

- Building a systems view of SDG synergies and trade-offs across different contexts;
- Developing integrated SDG models at an appropriate resolution as a basis for scenarios of possible future trajectories to influence policy making; and
- Developing integrated SDG planning and decision-making tools and solutions.

Improved ecosystems protection

Areas for scientific inquiry include:

- Building an integrated understanding of how to protect biodiversity and ecosystems from collapse, from the soil ecosystem to the social part of the human communities that live in those ecosystems;
- Developing contextual pathways and approaches for achieving biodiversity objectives within local socio-economic contexts;
- Assessing the value of ecosystem goods and services for human wellbeing (e.g. the benefits of 'Green Care' and spiritual values of biodiversity);
- Improving understanding of the potential of a bioeconomy: what are the economic benefits from biodiversity, contribution of biodiversity to the 'sustained productivity and stability' of ecosystems and the impact of this on reducing hunger and poverty, and biodiversity as the 'lifeblood of all businesses'; and
- Identifying ways of biodiversity and extinction accounting, especially in business reporting and corporate ethics.

Topic B: Economies for the People and the Planet

As the principal driver of human-induced planetary change and the collective human condition, the global economy should be transformed to one that is fair, inclusive, circular and sustainable (Srivastava et al., 2021). The research needs to advance understanding of the benefits, complexities, roles of different groups in society, necessary policies, regulations, incentives for advancing a more inclusive and sustainable economy in different contexts. More importantly, it will be critical to identify ways of overcoming existing impediments that slow the transition towards that economy, including regulatory barriers, market mechanisms, as well as social and cultural factors. The proposed research focus areas outlined below are intended to inform the transformation to such an economic future for humanity.

Just economies for a sustainable future: shifting from the growth paradigm to one that is in line with biophysical reality and with ethical considerations

Areas for scientific inquiry include:

- Defining key characteristics of just and more sustainable economic models;
- Identifying ways of decoupling economic growth from increasing environmental degradation;
- Rethinking value: increasing the value given to ecosystem services, to the sustainable use of resources and to improving human health and wellbeing. Integrating the value of ecosystem services in measures of economic performance;
- Identifying and addressing existing impediments that stall the adoption of a just, more sustainable economy;
- Identifying ways of overcoming entrenched economic disincentives to sustainability, including perverse subsidies and taxes that promote wasteful and harmful use of natural resources;
- Understanding the role of economic policy and regulations (e.g. trade, financial capital, WTO rules and free trade agreements) in hindering or facilitating the transition towards a more sustainable future and identifying required reforms;
- Identifying mechanisms for dealing with monopoly position of multinational corporations and their shareholders in order to limit negative environmental and unfair societal impacts;
- Building a better understanding of relationships between habits, social norms and regulations in transforming to a just, more sustainable economy; and
- Identifying models for financing the transition to a just and more sustainable economy.

Human dignity and social cohesion through equity and poverty reduction

Areas for scientific inquiry include:

- Identifying inclusive development practices that can deliver social cohesion, community resilience and a dignified future for all of humanity;
- Identifying structural changes required in the economy to reduce inequalities within and across nations (e.g. the future of individual and community property rights, income distribution at global and national levels, equity and inclusion in resource management and reform of trade agreements);
- Producing alternative bodies of knowledge on inequalities, outside Europe and North America; and
- Identifying lasting mechanisms that overcome the poverty trap and empower vulnerable communities.

Shifts to sustainable production and consumption

Areas for scientific inquiry include:

- Addressing the underlying drivers of unsustainable consumption and production patterns;
- Assessing the potential of a circular economy to drive transformation of industries, value chains and sectors. Identification of novel, more sustainable business models, production processes, goods and services;
- Dematerializing goods and services, particularly though increasingly circular life cycles;
- Developing less resource and energy intensive materials; increased reuse and recycling of materials and goods to address basic needs (e.g. housing, transport and alimentation); promotion of low-tech life-styles;
- Identifying regulations and incentives for directing private investments to sustainable production;
- Understanding how to stimulate a shift to more sustainable life-styles, especially in developed countries and among the growing middle classes in emerging countries; and
- Assessing the potential of a circular economy as a driver for more sustainable consumption.

The future of work

Areas for scientific inquiry include:

- Understanding how the future of work might look in a digital age and its implications for human development;
- Identifying key skills that will be required in the future to ensure continued economic participation and understanding how educational institutions and practices need to be reformed to build those skills; and
- Assessing the impact of a circular economy on jobs.

Topic C: Towards integrated and inclusive governance and capable institutions at all levels

The sectoral structure of government agencies is no longer adequate to deal with the complex challenges of the 21st century. Novel modes of governance, capabilities, policies and the formation of actors of change on local, national and global levels are required to support the achievement of the SDGs. To recognise the systemic and holistic nature of sustainability, there is a need for cross-sector coordination and more integrated, inclusive, accountable, adaptive and innovative governance structures at all levels. Building strong political institutions at the subnational, national and global levels is thus crucial for an integrated and peaceful implementation of the 2030 Agenda.

Giving the important role of governance in accelerating the societal transformations, it is critical to mobilize research, to build knowledge synthesis on types and characteristics of transformative governance arrangements and policy required to achieve the SDGs and on how to actually achieve needed changes through effective and accountable governance. This will require transdisciplinary knowledge creation with strong leadership from social science research.

Identifying effective governance models and arrangements capable of accelerating transformations towards sustainability

Areas for scientific inquiry include:

- Investigating the obstacles and enabling conditions that affect the implementation of the SDGs within national jurisdictions in different contexts and identifying ways of overcoming them;
- Identifying ways of overcoming siloed decision-making and achieving policy coherence across sectors, levels and actors;
- Understanding how to govern the transition process towards sustainability in an evidence-based and just manner;
- Improving understanding of how national and global institutions should be reformed and what institutional capacities should be built to enhance governance for sustainability; and
- Identifying effective mechanisms for increasing the transparency and accountability of governments, multinational companies and financial institutions.

Advancing multilateral cooperation

Areas for scientific inquiry include:

- Overcoming the 'tragedy of the commons': identifying effective mechanisms for governing global commons, shared resources and common threats (e.g., climate change, oceans and biodiversity);
- Identifying ways of overcoming obstacles to improved multilateral collaboration;
- Developing scenarios, which consider potential outbreaks of conflict dynamics, as transformations to sustainability are likely to be disruptive and, thus, could potentially trigger conflicts; and
- Identifying mechanisms for preventing and/or mitigating ongoing armed conflicts.

Analysing the 2030 Agenda through a governance lens and assessing its impact on real policy-making at different governmental levels (from global to local)

Areas for scientific inquiry include:

- Assessing how the implementation of the 2030 Agenda shapes and is shaped by modes of governance across different contexts; and
- Looking beyond the 2030 Agenda to help shape effective future global governance frameworks, ensuring productive contribution of a wide range of voices and disciplines to that debate.

Topic D: Digital transformations for humanity and inclusive sustainable development

Digital innovations have the potential to enable and scale up the implementation of the SDGs. However, they can also multiply already existing development problems (inequalities, power concentration, erosion of civil rights, and erosion of transparent and accountable democracies and governance capacities). The critical challenge now is to understand how to ensure that digital technologies and artificial intelligence advance rather than hinder the implementation of the 2030 Agenda.

Trustworthy, peaceful digital application and cybersecurity

Areas for scientific inquiry include:

- Understanding the opportunities of artificial intelligence applications for sustainable development and how they can be harnessed;
- Improving understanding of risks of disruptive technologies, such as machine learning, artificial intelligence, digital therapies and telemedicine, and identifying ways of minimizing them;
- Preventing and minimizing cybersecurity threats;
- Assessing the impact of digital technologies and digital economy on SDG attainment;
- Identifying trustworthy governance in a digital future that promotes sustainability;
- Identifying ways of bridging the digital divide;
- Understanding the effects of big data on data quality on sustainability; and
- Assessing the environmental footprint of digitalization and identifying ways of minimizing it.

Topic E: Understanding the processes of societal transformations in different contexts

There is a growing consensus that deep systemic changes – transformations – are needed to achieve the SDGs and other global agreements in the next decade. Transformation and transformative action have become common phrases in policy and public action, as well as in many areas of contemporary scientific inquiry. But what does transformation mean? How do we recognize processes with the potential for fundamental or radical systems change? There is a growing body of evidence on these issues. Whilst its focus falls predominantly on the challenges of global sustainability, its foundations have been built by sustained scholarship in the social and human sciences that addresses complex and often contested processes of socio-political, economic and cultural change, and the belief systems and institutional power structures that facilitate or obstruct it. This body of knowledge needs to be further harnessed and synthesized, and effectively utilized in the service of the 2030 Agenda.

