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Designing for Action: Principles of Effective Sustainability Measurement

Designing for Action: Principles of Effective Sustainability Measurement

Summary Report Prepared by the Commonwealth Scientific and Industrial Research Organization for the World Economic Forum Global Agenda Council on Measuring Sustainability

Authors: Deborah O'Connell, John Raison, Steve Hatfield-Dodds, Andrew Braid, Annette Cowie, Anna Littleboy, Thomas Wiedmann, Megan Clark

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Marc Levy
Deputy Director, Center for International Earth Science Information Network (CIESIN), Columbia University; Chair of the Global Agenda Council on Measuring Sustainability

James Cameron
Chairman, Climate Change Capital; Vice-Chair of the Global Agenda Council on Measuring Sustainability

Juan Carlos Castilla-Rubio
Chief Executive Officer, Planetary Skin Institute; Vice-Chair of the Global Agenda Council on Measuring Sustainability

Interest in sustainability is at an all-time high. This transformation has been brought about by two linked dynamics. First, high-profile challenges have driven home with sharp clarity that failure to achieve sustainability threatens all policy and business spheres, not merely the environment. The 2008 collapse of financial markets, the contagion of political crises linked to the Arab Spring, high volatility in energy and food markets, the increased impact and frequency of natural disasters, and the emergence of new diseases such as SARS, among other examples, have contributed to a dramatic convergence of views that sustainability is a pervasive challenge. Second, whereas sustainability was initially greeted as a threat to conventional public goals of growth, security and equity, and therefore deliberately shunted to the margins, today it is seen as both integrally supporting and essential to these objectives.

In short, sustainability is a permanent part of the decision-making landscape for communities, for policy-makers and for businesses – a defining feature of our age. As a result, more robust, operational approaches to measurement are called for so that mankind can manage sustainable pathways. Past efforts can provide valuable lessons to guide future metrics, but fundamental change is required. The traditional focal areas of sustainability – environmental degradation, resource scarcity, climate change, biodiversity loss, etc. – have escalated to alarming levels. An effective global strategy for measuring sustainability must not only respond to these environmental challenges but must also be able to provide evidence-based guidance to other more established economic and social agendas in an integrated manner.

We are committed to helping advance such a strategy and commissioned this Report as a key element of our work. In this Report, the Commonwealth Scientific and Industrial Research Organization (CSIRO) from Australia has documented the evolution in thinking about how to measure sustainability, and distilled crucial lessons for moving forward. Among some of the key conclusions we have drawn are the following:

- Sustainability metrics must be jointly produced by experts, users and systems designers, not in isolation. To embed metrics and decision support capabilities in living, breathing processes, communities of practice that share this goal and span relevant perspectives must be nurtured. When this is done well, measurement processes engender new, effective waves of participation across broad segments of society.
- We care about the healthy functioning of complex systems, and therefore our metrics must characterize systems function. In some cases, acting on this insight requires fundamentally new approaches; it is not easy but nothing short will suffice.
- One size will not fit all. For example, in some cases, there is plenty of useful information, it just needs to be

integrated, organized, transformed and made usable for a specific context and challenge; in others, new measurement streams must be developed. Metrics must be designed with a careful eye towards fitness for use.
- We live in a post-silo world. All the systems we care about, whether bounded by geography, sector or stakeholder, have major linkages to other systems. No system can manage its risks on its own; therefore sustainability metrics must be embedded in a broader networked ecosystem that permits transparent visualization of the interlinked risks and supports intelligent decision-making and joint management.

We conclude with a final observation: now is the time to think boldly. Technology is opening revolutionary possibilities (e.g. big data, Internet of things, mobility, etc). Emerging experiments in institutional forms are showcasing a new range of options for providing public goods effectively and efficiently. We must not be afraid to chart new ground.

Key Messages

1. *Sustainability measurement systems are effective when they are embedded firmly in management and decision-making processes that promote learning.*

Measurement has a crucial role, but is not sufficient. The need for improved information and understanding motivates and guides changes in practices and behaviour. Measurements need to be interpreted to be useful, and must be linked with evaluation and an iterative process of learning and acting. In particular, four key building blocks as essential:

- *Institutional mechanisms:* the formal and informal rules that provide the governance, oversight and stability necessary to implement the sustainability framework
- *Data & analytics – specification, collection, analysis and the use of projections:* data, which can consist of measurements, modelled interpolations or projections, used as the basis for evaluation
- *Evaluation:* interpreting the meaning or value of the data in relation to agreed sustainability objectives
- *Feedback:* the flow of information or action between components of the framework, including to catalyse changes that promote sustainability

To be effective in achieving sustainability, these four elements need to be addressed and linked across a range of scales. Greater availability of data will only be effective for sustainability if it is used within such an approach.

Recognizing the four building blocks of sustainability assessment can help identify the strengths and weaknesses of different tools, and ensure that approaches are used in ways that are fit for purpose. No single tool can meet every need across all scales, issues and applications.

2. *There are many approaches to assessing sustainability and the field is evolving rapidly. Current thinking identifies characterizing the functioning of physical, ecological and social systems that support human life, and the interaction of these systems, as especially important.*

The understanding and practice of sustainability have flourished over the two decades since the Rio Earth Summit in 1992. Many insights from the first decade have been translated into tools and approaches for policy-makers, businesses and other decision-makers. The science of sustainability has continued to develop in the second decade, often in response to weaknesses or gaps in the earlier concepts and analysis. More recent contributions are recognized by business and policy, but tools and implementation pathways are not yet mature.

Different approaches to assessing and implementing sustainability have different strengths, weaknesses and contributions. The diversity of these approaches can be confusing.

