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Science without borders

Making the SDGs successful

EDITORIAL

Science for the SDGs, science for the future

Science is being challenged as never before as the world contends with the profoundly complex problems of living sustainably and equitably. That battle now has a common, global ambition – the 2030 Agenda – and if science is to support its achievement, it is vital that we share a common vision of the kind of science we need. It is science that is open and inclusive, that shares its benefits universally, and that makes a difference to real-world problems not only by advancing our understanding, but also by contributing transformative societal responses. Science, in other words, that is solutions-oriented and one that provides so-called actionable knowledge.

Propelled by the 2030 deadline for achieving the Sustainable Development Goals (SDGs), significant change is occurring in the policies and practices of science. The nature of that change can be defined by three priorities, all of which the International Council for Science works to promote.

The first priority is the need for significantly enhanced collaboration within and between the different fields of science. The integrated nature of the SDGs calls for integrated science; science that is open to the perspectives and methods of different fields, but is also able to mobilise the very best of disciplinary expertise from across the scientific spectrum. Despite decades of promoting interdisciplinarity and recognising its profound relevance to complex global challenges, there are still real barriers to effective collaboration; a perennial problem that must be overcome.

The second priority is to create effective pathways for science to connect more directly and more effectively with policy and public action. This requires intervention at a number of levels, as well as new forms of engagement between science and society. There are ways that enable decision makers, policy shapers, practitioners, local communities and businesses to participate in processes of knowledge creation – not as clients, but as knowledge partners, working together with scientists in determining critical knowledge needs, research agendas, and collaborating in networks of mutual learning and problem-solving.

The third priority is for scientists to fully exploit the opportunities of the digital revolution; of big data, linked data, and machine learning. For science, the immensely enhanced capacity to acquire, store, analyse and communicate data at low cost allows us to understand and characterise complexity in unprecedented ways. It has created a new intellectual infrastructure that has great potential impact on the realisation of the SDGs. It is vital, therefore, that scientists all over the world are supported in using these tools, and do so responsibly, using open data policies and sound data management practices.

Taken together, these three priorities form the bedrock of a science that is an open, public enterprise. It is science for the SDGs and science for the future. But in mobilising a consensus for this kind of science, it is important to remember that the foundations on which it rests will depend on sustained, robust support for the development of scientific capacities worldwide, and for science systems in which disciplinary enquiry, curiosity and fundamental research are still valued.

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CONTENTS

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INTRODUCTION

Inclusive science: Promoting the interface between science, policy and society

Farooq Ullah discusses how more open and participatory science and research could bring significant success to the Sustainable Development Goals.

Science has had, and will have, an inestimable impact on our planet and its people. And while there is a growing recognition of the role society and stakeholders play in ensuring that science drives decision-making, it remains poorly understood and even less well utilised.

A 'standard' model (**Figure 1** – Mode 1) about the relationship between science and society is still very influential. This model is considered to be largely supply-driven and linear. However, the standard model is overly simplistic, and is not a good fit for the relationship between science and society under the dynamic and rapidly evolving conditions of global change. This linear view of the scientific method – and the binary nature of the science-policy interface – undermines the very importance of science and ignores both its true end user and its driver; society.

WHAT'S THE ALTERNATIVE?

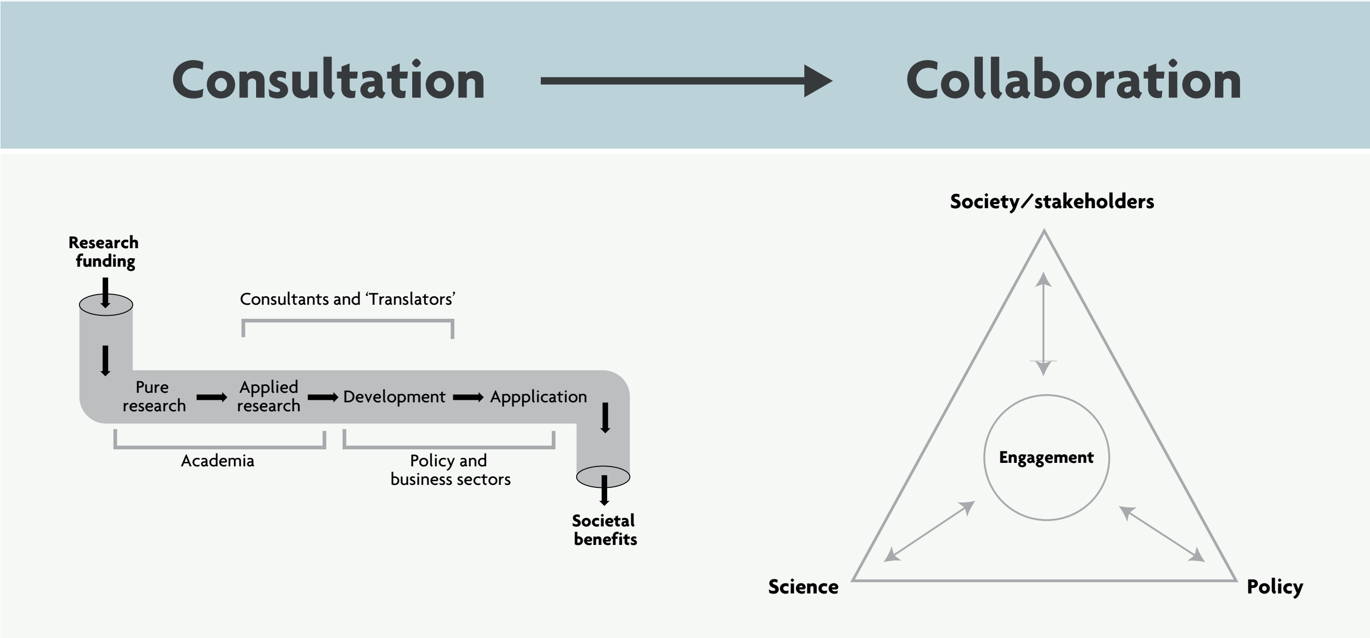
There is a need to move away from this sort of linearity towards a model based on more fluid and integrated engagement with stakeholders (as an active proxy for society) in order to develop demand driven and solution oriented science which then is actively applied to government, business and societal sectors. Rather than being a passive actor concerned only with discovery, in Mode 2 (**Figure 1**), society must play an increasingly active role in the co-design and co-production of knowledge to diagnose problems, to devise options for technical and policy solutions, and to help chart future pathways.

One of the main challenges will be to create partnerships between society, policy and science in order to advance research and eventually sustainability. Such triangular relationships must strive for continuous engagement and interaction between key actors throughout the scientific process; therefore the focus should be collaboration not merely consultation.

In order to add detail to the 'triangle' mode, four key questions must be explored:

- How can society and stakeholders better use science?
- How can science use society and stakeholders better?
- How do both society and science influence public policy decision-making?
- What does 'collaboration' look like in practical and processual terms?

INTRODUCTION



Knowledge production in Mode 1	Knowledge production in Mode 2
• Academic context	• Context of application
• Disciplinary (sometimes multidisciplinary)	• Transdisciplinary
• Homogeneity	• Heterogeneity
• Autonomy	• Reflexivity/social accountability
• Traditional quality control (peer review)	• Novel forms of quality control

▲ **Figure 1. Shifting to the science-policy-society triangle. (Adapted from Hessels and van Lente[1])**

BOX 1: TARGETS AND INDICATORS

When the 17 SDGs were published by the United Nations in September 2015, 169 targets were announced alongside them. These targets are nested under the Goals, breaking each down into concrete aims.

The targets, and the Goals themselves, were the result of an extensive public consultation which lasted for over two years, ensuring that the voices of the most vulnerable were heard, as well as stakeholders and civil society around the world.

Underpinning the targets, a set of 232 unique indicators were introduced in January 2016 as a way of accurately measuring progress towards the Goals. The indicators are placed into three tiers, based on availability of relevant data and the development status of their methodologies:

Tier 1: Indicator has an internationally established methodology, and data are regularly produced by at least 50 per cent of countries.

Tier 2: Indicator has an internationally established methodology, but data are not regularly produced.

Tier 3: Indicator does not yet have an internationally established methodology but it is being (or will be) developed and tested.

Science can be the great equaliser in the debate, in that it can provide a (reasonably) objective basis for discussion as well as common language through which different perspectives can be brought to bear when looking for innovative solutions. Making science more participatory and inclusive will provide a greatly improved application of science for all forms of decision-making, resulting in better outcomes.

HOW DO SCIENCE AND THE GOALS SERVE EACH OTHER?

2015 saw the ratification of the United Nation's Sustainable Development Goals[2] (SDGs, or Goals). Comprised of 17 Goals (**Figure 2**), 169 targets and 232 indicators (**Box 1**), it is a complex and comprehensive framework[3]. But crucially, it has given us a common grounding, a *lingua franca*, which transcends socioeconomic silos, overcomes political barriers and allows us – even requires us – to work together.

Unlike the Millennium Development Goals (MDGs), which focused primarily on social development priorities in low-income countries, the SDGs aim to tackle poverty eradication in a holistic way through the use of sustainable development. Therefore the SDGs are global in nature and apply to all countries, developing and developed alike. This core principle of universality which underpins the SDGs is vital, and must run through all implementation activities.

The SDGs will need to incentivise and drive relevant and contextualised change in all countries. The Goals will have to contribute to poverty eradication in low-income countries whilst addressing the patterns of consumption and production in the developed world; in both cases addressing the balance between economic development and environmental sustainability while promoting societal good.

But we know that public policy alone will be insufficient to achieve the SDGs. Therefore, organisations of all types, – the private sector, scientific bodies, academia and civil society alike – will need to understand their role in implementation, as well as the benefits of helping to achieve the Goals nationally and internationally.

Given ever increasing rates of economic, social, political and environmental change, there is an urgent need for the production and use of diverse knowledge to inform and respond to these changes. Science has a key role in translating and applying the SDGs (as global goals) to local contexts. This is not an easy task, therefore it must be evidence-led. However, the pursuit for new and inclusive knowledge must also be demand-driven and societally relevant to ensure that efforts to achieve the SDGs have local relevance and benefits, as well as contributing to global challenges.

THE RELATIONSHIP BETWEEN SCIENCE AND SOCIETY

Recognition that scientific and research practices can be strengthened by stakeholder engagement and therefore result in more valuable outcomes, is not new. There is significant evidence that demonstrates it optimises not only the quality of the research, but also enables mutual learning and knowledge exchange between researchers and their stakeholder community. The success of strategic stakeholder collaboration has been particularly noticeable in complex, interdisciplinary research that is associated with high levels of uncertainties and complexities such as environmental change. There are multiple reasons why humanity will benefit from more inclusive and integrated science, as it:

- adds legitimacy to research and reduces stakeholder scepticism during policy development, assessment or implementation;
- helps open up routes to blending basic fundamental and normative research without undermining either, and utilises traditional knowledge more effectively;
- leads to dialogue from a wider community, especially with those that have a critical role in public consultations; and

▲ **Figure 2. The 17 Sustainable Development Goals.**

- facilitates mutual learning and cross-pollination of ideas across research and stakeholder communities, helping to secure wider support for research whilst also identifying weakness in beliefs, perceptions and responses.

But all of this is easier said than done. Collaboration is hard and the debate concerning the relationship between science and society is as old as science itself. Therefore these concepts need to be applied not only to scientific projects, but also to the scientific method. This includes, crucially, changing the mindset of scientific funders. Once funders recognise the merit of an inclusive approach, they must make such initiatives part of their funding requirements.

Within social and historical studies of science, there is by now a broad consensus that scientific practices, agendas and norms are deeply embedded in social practices, agendas and norms. The way society produces knowledge is similar to the way science produces knowledge, but there is also an agreement that the relationship between them is two-way or even multidirectional: science influences society (the state, the market, civil society), as much as society influences science (indeed scientists are also a part of society as individuals).

SCIENCE AND GOVERNANCE – TWO PEAS IN A POD?

The need for multidirectional flow of information and influence is clearly stated within the 2030 Agenda; the material related to the SDGs contains a plethora of ideas, concepts and solutions. The key action will be assessing the quality and validity of these ideas, recognising that the bright ideas we need could come from anywhere and from anyone. Therefore, our responsibility is to ensure that we are inclusive and participatory in all our efforts, and not only in the production of knowledge.

The scientific and research community must, in turn, rise to the occasion and seek out the bold new ideas we need for achieving the Goals through inclusive scientific methods. Participatory governance is an idea that involves all stakeholders at every level; the hope is that it will result in better informed, and more thoroughly deliberated, decisions. It also means that all stakeholders will take greater ownership of the outcome and then be active in the delivery of its action on the ground, optimally in partnership with governments and other stakeholders. These modes of governance apply as equally to science as they do to politics.

Therefore, good governance is fundamental to the SDGs. We must actively promote effective, participative systems of governance at all levels of society and thus engage with people's creativity, energy and diversity.

In this exciting edition of the environmental SCIENTIST, we have a diverse selection of articles for you from an exceptional set of authors. We also are very pleased to include an editorial from Heide Hackmann, Executive Director of the International Council for Science, and an exclusive interview with Jonathan Porritt, Founding Director of Forum for the Future. Both will be sharing their thoughts on the role of science in working towards achieving the SDGs. As Nelson Mandela said "None of us acting alone can achieve success". While Mandela was referring to apartheid, I believe this sentiment is as true for the ultimate success of the Sustainable Development Goals. **ES**

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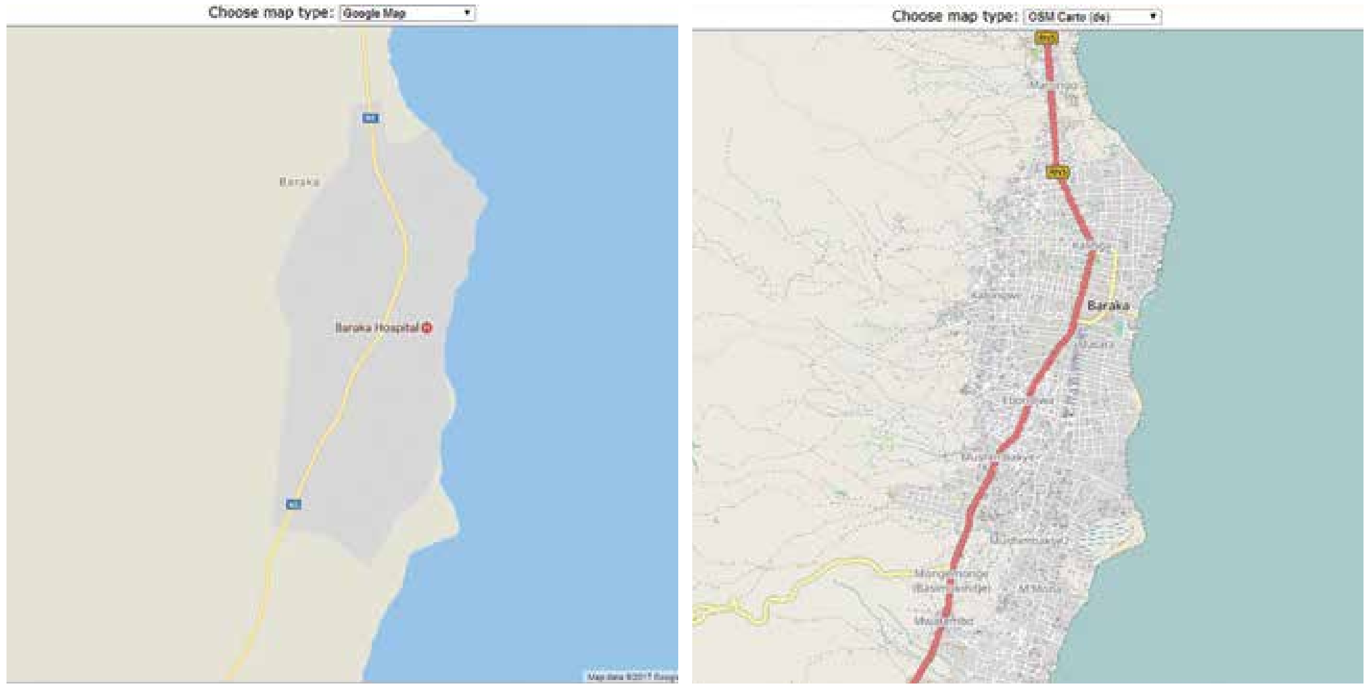
OpenStreetMap and the Sustainable Development Goals

Rebecca Firth discusses how OpenStreetMap provides a strong alternative to other mapping systems and helps underrepresented communities.

OpenStreetMap[1] (OSM) is an easy to learn open-source mapping tool, which enables anyone, anywhere, to edit the world map. The one million strong OSM community is managed by volunteers[2], with the community itself made up of groups from across the world, who all share a passion for the benefits of open map data, or a professional interest in OSM.

When creating the Sustainable Development Goals (SDGs, or Goals)[3] the United Nations (UN) General Assembly stated: "Quality, accessible, timely and reliable disaggregated data will be needed to help with the measurement of progress, and to ensure that *no one is left behind*"[4]. The role that OSM, the global OSM ecosystem and communities have to play in the 'Leave No One Behind' agenda is paramount. One seventh of the world's population now lives in informal urban settlements, often in overcrowded, unstable, unsanitary conditions, which are almost always unmapped[5]. Remote rural communities are often similarly absent from global maps. These populations live in intense vulnerability, not just to disasters and disease, but to being left behind by the global development agenda.

The Humanitarian OpenStreetMap Team (HOT)[6] has enabled over 35,000 volunteers[2] from over 50 countries to map in support of specific development programmes, and to build the resilience of places affected by natural disasters. HOT's mission is to enable people living in the highest risk and least developed countries to map the places they live, collecting micro-level geospatial data in inclusive projects with residents, and making the resulting data openly and freely available through OSM.



▲ **Figure 1. Baraka, a city of 120,000 people in the Democratic Republic of Congo. This population was completely missing from Google Maps (left), but visible in OpenStreetMap (right), thanks to the work of 70 volunteers.**

POWER TO THE PEOPLE

Volunteer mappers can learn from training events such as 'Mapathons' organised by Missing Maps[7] or through the wide variety of online tools created by the OSM Community, the most comprehensive of which is LearnOSM.org[8], which is available in 20 languages. Volunteers can map remotely, using satellite imagery to trace buildings and roads in other countries or map locally in the communities they live in, using a wide variety of low resource mapping tools to create the map and collect supplementary data. This ability to contribute both remotely and locally is one of OSMs greatest strengths for the Goals, as it enables global and local volunteers to contribute to the same cause. So far, HOT volunteers have mapped the homes of over 45 million vulnerable people in OSM (for example, **Figure 1**).

OpenStreetMap is more than just a useful tool; it enables volunteers to understand the realities of others whilst working towards shared goals. In what other project can a high school student in Europe meaningfully contribute to the same project as a Geographic Information System (GIS) enthusiast in Bangladesh or a south Sudanese refugee in Uganda? Harnessing the crowd for humanitarian good in this way brings the 'fortunate' and 'less fortunate' into the game of life together and they collaborate in humanitarian fieldwork that is useful to real people working to improve the situation on the ground. Humanitarian mapping is about highlighting and addressing equitable distribution of resources worldwide[9]; it recognises the difference between data captured in OSM, which describes the physical world around us, and census or survey data, which may capture personally identifiable information, along with attitudes, behaviours, experiences, opinions, and consumption habits. To understand and address these factors, visualisation on a map is key.

This ability for citizens to address global data shortages through open data is a paradigm shift in the way organisations and the development sector conceptualise, create, analyse, use and share data. Citizen Generated Data (CGD), falling broadly under the citizen science umbrella, is at its strongest when the power of the crowd - informal data producers - are harnessed to support and close gaps for formal data users such as the National Statistical Offices; it is one of the most innovative solutions available to close global data gaps. The UN Report, *A World that Counts*, refers to CGD as an enabling tool for the production of a 'people's baseline'[10] which gives ownership and action to citizens and not just to governments as decision makers. CGD is a relatively new field, with as yet limited formal guidance available despite a large number of successful practical projects - something HOT is leading in creating.

Many online companies, such as Google, are primarily interested in creating maps in places where income can be generated from advertising by local businesses; users can suggest edits to Google Maps, however these are all reviewed/controlled by Google. Furthermore, like the rest of Google's products, all data in Google Maps is privately owned, and is subject to fees. There are many drawbacks to closed data, not least the frustrations of residents constantly beleaguered by inaccuracies on

▲ **Figure 2. Residents' frustration with inaccuracies in Google Maps.**

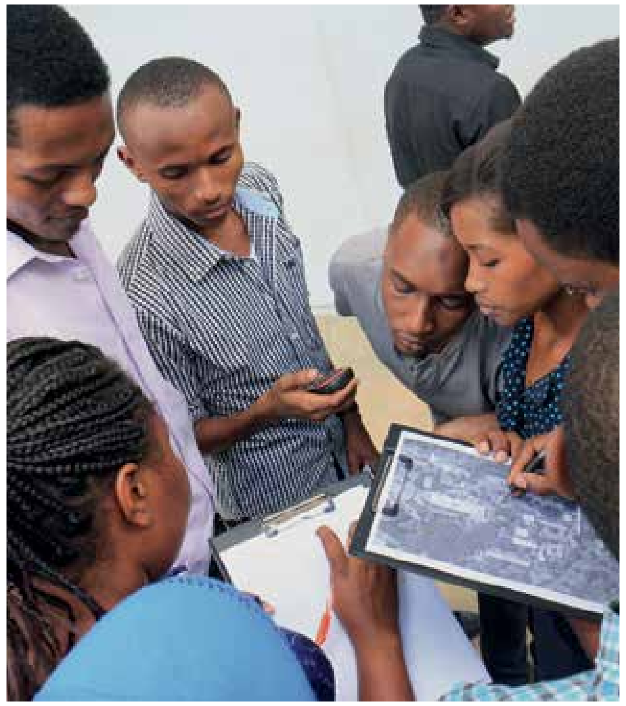
Google maps (see **Figure 2**), and the growing sense that individuals' data is simply becoming a product for Google to sell to others.