Harnessing scientific knowledge on processes of societal transformations, past and present

Areas for scientific inquiry include:

- Building an understanding of how to realize societal transformations in ways that are equitable and just, socio-politically feasible and culturally acceptable;
- Understanding how to manage change in a complex system that includes humans: what are the limits of our abilities to deliberately change systems? Under deliberate transformations, what are the better and worse ways of doing it?
- Identifying effective ways of overcoming key obstacles, pitfalls and sources of resistance to change to the sustainability transition; and
- Developing new, critical discourses that can transform and replace old, dominant discourses about the way society, economy and science are organized.

Creating culture, beliefs and behaviour change, and building capacities for biosphere stewardship

Areas for scientific inquiry include:

- Bridging divides between disciplinary perspectives on culture, beliefs and behaviour, and how they interact with natural and anthropogenic physical systems;
- Understanding approaches to, and the pros and cons of, deliberatively steering behaviours, beliefs and culture for sustainability efforts, for the long term and at scale;
- Understanding how to create new social norms for sustainability: understanding how habits are formed, broken and sustained; who the right messengers and champions are; how to change behaviour and decisions in different business, community and government organisations;
- Clarifying the mechanisms by which individuals' beliefs and behaviour are enabled and constrained by systems they participate in, and by which individuals contribute to change in those systems;
- Understanding which behavioural models and frameworks to apply where and when;
- Identifying effective mechanisms for mobilizing individual and collective action for sustainable development; and
- Developing novel educational concepts, pedagogical approaches and tools for preparing professionals and the future generation to understand and deal with the complex global challenges.

REFORMING SCIENCE SYSTEMS

Building on the inputs received from the global call and the literature review, this section outlines five broad areas with specific reform actions required for science systems, including science funding, to become more effective in supporting societal transformations towards sustainability. The identified areas include:

- Strengthening the directionality of science, strategic collaboration and governance;
- Changing the practice of science through new incentives and awards;
- Boosting research capacity in the Global South;
- Advancing Open Science globally; and
- Strengthening trust in science and relevance for policy.

Strengthening the directionality of science, strategic collaboration and governance

Pursue better coordination and strategic prioritization

The global landscape of actors working on the Sustainable Development Goals (SDGs) is continuously growing. While there is a great value in diversity, increasing fragmentation and complexity undermines the effectiveness of different efforts and threatens the attainment of the SDGs. A more coordinated and strategic approach to science and science funding is required to ensure that all efforts are connected and collectively contribute to addressing specific global challenges. An overview is needed of existing data, knowledge, capacities, skills, critical gaps, research priorities and key actors involved in SDG-related research and implementation. On possible approach is to develop a globally curated online collaborative platform where scientists, research institutions and science funders as well as non-academic stakeholders working on SDGs can tag their competences, interests, insights, projects and scientific work. The platform would help identify partners working on similar topics, facilitate synergies, minimize fragmentation and duplication and match existing knowledge with unsolved problems.

The United Nations Global Sustainable Development Report (UN GSDR, 2019) also calls for a globally coordinated knowledge platform that enables collection, aggregation, synthesis and public sharing of the rapidly growing but fragmented body of knowledge on sustainable development from scientific and non-scientific sources, including practical and indigenous knowledge.

Make science governance more democratic, open, transparent and accountable

Science policy-makers, funding agencies and researchers need to adopt the 2030 Agenda for Sustainable Development as a shared compass to increase the relevance and benefits of science and technology for the global community (UN GSDR, 2019). However, as the SDGs are diverse and often conflicting, the prioritization and pursuit of sustainability goals is fundamentally a political (not technical) matter. Social choices between alternative directions for science and development require participation and accountability.

Leading agencies in the governance of science should actively resist current technocratic tendencies and energetically assert the necessity for democratic oversight of the directions taken by research. The governance of science for sustainability should be explicitly problem-focused, giving balanced attention to a diversity of alternative possible responses. It needs to better acknowledge uncertainties and make space for divergent perspectives and contextual conditions.

There is a corresponding need for transparent, accountable and participatory methods to prioritize research funding, both across different areas of science and within specific fields. Science governance institutions and practices should become more democratic, open, transparent and accountable. Science funders need to scientifically assess how their grant-making practices are affecting the prioritization and directionality of science. Something akin to this is being undertaken under the Research on Research Institute supported by the Wellcome Trust.

Align science funding more closely with societal and environmental needs

Since its adoption, the 2030 Agenda has mobilized the global scientific community to produce relevant knowledge. However, only 10% of global research output relates to the SDGs (Wastl et al., 2020) and sustainability science still remains a limited field in the broader scientific landscape (UN GSDR, 2019). Furthermore, while the SDGs are starting to influence science funders' priorities, most research funding still prioritizes national scientific efforts that generate economic benefits over international collaboration to achieve societal and environmental benefits.

Given the scale and urgency of the global sustainability challenges, sustainability science should be scaled up significantly (UN GSDR, 2019). To this end, a stronger alignment of research funding priorities with the societal and environmental needs outlined in the SDGs is key. National and international science funding systems need to map their own activities more closely to sustainability measures, for example by explicitly tying research funding programmes and research evaluation criteria to the SDGs.

Strengthen the directionality of science and support large-scale mission-oriented research

Dedicated research funding streams for specific global challenges, with a common agenda and sharing of capacity, should be created with support from both the Global North and Global South. Funding should be directed to a set of large, focused projects that bring together international inter- and transdisciplinary research consortia and centres to address specific challenges in different contexts. These projects should not only focus on identifying technological solutions, but should aim to stimulate social transformation. Open data sharing, regular exchange of findings and re-adjustment of research priorities based on intermediate findings should be key elements of these projects. Under these large umbrella projects, more focused smaller research projects could also be supported. The European Council for Nuclear Research (CERN) and the Access to COVID-19 Tools Accelerator fund created to enable simultaneous research on vaccines for COVID-19 are examples of how it can be done.

Enhance collaboration between science funders

To accelerate the impact of science will require enhanced collaboration between national science funders, foundations, the private sector and donors. The COVID-19 pandemic has demonstrated that such collaboration is critical and possible. Science funders, however, need to overcome divergent institutional interests, better coordinate their efforts in working towards common goals and move to more synergistic approaches. To achieve this, more transparency from science funders will be required – in data sharing, funding calls, research assessments and policies, etc. Collaborative international funding schemes with equal funding procedures for all partners would facilitate global research on SDGs better than multiple national funding arrangements. Developing tailored collaborative funding mechanisms with more flexible governance arrangements that build on partners' strengths and take into account operational differences will be key.

Changing the practice of science through new incentives and awards

Make science systems more inclusive and equitable, facilitating a wider range of voices, institutions, types of knowledge and ways of learning

Scientific knowledge is produced by disciplinary experts in dominant ways of knowing, rather than through more comprehensive or complex understandings. As a result, knowledge production and use often lacks systemic thinking and is dominated by linear and fragmented understandings of reality (Fazey et al., 2020).

Knowledge exists in many shapes and forms and comes from many different societal actors, yet the very use of the word science to refer to all scholarship tends to exclude marginalized perspectives, indigenous knowledge and stakeholders without scientific training. This slows the emergence of new thinking and acting, and furthers the disconnect between research and real-world issues.

Dominant scientific traditions must become more prepared to question their categories, languages and assumptions, and be more open to dialogue and collaboration with diverse knowledge cultures. Achieving a more cohesive society that is able to address complex challenges requires far greater efforts to acknowledge and include the many ways in which knowledge is produced. Science systems need to become much more collaborative and inclusive of different forms of knowledge.

Engage with indigenous knowledge

Indigenous knowledge builds on the long-term understanding and practice of socio-ecological systems maintained by societies around the world. Engagement with indigenous people, who have a diversity of know-how and cultures, for new collaborations along the chain of knowledge production is needed to co-produce informed policy, improved evidence and implementation of the 2030 Agenda. Indigenous knowledge on megatrends such as biodiversity, climate change adaptation and land conservation should be documented. However, strong respect and ethics are crucial throughout the process. Harnessing and securing indigenous knowledge must be undertaken with regards to intellectual property rights, which belong to indigenous people (UN GSDR, 2019).

