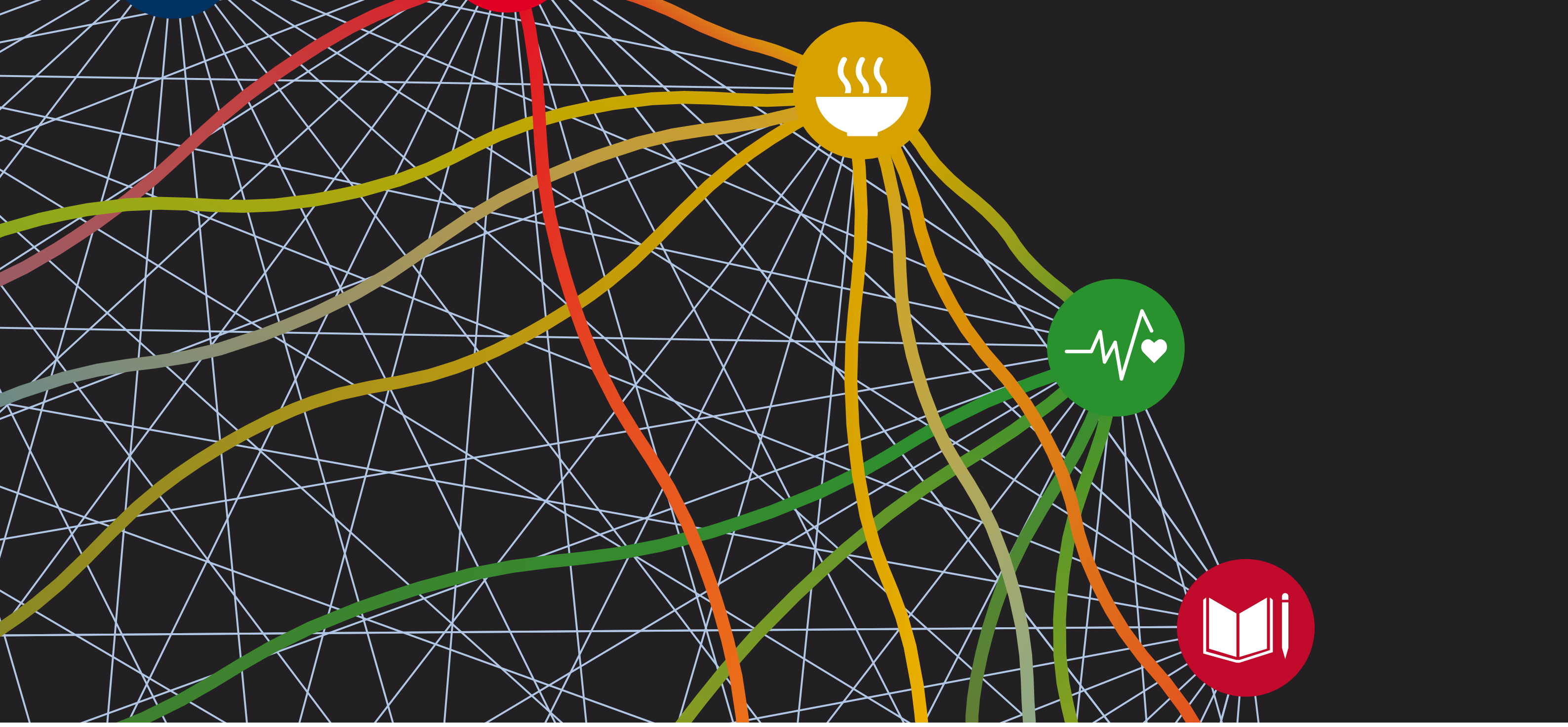
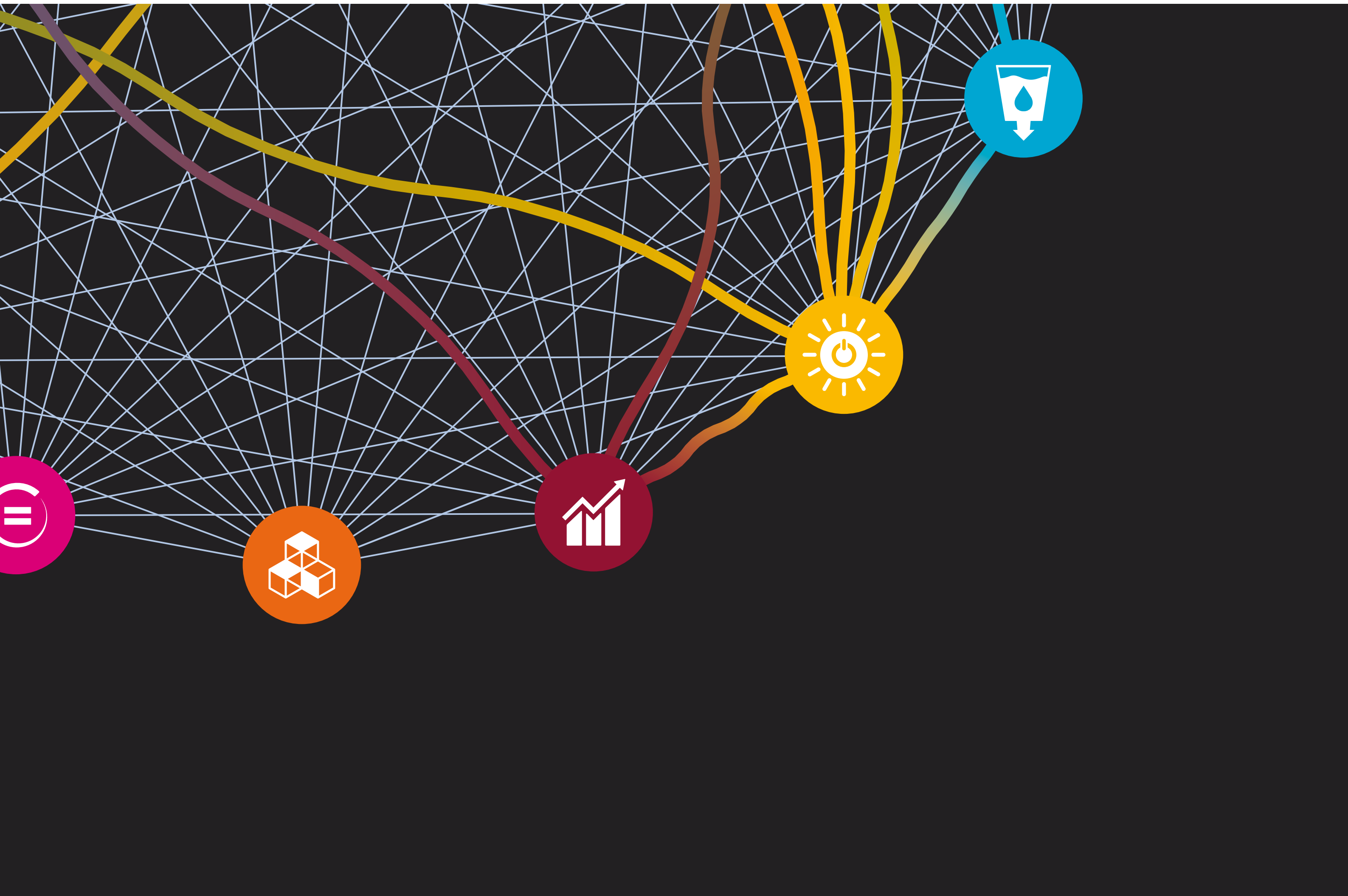


A GUIDE TO SDG INTERACTIONS: **FROM SCIENCE TO IMPLEMENTATION**

INTERNATIONAL COUNCIL FOR SCIENCE



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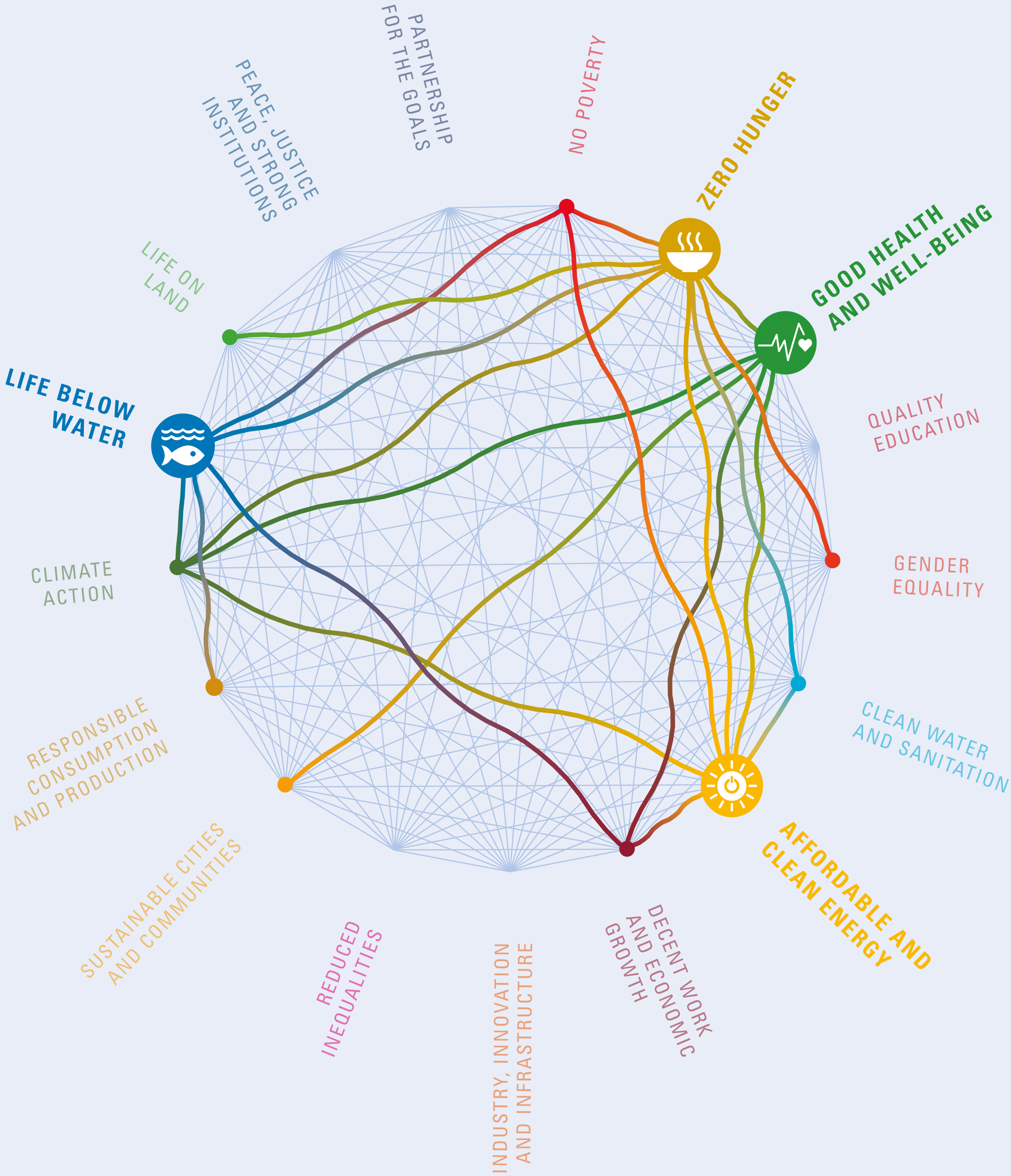

NO POVERTY
ZERO HUNGER
GOOD HEALTH AND WELL-BEING
QUALITY EDUCATION
GENDER EQUALITY
CLEAN WATER AND SANITATION
AFFORDABLE AND CLEAN ENERGY
DECENT WORK AND ECONOMIC GROWTH
INDUSTRY, INNOVATION AND INFRASTRUCTURE
REDUCED INEQUALITIES
SUSTAINABLE CITIES AND COMMUNITIES
RESPONSIBLE CONSUMPTION AND PRODUCTION
CLIMATE ACTION
LIFE BELOW WATER
LIFE ON LAND
PEACE, JUSTICE AND STRONG INSTITUTIONS
PARTNERSHIP FOR THE GOALS

EXECUTIVE SUMMARY

The United Nations' *2030 Agenda for Sustainable Development* was adopted in September 2015. It is underpinned by 17 Sustainable Development Goals (SDGS) and 169 targets. National policy-makers now face the challenge of implementing this indivisible agenda and achieving progress across the economic, social and environmental dimensions of sustainable development world-wide. As the process moves towards implementation, there is a need to address the scope and systemic nature of the 2030 Agenda and the urgency of the challenges. This requires a wide range of tools and science-based analysis to navigate that complexity and to realise the ambition.

This report explores the nature of interlinkages between the SDGS. It is based on the premise that a science-informed analysis of interactions across SDG domains – which is currently lacking – can support more coherent and effective decision-making, and better facilitate follow-up and monitoring of progress. Understanding possible trade-offs as well as synergistic relations between the different SDGS is crucial for achieving long-lasting sustainable development outcomes. A key objective of the scoring approach described here is to stimulate more science-policy dialogue on the importance of interactions, to provide a starting point for policy-makers and other stakeholders to set their priorities and implementation strategies, and to engage the policy community in further knowledge developments in this field.

UNDERLYING PRINCIPLES

All SDGS interact with one another – by design they are an integrated set of global priorities and objectives that are fundamentally interdependent.

Understanding the range of positive and negative interactions among SDGS is key to unlocking their full potential at any scale, as well as to ensuring that progress made in some areas is not made at the expense of progress in others. The nature, strengths and potential impact of these interactions are largely context-specific and depend on the policy options and strategies chosen to pursue them. SDG16 (good governance) and SDG17 (means of implementation) are key to turning the potential for synergies into reality, although they are not always specifically highlighted as such throughout the report. For many if not all goals, having in place effective governance systems, institutions, partnerships, and intellectual and financial resources is key to an effective, efficient and coherent approach to implementation.

Policymakers, practitioners and scientists working at the global, regional, national and local levels on implementing or supporting the implementation of the SDGS are the intended audience for this report.