Sustainable development and sustainability mean different things to different people, and across different contexts. This means that creating workable operational tools for assessing and promoting sustainability will always require judgements that are subject to legitimate debate. Even with widely well-accepted definitions for sustainability and sustainable development, the central questions of "sustaining what, for whom, where, and for how long?" remain laden with human values and social choices. These questions are therefore very context-specific, differing across time, space and cultures.

Contemporary thinking, summarized in this Report, recognizes that social-ecological systems are complex and highly dynamic, are often under increasing interacting pressures and are undergoing rapid change. This is placing stress on the minimum level of ecosystem functions needed to underpin human well-being in the future. In some cases social and economic capacity to maintain future well-being is also under threat.

3. *Ultimately, sustainability can only be achieved on a global scale, across all sectors, over very long time frames. But it is important to recognize progress towards this ultimate goal.*

It is useful to distinguish between supportive, necessary and sufficient conditions for achieving sustainability:

- Raising awareness of sustainability issues, engaging decision-makers and improving the information available are typical supportive actions, making it more likely that products and practices will be increasingly sustainable.
- Building this information into decision processes, strengthening organizational incentives and addressing barriers to sustainability are necessary steps towards achieving sustainability, but may not – of themselves – be sufficient to achieve sustainable products and processes.
- Establishing cradle-to-grave stewardship arrangements that have low or zero environmental impacts while also making positive contributions to stakeholder well-being and living standards can be considered sustainable within a domain.

All steps towards sustainability should be rewarded because they help build momentum and the appetite to take harder necessary steps towards sustainability. But care should be taken not to over-state or over-claim what has been achieved, as this may reduce support for further action.

4. *The next phase of this project will develop guidance to simplify choosing the right assessment approaches for different purposes, and to make their use more effective in promoting sustainability.*

This phase will be developed through collaboration between member institutions of the Global Agenda Council on Measuring Sustainability, the CSIRO and other partners.

Introduction

More than two decades after the Rio Earth Summit, the world is far from being on track to a more sustainable future. Accelerating greenhouse gas emissions, changes to our oceans and climate change, increasing frequency and impact of weather extremes, declining biodiversity and ecosystem health, and sharp tensions between food, energy and climate security have brought a renewed focus to the need for practical tools and actions to achieve sustainable development.

There is also a growing realization that improving the sustainability performance of businesses can reduce risk and improve traditional wealth creation. Attention to the triple bottom line improves the financial bottom line. Creating durable global value for stakeholders can also create durable value for shareholders. Perhaps more fundamentally, sustainability cannot be achieved without business taking a more active role.

Ironically, the sustainability science and assessment tools that underpin these efforts are multiplying and evolving rapidly. The diversity of these approaches can be very confusing.

This paper provides a summary of a more detailed full Report commissioned by the World Economic Forum Global Agenda Council on Measuring Sustainability. Its purpose is to provide a framework and guide for people engaging with the complex and evolving sustainability literature and the development and application of sustainability assessment tools.

It is crucial to recognize that “measuring sustainability” is necessary but not sufficient for achieving sustainability. Improved information and understanding is needed to motivate and guide changes in practices and behaviour. As a result, sustainability assessment will be most effective when measurement and evaluation are understood as part of a wider iterative process of learning and acting.

The first section of the Report thus identifies four key building blocks of effective sustainability assessment, and proposes a framework for how these fit together, based on the review of a wide range of literature. The four building blocks are (i) institutional mechanisms, (ii) data & analytics, (iii) evaluation, and (iv) the feedback between these. The Report argues that sustainability assessment will be most effective when all four elements are addressed and linked across a range of scales and issues. Recognizing the four building blocks of sustainability assessment can help identify the strengths and weaknesses of different tools and ensure that approaches are used in ways that are fit for purpose. No single tool can meet every need across all scales, issues and applications. The section concludes that sustainability can only ultimately be achieved on a global scale, across all sectors, over very long time frames – but that it is important to recognize progress towards this ultimate goal.

In an appendix, the Report provides an overview of how sustainability science and measurement has developed over the last two decades, including a summary of the major approaches to sustainability assessment and their strengths, weaknesses and distinctive contributions. It finds that sustainability science has flourished over recent years. Many insights from the decade after the Rio Earth Summit have been translated into tools and approaches for policy-makers, businesses and other decision-makers. Eight broad types of assessment approaches are identified (summarized in Table 1 in the Appendix). The science has continued to develop – often in response to weaknesses or gaps in the earlier thinking – and four emergent themes in the more recent literature are identified (summarized in Table 2 in the Appendix). These more recent developments have generally not yet been translated into practical assessment tools and implementation frameworks.

This summary Report is intended to provide an overview of the major insights and content of the full Report. Some issues – such as case studies of sustainability assessment in specific sectors – are not covered at all, and more technical users are encouraged to look at the full Report:

Navigating Sustainability: Measurement, Evaluation and Action
www.csiro.au/measuring-sustainability

The next phase of this project will focus on developing more detailed guidance to simplify choosing the right assessment approaches for different purposes and to make their use more effective in promoting sustainability. This will be developed through collaboration between members of the Global Agenda Council on Measuring Sustainability, the CSIRO and other partners.

For more information please see the contact details on the back cover of this Report.

Please refer to the last page for a full list of Members of the Global Agenda Council on Measuring Sustainability.

A General Framework for Implementing and Assessing Sustainability across Scales

A key argument of this Report is that measurement and evaluation have crucial roles in promoting sustainability, but are not – of themselves – sufficient to achieve sustainability. Improved information and understanding needs motivate and guide changes in practices and behaviour. This requires linkages from data and evaluation to decision-making and action, and back again.

This implies that measuring sustainability will be most effective when measurement and evaluation are understood as part of a wider iterative process of learning and acting.