Transcend science nationalism, particularly for issues of international importance

Currently research on the SDGs has a profile of around 80% domestic collaboration, 15% bilateral and 5% multilateral (Digital science, 2020). In the face of shared challenges, which are too complex and global in nature to be addressed by one country alone, there is a critical need to increase opportunities for international research collaboration.

Promote transdisciplinary research

For science to have a positive impact it needs to better connect with a range of societal actors, especially those who stand to be most impacted, and meaningfully integrate their needs and perspectives into the research process. Transdisciplinary research provides tools to achieve this. It not only stimulates closer cross-sectoral collaboration and better mutual understanding of divergent interests, but increases the ownership of results by different stakeholders. It also improves the ability to ask better scientific questions, and changes the paradigm of how scientists pursue science to include a solutions orientation. Through long-term partnerships, transdisciplinary research helps to create societal resilience to the shocks of "wicked" problems and contributes to increased support for science among the public at large.

Knowledge co-production, however, is not without costs, and these can represent a significant burden for participants. Novel methods are needed to help reduce costs and ensure effectiveness of and satisfaction with co-design and co-production. Overall, there is a need to become much savvier about how science partners with societal actors. The relations between societal actors and science will vary dramatically across issues, scales and contexts. A blanket approach promoting inclusion of all actors at the same time may be a recipe for stalemate. Therefore, a wider range of partnership possibilities should be considered, grounded in how these work in the real world rather than idealized prescriptions, for real progress in building partnerships between science and societal actors.

Facilitate long-term science-policy-society collaborations

Governments at every level should institutionalize science-policy-society alliances focused on co-designing, implementing and monitoring context-specific pathways to sustainable development. Actors from science, policy, the private sector and civil society must fundamentally rethink their partnerships and create experimental spaces for collaboration on transformation pathways – collaboration in which scientists and societal actors at different levels innovate sustainable solutions and develop, test and practice new routines in everyday life and business. Building effective collaboration with research capacities in the private sector will be critical to resolving many complex social and environmental problems.

Science-policy cooperation in particular needs to be intensified at the level of individual research projects and institutions to enable SDG implementation. This calls for a deeper understanding of science-policy interface processes. Strengthening the policy-science interface and enhancing policy coherence for sustainable development will also require a restructuring of national policy architectures. Engaging scientific representatives in national bodies for SDG implementation on a more formal and permanent basis is an important step towards strengthening the policy-science interface for the sustainability transformation.

Support interdisciplinary research through experimental and/or high-risk, high-reward projects

Such projects give researchers from different disciplinary backgrounds the opportunity to build long-term relationships and explore novel modes of collaborative research. The critical challenge is to understand how to facilitate effective and fruitful knowledge exchange between diverse disciplines, without diluting the capacity of each to effectively focus on their own part of the problem.

Stimulate a step-change in the role and support given to the arts, humanities and social sciences within inter- and transdisciplinary research

A primary focus should be on society: its mechanisms, dynamics, worldviews, values, and the instruments that help people shape people, rather than people shaping the biophysical world directly. In that respect, the inclusion of the arts, humanities and social sciences along with societal actors is paramount to maximize the relevance, legitimacy and uptake of research results that will lead to achievement of the SDGs. There is a need to better integrate insights, theory, knowledge on human behaviour, social relations, institutions and politics to inform and help shape society's response to the SDG challenges. The importance of the arts, humanities and social sciences should not only be recognized at the individual and project level; there is also a need for a complete overhaul of research funding and evaluation systems at the national and international level to enable the meaningful integration of these domains into sustainability research from the outset, and not as an afterthought.

Furthermore, the share of research funding going towards the social sciences needs to increase substantially. For research on issues related to climate change, for example, the natural and technical sciences received 770% more funding than the social sciences between 1990 and 2018 (Overland and Sovacool, 2020). Such patterns are highly likely to be replicated in other areas of sustainable development research.

Mobilize and improve the use of existent knowledge

There are large bodies of academic, local and traditional knowledge that remain un-mobilized and under-used. The translation of existing knowledge into effective measures for change remains a critical gap. Science funding should not only support knowledge production, but also provide incentives for researchers to engage with policy and practice in order to promote the use of research evidence to inform choices and generate positive impacts. Implementation science also requires more attention within science systems as it explores methods and strategies to promote the uptake of effective interventions into practices, programmes and policies. Furthermore, large areas of existing knowledge should be systematically collected and synthesized in international and regional scientific assessments to build consensus on key issues and to explore new potential areas of application.

Redefine "excellence" and initiate new methods to evaluate research

Evaluation should break the grip of global rankings and leagues and the dominance of journal-level metrics like impact factor, in order to recognize, reward and value research that is engaged, solution-oriented and positioned for use. Funding systems need to move from an output paradigm to outcomes and impact evaluation. To really benefit sustainable development, a scientific publication should be the first step rather than the final product. Traditional science often stops with the publication because there is little funding available for other deliverables and/or translational science. Funding agencies should consider how to increasingly reward proposals that include deliverables beyond scientific publications and that take the scientific outcomes further.

Evaluation and review systems for funding research should also evolve to ensure that science is better connected with society. New evaluative criteria are required to support inter- and transdisciplinarity, including with the arts, humanities and social sciences. Similarly, new evaluative criteria are required to support contributions from indigenous knowledge and citizen science. These evaluation criteria should reflect social and environmental benefits of research, as well as the complexity and long-term challenges (rather than quick fixes) that substantive sustainability transformations imply. Effective ex ante and ex post evaluations should be conducted to assess the impact of research projects. For that, clearer guidelines should be developed for funding councils and universities to evaluate inter- and transdisciplinary research. Research Quality Plus is one example used to evaluate research for development.

Academic systems should also reward inter- and transdisciplinary co-creation of actionable knowledge and provide opportunities for long-term career development of inter- and transdisciplinary scholars, especially for early career scientists. Currently such opportunities are rare.

Establish transdisciplinary reference groups to assess research proposals

These reference groups include relevant disciplines for each project and also experts on transdisciplinarity who can help make the connections between the different approaches. Experts, including beyond academia, who have successful experiences in conducting transdisciplinary solution-oriented research could provide the leadership in reviewing proposals and manuscripts.

Shift from short-term project-based to long-term funding

Real progress and impact require consistent and long-term funding with an institutional and funder understanding that the outcomes may be "non-traditional". Too much time is spent building research groups, creating fundamental trust and reciprocal working relationships, which are disbanded once funding stops. A longer-term funding system would enable research to build on existing partnerships. Therefore, long-term funding and support should be provided for research teams and institutions that are addressing wicked and complex problems. These teams should be drawn from various disciplines, including the arts, humanities and social sciences, and engage a range of relevant societal actors in the research process. To this end, research funding calls should have an explicit emphasis on social impacts of research and on inter- and transdisciplinarity, and should provide incentives for societal engagement and the promotion of evidence use, not simply its production. The development of these calls should also benefit from the input of the policy-makers whose responsibility it is to craft programmes that will use the knowledge that researchers create.

Prepare science systems to deal with future crises

The agility, quality and relevance of science need to be improved to deal with future crises. This can be supported by adapting funding regulations and mechanisms to deal with emergencies, promoting a systemic approach and providing incentives to redirect research. Publication needs to be sped up, both by ensuring quality control of pre-prints and incentivizing the publication of interim products of research. Mobilizing private sector science and technology platforms can also help science systems combat crises more effectively.

Build necessary capacities and skills

Being capable of working with complexity, values and diverse interests will be essential to dealing with contemporary wicked challenges. To this end, inter- and transdisciplinarity should be integrated into education and training of researchers at all levels (undergraduate, graduate and postdoctoral). Building science communication, facilitation and negotiation skills should also be considered as part of undergraduate and postgraduate studies. This will prepare scientists to act as knowledge brokers and to lead engagement with different stakeholders, bridging the divide between science, policy and society. Training in managing inter- and transdisciplinary research projects should also be offered.

Tackling complex problems will require strengthened systems thinking capacities globally. There is also a need to develop a greater foresight and predictive capacity, especially on near-term timescales (daily to decadal) to make science more relevant to society. This would require both scalable community cyberinfrastructure to support near-real-time monitoring and forecasting, and education and training in predictive methods. Given the growing role of artificial intelligence and machine learning in science, data-driven analytical capacities of researchers would also need to be strengthened.