SYMBIOSIS WITH THE UN GOALS

OSM mapping directly support projects to both measure and meet the majority of the 17 Goals; its data can inform the entire project lifecycle, from the initiation and identification of priorities, to monitoring progress, and finally measuring impact and reporting. First and foremost, communities not counted during civil registration, when displaced or through other company or government map providers, can be counted using OSM. In short, when made visible in OSM, these communities cannot be ignored. OSM also supports the Goals by enabling the identification of available services and vulnerabilities at an increasingly local level, giving decision makers the data they need to take action, and thus influencing logistic and route planning decisions. Its data is used by many high profile organisations including the World Bank, Red Cross, and Médecins Sans Frontières (MSF). To quote Ivan Gayton, former Technology Innovation Advisor for MSF, "When you have a place like South Sudan, where millions of people live and die without ever figuring in a database anywhere, their names will never be written down. To not be on the map is quite a powerful statement of uncaring. I tell people at Mapathons sometimes 'That house you're tracing right now, that hut – that's the first time in the history of humanity someone cared enough about them to take note'".

STEPPING UP TO THE CHALLENGES OF THE GOALS

One of the greatest challenges the SDGs present is of data. Quality, quantity, accessibility, and regularity are critical to measuring progress against the SDGs, and superior data gives communities greater power to advocate. The first UN World Data Forum, held in January 2017, brought together international communities to talk about the measurement challenges the SDGs bring. The 17 Goals come with a complex set of 232 indicators, the data points each country will need to measure to demonstrate their progress against the Goals[11]. Geospatial data is critical to this because 26 per cent of the indicators have such a component. It is impossible to measure indicators such as 'proportion of population using safely managed drinking water services' and 'proportion of the rural population who live within 2 km of an all-season road', without knowing where these services are, and where the population live in relation to them. Additionally, OSM addresses the challenge of regular monitoring and evaluation of projects because its data can be updated constantly, meaning SDG progress can be monitored continuously rather than waiting for survey results, or a ten year census. For OSM to make a true impact against the SDGs, governments must embrace it[12]. It is increasingly becoming a government standard, for example in Malawi, Tanzania and Liberia, but work still needs to be done to increase data literacy amongst government stakeholders, and promote the value of open data across government agendas.



▲ **Figure 3. Students mapping for flood resilience and Goal 6 (Clean Water and Sanitation) in Dar es Salaam, Tanzania.**

The examples of projects not just helped, but made possible through OSM, are wide ranging and cover issues from financial inclusion[13] to female genital mutilation[14]. A broad discussion of these is available in the 'OpenStreetMap for the Sustainable Development Goals Toolkit' on the Global Partnership for Sustainable Development Data website[15].

Data is not meaningful in isolation; OSM projects have the greatest impact when local and national government, and humanitarian actors, are key stakeholders in projects (and use the data to affect change). In HOT project methodology, the process is equally as valuable as the data. Through truly participatory projects which empower local communities and young people to gain and use skills to affect social change, and become leaders in their communities, HOT projects also directly contribute to Goal 8 (Decent Work and Economic Growth). This isn't just development happening to people, it is true collaboration. One example of this is a 2016 HOT project to map every public toilet in Dar es Salaam, Tanzania, which provided: the data to measure performance against the water and sanitation indicators; the identification of under-served areas (Goal 6 – Clean Water and Sanitation); and the ability to triangulate sources of cholera outbreaks (Goal 3 - Good Health and Wellbeing)[16] (**Figures 3 and 4**). The maps were created by volunteers and students from local universities.

Data quality is typically the greatest area of concern in crowdsourced projects, together with high-level decision makers making policy and project decisions that do not translate into benefits for the intended beneficiaries. Research has repeatedly demonstrated that the OSM database is as accurate, and in some cases more accurate, than data sources produced by official entities in traditional 'top-down' exercises[12]. Its dynamic nature makes it easier to keep map data up-to-date than in traditional closed systems; this is particularly true in areas with active local mapping communities, thus pointing to the need for governments to engage, collaborate with and support these communities at a local level. After all, the people who are really going to be able to give you accurate information aren't usually government officials, but the people whose houses are annually flooded, whose belongings are ruined and lives upturned. They are the best source of the data that's needed to help them. All we need to do is ask.

ES

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FURTHER INFORMATION:

- Learn more about HOT: www.hotosm.org
- Learn to map: www.learnOSM.org
- Open Mapping for the SDGs toolkit (Global Platform for Sustainable Development Toolkit): www.data4sdgs.org/open-mapping-for-the-sdgs
- Contact: info@hotosm.org

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▲ **Figure 4. HOT Tanzania staff member Dorica Mgusi, a graduate of Ardhi University, at a community meeting in a ward of Dar es Salaam.**

ANALYSIS

The economics of the Sustainable Development Goals

Dr Simon Zadek sets out how the global economy can support the implementation of the SDGs.

Today's US$80 trillion annual global economy delivers livelihoods for billions of people. Economic growth over the last half a century alone has lifted hundreds of millions of people out of poverty, unlocking resources for improved health and education, and enabling us to address many of the objectives embodied by the Sustainable Development Goals (SDGs, or Goals). Yet despite such successes, the global economy will have to change dramatically if we want to meet the Goals by 2030, or indeed at all. 'Business as usual' will not only fail to deliver, but may actually move us away from our collective aspirations.

WHAT'S THE CURRENT FINANCIAL SITUATION?

Today's global economy delivers much that is needed, and much to admire and desire. But it also has many unintended negative effects. Income inequality within nations has risen rapidly over recent decades. New manifestations of poverty have become an embedded part of many middle and upper income, as well as so-called developing countries. Decades of excessive consumption, powered by low cost production in China, has resulted in significant global economic and financial imbalances, and has accelerated environmental damage and climate change. Such consequences of this period of globalisation have contributed to an unemployment crisis in many developed countries, soon to deepen and broaden as automation removes hundreds of millions of job opportunities. Populist politics in this context is an unsurprising outcome, along with retrograde views about everything from political rights to environmental stewardship.

So on the eve of this phase of globalisation, we must count its costs as well as plentiful material benefits. Most pressing is that the ecosystem on which we all depend is in a precarious state. An average of 26.4 million people have been displaced from their homes by natural disasters every year since 2008 – equivalent to one person every second[1]. It is estimated that 6.5 million premature deaths result every year from exposure to poor air quality linked to energy production processes[2] and 21 of the world's 37 largest aquifers have passed their sustainability tipping point[3]. Greenhouse gas emissions add energy to the Earth's system at a rate

ANALYSIS

equivalent to the detonation of four nuclear bombs every second[4].

Needless to say, environmental and climate challenges translate into social, economic and ultimately political stresses. Migration from the Middle East to Europe has many roots, one of which is the impact of climate change on regional livelihoods, communities and security. Resulting migration into Europe has in turn impacted the political climate, influencing critical turning points such as Brexit and more broadly the rise of political movements averse to the pursuit of global public goods.

The global economy has to pivot towards an inclusive, green, climate-resilient pathway, and quickly. Some vital signs offer optimism: falling costs of clean technology have led to an upsurge in investment, notably in solar energy; and increasingly, planned coal-fired power stations are being shelved, notably in China and now also in India. Low cost battery technology will soon be with us, opening massive opportunities for investments in a new energy system that will deliver clean, low-carbon, distributed power that will light up our homes and hospitals, and drive our cars, trains and eventually our planes. Intersecting and amplifying these developments is the digital revolution that will transform our relationship with our physical world, and our use of natural capital. The 'internet of things' (enabling the cradle-to-cradle digital tracking of everything we produce and use), combined with localised production enabled through automation, holds out the prospect of building circular economies for everything from cars to shirts, enabling us to reduce the use of new natural capital to almost, if not actually, zero.

WHERE ARE THE WEAKNESSES?

Humans' technological prowess however, is matched by our weak track record in creating large-scale collective action for the common good, and our inimical capacity to resist or compete away changes that could benefit us all. An estimated US$5-7 trillion a year is needed to realise the SDGs, mainly for low-carbon, productivity-enhancing and infrastructure investment in developing countries. Yet today, the global US$300 trillion financial system has failed to channel peoples' savings into these investments, profiting more by having them languish in pension funds earning paltry or zero interest rates, and thus threatening the security of tomorrow's pensioners. Indeed, such low interest rates are attributable in large to the efforts of central banks to reboot the global economy through easy money policies that, in practice, have mainly benefited the owners of financial assets. Such owners are the very richest one per cent, whose visible enrichment has underpinned the populist economics that makes international cooperation so difficult.

Realigning the global economy with the SDGs is not like drawing a blueprint for a car, or designing a building.

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ANALYSIS

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Hundreds of billions of transactions every day trade billions of products, made by hundreds of millions of businesses, across hundreds of thousands of different legal and policy jurisdictions. In so complex and dynamic a system even the simplest and best-intended policy measures can have the most unexpected consequences. Reaching agreement at a global level is painfully difficult at best and often seemingly impossible, which illuminates the astonishing success of the Paris Agreement on climate, and the universal embrace of the Goals themselves. Yet making things happen quickly at a greater scale is tough, highlighting the considerable challenge in implementing the Goals and the Paris Agreement in a meaningful timescale.

WHAT DOES THE FUTURE HOLD?

Transforming the global economy, at scale and in time, is possible. Watchers, entrepreneurs and activists might keep their eyes on the following five areas to assess or contribute to progress. Narrative, first and foremost, counts. We need to make the Goals everyone's dashboard, from national accounting to business reporting, and from the teachings in churches, temples and mosques to the curriculum of every classroom. Moreover, such a narrative needs to offer a vision of how success in reaching these Goals can be integral to the next phase of globalisation.

Second, we need to align the global financial system, the lifeblood of the global economy, with the Goals. The UN Environment Programme's Inquiry into Design Options for a Sustainable Financial System, an initiative launched in 2014 to explore how financial and capital markets could more effectively internalise sustainable development into decision-making, has demonstrated beyond any doubt the critical importance of this agenda, and the practicality of advancing it.

Third, we need to harness the power of knowledge, notably the capacity of clean technology to deliver green, zero marginal-cost energy, and the penetrating influence of digital technology. The nexus between the two, for example, has proven potential in delivering distributed renewable energy at scale to poor communities through the use of mobile payment platforms, increasingly combined with big data, crowd-funding and blockchain.

Fourth, we need to reinvent the means to ensure an equitable distribution of income, especially as automation undermines the role of many labour markets in recycling the financial fruits of production. Ideas like 'basic income' for all may have come of age, both for reasons of equity and to secure macroeconomic stability.

Finally, we need to evolve new forms of accountability. The pillars of democracy and good governance are threatened on many fronts, from the dynamics of populism through to the intrusive aspects of big data and artificial intelligence, and, internationally, as multilateralism reinvents itself to meet the challenges of a new era of globalisation. ES

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Encouraging interdisciplinarity beyond the sciences

Robert Ashcroft reflects on the need for cross-sector partnerships to deliver the SDGs and proposes a series of principles for successful collaboration.

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FEATURE

The word 'interdisciplinarity' will be familiar to all scientific researchers, and to those involved in science policy or funding. It is now generally accepted that traditional disciplinary boundaries must become more permeable; in fact, major research funding calls increasingly encourage, if not require, the involvement of researchers from different disciplines.

In 2015 the journal *Nature* ran a special issue on interdisciplinarity. The editors noted that "Done correctly, [interdisciplinary science] is not mere multidisciplinary work – a collection of people tackling a problem using their specific skills – but a synthesis of different approaches into something unique"[1]. The editors go on to argue that "The best interdisciplinary science comes from the realisation that there are pressing questions or problems that cannot be adequately addressed by people from just one discipline". In essence, they imply that the best interdisciplinary research is challenge-led. There are few greater challenges than those encompassed in the Sustainable Development Goals (SDGs, or Goals), and as this issue of the environmental SCIENTIST highlights, science has a key role to play in addressing them.

SUSTAINABLE DEVELOPMENT AND INTERDISCIPLINARITY

Sustainable development has been traditionally understood to have three strands: economic, social, and environmental. These strands are interlinked, but have tended to organise around different disciplinary traditions and concepts, and as such, different languages and world-views have emerged which often characterise work in these sectors. However, sustainable development has, at its core, a recognition of the need for integrated and holistic solutions. Agenda 2030 for Sustainable Development (Agenda 2030) and the SDGs represent an important call to re-engage with this approach[2]. The seventeenth Goal focuses explicitly on developing partnerships to deliver the Goals, and Agenda 2030 highlights that the SDGs must be considered "integrated and indivisible"[2].

Environmental and sustainability scientists are embracing this integration, spanning traditional divides in their work. Indeed, although across the sciences there are undoubtedly issues to be resolved to improve support for this work institutionally, interdisciplinarity is now being recognised as fundamental to the future of research. However, we must ensure that through a focus on interdisciplinary research, we do not confine ourselves to a broader scientific silo. Challenge-led research requires an open and collaborative approach in which scientists represent just one of a diverse group of actors. Tackling grand challenges, or 'wicked problems'[3], will require engagement with stakeholders outside of the scientific research process, and a much greater level of involvement in the negotiation of solutions than the scientific sector has traditionally been comfortable with.

Of course, not all scientists conduct research; applied scientists carry out vital work across industry and government and are more familiar with the need to collaborate across disciplinary and professional boundaries. For applied scientists, translational and negotiating skills are fundamental to their work. There is nevertheless a need for even these professionals to consider their approach to collaboration and how more innovative, productive partnerships could be formed and embedded.

SEEKING CROSS-SECTOR COLLABORATION

In recognition of this challenge, in early 2017 the Institution of Environmental Sciences (IES) began a programme of work seeking to explore the drivers and barriers to cross-professional and interdisciplinary collaboration. This initiative was launched with a workshop at the annual conference of the UK Stakeholders for Sustainable Development (UKSSD). Facilitated by IES Vice-President John Baines, this session was attended by over fifty professionals who are or have been engaged in some way in delivering the SDGs, and were also from a broad range of disciplinary backgrounds. After contributions from three speakers who are breaking free of sustainable development's three traditional strands in their own work, participants were invited to discuss the drivers of and barriers to interdisciplinary collaboration. These group discussions were lively and interesting, with each individual bringing different case studies from their own professional experience. As the session progressed, facilitators encouraged participants to begin to develop a framework for successful collaboration; a set of principles which they felt were important for interdisciplinary partnership building.

The key points raised in these discussions can be usefully broken down into three themes: benefits of collaboration; barriers to effective collaboration; and drivers or catalysts for collaboration.

BENEFITS OF COLLABORATION

It is often considered a truism that collaboration is beneficial (of course working together must be more efficient and effective) but, on reflection, most of us can identify times when working with others has taken a great deal of time to manage and has not delivered the results anticipated. Similarly, some long term collaborations can simply become the norm and go stale, with the initial goals forgotten. Nevertheless, well designed and brokered partnerships can deliver significant benefits, particularly when they bridge or break down disciplinary boundaries. How these partnerships should be managed will be addressed later, but first it is important to consider why they are useful.

Unsurprisingly, our participants highlighted that the pooling of resources on collaborative projects can significantly increase efficiency and impact. This

has always been an important benefit and driver of collaboration. However, in an era of restricted funding, and challenges ever growing in both complexity and magnitude, it becomes even more significant.

Participants also highlighted that successful cross-sector collaborations have often challenged their own thinking, opening their eyes to new methods and approaches. Challenging the *status quo* and embedded organisational routines was identified as the second major benefit of partnership working; these benefits are most pronounced when working with organisations or individuals from outside one's normal sphere of experience. However, these partnerships are more challenging to develop, and require the building of trust and understanding between all parties.

BARRIERS TO EFFECTIVE COLLABORATION

The most commonly cited barrier to collaboration was waiting for the perfect circumstances – many participants agreed that when organisations wait for everything to be perfect, nothing ever happens. Sometimes you just have to start the process.

Translational difficulties were also a common frustration to collaboration, with participants noting that misunderstandings around sector-specific terminology can result in tensions when discussing issues and actions. Developing a shared language around project aims and activities is important, as is fostering an open, learning atmosphere where questions are invited and a joint understanding can be developed.

A related, but perhaps more complex challenge identified by many participants was differences in organisational culture. This was considered to refer to both functional matters, such as team or decision-making structures and flexibility of job roles, and personal factors relating to attitude and approach. Differences in organisational strategy, practical planning, or ethical framework are perhaps products of both institutional and personal cultures within organisations and highlight the complexity of addressing this challenge. Many of the other barriers identified by participants at our workshop were found to be rooted in cultural differences. Building trust between teams and individuals is essential if these challenges are to be overcome.

During projects, participants noted that differing expectations regarding aims and focus can cause friction, and even lead to the failure of partnerships. Even where a clear vision has been established to which all partners are committed, continual review to retain focus and to check project progress against agreed milestones is very important.

DRIVERS AND CATALYSTS FOR COLLABORATION

Much discussion around partnership building tends to focus on structural or institutional factors and processes. Although organisational strategy is undoubtedly important, participants at our workshop emphasised that one of the most important drivers for collaboration is the involvement and leadership of motivated and enthusiastic individuals. These leaders are needed to develop a vision which can motivate others, and can act as partnership brokers both within their own organisations, and beyond. Engaged individuals inevitably play a major role not just in shaping vision, but also in facilitating the trust-building on which successful partnerships are built. Of course, in some cases organisations can quickly identify a shared purpose or ethical framework, easing this process, and indeed sometimes it is these shared principles which bring organisations together to cooperate.

Participants noted that there are numerous 'pull' factors which can drive collaboration; when each party can identify a specific need which could be met by working in partnership, this can be much easier to broker. For instance, identified resource or expertise deficits can drive the development of partnerships for specific purposes, which in some cases can continue to deliver benefits beyond the initially identified requirement.

One alternative driver to the need-based model explored above was a 'challenge-based approach'. In this approach, a specific challenge or mission is identified around which organisations with different skills,

expertise and resources can then coalesce with a shared purpose. In a sense this model is less transactional, and more vision-driven. This model perhaps most closely aligns with the processes of interdisciplinary research which will be familiar to scientists and other researchers, where different skills and expertise are brought together to tackle complex and challenging research problems.

PRINCIPLES FOR COLLABORATION

After analysing in detail the rich material generated by the workshop discussion summarised above, certain key principles began to emerge, regarding both how to establish successful partnerships, and how to maximise the benefits of ongoing collaboration. The framework presented in **Figure 1** attempts to capture these principles across the three stages of project conception, development and delivery. Of course, in successful partnerships there will be significant overlap between these stages, particularly in conception and development, and so this framework should be considered a conceptual model for further debate and discussion; it in no way represents a roadmap for partnership building, which would risk being insufficiently flexible to accommodate the contextual variety which successful partnerships must be sensitive to.

Clearly, in this framework, the process of co-creation and vision development are linked, and trust building should occur alongside, and as an important component of both processes. Similarly, a vision in which all partners feel a degree of ownership, and good working relationships between teams and individuals are important if collaborative projects are to be delivered effectively and reach their potential. It is only through the development of trust that participants in collaborative projects develop the confidence to truly embrace alternative approaches.

However, what this model fails to do is explicitly recognise the importance of motivated individuals in brokering and driving successful cross-sector partnerships. The key role these leaders play has long been recognised in other fields such as protected area management[4].

BROADENING HORIZONS

Returning to *Nature's* 2015 special issue, one article identifies five principles of its own which the authors have used in growing their own interdisciplinary team to tackle environmental and sustainability challenges[5]. These are: (1) forge a shared mission; (2) develop 'T-shaped' researchers (who are "Able to cultivate both their own discipline, and to look beyond it"); (3) nurture constructive dialogue (by avoiding disciplinary jargon, fostering respect for different disciplinary norms and reflecting on what is working in collaborative interactions); (4) give institutional support; and (5) bridge research, policy and practice. Again, parallels emerge here with our own principles for wider cross-sector professional collaborations.

Despite recounting their own success story in building an interdisciplinary team, the authors of the paper note that interdisciplinary research is still on the margins. It could be argued that this is changing, with funding and institutional structures increasingly encouraging collaborative work, but there is undoubtedly further to go. However, to address the wicked problem of sustainability, we must think more ambitiously about interdisciplinarity. We must seek to embed interdisciplinary thinking and principles across society, throughout all sectors and professions. Yes, we must also foster expert knowledge, but we must strive to use it better and more innovatively, in order to achieve the Goals. We hope that the framework presented here will serve to provoke further discussion about how cross-sector collaborations can be better promoted and mainstreamed across our society. We look forward to continuing this debate and developing this model further through our own collaborations and partnerships, including with UKSSD.