KEY FINDINGS

- The four SDGS analysed in detail in this report (SDG2, SDG3, SDG7, SDG14) are mostly synergistic with the other SDGS.

- Using a 7-point scale, a team of scientists evaluated the key target-level interactions between an 'entry goal' and all other goals, and attributed a score to these interactions based on their expert judgment and as justified through the scientific literature. The score most often allocated is +2 ('reinforcing').

- The assessment identified 316 target-level interactions overall, of which 238 are positive, 66 are negative, and 12 are neutral.

- This analysis found no fundamental incompatibilities between goals (i.e. where one target as defined in the 2030 Agenda would make it impossible to achieve another). However, it did identify a set of potential constraints and conditionalities that require coordinated policy interventions to shelter the most vulnerable groups, promote equitable access to services and development opportunities, and manage competing demands over natural resources to support economic and social development within environmental limits.

- The process of systematically identifying and scoring interactions across the 17 SDGS using a common terminology is very valuable. It allows broad multi-disciplinary and multi-sectoral conversations, makes it possible to synthesise knowledge and to scope knowledge needs, and provides rational and concrete focal points (clusters of targets that need to be addressed together) for an integrated approach to implementation and monitoring.

- This approach provides a basis for a science-policy dialogue on translating integrated science for the achievement of the SDGS. As a tool for policy coherence, it provides an understanding of the conflicts and synergies to be managed across government departments and sectors, understanding where the emphasis should be put for efficient and effective action, and identifies who needs to be brought to the table to achieve collective impacts across multiple interacting policy domains.

- There is clearly no one-size-fits-all approach to understanding target interactions, and building on this work will require a commitment to continuous iteration and improvement.

SCIENCE-INFORMED ANALYSIS OF THE SUSTAINABLE DEVELOPMENT GOALS AND THEIR INTERACTIONS

ASSESSMENT FRAMEWORK

The framework on which this work is based identifies causal and functional relations underlying progress or achievement of the sustainable development goals and targets: positive interactions are assigned scores of +1 ('enabling'), +2 ('reinforcing') or +3 ('indivisible'), while interactions characterised by trade-offs are scored with -1 ('constraining'), -2 ('counteracting'), or -3 ('cancelling'); neutral interactions between SDGs are assigned 0. By systematically assessing the interactions and relationships between goals and targets, this report supports horizontal coherence across sectors.

The framework informs, but is not in itself a priority setting exercise nor is it a comprehensive mapping of all potential interactions. It can be applied at multiple scales (international, national, sub-national) through a thematic or geographic entry, and the analysis is based on existing literature and expert judgment.

SCORING EXAMPLE: EFFECTS OF CLEAN ENERGY ON AIR QUALITY AND HEALTH

Sustainable energy that is carbon-free is largely also pollution-free. This means that, in most cases, efforts to increase energy access (target 7.1), expand the share of renewables in the energy mix (target 7.2), and promote energy efficiency (target 7.3) will lead to a simultaneous reduction in air pollutant emissions. As a consequence, interaction between the SDG7 targets and target 3.9 (reducing air pollution) is considered reinforcing and so is allocated a score of +2. Nevertheless, achieving SDG7 may not in itself be enough to meet the air quality targets of SDG3: additional pollution control technologies and measures may be required.

FIRST APPLICATION

Key interactions for Food/Agriculture (SDG2), Health (SDG3), Energy (SDG7) and Oceans (SDG14) are tested using the scoring frame-work. This selection represents a mixture of key goals aimed at human well-being, ecosystem services and natural resources – it does not imply any prioritisation. This selection also covers a range of development and environmental priorities, including three goals under review at the 2017 High-Level Political Forum (SDG2, SDG3, SDG14). Each of these goals exhibits both positive and negative target-level interactions with the other SDGs.

In attempting to combine expert judgment, the seeking of new evidence in the scientific literature and extensive deliberations about the character of different interactions, it soon became clear that despite starting from similar understanding about interactions and the main conceptual underpinnings of the framework, the different teams quickly developed different interpretations of how to apply the framework and score the interactions. This poses a challenge in terms of replicating the study.

Nevertheless, a strength of the approach was that it generated a highly iterative process for deepening the understanding of target interactions. Each team had valuable debates about the terms of the scale and several revisions were made to scores in different chapters over the course of the work. In fact, in many respects it could be argued that the process of deciding on the score was possibly more valuable than the final result, since it required a detailed study of the literature, a consideration of the issues and potential context dependencies, a review of limitations and gaps in current knowledge, and discussion with others. To this extent, the assessment becomes a vehicle for triggering the conversation, interpretation and learning process.

SDG 2: END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE

Together with ending poverty, eradicating hunger around the world is central to the 2030 Agenda. SDG2 frames this in the context of eradicating malnutrition through increasing agricultural production sustainably. SDG2 in itself is a compelling case for recognising and managing interdependencies: achieving food and nutrition security, and increasing agricultural production and income for farmers, while achieving resilient and sustainable food systems will be challenging to achieve simultaneously.

KEY INTERACTIONS WITH OTHER GOALS

2 + 1

Eradicating poverty cannot be achieved without ensuring food and nutrition security for all. While SDG2 is a strong enabler for SDG1, increasing agricultural production, productivity and incomes require complementary policies that benefit the poor and vulnerable communities in rural areas and reduce their exposure to adverse environmental shocks.

2 + 3

Health and well-being cannot be achieved without access to a sufficient quantity and quality of food. How the SDG2 targets related to increasing agricultural production and productivity are implemented, will have a major influence on soil and water quality, land use, and ecosystem health and functioning, which are key environmental determinants of health. Other factors such as rural income stability from agriculture and related sectors are also important. Achieving SDG3 supports SDG2, because a healthy population is essential for achieving nutrition and agricultural production targets.

2 + 5
Achieving the targets related to access to food, quality nutrition for all, and agricultural incomes will provide key enabling conditions for women's empowerment and gender equality as it opens up development opportunities for women. Conversely, gender equality and enhancing women's rights can help achieve the targets related to sustainable, increased food production and nutrition, and can enhance the role of women in agriculture.

2 + 6
Food production is strongly dependent on and affects the quality and availability of water, because boosting agricultural production can increase water withdrawals and worsen land and water degradation. Moreover, achieving nutrition targets requires access to clean water and sanitation. Counteracting these potential trade-offs will require sustainable agricultural systems and practices, and enhanced water governance to manage growing and competing demands on water resources.

2 + 7
Agriculture, food production and consumption are strongly dependent on energy services; conversely biomass and agricultural waste are potential sources of renewable energy. However, competition over the same resources (land, water) can result in trade-offs between both goals.

2 + 13
Agriculture is an important source of greenhouse gas emissions and so contributes to climate change. Conversely, climate change has wide-ranging impacts on agriculture and food security through extreme weather events as well as long-term climatic changes (such as warming and precipitation changes) and will significantly constrain the achievement of SDG2. Sustainable agricultural practices play an important role in climate adaptation and mitigation (such as improving soils and land quality, genetic diversity, and bioenergy).

2 + 15
Healthy ecosystems provide vital services, from soil and water quality, to genetic diversity and pollination. Agriculture is a key driver impacting ecosystems. Sustainable agricultural systems and practices contribute to ecosystem health. However, increased agricultural production and productivity, if not sustainable, can result in deforestation and land degradation, jeopardising long-term food security. A careful balance is needed between achieving food for all and conserving and restoring ecosystems.

→ **75 target-level interactions:
50 (positive), 1 (neutral) and 24 (negative)**

IMPLICATIONS FOR IMPLEMENTATION

Eradicating hunger and ensuring food security is a bottom-line requirement for achieving sustainable development and well-being. This will require a careful and context-sensitive assessment of the needs and critical trade-offs that may occur with other goals and targets. Multi-level governance and multi-stakeholder partnerships, capacity development from the institutional to the individual level, resource mobilisation towards research, innovation and technology development to mitigate trade-offs and supportive policies and investments are needed to realise the full potential of SDG2 and related targets and goals.

SDG 3: ENSURE HEALTHY LIVES AND PROMOTE WELL-BEING FOR ALL AT ALL AGES

Health is both a key enabler and a critical outcome of sustainable development. The health of people and the health of the planet are fundamentally interdependent. Poverty is a structural factor influencing health. In the future, climate change is likely to become the key determinant of health. There are strong synergies among the SDG3 targets which require progress to be made on all 12 targets to achieve health outcomes for all.

KEY INTERACTIONS WITH OTHER GOALS

3 + 1

Universal health care linked with a strong workforce and supportive research infrastructure underpins all health targets. Reducing communicable diseases combined with enhanced sexual and reproductive health care can reduce newborn, infant and maternal mortality. Controlling tobacco and reducing substance abuse and exposure to hazardous chemicals also reduces mortality.

3 + 2

Health cannot be achieved without access to sufficient and quality nutrition. Moreover, food production and agricultural practices may also affect health directly, including through improved soil and water quality, and indirectly through changes in incomes. But if not properly managed, increasing agricultural productivity could harm health through, for example, damaging ecosystems and increasing pathogen habitats.

3 + 8

A healthy population is a prerequisite for development and underpins economic growth. The interaction between health and economic growth is mostly synergistic because economic growth, when sustainable and equitable, enables health and well-being through access to decent work, food, housing, medical care and education, which in turn contribute to higher productivity and income generation. However, the synergies are highly dependent on economic development being directed towards enhancing social and natural capital to achieve long-term health gains.

3 + 11

Cities concentrate a growing part of the global population and have a critical influence on physical and mental health. Sustainable urban planning, and decent and affordable housing support mental health and access to health services, and reduce non-communicable diseases and limit environmental impacts.

3 + 13

Climate change is already having significant impacts on health. Many of these impacts are direct (such as the effects of heat stress on ability to work outside), while others are indirect and arise through climate change that promotes the spread of disease or contributes to food and water insecurity, or to mass movements of people. Failure to address the climate action goal will make achieving the health goal impossible. As well as major long-lasting health impacts, climate mitigation would have some immediate health benefits (such as through better air quality).

→ 86 target-level interactions: 81 (positive) and 5 (negative)

IMPLICATIONS FOR IMPLEMENTATION

Implementing the health dimensions of the SDGs will require strengthening national health systems, dedicated laws and regulations to protect people and the natural environment from harmful substances, increased investment in health but also infrastructure that supports health and well-being (i.e. sustainable urban design and planning), and policies that mainstream health concerns from the local (city planning, health and safety in work places) to the global scale (preventing and preparing for large epidemics, engaging in multi-stakeholder alliances to tackle antimicrobial resistance, preparing for health impacts of climate change).

SDG 7: ENSURE ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL

Modern energy is fundamental to human development, and the services that energy makes possible are widespread throughout the industrialised world. But not everyone has access to the benefits that modern energy can provide.

KEY INTERACTIONS WITH OTHER GOALS

7 + 1

Ensuring the world's poor have access to affordable, reliable and modern energy services supports the goal of poverty eradication. However, decarbonising energy systems by promoting renewables and increasing energy efficiency could cause price shocks, and so prevent universal access to modern energy supplies. Because some of the poorest parts of the world have some of the highest renewable energy potential, making use of this potential could help to reduce poverty.

7 + 2

Energy supports food production; conversely, agriculture can play an important role in meeting the energy goal, especially through biofuels. A well-studied (potential) trade-off is competition between biomass for energy and crops for food.

7 + 6

Thermal cooling and resource extraction require substantial amounts of water; while wastewater from the energy sector releases large quantities of thermal and chemical pollution into aquatic ecosystems. In most cases, increasing the share of renewables in the energy mix and increasing energy efficiency would support the water targets. However, expanding biofuels or hydropower use could increase pressure on water resources.

7 + 8

Deploying renewables and energy-efficient technologies can encourage innovation and reinforce local, regional and national industrial and employment objectives. Decarbonising energy systems through greater use of renewables and energy efficiency could constrain economic growth in some countries.

7 + 13

An immediate and significant increase in renewables and increased energy efficiency is an essential part of efforts to keep global warming to well below 2°C above pre-industrial levels. Providing access to modern energy services to all will not exacerbate climate change.

→ 58 target-level interactions:
46 (positive), 10 (neutral) and 2 (negative)

IMPLICATIONS FOR IMPLEMENTATION

The transition towards clean, efficient and modern energy for all will require policies geared toward avoiding potential negative impacts as well compensation mechanisms that support the most vulnerable groups. Policies to manage the energy-land-water nexus are critical for avoiding competition over resources and adverse environmental impacts. Policy frameworks that help mobilise investment would be helpful in achieving each of the three SDG7 targets.

SDG 14: CONSERVE AND SUSTAINABLY USE THE OCEANS, SEAS AND MARINE RESOURCES FOR SUSTAINABLE DEVELOPMENT

The oceans provide vital services to people and the planet. A decline in ocean health, productivity and resilience due to increasing human pressures by mostly land-based pollution, climate change-induced warming and sea-level rise, ocean acidification and over-exploitation of marine resources is a major threat to achieving sufficient nutrition, livelihoods and economic growth, especially for coastal communities. Other important ecosystem services such as recreation and coastal protection are also affected. Achieving SDG14 strongly depends on progress under other goals.

KEY INTERACTIONS WITH OTHER GOALS

14 + 1

Healthy, productive and resilient oceans and coasts are a critical enabler of poverty alleviation, environmentally sustainable economic growth, and human well-being, especially in coastal communities. But despite various co-benefits for building resilient communities, achieving SDG14 could limit access to the resources and ecosystem services necessary to alleviate poverty.

14 + 2

Oceans are essential for ensuring food security and meeting nutritional needs. Establishing marine protected areas could limit access to marine resources for food and nutrition security; however, fisheries and other natural resource uses generally benefit from sustainable practices and balanced conservation measures. Increased agricultural production could damage ocean health through nutrient run-off and related pollution.

14 + 8

Sustainable growth of marine and maritime sectors supports employment and economic growth. Short-term resource exploitation may impact the productivity and resilience of oceans and coasts while trade-offs are possible where management and conservation measures limit economic growth.