Boosting research capacity in the Global South, especially in low- and middle-income countries

Increase support for scientific research, capacities and infrastructure in the Global South

European nations are currently the major producers of research focused on the SDGs, with North America, Asia and the Pacific contributing less; while Africa, Latin America and the Arab States are smaller participants, even though the SDGs are key concerns in these regions (Institute for Scientific Information, 2019). The highly uneven global distribution of scientific capacity and knowledge production and access threatens to derail the 2030 Agenda. There is need for a major coordinated effort to make all relevant scientific knowledge accessible, especially to low- and middle-income countries, and to build knowledge societies in the longer term. The least developed countries urgently need context-specific knowledge on the SDGs. In this context, long-term sources of funding should be secured for higher education and research institutions to build local research capacities. Research and training should be particularly strengthened in relation to issues focused on sustainability. It is important to ensure that funding support for research institutions also entails their capacity to offer science advice to government, in which they are able to take account of the local context.

Enhancing digital infrastructure and improving digital connectivity access and costs in the South should be a key focus. Support for research, researchers and institutions should include lowering the costs of publishing and data deposition and access.

Increase support for international collaboration led by partners located in the South

International research collaborations are critical for countries in the South that have limited local capacities. However, many external research collaborations are inequitable, driven by external partners with their interests and perspectives. Furthermore, despite the growing interest in international research collaboration, few international research funding schemes provide opportunities for all countries to participate. Most funding flows between institutions in different high-income countries, with some directed for cooperation with African partners. Most national research funders support primarily scientists from their countries. Funding calls are often poorly publicized in the South, and rarely allow researchers from low- and middle-income countries to act as primary researchers. These researchers have little time or funding to strategically choose partners or collaborate with them. Institutions in the Global South are funded predominantly for data collection rather than research project development and implementation. The majority of funding for international collaboration is awarded in contexts which reinforce the existing bias in research systems and which do not lead to the desired long-term capacity development. There is a clear need to create mechanisms ensuring more global cooperation through equitable partnerships that enable Southern researchers to participate on a more equal basis. Researchers in the South should have a leading role in defining the research agenda. Their interests and perspectives should be fully reflected, including in how funding is distributed and how academic rewards are structured. Such collaborations should also contribute positively to enhancing local research capacities.

Advancing Open Science Globally

Promote Open Science for the achievement of the SDGs

Open Science can enhance efficiency, effectiveness and equity in science systems, thereby maximizing the public good achieved through investment in scientific efforts and infrastructure. Open access to scientific knowledge (including data upon which research conclusions are based) can enhance the efficiency of funds and time invested in research needed for social progress by enabling scientific efforts to build upon rather than duplicate previous work. It can also increase effectiveness by aligning research to issues relevant to solving societal problems, and create social buy-in for solutions developed through such science. Removal of barriers to participation in the process of science and promotion of equity and fairness in science systems is an additional goal of Open Science that is directly relevant to the SDGs, along with having implications for the relevance and impact of scientific knowledge.

Open Science can additionally be a step towards promoting collaborative approaches that are called for by the 2030 Agenda, across geographies and disciplines. The need for such concerted efforts and shared progress are becoming increasingly clear in the light of current health and environmental emergencies as well as in pursuit of other SDG goals. The Open Science concept encompasses several layers and includes open involvement in science by a diverse set of stakeholders; open access to scientific data; open access to the infrastructures that enable widespread engagement and communication; and open access to the record of science (open science publishing).

Reform publishing systems to help science better serve the public good

While the number of scientific journals and articles and the quantum of scientific knowledge generated have increased, especially with the advent of digital tools and platforms, access to this knowledge remains restricted and in the hands of commercial publishers (ISC, 2021). This is especially untenable where the research has been funded by taxpayers through universities, public science funders and other public institutions. The metrics for evaluating scientific work that influence funding decisions are currently heavily focused not on scientific merit but indirect indicators such as journal impact factors and citations, which creates an undue pressure to publish (and to do so in certain journals). This skews incentives and remains a barrier to Open Science.

Monopolistic behaviour on the part of certain publishers; the need for ensuring transparent and robust peer review; the development of digital technologies and the changes they have brought to scientific publishing; and questions of access to scientific knowledge, fairness and equity have all come to bear in an increasing demand to reform current publishing systems and move towards Open Science models.

Traditional scientific publishing business models are not conducive to Open Science. High paywalls erected by many publishers inhibit access and are highly inefficient in ensuring that scientific output is openly accessible in ways that maximize its value to science and society. In response to this, several Open Science journals, repositories and platforms have been set up to enable greater access to scientific output with different levels of openness for producers and consumers of content. This is beneficial to users as well as providers of scientific knowledge, who can reach a wider audience and contribute to the work of other researchers more easily, including those who may not have access or ability to pay high journal fees. Sticky issues including sustainable funding models, functional peer review processes and measures to maintain the quality of published work in Open Science models continue to be discussed.

Focus on the critical issues of data and infrastructure in the Open Science puzzle

Robust, transparent and accessible data are likely to be fundamental inputs to any scientific progress addressing the SDGs. The collection, sharing and use of various kinds of data that are relevant to address sustainability challenges needs to evolve. In an Open Science system, scientific data must be accessible for scrutiny and scientists should be positioned not as data owners but as data custodians on behalf of the public. This has implications for scientific practice at various stages for scientists, funders, science organizations including universities, publishers and providers of digital research infrastructure. Structures and processes that enable open data collection, curation and access will need to be supported and incentivized. For instance, funders and journals could require that science they fund or publish is linked to data stored in well-managed open repositories.

The availability of infrastructure for enabling access to and use of open data for scientific investigations across disciplines is fundamental to achieving the SDGs. Lack of investment in such infrastructure directs critical resources into data collection which is neither transparent nor accessible for re-use. There remain, however, major issues in the governance and management of scientific data and data infrastructure to be grappled with. Data repositories that are well managed and present data in an accessible and transparent way will be essential to the Open Science project. These platforms should be characterized by ease of use for both producers and users of data, and be accessible across borders and institutions (including to users in low- and middle-income countries). Clear guidelines for users and clarity on standards and processes is needed. Capacity building will be required to enable successful embedding of Open Science practices, including data management, into the conduct of science.

Ensure inclusiveness to generate SDG-relevant science

Open Science creates possibilities for previously excluded groups not only to benefit from science, but to participate in its production. This democratization of the scientific process will be essential if research efforts are to address the challenges faced by communities around the world, including the disadvantaged and vulnerable. Enhanced diversity of actors, scientific practices, output and topics along with increased engagement between science and society can expand our ways of knowing and understanding the world, increase the practical applicability of science, and foster socio-political legitimacy through jointly created knowledge.

The possibilities of engaging different stakeholders in knowledge production could range from deliberative processes for public policy development, to community engagement in data collection and knowledge production, to citizen science. Large-scale community engagement, for example, could be very useful in detailed or widespread data collection around key SDG challenges including biodiversity and climate tracking or air and water quality.

Consider equity as a crucial measure of a healthy Open Science system

Open Science has also gathered support in view of its potential to help increase the access and affordability of scientific information and to redress inequalities across geography, gender, ethnicity or capacity to pay. However, questions of equity and inclusiveness need to be actively considered in developing models, policies and structures for Open Science to ensure that the digital divide and difference in context and capacities between high- and low-income countries do not exacerbate current inequalities in practice.

Create an enabling environment, incentives and long-term investments in Open Science

Science funders will need to play a key role in promoting Open Science. They will need to create an enabling environment and apply the right pressures to push science systems to be more open in the productions and dissemination of scientific knowledge. The fact that Open Science can enhance the efficiency of science funding and increase the impact of the output created through such funding is a strong argument in favour of funders supporting these models.

Investments in infrastructure and services required for Open Science (including, but not limited to, repositories and platforms providing research products such as data or publications) remains an important enabling condition, and must be combined with the goal of such infrastructure promoting social over commercial interests. This could include support for research towards sustainable funding models for scientific publishing and data curation. Investments also need to be made in developing and promoting policies, processes and standards aimed at increasing access while maintaining the quality of scientific output.

In order to enhance uptake and address equity concerns, funders will also need to support capacity building efforts for researchers and institutions, especially in low-income countries. Other measures to ensure a level playing field could include efforts to reduce the digital divide, promote international cooperation on Open Science and increase awareness of Open Science principles and processes.

Along with the above-mentioned enabling conditions, where appropriate, funders can also require that scientific knowledge and data produced through their contributions be available openly. This will mean that rather than using the traditional metrics for evaluating scientific work (such as journal impact factor), funders will need to find alternative means of judging scientific merit in order to incentivize Open Science practices.

These measures will contribute to transforming scientific culture and aligning incentives for various actors in science systems to focus efforts on maximizing public good.