Ultimately, reflecting on the Goals as a whole, the inclusion of Goal 17 (Partnerships for the Goals), has provoked welcome discussion about how we strive to achieve these ambitious but essential targets. However, its inclusion still seems somewhat incongruous in the context of this "integrated and indivisible" agenda.

CONCEPTION

PROJECT CO-CREATION

It is important all partners are engaged in identifying the partnership's aims, or the problem to be solved.

TRUST BUILDING

Alongside vision development partners must work to overcome cultural differences by developing a shared language and appreciation for alternative perceptions and approaches.

DEVELOPMENT

A SHARED VISION

Partners must work together to develop a shared vision to which all are committed.

DELIVERY

AGREED RESOURCE EXPECTATIONS

A clear understanding of who will deliver what is important for maintaining the confidence and commitment of all partners.

CONTINUAL REVIEW

Continual review to retain focus and measure progress continual review against agreed milestones is important.

JOINT COMMUNICATIONS STRATEGY

Friction can develop where partners have different expectations regarding external reporting on project progress.

FLEXIBILITY

Whilst milestones are important, partnerships must remain sensitive to changes in the external environment which may require adjustment to planned activities.

▲ **Figure 1. A draft framework for interdisciplinary professional collaboration.**

In practice, partnerships must underpin all of our efforts to achieve these targets, and we must pursue these collaborations with urgency and enthusiasm. Perhaps throughout these discussions we would do well to remember the words of one of our workshop participants: "You can't wait for everything to be perfect - sometimes you just have to get started". ES

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Physics education in sub-Saharan Africa

Linsey Clark highlights the work of the Institute of Physics in bringing sustainable socioeconomic benefits to developing countries.

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At the Institute of Physics, we are host to a wealth of knowledge in science policy, public engagement, diversity, degree accreditation, and in particular, physics education.

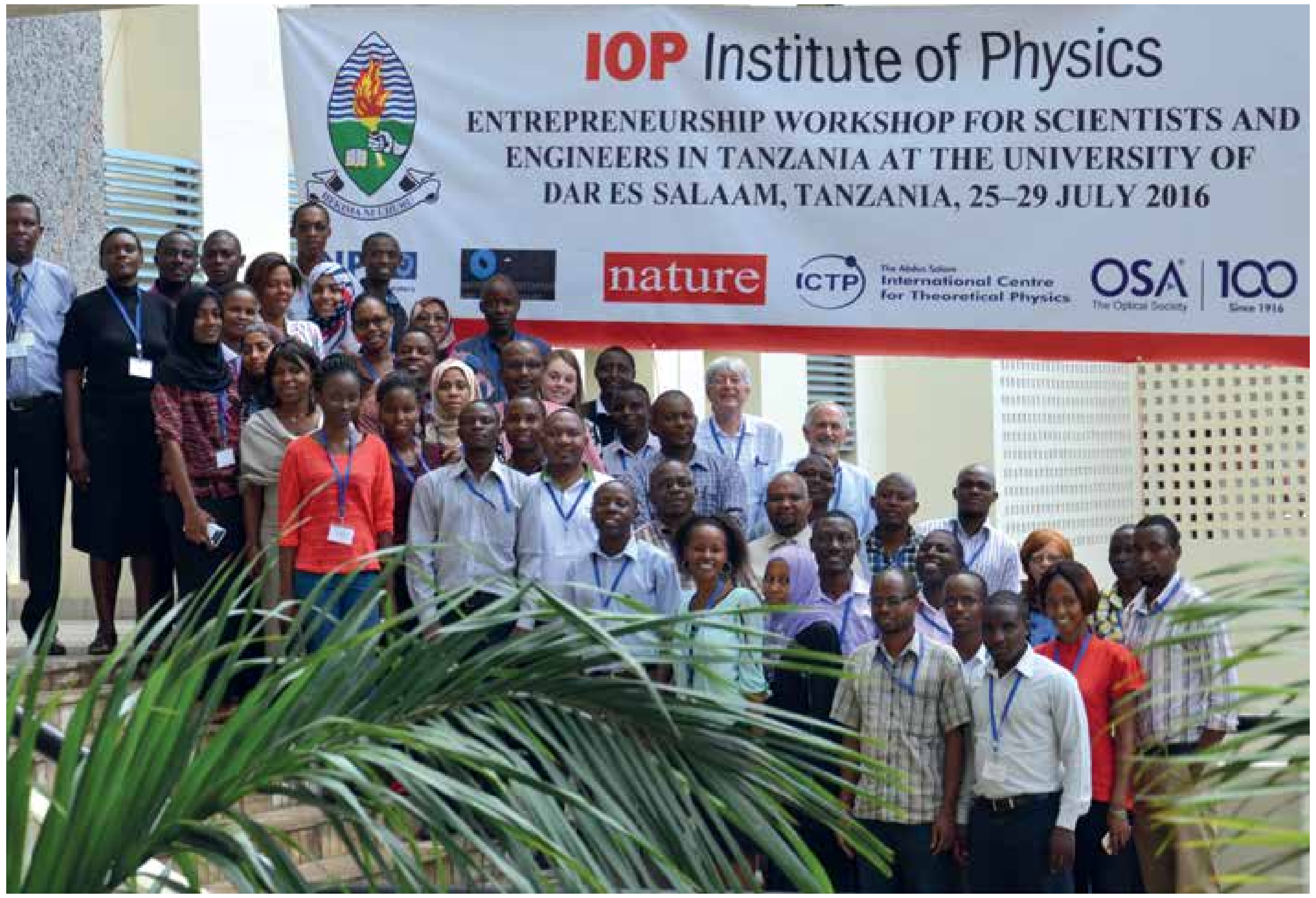
Our community of members from all over the world are engaged in various activities to further the discipline, from organising conferences and workshops, through to promoting interaction between academia and industry, and to recognising and awarding excellence. That puts us in an especially strong position to be able to draw on our expertise to work with international and local partners, so that we can develop scientific capacity in low and middle income countries. This work cuts across many of the Sustainable Development Goals (SDGs, or Goals). Physics and the society-changing innovations it spawns will be increasingly at the forefront of sustainable development in the future: physics is a global driver for change.

The specific Goal most directly relevant to the Institute of Physics' (IOP) international programme is Goal 4 (Quality Education), which has been created to "Ensure inclusive and equitable education and promote lifelong learning opportunities for all". The current programme contributes to Goal 4 in three principle ways: through the practical physics teacher training project, workshops on entrepreneurship for scientists and engineers in developing countries, and via the establishment of a Science Technology Engineering and Mathematics (STEM) Centre of Excellence in Mtwara, Tanzania.

WHY PHYSICS IS IMPORTANT

The IOP's approach to international development is based on the particular context in which we operate – why physics education matters and the way it typically falls short of its full potential. We see time and time again how physics-based technologies improve all our lives, sometimes by revolution, often simply by evolution. But turning a discovery on the laboratory bench into a product on a store shelf isn't necessarily a straightforward or intuitive process. And on a more basic level, creating a strong science and engineering base allows any country to solve its own problems, and address its own challenges without having to import expertise from elsewhere, often

CASE STUDY



▲ **Figure 1. An IOP entrepreneurship workshop in 2016 in Dar es Salaam. (© IOP)**

at considerable expense. This also has a knock-on effect and contributes to several of the other SDGs – Goal 7 (Affordable and Clean Energy); Goal 8 (Decent Work and Economic Growth; and Goal 9 (Industry, Innovation and Infrastructure) – by empowering people to find and work towards their own solutions.

Building that science base, of course, requires a supply of scientifically qualified people, making education a natural priority. This isn't always easy in the developing world, with rurally based populations, a paucity of equipment, and the lack of a teacher training pipeline all combining to form obstacles. But these barriers are far from insurmountable, and the three strands of the IOP's international work described below tackle these various concerns in specific ways.

TRAINING FOR PHYSICS TEACHERS

In many parts of sub-Saharan Africa, science is learnt without a sufficient understanding of its possible applications. Experimental work offers such an understanding to the students. It is essential in relating theory to real life, developing a thorough understanding of concepts, and offers information beyond that required merely to get through an exam.

There is little or no experimental equipment in many parts of Africa and this can be even more problematic when teaching physics than for the other sciences; for example, it is challenging to explain about electricity without a reliable power supply. Meanwhile, classes are large, often with as many as 100 students sharing a classroom, and although science education is valued, budgets are small and pay is low, meaning it is hard to recruit and retain the best graduates into teaching.

The IOP's practical physics teacher training project aims to change this by providing practical teacher training in Ghana, South Africa and Tanzania, with a focus on simple experiments that can be transferred to the classroom. The idea is that by supporting teachers and teacher-trainers (who then transfer the knowledge gained to their students), we can continue the cycle of learning in schools. This involves facilitating training for local teachers to enhance their subject knowledge and their practical skills, providing information and communication technology and experimental equipment, setting up local resource centres available to communities within a broad area, and encouraging students to make the most of the opportunities physics has to offer. To help make sure that all these efforts are maintainable, the IOP also provides training to local craftsmen to build experimental equipment and manage the resource centres, facilitating self-sustainability and enhancing employment prospects.

We have successfully run similar projects for more than a decade, but are currently focusing our efforts on a smaller number of countries, and allowing local organisations to build on what we began in others. By doing this we hope to be able to open many doors for people, and create lasting change.

ENTREPRENEURSHIP FOR SCIENTISTS AND ENGINEERS

IOP workshops on entrepreneurship (**Figures 1, 2** and **3**) are intended to close skills gaps for scientists and engineers who are very knowledgeable in their chosen subject, but who don't have the expertise to turn ideas or research into a viable commercial enterprise.

Our work in this area began back in 2005 with the World Conference on Physics for Sustainable Development, organised in Durban by the International Union for Pure and Applied Physics, which brought together scientists from developed and developing countries. Several priority areas were identified at the conference as most relevant to the needs of developing countries and the IOP was charged with taking the lead on physics and economic development. It was recognised that, for developing countries to receive social and economic benefits from entrepreneurship, greater education and training for science and engineering students was a useful tool for sustainable growth.

It is perhaps unsurprising that skills gaps in this area were identified. While scientists have strong ideas – it is a fundamental part of the job after all – the world of business is often as much a mystery to them as the nuances of quantum mechanics are to your average Chief Executive.

Working in collaboration with the Abdus Salam International Centre for Theoretical Physics, the IOP co-sponsored a pilot workshop in Trieste in 2006, which established a programme of at least two workshops a year to promote the role of physics in generating a knowledge-based economy. This has helped participants to develop the skills needed to commercialise their ideas and bring them to market. A number of sessions in each workshop are tailored to relate to situations in the host country. For example, a recent entrepreneurial workshop in Tanzania included sessions from government departments, an incubator production company based in Dar es Salaam, and the local patent office.

To date, a few dozen workshops have been held in scores of countries. They have reached hundreds of scientists and engineers, helping them to bridge the gap between science and business by teaching them about intellectual property, business plans, finance

▲ **Figure 2. An introduction to entrepreneurship workshop in Tanzania. (© IOP)** options, and much more (**Figure 4**). Furthermore, the workshops encourage productive employment through the formation of businesses, and as a consequence, the creation of local jobs – indeed, the notion of job-creation is constantly highlighted during the workshops. Many participants have gone on to start viable businesses, with commercialisations ranging from quantum cryptography to sensor technology for mobile applications and hardware.

A STEM CENTRE OF EXCELLENCE

A budding example of a concentrated effort in a specific area is the project being led by the African Institute for Mathematical Sciences (AIMS) in Tanzania, which is being supported by several other national and international organisations including the IOP. AIMS is working to establish a STEM Centre of Excellence in the Mtwara region of Tanzania. This has been funded by the natural gas exploration company BG Tanzania, and again, it is intended that this will promote the importance of education and create a place where STEM education can be supported in a sustainable way. This Centre will build on past projects in, use existing knowledge, expertise and contacts, and will make use of the IOP's extensive experience of physics education and teacher training.

Efforts to establish the Centre are based on three distinct phases:

- Phase 1 will clarify expectations and commitments of the Mtwara Teacher Training College and the local government, and formulate a range of options for getting the Centre up and running.

- Phase 2 will develop the chosen option into a specific and detailed plan for providing high quality teacher training, outline how the Centre will deliver this training, and provide estimated costs and strategies to develop the most appropriate resources.

- Phase 3 will develop a sustainability plan to ensure long term funding with a menu of options for organisations to sponsor.

We are also planning to use our teacher training work in Tanzania to feed into how the Centre is run, such as using low cost experiments within schools and to train teachers. We have many years' experience in this area that we can use to inform other projects in the future.

A SUSTAINABLE FUTURE THROUGH PHYSICS

Overall, the work within the IOP's capacity building programme to make a significant difference to education around the globe, fits well with the wider objectives expounded by the Goals. We will continue to develop and improve these programmes further based on lessons learnt. We will also continue to work with partners to expand our reach to develop sustainable programmes in a variety of low and middle-income countries, thus helping as many people as possible to benefit from the opportunities that science and technology can offer. ES

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▲ **Figure 3. An IOP entrepreneurship workshop in Brazil. (© ICTP-SAIFR)**

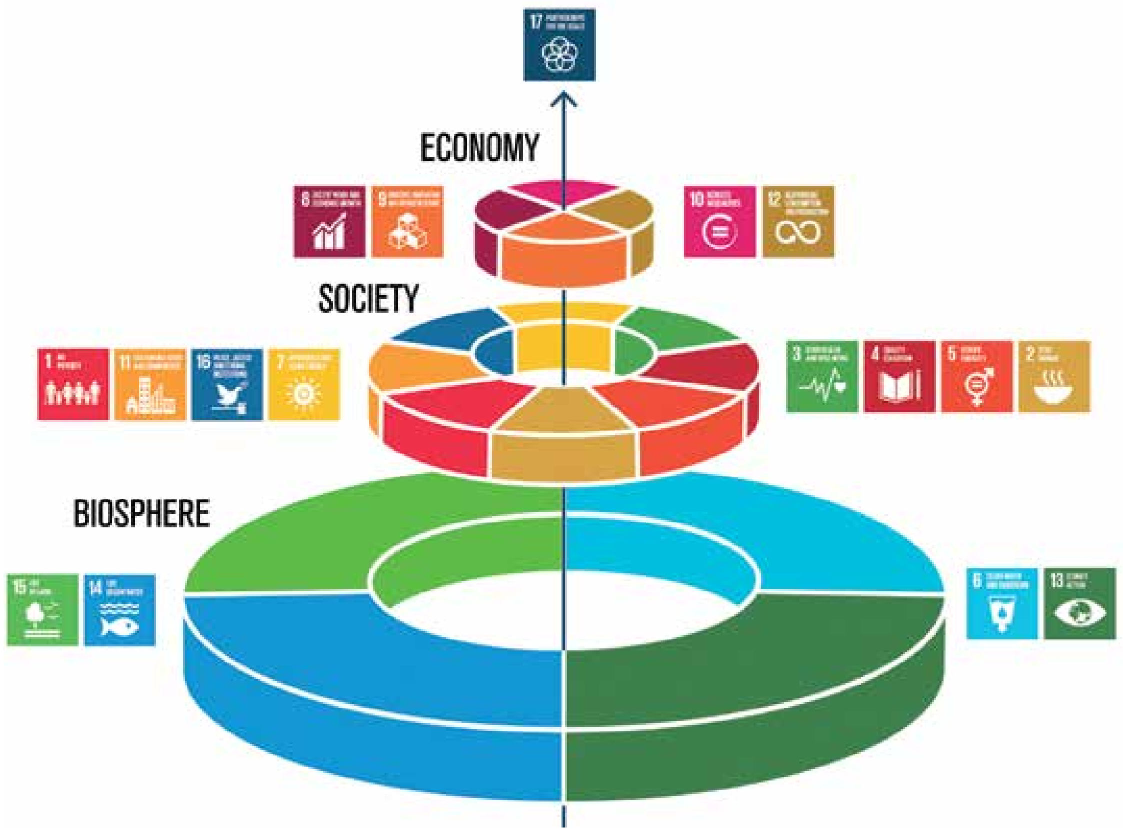
▲ **Figure 4. A science communication workshop in Dar es Salaam. (© IOP)**

Data challenges for the Sustainable Development Goals

Mario Hernandez considers methods and difficulties of measuring global performance towards the Goals.

It is a sunny day in Mexico 1968. Eight runners are ready to run the 100 metre race at the Olympic Games. Everyone in the stadium knows that the 10 seconds record, or indicator, may be a limit for humankind - but after 9.95 seconds, for the first time ever, a human being was able to run 100 metres below the previous record (indicator) of 10 seconds.

In 1997, the Organisation for Economic Co-operation and Development (OECD) Programme for International Student Assessment (PISA), was created. It represents a commitment by the governments of OECD countries to monitor the outcomes of education systems, in terms of student achievement, within a common, internationally agreed framework. Policy makers



▲ **Figure 1. Dividing the SDGs into Biosphere, Society and Economy. Credit: Johan Rockström and Pavan Sukhdev, who present this new way of viewing the SDGs. (© Azote Images for Stockholm Resilience Centre[2])**

▲ **Figure 2a. Satellite image of Shanghi, China, in April 1984. (Source: NASA Earth Observatory "Sprawling Shanghai" by Adam Voiland. © NASA)**

1.	Singapore
2.	Japan
3.	Estonia
4.	Chinese Taipei
5.	Finland
6.	Macao (China)
7.	Canada
8.	Viet Nam
9.	Hong Kong (China)
10.	B-S-J-G (China)

▲ **Table 1. OECD/PISA snapshot of performance in science, reading and mathematics (only the first 10 countries are shown). Source: OECD[1]**

around the world use the PISA indicators to: gauge the knowledge and skills of students in their own country/economy in comparison with those in other participating countries; establish benchmarks for improvements in the education provided and/or in learning outcomes; and understand the relative strengths and weaknesses of their own education systems. As a result, the indicators of PISA have created 'healthy competition' amongst countries, with most of them trying to improve their national educational systems in order to obtain a higher rank within the PISA indicators[1] (**Table 1**).

On the 1st January 2016, the world officially began implementation of the 2030 Agenda for Sustainable Development – the transformative plan of action based on 17 Sustainable Development Goals (SDGs, or Goals) – to address urgent global challenges over the next 15 years. This agenda is a road map for people and the planet that will build on the success of the Millennium Development Goals, and ensure sustainable social and economic progress worldwide. It seeks not only to eradicate extreme poverty, but also to integrate and balance the three dimensions of sustainable development – economic, social and environmental – in a comprehensive global vision. In order to measure progress, a global indicator framework was developed by the Inter-Agency and Expert Group on Sustainable Development Goal Indicators (IAEG-SDGs). Through an excellent participative exercise, this international effort allows governments to play a key role in developing and implementing an effective monitoring framework for the SDGs. A total of 232 indicators were defined. Some experts point out that the total number of indicators listed in the revised global list of indicators is 244, however as nine indicators repeat in some targets, the actual total number of unique indicators in the list is 232.

▲ **Figure 2b. Satellite image of Shanghi, China, in June 2016. (Source: NASA Earth Observatory "Sprawling Shanghai" by Adam Voiland. © NASA)**

Similar to the record of 10 seconds, as an indicator for the 100 metre race or the OECD/PISA indicators for education, world agreement on 232 indicators to measure progress towards sustainability allows us to have a framework for measurement. The 'indicator' of the 100 metre world record run is relatively easy to measure, but the indicators for the SDGs will be very complex to develop and measure. They will require timely and reliable disaggregated data. These data requirements for the global indicators are almost as unprecedented as the SDGs themselves and constitute a tremendous challenge to all countries. Nevertheless, fulfilling these requirements through building national statistical capacity is an essential step in establishing where we are now.

What is questionable is whether we have all the data necessary, and whether we can measure all countries equally with the same set of indicators, knowing that the data quality differs significantly amongst countries.

HOW DO WE MEASURE GLOBAL PERFORMANCE?

It is important to understand that all SDGs are interlinked and these nexus are extremely important. For example, in countries which economies are mostly based on the use of natural resources, the local society should exploit the biosphere in a sustainable form, in order to contribute to the national economy. In this way, the three elements of biosphere, society and economy are interlinked. In order to better illustrate our purpose, we use the excellent scheme of the Stockholm Resilience Centre, who divide the SDGs as shown in **Figure 1.**

Let us then try to describe the associated data that we have for each of the components. Starting with the biosphere, we do not have any tools to accurately measure the number of individuals of each of the flora and fauna species of the earth. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species™[3] is widely recognised as the most comprehensive, objective global approach for evaluating the conservation status of plant and animal species. New scientific approaches consider that

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maybe we should not just concentrate on the number of a species in an ecosystem, but equally important to keeping an ecosystem healthy and resilient are the species' different characteristics and the things they can do, measured in terms of specific traits like body size or branch length.