14 + 11

Coasts are attractive for urban development, often due to opportunities for economic activities and the availability of natural resources, but coastal settlements are a major factor in increasing environmental pressures along the coast-sea interface. Conflicts may occur where ocean and coastal conservation limit options for housing, infrastructure or transport upgrading, but achieving SDG14 also reinforces sustainable urban planning and resilient coastal settlements.

14 + 12

Achieving SDG14 and sustainable consumption and production go hand in hand, not only in ocean-based industries and coastal communities. Ending overfishing, sustainably managing marine and coastal ecosystems and reducing marine pollution supports the efficient use of natural resources and reduces food loss while sustainable consumption and production patterns will reduce marine pollution and support sustainable resource extraction practices.

14 + 13

Oceans and coastal ecosystems both affect and are affected by climate change. Thus, achieving SDG14 and SDG13 is highly synergistic, such as through conservation of coastal ecosystems acting as blue carbon sinks. Careful management is needed to ensure that climate adaptation and coastal and marine protection measures do not conflict.

→ 97 target-level interactions:
61 (positive), 1 (neutral) and 35 (negative)

IMPLICATIONS FOR IMPLEMENTATION

Achieving SDG14 without compromising the achievement of other SDGs means much needed protection and restoration measures for coastal and marine ecosystems must be carefully balanced against the sustainable exploitation of marine resources. Integrated management and planning across geographical scales and administrative silos, particularly at the regional level, will enable coastal states to better safeguard, conserve and sustainably use ocean resources within their jurisdiction and in areas beyond national jurisdiction. The current ocean governance framework is fragmented and needs to be strengthened. In addition, ocean literacy is still poor and enhanced capacity building and awareness raising are needed to support the implementation of SDG14 at all levels. Ocean and coastal monitoring frameworks need to be further developed, harmonised and strengthened, since they provide the data to assess progress in the full implementation of SDG14.

NEXT STEPS

The conceptual framework and assessment of key interactions between the four Sustainable Development Goals presented here are intended to represent a starting point for further work towards a more complete understanding of how the full set of goals fit together. The framework guides a more detailed analysis and enables structured deliberations on how to implement the 2030 Agenda coherently, in order to maximise development outcomes. Making interactions explicit and understanding the full impacts of policies and actions across goals, stimulates important knowledge gathering and learning processes and has very concrete and tangible value for achieving efficiency and effectiveness in goal implementation, for driving meaningful multi-stakeholder partnerships, and for country-level monitoring, evaluation and review.

INTRODUCTION
A FRAMEWORK FOR UNDERSTANDING SUSTAINABLE DEVELOPMENT GOAL INTERACTIONS

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David McCollum

THE SUSTAINABLE DEVELOPMENT GOALS

Implementation of the 2030 Agenda for Sustainable Development, adopted by world leaders in September 2015 at a historic United Nations Summit and underpinned by 17 Sustainable Development Goals (SDGS) and their associated 169 targets, began on 1 January 2016. The SDGS are expected to guide governments as they work to address some of the most pressing challenges facing humanity.

The SDGS were developed following the United Nations Conference on Sustainable Development in 2012 ('Rio+20') and build on the Millennium Development Goals (MDGS) adopted in September 2000 as part of the UN Millennium Declaration. The SDGS provide a more holistic and integrated approach to development than the MDGS, thus continuing the legacy of the Brundtland Commission (UN, 1987) and the Rio Declaration on Environment and Development (UN, 1992). They are designed to be universal and therefore apply to all countries – poor, rich and middle-income alike – and to all segments of society. Although each focuses on a different topic area, the SDGS are meant to be integrated, indivisible and collectively support a development agenda balancing the economic, social and environmental dimensions of sustainability. (see blue text below)

While not legally binding, the SDGS do provide a globally endorsed normative framework for development. Governments and other stakeholders are expected to establish national and regional plans for their implementation. The 2030 Agenda is neither a blueprint for specific action nor for navigating the complexities and trade-offs that will undoubtedly emerge during implementation.

OVERALL AIM OF THE SDGS

The Sustainable Development Goals (SDGS) promote human dignity and prosperity while safeguarding the Earth's vital biophysical processes and ecosystem services. They recognise that ending poverty and inequality must go hand-in-hand with strategies that support sustainable economic growth, peace and justice; address fundamental social needs, including education, health, social protection, and job opportunities; and do all this while also tackling climate change and enhancing environmental protection. Detailed information on the 17 SDGS and their associated 169 targets is available at https://sustainabledevelopment.un.org/?menu=1300.

BACKGROUND

Although governments have stressed the integrated, indivisible and interlinked nature of the SDGS (UN, 2015), important interactions and interdependencies are generally not explicit in the description of the goals or their associated targets. In 2015, the International

Council for Science (ICSU) identified some interactions across SDGS at the goal and target-level (ICSU and ISSC, 2015). This report goes further, by exploring the important interlinkages within and between these goals and associated targets to support a more strategic and integrated implementation. Specifically, the report presents a framework for characterising the range of positive and negative interactions between the various SDGS, building on the work of Nilsson et al. (2016), and tests this approach by applying it to an initial set of four SDGS: SDG2, SDG3, SDG7 and SDG14. This selection presents a mixture of key SDGS aimed at human well-being, ecosystem services and natural resources, but does not imply any prioritisation.

While the scientific community has emphasised the need for a systems approach to sustainable development (e.g. GEA, 2012; PBL, 2012; SEI, 2012; Stafford Smith et al., 2012), policymakers now face the challenge of implementing the SDGS simultaneously with the aim of achieving progress across the economic, social and environmental dimensions worldwide.

This work provides a starting point to addressing this challenge. It has been led by ICSU with the support of several internationally renowned scientific institutes, including the Institute for Advanced Sustainability Studies (IASS), the Kiel based Future Ocean cluster, the International Food Policy Research Institute (IFPRI), the French National Research Institute for Sustainable Development (IRD), the International Institute for Applied Systems Analysis (IIASA), Monash University, the New Zealand Centre for Sustainable Cities, and the Stockholm Environment Institute (SEI). It is based on the premise that a science-informed analysis of interactions across SDG domains, and how these interactions might play out in different contexts, can support more coherent and effective decision-making, and better facilitate follow-up and monitoring of progress. Such an analysis will also make it possible to better highlight inequalities concerning progress made, which will in turn make it easier to identify corrective measures as well as help to avoid unintended side-effects.

WHY ARE INTERACTIONS IMPORTANT?

The 2030 Agenda for Sustainable Development is often referred to as an integrated agenda and its advocates frequently describe it as an ‘indivisible whole’. What does this mean in practice? First, in contrast to the conception of the Rio ‘pillars’ of economic development, social development and environmental protection, the three dimensions of sustainable development are described in the introductory sections of the 2030 Agenda as intertwined, cutting across the entire Agenda. These interactions also featured strongly in the deliberations of the Open Working Group that developed the SDGS. In fact, while most of the 17 SDGS have a clear starting point in one of the three pillars, most actually embed all three dimensions within their targets. For example, SDG2

"End hunger, achieve food security and improved nutrition and promote sustainable agriculture" contains targets with social (e.g. malnutrition and vulnerability), economic (e.g. agricultural productivity and agricultural trade) and environmental dimensions (e.g. genetic diversity and climate resilience). Second, there are significant interactions between SDGs. Continuing with the example of SDG2, a commonly discussed set of interactions lies in the nexus between food, water and energy (Weitz et al., 2014) as reflected in the linkages between SDG2, SDG6 and SDG7. For instance, water is required in the energy sector for cooling in thermal power plants and for generating hydro-electricity; energy is required for residential and industrial water usage, and for pumping water for irrigation; and water is needed for all food and bioenergy production. Third, because of the strength of these linkages, achieving targets under these goals can lead to trade-offs between competing interests: for example, food production may compete with bioenergy production for the same land or water. Finally, the SDG2 targets interact with a much broader set of targets and goals, such as those preventing childhood death (target 3.2), reducing food waste (target 12.3), encouraging sustainable business practices (target 12.6), conserving marine areas (target 14.5) and ensuring rights to control over land and natural resources (target 1.4).

Articulating and understanding the many interlinkages helps to explain why the 2030 Agenda must indeed be treated as an 'indivisible whole'. However, in that phrase there is a hidden presumption that the interactions between goals and targets are – for the most part – mutually supporting: in order to make progress in one area, progress must also be made in others. Yet, both the research community and policymakers have already highlighted that there can be conflicts and trade-offs between goals (PBL, 2012; IRP, 2015; LeBlanc, 2015).

Given budgetary, political and resource constraints, as well as specific needs and policy agendas, countries are likely to prioritise certain goals, targets and indicators over others. As a result of the positive and negative interactions between goals and targets, this prioritisation could lead to negative developments for 'non-prioritised' goals and targets. An example is the potential prioritisation of SDG2, whose progress might well lead to adverse impacts for several of the SDG15 targets (on terrestrial ecosystems), for example by converting rainforest to agriculture. Even if countries continue under business-as-usual conditions for agricultural production, terrestrial ecosystems could deteriorate below current levels within a short timeframe. Moreover, due to globalisation and increasing trade of goods and services, many policies and other interventions have implications that are transboundary in nature, such that pursuing objectives in one region can impact on other countries or regions' pursuit of their objectives. For example, there could be increased deforestation in some countries as a result of enforced logging bans in other, often neighbouring, countries, or there could be changes in national trading policies that impact on the availability of goods and services in other countries. Similarly, pursuing a policy for biofuels in one region can drive up prices of food crops else-where and thus foster hunger for the poorest – yet, sustainable development of biofuels could also encourage investment and market developments that improve overall food security (Osseweijer et al., 2015; Kline et al., 2016).

In the policy arena, most discussions about coherence and interlinkages in the 2030 Agenda have focused on either simply establishing that there is a link, or discussing the existence of trade-offs and synergies between topic areas (representing whether an interaction is broadly beneficial or adverse) and the need to map them and identify ways to alleviate or remove trade-offs or their costs, as well as maximise synergies (e.g. PBL, 2012; IRP, 2015).

However, interactions between SDGS currently have a weak conceptual and scientific underpinning, and there is a clear need for approaches and tools that can support analysis of the nature and strengths of these interactions, and the extent to which they constrain or enable policy and action. Indeed, there is a need to develop guidance and tools that can help policymakers, investors and other actors to identify and manage the benefits and risks of achieving the various goals and targets. In particular, it is important to deploy a more nuanced view of interactions, and to move the discourse beyond the simple notion of trade-offs and synergies. Attempts have been made in recent years. For example, Weitz et al. (2014) and Coopman et al. (2016) applied an approach for interlinkages with three categories – supporting, enabling and relying (with sub-categories). International agencies have also published increasingly advanced approaches to identifying and evaluating interactions (e.g. UNESCO, 2016; UN, 2016).

Thinking carefully about SDG interactions and more specifically about the range of different types of interaction is important because they may have very different implications in terms of implementation action. The nature and dynamics of the interactions need to be better understood before policy can be formulated, including the setting of context-specific (such as national or local) targets and indicators. Such analyses should be conducted with a view to providing a useable knowledge base for both policy-level decision support and the design of implementation strategies.

In short, there is a lack of information on this topic and more research is needed. For this reason, ICSU (2016) and Nilsson et al. (2016) have developed a tool, or framework, whereby interactions between SDGS and targets are classified on a seven-point ordinal scale, indicating the nature of the interaction with other targets, and the extent to which the relationship is positive or negative (see graphic p. 24). This framework has been applied throughout the individual chapters of the current report.

GOALS SCORING

INDIVISIBLE

The strongest form of positive interaction in which one objective is inextricably linked to the achievement of another. Reduction of air pollution (12.4) is indivisible from improved health and reducing non-communicable diseases (3.4).

+3

Outdoor and indoor air pollution is responsible for 7 million deaths annually, as well as respiratory and cardio-vascular disease but also increases in perinatal deaths. In 2012, ambient (outdoor) air pollution was responsible for 3 million deaths, representing 5.4% of the total deaths. Worldwide, ambient air pollution is estimated to cause about 25% of the lung cancer deaths. Major urban centers in low and middle-income countries are the most exposed to this burden. (WHO, 2016).

REINFORCING

One objective directly creates conditions that lead to the achievement of another objective. Increasing economic benefits from sustainable marine resources use (14.7) reinforces the creation of decent jobs and small enterprise in e.g. tourism (8.5 and 8.9)

+2

Sustainable and diversified strategies for using the marine resource base open up opportunities for small enterprises in fisheries or other harvesting and associated value-addition activities, as well as activities related to tourism. Many SIDS and LDCs that are rich in these resources also have poor, vulnerable and marginalized coastal communities.

ENABLING

The pursuit of one objective enables the achievement of another objective. Developing infrastructure for transport (9.1) enables participation of women in the work force and in political life (5.5)

+1

Affordable public transport promotes social inclusion, more equal access to different parts of the city, and enabling employment for marginalized groups. In many places, women do not have access to a car and depend on public transport, walking or bicycling to get around, to work places and to social or political activities (NCE, 2016; GSDR, 2016)

CONSISTENT

A neutral relationship where one objective does not significantly interact with another or where interactions are deemed to be neither positive nor negative. By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution (14.1) is consistent with target 3.5 Strengthen the prevention and treatment of substance abuse, including narcotic drug abuse and harmful use of alcohol.

0

There is no significant interaction between the two targets.

CONSTRAINING

A mild form of negative interaction when the pursuit of one objective sets a condition or a constraint on the achievement of another. Conserving coastal areas (14.5) and development of safe affordable housing and basic services (11.1) may constrain each other

-1

Establishing protection areas in the coastal zone and expanding urbanization, infrastructure or transport risks spatial competition especially in densely populated areas. Integrated coastal zone management and marine spatial planning tools are readily available to mitigate spatial competition.

COUNTERACTING

The pursuit of one objective counteracts another objective. Ensuring access to safe, nutritious and sufficient food can counteract sustainable water withdrawals (6.4) and reduction of chemicals releases (12.4)

-2

Increasing productivity in agriculture is a necessary (but not sufficient) condition to improve food security. In many places, this might entail increased and/or better irrigation as well as increased use of agro-chemical inputs.