Many attempts have been made to define sustainability over the past 25 years. In this Report, a broad definition is used in the tradition of the 1987 report by the UN World Commission on Environment and Development, defining sustainability and sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This embraces the central notions of the planet and its people enduring in perpetuity, while maintaining human health, prosperity and well-being. This is commonly translated into a concept of three interdependent "pillars" of sustainability, maintaining environmental, social and economic health.

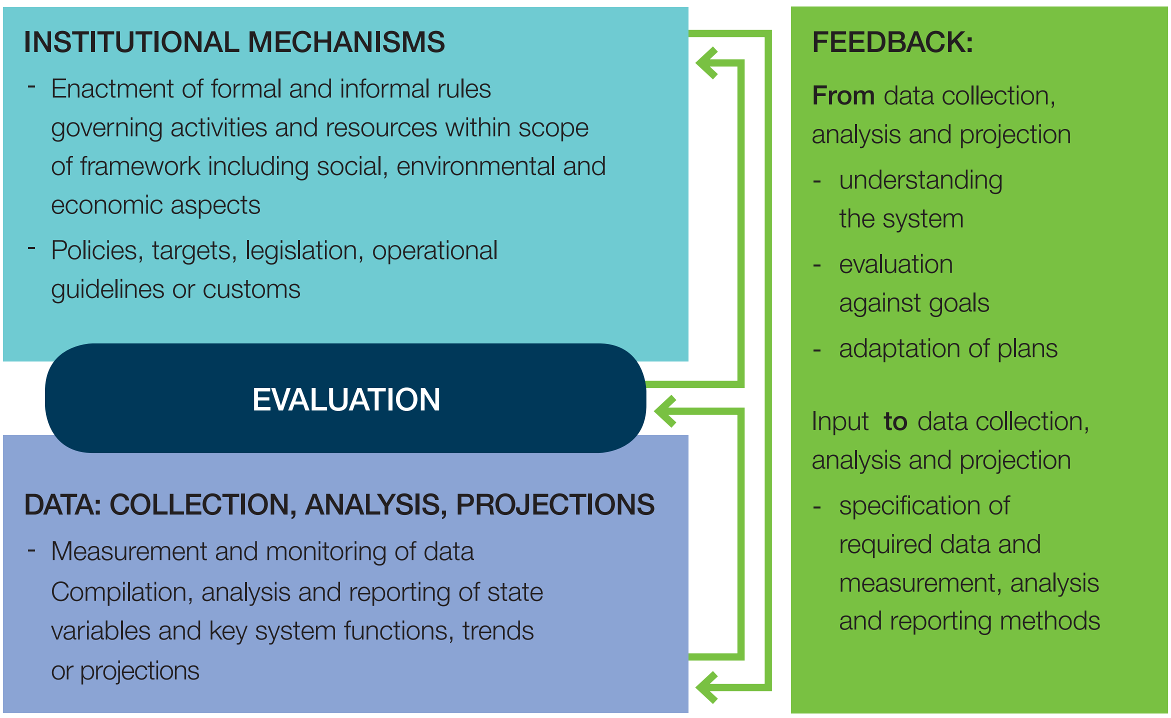
Within the use of these well-accepted definitions of sustainability and sustainable development, answers to the central questions of "sustaining what, for whom, where and for how long?" largely reflect human values and social choices, which are context-specific and therefore differ across time, space and cultures. Addressing these questions requires methods and fora for negotiation. It also relies on knowledge about the future, which is unavoidably uncertain, with many types of unknowns. Therefore, translating definitions for sustainability and sustainable development into practice and the assessment of outcomes is challenging and continues to evolve.

Taking a System Perspective

Based on the review of a broad range of literature and approaches (see the full Report), a "sustainability framework" (Figure 1) comprised of four generic or universal building blocks is proposed:

- **Institutional mechanisms:** the formal and informal rules that provide the governance, oversight and stability necessary to implement the sustainability framework
  The critical elements of stakeholder consultation, goal setting, review, adaptation and compliance are included in the institutional mechanisms.
- **Data & analytics – specification, collection, analysis and the use of projections:** data, which can consist of measurements, modelled interpolations or projections, used as the basis for evaluation
  Data can be analysed to understand and report the key system variables, functions, trends and projections within the context of the given purpose.
- **Evaluation:** interpreting the meaning or value of the data in relation to agreed sustainability objectives
  This includes methods that may be applied to contextualize and analyse, quantify and judge the various trade-offs between delivered outcomes at various scales and between different sectors.

Figure 1: The Four Elements of a Robust Sustainability Framework



- **Feedback:** the flow of information or action between components of the framework, including to catalyse changes that promote sustainability
  In a well-functioning framework, robust data should be used to judge the success of policy, legislation or operational guidelines in achieving goals and targets, themselves embedded in evolving social and economic contexts. Institutional mechanisms can in turn modify policy, targets or guidelines and/or specify changed sustainability evaluation methods, or data to be used.

This framework is nested within the concepts of adaptive management, governance and learning. These concepts are crucial to promoting sustainability in complex and uncertain real-world situations. The framework is explained in more detail in the full Report.

Sustainability measurement and evaluation must account carefully for scale. The elements of the framework (Figure 1) are generic building blocks, but play out differently at enterprise, national and international scales. An enterprise may be considered sustainable even though the resource-use patterns of the economy it operates within are not currently sustainable. Approaches will be devised and applied in individual enterprises, sectors and nations and should be evaluated against the appropriate sustainability goals or criteria for that scale.