Contrary to the lack of tools to measure species or associated species-health, in some areas such as monitoring the changes in the Earth's ecosystems, humankind has made tremendous progress in developing appropriate monitoring tools. Since 1972, satellite sensors have been acquiring data about our planet. Earth observation satellites, combined with the international work of the Group on Earth Observation (GEO/GEOSS), have provided terabytes of data which are easily accessible for any part of the world. For example, satellites are providing continuous and coherent data that is being used to better manage human settlements. **Figures 2a** and **2b** show the growth of Shanghai between 1984 and 2016. Developed areas appear grey and white; farmland and forests are green; and shallow, sediment-filled water is tan. Assessment of satellite images shows that Shanghai had 308 km^2 of urban area in 1984. By 2014, the number was 1,302 km^2. As summarised by the IAEG-SDGs[4], the tremendous advantage of having similar sensors monitoring the Earth means that the satellite data is:

- **Consistent**: global monitoring over the 15-year time span of the SDGs, for any country in the world, regardless of that country's Gross Domestic Product (GDP).
- **Trustworthy:** reliable recording and reporting of data.
- **Transboundary:** data from national to basin scale.
- **Transparent:** the weaknesses and strengths of methodologies are identified.
- **Verifiable:** the information can be traced to its origin.
- **Feasible:** the data can be recorded in a practical and realistic way.
- **Pragmatic:** the collected data and methodology used for the indicators can be used for strategy planning, awareness raising, risk assessment and the development of policies.
- **History:** long-term trend analysis, for example, climate change.
- **Sustainable:** open and free operational data.

Ideally we would like all data, not only satellite data, to be consistent, reliable and transboundary – all of the above. Only then we would be able to compare environmental data (biosphere) with socioeconomic data.

Unfortunately this is by far not the case for social data. It is extremely difficult to obtain and periodically update census data: countries are not consistent in their methodologies; some data is unreliable; data is not transboundary nor verifiable; sometimes weaknesses are not identified or cannot be disaggregated; and as data is administratively based, it is difficult to know exactly where the people are. This is the biggest challenge that we will face in order to accurately report on the SDGs indicators.

CITIZEN PARTICIPATION

Fortunately, similar to satellites, citizens now have their own sensors in their smartphones; our messages are sent through social media, and our position is recorded alongside our activities (e.g. use of credit card, items that we buy, and where we move during the day). New 'Big Data' technologies could enable us to make use of all this information, for example in order to know how certain populations are moving to work and where are they gathering at a certain times of the day. This information would tremendously enrich the social data needed to measure against the SDGs indicators. Unfortunately most of this information is in the hands of commercial companies and as they are very much aware of the value of this data, they will not make it freely accessible. Furthermore, there are a series of related ethical and privacy issues that we will need to take into consideration. Therefore, a full societal transformation is first required so that we can make use of these new emerging sources of information.

With respect to economy, countries have made significant efforts to measure their own national economic outputs. By agreeing to the SDGs, countries have pledged to leave 'no one behind'. This implies that it will be necessary to disaggregate the current economic data in order to be able to identify income, sex, age, race, ethnicity, migratory status, disability and geographic location. This is a challenge for all of the SDGs.

WHO IS PULLING THEIR WEIGHT?

Finally, amongst the indicators we will need to include the efforts made by each country to get the most accurate data possible. As an anecdote, when I was working for the World Heritage Convention, countries were requested to report about the state of conservation of their properties. Some countries did not make any particular effort and they just reported that everything was fine, but Germany, for example, invested a tremendous effort and reported a large amount of detailed information for each property. If these reports are not assessed carefully, it seems that a country that has not made any effort and is reporting "no problems" is doing much better than a country that is putting in a tremendous effort, and as a consequence is providing a very detailed list of minor issues. Let us consider Goal 14 (Life Below Water): in relation with good coastal monitoring practices, the US National Oceanic and Atmospheric Administration (NOAA) removed 198 kg of derelict fishing floats and gear, plastics, and one tyre in a Hawaiian bay, in only a couple of hours. While this shows that NOAA is putting in an excellent effort in identifying and removing internationally produced waste, these types of results should not mislead us in concluding that NOAA is doing badly with respect to Goal 14; all efforts should be encouraged and those not putting any effort should be identified.

The framework of the indicators for the SDGs is an extraordinary start and science needs to support it by becoming a full partner. The process is far from perfect, and therefore the international community should take advantage of the expertise and results of key international programmes and international activities. Amongst them are the United Nations, GEO/GEOSS, the US National Aeronautics and Space Administration, the European Space Agency, the Center for International Earth Science Information Network, the Committee on Data for Science and Technology, the World Data Systems and Future Earth. It is becoming confusing to have so many initiatives running in parallel; improved coordination will be required. Slowly, with the joint effort of everyone, we might be able to put together the best datasets to measure progress in making our use of the planet sustainable. ES

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ANALYSIS

ANALYSIS

The scientific and technological community in the Sustainable Development Goal process

Ruben Zondervan considers the engagement of the scientific community with the UN SDG negotiations, and how science could be better incorporated in this process.

A functioning international science-policy interface will be essential for the implementation of the 2030 Agenda for Sustainable Development and achieving the Sustainable Development Goals (SDGs, or Goals). The science-policy interface is a process between scientists and policy makers that aims to exchange and develop knowledge in order to improve policy decisions, often in combination with efforts to increase the policy relevance of research. Since the 2012 United Nations (UN) Conference on Sustainable Development (Rio+20) when the idea for the SDGs was first placed on the international agenda and their subsequent adoption in September 2015, it has been realised that the science-policy interface is far from what it should be.

This article reviews the role of the science community, as represented in the UN system by the Scientific and Technological Major Group, during the UN Open Working Group (OWG) process. The latter was the main intergovernmental process for the development of the Goals between the Rio+20 and the 2015 UN Sustainable Development Summit.

HISTORICAL CONTEXT

In the early days of global sustainable development policies, the 1972 UN Conference on the Human Environment stated that science and technology must be applied to the identification, avoidance and control of environmental risks, and the solution of environmental problems for the common good of mankind, as well as that of scientific research; development must be promoted and the free flow of up-to-date scientific information and transfer of the experience must be supported[1]. In 1992, the UN Conference on Environment and Development in Rio de Janeiro repeated the call to states to cooperate to strengthen capacity building for sustainable development by: improving scientific understanding through exchanges of scientific and technological knowledge; making science more accessible; and contributing effectively to the decision-making processes concerning environment and development[2]. A further twenty years later, Rio+20 repeated these calls and emphasised the need to strengthen the science-policy interface and for inclusive, evidence-based and transparent scientific assessments to be conducted[3].

ANALYSIS

Major Group	Number of Statements for OWG 1-13
Business and Industry	16
Children and Youth	14
Farmers	2
Indigenous people	10
Local authorities	20
NGOs	17
Scientific and Technological	10
Women	45
Workers and Trade Unions	7

▲ **Table 1. Number of formal interventions per Major Group in the Open Working Group process.**

Speaker Category	Number of Statements
Member States	227
UN	28
Other international organisations	19
Multinational corporations	12
NGOs/International NGOs	11
Banks	6
Foundations	5
Major Groups	4
Others	7

▲ **Table 2. Number of formal interventions per category of speakers at the 2015 UN Sustainable Development Summit.**

Rio+20 also agreed on a process to develop the SDGs through the UN OWG; the full involvement of relevant stakeholders and expertise from civil society, the scientific community and the UN[3] had to be ensured. In the policy area of sustainable development, this meant a leading, though not exclusive role, for the UN Major Groups.

The Major Group system was an outcome of the 1992 UN Conference on Environment and Development. Nine sectors of society were identified as the main channels through which broad participation would be facilitated in activities relating to sustainable development. Like any other element in the intergovernmental negotiation process, UN Member States ultimately decide upon the modalities of participation which are coordinated by the UN Department of Economic and Social Affairs/ Division for Sustainable Development, in collaboration with the 'Organizing Partners'. For the Scientific and Technological Major Group, the Organizing Partners are the International Council for Science (ICSU), the World Federation of Engineering Organisations, and the International Social Science Council (ISSC).

A MISSED CHANCE FOR SCIENTIFIC CONTRIBUTION?

With the need for and importance of science consistently included in all conference declarations since the initial 1972 UN Conference on the Human Environment, and through a formal role in the OWG process, the Scientific and Technological Major Group was in a good starting position to feed state-of-the-art scientific knowledge into the intergovernmental negotiations that shaped the SDGs.

A quick glance at some numbers in **Table 1** indicates however, that this opportunity was unfortunately not fully utilised.

The ten statements made by the Scientific and Technological Major Group were not spread out evenly over the thirteen different sessions. Instead, two were made at the fifth session (OWG5), four at OWG8, three at OWG11 and one statement at OWG12. The ten statements covered four of the thematic areas of the OWG: Sustained and Inclusive Growth; Energy; Oceans and Seas; and Forests and Biodiversity. Given the 26 thematic areas, this limitation is disappointing, not least because a scientific contribution was relevant and needed for all of the thematic areas. Furthermore, unlike most other Major Groups, the Scientific and Technological Major Group did not contribute to the compilation summaries created after some of the OWG sessions.

The Goals were adopted as part of 2030 Agenda for Sustainable Development at the 2015 UN Sustainable Development Summit and convened as a high-level plenary meeting of the UN General Assembly. This Summit admittedly was a celebratory event and anything but an occasion to promote the role of science or bring to bear scientific knowledge into the policy process. Nevertheless, the complete absence of any statements on behalf of the scientific community or institution is noteworthy (see **Table 2**).

FROM STATEMENTS TO IMPACT

Obviously, the quantity of statements has no direct correlation with quality or impact. However, the number indicates a comparatively low level of active engagement by the science and technology community, though one could certainly argue that it is unfair to assess the efforts of the scientific community by the number of statements they submit. The same community was engaged intensively with the process through production of policy briefs, position papers, hosting of side-events, providing scientific advice to delegations and UN entities, and through other channels and bodies than the Major Group.

There are however two aspects that indirectly link quantity of statements to impact. The first link between quantity and impact is institutional. The whole Major Group system is flawed with design errors resulting in serious questions about its inclusiveness and accountability. But despite the structural problems with the Major Group system, which can neither be brushed aside nor be easily be resolved, it is the only formal mechanism for stakeholders' input into the process; a mechanism which took stakeholders years of efforts, and some luck, to get established. And it is a mechanism that, despite its flaws, seems able to facilitate the inclusion of stakeholder interests in the intergovernmental processes[4].

Beyond the Major Groups, an 'acronym soup' is being concocted with the likes of the Secretary General's Scientific Advisory Board (UNSG SAB), the Sustainable Development Solutions Network (SDSN), and the various high-level advisory groups. The issues with all of these however, is that they have no formal role or rights in the intergovernmental negotiation process – the place that in the end matters most – and that their influence or even mere existence, depends on the grace of the Secretary General or the willingness of the UN system and Member States to listen to them. The willingness by Member States to listen to the Major Groups sometimes too comes under pressure from states with limited interest in the inclusion of stakeholders' perspectives. The institutionalised embedding of the Major Groups in the process however, makes this formal mechanism quite resilient to political pressure.

It is, or should be, therefore of crucial interest to all constituencies represented in the nine Major Groups to ensure that this mechanism, despite its flaws, is used and thereby maintained. The less activity in this mechanism, the more it will erode and potentially see its resilience crumble.

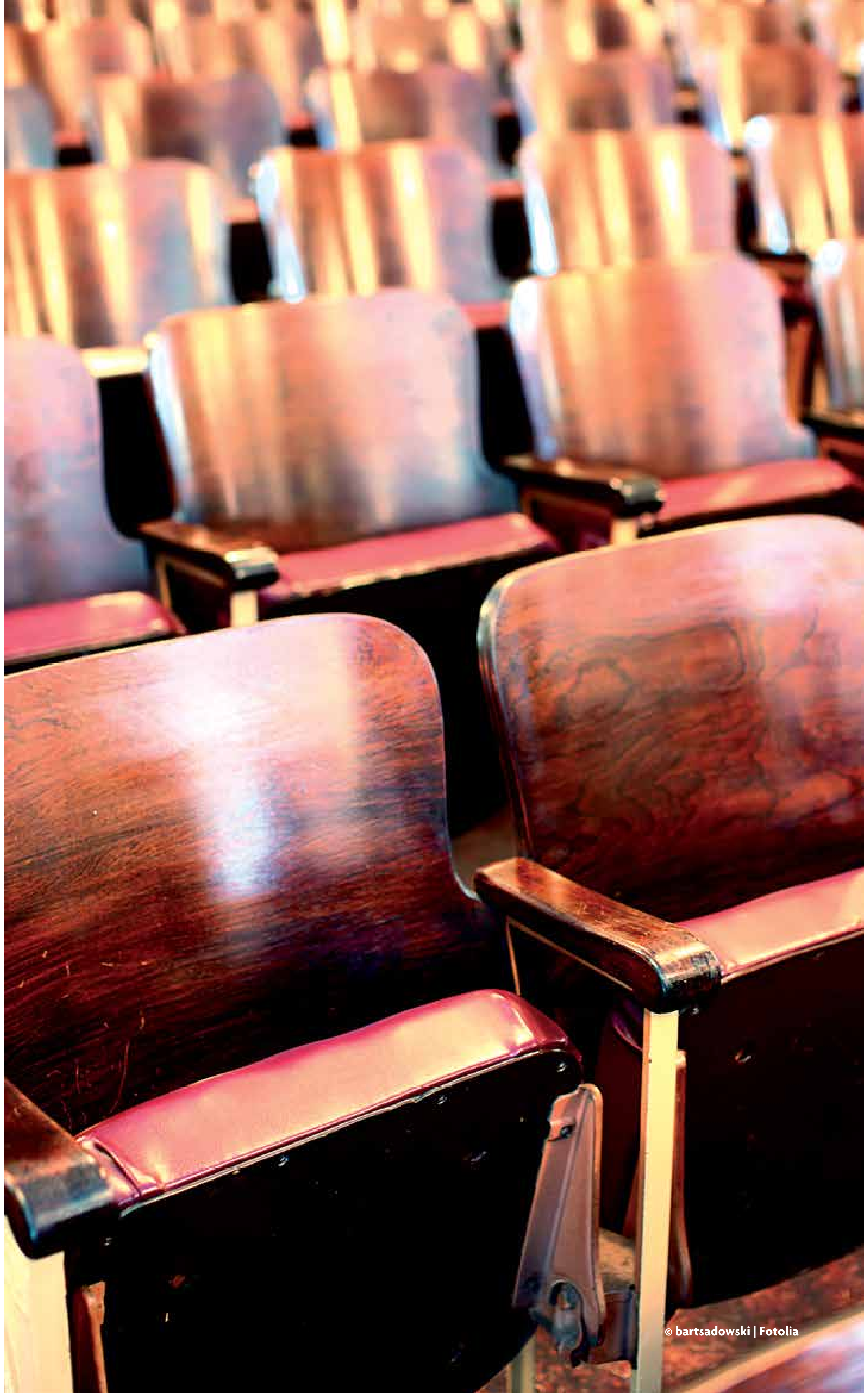
The second link between quantity and impact is procedural. In addition to being a contribution to an active Major Group system, a statement by the Scientific and Technological Major Group has two additional functions. First, it shows to the constituency that the Major Group is actually striving to represent its interest (and thereby increasing its legitimacy), and that scientists are willing to engage in its work or at least take note of and interest in the respective policy processes. Second, and more importantly, the statements (despite on average two minutes only) also indicate to the negotiators that the constituency has an interest in and wants to contribute to the agenda at hand.

Regardless of how good and how well-tailored to the actual negotiations the statement is, a single two minute statement will not, as such, do much in terms of impact. A series of consistent, well-crafted and agenda-relevant statements at all opportunities will have greater impact. Providing statements at each session however also means building trust and recognition with the negotiators and other actors, and building institutional knowledge of the policy process within the Major Group. One also needs to take into account that having a representative of a Major Group at a statement reading, usually means having at least that person, if not even a small delegation, present during the entire session and thus being available for follow-up conversations. Having established trust and recognition will make this work 'in the corridors' much more effective. From this perspective, the simple number of statements is a not only a solid proxy for the overall activity level of a Major Group, but also indirectly for its impact.

STRENGTHENING THE SCIENCE

A review from a scientific perspective of the targets for the SDGs undertaken by ISSC and ICSU (though not in their capacity as coordinating partners of the Major Group) concluded that out of 169 targets underpinning the 17 Goals, 49 (29 per cent) are considered well developed, 91 targets (54 per cent) could be strengthened by being more specific, and 29 (17 per cent) require significant work[5]. To be clear, the Goals were never intended to be a set of priorities derived from a rigorous scientific analysis, or to be formulated according to state-of-art scientific knowledge. This however, does not relieve the scientific community in general, and the Scientific and Technological Major Group in particular, from making the best efforts to feed scientific knowledge into their processes.

There are many aspects of the science-policy interface regarding the SDGs that could and should be improved, many of them independent of the Major Group. There are also several aspects of the Major Group that could be improved[6]. But as the above reflections on the, at best, moderate activity levels of the Scientific and Technological Major Group in the OWG process show, there is one simple improvement which could be made without any significant change to the Major Group and one that would be independent of any external dynamics: attendance of and activity during the formal sessions. While the OWG process has been completed, the annual High-Level Political Forum meetings on the Goals, as well as other intergovernmental meetings on sustainable development like the UN Environment Assembly, are opportunities *par*



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excellence for the Scientific and Technological Major Group to improve its impact simply by being there and active.

Improved attendance and activity would require moderate additional resources, but also a slight change in mentality in the scientific community in understanding the political process would help. Scientific knowledge in some sense can be seen as a special commodity. However, scientific institutions like the Scientific and Technological Major Group are just actors amongst many others in the policy process. It is not enough to point out the value of the content that scientific actors can contribute; but also the delivery of that content has to be much more aligned with the 'policy game'.

Increased activity is just an incremental improvement that neither addresses underlying structural deficits, nor significantly and systemically advances or changes the role, quality, and impact of the scientific community in the science-policy interface for the implementation of the Goals. However, with only 13 years remaining to achieve the Goals, this is not a long time in the scientific realm; we can no longer ignore the 'low hanging fruit'. **ES**

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Repurposing business around the meeting of human needs

Dr Mark Everard debates how consideration of the SDGs in the product life cycle of PVC can ultimately positively impact on global wellbeing.

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FEATURE

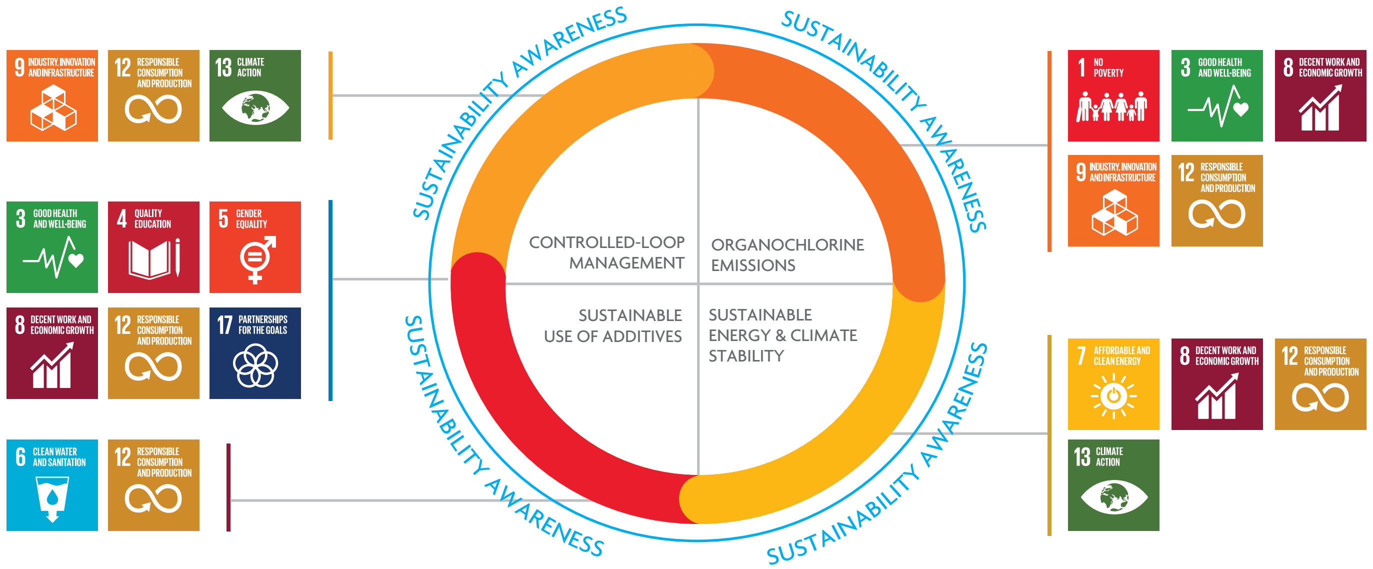
The polyvinyl chloride (PVC) macromolecule, discovered in the nineteenth century and first patented in Germany in 1913, found early uses in the United States as a rubber replacement and, during the Second World War, as insulation for wires on ships. Largely due to its adaptability, low cost, chemical resistance, durability, processability and inherent recyclability, PVC plastic (also known as vinyl) is today the third largest-selling plastic globally after polyethylene and polypropylene. However, in the 1990s the PVC industry did not enjoy the greatest environmental reputation, in part due to what in hindsight were lax practices, but also related to its association with chlorine chemistry.