CANCELLING

The most negative interaction is where progress in one goal makes it impossible to reach another goal and possibly leads to a deteriorating state of the second. A choice has to be made between the two. Developing infrastructure (9.1) could be cancelling the reduction of degradation of natural habitats in terrestrial ecosystems (15.1)

-3

In underdeveloped regions, developing roads, dams, and power grids might be a high priority, although it will cause some unavoidable fragmentation of habitats and compromising the integrity of the natural ecosystem, leading to risks to biodiversity as well as social risks.

BEYOND TRADE-OFFS AND SYNERGIES – A SEVEN-POINT SCALE

The framework identifies categories of causal and functional relations underlying progress or achievement of goals and targets. The scale ranges from -3 to +3, from instances where progress on one target acts to cancel progress on another to where progress on one goal is inextricably linked to progress on another. Complementing the scale are a number of key dimensions (time, geography, governance, technology, directionality) that describe the interactions and define the context in which they occur. Most interaction scores depend on these dimensions – and putting in place the right policies and technologies might shift the score to a more positive one.

To be more specific, positive interactions are assigned scores of either +1 ('enabling'), +2 ('reinforcing'), or +3 ('indivisible'), while interactions characterised by trade-offs are scored with -1 ('constraining'), -2 ('counteracting'), and -3 ('cancelling'). Thus, the magnitude of the score, in whichever direction, provides an indication of how influential a given SDG or target is on another. For instance, a value of +1 corresponds to an 'enabling' relationship, wherein the achievement of one objective (such as providing electricity access in rural homes, SDG7) creates conditions for furthering another (such as child and adult education, SDG4). Meanwhile a higher score of +3 corresponds to an 'indivisible' relationship, wherein one objective is inextricably linked to the achievement of another. For example, ending all forms of discrimination against women and girls (target 5.1) is absolutely necessary for ensuring women's full and effective participation in society (target 5.5). As an example of a negative interaction, the relationship between on the one hand boosting a country's economic growth (target 8.1) and on the other reducing waste generation (target 12.5) might be assigned a score of -2 ('counteracting'), since the former potentially clashes with the latter (unless mechanisms are put in place to prevent this, such as circular economy strategies that include effective waste prevention or substantially increasing recycling rates). Finally, for SDGs and targets exhibiting no significant positive or negative interactions, a score of 0 ('consistent') is assigned. Because interactions can manifest at the broad goal level, the more detailed target-level and even at the level of individual development actions, the framework has been designed to be applicable across multiple geographic scales (local to global), and for determining the impacts of planned actions as well as for evaluating the wider implications of actions that have already taken place.

Not all linkages between SDGs and targets will fall neatly into one of the seven points on the scale, but the scale does provide a sufficiently wide range to classify most relationships.

Choosing the level at which to apply the scale (goal, target or action) depends on the purpose of the assessment. In some cases, having reached a target, the issue is then whether this will directly affect another policy area or target under the same goal or under another goal. The focus then shifts to the physical interaction – how one set of conditions in society or the environment affects our ability to attain another set of objectives. In other cases, the issue could be how policy instruments, actions or investments put in place to pursue one SDG target would affect the ability to pursue another policy area. The latter reflects standard impact assessment procedure, and can be used to mitigate negative interactions already in the project or policy formulation stage.

In practice, it will usually be a combination of examining instruments and targets that is required to identify an effective strategy. For example, the introduction of a fuel tax to promote energy efficiency (target 7.3) will have certain distributional (SDG10) consequences, such that lower income or rural populations are disproportionately affected by the tax, although improved energy efficiency in itself may not have such consequences. It should be possible both to simulate implementation strategies with integrated assessment models that test the relationship and monitor empirically the nature of interactions during implementation in reality. Over time, with the support of the scientific community, those in charge of monitoring the SDGS should be able to develop an ever improving dataset for systematically monitoring progress.

It should be noted that the position of a given interaction on the seven-point scale is rarely absolute. The position and nature of the interaction depend on the context within which the interaction occurs. It should also be clear that a good development action is one where all negative interactions are avoided or at least minimised, while at the same time maximising significant positive interactions; but this by no means suggests that policymakers should avoid attempting progress in those targets and goals that are associated with significant negative interactions – it merely suggests that in these cases policymakers should tread more carefully when designing policies and strategies.

KEY DIMENSIONS THAT SHAPE INTERACTIONS

A number of dimensions can be used to contextualise the assessment of specific synergies and trade-offs, providing deeper insights into elements and areas that the SDG- and target-level interactions depend on. These include directionality, place-specific context dependencies, governance, technology and time-frame. Each is now discussed in turn, with examples given to aid the explanation. In case-study analysis, it is important to discuss these contextual considerations at the same time as the assigned score. Understanding what interactions depend on, or whether they are intrinsic, is key to mitigating negative interactions and maximising positive ones. In other words, changes in these dimensions can often enable a shift from a negative to a more positive interaction, or vice versa. Also, an analysis of a given interaction should, if possible, include an assessment of the uncertainty given the current state of knowledge.

DIRECTIONALITY

Interaction between two SDGs or targets can be unidirectional, bidirectional, circular or multiple. A unidirectional relationship means that objective A affects B, but B does not affect A. For example, electricity access (target 7.1) is needed for powering clinics and hospitals for the delivery of essential health care services (target 3.8), but health care services in clinics and hospitals are not needed for providing electricity access. On the other hand, a bidirectional relationship means that A affects B, *and* B affects A. For example, providing more access to transport today (target 11.2) is likely to lead to higher greenhouse gas emissions (target 13.2), thus exacerbating climate change, while measures taken to reduce greenhouse gas emissions can constrain transport access. In the case of bidirectionality, interactions can also be symmetrical (where the impact is similar in type and strength) or, more commonly, asymmetrical, where A affects B more, or in different ways, compared to how B affects A. In a circular relationship A affects B, which affects C, which in turn affects A. In a multiple relationship A affects B, C, D etc.

A comprehensive approach that takes into account directionality can be pursued whereby SDG targets are presented in a matrix and juxtaposed, and all potential interactions are analysed and scored, including A to B and B to A.

PLACE-SPECIFIC CONTEXT DEPENDENCY

Some relationships are generic across borders while others are highly location-specific; and the scale of the analysis can have a significant effect on results. For example, the issue of trade-off between bioenergy (target 7.2) and food (SDG2), which has gained significant attention in policy debates (see for example, Rosegrant et al., 2008) does not appear prominently in northern European countries such as Sweden or Finland (Ericsson et al., 2004). On the contrary, farmers and forest owners can both benefit from the diversification of markets, because it makes their supply chains less vulnerable as a whole. As a result, farmers may invest more and both food systems production and energy systems are stronger (Kline et al., 2016).

However, such geography-dependent relationships can have significant spill-over effects, due to international trade. Hence, even if bioenergy in the Nordic countries is not considered to affect their food security, a change in their food export patterns in response to increased national bioenergy production would still impact food security globally, through changes in trade and international prices of agricultural commodities. This dependency is not limited to natural conditions, but can include level of development, configuration of political and economic interests, social and cultural attitudes, and many other aspects.

Thus, what constitutes a positive interaction and a negative interaction can differ from one context to another and from one scale to the next. Hence scientific evidence in one area that does not hold for a different scale or target area may appear highly contradictory at first glance. But using the SDGs as a knowledge management grid could help to clarify what evidence refers to what context, and how knowledge can be generalised.

GOVERNANCE DEPENDENCY

In some cases, the negative nature of a relationship can be the result of poor governance. For example, industrialisation (target 9.2) has sometimes been associated with infringement of rights (target 1.4), where commercial actors have taken over lands used by local communities without consultation or compensation and with the exclusion of those communities from work opportunities. However, this negative interaction is not necessarily intrinsic to the industrial activity itself, but rather derives from inadequate governance. Negative impacts on local communities are more likely to occur, or tend to be stronger, when institutions and rights are weak.

TECHNOLOGY DEPENDENCY

In some cases, while a strong trade-off may exist, there may be technologies that, when deployed, will significantly mitigate this trade-off, or even remove it. One example is growth in mobility (namely personal motorised transport) which, at present, conflicts with climate change mitigation efforts. In the future, however, the transition towards zero-emission cars fuelled by renewable electricity could largely remove this trade-off. However personal vehicle impact on land-use change will remain.

TIME-FRAME DEPENDENCY

Some interactions develop in real time, while others show significant time lags. For example, increases in fertiliser use will boost agricultural productivity that season (target 2.4), thereby increasing food availability and contributing to food security over the short term. Similarly, harvesting remaining fish stocks can have important food security (target 2.1), nutrition (target 2.2) and poverty alleviation (target 1.1) benefits in the short term, possibly to 2030. However, these practices might well have longer-term adverse impacts on several SDGs, ranging from SDG14 on the sustainable use of oceans to SDG2, SDG15 and SDG1, among others. Moreover, some interactions may be restricted in time to the actual period of intervention (i.e. when the intervention ceases, the interaction stops), while others are irreversible or take a very long time to dissipate (i.e. until the affected systems recover). Irreversible impacts are well known in land and ocean ecosystems, such as species extinction, collapsed fisheries or eutrophication (e.g. in the Baltic Sea, Lindegren, 2009; HELCOM, 2010).

THE ROAD TO POLICY COHERENCE

By systematically assessing the interactions and relationships between SDGs and targets, this report aims to support horizontal coherence across sectors. Coherence can be defined as *"an attribute of policy that systematically reduces conflicts and promotes synergies between and within different policy areas to achieve the outcomes associated with jointly agreed policy objectives"* (Nilsson et al., 2012:396). However, it is also important to keep in mind the other dimensions of policy coherence (OECD, 2016, see graphic). These additional dimensions, that become visible during implementation, concern alignment between and across countries, across levels of government, across governance mechanisms, and across the implementation continuum.

HORIZONTAL AND VERTICAL INTERACTIONS AND COHERENCE RELATIONSHIPS

SECTORAL COHERENCE	TRANSNATIONAL COHERENCE	GOVERNANCE COHERENCE	MULTILEVEL COHERENCE	IMPLEMENTATION COHERENCE
from one policy sector to another	from one jurisdiction to another (PCD)	from one set of interventions to another	from global/international agreements to national and local policy	from policy objective through instrument design to practice

An important type of coherence relationship exists across transnational jurisdictions. This ties in directly to the policy coherence for development agenda (OECD, 2016) – observing to what extent the pursuit of objectives in one country has international repercussions or affects the abilities of another to pursue its sovereign objectives.

In addition, coherence relationships need to be observed across multiple levels of government. Here, in the context of the 2030 Agenda, there may be a mismatch between the goals and targets established at the global level, and the agenda as interpreted at national level and acted upon at the local level.

Coherence can also be examined across governance interventions. For example, policymakers and planners put in place different legal frameworks, investment frameworks, capacity development mechanisms and policy instruments that may or may not pull in the same direction. In fact, it is often the case that while new policies and goals can be easily introduced, institutional capacities for implementation are not aligned with the new policy designs, because the former are commonly more difficult to develop (OECD, 2016; Gupta and Nilsson, 2017).

Finally, coherence relationships should be considered along the implementation continuum: from policy objective, through instruments and measures agreed, to implementation on the ground. The latter often deviates substantially from the original policy intentions, as actors make their interpretations and institutional barriers and drivers influence their response to the policy (Pressman and Wildavsky, 1973; Nilsson et al., 2012).

FIRST APPLICATION OF THE SCALE

Subsequent chapters apply the framework as presented here to key interactions for SDG2, SDG3, SDG7 and SDG14. This selection presents a mixture of key SDGS aimed at human well-being, ecosystem services and natural resources, but does not imply any prioritisation.

The chapters follow a similar structure. Each starts by presenting an overview of interactions between a single SDG (the 'entry goal' focus of the chapter) and the other 16 SDGS, staying at goal level. Taking into account all the underlying targets of the entry goal, a set of key interactions is then identified between the entry goal targets and those of numerous other SDGS, principally interactions within the range of the highest magnitude or strongest impacts based on available scientific literature and expert knowledge. Using the typology and seven-point scale described earlier, the chapter then provides an assessment of the selected target-level interactions and the context in which they *typically* occur. Illustrative examples from different world regions show how these linkages manifest in practice. Policy options are identified for how to maximise positive interactions and minimise negative interactions between now and 2030, and beyond. Each chapter concludes with a list of key knowledge gaps related to the interactions studied.

The scoring approach described here offers a means by which multidimensional, complex and wide-ranging scientific evidence can be 'translated' and summarised in the form of an interpretive framework. The end product is such that evidence gathered from scientific research can be fed into deliberations between policymakers for different topic areas in an accessible, understandable and directly comparable form.

The report does not aim to present a fully comprehensive analysis of all possible interactions for a given SDG and its underlying targets. Rather, the aim is to illustrate, by focusing on a subset of the key interactions, how the scoring framework can be applied in practice. Going forward, a comprehensive analysis of this type could, and should, be carried out on all SDGS. It is hoped that this report inspires the development and synthesis of empirical research on interactions across all the SDGS in different parts of the world, and among different scientific and policy communities.

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SDG 2 END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE

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INTRODUCTION

SDG2 integrates and links food security, nutrition and a sustainable and climate-resilient agriculture. A focus on the role of small producers in the agriculture sectors is an important element. This multi-dimensional goal encompasses several specific targets, and these can be subdivided into three interrelated components: ending hunger and improving nutrition (social dimension: 2.1, 2.2), achieving food security through productivity improvement and income increase (economic dimension: 2.3, 2.a, and to a certain extent 2.b and 2.c), and promoting sustainable agriculture (environment dimension: 2.4, 2.5).