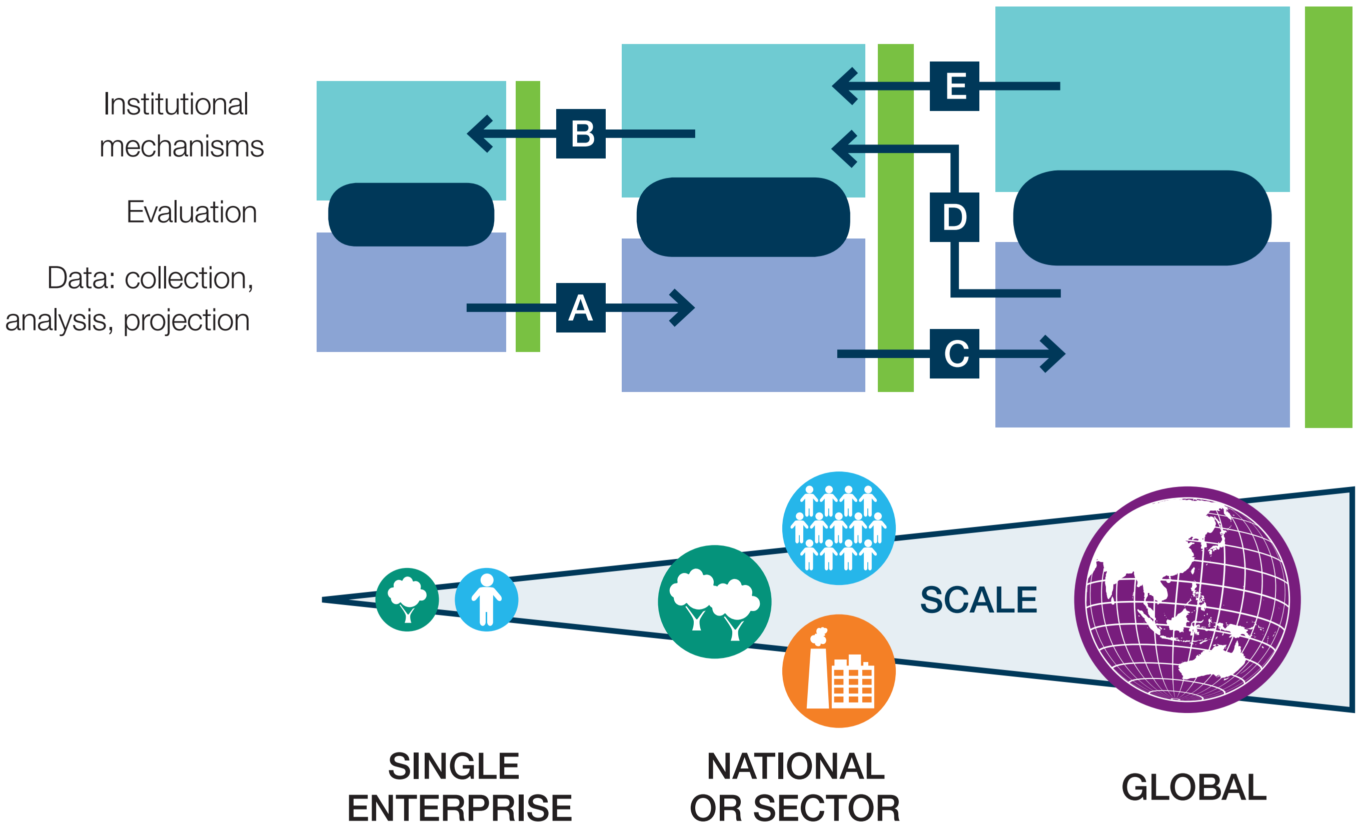
Linked activities in each of the four elements (institutional mechanisms, evaluation, data & analytics, and feedback) thus need to be integrated across different scales (Figure 2). Individual enterprises, each sector of a national economy and each country can aim for sustainability in relation to local goals, and contribute to sustainability at the next scale up or down (e.g. regionally, nationally, globally). Improving the sustainability of the whole system may sometimes involve a transformation or loss and/or addition of individual enterprises, or even whole industry sectors, to adjust the whole towards a more sustainable outcome. Effective activity in each element, at each scale, and effective links across scales are required to achieve global sustainability outcomes. Similarly, activity in any one of the elements can make a partial contribution towards global sustainability outcomes.

Many examples in the full Report demonstrate how these linkages occur, with particular focus on some industry sectors such as forestry, bioenergy and extractive industries. A few illustrative examples are provided here. For example in Australian forestry, agreed Criteria and Indicators (C&I) are used to report on enterprises at the local scale (Forest Management Unit level.) These data may feed into one of several sustainability certification schemes, as well as into business and operational plans. Some of the data are aggregated and reported at the state and national scales (A in Figure 2), and internationally. Data from other sectors and resources will be required for a full national evaluation of the sustainability of aggregate or cumulative impacts of the forestry sector in the context of other sectors, the whole economy and broader land use.

Feedback from national-scale sustainability evaluation could lead to changes in national plans, targets, regulation and legislation that impact on individual enterprises, or

Figure 2: Feedback Mechanisms and Interactions across Scales in a Robust Sustainability Framework

NB: See text for explanation of A–E.



institutional, business plans and operational guidelines may need to be changed (B in Figure 2).

Data collated, analysed and evaluated at the national level would be required, together with data from other countries and other systems data for international sustainability reporting and evaluation (C in Figure 2), e.g. Millennium Ecosystem Assessment.

The outcome of an international evaluation may influence national goals, targets, plans, etc. This response could occur directly (D in Figure 2) – through a nation's evaluation of the international data or indirectly (E in Figure 2) through the international data leading to changes in international agreements, which flow through to national changes. The linking of the elements across scales must be agreed, and this has important consequences for negotiating ownership of the process, as well as the collection, management and ownership of data at all levels.

Key success factors for an effective, robust and flexible system are summarized in the full Report.

Dealing with Cross-sector Interactions – The Food-Water-Energy Nexus

It is clear that the next few decades will see an intensification of multiple challenges at the nexus of energy, water and food. Demands for each of these will increase with population growth, economic development and rising incomes (see the full Report for more details). These trends will add to pressures on water resources, food production, energy security and climate. Despite growing attention and concerns, decision-makers typically remain ill-informed, and robust assessments that account for and integrate across the different dimensions of the nexus are scarce.