In a tale told elsewhere, the UK PVC industry came to recognise that sustainable development – linking social and environmental with economic progress – was fundamental to the survival of a business sector under intense non-governmental organisation (NGO) and media pressure. The Natural Step (TNS), a science-based sustainable development NGO, was asked to address the current state of sustainability of the industry and its products, and the steps necessary to engage seriously with sustainable development. A report published in 2000 summarised five TNS sustainability challenges for the PVC industry (see **Box 1**).

BOX 1: THE FIVE TNS SUSTAINABLE DEVELOPMENT CHALLENGES FOR THE PVC INDUSTRY

1. The industry should commit itself long term to becoming carbon-neutral.
2. The industry should commit itself long term to a controlled-loop system of PVC waste.
3. The industry should commit itself long term to ensuring that releases of persistent organic compounds from the whole life cycle do not result in systemic increases in concentration in nature.
4. The industry should review the use of all additives consistent with attaining full sustainability, and especially commit to phasing out long term substances that can accumulate in nature or where there is reasonable doubt regarding toxic effects.
5. The industry should commit to the raising of awareness about sustainable development across the industry, and the inclusion of all participants in its achievement.

To cut a very long story short, these five challenges were accepted and actively engaged with by those pioneering industry players. They have subsequently progressed to underpin today's VinylPlus®[1] voluntary commitment amongst the entire PVC industry (**Figure 1**), including its suppliers, at European Union (EU)-28 level.



▲ **Figure 1. The five commitments of VinylPlus® (Source: VinylPlus Progress Report[2])**

THE SHIFTING SUSTAINABLE DEVELOPMENT NARRATIVE

The Brundtland Commission's 1987 framing of sustainable development embodied a powerful intergenerational commitment to the meeting of human needs. However, its subsequent embedding in regulation and chemical sector management tools has fallen well short of this ideal. Life Cycle Assessment (LCA) and Environmental Product Declarations (EPD) tools, and regulations such as the EU's Registration Evaluation Authorisation and Restriction of Chemicals (REACH), tend to focus on adverse impacts. In essence, the focus is on how 'bad' chemicals may be for the environment and human health. Furthermore, impact is often simplistically addressed as potential hazard rather than risk, taking account of exposure and stewardship. Though it remains important to understand and reduce such negative impacts, the focus on meeting human needs has been lost in transposition.

The study of human needs has a long history. The work of Abram Maslow, recognising a 'hierarchy of needs'[3,4], was seminal. Manfred Max-Neef and colleagues took a less hierarchical view of an otherwise broadly similar set of needs, adding to this that a range of 'satisfiers' (physical things, settings, qualities and actions) was equally necessary to fulfil them[5]. In essence, 'stuff' is necessary to satisfy human needs, such as a roof for shelter and pipes for the conveyance of clean water and sanitation.

It is here that the United Nation's (UN) 17 Sustainable Development Goals (SDGs, or Goals) make a welcome addition to limitations in what had become a limited but widely accepted sustainable development narrative, redirecting the primary focus to meeting diverse human needs. The debate then turns to how can these needs be met with appropriate 'satisfiers' on a sustainable basis.

SYSTEMIC UNDERSTANDING

The SDGs have to be understood in a systemic context. This entails addressing all Goals as an inherently interconnected set, rather than 'cherry picking' a favoured subset. It also involves ensuring that development works for all people; as the UN Development Programme (UNDP) describes it "Meeting citizens' aspirations for peace, prosperity, and wellbeing, and to preserve our planet"[6].

It could be easy for a company, value chain or other institution to fall into the trap of selecting just a few Goals; a 'siloed' approach that rather misses their systemic framing. For their effective implementation, but also as a spur to innovation, it is important that all the SDGs are considered as an interconnected and intimately interdependent suite. Major opportunities arise from addressing them thus in an integrated way.

PVC, PIPES, EQUALITY AND IMPROVING WELLBEING

To illustrate the importance and potential benefits of a systemic approach for society as a whole, and in this case, also the PVC value chain, we can look at an example; PVC pipes (**Figure 2**). We can simplify the argument for the product by addressing high-level Goals rather their subsidiary sub-targets.

FEATURE

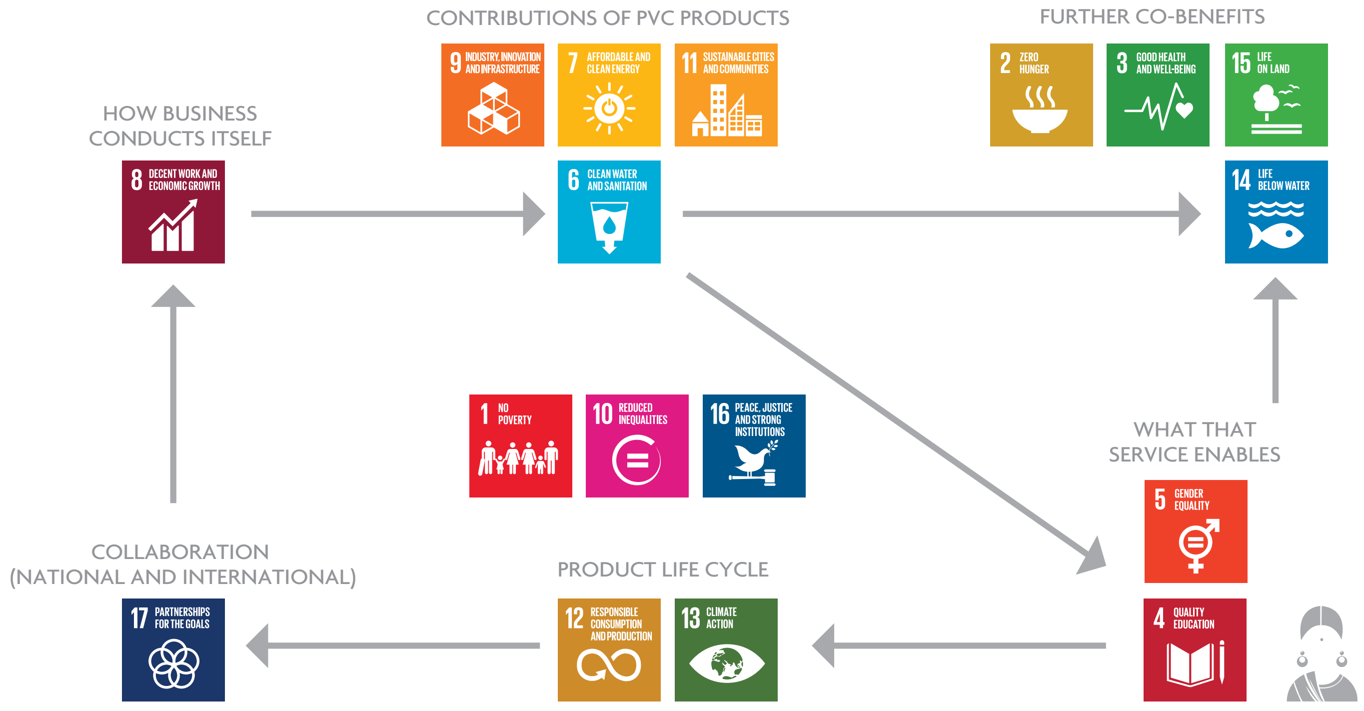
It should be taken as axiomatic that responsible businesses will have strong regard to Goal 8 (Decent Work and Economic Growth). However, as a purpose (providing satisfiers of human needs), the adaptable, flexible, cheap, durable and inherent recyclable properties of PVC suit it well to the provision of piped water and sanitation, underpinning aspects of Goal 6 (Clean Water and Sanitation). PVC can also play important roles in Goal 7 (Affordable and Clean Energy) and Goal 9 (Industry, Innovation and Infrastructure) and other contributions to Goal 11 (Sustainable Cities and Communities), but we will focus just on the role of PVC pipes here.

In developing countries in particular, greater efficiencies in the handling of water can massively reduce the drudgery of women: the traditional primary natural resource stewards who might spend 6-7 hours a day fetching water of dubious quality, often gathered at great personal risk. Piped water solutions not only create a more readily available and safe source, but are a major contributor to Goal 5 (Gender Equality). If women are freed from the drudgery of daily water collection, this liberates them to contribute to productive enterprises, such as engagement in community governance, traditional medicine and education (Goal 4). Other benefits from a stable and safe water supply include improved food productivity (Goal 2 – Zero Hunger), promoting Goal 3 (Good Health and Wellbeing), and lifting the pressure on terrestrial and aquatic ecosystems (Goal 15 – Life on Land and Goal 14 – Life Below Water).

When industry takes responsibility for product life cycles, particularly the TNS/VinylPlus challenge of controlled loop recycling, it makes strong contributions to Goal 12 (Responsible Consumption and Production) and Goal 13 (Climate Action), also noting that PVC pipes already have a lower embedded carbon content than other pipe materials due to their chlorine content. International collaboration in the PVC value chain can also contribute to Goal 17 (Partnerships for the Goals) and reinforce business commitments under Goal 8 (Decent Work and Economic Growth).

Whilst PVC pipes themselves do not directly contribute to Goal 1 (No Poverty), Goal 10 (Reduced Inequalities) and Goal 16 (Peace, Justice and Strong Institutions), they certainly play supporting roles in making them more achievable.

There is, in essence, a spectrum of direct, indirect and supporting roles that this industry and material sector example can make to addressing all of the SDGs as a connected set. Some contributions may be self-beneficial in identifying new profitable markets serving consensual needs. The same principle of systemic vision, engagement, differential contributions and potential opportunities



▲ **Figure 2. Considering the SDGs systemically, using the example of PVC pipes.**

across the seventeen Goals applies to all other businesses, and indeed societal sectors.

REPURPOSING BUSINESS

Why do we have businesses at all? Business emerged from the Industrial Revolution as a model for converting raw resources into useful products to meet human needs. The unprecedented wealth this generated engendered a golden age of philanthropy during which captains of industry reinvested a proportion of their unprecedented personal wealth in public 'goods', such as libraries, civic parks, hospitals, schools and museums. Business subsequently lost its way by the 1980s, with competitive profit-taking and a 'greed is good' ethos often framed as a sole goal at any wider cost. Since that nadir, a journey back to primary purpose can be discerned in emerging recognition of the need for a 'triple bottom line' sustainable pathway of development, corporate social responsibility and other initiatives. Leading enterprises grasped social and environmental responsibilities as a differentiator, averting bad press and supply chain instability, promoting preferred supplier status and giving confidence to staff and investors. A further incentive today is that, in the internet age, disclosure of bad practice is only two clicks of a mouse away.

What the SDGs bring to this repurposing of business is explicit recognition of the spectrum of needs that business exists to serve; the 'missing half' of the sustainable development narrative. Yes, business sectors have to continue addressing the challenges of becoming 'less bad' for the environment and human health, but they can also engage proactively and meaningfully with their role and primary purpose of meeting consensual human needs with appropriate 'satisfiers' on a sustainable basis.

ENDURING AND EMERGING CHALLENGES

Factors underpinning the TNS sustainability challenges and VinylPlus commitments – carbon and climate change; controlled loop; releases of persistent substances; sustainable use of additives; and engagement of the whole societal value chain – are not likely to become redundant any time soon. Indeed, they are increasingly pressing as global population grows, becomes more clustered in urban centres and grapples with meeting its needs from a dwindling natural resource base.

The principle of meeting greater human needs with less physical resource will continue to impinge on the world and frame business opportunities that can satisfy needs efficiently. The PVC challenges remain valid for transparent progress. However, the SDGs elevate the purpose of business beyond merely being 'less bad', but rather addressing human needs in the most sustainable way.

This brings us to two questions: firstly, what other materials, if any, achieve all of these challenges throughout their societal life cycle today?; and secondly, on the 'level playing field' of scientific objectivity, what materials most optimally address the diversity of challenges entailed in satisfying human needs? For durable, long-lived applications, such as water pipes, windows, insulation and shelter, the durable, adaptable and recyclable properties of PVC might represent the most sustainable options if all other challenges are seriously engaged. For short-life applications that end up inevitably contaminated and likely to enter mixed waste streams, alternative biodegradable materials might provide better 'satisfier' products.

Audited progress made under the EU-wide VinylPlus voluntary commitment is a flagship for serious engagement with sustainable development, recognised by the UN and as an exemplar for the circular economy by the EU. Contextualising these aspirations towards sustainability within the SDGs provides the value chain with the formerly missing element, and a higher purpose, of demonstrably making optimally sustainable contributions to meeting a diversity of consensual human needs. ES

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Matthew Byerly – Associate
Cathriona Cahill – Associate Environment
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Samuel Gold – Environmental Officer
Fiona Goode – Senior Consultant Engineer
Tony Hadibarata – Associate Professor
Michelle Hale – Associate Head (Education)
David Harman – Projects Director
James Hayward – Senior Project Manager
Cyril Hemery – Radioactive Waste Management Consultant
Cerys Hodson – Pollution Performance Coordinator
Christopher Hutton – Emissions Consultant
Nikolaos Kastelis – Graduate Air Quality Consultant
Robert Kennedy – Principal Environmental Consultant
Ian Kirk-Ellis – Associate
Theodoros Kolonas – Environmental & Sustainability Consultant
Matthew Le Maitre – Hydrographer
Neil McIntosh – Senior Engineer
Anna McMahon – Senior Air Quality Consultant
Jemma Newsome – Energy Consultant
Stuart Nock – Environmental Scientist
Emma Oliveira – Associate
Niamh O'Neill – Project Scientist
Alexandra Osborn – Associate Director
Richard Park – Senior Environmental Scientist
Katie Rawlins – Associate Director, Ground Risk & Remediation
Caitriona Reilly – Principal Scientist
Robert Reuter – Associate Director
Edward Richardson – Senior Geo-Environmental Engineer
Caireen Ros – Graduate
Timothy Ryle – Senior Ecologist
Sherril Subrayan – Senior Environmental Consultant
Lucy Thomas – Head of Science Projects
Alexandros Tsirtsikos – Environmental Scientist
Edwin Turnbull – Technical Director - Sustainability
Kevin Turpin – Principal Air Quality Consultant
Marc Walshe – Associate Environment
Ramdas Wani – Freelance Consultant for EIA, Energy & ISO
Martin Westwood – Consultant Environmental Scientist
Matthew Whalley – Associate Director – Environmental Planning
Naomi Wise – Research Scientist
Yee-keung Wong – Assistant Professor
Joanna Woof – Assistant Air Quality Consultant
Terence Wraxton – Senior Geo-Environmental Consultant

Associate is for individuals beginning their environmental career or those working on the periphery of environmental science.

Jovanna Arndt – Graduate Air Quality Scientist
Harry Atkin – Graduate Environmental Consultant
Amy Atkins – Post-Doctoral Researcher – Environmental Geochemistry
Domenico Avagnano – Graduate
Anna Basley – Soil Scientist
Ragna Bergk – Graduate
Christopher Blackhall – Ecologist
Christopher Brown – Graduate
Rosaria Buchanan – Environmental Advisor
Ewa Cieslak – QHSE Advisor
Emily Clough – Lecturer in Politics
Alexander Cooke – Environmental Scientist
Noelle Crimmins – Graduate Environmental Scientist
Joshua Davies – Air Quality Consultant
Andrew Day – Graduate Air Quality Consultant
Sudeep Deshmukh – Associate
Stuart Desmond – Assistant Consultant
Dominic Eardly – Graduate
Kieran Evans – Graduate
Thomas Fisher – Flood & Water Management Project Officer
Tracey Fram – Environmental Planning Consultant
Scarlett Franklin – Sustainability Consultant
Rachel Graham – Environmental Scientist
Lauren Growns – Air Quality Consultant
Peter Kerrison – Environmental Planning Consultant
Benjamin Lewis – Project Manager
Fang Lin – Assistant Air Quality Consultant
Laurence Lovell – Graduate Environmental Consultant
Alexander Lowenhoff – Environmental Consultant
Honor Mann – Environmental Scientist
Emma Martin – Graduate
Shannen McEwen – Graduate
Eleanor McGhie – Engineer
Christopher Norris – Graduate
Joshua Nunn – Consultant
John O'Kane – Environmental Scientist
Rocas Okochi – Graduate
Uzoma Okwosha – Postgraduate Researcher
Olajide Olawoyin – Student
Yelena Ortega – Air Quality Consultant
Weronika Piekarowicz – Graduate
Federica Pignataro – Sustainability Executive
Carl Ramskill – Graduate Air Quality Consultant
Noel Salmon – Graduate
Florence Saunders – Student
Jack Thompson – Environmental Scientist
Zhe Tian – PhD Student
James White – Graduate
Matthew Woodhatch – Environmental Consultant
Eleanor Wright – Graduate

Affiliate is for individuals with an interest in environmental issues but don't work in the field, or for students on non-accredited programs

Nassim Azzout – Student
Charles Boosey – Commercial Farmer
Caroline Borowski – Graduate
Silvia Fiorini – Environmental Advisor
Anthony Jennings – Acoustic Consultant
Panchami Menon – Student
Helen Newsom – Retired
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CASE STUDY

Seafood certification and the SDGs: Linking ocean health with people's lives and plates

Lucy Erickson describes the work of the Marine Stewardship Council in creating a global supply of environmentally responsible seafood.

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The health of the ocean is inextricably linked to human wellbeing, and fisheries are vital for food security, livelihoods and the sustainable development of billions of people worldwide. In 2014, fishery exports from developing countries were valued at US$80 billion, higher than all other food commodities (including meat, rice and sugar) combined[1]. However, the protection of this resource is an ongoing challenge for the global community. Since 2009, the percentage of overfished stocks worldwide has hovered around 30 per cent[1], and poorly managed fisheries have contributed to the degradation of marine ecosystems around the world.

While recent research highlights the efforts of fisheries in developed countries to improve sustainability, significant challenges remain, particularly in the developing world where 73 per cent of seafood is caught[2]. In this context, restoring ocean health and ensuring the sustainable use of marine resources requires a holistic approach, drawing on science and environmental conservation as well as addressing social and economic challenges. The United Nations (UN) Sustainable Development Goal 14 (Life Below Water) can't be achieved without considering the other UN Sustainable Development Goals (SDGs, or Goals) which encompass the alleviation of poverty, hunger, and poor working conditions and the promotion of economic growth, sustainable consumption and climate action. Equally, ending overfishing has been identified as a pre-requisite to achieve many targets across the Goals[3].

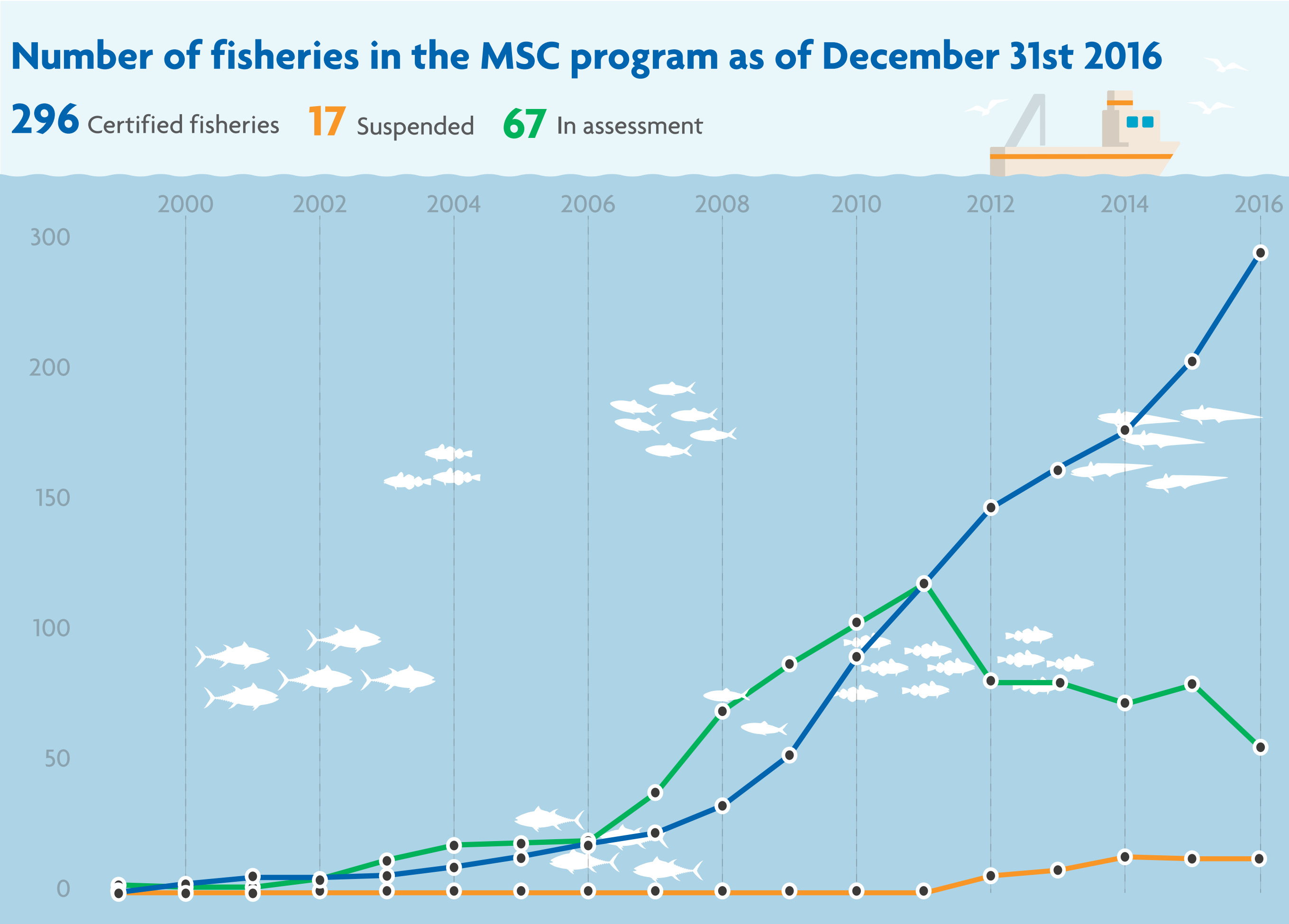
Credible certification and eco-labelling programmes are one tool with applicability across a broad range of the Goals and are part of the solution for ending overfishing globally[2].