Strengthening trust in science and relevance for policy

Put far greater emphasis on science education amongst all sections of the population and on science communication

Scientific knowledge and its potential applications are often poorly understood by the general public. Insufficient understanding and appreciation of science undermines the legitimacy of science and restricts its application in policy. All scientists should be expected to engage with the public and to see themselves as advocates for science. Scientists need to see the need to move well beyond their academic audience and seek to reach as wide an audience as possible. Scientists need to change the way in which they present scientific findings. Quality science communication that reaches all socio-economic areas across the globe is key. Science needs to revolutionize the system it uses for communicating in a way that is accessible to all unfamiliar with its methods. Engagement by science and scientists needs to be very broad-based – with non-governmental, especially grassroots and youth-led, organizations; work cooperatives; start-ups; student associations; and associations of the general public. To ensure research findings are widely disseminated in accessible print and electronic media, all funded research should make provisions for communication.

Find technical and policy solutions to social media and internet driven acceptance of false information and alternative realities

These platforms are driving social division and disconnect from science and rational decision making. Scientists and the organizations of science should be supported to actively combat misinformation and false science within their domains and disciplines.

Increase the number of scientists within government and enhance transparency in respect to science advice

Governments are often inadequately informed on science and its relevance to policy. Few scientists are located in government, and levels of understanding of science on the part of policy-makers and government administrations are often inadequate. While COVID-19 has seen science and scientists become far more prominent in policy making, there have, in many instances, been tensions between scientists offering advice and policy-makers. Lack of transparency on the science advice given to government, and on government deliberations as to the application of that advice, further undermine trust in science and the efficacy of policy adopted. Therefore, it will also be critical to enhance transparency in respect to science advice as well government deliberations and treatment of such advice.

Undertake cross-country studies of institutions and practices for policy advice, generating principles to be followed that strengthen the linkages between science and policy

While there is no one best model, and every country will have its own arrangements for science advice to policy, the different approaches need to be studied and lessons learnt about the institutional arrangements most conducive to effective evidence-based policy making.

LIST OF REPORTS AND ARTICLES REVIEWED

AAS. 2020. Priority Areas of Support on Climate Change and Development in Africa: Outcome Document of the AAS Climate Change Experts Consultative Meeting.

Addison, P. F., Bull J. W., and Milner-Gulland, E. 2019. Using conservation science to advance corporate biodiversity accountability. *Conservation Biology*, Vol. 33, No. 2, pp. 307–18. https://doi.org/10.1111/cobi.13190

Adler, R., Mansi, M., and Pandey, R. 2018. Biodiversity and threatened species reporting by the top Fortune Global companies. *Accounting, Auditing & Accountability Journal*, Vol. 31, No. 3, pp. 787–825. https://doi.org/10.1108/AAAJ-03-2016-2490

Akhtar, F., and Rehmani, M. H. 2015. Energy replenishment using renewable and traditional energy resources for sustainable wireless sensor networks: A review. *Renewable and Sustainable Energy Reviews*, Vol. 45, No. C, pp. 769–84. https://doi.org/10.1016/j.rser.2015.02.021

Allen, B., and Tamindael, L. E., Bickerton, S. H., and Cho, W. 2020. Does citizen coproduction lead to better urban services in smart cities projects? An empirical study on e-participation in a mobile big data platform. *Government Information Quarterly*, Vol. 37, No. 1, p. 101412. https://doi.org/10.1016/j.giq.2019.101412

Atkins, J., Maroun, W., Atkins, B. C., and Barone, E. 2018. From the Big Five to the Big Four? Exploring extinction accounting for the rhinoceros. *Accounting, Auditing & Accountability Journal*, Vol. 31, No. 2, pp. 674–702. https://doi.org/10.1108/AAAJ-12-2015-2320

Auestad, N., and Fulgoni III, V. L. 2015. What current literature tells us about sustainable diets: emerging research linking dietary patterns, environmental sustainability, and economics. *Advances in Nutrition*, Vol. 6, No. 1, pp. 19–36. https://doi.org/10.3945/an.114.005694

Aznar-Sánchez, J. A., Piquer-Rodríguez, M., Velasco-Muñoza, J. F., and Manzano-Agugliaro, F. 2019. Worldwide research trends on sustainable land use in agriculture. *Land Use Policy,* Vol. 87, p. 104069. https://doi.org/10.1016/j.landusepol.2019.104069

Bai, X., Colbert, M., McPhearson, T., Roberts, D., Siri, J., Walsh, B., and Webb, B. 2019. Networking urban science, policy and practice for sustainability. *Current Opinion in Environmental Sustainability*, Vol. 39, pp. 114–22. https://doi.org/10.1016/j.cosust.2019.08.002

Bibri, S. E., and Krogstie, J. 2017. Smart sustainable cities of the future: an extensive interdisciplinary literature review. *Sustainable Cities and Society*, Vol. 31, pp. 183–212. https://doi.org/10.1016/j.scs.2017.02.016

Bilali, H., 2019. Research on agro-food sustainability transitions: a systematic review of research themes and an analysis of research gaps, *Journal of Cleaner Production*, 221, pp. 353–64, https://doi.org/10.1016/j.jclepro.2019.02.232

Blicharska, M., Smithers, R. J., Mikusiński, G., Rönnbäck, P., Harrison, P. A., Nilsson, M., and Sutherland, W. J. 2019. Biodiversity's contributions to sustainable development. *Nature Sustainability*, Vol. 2, No. 12, pp. 1083–93. https://dx.doi.org/10.1038/s41893-019-0417-9

Boiral, O., and Heras-Saizarbitoria, I. 2017. Managing biodiversity through stakeholder involvement: why, who, and for what initiatives? *Journal of Business Ethics*, Vol. 140, No. 3, pp. 403–21. https://doi.org/10.1007/s10551-015-2668-3

Bonilla-Bedoya, S., Mora, A., Vaca, A., Estrella, A., and Herrera, M. Á. 2020. Modelling the relationship between urban expansion processes and urban forest characteristics: an application to the Metropolitan District of Quito. *Computers, Environment and Urban Systems*, Vol. 79, p. 101420.

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., König, A., von Wehrden, H., Schäpke, N. A., Laubichler, M. D., and Lang, D. J. 2020. A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nature Sustainability*, Vol. 4, pp. 93–100. https://doi.org/10.1038/s41893-020-00616-z

Centobelli, P., Cerchione, R., and Esposito, E. 2018. Environmental sustainability and energy-efficient supply chain management: a review of research trends and proposed guidelines. *Energies*, Vol. 11, No. 2, p. 275. https://doi.org/10.3390/en11020275

Chang, R.-D., Zuo, J., Zhao, Z.-Y., Zillante, G., Gan, X.-L., and Soebarto, V. 2017. Evolving theories of sustainability and firms: history, future directions and implications for renewable energy research. *Renewable and Sustainable Energy Reviews*, Vol. 72, pp. 48–56. https://doi.org/10.1016/j.rser.2017.01.029

Chavarro, D., Tang, P., and Rafols, I. 2014. Interdisciplinarity and research on local issues: evidence from a developing country. *Research Evaluation*, Vol. 23, No. 3, pp. 195–209.

Clark, R., Reed, J., and Sunderland, T. 2018. Bridging funding gaps for climate and sustainable development: pitfalls, progress and potential of private finance. *Land Use Policy*, Vol. 71, pp. 335–46. https://doi.org/10.1016/j.landusepol.2017.12.013

Cornell, S., Berkhout, F., Tuinstra, W., Tàbara, J.D., Jäger, J., Chabay, I., de Wit, B., Langlaish, R., Mills, D., Moll, P., Otto, I. M., Petersen, A., Pohll, C., and van Kerkhoff, L. 2013. Opening up knowledge systems for better responses to global environmental change. *Environmental Science & Policy*, Vol. 28, No. 0, pp. 60–70. http://dx.doi.org/10.1016/j.envsci.2012.11.008

del Río Castro, G., Fernández, M. C. G., and Colsa, Á. U. 2020. Unleashing the convergence amid digitalization and sustainability towards pursuing the Sustainable Development Goals (SDGs): a holistic review. *Journal of Cleaner Production*, Vol. 280, p. 122204. https://doi.org/10.1016/j.jclepro.2020.122204

Delina, L. L., and Sovacool B. K. 2018. Of temporality and plurality: an epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. *Current Opinion in Environmental Sustainability*, Vol. 34, pp. 1–6. https://doi.org/10.1016/j.cosust.2018.05.016

Digital Science, 2020. *Contextualizing Sustainable Development Research*. https://doi.org/10.6084/m9._gshare.12200081

Dolšak, N., and Prakash, A. 2018. The politics of climate change adaptation. *Annual Review of Environment and Resources*, Vol. 43, pp. 317–41. https://doi.org/10.1146/annurev-environ-102017-025739

Dora, C., Haines, A., Balbus, J., Fletcher, E., Adair-Rohani, H., Alabaster, G., Hossain, R., de Onis, M., Branca, F., and Neira, M. 2015. Indicators linking health and sustainability in the post-2015 development agenda. *Lancet*, Vol. 385, pp. 380–91. https://doi.org/10.1016/S0140-6736(14)60605-X

EASAC, 2020. Towards a sustainable future: transformative change and post-COVID-19 priorities, A Perspective by EASAC's Environment Programme.