The three-fold nexus of energy, food and water provides a tractable but still extremely challenging entry point for considering sustainability, and naturally draws in the social, economic and environmental dimensions of sustainability. The scope of specific analyses within this framework can and should be tailored to the specific issues that are most material to the decisions under consideration.

Working across sectors and scales draws attention to "outward" and "inward" threats to sustainability. An outward pressure occurs when products and practices result in risks or pressures at other scales or in other issue domains. An inward pressure occurs when the sustainability of a product or process is threatened by something that occurs outside the system boundary for the management and assessment framework (requiring some reflection on whether this boundary is appropriate). In general, these threats and pressures should be physically dealt with as close to the source as possible, but this may be best achieved through establishing incentives and institutions that may be quite distant from the direct physical causes.

Social and Technical Contributions of Sustainability Assessment

The central purpose of sustainability assessment is to clarify near-term choices and long-term consequences, across an inclusive balance sheet, assisting risk management and management decisions.

In this context, it is useful to note that formal assessment and decision-support processes – and science more generally – have both a "technical" and a "social" role and contribution. Most discussions of decision support focus on its technical contribution, helping to account for multiple causes and impacts within a well-defined decision context. This typically presumes a clear decision mandate (with specified decision criteria, and an identified decision-making group) or a shared framework of objectives and ideas.

Many sustainability-related debates and decisions do not occur in such a well-structured decision context however. The system perspective provided by the generic sustainability framework in this paper (and many of the other approaches reviewed in the full Report) can assist the social processes of defining "the problem", and building a shared understanding or working consensus on the key uncertainties and potential options to be explored.

Recognizing "Success" without Ignoring the Challenge of Sustainability

Assessing progress towards – or the achievement of – sustainability or sustainable development is complex.

A first well-understood issue is that the precise definition of sustainability is intrinsically contestable, like related notions of progress, well-being, justice, development, and so on. In particular, sustainability assessment will almost always need to assign some form of weights to different elements of the triple bottom line (or other descriptions of values and benefits as determined by the chosen analytical approach), to judge whether reductions or adverse impacts in some domains are outweighed by increases or improvements in others.

A second, more difficult, issue is the minimum legitimate scale and scope for assessing sustainability. It is a truism that "there cannot be a sustainable part of an unsustainable whole". But it is also true that "the longest journey must begin with a single step". This tension is central to the use of measurement and evaluation systems to promote sustainability. To be tractable and useful, all measurement systems must have boundaries. For example, an assessment system may deal with energy use and emissions, but not all aspects of climate change. Another system may deal with environmental impacts, food security and labour standards – but for a defined region or jurisdiction, or for the supply chain of a specific company.

In practice these issues are already substantively addressed in many measurement and evaluation frameworks, which typically are careful to define both the issue or product being assessed and the criteria used for this assessment. This implies that a central issue may be the use and communication of the results of the assessment.

Some of the above issues can be addressed by distinguishing between supportive, necessary and sufficient conditions for achieving sustainability:

– Raising awareness of sustainability issues, engaging decision-makers and improving the information available are typical supportive actions, making it more likely that products and practices will be increasingly sustainable.
– Building this information into decision processes, strengthening organizational incentives and addressing barriers to sustainability are necessary steps towards achieving sustainability, but may not – of themselves – be sufficient to achieve sustainable products and processes.
– Establishing cradle-to-grave stewardship arrangements that have low or zero environmental impacts while also making positive contributions to stakeholder well-being and living standards can be considered sustainable within a domain.

All steps towards sustainability should be rewarded because they help build momentum and the appetite to take harder necessary steps towards sustainability. But care should be taken not to over-state or over-claim what has been achieved, as this may reduce support for further action.

Ultimately, sustainability criteria need to be met on a global scale over very long time frames.

Conclusion: The Task Ahead

Achieving sustainability is one of the most important and urgent challenges for humanity. Human pressures already exceed the safe coping capacity of the planet in some areas. In some cases, such as greenhouse gas emissions, humankind has only one or two decades to achieve a substantial change in trajectory – or risk extreme impacts.

Practical action at scale is required by hundreds of national governments, thousands of local governments, millions of businesses and billions of people around the world.

Sustainability assessment tools have a crucial role in informing, guiding and motivating this action – and are already making an important contribution. Existing tools are not perfect and will continue to be refined. New tools and approaches will need to be developed and implemented, addressing gaps and providing new traction and value. Technical, economic and social challenges will need to be addressed and overcome. A growing number of public and private enterprises will engage in different ways, for different reasons, around different aspects of sustainability. All members of this community of providers and practitioners have a contribution to make to building momentum, deepening engagement and improving outcomes.

The Global Agenda Council on Measuring Sustainability has a central role in promoting an improved understanding of the importance and value of measuring sustainability as a means to enable and better manage sustainable and resilient pathways for development, and in helping businesses, governments and communities identify and develop tools and frameworks that meet their specific needs.

The Global Agenda Council on Measuring Sustainability, the CSIRO and partners look forward to continuing collaboration and mutual learning, together working towards a better, more prosperous and more secure world.

Appendix: Major Developments in Sustainability Theory and Practice during the Last 20 Years

The purpose of this appendix is to situate the approach described in this Report within the context of a broader evolution in thinking about sustainability. The major trends are identified and how they relate to emerging understanding and practice is demonstrated.