THE MARINE STEWARDSHIP COUNCIL

The Marine Stewardship Council (MSC) is an international non-profit organisation established to address the problem of unsustainable fishing and safeguard seafood supplies for the future. The MSC is widely recognised as a leader in wild capture certification, with 12 per cent of global marine catch currently certified.

The MSC's science-based ecolabel and fishery certification program contributes to the health of the world's oceans by recognising and rewarding environmentally sustainable fishing practices and influencing the choices people make when buying seafood. Our theory of change holds that consumer desire and market demand for products bearing our ecolabel encourages fisheries to achieve MSC certification, and that the efforts of these fisheries to demonstrate sustainability result in positive change on the water.

As part of the Concept Paper on *Partnership Dialogue 4: Making Fisheries Sustainable* at the UN Ocean Conference, the MSC program was recognised as a promising tool for developing partnerships and sustainable seafood supply chains[4]. One example of a global partnership supported by the MSC is the 'Seafood Business for Ocean Stewardship' initiative. Led by the Stockholm Resilience Centre, the initiative connects the global seafood business to science in support of Goal 14 and includes an ocean stewardship pledge from 10 of the world's largest seafood companies[5].



▲ Figure 1. In December 2016, 296 fisheries in 34 countries were certified as sustainable to the MSC Fisheries Standard. hundreds of fisheries are not yet ready for assessment and are engaged in pre-assessment activities and fishery improvement projects. (© Steve Rocliffe/MSC)

▲ Figure 2. Scientists from the Zoological Society of London captured images of the seafloor in West Greenland as part of a project to map benthic habitats. (© Chris Yesson/Institute of Zoology)

BOX 1: THE MSC FISHERIES STANDARD

"The MSC Fisheries Standard is based on the UN Food and Agriculture Organisation (FAO) guidelines and incorporates global best practice in fisheries science and management as well as input from stakeholders around the world." *Dr David Agnew, Science & Standards Director at the MSC.*

The first iteration of the MSC Fisheries Standard was published in 1999. Since then, over 300 fisheries have become certified (**Figure 1**). In 2017, MSC became the first global sustainable seafood certification program to achieve recognition from the Global Sustainable Seafood Initiative, confirming it meets international requirements for credibility and rigour.

CERTIFIED FISHERIES AND LIFE UNDER WATER

By incentivising best practice in the fishing industry, the MSC contributes to several of Goal 14's targets including ending overfishing, implementing ecosystem management, and eliminating illegal, unreported and unregulated fishing[6].

Every year, the MSC carries out a comprehensive analysis of the impact of its program in safeguarding marine resources. The MSC Global Impacts Report 2017 contains the results of this analysis, and includes more than a thousand examples of positive change made by certified fisheries to safeguard fish stocks and marine habitats[7].

Of the sustainability improvements made by MSC certified fisheries, 117 actions by 39 fisheries contributed to improving habitat status, management and information. In total, MSC certified fisheries have been involved with 46 new scientific research projects as part of efforts to better understand and minimise impact on habitats.

The certification process often facilitates partnerships between the fishing industry and environmental scientists. For example, a recent collaboration between the Zoological Society of London and Sustainable Fisheries Greenland uncovered new information about seafloor habitats in Arctic waters (**Figure 2**), leading to the designation of a Marine Protected Area to safeguard corals and sponges, and ensuring the long term sustainability of the fishing fleet[7].

As advances are made in fisheries and environmental science, the MSC Fisheries Standard (**Box 1**) is continually updated to reflect evolving best practice. Stakeholders, including a broad range of scientists, contribute to these changes through the MSC's policy development process.

> "Fisheries and marine ecosystems are vital for ocean health, food security, and economic development, so it is critical that they are managed sustainably."

© Ulf Bergland

CASE STUDY

ZERO HUNGER AND ECONOMIC PRODUCTIVITY

MSC certified fisheries can also help to deliver sustainable development targets relating to food security and sustainable economic growth.

Maintaining or rebuilding fish stocks to sustainable levels is essential to ensure the long term availability of food[8] and good scientific advice underpins the ability of fishery managers to deliver effective management practices. In this way, marine and environmental scientists, along with the growing number of MSC certified fisheries, play a key role in delivering SDG targets.

Although these are not guaranteed, many fisheries, traders, processors and retailers have experienced economic benefits, including access to preferred markets and price premiums, as a result of MSC certification. Amongst these is the South African hake trawl, where a recent analysis concluded that losing MSC certification would result in a 37.6 per cent loss of value over five years, and put 5,000-12,000 jobs at risk[9].

However, while the intended environmental impacts of the MSC program are clearly prescribed, the social and economic effects that emerge from its implementation are variable and context-specific. The MSC is currently developing a method to study the emergent effects resulting from certification in order to offer a more holistic evaluation of its impact, and to evaluate how efforts to improve environmental sustainability affect social and economic development goals. Recent research in the journal *Science* highlighted how comparatively little research has been undertaken on the social dimension of seafood sustainability[10] and we hope that our project will contribute to fill this gap.

RESPONSIBLE CONSUMPTION

In 2016, the largest ever global analysis of attitudes to seafood consumption was carried out on behalf of the MSC. The research found that sustainability is a key driver for seafood purchase. Across 21 countries, sustainability was rated as more important than price and brand, with 72 per cent of seafood consumers agreeing that in order to save the oceans, shoppers should only consume seafood from sustainable sources[11].

Using credible sustainability standards is one of the most concrete and direct ways for businesses, from independent restaurants to multi-national corporations, to contribute to Goal 12 (Responsible Consumption and Production)[6]. As part of the latest GlobeScan/SustainAbility Survey (March 2017), 500 sustainability professionals were asked which Goal was the most important for society to focus on in order to achieve the greatest progress towards sustainable development. Goal 12 was ranked joint third out of 17 goals, highlighting its importance[12].

▲ **Figure 3. Ben Tre clam fishery in Vietnam. (© Leonard Faustle)**

As a market for sustainably produced goods enables economic benefits for certified fisheries as well as positive change on the water, consumers help to deliver the Goals by choosing to purchase traceable and sustainable seafood.

THE FUTURE OF SUSTAINABLE SEAFOOD

In order to restore overfished stocks by 2020 and achieve the targets set within Goal 14, recent research from the FAO concluded that greater emphasis must be placed on replicating successful sustainable fisheries policies from developed countries across to the developing world[2].

This can be difficult due to challenges with governance, data availability and management systems in less developed countries. The MSC recognises the need to address these challenges and ensure the sustainability of small-scale and developing world fisheries. To this end the MSC's Developing World Program includes initiatives such as capacity building training, fishery improvement tools and a risk-based framework for assessing data deficient fisheries; all aimed at improving the accessibility of certification. Vietnam's Ben Tre hand gathered clam fishery was the first small scale fishery in Southeast Asia to achieve MSC certification (**Figure 3**).

Climate change is also an area of growing concern. In the 2017 GlobeScan/SustainAbility Survey, Goal 13 (Climate Action) was considered to be the most important goal for society to focus on in order to achieve sustainable

development[12], and climate-related impacts are becoming increasingly important for fishery scientists and managers. The ecological sustainability required for MSC certification can help mitigate negative impacts by improving the resilience of fisheries and marine ecosystems in a rapidly changing world.

Fisheries and marine ecosystems are vital for ocean health, food security, and economic development, so it is critical that they are managed sustainably. Goal 14 is integrated with and indivisible from other goals that focus on poverty, hunger, decent work, sustainable consumption and climate action. Credible eco-labelling and certification programmes, such as the MSC, are one tool to enable fisheries scientists, conservation practitioners and social scientists to join with industry, governments, businesses, non-governmental organisations and consumers to deliver the SDGs. ES

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Environmental sustainability and gender equality: The perils of ignoring the synergies

Bina Agarwal discusses how addressing gender inequality is of utmost importance if we are to achieve key environment-related Sustainable Development Goals.

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It is striking that none of the Sustainable Development Goals (SDGs, or Goals) which are centrally focused on the environment – forests, oceans and climate change – mention gender equality in their targets and indicators. This is a major lapse, given the important synergetic links between the goals of environmental sustainability and gender equality.

IMPROVING FOREST MANAGEMENT

Goal 15 (Life on Land) seeks to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The key element here is forest management, which impinges on the other elements, in addition to mitigating climate change through carbon sequestration.

One in six persons globally depend on forests for basic subsistence needs, especially supplementary food. This includes 60 million indigenous people who are almost wholly forest dependent[1]. A large proportion of these are rural women in developing countries, who can play a critical role in regenerating forests, ecosystems, and biodiversity[2,3,4].

The particularity of women's roles in forest management stems from several factors[2]. Women use forests to a greater extent and differently from men, drawing from them firewood, fodder, food and other non-timber products, while men draw on forests mainly for timber. In turn, this differential use leads to gender-specific knowledge of ecosystems. Also, women use forests frequently, while men do so sporadically. The forest products that women extract for subsistence typically have short gestation periods and do not involve logging, while the products that men extract, such as timber, usually have long gestation periods and tend to involve logging which can be environmentally destructive. These differentiated uses mean that although both genders have stakes in forest conservation, women's and men's stakes do not always overlap, and including women in forest governance can thus prove key to sustainability.

In practice, women are largely excluded from forest management institutions[2,5]. We therefore miss out on a major point of synergy. There is growing evidence that when women are included in sufficient numbers to constitute a critical mass (say one-third), so that they can participate effectively in forest protection committees, conservation outcomes tend to be measurably and significantly better[2,6]. These beneficial effects arise from women's increased vigilance through informal patrolling of the forest (that supplements men's efforts), and their ability to ensure greater compliance of forest use rules by other women, both in their own village and in neighbouring villages. Including women also increases their incentive to protect the forest, since they can help formulate rules that allow greater (but within limits) extraction of firewood, fodder and other essential items. Moreover, women's knowledge adds to the pool of knowledge about local ecology, sustainable extraction and replanting practices. Greater gender equality in forest governance would thus clearly advance the goal of sustainable forest and ecosystems management.

TOWARDS WOMEN-MANAGED INLAND FISHERIES?

Next we consider Goal 14 (Life Below Water), which focuses on conservation and sustainable use of oceans and marine resources. Unlike forests, where women are usually the primary extractors of diverse products, men do most of the harvesting of sea products from marine resources. In 2008, across 86 countries, women constituted only 12 per cent of fish harvesters. They are more involved in small-scale and inland fish production, constituting almost 46 per cent of workers in small-scale fisheries and 54 per cent in inland fisheries[4].

Men typically control fishing equipment, especially large boats and machinery, while women dominate in post-harvest work, especially marketing. In Asia and West Africa, 60 per cent of the seafood is marketed by women[7], and the preparation of fish food – a key part of diets – also falls mainly in women's domain[8]. The depletion of fish resources thus adversely affects both genders in terms of income loss, but particularly affects women and children in terms of nutrition,

OPINION

given gender-unequal distribution of resources within families. Moreover, women are more exposed to plastic-related chemicals in inland water systems, and pregnant women can be especially harmed by consuming fish contaminated with pollutants such as methyl mercury[4].

Both men and women who are dependent on fisheries for income or subsistence consumption thus have a stake in conserving marine resources and inland fisheries, and can play key roles in their regulation and management. They can also contribute their complementary knowledge of fisheries to help improve conservation and biodiversity. Most importantly, the expansion of inland aquaculture – much of which falls in women's domain – can provide an alternative, more sustainable source of fish food than open sea fishing. A shift towards inland fish production could thus increase the chances of conserving ocean/sea ecosystems, by reducing the incentive to over-extract from them.

Women's roles in conserving and regenerating oceans/seas/marine resources can thus prove significant not only directly, in so far as communities living near these resources are (or could be) involved in their management, but also by substituting these sources with inland fisheries. Although few studies examine women's roles in governing inland fisheries[6,7], insights drawn from forest governance could be applied here, such as the positive effect on conservation of including a critical mass of women in their governance.

WOMEN, CLIMATE CHANGE AND FOOD SYSTEMS

The third Goal of key importance for the environment is climate change. Goal 13 (Climate Action), emphasises: "Take urgent action to combat climate change and its impacts". Climate change impact is a vast area, but for illustration consider the effect on food systems. Climate change is predicted to greatly reduce the yields of food staples, due to an increase in the frequency of droughts and floods, heat stress, water stress, erratic rainfall, and pest attacks. The effects are expected to be especially negative in South Asia and sub-Saharan Africa[9] – regions where the majority of the world's poor live.

Women play a central role in agricultural food systems as producers, consumers and family food distributors[2]. They also constitute a substantial and growing proportion of the agricultural labour force: in 2008, 43 per cent of all farm workers in Asia were female, and in Africa women formed almost 50 per cent of all agricultural workers[10]. Yet women face severe inequalities as farmers in their access to land[11,12], credit, and essential inputs, such as fertilisers, irrigation, technology, information, and markets[13]. These disadvantages could multiply with climate change, since technical advances in heat resistant or water-conserving crop varieties, or adaptation and mitigation practices are less likely to reach women. In contrast, it is assessed that if women had the same access to inputs as men, their yields could be 20 to 30 per cent higher, and total agricultural output in developing countries could rise between 2.4 to 4 per cent[13].

Gender inequalities in resource access not only reduce women's ability to realise their potential as producers, they also affect food distribution within the family, leading to gender-unequal nutritional outcomes, as measured, for instance, by anthropometric and malnourishment indices for girls and boys, and anaemia amongst women[14,15]. Hence, climate change induced decline in the availability of household food, be it in calories or protein and mineral content, is likely to affect women and girls more than men and boys. Time spent on food production, processing and preparation – to which women already contribute between 60 to 70 per cent of total labour[16] – is also likely to rise with climate change. In addition, in so far as climate change negatively impacts on inland fisheries and water bodies or forests, it will reduce the availability of household food and women's incomes from these sources.

To combat adverse climatic effects on families and communities, it is thus essential to aim at gender equality in access to land and other resources. Women's use of agroecological practices which can help cushion climate risk and restore soils and local ecosystems[17], and group approaches to farming which enable small farmers to pool their scarce resources to create more viable production units[18], could also make a notable difference.

In sum, the goal of gender equality (Goal 5), which targets women's access to land, financial services, natural resources, and full participation in public life, cannot be ignored without jeopardising our ability to attain the goals of environmental sustainability, given the synergies between these goals. Indeed these synergies call for an expansion of the scope of gender equality indicators well beyond those included in Goal 5. **ES**

This piece draws on the author's background concept notes written for UN Women's Research & Data Section 2018 Report: 'Gender Equality in the 2030 Agenda for Sustainable Development'.

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Rural development in Kenya: Leading the way for the SDGs in Africa

Joseph Martin highlights the world leading contribution Kenya is making towards a sustainable source of renewable energy for rural communities.

In late 2004, four years after the Millennium Development Goals (MDG) were agreed upon, Kenya started to action the eight goals it had promised to deliver at the turn of the century. Much progress had been made, although much more could also have been delivered. The successor to the MDGs, the Sustainable Development Goals (SDGs, or Goals), heralds a new era of promise and eagerness. On the 1st January 2016, the 17 SDGs of the 2030 Agenda for Sustainable Development were proposed. The onus is now on the Kenyan Government and the people of this inspiring country to deliver on its promises before 2030.

"The biggest challenge after another 15 years is that Kenyans will have to answer what we achieved because Kenya led the rest of the world to come up with these goals" stated Gideon Mailu, the Director of Devolution and Planning at the Ministry of Devolution[1]. The SDGs, combined with the Kenya Vision 2030 blueprint, seek to ensure rural development in Kenya will finally deliver lasting outcomes which self-sustain the country to 2030 and beyond.

CASE STUDY

KENYA: A GLOBAL TRADE INVESTMENT HUB

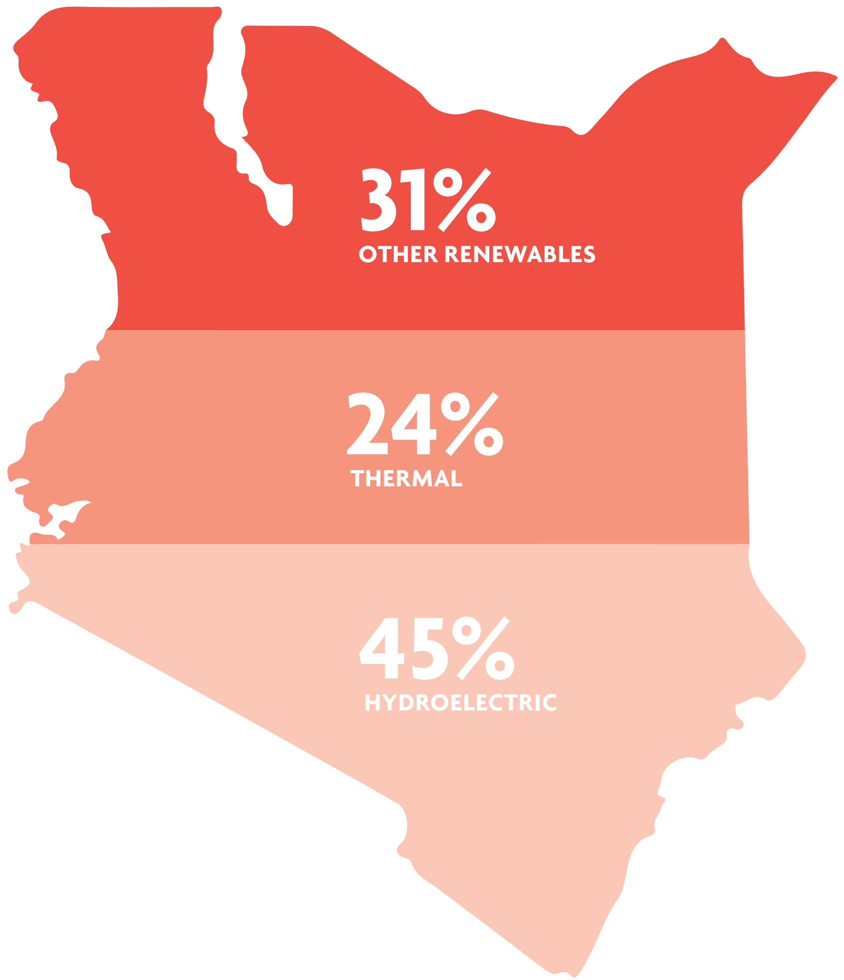
Kenya's growth in recent years shows no signs of abating. In 2015, the country was the third fastest growing economy in a global survey of 57 economies projected to register rapid growth that year[2]. That placed Kenya alongside China and India, amongst a select few others, as the only economies hitting a five per cent growth rate in 2015. Policy reforms and infrastructure development have reduced the cost of doing business in Kenya and global corporations are investing their money in a country which is displaying itself as a leading light of Africa. All indications are that Kenya is fast becoming a favoured business hub, not only for oil and gas exploration, but also for manufacturing, transport and information technology. All of these positives factor into Goal 9 (Industry, Innovation and Infrastructure) and Goal 17 (Partnerships for the Goals). The Kenya Private Sector Alliance (KEPSA) and the Government of Kenya have facilitated cross-border trade initiatives which will in time create more employment opportunities and diversify the Kenyan economy even further[2]

RENEWABLE ENERGY: TOWARDS A GREEN ECONOMY

One of the key ways in which Kenya is moving forward has been through investment in renewable energy technologies, such as geothermal, wind and solar powered projects (**Figure 1**). Kenya is pushing towards the cutting edge of renewable energy technology, and making progress on key SDGs in the process, particularly Goal 7 (Affordable and Clean Energy).

The UK Kenya Renewable Energy Conference held in Nairobi in October 2016 brought together key stakeholders and investors in the global renewables sector. In his remarks, the British High Commissioner to Kenya said: "The UK and Kenya are at the vanguard of renewable energy, clean technology, and innovation. Kenya has one of the most active renewable energy sectors in Africa, and the UK is a global leader in many of the sectors for which Kenya has the greatest demand"[3].