Ebi, K. L., Harris, F., Sioen, G. B., Wannous, C., Anyamba, A., Bi, P., Boeckmann, M., Bowen, K., Cissé, G., and Dasgupta, P. 2020. Transdisciplinary research priorities for human and planetary health in the context of the 2030 Agenda for Sustainable Development. *International Journal of Environmental Research and Public Health*, Vol. 17, No. 23, p. 8890. https://doi.org/10.3390/ijerph17238890

Edler, J., Cunningham, P., and Gök, A. 2016. *Handbook of Innovation Policy Impact*, Edward Elgar Publishing.

Ehrensperger, A., de Bremond, A. Providoli, I., and Messerli, P. 2019. Land system science and the 2030 agenda: exploring knowledge that supports sustainability transformation. *Current Opinion in Environmental Sustainability*, Vol. 38, pp. 68–76, https://doi.org/10.1016/j.cosust.2019.04.006

Enfors, E. 2013. Social–ecological traps and transformations in dryland agro-ecosystems: using water system innovations to change the trajectory of development. *Global Environmental Change*, Vol. 23, No. 1, pp. 51–60. https://doi.org/10.1016/j.gloenvcha.2012.10.007

European Climate Foundation. 2018. NET ZERO BY 2050: zero emissions pathways to the Europe we want.

Fauzi, R. T., Lavoie, P., Sorelli, L., Heidari, M. D., and Amor, B. 2019. Exploring the current challenges and opportunities of life cycle sustainability assessment. *Sustainability*, Vol. 11, No. 3, p. 636. https://doi.org/10.3390/su11030636

Fazey, I., Moug, P., Allen, S., Beckmann, K., Blackwood, D., Bonaventura, M., Burnett, K., Danson, M., Falconer, R., and Gagnon, A. S. 2018. Transformation in a changing climate: a research agenda. *Climate and Development*, Vol. 10, No. 3, pp. 197–217. https://doi.org/10.1080/17565529.2017.1301864

Fazey, I., Schäpke, N. et al. 2020. Transforming knowledge systems for life on Earth: visions of future systems and how to get there. *Energy Research & Social Science*, Vol. 70, p. 101724. https://doi.org/10.1016/j.erss.2020.101724

Fedele, G., Donatti, C. I., Harvey, C. A., Hannah, L., and Hole, D. G. 2019. Transformative adaptation to climate change for sustainable social-ecological systems. *Environmental Science & Policy*, Vol. 101, pp. 116–25. https://doi.org/10.1016/j.envsci.2019.07.001

Feola, G. 2015. Societal transformation in response to global environmental change: a review of emerging concepts. *Ambio*, Vol. 44, No. 5, pp. 376–90. https://doi.org/10.1007/s13280-014-0582-z

Foran, J. 2019. System change, not climate change: radical social transformation in the twenty-first century. in *The Palgrave Handbook of Social Movements, Revolution, and Social Transformation*, Berch Berberoglu, Switzerland, Springer, pp. 399–425.

Frank, A. S., and Schäffler, L. 2019. Identifying key knowledge gaps to better protect biodiversity and simultaneously secure livelihoods in a priority conservation area. *Sustainability*, Vol. 11, No. 20, p. 5695. https://doi.org/10.3390/su11205695

Frank, B., and Kalfagianni, A. 2020. Planetary justice: a research framework, *Earth System Governance*, Vol. 6, p. 100049. https://doi.org/10.1016/j.esg.2020.100049

Frantzeskaki, N., and Rok, A. 2018. Co-producing urban sustainability transitions knowledge with community, policy and science, *Environmental Innovation and Societal Transitions*, Vol. 29, pp. 47–51. https://doi.org/10.1016/j.eist.2018.08.001

Furstenau, L. B., Sott, M. K., Kipper, L. M., Machado, E. L., Lopez-Robles, J. R., Dohan, M. S., Cobo, M. J., Zahid, A., Abbasi, Q. H., and Imran, M. A. 2020. Link between sustainability and industry 4.0: trends, challenges and new perspectives. *IEEE Access*, Vol. 8, pp. 140079–96. https://doi.org/10.1109/ACCESS.2020.3012812

Future Earth. 2020. Digital disruptions for sustainability: managing the digital age is a climate issue.

Garcia-Llorente, M., Rubio-Olivar, R., and Gutierrez-Briceno, I. 2018. Farming for life quality and sustainability: a literature review of green care research trends in Europe. *International Journal of Environmental Research and Public Health*, Vol. 15, No. 6, p. 1282. https://doi.org/10.3390/ijerph15061282

Giles-Corti, B., Lowe, M., and Arundel, J. 2020. Achieving the SDGs: evaluating indicators to be used to benchmark and monitor progress towards creating healthy and sustainable cities. *Health Policy*, Vol. 124, No. 6, pp. 581–90. https://doi.org/10.1016/j.healthpol.2019.03.001

Glandon, D., Meghani, A., Jessani, N., Qiu, M., and Bennett, S. 2018. Identifying health policy and systems research priorities on multisectoral collaboration for health in low-income and middle-income countries. *BMJ Global Health*, Vol. 3, p. e000970.

Gluckman, P., and Hanson, M. 2006. *Mismatch: Why Our World no Longer Fits our Bodies*, 1st ed, Oxford, Oxford University Press.

Gordon, D. J., and Johnson, C. A. 2018. City-networks, global climate governance, and the road to 1.5°C. *Current Opinion in Environmental Sustainability*, Vol. 30, pp. 35–41. https://doi.org/10.1016/j.cosust.2018.02.011

Haberl, H., Wiedenhofer, D., Pauliuk, S., Krausmann, F., Müller, D. B., and Fischer-Kowalski, M. 2019. Contributions of sociometabolic research to sustainability science. *Nature Sustainability*, Vol. 2, No. 3, pp. 173–84. https://doi.org/10.1038/s41893-019-0225-2

Hassan, A. M., Roberts, L., and Atkins, J. 2020. Exploring factors relating to extinction disclosures: what motivates companies to report on biodiversity and species protection? *Business Strategy and the Environment*, Vol. 29, No. 3, pp. 1419–36.

Hossain, M. U., Ng, S. T., Antwi-Afari, P., and Amor, B. 2020. Circular economy and the construction industry: Existing trends, challenges and prospective framework for sustainable construction. *Renewable and Sustainable Energy Reviews*, Vol. 130, p. 109948. https://doi.org/10.1016/j.rser.2020.109948

Hu, X., and Chong, H.-Y. 2019. Environmental sustainability of off-site manufacturing: a literature review. *Engineering, Construction and Architectural Management*, Vol. 28, No. 1, pp. 332–50, https://doi.org/10.1108/ecam-06-2019-0288

Hynes, W., Lees, M., Müller, J. M. 2020. *Systemic Thinking for Policy Making: The Potential of Systems Analysis for Addressing Global Policy Challenges in the 21st Century*. Paris, France, OECD Publishing. https://doi.org/10.1787/879c4f7a-en

Institute for Scientific Information. 2019. Navigating the Structure of Research on Sustainable Development Goals.

International Science Council. 2020. *Conversations on Rethinking Human Development*, International Science Council, Paris.

International Science Council. 2020. Open Science for the 21st Century, Draft ISC Working Paper.

International Science Council. 2021. *Opening the record of science: making scholarly publishing work for science in the digital era*. Paris, France, International Science Council. https://doi.org/10.24948/2021.01

IPBES. 2019. Summary for policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Chapter 5. Pathways towards a Sustainable Future.