Overview of Linkages between Sustainability Science, Assessment Tools and Global Initiatives

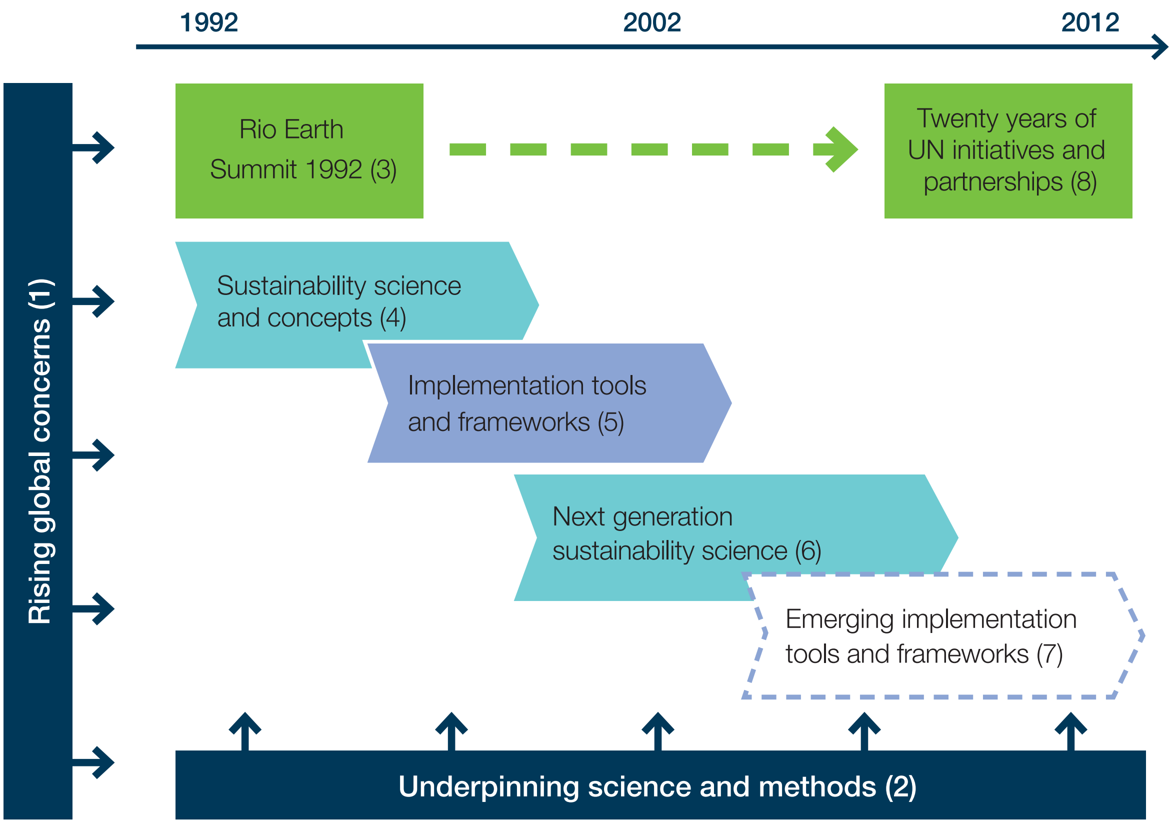
Figure A provides an overview of the evolution and development of scientific concepts, assessment tools and approaches, and UN initiatives.

Global concerns around interlinkages between pollution, poverty and environmental degradation gathered momentum in the early 1960s, and rose to the top of the UN agenda in the late 1980s (represented as (1) in Figure A). This was partly based on the disciplinary science and methods that had been developing, and that continue to develop and inform sustainability research (box (2) in Figure A).

The Rio Earth Summit in 1992 (box (3) in Figure A) was a catalyst to a new round of science informing sustainability theory and practice. For the purposes of this Report, science development and implementation are loosely divided into two phases:

– The first decade after the Rio Summit: This science is relatively well-developed (4) and has some fairly mature implementation pathways (5) that can be used by policy-makers, economic operators or other decision-makers.
– The second decade after the Rio Summit: The "next generation sustainability science" is emerging. Many of the limitations of the earlier science constructs are being addressed. However, the science is still maturing (6), and the implementation pathways are in the early stages (7).
–
– Further discussion of rising global concerns (box (1) in Figure A) and of the Rio Earth Summit 1992 (3), as well as a review of the 20 years of UN initiatives and partnerships since the Rio Summit (8) are excluded from this short Report. Included below are summaries of the underpinning science and methods (box (2) in Figure A), sustainability science (boxes (4) and (6) in the Figure) and implementation tools (boxes (5) and (7) in the Figure). All of these areas are discussed in detail in the full Report.

Figure A: The Evolution of Sustainability Science and Concepts, and Implementation Tools and Frameworks



Underpinning Science and Methods

1. The Contribution of Disciplinary and Interdisciplinary Sciences

A wealth of scientific study using a range of approaches supports sustainability assessment:

- *Discipline-based* science, including ecology, hydrology, agronomy, the social sciences, economics, etc.; these disciplines provide knowledge about human values and behaviour, ecosystem functions and dynamics, and economic activities
- *Place-based* multidisciplinary and interdisciplinary research to solve emerging issues at specific locations (for example examining the interaction of ecological, hydrological, socio-cultural and economic factors within particular geographic areas)
- *Integrative research* around sustainability issues, including:
  - *problem-based* approaches defined by specific challenges or tensions (examples include food or water or energy security, climate change vulnerability, the food-water-energy nexus)
  - *goal-oriented* approaches (such as those focused on eradicating poverty)
  - *solution-based* approaches that are seen as intrinsically linked to promoting sustainability (current examples include green (economic) growth, green cities, green jobs, a decoupled or de-carbonized economy, climate ready agriculture; previous examples include people-centred development, participatory governance, or triple-bottom-line thinking)

All of these approaches provide vital concepts, data and methods to underpin the understanding and assessment of sustainability.