This brief description of SDG2 – the 'entry level goal' for this assessment – is followed by an overview of interactions at goal level between SDG2 and the other 16 SDGS. Taking into account all the underlying targets of this entry goal, a set of key interactions is then identified between the SDG2 targets and those of other SDGS, focusing on interactions with high magnitude or strong impacts based on available scientific literature and expert knowledge. The typology and seven-point scale for characterising the range of positive and negative interactions described in the opening chapter to this report is used to assess the selected target-level interactions and the context in which they *typically* occur. Illustrative examples from different world regions show how these linkages manifest in practice. Policy options that can enhance positive and reduce negative interactions between now and 2030, and beyond are also described. The chapter concludes with a list of key knowledge gaps related to the interactions studied.

KEY INTERACTIONS AT **GOAL LEVEL**

2 + 1

Ensuring that all people have access to safe, nutritious and sufficient food all year round is inextricably linked to poverty eradication and, as such, addressing undernutrition is indivisible from addressing poverty. According to the World Bank (2007), growth in agriculture is at least twice as effective in reducing poverty as growth in any other sector. There are multiple pathways through which increases in agricultural productivity can reduce poverty; key among these are increased incomes and associated multiplier effects stimulating employment in the rural and urban non-farm sectors through forward and backward linkages. However, success in agriculture does not always reduce poverty and not for everyone. This is the case in Brazil where agricultural growth in some regions has been concentrated in a dynamic export-oriented sector of large capital-intensive farms. As a result, agricultural employment declined with few poverty reduction effects. Moreover, in pursuing some of the SDG2 means of implementation, such as trade liberalisation, poverty levels might increase for some strata of society, at least in the short term and if no safety nets are established (Winters et al., 2004). Furthermore, some policies developed to improve food security for the poor, such as price controls, may have perverse impacts, such as depressing farm income. Although some evidence indicates a shift in the concentration of poverty levels from rural to urban areas, rural people continue to represent the largest segment of the world's extreme poor. However, while a large proportion of the world's extreme poor are concentrated in sub-Saharan Africa (World Bank, 2016), South Asia remains home to the largest concentration of undernourished people.

2 + 2

Synergies and trade-offs can also occur between the five targets and three implementation mechanisms of SDG2. Generally the targets of ending hunger and achieving food security benefit from achievements on the economic (productivity improvement) and environmental front (sustainable agriculture) and are supported by investments in agricultural research, trade and market development. However, trade-offs can occur between the agricultural economy versus sustainability focused targets. For example, yield gaps are particularly high in sub-Saharan Africa for some of the region's major staple crops (World Bank, 2007). Closing these gaps through agricultural productivity improvement can, however, constrain the sustainability of agriculture. As an example, Duflo et al. (2008) found that in the short term, productivity increases in Kenya may be achieved most cost-effectively through the use of inorganic fertilisers, but this can adversely affect ecosystems and, in the long-term, the sustainability of the agricultural sector and its productive capacity. Based on a comprehensive meta-analysis, Ponisio et al. (2015) found a large heterogeneity in the performance of all types of production system and that diversification practices appear to be key in enhancing yields and profit. In this sense, solutions that support both productivity enhancements and sustainable agro-ecosystems do exist. Examples are context-specific and can include crop rotation to enhance soil health, permanent soil protection by cover crops or residues, no-till agriculture, increased nutrient use efficiency, low- or high-tech precision agri cultural methods, integrated soil fertility and integrated land and water management approaches (Rosegrant et al., 2014). Trade-offs can also occur between targets for agricultural production and nutrition, because increase in the agricultural production and affordability of low-nutrient and energy-rich foods can contribute to macro and micronutrient deficiencies (Johnston et al., 2014). In addition, trade-offs may arise if rural infrastructure development does not pay attention to the needs of smallholder food producers as well as biodiversity protection. Lastly, international trade patterns may enhance or constrain the economic situation of small-scale food producers.

2 + 3

Malnutrition remains one of the main contributors to the global burden of disease. Globally, 45% of child deaths under the age of five are linked to malnutrition – prominently in sub-Saharan Africa (WHO, 2016). In other words, being malnourished in any form carries significant risks to health and well-being. Agriculture influences mental, emotional and physical health directly through its ability to provide a sufficient quantity of nutritious foods for direct household consumption or in the marketplace. Quality food and nutrition status is a fundamental and crucial driver for health and well-being. However, unsustainable agricultural practices can constrain or even counteract healthy lives as a result of soil degradation and water pollution due to excessive use of chemicals (fertilisers, pesticides) and poor crop and livestock management practices; health risks associated with air pollution (e.g. sugar cane burning, or swamp drainage and clearing for agriculture), zoonotic diseases and poor food safety practices. Adequate consumption of a range of micronutrients over the course of a lifetime is also key to ensure a healthy and balanced diet and can be influenced by the diversity of foods grown. However, while improving agricultural production is essential for nutrition outcome, there are many complementary pathways including nutrition education, enhanced childcare practices, and empowerment of women in the household that are important to achieve nutritional outcomes (Ruel et al., 2013).

2 + 4

Chronic undernutrition, such as stunting, reduces intellectual capacity with possibly lifelong, irreversible consequences and might also affect subsequent generations (Victora et al., 2008). Undernutrition thus acts as a drag on education: compounding the negative effects of many other characteristics of poverty, it is associated with delayed school enrolment, impaired concentration, more schooling lost to illness, and drop-out before completion. Just as health outcomes and nutritional status are inextricably linked, the ability to learn and the nutrition of a child are mutually supportive. Moreover, a mother's educational level is an important determinant of the nutritional status of her children. Micronutrient deficiencies also affect learning ability. Almost 2 billion people worldwide are believed to be lacking in dietary iodine, including around 240 million children, and this is correlated with up to a 15-point reduction in IQ levels (WHO, 2013; Webb, 2014). Tackling undernutrition can reinforce educational efforts because children can concentrate and perform better in school with potentially lifelong positive impacts on earning capacity and well-being. Equal access to education for sustainable development and sustainable lifestyles interacts positively with food and nutrition security and also more sustainable agriculture. Such education can play a key role in helping people move towards more sustainable farming methods, and for under standing nutrition information. Similarly, in countries with high obesity rates, nutrition education can reduce the risk of non-communicable diseases such as heart disease, stroke, diabetes and cancer. Not addressing food security and nutrition and associated agricultural production practices also affects education outcomes negatively when children are kept out of school because they need to work on farms for subsistence production or elsewhere to help generate income to purchase food. Worldwide, 60% of all child labourers in the 5–17 year age group are engaged in agriculture (including farming, fishing, aquaculture, forestry, and livestock), amounting to over 98 million girls and boys (ILO, 2016).

2 + 5

Gender inequalities are the most pervasive of all inequalities, and interactions between this goal and the other SDGs are strong. Ending hunger and improving nutrition is crucial for women due to their key roles in food production, food preparation, and child care, but also because of their special vulnerabilities related to reproductive health. Furthermore, undernourished girls and women are often least able to take advantage of development resources (be it microcredit, schooling or paid jobs) because of lower work capacity due to undernutrition, sickness and inability to travel or join meetings that could be to their benefit. They are therefore less able to contribute to the goals of equality and empowerment. Empowering women in agriculture through increasing their decision-making over agricultural production and incomes has been shown to improve both family health and nutrition outcomes. According to the FAO, if women farmers had the same access to agricultural inputs, education and markets as men the number of hungry people could be reduced by 100–150 million in the 34 countries studied (FAO, 2011). Thus, through providing greater access to resources and productive assets for sustainable agriculture to women, SDG2 is also enabling gender equality and women's empowerment.

2 + 6

Progress in working towards 'zero hunger' is highly dependent on progress in ensuring availability and sustainable management of water and sanitation. Agriculture is by far the main water user. Irrigated agriculture accounts for 70% of water withdrawals and a higher share of water consumption. The interactions between SDG2 and SDG6 are undisputable with some targets enabling the achievement of others, while others are constraining and yet others are in conflict. Two of the most obvious ways to lift agricultural productivity are to expand access to irrigation and to increase the use of synthetic fertilisers and pesticides. But unless carefully planned and managed, both activities have the potential to undermine the availability, sustainability and quality of water for agriculture and for other water users. Similarly, livestock waste can constrain the protection of water-based ecosystems. Ensuring sustainability of agricultural production systems can help address this constraint. Currently about 663 million people still lack access to safe water and 2.4 billion do not have access to adequate sanitation (UNICEF/WHO, 2015). Evidence suggests a direct link between unsafe drinking water and adverse nutrition outcomes through various infectious water-borne and water-related diseases, such as malaria, diarrheal disease, and nematode infections as well as a more recently studied phenomenon called environmental enteric dysfunction, an acquired disorder of the small intestine (Dangour et al., 2013). Finally, demand for biofuels is projected to increase dramatically in the medium-term under different climate mitigation strategies; competition for water (and land) with SDG2 targets and SDG6 targets is likely to increase as a result.

2 + 7

Sustainable agriculture as well as food security and nutrition are highly dependent on energy security (affordable, easily accessible, and reliable energy supplies), because energy is often used to increase food production (agricultural chemicals, machinery, irrigation, post-harvest processing, storage and transportation, etc.). Remote agricultural areas without access to fertilisers and pesticides or electricity connections (or solar pumps) face greater challenges in increasing agricultural productivity. Conversely, agricultural production can play an important role in achieving affordable, reliable, sustainable and modern energy for all through the production of biofuels and biogas. Global energy demand is expected to increase by 48% between 2012 and 2040 – with most of the increase among the developing non-OECD nations (EIA, 2016). The interactions between these trends and SDG2 depend on (climate) policy and fossil energy prices, but could mean that more crops are diverted for use as biofuels. Furthermore, methane production from agricultural wastes (animal or plant-based) can contribute to meeting the renewable energy targets set for 2030, as can dedicated bioenergy resources (agroforestry or biofuels crops).

2 + 8

Agriculture provides a livelihood for many of the most poor and vulnerable people and supports pro-poor economic development. By increasing sustainable agricultural productivity and incomes of smallholder women and men, SDG2 can participate in sustainable economic growth. Key areas for women's participation in economic growth through agriculture include ensuring their access to financial services knowledge and markets, strengthening agriculture capacity to climate adaption, and increasing investment in rural infrastructure. Especially in remote rural areas that are cut off from most alternative employment opportunities, agriculture is often the only viable source of both employment and food and nutrition security. When rural economies develop, productivity growth in agriculture has shown to be a key aid to overall economic growth through releasing surplus labour to non-agricultural sectors, thereby spurring growth in these sectors and in the overall economy. Advances in decoupling economic growth from environmental degradation may be constrained by a focus limited to doubling agricultural productivity. Moreover, the agriculture sector is known to have an important buffer function during economic crises, with people losing their jobs in cities during financial turmoil switching to temporary employment in the agriculture sector. This was well documented during the Asian financial and economic crisis of 1989/1990 (e.g. Rosegrant and Hazell, 2000). Another important linkage relates to employment. Agricultural production strategies and systems can constrain the achievement of decent employment as 60% of all child labourers in the 5–17 year age group are engaged in agriculture (ILO, 2010). Moreover, the agriculture sector in some countries thrives on temporary migrant workers, often with limited legal and other protection. Finally, some economic growth strategies can constrain advancement of the agriculture sector, for example, if countries choose import-substitution industrialisation policies to move agrarian into industrialised economies, by taxing the agricultural surplus and moving the resources to the industrial sector (Rosegrant and Hazell, 2000).

2 + 9

With changing demographic conditions and changing patterns of food demand, there is a growing need for the design and development of more efficient integrated systems of food production, processing, preservation and distribution as well as reliable transportation and logistics infrastructure with roads facilitating access to markets (Knox et al., 2013). Infras tructure including affordable and water-use efficient irrigation, transportation, communication (e.g. internet access) and market (e.g. cold chain) facilities, could make a major contribution to achieving SDG2. Moreover, with growing climate variability and extremes, resilient transportation infrastructure, allowing food transport from surplus to climate stressed areas, will become increasingly important. Access to physical infrastructure is in this sense an important factor for the interaction between productivity and income. From an SDG2 perspective, developing and upgrading rural infrastructure, integrating small-scale enterprises into value chains, and enhancing investment in agricultural research are aligned with SDG9; however, if such infrastructure, research and financial services favours some producers over others, then achieving targets under SDG9 might constrain achievement of some SDG2 targets and/or reduce equity in access to such infrastructure (UN, 2016). For instance, more resilient infrastructure, such as larger dams supporting irrigation infrastructure, or wider, asphalted roads may address the needs of agri-exporters while ignoring those of smallholders and the food insecure. Such infrastructure may also accelerate biodiversity loss, over-extract of water resources, and ignite other unsustainable practices.

2 + 10

Hunger and food security are closely related to poverty, and thus to inequality. Reduction or elimination of inequality in the policy and legal arenas should enhance food and nutrition security as well as sustainable agricultural production. Empowering small-scale food producers, both women and men (who represent an important segment of the world's extremely poor) and ensuring their equal access to resources such as land, facilitates the reduction of inequality. Of note, trade liberalisation, an implementation mechanism suggested under SDG2, can adversely affect achieving the equality targets under SDG10, if small-scale farmers are not linked to value chains and markets and other non-competitive farming enterprises face import prices below local and national production costs. Trade liberalisation can also constrain a country's capacity to provide some forms of subsidies to domestic farmers or consumers to address internal inequalities. However, trade liberalisation can also support achieving SDG2 through making food more affordable to poor farmers, most of whom are net buyers of food, and to consumers.

2 + 11

Progress in food security and nutrition, increased agricultural productivity and more sustainable food production systems will reinforce the inclusiveness and sustainability of cities. Specifically, increased agricultural productivity – freeing up agricultural land for urban growth – can support progress on expanding green spaces and other city expansion needs. However, cities are generally built on prime agricultural land with stable water resources and uncontrolled expansion on these areas might constrain achieving SDG2, by removing further land resources and by consuming and polluting water resources. Urban agriculture can address this potential trade-off to some extent, through growing food on soil-less agriculture or hydroponics, vertical farming, aeroponics, nutrient-film-techniques, aquaponics, and through recycling of nutrients in wastewater. Urban agriculture thus can contribute to social welfare and sustainable development of cities and can support development of green spaces. It can also contribute to waste avoidance and recycling of organic waste in cities (Goldstein et al., 2016). Advancing rural-urban linkages will support sustainable agricultural productivity and income generation – peri-urban environments often house high-value vegetable and livestock production systems whose sustainable management is key to urban food and nutrition security. Of note, urban dwellers tend to consume more processed foods and, at least in low-income developing countries, tend to house more obese people and in some places (e.g. cities in Latin America and elsewhere) also more undernourished people than rural areas. Addressing the triple burden of malnutrition (obesity, undernutrition and micronutrient deficiencies) is therefore an important linkage between SDG2 and SDG11 that deserves further attention.