The most striking aspect of these developments so far has been the number and range of geothermal projects which are pushing Kenya towards a green economy. Kenya relies heavily on geothermal and hydro power for its electricity, providing the bulk of the country's total 2,341 MW output. According to global consulting firm McKinsey, Kenya possesses 40 per cent of Africa's 15,000 MW of proven geothermal potential; however, the country has only tapped into less than 2 per cent[4] of this potential.



▲ **Figure 1. Current proportions of renewable energy generation in Kenya. (Adapted from Power Africa[7])**

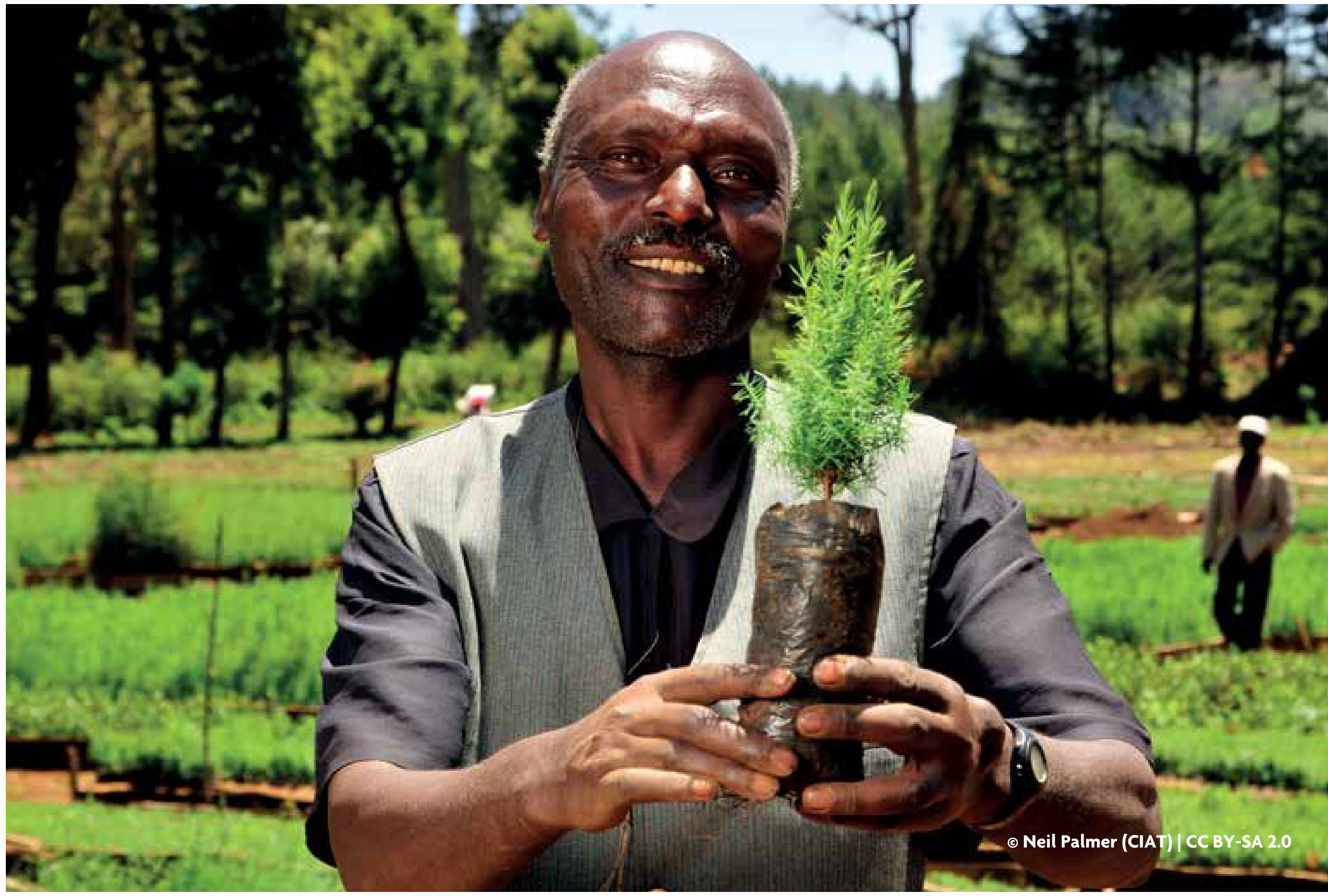
Kenya's Great Rift Valley contains vast amounts of geothermal resource potential, providing ideal conditions for long term power generation. These resources provide an opportunity to develop clean and reliable sources of energy, and to help the country move towards a sustainable energy future[5]. The Climatescope 2015 report places Kenya sixth in the world for large investments in renewable energy[6].

Kenya is already meeting many SDGs such as Goal 7 and Goal 11 (Sustainable Cities and Communities), by investing in small scale renewable technologies. Power Africa, a US government initiative to bring investment to Africa, has grown significantly. In Kenya, this project focuses on using innovative solutions to connect rural Kenyans to the electricity grid, and is actively supporting small on and off-grid power generation projects for small communities[7].

Other small scale community based projects include the first ever on-grid biogas plant in Africa. This plant began operations in Kenya in April 2015 at Gorge Farm Energy Park in Naivasha. It is capable of generating up to 2.2 MW from anaerobic digestion of local organic crop waste.

AGRICULTURE AND FOOD SELF SUFFICIENCY IN KENYA

Agriculture is a key facet of a variety of SDGs. In particular Goal 1 (No Poverty), Goal 2 (Zero Hunger) and Goal 3 (Good Health and Well-being). In many areas of Kenya, water erosion combined with the intensive usage of inorganic fertilisers has resulted in overall poor soil fertility. This has led to low crop productivity and farm yields, especially of maize and other food crops. Farmers in areas such as Siaya are therefore often caught in a vicious cycle of decreasing soil fertility, which necessitates the buying of expensive chemical fertiliser to improve crop yields, but which in the long run will degrade their soil even further. Low crop yields directly result in lack of food and undernourishment for subsistent farming households[8]; this in turn has limited Kenya's ability to meet Goals 1 – 3 on a consistent basis.



However, the situation is now changing. The World Bank BioCarbon Fund has developed a methodology in Kenya to quantify and give credit for the greenhouse gas benefits of Sustainable Agriculture Land Management (SALM) practices. This programme has been a great success for Kenya, allowing rural communities to grow food produce, but at the same time employing sustainable farming practices which have lower carbon production[9]. Conservation agriculture in Kenya now involves crop rotation, organic compost production and site specific tillage practices which are tailored to each region of Kenya. This has allowed Goal 15 (Life on Land), to flourish as communities build networks of productive food economies all over Kenya.

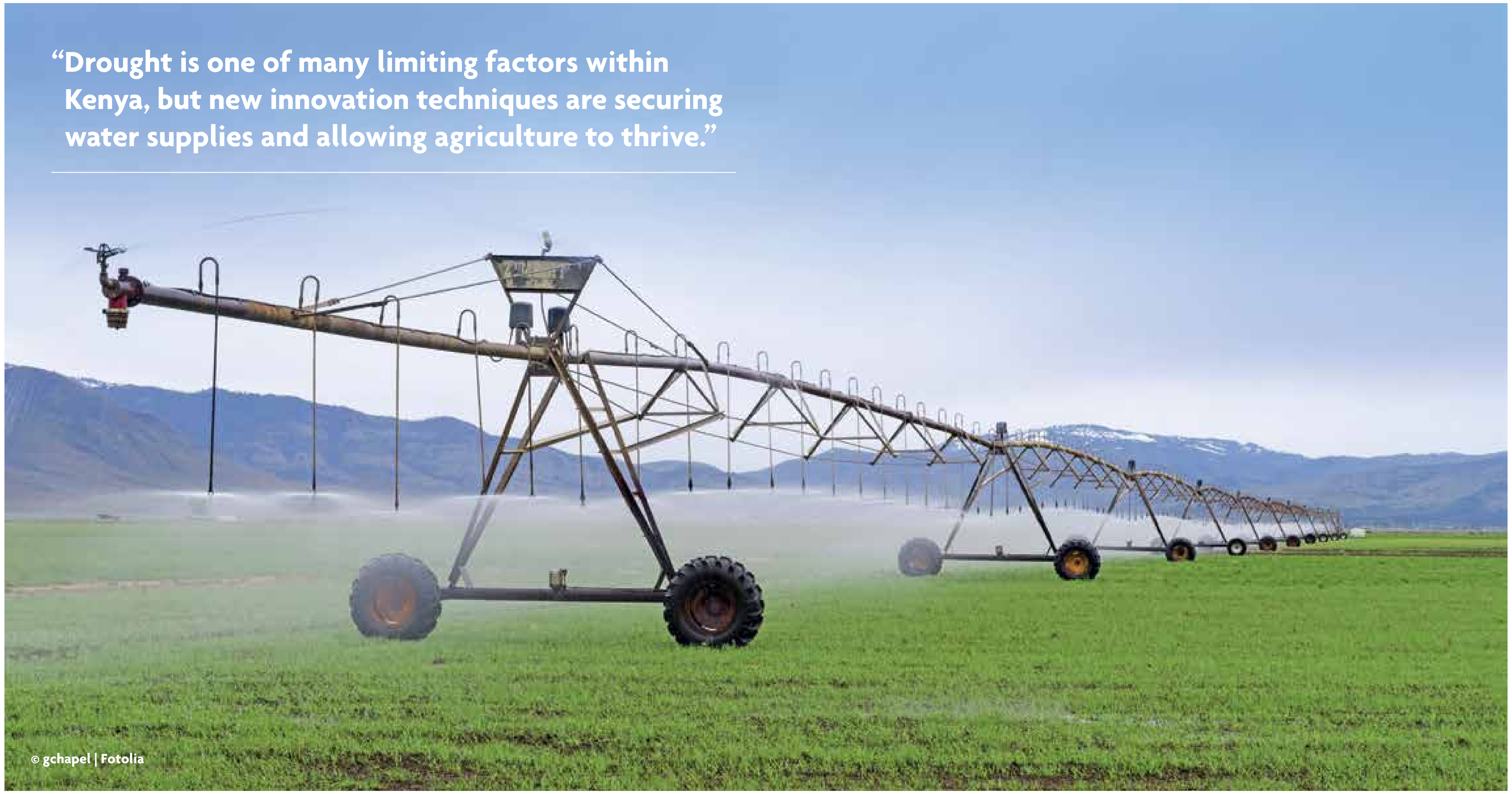
AGRICULTURE AND WATER IRRIGATION TECHNIQUES

Drought is one of many limiting factors within Kenya, but new innovation techniques are securing water supplies and allowing agriculture to thrive irrespective of climatic conditions. The World Food Programme (WFP)[10] has recently assisted Kenya in new dryland farming techniques which have improved crop yields. The communities take the lead in selecting activities that would improve their families' food security, especially during the dry periods. The WFP provides food or cash transfers to the families in return for their work on the community projects, and together with partners, provides technical skills and tools to the community[11]. This has allowed progress towards many of the SDGs at a local level within Kenya.

However in March 2017, the Food and Agriculture Organization of the United Nations reported that drought in the Horn of Africa was still a major problem and produced a Drought Action Plan for cross-border cooperation. The lack of rainfall during the rainfall season of 2016 had resulted in livestock devaluation, desertification and migration of farming families[12]. This report highlighted the stark problems which remain, despite the significant progress which has been made. If the Goals are to be met, these problems must be resolved with

CASE STUDY

“Drought is one of many limiting factors within Kenya, but new innovation techniques are securing water supplies and allowing agriculture to thrive.”



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cooperation and support of multiple governmental and non-governmental organisations.

STRENGTHENING KENYA’S CROSS-BORDER POTENTIAL

In order for Kenya to meet all 17 SDGs, it must proactively engage with its neighbouring countries; Ethiopia, Somalia, South Sudan, Tanzania, and Uganda. As a result, its future will largely be dependent on the cross-border relationships it forges as the country drives forward renewable energy technologies and innovation farming practices. Cross-border areas are characterised by poor infrastructure and basic service provision[13]. In 2015, a US$200 million five-year cross-border ‘Integrated Programme for Sustainable Peace and Socio-economic Transformation’ was launched by the Kenyan and Ethiopian Governments of Marsabit County of Kenya and Borana Zone, Ethiopia.

As part of the agreement between the two countries, environmental protection, trade, development and peaceful coexistence in their border regions are to be a primary focus. This programme is focused on improving cross-border areas in terms of livestock trade and untapped energy sources, such as solar water wells and mining activities – all of which will create employment for cross-border communities. If Kenya can improve its position both regionally within Africa and on a more global scale, the majority of the SDGs can be achieved.

Kenya is a country which is experiencing rapid growth and development in terms of its social, environmental and economic indicators, and it is already meeting numerous SDG targets. Investment from the USA, the UK and global corporations are evidence that Kenya is initiating change rather than reacting. Renewables continue to expand at a rapid rate and it is the responsibility of the Kenyan Government to ensure an equal share in the benefits this will deliver, particularly for rural communities in the Great Rift Valley. There is also evidence to suggest agricultural practises are improving with the help of the United Nations Development Programme, the Kenyan Government and foreign investment which is still crucial, particularly to cross-border areas. Trade and investment opportunities in Kenya must filter down to rural communities to prevent an imbalance in investment and what is actually occurring in marginal rural communities. Kenya is on course to be the leading light of Africa in terms of deliverance of the SDGs.

ES

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New technological solutions for the Sustainable Development Goals and beyond

Nebojsa Nakicenovic and **Caroline Zimm** discuss how research into innovative technology and support from policy makers is essential for moving towards a more sustainable society.

ANALYSIS

Technology in the broader context of science and innovation is central to human and sustainable development. The main drivers of global change and the core resources for addressing sustainability challenges are people, their technology choices and behaviours. These drivers define the relationship amongst all forms of human capital (such as knowledge including know-how and know-why), natural capital (such as land, water, energy, or the atmosphere), and the services they provide (such as food, lighting and clean air) which are essential for wellbeing. Technology is a key determinant for which type of natural resources are used, at what level of efficiency, how the use of one resource affects others positively (through efficiency gains for example), or negatively (through waste or pollution). As such, technology is the main mediator between humanity and the environment.

The Sustainable Development Goals (SDGs, or Goals) unanimously adopted in September 2015 by the United Nation's General Assembly, set a very high ambition for socioeconomic development and environmental sustainability. Their resolution on Transforming our world: the 2030 Agenda for Sustainable Development[1] sets out 17 Goals to be achieved by 2030. The SDGs are the short term goals of the long term aspirational transformation towards prosperity for all within a stable 'Earth-system'. Its 169 targets provide a detailed list of the action areas identified to implement this vision. The World In 2050 (TWI2050)[2] initiative is set to provide the science and policy for achieving all the SDGs in an integrated manner, so as to avoid potential conflicts amongst them and reap the benefits of the potential synergies of achieving them in unison (see **Box 1**).

BOX 1: 'THE WORLD IN 2050' INITIATIVE

'The World in 2050' (TWI2050) is a global research initiative that was launched by the International Institute for Applied Systems Analysis (IIASA), the Sustainable Development Solutions Network (SDSN), and the Stockholm Resilience Center (SRC). The initiative brings together a network of leading policymakers, analysts, modelling and analytical teams, and organisations from around the world to collaborate in developing pathways towards sustainable futures and policy frameworks needed for implementing the SDGs, and more importantly, for achieving much needed transformational change.

TWI2050 aims to demonstrate the feasibility of a sustainable future for all and the role of technology within that future, thus providing urgently needed knowledge on technological behaviour to achieve the SDGs.

More information: www.twi2050.org

TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

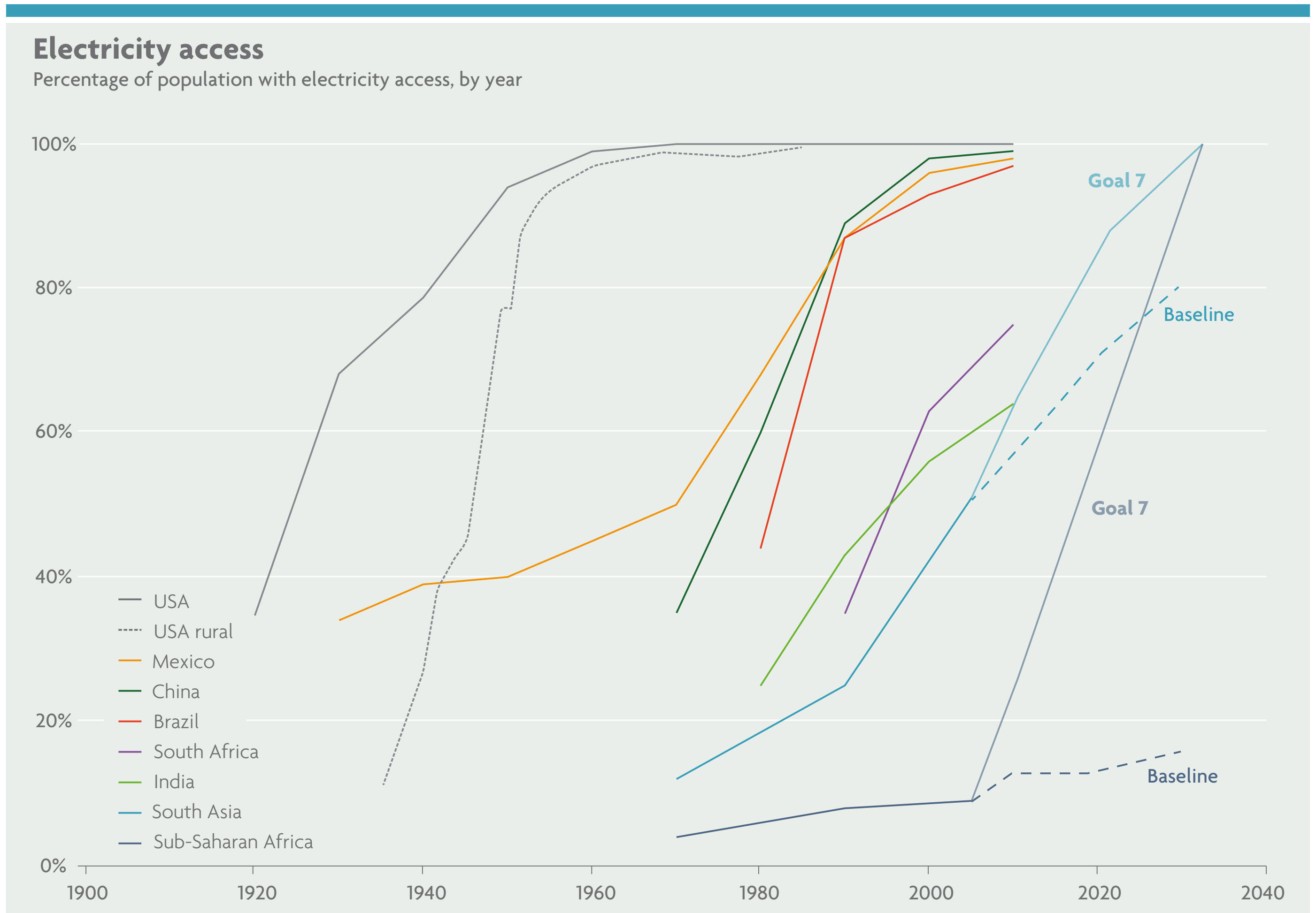
Science, technology and innovation are crucial for achieving the United Nations 2030 Agenda[1]. This Agenda strongly acknowledges the enabling role of technology: the term 'technology' is the fourth most commonly used noun (after 'countries', 'development' and 'access') within the Goals. In addition, technology examples feature prominently in several Goals, such as transport, energy and health, as do the related terms of innovation, science and knowledge.

One key concern addressed in the SDGs is improving access to technologies that satisfy basic human needs. Not only does humanity have to switch to more environmentally sound technology in general, it also has to achieve universal access for those excluded. While technology has provided parts of the global population with ever increasing living standards, about two and half billion people still lack access to clean cooking technologies[3], and another two and half billion do not have access to modern sanitation facilities[4]. Almost 800 million go hungry every night[5] and more than one billion do not have access to electricity[3]. **Figure 1** illustrates the rapid diffusion of access to electricity in a number of developed and developing countries, and the remaining gap (most often in rural areas) to achieve universal access to electricity by 2030 (Goal 7 – Affordable and Clean Energy). The figure shows that rural electrification was achieved very quickly in the USA, indicating that the challenge can be tackled with political will and the right investment environment.

Those lacking access have to bear the brunt of the negative environmental externalities linked to technology use by the affluent, such as air pollution, climate change and ecosystem degradation. This can be attributed to the high consumption and waste intensive patterns of the billion richest people. With the rise in the 'global middle class' from about two billion in 2010 to an estimated five billion by 2030[6], the historical development trajectories stand in direct conflict with the vision of the SDGs. Scaling up of existing advanced technological solutions with low adverse environmental impacts, together with new technologies with close-to-zero impacts, are required at an unprecedented scale for creating future systems that can simultaneously fulfil all 17 Goals.