2. The Role of Data

The term "data" is a catchall for measurements, projected trends, modelled estimates and estimates of numerical attributes for concepts that cannot even be empirically measured. Because sustainability is multidimensional and operates across temporal and spatial scales, no single measure can be used to describe it. Many efforts have attempted to produce simplified interpretations of highly complex interactions and data sets. These are often framed as indicators, which can range from relatively simple observations of variables (e.g. temperature), to moderately complex indicators based on measured data (e.g. metrics that describe forest fragmentation and risks to biodiversity), to indicators that are highly theoretical concepts that cannot be measured empirically (e.g. climate vulnerability, food security, sustainable competitiveness). Such indicators are also referred to as "data" in the sustainability discourse. However, some compound indicators also include elements of evaluation and assessment and are better referred to as an evaluation method (than as "data").

For even the most basic level of data (e.g. measured observations), complexities exist relating to scale, the need to interpolate in time or in space, and the issue of understanding future responses of social-ecological systems that cannot be measured directly. Therefore, even a complete, high-resolution set of measurements cannot provide a reliable picture of future changes. Improving the capacity to make sufficiently accurate projections into the future is a critical and challenging task. Because it is of such fundamental importance, there are whole fields of endeavour around understanding the uncertainty of projections of data or indicators.

Many of the data sets important to sustainability assessment are difficult, time-consuming and expensive to collect. A major international effort has improved the efficiency and adequacy of observations and measurement of key system variables and/or proxies or surrogates. For example, technologies such as remote sensing and other sensor technologies have provided very powerful measurement capabilities at a range of scales. Yet despite the improvements in technology and the collection and collation of many large data sets, publicly available, high-quality data that would enable organizations or countries to evaluate or assess how they fare in the area of sustainability are lacking. One argument suggests that the availability of high-quality data will enable countries to monitor the rise or decline in prosperity and quality of life for their citizens, and determine appropriate policies.

With the increase in capacity to observe and measure, however, comes a parallel requirement to increase the capacity for analysing, evaluating and synthesising to derive meaning from the vast volumes of data collected. The argument in this Report is that, although access to high-quality data is required for sustainability to be assessed, progress in sustainable development requires a robust construct for evaluation and interpretation of the data, in order to support policies and decision-making.

The First Decade after Rio: Sustainability Science and Concepts, and Implementation Tools and Frameworks

In the first 10 years after the Rio Summit, "sustainable development" concepts drove the development of methodological approaches in the science domain, which then flowed across to decision-making in the implementation domain. These concepts included:

- realizing the importance of addressing sustainability at a range of scales, critically at the global level, which led to processes for setting international goals and targets
- considering inter- and intra-generational equity, with a long-term perspective
- taking a broad-based approach to human needs and well-being, including an integrated or multifactor approach to analysis and decision-making
- assessing changes in human, natural and manufactured capital over time, or valuing the contributions of different capital stocks to human well-being
- using a triple-bottom-line approach with three "pillars": environmental, social and economic (a fourth pillar, governance, was added later in particular cases)

A suite of formal sustainability schemes have been developed and implemented by enterprises, corporations and industry sectors worldwide. These schemes assess and report the "sustainability" of their activities for stakeholders or customers; underpin certification of sustainable products; and inform continuous improvement of their operations.

The main science constructs, as well as their maturity in implementation, are shown in Table 1. These approaches have varying degrees of coherence, maturity, on-ground success or ongoing relevance. The initiatives that are most mature in their implementation can be characterized as relevant to:

– single aspects of sustainability, such as greenhouse gas emissions, water quantity and quality, or pollutants, which are often split further according to the specific goals or policy objectives of each
– individual enterprises or economic sectors, such as forestry or mining
– geographic or jurisdictional regions, such as farms, catchments, states, countries

Table 1: Approaches to Sustainability Assessment and Reporting in the First Decade after the Rio Earth Summit

Further details, including full references for all citations, are provided in the full Report.

Type of approach	Name of approach	Maturity in implementation	Example(s) of implementation
Use of Indicators	Simple indicators	Mature	Numerous examples, including Australia's Sustainable Forest Management Framework e.g. Indicator 1.1.a - Area of forest by forest type and tenure
	Compound and complex indicators	Early stage	World Economic Forum's sustainably-adjusted Global Competiveness Index (GCI)
Impact Assessment and Related Approaches	Environmental Impact Assessment (EIA), Social Impact Assessment (SIA)	Mature	Standard practice in many countries for all new developments
	Life Cycle Assessment (LCA)	Mature	Roundtable on Sustainable Biofuels Fossil Fuel Baseline Calculation Methodology (RSB-STD-01-003-02)
Maintenance of Capital Stocks and Flows	Triple Bottom Line (TBL) Sustainability Reporting	Mature	Australian Government DSEWP&C "Environmental performance reporting" The Global Reporting Initiative (GRI)
Schemes and Standards for Measuring, Assessing, Reporting and Certifying Sustainability	Principle-Criteria-Indicator, Certification of Sustainable Production	Mature	Montreal Process Criteria and Indicators of Sustainable Forest Management Forest Stewardship Council Forest Products Certification The Carbon Disclosure Project The Standards Map, providing users with information enabling them to analyse and compare information on 120 voluntary standards operating in over 200 countries, and certifying products and services in more than 80 economic sectors
(Driver-Impact) Pressure-State-Response (DIPSR)	Pressure-State-Response (PSR)	Mature	Australian Government DSEWP&C State of the Environment Report 2011 OECD Environmental Indicators 2008
Accounting System Approaches	System of Integrated Environmental and Economic Accounting (SEEA)	Mid-stage	SEEA Central Framework, adopted in 2012 as an international standard by the United Nations Statistical Commission, supported by the European Commission, FAO, IMF, OECD, UN and World Bank
	Consumption-based Accounting (CBA)	Mid-stage	United Kingdom 2011-2013 - Department for Energy and Climate Change (DECC) with the University of Leeds, developing a CBA Indicator for GHG emissions