2 + 12

Most aspects of SDG12 support progress in SDG2 and vice versa. For example, the 10-year Framework of Programmes on Sustainable Consumption and Production Patterns is housed at UNEP (and not at UN FAO) and aims at raising awareness, building capacity, developing information as well as synergies and cooperation toward more sustainable food systems, which directly strengthen all areas of SDG2. Similarly, the subsequent efficiency, waste and loss reduction targets and the aim to manage chemicals more judiciously directly support SDG2 in terms of increased productivity and more sustainable natural resource use. While SDG2 focuses more on the production end and nutritional outcomes, SDG12 focuses on the processing, distribution and procurement side of the food system, which complements and completes the food system perspective. However, if developing countries, where most food is produced, distributed and consumed, would use the SDG12 focus on industrialised countries as a reason to not make progress on SDG12 themselves or would await funding and support from industrialised countries before embarking on progress, then some aspects of SDG2 (and SDG12) might not be achieved. An additional constraint could develop if the implementation mode proposed for rationalising inefficient fossil-fuel subsidies is implemented in agriculture and the food value chain without putting alternatives in place. The direct elimination of such subsidies could lead to increased food prices which, in turn, could constrain achieving 'zero hunger' by making food less affordable to the poor.

2 + 13

Rising temperatures, changing precipitation patterns, and the intensity and frequency of extreme weather events adversely affect agricultural production systems, particularly those in developing countries, which in turn constrains the achievement of 'zero hunger' and nutritional objectives under SDG2.
It is important that investments in agriculture increase the sector's resilience and adaptive capacity to climate change; for example, by mobilising large funds for climate mitigation and adaptation. How climate adaptation and mitigation options are implemented in the agriculture sector under the climate change frameworks (e.g. through biofuel development, short-term coping mechanisms or long-term adaptation/mitigation strategies) will be decisive for achieving SDG2. At the same time, unsustainable agriculture, deforestation and other types of land use account for about 24% of total anthropogenic greenhouse gas (GHG) emissions (IPCC, 2014). Achieving SDG13 will thus require the reduction of GHG emissions in agriculture and related activities and depending on which actions are taken, ending hunger, doubling agricultural productivity and ensuring more sustainable food production systems may be achieved faster or slower, or not at all. A range of actions could be impactful in this area, such as a moratorium on further expansion of agricultural areas into tropical forests or peatlands, a tax on highly emitting livestock production systems, increased

R&D toward new technologies that increase fertiliser nutrient use efficiency levels of plants, the accelerated adoption of no-till agriculture, and additional support to agroforestry systems. By integrating action on sustainability with action on productivity improvement (smart agriculture) and soil organic matter sequestration, agriculture could be seen as part of the solution not only to mitigate agricultural GHG emissions but also to strengthen adaptation strategies.

2 + 14

More than 3 billion people depend on marine and coastal resources for their livelihoods (United Nations, 2015b). More sustainable ocean fisheries and better access for small-scale fishers and residents of small-island states to these resources will support food security and nutrition in the long term. More research and solutions for ocean acidification would also support food security and nutrition. However, strong marine protection limiting fisheries development in the short term, can adversely affect the hunger and nutrition targets of SDG2 and can constrain livelihoods and food security of poor populations in coastal areas. Sustainable agricultural practices can support the prevention of marine pollution from land-based activities, including nutrient pollution, and can facilitate the conservation and sustainable development of the oceans. However, poorly managed agricultural processes and activities (such as nutrient runoff and diffuse pollution) may have adverse impacts on water supply and the oceans. A well-known example of largely agricultural-driven pollution is the hypoxia in the Gulf of Mexico (Hufnagl-Eichiner et al., 2011). Similarly, clearing coastal habitats such as mangrove forests that protect coastlines and sustain coastal habitat for intensive aquaculture production, could help end hunger and improve nutrition over the short term, but could also exacerbate food security concerns over the long term.

2 + 15

The Millennium Ecosystem Assessment identified agriculture as the major cause of land use change, land degradation and desertification (MEA, 2005). As such, SDG15 could constrain the aim of zero hunger, improved nutrition and increased agricultural productivity, at least in the short term. A key trade-off is *extensification*, namely a focus on low-input agriculture (e.g. some organic agricultural systems), to preserve existing agro-ecosystems versus *intensification* where inputs per unit of land are substantially increased with better seed and other technologies and management practices. While intensification reduces the need to expand agricultural areas, in many cases water consumption and pollutant runoff are increased. In some cases, increased income from intensified agriculture might accelerate deforestation, but globally, the long-term focus on intensification in much of the world has reduced deforestation rates dramatically. On the other hand, SDG15 largely supports sustainable agricultural production and genetic diversity. For SDG2 and SDG15 to become mutually reinforcing, sustainable ecological processes need to be supported, without adverse impacts on land, water and biodiversity (e.g. pollinators) and without further deforestation and associated biodiversity losses and climate change impacts. The conservation of forests, wetlands, mountains and drylands can constrain increases in both agricultural production area and crop yield as well as livestock number and yield, unless this increased production is achieved using more sustainable management practices. Other linkages between SDG2 and SDG15 concern the conservation of genetic diversity of seeds, plants and animals; an area with shared targets.

2 + 16

Achieving SDG2 is highly dependent on political stability, peace, just and inclusive societies, and effective accountable and inclusive institutions. Hunger and food insecurity are sources of political instability, conflict and war – to the point that hunger is, at times, deliberately used in conflicts as a weapon to starve opponents into submission (seizing or destroying food stocks, livestock, cutting off marketed supplies of food, targeting farmers, land-mining, etc.). And, if food insecurity is not already a factor contributing to war and civil strife, then hunger and undernutrition are often the result of such activities, as farmers need to leave their land to flee insecurity, abuse and destruction and/or agricultural inputs or outputs cannot be moved to where they are needed, and support through food aid is often restricted or not available. On the other hand, effective, transparent and accountable institutions are needed at all levels of government to support sustainable agriculture, food and nutrition security and the empowerment of certain marginal groups such as women, indigenous peoples, family farmers, pastoralists and fishers. Justice for all and non-discriminatory laws lead directly or indirectly to securing fair access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities. Armed conflict and broader forms of violence undoubtedly undermine the achievement of food security, improved nutrition and sustainable agricultural systems. Civil war and conflict are also detrimental to the preservation of seed and plant banks, as the impacts on ICARDA's (International Center for Agricultural Research in the Dry Areas) gene bank in Syria has shown (Bhattacharya, 2016). Conversely, food insecurity has the potential to become the leading cause of conflict in the 21st century in the absence of national, regional and global political measures to enhance food solidarity, particularly in crisis situations.

2 + 17

SDG17 lists the main enablers for implementing the entire SDG framework, with structures around five sub-categories: finance, technology, capacity-building, trade, and systemic issues (including policy and institutional coherence, multi-stakeholder partnerships, data, monitoring and accountability). These are all linked with SDG2. For instance, finance enhancement can reinforce investment in rural infrastructure for agriculture. Enhancing technology and capacity building can also lead to the strengthening of agriculture's capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters. Enhancing multi-stakeholder partnerships, data, monitoring and accountability, and especially policy and institutional coherence, should also positively impact SDG2. Some trade-offs can emerge insofar as trade liberalisation may not fit with some countries' policy spaces, if they seek to establish and implement policies for poverty eradication and sustainable development. Furthermore, non-discriminatory international trade regulation may limit the capacity for some countries, mostly those in development, to protect their national agriculture production and small-scale food producers.

KEY INTERACTIONS AT **TARGET-LEVEL**

SDG2 is an integral part of the 2030 Agenda, linking to all 16 other SDGS. This section analyses some of these interactions, from the perspective of SDG2, with a selected set of SDGS in detail at the target-level. SDGS were selected based on the strength of the interactions with SDG2 and the magnitude and scale of impact in relation to the overall objective of the 2030 Agenda, while ensuring a balanced consideration of the economic, social and environmental dimensions. Target-level interactions are judged to fall within one of seven categories and are scored accordingly: indivisible (+3), reinforcing (+2), enabling (+1), consistent (0), constraining (-1), counteracting (-2), and cancelling (-3). Following a generic analysis of the selected interactions, specific examples are provided to illustrate how interactions unfold in different geographical and policy contexts.

Seven goals were selected for detailed analysis:

SDG1
SDG3
SDG5
SDG6
SDG7
SDG13
SDG15

SDGS were selected based on the strength of the interactions with SDG2, while ensuring a balanced consideration of the economic, social and environmental dimensions. While there are also obvious linkages between SDG12 and SDG2, it was considered that these are less insightful than those between SDG2 and the other SDGS selected for detailed analysis.

Illustrative examples are used to show the context-dependency of the interactions and provide a more practical entry point to characterising SDG2 interactions among the 'integrated and indivisible' SDGS. These concern three geographic regions:

West Africa (Senegal)
Amazonia
California (USA)

SDG 2 + SDG 1

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
2.1, 2.2 ⟶ 1.1, 1.2	Food and nutrition security are indivisible from the eradication and reduction of poverty	+3	Strengthen interaction issues via national, regional and international governance. Co-design and co-develop mechanisms to mitigate the negative interactions and target particular resiliency needs by ensuring that the poor and small-scale food producers' interests are fully addressed
2.3 ⟶ overall SDG1	Increasing small-scale food producer productivity and income reinforce the fight against poverty	+2	
2.3 ⟶ 1.4	Equal access to land and other productive resources is directly aligned with securing equal rights to economic resources	+2	Advance agricultural research and development with a focus on pro-poor technology development; with complementary investments in safe drinking water, social protection systems, and rural roads
2.3 ⟶ 1.5	Increasing agricultural productivity without sustainability (2.4) will increase vulnerability to climate-related extreme events and other shocks – primarily in developing countries and for poor segments of societies. Thus, 2.3 and 2.4 need to be achieved in tandem	-1/ -2	Increase small-scale food producer capacities and empowerment (knowledge, economic resources, basic services, rights); in particular put in place the economic mechanisms that increase the wealth of small farmers and reduce their vulnerability to uncertainties: access to land, access to productive and non-productive assets
2.4 ⟶ 1.5	Enhancing adaptive capacity in agriculture may enhance the resilience of the poor as long as they are fully included in adaptation strategies	0/ +1	Enhance diets and improve nutritional outcomes of a population to break the intergenerational cycle of poverty and at the same time generate accelerated shared economic growth. Such interactions could be reinforced via social programmes in nutrition education
2.b ⟶ 1.b	Removal of trade restrictions could constrain the creation of pro-poor policy frameworks by limiting the range of policy actions, at least in the short term	-1	Build resilience by setting up pro-poor policy frameworks and safeguards for poor and vulnerable small-scale food producers within a competitive market environment Ensure inclusive participation in trade negotiations and in addressing trade related issues. Consider the situation of the poorest countries in the agriculture sector and design trade policy accordingly. Address factors leading to market failure such as limited market access. Set up complementary policies to trade reform – such as strengthening social protection systems for those losing out from trade and develop capacities to explore beneficial changes Consider the role of diversification in strategies to improve production, productivity, employment, income nutrition and sustainability, as well as to reduce risks associated with market volatility, climate change and natural disasters

KEY POINTS

SDG2 enables and can reinforce SDG1 through enhanced food and nutrition security – which are essential to reduce poverty and eradicate extreme poverty

Supporting small-scale food producers can lead to substantial poverty reduction as rural people constitute the largest segment of the world's ultra-poor

A possible constraint is the potential impact of trade liberalisation, because small-scale farmers, at least in the short term, might be adversely affected by import surges and highly competitive foreign products or food dumping practices

If targets on agricultural productivity and on ensuring sustainable food production are not implemented in tandem, the poor and those in vulnerable situations are likely to be most affected

KEY INTERACTIONS

There are many pathways through which increases in agricultural productivity can reduce poverty. Food and nutrition security **(2.1, 2.2)** are inextricably linked to reducing and eradicating poverty **(1.1, 1.2)**. Without proper nutrition, humans cannot reach their full potential. Enhancing diets and improving nutritional outcomes of a population is important to break the intergenerational cycle of poverty and at the same time generate accelerated shared economic growth. Effects will have many beneficial impacts on individuals, families, communities and countries (IFPRI, 2015).

Although recent data show the rural/urban gap in poverty to be declining, with the poor urbanising faster than the population as a whole (Chen and Ravallion, 2007), rural people still represent a large proportion of the world's extreme poor (i.e. those living on less than US$ 1.90 per day). With wide regional variation, 80% of the world's poor live in rural areas, 64% work in agriculture, 44% are 14 years old or younger, and 39% have no formal education (World Bank, 2016).

It is usually assumed that growth in agriculture is at least twice more effective in reducing poverty than change in any other sector (World Bank, 2007). In this sense, a focus on small-scale food producers and aiming at doubling their agricultural productivity and incomes (through equal access to land and other productive resources and inputs) **(2.3)**, and on resilient agriculture and adaptation practices **(2.4)** should provide significant means to achieve SDG1. Such a focus can even reinforce targets on access to equal rights to economic resources and basic services (including control over land) **(1.4)** and on building resilience of the poor and those in vulnerable situations **(1.5)**. Women are identified in both SDG1 and SDG2 as a target group to support and empower.