TECHNOLOGICAL (R)EVOLUTION

Technology comprises both social dimensions (norms and institutions) as well as technological hardware (processes, products, and infrastructures). This is especially relevant for the successful and rapid technology diffusion[7] the SDGs call for. From this perspective, technology transfer of hardware alone is not a sufficient concept because social dimensions are concerned with the skills and institutions that need to be developed in order to benefit from advanced and new technologies. In this regard,



▲ **Figure 1. Diffusion of electricity access for select countries as percentage of population with access. (Adapted from Fig 19.5, Chap. 19, GEA[3])**

technology diffusion is primarily an endogenous process that can be enhanced through cooperation, capacity building and co-financing but not simply 'transferred' like hardware. This relates to adaptation to local circumstances, technology use and the need to develop national innovation ecosystems. Hardware plays a minor role in technology development and transfer; in other words, technology takes the form of disembodied and embodied knowledge and as such is a continuous learning process. It is, together with human knowledge, the only truly renewable resource and is a cumulative process requiring long term commitments and strategies[8,9] – this is exemplified through historical examples of technological 'forgetting' (the TriStar (L-1101) passenger aircraft[10] is one such example).

People develop and use technology in a broader context by way of a learning process. Hardware on its own is meaningless; it has to be assessed and developed in the context of the systems in which it is embedded. The technology system includes people and their institutions, and the knowledge, skills and cultural aspects related to its use and evolutionary history. It also includes the technology's characteristics, such as the resources used, and its direct and indirect impacts – positive and negative – thus providing many entry points for policy makers.

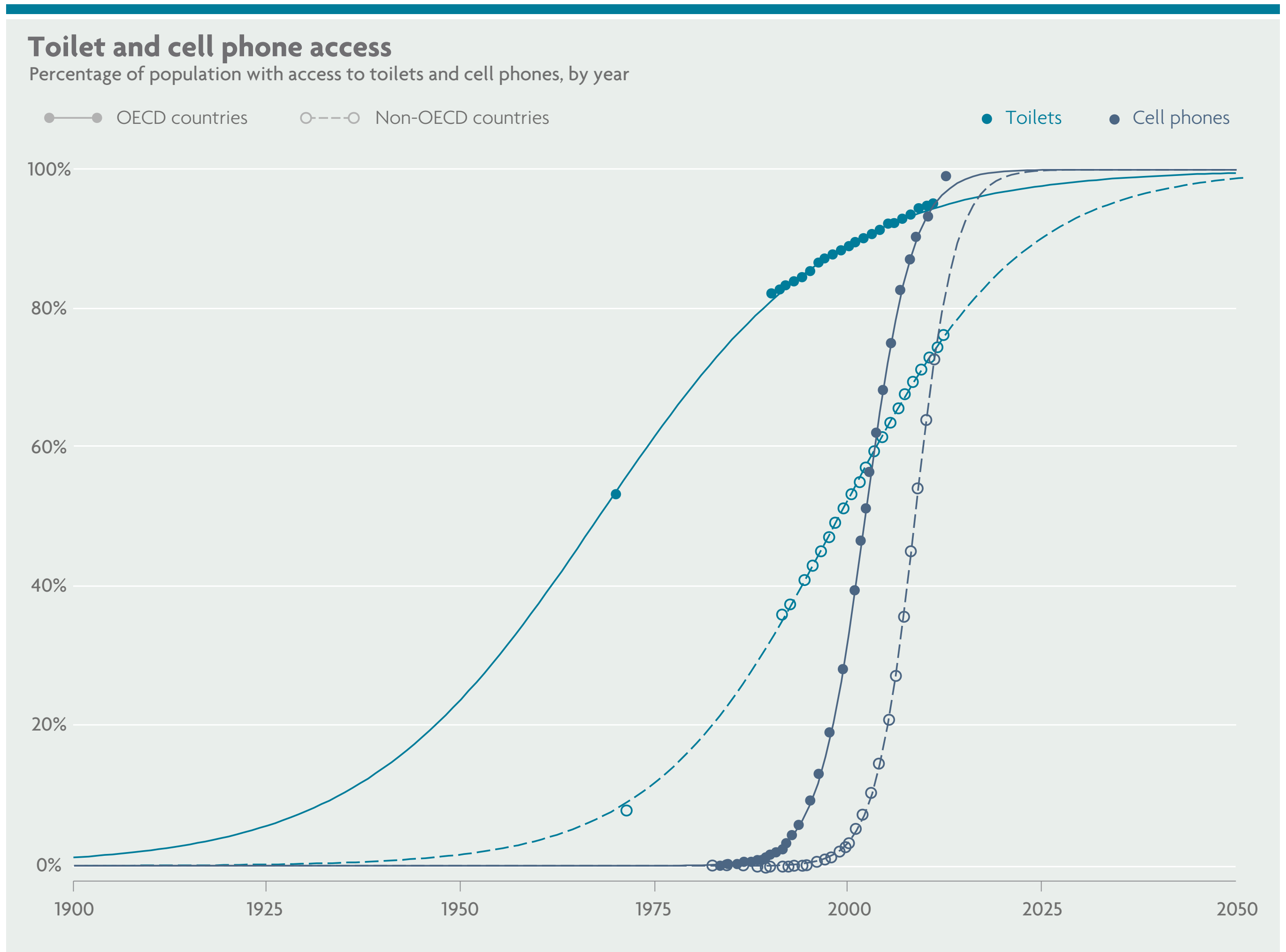
Policy makers have a deep interest in technology as it spurs economic development, but they too need to understand the different technologies within their systems. A key challenge for policy makers lies in creating a level playing field, and ideally accounting for externalities. Simply stated, public decision-makers are no better at identifying technological winners than anyone else. What is required is a competitive environment that nurtures innovations. Novel technologies often compete with well-established technologies supported through subsidies, favourable policies, or simply traditional inertia. Policymakers can alleviate these skewed market conditions and uncertainties by de-risking investments, and ensuring stable economic and institutional circumstances. The private sector is responsible for the largest share in developing and deploying technologies worldwide, but needs appropriate incentives and stable perspectives to invest in.

Research is needed to further the understanding of technology systems; studying the patterns, drivers, constraints, and impacts of technological change is required to identify viable options and policies that will accelerate the transformation of society towards a sustainable future. While technological change will always occur, high uncertainties remain about which technologies succeed. **Figure 2** provides an example of differences in technology diffusion rates, which raises the question why mobile phones have come close to reaching almost seven billion people[11] on the planet within three to four decades (including those without access to electricity), while two and half billion still lack access to safe sanitation after a century[4]. Detailed explanations are possible, but in the deeper sense, we do not have a theory that can capture the essential difference between the two diffusion processes. What can we learn from the success story of mobile phones for the diffusion of other technologies conducive for sustainable development?

To achieve sustainable development, available technologies should not be underestimated, some of which have already been proven and in need of up-scaling, while others are in an earlier diffusion phase. Additionally, incremental improvements alone will not be sufficient and technology revolutions will take over a substantial part in the transformation towards sustainability. It should be remembered that technological change is non-linear and true transitions are radical; disruptive change will therefore occur which will result in some actors leaving the market and for some, loss of investment.

System change is also costly and lock-ins, especially related to larger infrastructures, such as the electricity grid, sewage or transport systems, inhibit change and novel technology diffusion. On the other hand, inertia creates long term path dependencies, which support technological evolution with incremental change, but not revolutions, which can be seen more in end-use technologies.

The digital revolution has surprised society in many ways. It has emphasised the power of granular technologies, which are small scale, divisible, and have low unit cost. They also offer a series of potential benefits for rapid transitions. Novel analysis of historical data shows that granularity enables faster and less risky diffusion outcomes. Granular energy and end-use technologies have higher learning rates – relative unit cost reductions per doubling of cumulative output – than energy supply side technologies[12]. They offer a larger potential for system transformation, and greater equitably distributed



▲ **Figure 2. Technology diffusion compared: Diffusion of cell phones vs. toilets for OECD countries (solid) and non-OECD countries (dashed) (Data source: World Bank WDI, 2016[11] | CC BY. Model fit and graphic courtesy of Arnulf Grubler, IIASA.)**

benefits. In view of the Goals, a paradigm shift in focus from supply to demand can facilitate a rapid transition. In many sectors, such as in the case of energy, household level and distributed electricity generation (such as solar home systems) prove more successful in delivering last-mile electricity access than industry-scale centralised systems feeding the grid.

TECHNOLOGY IS NOT A SILVER BULLET

Technology was at the core of the agricultural, industrial and digital revolution. The next technological revolution towards sustainability will most certainly transform the world again and poses huge opportunities as well as threats for humanity. While technology is indisputably a transformative force, its application does not inherently promote human development. As a paradox, technology is the solution to many problems and simultaneously the cause of others. The power of technology can be deployed to support criminal and harmful activities, such as conflicts and wars as well as human and drug trafficking, thus threatening the achievement of the SDGs. Diesel generators, for example, bring urgently needed energy services to remote villages while emitting greenhouse gases. The internet both democratises information by providing easy access to knowledge, but it also facilitates organised crime; this is not just due to flawed law enforcement or misuse as technology design itself can be a key enabler. While novel technologies and innovations often provide solutions to a pertinent problem, they can come with undesirable side effects, which society sometimes only notices later in time – climate change being a prominent example. For many technologies in use today, humanity is lacking knowledge on their long term negative effects.

TOWARDS A TRANSITION TO KNOWLEDGE SOCIETIES

Technological change plays a key role in long term social transformations. The changes currently underway – such as the digital or sharing economy – are significant. With the advent of 'knowledge societies', many current

ANALYSIS

technological transitions favour non-material benefits that support human wellbeing. Yet still, humanity possesses technology to eradicate itself within hours. At the same time, we have proven the innovative power to fight diseases, overcome man-made global environmental degradation, such as the ozone hole or acid rain, and reach the moon – with the help of technology.

Technological change is crucial for achieving the SDGs and harnessing its full potential will maximise the social, economic, and environmental benefits. The window of opportunity is closing to use innovative power to get on the transformative track toward sustainability as there are only a few years left, which in terms of technological change, is a mere wink. Still, the new global social contract of the SDGs gives hope that humanity has decided to set out on a sustainable development path and technology will be a primary enabler, which needs to be nurtured and developed for the benefit of all. **ES**

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OPINION

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The transition towards sustainable development

Michelle Reeve talks to **Jonathon Porritt** about some of the challenges and responsibilities involved in making the Sustainable Development Goals successful.

Jonathon Porritt CBE is Co-Founder of Forum for the Future[1], the UK's leading sustainable development charity. He is an eminent writer, broadcaster and commentator on sustainable development. Amongst other roles, he was formerly Director of Friends of the Earth, co-chair of the Green Party and a Trustee of WWF UK. He was awarded a CBE in 2000 for services to environmental protection.

We asked Jonathon for his views on some of the difficulties faced in working towards the United Nation's (UN) Sustainable Development Goals (SDGs, or Goals), what science's role is in this work, and how Forum for the Future is contributing to a sustainable future.

What do you consider to be the role of science, and the scientific community, in the transition towards sustainable development?

It is quite interesting to reflect on the progress made since the UN's first conference on the environment and human development, back in 1972, which was first of the whole series of these global conferences that have led to things like the Millennium Development Goals (MDGs) and then the Sustainable Development Goals.

At that stage, the amount of information and good science available to policy makers and politicians was pretty thin. The UN's Environment Programme was first established in June 1972. Since then, we've seen this extraordinary flowering of scientific endeavour in every single one of the SDGs. Quite honestly, without that, the idea that the UN member states would be able to sign off on anything quite as ambitious, especially in all the associated targets underpinning the Goals, is impossible. My view is that the massive shift in the weight of scientific evidence available to policy makers in the last 40-50 years is the principal reason why we can now come to international agreements of this kind.

As well as science, civil society, politics and business are also involved in working towards the SDGs. Who do you see driving this work, and who might hold it back?

The citizen science side of it is really interesting and complicated. On a completely random count, I suspect you might find one in 100 people who'd even heard of the SDGs, let alone knew what they were. That means that it's essentially the non-governmental organisations (NGOs) that have really taken up the mantle of making the SDGs relevant to their own organisation and to their members.

There's a strong level of engagement from the environmental, development and human rights organisations. I think the health NGOs have been so focused on wrapping up the last stages of the MDGs

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that maybe they haven't as yet moved completely into the SDGs. But overall it's a pretty impressive picture, so that's encouraging.

Big companies have got their teeth into this. If you look at the spectrum of corporate engagement with the SDGs, you've got a small vanguard of progressive companies out there, basically saying: "This gives us an even stronger mandate for change". Then you've got a mass of companies saying: "Yes, we're aware of the SDGs". They're doing what I call 'correlation' – they already have a set of sustainability targets, so will correlate what they're already doing against the SDGs. There's been a mass outbreak of SDG iconography – you see the icons everywhere! This is something of a mixed blessing: it doesn't really mean that they've internalised the whole picture behind the SDGs, but at least they're on the ball. And then, I'm sorry to say, there are a vast number of companies who've never heard of the SDGs, will never have any interest in them, and will just be getting on with their business anyway.

On the political front, we've yet to see how that's going to work out. Some countries have been very focused on this, through their existing endeavours in this area. More progressive European countries, in particular, have picked up the challenge. The UK, I'm sorry to say, hasn't really seized hold of the challenge in the way we would want. But we shouldn't be too surprised at that, given the current status of sustainable development inside this Government, which I can only describe as near zero.

It's a patchy picture, to be honest. I think the UN itself is going to have quite a challenge raising the sights of member countries, and politicians in particular, to start looking at implementation plans and getting a real move on.

You say that the UK is struggling with the SDGs challenge – could you expand on that? Which goals do you think the UK will find most difficult to address?

This is such an important issue. When the Sustainable Development Commission existed, which I was Chair of for nine years, the idea that the Government wouldn't have a fully-fledged set of sustainability targets and outcomes would have been ridiculous.

You only have to go back to something like the Earth Summit's Local Agenda 21[2], where every municipality around the world was invited to develop its own action plan for developing integrated sustainable development – environment, health, economics, communities etc – at the local level. In the UK we got to the point in Tony Blair's Government where over 90 per cent of local authorities had their own fully signed-up, targeted and deliverable set of sustainable development metrics – astonishing to think of that now!

OPINION

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The number of local authorities in the UK fully engaged in this now are few and far between. The capacity has been hollowed out; there's hardly anybody there to do it, for one thing. So the contrast between where we were pre-2010, and where we are now, is dramatic.

This Government wouldn't really know how to do the cross-cutting, horizontal connectivity between different departments. The whole concept of sustainable development depends on making these connections, as well as on a proper understanding of the SDGs themselves. You have to focus on the joins between all the different goals. I wish I could put a happier stamp on this, but honestly, it's quite a gloomy picture in that regard. It means that we're right back into siloed delivery – department by department. A few departments will take the linkage to the SDGs seriously, but it won't change what they're planning to do anyway. And when the Government presents its plan on cross-cutting SDGs delivery, it'll be a pretty thin document.

Let's be honest, this UK Government today sees sustainability as a synonym for the environment. They would automatically think about those things that relate to resource use, the natural environment, biodiversity, climate, water, and so on. But socioeconomic aspects of sustainable development have never been a comfortable fit for this Government. They would particularly wrestle with some of the goals around social justice, health inequalities and wellbeing.

Several articles in this journal have highlighted that achieving the SDGs will involve collaboration across traditional disciplinary or professional boundaries. How can we do this better?

That's critical, and it remains difficult. One of the priorities for the Sustainable Development Commission was to focus on aspects of economic and social policy first, making sure that those policies were delivered in ways compatible with the biophysical constraints in which all societies have to operate.

Take health issues, for instance. Over the years, many Ministers have gabbled on about the importance of addressing health inequalities head on – through public health community-based or preventative interventions – to help eliminate those sources of ill health, both mental and physical, that lead to an array of chronic and acute problems, later on in people's lives. Yet the percentage of our total spend that goes on primary care and addressing health inequalities head on is still ludicrously inadequate. This drives me crazy!

You can see this reflected now in the debate about air quality, where you can see exactly how things go wrong. The Department of Health will have one set of views; the Department of Transport, a different set of views; the Treasury, another set of views.

The idea that the Government is open to really effective, joined-up, cross-departmental delivery, on issues of this kind, has completely disappeared. We now see between 30,000 and 40,000 premature deaths a year, and a huge drain on NHS budgets, simply because of the number of people affected by very poor air quality. There's a huge sense of frustration amongst professionals that even when the science is as strong as it is here, you still can't achieve the necessary connectivity inside government.

To be fair, joining things up in government has never been easy. Money gets distributed down vertical silos. Political influence and power flow down vertical silos. So, doing this cross-cutting stuff is indeed really difficult. You have to work at it. And at the moment, there's just no readiness to work at it.

The global population is predicted to reach nine billion by 2050. Do you think this population increase will undermine the work towards the SDGs?

Almost by definition, if a country's population is growing faster than its economy is growing, then there's a problem. That country will not be able to keep up with investments in public services, especially in terms of health, education and social care. Investment in infrastructure will not be able to keep up, making it almost impossible to deliver a thriving society for an increased number of people every year.

In my opinion, delivering on every single one of the SDGs will be made a great deal harder by virtue of the fact there will be more and more human beings whose needs will need to be met by the end of this century. I can't put it more simply than that.

So I'm deeply concerned about the reduction in funding available to countries that really need it most – prioritising investment in reproductive healthcare, family planning, and on education for girls. These are the three things that we know represent the fastest route to reducing average fertility in any country. For instance, if you look at the amount of money projected to be available to African countries for family planning programmes over the next decade, a genuinely scary deficit opens up in front of one.

I'd like to see a really sophisticated approach to family planning – obviously, non-coercive, women-led family planning programmes. For me, that is the starting point for ensuring genuinely sustainable development becomes the norm in the second half of this century.

What are Forum for the Future's plans around the SDGs? Is there anything you're working on right now?

It's always been our hallmark that we're a partnership-based organisation. We do a bit of work with governments, but we work largely on opportunities to connect people in business and people in civil society. Our work with our business partners allows us to emphasise the importance of the SDGs, and remind companies that you can't just cherry pick those Goals that are most convenient for you! We still see a lot of that, and it's worrying, because it means they're not thinking in integrated ways about sustainable development.

Here's an example. One of the biggest challenges we face in terms of the wider agenda is the intensity of meat consumption in our diet – not just rich-world diets, but increasingly in poorer, still developing countries. Animal-based protein, and the agricultural expansion needed to meet the needs of rearing ever-larger numbers of livestock, is a vast part of humankind's total footprint.

If you look at this in terms of the SDGs, the integration is incredibly powerful. From a health and nutrition point of view, it's now proven that consuming less animal-based protein in terms of overall protein intake is really good for people's diets. From an agricultural point of view, the reduction in the total amount of protein that humankind uses results in more resilient agricultural systems. From an animal welfare point of view, reducing our dependence on animal-based protein would be the single biggest thing we could do to stop the astonishing cruelty still inflicted on billions of creatures around the planet.

You can go on to look at this from the perspective of climate change, water consumption, energy consumption, waste and so on: reducing meat consumption touches on so many of the SDGs.

In Forum for the Future, we have a very ambitious programme looking at the future of called The Protein Challenge 2040[3]: what needs to happen to ensure that we can source enough protein for more than nine billion people on a sustainable basis by 2040? If the inevitable increase in demand is met in completely conventional ways, through increased dependence on animal-based protein, we're in serious trouble. Alternatively, if we start to develop a much more strategic approach to alternative forms of protein, in particular plant-based proteins, then we've got a real chance of transforming the entire food production system. There is an astonishing increase now in the ways in which we can use plants to provide substitutes for animal-based inputs into the food economy in general.

One of the most exciting things going on right now is the sheer number of insights coming forward from entrepreneurs and scientists involved in the field of industrial biotechnology – focusing on solutions for a world less dependent on animal-based protein. I don't want to exaggerate this, but if we can't achieve reduced consumption of animal-based protein, then there probably isn't a sustainable future for humankind of any description whatsoever. Our land use patterns,

and consumption of energy, and water, and depletion of soil, and everything else, would just blow the system. Much of that new thinking comes from smaller, smarter companies. Sometimes, the bigger incumbent companies in a sector become a huge barrier to progress in themselves. For instance, in the energy sector, Forum stopped working with BP and Shell over six years ago, and with all the big six energy companies here in the UK three or four years ago – on the grounds that they were never going to be able to play a constructive role in the transition to a sustainable energy future. As incumbents, they have all become significant blockers. All the new thinking, all the innovation that is transforming that marketplace, is coming from much smaller players, with an incredible infusion of IT-based software and technological innovation now available to policymakers. We now work almost exclusively with that pool of innovators to reshape the UK's energy system.

Are there any final points you'd like to raise for readers of the environmental SCIENTIST?

The more we look at this, the more important it is that we should emphasise the role of citizens – and not just of NGOs collectively. For instance, we've just finished a study for the EU, funded through the EU Innovate programme[4], which involved 12 universities all around Europe, with Forum as the only non-scientific organisation involved. What we found was extraordinary: there's a massive amount of innovation in citizens' groups around the whole of Europe.

We wrote a report[5] for the EU Commission, making a number of recommendations that policy-makers inside the EU should not neglect this issue about innovation. There's still a tendency to see innovation as something that is done either by large businesses, or by brilliant entrepreneurial start-ups. We forget that a lot of innovation is best described as citizen innovation, with an extraordinary potential for transformational benefits. And that really matters as far as the SDGs are concerned! **ES**

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