Risk Assessment and Management to Deal with Uncertainty	Risk Assessment and Management	Mature	ISO 31000 – Risk Management Australian and New Zealand Standard AS/NZS 31000: 2009 Risk Management – Principles and Guidelines
Management Approaches: Adherence to Prescribed Approaches	Best Management Practices (BMP), Codes of Practice, Environmental Management Systems (EMS)	Mature	Cotton Australia's MYBMP, a best management practice tool for Australia's cotton growers Victorian Department of Primary Industries and Agriculture, Australia – Environmental Management Systems in Victorian Agriculture
	Adaptive Management	Mid-stage	Canadian Environmental Assessment Agency – Operational Policy Statement: Adaptive Management Measures under the Canadian Environmental Assessment Act

The Second Decade after Rio: Next Generation Sustainability Science and Emerging Implementation Tools and Frameworks

By 2000, many studies tracking the progress of sustainable development concluded that, while significant progress in many of the initiatives stemming from the Rio Earth Summit had been made, more focus had been placed on those aspects related to human development, at the expense of the environment. Around this time, the concept of "sustainability science" emerged and gained traction. Some of the more contemporary approaches are listed in Table 2, with brief examples. Because the science is still under development, implementation has been limited. Certain ideas have been picked up by industry sectors and in some innovative policy environments, but no formalized schemes or standards exist as yet that enterprises or sectors can use.

Table 2: Next Generation Sustainability Science Approaches

Further details, including full references for all citations, are provided in the full Report.

Type of approach	Maturity in implementation	Examples
Scenario Analysis and Integrated Assessment	Early stage	Intergovernmental Panel on Climate Change (IPCC) – 5th Assessment Report (AR5)
Millennium Ecosystem Assessment (MA) or Ecosystem Services Approach	Early stage	Millennium Ecosystem Assessment UK National Ecosystem Assessment 2011
Resilience Thinking, Thresholds and Planetary Boundaries	Not implemented	Resilience Practice: Engaging the Sources of our Sustainability, Brian Walker and David Salt (2012), exploring the application of resilience theory to real-world situations
Adaptive Governance	Not implemented	Adaptive governance and climate change, Ronald D. Brunner, Amanda H Lynch (2010), arguing for decentralized adaptive governance to provide diversity and innovation in addressing climate change

A significant shift has occurred in the last 10 years, based on the recognition that a solid scientific foundation is necessary to define the prerequisite levels of ecosystem functioning needed to meet long-term social or economic goals. Contemporary approaches incorporate the following key characteristics:

- recognition of the need for methods and fora for dialogue, and for understanding human values and choices at different scales, locations and times (including current and future generations)
- consideration that systems are dynamic – the desired goal is not necessarily a state of equilibrium – and the explicit recognition of thresholds (rapid, non-linear changes of state or condition), which may be irreversible if transgressed
- acknowledgement that a level of minimum ecosystem functioning is a prerequisite for the continued delivery of benefits to humans into the future; variously termed "planetary boundaries" or "safe operating zones"
- necessity to deal with uncertainty and unknowns in a sophisticated and more realistic way – recognizing that there may be many future shocks, some of which may be predictable and others not. These include natural disasters, economic shocks and social shocks; therefore the linked social-ecological system will benefit from building resilience ("resilience thinking") and actively managing alternative pathways to transition to desired futures
- recognition that assessments covering a shorter time period than the time scale of important processes will not adequately capture the associated variability, e.g. for long-term cycles such as climatic or economic trends
- recognition that many environmental problems originate from a mismatch between the scale at which ecological processes occur and the scale at which decisions are made. Outcomes at any given scale can be determined by interactions of ecological, socio-economic and political factors from other scales; therefore contemporary approaches accommodate nested scales from the local to global scale
- provision of a basis for decision-making according to multiple integrated goals

Several of these approaches and constructs are not mutually exclusive and may be used in a complementary fashion to work in concert or provide multiple "lines of evidence" in assessing sustainability outcomes.

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Members of the Global Agenda Council on Measuring Sustainability

Marc Levy, Deputy Director, Center for International Earth Science Information Network (CIESIN), Columbia University; Chair of the Global Agenda Council on Measuring Sustainability
James Cameron, Chairman, Climate Change Capital; Vice-Chair of the Global Agenda Council on Measuring Sustainability
Juan Carlos Castilla-Rubio, Chief Executive Officer, Planetary Skin Institute; Vice-Chair of the Global Agenda Council on Measuring Sustainability

Nelmara Arbex, Deputy Chief Executive, Global Reporting Initiative (GRI)
Ian Cheshire, Group Chief Executive, Kingfisher
Megan Clark, Chief Executive Officer, Commonwealth Scientific and Industrial Research Organization (CSIRO)
James Fruchterman, President and Chief Executive Officer, The Benetech Initiative
Tim Kelsey, National Director Patients and Information, NHS Commissioning Board
Vipin Kumar, William Norris Professor and Head Computer Science and Engineering, University of Minnesota
Gerald Nelson, Professor Emeritus, University of Illinois at Urbana-Champaign
Carlos Afonso Nobre, National Secretary of Research and Development Policies, Ministry of Science, Technology and Innovation, Brazil
Lindene Patton, Chief Climate Product Officer, Zurich Insurance Group
Johan Rockström, Executive Director, Stockholm Resilience Centre
Sheng Fulai, Chief, Research and Partnership Unit, Economic and Trade Branch, United Nations Environment Programme (UNEP)
Paul Simpson, Chief Executive Officer, Carbon Disclosure Project
Dmitry Vasilkov, Chief Executive Officer, Ecoterra

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World Economic Forum
91–93 route de la Capite
CH-1223 Cologny/Geneva
Switzerland

Tel.: +41 (0) 22 869 1212
Fax: +41 (0) 22 786 2744

contact@weforum.org
www.weforum.org