However, interactions between the means of implementing SDG2 and SDG1, such as removal of trade restrictions in world agricultural markets **(2.b)** versus the creation of pro-poor policy frameworks **(1.b)** can be constraining. There is a surprising number of knowledge gaps about trade liberalisation and poverty, with disputed evidence on 'automatic' long-term gains, which remain elusive even though often asserted (Chabe-Ferret et al., 2007). In terms of developing countries, some research suggests that the consequences of agricultural trade liberalisation are very uneven. In middle-income developing countries, liberalisation can be a source of substantial growth, particularly in a high-performing export sector. However, in poorer countries such as Least Developing Countries (LDCs), liberalisation can have overall negative consequences, owing to terms-of-trade effects and supply-side constraints (Bureau et al., 2006). Negative consequences will necessitate further special and differential measures by countries in trade regulations. Without these, **target 2.b** can constrain the achievement of doubling incomes of small-scale food producers **(2.3)** by setting-up a competitive market environment, which might not be pro-poor unless safeguards, for example in the form of social safety nets, are implemented for poor and vulnerable farmers.

Furthermore, **targets 2.3** and **2.4** need to be achieved in tandem as one can counteract the other, and negatively affect the poor and those in vulnerable situations. Unsustainable agriculture, deforestation and other land use changes, currently responsible for 24% of global GHG emissions (IPCC, 2014), can counteract **target 1.5** by increasing the exposure of vulnerable populations to climate-related extreme events and other economic, social and environmental shocks and disasters – primarily in developing countries and poor segments of societies. In addition, land-use change, conventional agricultural practices and pesticide use can impact negatively on the health and diversity of pollinators and the provision of pollination. Many of the world's most important cash crops are pollinator-dependent – crops such as coffee and cocoa in developing countries, or almonds in developed countries, represent an important source of income. Pollinator loss will constrain economic development, employment and income for millions of people and limit capacity to reach SDG1 (IPBES, 2016). Finally, the objective of doubled agricultural productivity **(2.3)** could, if successfully achieved, lead to substantial declines in producer prices, rendering farming non-profitable, and leave many farmers worse off unless safety nets are put in place and non-competitive farmers are successfully integrated into other employment opportunities.

KEY UNCERTAINTIES

The main uncertainty is that pursuing SDG1 and SDG2 targets does not always reduce poverty and improve food and nutrition security everywhere and for everyone. As such, there is no guarantee that pro-poor agricultural development policies reduce poverty everywhere or that poverty-focused policies improve food security everywhere. To ensure that pro-poor policies are always conducive to enhanced food and nutrition security and sustainable agriculture requires a complex policy framework that differs by geography and status of development. There is no one-size fits all, which is why poverty reduction policies do not necessarily make everyone food secure.

KEY DIMENSIONS

Time: The contribution of SDG2 to SDG1 has different time dimensions depending on the policy instrument or investment made. For instance, conventional agriculture based on synthetic chemical inputs could help alleviate hunger and thus help achieve SDG1 in a shorter time than a focus on more sustainable agriculture might; however, intense agriculture without taking sustainability into account can reduce the long-term ability to produce food for future generations.

Geography: There is a gradual shift from rural to urban for the majority of the poor and food insecure populations, a transition that has already happened in Latin America and that will soon be complete in parts of Asia and especially in Africa. Nevertheless, remote rural areas are still likely to contain some of the poorest and most food insecure people for decades to come.

Governance: Trade-offs between SDG2 and SDG1 can be mitigated by national, regional and international governance. Compensation mechanisms can be designed, if needed, to ensure that the poor and small-scale food producers' interests are taken into account in the design of pro-poor policy frameworks. Furthermore, mechanisms such as targeted cash and food transfer systems for the rural and urban poor, market-based mechanisms to increase demand for smallholder production through public procurement (e.g. the National School Feeding Programme, and Food Purchase Programme in Brazil) or water and land rights for rural dwellers, can play important roles in ensuring convergence and synergies between the two goals.

Technology: Advances in agricultural research and development (with a focus on gender-responsive, pro-poor technology development), with complementary investments in safe drinking water, social protection systems, and rural roads, would all support poverty alleviation while also enhancing food and nutrition security. Supporting institutions, such as secure land and water rights, and sound governance mechanisms that ensure access by the poor to natural resources to grow and access food, are also crucial. Technology development, innovative agricultural practices, and the application of traditional practices and ancestral knowledge in agriculture can mitigate potential constraints between **targets 2.3** and **2.4** and thus help reach targets under SDG1. For instance, Climate Smart Agriculture could support sustainable increases in agricultural productivity, farmers' incomes, and can help build resilience to climate change which would benefit the poorest and most vulnerable.

Directionality: The interactions are close to being unidirectional, as long as poverty reduction does not reduce access to food and nutrition and does not adversely affect sustainable agricultural production systems.

SDG 2 + SDG 3

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
2.1, 2.2 ⟶ 3.1, 3.2	Ensuring food and nutrition security directly creates conditions that lead to the reduction of maternal mortality and preventable deaths of newborns	+1/ +2	Develop strong, open and independent institutions that promote nutritive and healthy food to reinforce the synergies between the two goals; implement nutrition-focused policies; support nutrition security through complementary pathways such as social and human capital programme devel opment, including on nutrition education, enhanced childcare practices, and empowerment of women in the household
2.1, 2.2, 2.3, 2.4 ⟶ 3.3	Food and nutrition security and stable agricultural employment help reduce communicable diseases owing to better nutrition and health status and because better rural incomes help prevent the pursuit of unsafe practices leading to communicable diseases	+1/ +2	Promote sustainable agriculture including farming diversification techniques that reduce use of hazardous chemical inputs
2.3 ⟶ 3.9, 3.1, 3.2, 3.4	Increasing agricultural productivity via conventional agriculture can increase soil and water pollution constraining the reduction of deaths and illness caused by hazardous chemicals. Such chemicals can adversely affect human health, particularly of newborns, but can also affect perinatal death and cancer outcomes in the overall population	-1/ -2	Support better rural incomes, stable agricultural employment, nutrition and health status, and help prevent the pursuit of unsafe practices leading to communicable diseases Further support understanding and raise awareness among governments, industry, and consumers, that agriculture, food, nutrition, health, culture, the environment, and the achievement of SDGs are strongly interdependent
2.3 ⟶ 3.4	Doubling agriculture productivity by mainly focusing on low-nutrient and energy-rich foods (calories) will constrain the fight against non-communicable diseases. This interaction is also counterbalanced by targets on nutrition	-1	Set up appropriate measures to counteract the increased health risks from irrigation services (e.g. malaria); or other agriculture-related health risks, such as those associated with pesticides and fertilisers
2.3 ⟶ 3.3	Extensification of agriculture may increase deforestation. Often accompanied by irrigation, intensification can, in some regions, increase the incidence of waterborne diseases if no hazard mitigation measures are taken, leading to an increase in communicable diseases such as malaria, counteracting its prevention	-2	Set up incentives and regulations in favour of sustainable agriculture and against uncontrolled deforestation to limit malaria increase and other diseases

KEY POINTS

Providing those in vulnerable situations with sufficient, safe and nutritious food contributes to reduced maternal mortality and preventable deaths of newborns and children under 5 years of age. Food and nutrition security and stable agricultural employment can also help reduce epidemics of communicable diseases such as AIDS, malaria, and tuberculosis, among others

Depending on the agricultural practices used, doubling agricultural productivity may constrain the elimination of death and illness from water and soil pollution and the ending epidemics of communicable diseases such as malaria

If nutrition security is not fully embraced, a focus on low-nutrient and energy-rich foods may counteract the reduction of premature mortality from non-communicable diseases

KEY INTERACTIONS

Good health is not possible without good nutrition – the two are indivisible. Ending hunger, improving nutrition and achieving food security through sustainable agriculture reinforces the reduction of maternal mortality **(3.1)** and creates positive conditions for ending the preventable deaths of newborns and children under 5 years of age **(3.2)**. In this sense, a major item of **target 2.2** is to address the fundamental problem of malnutrition, both undernutrition and obesity. Although agricultural productivity improves food availability, better nutrition for children does not follow automatically (Masset et al., 2011). Creating an enabling environment for nutrition improvements requires more holistic approaches, including investment in social and human capital programme development, nutrition education, enhanced childcare practices, and empowerment of women in the household (Ruel et al., 2013).

Food and nutrition security and stable agricultural employment strongly enable the reduction of epidemics such as HIV **(3.3)** due to better nutrition and health status and better rural incomes helping prevent the pursuit of unsafe practices leading to communicable diseases. For instance, a recent study in Africa showed how local rainfall shocks can be a large source of income variation for rural households and can increase infection rates in HIV-endemic rural areas (Burke et al., 2015). According to this study, income shocks explain up to 20% of variation in HIV prevalence across African countries, suggesting existing approaches to HIV prevention could be bolstered by helping households manage income risk better.

There are negative interactions between reducing premature mortality from non-communicable diseases **(3.4)** and diets dominated by low-cost, highly processed food, which continue to increase worldwide. Over the past 50 years, consumption of sugar has tripled worldwide. Like tobacco and alcohol, 'added sugar' has been identified in many studies as a driver for abuse that could lead to diseases such as liver toxicity and other chronic diseases (Lustig et al., 2012). Negative interactions are mitigated by targets aimed at fighting malnutrition **(2.1, 2.2)**.

Depending on the agriculture practices used to double productivity, potential constraints can occur for reducing the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution **(3.9)**. For example, forest fires and soil cultivation in Amazonia are responsible for a significant erosion of land surfaces. Erosion of oxisols was identified as one of the main mercury enrichment processes in floodplains. Deforestation thus increases soil mercury mobilisation by runoff, which may explain the increase in mercury burden in Amazonian aquatic ecosystems in newly colonised watersheds (Roulet and Maury-Brachet, 2001).

Chemicals used in pesticides and fertilisers can adversely affect human health, particularly for newborns, but can also affect perinatal death and cancer outcomes in the overall population – thus constraining the achievement of targets concerning maternal mortality **(3.1)**, mortality of newborns and children under the age of five years **(3.2)** and mortality from non-communicable diseases **(3.4)** (Daniels et al., 1997; Vinson et al., 2011; Brainerd et al., 2014). In addition, conventional agricultural practices leading to pollinator loss may constrain production of pollinated crops such as vegetables, fruits, nuts, seeds, and oils. Many of these pollinator-dependent food products are important dietary sources of vitamins, micronutrients and minerals, without which the risks of malnutrition could increase (IPBES, 2016).

Doubling agricultural productivity **(2.3)** could constrain the reduction of premature mortality from non-communicable diseases **(3.4)** if this increase focuses on low-nutrient and energy-rich foods, such as cereals, tubers, and fats. These agricultural products are contributing to the triple burden of undernutrition, micronutrient deficiency, and obesity with its associated health issues, such as stunting, anaemia, and diabetes (Tappy et al., 2010). The poor are adversely affected in this respect because energy-rich, low-nutrient foods are becoming more affordable to them worldwide (Bernard, 2015). **Target 2.1** aims to limit this negative interaction by pointing to the need for safe and nutritious food and **target 2.2** focuses on eliminating both under-nutrition and obesity. Prevention, including a healthy and well-balanced diet, is pivotal to avoiding disease, a worsening of health-related conditions and hospitalisation. While emphasising productivity, the need for diversification of food production (not mentioned in **target 2.3**) may provide broader options for healthy diets.

Potential trade-offs could arise between the target to double agricultural productivity **(2.3)**, which may lead to practices and outcomes such as deforestation or irrigation that, in turn, lead to an increase in communicable diseases such as malaria **(3.3)**. Changes in biodiversity due to deforestation have been reported to have adverse effects on the risk of malaria in the Brazilian and Peruvian regions (Whitmee et al., 2015; Li et al., 2016). Mosquitoes that transmit malaria can benefit from deforestation due to the creation of new breeding sites, a reduction in biodiversity (including impacts on predators/prey relations), and the creation of favourable microclimates for mosquitoes to survive and reproduce (e.g. by increasing humidity). Past studies have shown that increased numbers of vectors following irrigation can lead to increased malaria in areas of unstable transmission, where people have little or no immunity to malaria parasites, such as in the African highlands and desert fringes (Ijumba and Lindsay, 2001). For instance, in northern Ethiopia, the construction of micro-dams and irrigation systems to minimise dependence on rainfed agriculture and improve food production systems led to an increase in the incidence of malaria among children under 10 years of age living near dams (Ghebreyesus et al., 1999). Similarly, failures in agriculture and vulnerability of the poorest to agricultural shocks can increase HIV AIDS infection rates, with further increases driven by poor nutritional status.

KEY UNCERTAINTIES

How consumer behaviour and preferences might change over time is unclear, especially regarding the adoption of healthier consumption patterns, and might affect or be affected by trends and methods for agricultural intensification and land use.

KEY DIMENSIONS

Time: Changes toward more sustainable and nutrition-sensitive agriculture to support healthy lives can be implemented in a relatively short period – focusing on agricultural products that enhance nutrition, without adversely affecting overall food availability. However, changing dietary patterns to address obesity can take much longer to achieve; similarly adverse impacts from poor agricultural practices can be quickly visible but might be difficult to address.

Geography: Remote rural areas contain some of the poorest and most food and health insecure people (75%). Although all regions are affected by non-communicable diseases, chronic disease disproportionately affects low- and middle-income countries where nearly three quarters of deaths occur (28 million) (WHO, 2014). Once considered a high-income country problem, overweight and obesity are now an increasing issue in low- and middle-income countries, especially in urban settings.

Governance: Strong and open institutions in favour of promoting nutritious and healthy food can play a significant role in reinforcing the synergies between SDG2 and SDG3. Incentives and regulations in favour of sustainable agriculture and against uncontrolled deforestation would mitigate some of the trade-offs.

Technology: Innovation in agricultural practices, or in highly nutritive (new) food products (insects, etc.) can also address some of the trade-offs between SDG2 and SDG5.

Directionality: Mostly unidirectional – SDG2 affects SDG3, but poor health status can also reduce the absorption of food; here health-based solutions can help improving SDG2 outcomes.