Kabisch, S., Finnveden, G., Kratochvil, P., Sendi, R., Smagacz-Poziemska, M., Matos, R., and Bylund, J. 2019. New Urban Transitions towards Sustainability: Addressing SDG Challenges (Research and Implementation Tasks and Topics from the Perspective of the Scientific Advisory Board (SAB) of the Joint Programming Initiative (JPI) Urban Europe). *Sustainability*, Vol. 11, No. 8, p. 2242. https://doi.org/10.3390/su11082242

Köhler, F., Geels, W. et al. 2019. An agenda for sustainability transitions research: state of the art and future directions, *Environmental Innovation and Societal Transitions*, Vol. 31, pp. 1–32. https://doi.org/10.1016/j.eist.2019.01.004

Lange Salvia, A., Leal Filho, M., Londero Brandli, L., and Sapper Griebeler, J. 2019. Assessing research trends related to Sustainable Development Goals: local and global issues, *Journal of Cleaner Production*, Vol. 208, pp. 841–49, https://doi.org/10.1016/j.jclepro.2018.09.242

Le Gal, E. 2016. Exploring new research directions for achieving a sustainable future: what can be learned from the biofuel weed risk case study? *Asia Pacific Journal of Environmental Law*, Vol. 19, No. 1, pp. 55–78.

Lee, H.-T., Song, J.-H., Min, S.-H., Lee, H.-S., Song, K. Y., Chu, C. N., and Ahn, S.-H. 2019. Research trends in sustainable manufacturing: a review and future perspective based on research databases. *International Journal of Precision Engineering and Manufacturing-Green Technology*, Vol. 6, No. 4, pp. 809–19. https://doi.org/10.1007/s40684-019-00113-5

Li, Y., Yang, J., and Song, J. 2017. Design structure model and renewable energy technology for rechargeable battery towards greener and more sustainable electric vehicle. *Renewable and Sustainable Energy Reviews*, Vol. 74, pp. 19–25. https://doi.org/10.1016/j.rser.2017.02.021

Mastrángelo, M.E., Pérez-Harguindeguy, N., Enrico, L. et al. 2019. Key knowledge gaps to achieve global sustainability goals. *Nature Sustainability*, Vol. 2, pp. 1115–21. https://doi.org/10.1038/s41893-019-0412-1

Mayhew, S. H., Newman, K., Johnson, D., Clark, E., Hammer, M., Mohan, V., and Ssali, S. 2020. New partnerships, new perspectives: the relevance of sexual and reproductive health and rights for sustainable development. *Health Policy*, Vol. 124, No. 6, pp. 599–604. https://doi.org/10.1016/j.healthpol.2019.03.010

McElwee, P., Turnout, E., Chiroleu-Assouline, M., Clapp, J., Isenhour, C., Jackson, T., Kelemen, E., Miller, D. C., Rusch, G., and Spangenberg, J. H. 2020. Ensuring a post-COVID economic agenda tackles global biodiversity loss. *One Earth* 3 (4). https://doi.org/10.1016/j.oneear.2020.09.011

Mechler, R., Stevance, A.-S., et al., 2021. *Transformations within reach: Pathways to a sustainable and resilient world - Enhancing Governance for Sustainability*. IIASA Report. IIASA-ISC.

Mulatu, K. A., Mora, B., Kooistra, L., and Herold, M. 2017. Biodiversity monitoring in changing tropical forests: a review of approaches and new opportunities. *Remote Sensing*, Vol. 9, No. 10, p. 1059. https://doi.org/10.3390/rs9101059

Næss, P. 2016. Built environment, causality and urban planning. *Planning Theory & Practice*, Vol. 17, No. 1, pp. 52–71. https://doi.org/10.1080/14649357.2015.1127994

Nagendra, H., Bai, X., Brondizio, E. S. et al. 2018. The urban south and the predicament of global sustainability. *Nature Sustainability*, Vol. 1, pp. 341–49. https://doi.org/10.1038/s41893-018-0101-5

Neeff, T., and Piazza, M. 2020. How countries link forest monitoring into policy-making. *Forest Policy and Economics*, Vol. 118, p. 102248. https://doi.org/10.1016/j.forpol.2020.102248

Nielsen, J., and Farrelly, M. A. 2019. Conceptualising the built environment to inform sustainable urban transitions. *Environmental Innovation and Societal Transitions*, Vol. 33, pp. 231–48. https://doi.org/10.1016/j.eist.2019.07.001

Nielsen, U. N., Stafford-Smith, M., Metternicht, G. I., Ash, A., Baumber, A., Boer, M. M., Booth, S., Burnside, D., Churchill, A. C., and El Hassan, M. 2020. Challenges, solutions and research priorities for sustainable rangelands. *The Rangeland Journal*, Vol. 42, No. 5, pp. 359–73. https://doi.org/10.1071/RJ20059

Nowotny, H., Scott, P. B., and Gibbons, M. T. 2013. *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty*, Oxford, John Wiley & Sons.

O'Brien, K. 2016. Climate change and social transformations: is it time for a quantum leap? *WIREs Climate Change*, Vol. 7, pp. 618–26. https://doi.org/10.1002/wcc.413

Overland, I., and Sovacool, B. K. 2020. The misallocation of climate research funding. *Energy Research & Social Science*, Vol. 62, 101349, pp. 1–13, https://ssrn.com/abstract=3514503

Pauliuk, S. 2020. Making sustainability science a cumulative effort. *Nature Sustainability*, Vol. 3, pp. 2–4. https://doi.org/10.1038/s41893-019-0443-7

Pelling, M., Leck, H., Pasquini, L., Ajibade, I., Osuteye, E., Parnell, S., Lwasa, S., Johnson, C., Fraser, A., and Barcena, A. 2018. Africa's urban adaptation transition under a 1.5 climate. *Current Opinion in Environmental Sustainability*, Vol. 31, pp. 10–5. https://doi.org/10.1016/j.cosust.2017.11.005

Phelps, D., and Kelly, D. 2020. A call for collaboration: linking local and non-local rangeland communities to build resilience. *The Rangeland Journal*, Vol. 42, No. 5, pp. 265–75. https://doi.org/10.1071/RJ20048

Pitasi, A., Brasil Dib, N., and Portolese, G. 2018. Legislative innovation. Towards a global law. Making process: the case of global citizenship policy modelling. *International Review of Sociology*, Vol. 28, No. 3, pp. 392–402. https://doi.org/10.1080/03906701.2018.1529102

Prieur-Richard, A-H., Brenna., W. et al. 2019. Global Research and Action Agenda on Cities and Climate Change Science - Full Version.

Rafique, S. F., Shen, P., Wang, Z., Rafique, R., Iqbal, T., Ijaz, S., and Javaid, U. 2018. Global power grid interconnection for sustainable growth: concept, project and research direction. I*ET Generation, Transmission & Distribution*, Vol. 12, No. 13, pp. 3114–23.

Ramankutty, N., and Coomes, O. T. 2016. Land-use regime shifts: an analytical framework and agenda for future land-use research. *Ecology and Society*, Vol. 21, No. 2, p. 1. http://dx.doi.org/10.5751/ES-08370-210201

Randers, J., Rockström, J., Stoknes, P.E., Golüke, U., Collste, D., and Cornell, S. A. 2018. Transformation is feasible: How to achieve the sustainable development goals within planetary boundaries. A report to the Club of Rome from Stockholm Resilience Centre and BI Norwegian Business School

Reade, C., Thorp, R., Goka, K., Wasbauer, M., and McKenna, M. 2015. Invisible compromises: global business, local ecosystems, and the commercial bumble bee trade. *Organization & Environment*, Vol. 28, No. 4, pp. 436–57.

Ren, R., Hu, W., Dong, J., Sun, B., Chen, Y., and Chen, Z. 2020. A systematic literature review of green and sustainable logistics: bibliometric analysis, research trend and knowledge taxonomy. *International Journal of Environmental Research and Public Health*, Vol. 17, No. 1, p. 261. https://doi.org/10.3390/ijerph17010261

Roberts, L., Hassan, A., Elamer, A., and Nandy, M. 2021. Biodiversity and extinction accounting for sustainable development: a systematic literature review and future research directions. *Business Strategy and the Environment*, Vol. 30, No. 1, pp. 705–20. https://doi.org/10.1002/bse.2649

Rogge, N., Theesfeld, I., and Strassner, C. 2020. The potential of social learning in community gardens and the impact of community heterogeneity. *Learning, Culture and Social Interaction*, Vol. 24, p. 100351.

Rovenskaya, E., Kaplan, D., and Sizov, S. 2021. *Transformations within reach: Pathways to a sustainable and resilient world - Strengthening Science Systems*. IIASA Report. IIASA-ISC.

Rozhenkova, V., Allmang, S., Ly, S., Franken, D., and Heymann, J. 2019. The role of comparative city policy data in assessing progress toward the urban SDG targets. *Cities*, Vol. 95, p. 102357. https://doi.org/10.1016/j.cities.2019.05.026

S20. 2020. Foresight: Science for Navigating Critical Transitions.

Sachs, J.D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., and Rockström, J. 2019. Six Transformations to achieve the Sustainable Development Goals. *Nature Sustainability*, Vol. 2, pp. 805–14. https://doi.org/10.1038/s41893-019-0352-9

Schindler, S., Mitlin, D., and Marvin, S. 2018. National urban policy making and its potential for sustainable urbanism. *Current Opinion in Environmental Sustainability*, Vol. 34, pp. 48–53. https://doi.org/10.1016/j.cosust.2018.11.006

Schneider, F., Kläy, A., Zimmermann, A.B., Buser, T., Ingalls, M., and Messerli, P. 2019. How can science support the 2030 Agenda for Sustainable Development? Four tasks to tackle the normative dimension of sustainability. *Sustainability Science*, Vol. 14, pp. 1593–1604. https://doi.org/10.1007/s11625-019-00675-y

Schot, J., and Steinmueller, W. E. 2018. Three frames for innovation policy: R&D, systems of innovation and transformative change. *Research Policy*, Vol. 47, No. 9, pp. 1554–67. https://doi.org/10.1016/j.respol.2018.08.011

Shibin, K., Gunasekaran, A., Papadopoulos, T., Dubey, R., and Mishra, D. 2016. Sustainable consumption and production: need, challenges and further research directions. *International Journal of Process Management and Benchmarking*, Vol. 6, No. 4, pp. 447–68. https://doi.org/10.1504/IJPMB.2016.079678

Shrivastava, P., Stafford Smith, M., O'Brien, K., and Zsolnai, L. 2020. Transforming Sustainability Science to Generate Positive Social and Environmental Change Globally. *One Earth*, Vol. 2, No. 4, pp. 329–40.

Silva, S., and Guenther, E. 2018. Setting the research agenda for measuring sustainability performance–systematic application of the World Café Method. *Sustainability Accounting, Management and Policy Journal*, Vol. 9, No. 4, pp. 455–69. https://doi.org/10.1108/SAMPJ-06-2017-0060

Sperling, F., Havlik, P., Denis, M., Valin, H., Palazzo, A., Gaupp, F., and Visconti, P. 2020. *Transformations within reach: Pathways to a sustainable and resilient world - Resilient Food Systems*. IIASA Report. IIASA-ISC.

Srivastava, L., Gomez Echeverri, L., and Schlegel, F. 2021. *Transformations Within Reach: Pathways to a Sustainable and Resilient World - Synthesis Report*. Laxenburg, Austria, IIASA and ISC.

Timko, J., Le Billon, P., Zerriffi, H., Honey-Rosés, J., de la Roche, I., Gaston, C., Sunderland, T. C., and Kozak, R. A. 2018. A policy nexus approach to forests and the SDGs: tradeoffs and synergies. *Current Opinion in Environmental Sustainability*, Vol. 34, pp. 7–12. https://doi.org/10.1016/j.cosust.2018.06.004

Tortajada, C., and Biswas, A. K. 2018. Achieving universal access to clean water and sanitation in an era of water scarcity: strengthening contributions from academia. *Current Opinion in Environmental Sustainability*, Vol. 34, pp. 21–5. https://doi.org/10.1016/j.cosust.2018.08.001

Trutnevyte, E., Hirt, L. F., Bauer, N., Cherp, A., Hawkes, A., Edelenbosch, O. Y., Pedde, S., and van Vuuren, D. P. 2019. Societal transformations in models for energy and climate policy: the ambitious next step. *One Earth*, Vol. 1, No. 4, pp. 423–33. https://doi.org/10.1016/j.oneear.2019.12.002

Turner, C., Aggarwal, A., Walls, H., Herforth, A., Drewnowski, A., Coates, J., Kalamatianou, S., and Kadiyala, S. 2018. Concepts and critical perspectives for food environment research: a global framework with implications for action in low- and middle-income countries. *Global Food Security*, 18, pp. 93–101, https://doi.org/10.1016/j.gfs.2018.08.003

TWI2050 - The World in 2050. 2018. Transformations to achieve the Sustainable Development Goals. Report prepared by the World in 2050 initiative. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.

TWI2050 - The World in 2050. 2019. The digital revolution and sustainable development: opportunities and challenges. Report prepared by the World in 2050 initiative. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria. Available at www.twi2050.org.

Uchiyama, C., Stevenson, L. A., and Tandoko, E. 2020. Climate change research in Asia: a knowledge synthesis of Asia-Pacific Network for Global Change Research (2013–2018). *Environmental Research*, Vol. 188, p. 109635. https://doi.org/10.1016/j.envres.2020.109635

UN GSDR. 2019. Independent Group of Scientists appointed by the Secretary-General, *Global Sustainable Development Report 2019: The Future is Now – Science for Achieving Sustainable Development*, United Nations, New York.

UN. 2020. UN Research Roadmap for the COVID-19 Recovery.

UNDP. 2020. Human Development Report 2020. The Next Frontier: Human Development and the Anthropocene.

UNEP. 2021. Making peace with nature: a scientific blueprint to tackle the climate, biodiversity and pollution emergencies. Nairobi. https://www.unep.org/resources/making-peace-nature

Van Bers, C., Delaney, A., Eakin, H., Cramer, L., Purdon, M., Oberlack, C., Evans, T., Pahl-Wostl, C., Eriksen, S., Jones, L., Korhonen-Kurki, K., and Vasileiou, I. 2019. Advancing the research agenda on food systems governance and transformation. *Current Opinion in Environmental Sustainability* Vol. 39, 94–102. https://doi.org/10.1016/j.cosust.2019.08.003

Van Hoof, L., Fabi, G., Johansen, V., Steenbergen, J., Irigoiene, X., Smith, S., Lisbjerg, D., and Kraush, G. 2019. Food from the ocean; towards a research agenda for sustainable use of our oceans' natural resources. Marine Policy, 105, pp. 44–51. https://doi.org/10.1016/j.marpol.2019.02.046

Visbeck, M. 2018. Ocean science research is key for a sustainable future. *Nature Communications*, Vol. 9, p. 690. https://doi.org/10.1038/s41467-018-03158-3

WEF. 2020. The 2020 Global Risks Report.

WEF. 2020. The Future of Nature and Business.

Wolfram, M., and Frantzeskaki N. 2016. Cities and systemic change for sustainability: prevailing epistemologies and an emerging research agenda. *Sustainability*, Vol. 8, No. 2, p. 144. https://doi.org/10.3390/su8020144

Wyborn, C., Montana, J. et al. 2020. Research and action agenda for sustaining diverse and just futures for life on Earth. Biodiversity Revisited. https://doi.org/10.13140/RG.2.2.12086.52804/2

Yegros-Yegros, A., Rafols, I., and D'este, P. 2015. Does interdisciplinary research lead to higher citation impact? The different effect of proximal and distal interdisciplinarity. *PloS One*, Vol. 10, No. 8, p. e0135095. https://doi.org/10.1371/journal.pone.0135095

Zahraee, S. M., Shiwakoti, N., and Stasinopoulos, P. 2020. Biomass supply chain environmental and socio-economic analysis: 40-years comprehensive review of methods, decision issues, sustainability challenges, and the way forward. *Biomass and Bioenergy*, Vol. 142, p. 105777. https://doi.org/10.1016/j.biombioe.2020.105777

Zakeri, B., Paulavets, K., et al. 2021. *Transformations within reach: Pathways to a sustainable and resilient world - Rethinking energy solutions*. IIASA Report. IIASA-ISC.

Zhao, X., Ke, Y., Zuo, J., Xiong, W., and Wu, P. 2020. Evaluation of sustainable transport research in 2000–2019. *Journal of Cleaner Production*, Vol. 256, p. 120404. https://doi.org/10.1016/j.jclepro.2020.120404

Zierhofer, W., and Burger, P. 2007. Disentangling transdisciplinarity: an analysis of knowledge integration in problem-oriented research. *Science & Technology Studies* Vol. 20, No. 1, pp. 50–72. https://doi.org/10.23987/sts.55219

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