SDG 2 + SDG 5

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
2.1, 2.2 ⟷ overall SDG5	Ensuring food and nutrition security reinforces women's empowerment. In turn, women's empowerment is enabling nutrition security due partly to their role in food production and preparation and their greater inclination to spend resources they control on family nutrition and health	+2	Support policies that ensure adequate and sufficient diets for everyone; as well as policies that strengthen women's empowerment in agriculture. Promote equal access to productive resources, rights and services in agriculture can reinforces the synergetic interactions between women's empowerment and food and nutrition security Further explore and invest in in gender-equitable agricultural innovations. Technologies that improve access to assets and resources and save women's time are particularly important for women's empowerment
2.3 ⟶ 5.5, 5.a	Promoting investment in rural infrastructure, securing equal access to productive resources (including land), and increasing income strengthens women's empowerment and gender equality	+2	
2.a ⟷ 5.b	Access to technology is an important lever to enable women's empowerment in agriculture and overall – the two means of implementation mutually reinforce each other	+1	

KEY POINTS

SDG2 interacts with and reinforces the achievement of SDG5 in many ways, ranging from food and nutrition security for all, and especially for women and girls, to gender equality in access to productive resources, and to promoting gender-equitable investment in rural infrastructure

SDG2 facilitates the use of technologies to promote women's empowerment along agricultural value chains, for enhanced nutrition outcomes, and in the maintenance of genetic resources

KEY INTERACTIONS

Targets 2.2 and **2.3** include a specific reference to the need for gender equality for achieving the full agricultural and nutrition potential envisioned. Ensuring food security with a special focus on reducing undernutrition in adolescent girls and women of childbearing age will support them to take full advantage of development resources. Empowering women is crucial for achieving SDG2 due to the important role many women have in food production, food preparation, child care and for overall nutritional outcome in families, as well as their specific vulnerabilities related to reproductive health (Pinstrup-Andersen, 2011; Duflo, 2012). Recognising that women are often over-represented among the rural poor, **target 2.3** calls for a doubling of the agricultural productivity and incomes of small-scale food producers, particularly women. **Target 2.3** links investment in sustainable agriculture with the establishment of pro-poor and gender sensitive development strategies. Smallholder female farmers face specific barriers to increasing agricultural productivity, such as restricted access to information, technologies, finance, and voice in farmer-related associations, compounding restrictions imposed by unequal access to education in many countries and regions. Since women's lack of, or limited access to, productive resources is among the main reasons why they are poorer and often less efficient than men as economic agents (Asian Development Bank, 2013), by promoting investment in rural infrastructure with equal access to productive resources (including equal access to land, technologies and financial services), **target 2.3** can help increase women's full and effective participation at all levels of decision-making **(5.5)**, and can reinforce women's equal right to economic resources as well as access to financial services and ownership over their land and other forms of property **(5.a)**. Unequal access to land is a major factor limiting empowerment of women farmers because land is a pivotal resource for meeting subsistence needs, and for accessing other goods and services, such as credit. If women farmers had the same access to agricultural inputs, education and markets as men the number of hungry people could be reduced by 100–150 million in the 34 countries studied (FAO, 2011).

By promoting investment in agricultural research and extension services, as well as technology development, **target 2.a** enhances the use of enabling technologies to promote women's empowerment **(5.b)**.

KEY UNCERTAINTIES

There is insufficient knowledge about links between gender equality and several aspects of SDG2. Food systems and gender equality are highly location-specific and therefore require contextualised and integrated research, policies and investments.

KEY DIMENSIONS

Time: For improvements in SDG5 to *translate* into improvements of SDG2 may take generations because social norms related to gender inequality change slowly.

Geography: Linkages between SDG5 and SDG2 are highly location-specific.

Governance: Strong institutions establishing gender responsive development strategies are key to capitalising on synergies between SDG2 and SDG5.

Technology: Gender-responsive agricultural technologies and innovations have a large potential to bridge the gender gap in agricultural productivity, food security and nutrition, and can reinforce positive synergies between SDG2 and SDG5. Technologies that improve access to assets and resources and save women's time are particularly important for women's empowerment in agriculture.

Directionality: The tendency is a bidirectional positive interaction between SDG2 and SDG5.

SDG 2 + SDG 6

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
2.4 ⟶ 6.3	Sustainable agriculture enables the improvement of water quality by reducing pollution	+1	Promote sustainable agricultural technologies that support land and soil quality improvement and the protection/restoration of water related ecosystems. For instance: more diverse rotations and associations in agriculture (including industrial agriculture) are often less energy-consuming and use fewer pesticides and fertilisers, lowering freshwater toxicity
2.4 ⟶ 6.6	Sustainable agriculture, improving land and soil quality reinforces the protection/restoration of water-related ecosystems	+2	
2.2, 2.1 ⟵ 6.1, 6.2	Safe and affordable drinking water and adequate and equitable sanitation are essential to address undernutrition	+2	
2.3 ⟶ 6.1, 6.2, 6.4	Competition over water can result in trade-offs. Intensive conventional agriculture can constrain and in some cases counteract access to safe drinking water, proper sanitation, and the fight against water scarcity	-1/ -2	Promote sustainable agricultural technologies and research/ technology activities, such as breeding of drought tolerant crops, or use of advanced irrigation technologies to reduce water use in agriculture; develop guidelines for sustainable agricultural water use to engage all sectors on the important topic of water savings
2.3 ⟶ 6.3, 6.6	Pollution due to unsustainable agriculture can constrain or even counteract the reduction of water pollution and the protection / restoration of water and related ecosystems	-1/ -2	Enhance institutional capacity, and improve communication and coordination between public departments to design coherent water resource policies and regulatory practices to address water scarcity and pollution

KEY POINTS

Sustainable agriculture that helps maintain ecosystems and progressively improves soil and land quality should lead to the improvement of water quality and quantity through reduced pollution and should reinforce the protection and restoration of water-related ecosystems

Some targets are reinforcing, with SDG6 enhancing access to safe and affordable drinking water for all, and adequate and equitable sanitation for all being essential for ending all forms of malnutrition

Increasing agricultural productivity can limit access to safe drinking water and adequate and equitable sanitation, which, in turn, can increase the number of people affected by water scarcity and pollution

Conventional food production and processing systems can constrain the reduction of water pollution and can counteract the protection and restoration of water-related ecosystems, including aquifers

KEY INTERACTIONS

Pressure on freshwater resources is increasing throughout the world. With food production responsible for the largest share of freshwater withdrawals, SDG2 is highly dependent on the achievement of several SDG6 targets. Irrigated agriculture accounts for 70% of water withdrawals globally, and this can rise to more than 80% in some regions (FAO-AQUASTAT, 2016). Global demand for water is expected to grow significantly for all major water use sectors, with total demand expected to increase by about 20% by 2050 (Connor and Webber, 2014). In this context, ensuring sustainable agricultural practices that help maintain ecosystems and progressively improve soil and land quality **(2.4)** should lead to improvement of water quality **(6.3)** and protection and restoration of water-related ecosystems **(6.6)**. These positive synergies are often bidirectional. For example, ending all forms of malnutrition **(2.2)** has strong and direct links with enhancing access to safe and affordable drinking water for all **(6.1)**, and adequate and equitable sanitation for all **(6.2)**.

Expansion of agricultural land to avoid overuse of chemicals, can lead to deforestation and adverse impacts on water-based ecosystems. Similarly, unsustainable intensification of agriculture **(2.3)** to help end hunger can lead to overuse, and pollution of water resources, which in turn could exacerbate food security concerns. Demand for various types of biomass is projected to increase dramatically in the medium-term, due to population growth, growing wealth, urbanisation, and changing d ietary patterns (OECD/FAO, 2014). In this context, competition over water can result in trade-off between SDG2 (mainly **2.1, 2.2, 2.3, 2.a**) and SDG6.

Conventional food production can deplete groundwater resources, pollute water bodies (e.g. eutrophication), and can reduce non-agricultural water availability and use, such as for drinking water (e.g. through soil degradation and resulting siltation of downstream reservoirs). Reversal of land and water degradation, and pumping of groundwater from greater depth are generally very costly, energy-intensive, and adversely affected by climate change. Intensification of land use might also reduce water quality and availability where rates of water extraction for irrigation exceed rates of replenishment. In this context, doubling agriculture productivity **(2.3)** could have negative impacts on universal access to safe drinking water **(6.1)**, and adequate and equitable sanitation **(6.2)** and counteract the reduction of people suffering from water scarcity **(6.4)**.

Conventional food production and processing systems release pollutants that build up in the environment, including waste and pollution of water supplies. They also have negative impacts on overall efficiency of water and land use for other ecosystem services – which constrain the reduction of water pollution **(6.3)** and the protection and restoration of water related ecosystems, including aquifers **(6.6)**.

Non-achievement of SDG6, can adversely affect food prices and increase food price volatility **(2.c)**, in addition to constraining all other targets under SDG2. Nevertheless, while food price volatility is higher with insufficient water availability in agriculture, functioning food markets can help move food from water abundant to more water constrained regions **(2.b)**.

KEY UNCERTAINTIES

Water availability for food systems is under growing threat from increasing non-agricultural demands, agricultural uses, and climate change. How these various factors will play out and what level and type of investments will be undertaken to reduce these risks and uncertainties is a further uncertainty.

KEY DIMENSIONS

Time: Some elements of the interactions are short-term (i.e. no water, no food, no safe drinking water, and no proper nutrition), while others are longer-term (e.g. water pollution and longer-term degradation).

Geography: (1) Linkages are geography- and climate-specific, but some general 'rules' hold (i.e. no water, no food unless trade in food is well established). Water productivity in kcal per m^3 varies widely among crops, cropping systems, and water and agricultural management practices, which are subject to cultural preferences and traditions. (2) Global trade in goods and water-intensive products (virtual water flows) can offset high national water consumption levels, allowing countries with limited water resources to rely on water resources in other countries. Approximately 40% of the world's population lives in transboundary river or lake basins with hydrological and associated social and economic interdependencies. In countries where competition over and pollution of transboundary water resources increases, tensions and conflicts between countries can arise.

Governance: Governance over water resources remains relatively weak, particularly in terms of water quality, which affects food and nutrition security in many ways. Strong institutions and policies as well as regulations on water resources are essential for addressing some of the competition over water use between SDG2 and SDG6 targets. Good governance and strong institutions could also help ensure that agricultural productivity is increased through sustainable agricultural practices, which in turn enable the achievement of some SDG6 targets.

Technology: A wide range of technologies that affect water use in agriculture are in use and more are under development. They range from low-cost technologies, such as rainwater harvesting to the breeding of drought, heat and submergence tolerant crops, to advanced irrigation technologies that support irrigation scheduling and accurately and on time meet crop water demands and the use of precision agriculture techniques, including the use of soil, plant and weather sensors. Further observations, technologies, modelling and decision-support systems based on soil moisture to improve targeted irrigation can play an important role in enhancing the sustainable use of fresh water.

Directionality: Interactions are bi-directional. For example, maintaining water quality might constrain the doubling of agricultural productivity but would support nutrition security.

SDG 2 + SDG 7

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
2.3, 2.4 ⟶ 7.1, 7.2	Increasing food productivity and farmers' revenues may enable the increase of renewable energy in the global energy mix via biofuel production. This may also increase access to affordable, reliable and modern energy services	+1	Design policies geared toward avoiding competition for land between energy and food purposes and 'land grabbing' Promote the creation of sustainable bioenergy-related jobs and diversified income for small food producers Maximise energy production from agricultural wastes Promote local production of renewable energy and ensure careful planning and multi-stakeholder participation in large infrastructure development projects that may impact freshwater ecosystems, agricultural lands and local communities' livelihoods. Further explore technology for higher crop yields, and target bioenergy production on degraded land if competition with land and water for food can be avoided
2.3, 2.1 ⟵ 7.3, 7.1	Affordable energy and improving energy efficiency for agriculture may facilitate increases in food production, farmer revenues, and indirectly food and nutrition security	+2	
2.3 ⟶ 7.1, 7.2	Competition over land and water can results in trade-offs. Doubling agricultural production may constrain the use of water at the expense of increasing renewable energy sources (e.g. hydropower) or the use of other water-related energy sources	-1/ -2	
2.1, 2.2 ⟶ 7.1, 7.2	Food and nutrition security may constrain the use of water and land, at the expense of energy production such as bioenergy	-1	

KEY POINTS

Agroforestry, biofuel crops, and the use of agricultural waste can enable an increase in renewable energy in the global energy mix

Agriculture aiming at energy production can enable the increase of small farmers' revenues through more diversified production, and support universal access to affordable, reliable and modern energy services

Affordable energy and better energy efficiency can enable increased agricultural productivity and revenues and by doing so, provide broader support for ending hunger and malnutrition

Competition over the same resources (land and water) may result in negative interactions between SDG2 and SDG7. Increased agricultural production and food and nutrition security may constrain the use of land and water for bioenergy, thus limiting the increase of renewable energy and constraining universal access to energy. Similarly, bioenergy development can constrain use of agricultural by-products for soil fertility enhancement and can adversely affect food and nutrition security targets through competition for land, water and biomass

KEY INTERACTIONS

Ending hunger, undernutrition and food insecurity through sustainable agriculture interacts at several levels with ensuring access to affordable, reliable, sustainable and modern energy for all. With worldwide energy demand expected to increase by 48% between 2012 and 2040 (EIA, 2016), agroforestry, biofuel crops, and the use of agricultural wastes (animal or plant), can support progress on SDG7. In this sense, sustainable agriculture, mainly through doubling agricultural productivity (**2.3**) and ensuring sustainable food production systems (**2.4**) can help increase the share of renewable energy in the global mix (**7.2**). In addition, biofuels as part of the production mix can lead to the diversification of agriculture from which farmers can benefit and thus lead to positive synergies with **target 2.3** focusing, among other things, on doubling revenues of small-scale food producers. This can facilitate and enable universal access to affordable, reliable and modern energy services (**7.1**).

Reciprocally, improving energy efficiency (**7.3**) and better access to affordable, reliable and modern energy services (**7.1**) can provide crucial leverage such as better access to water-pumping and irrigation systems, or other energy-intensive agriculture technologies, such as processing, storage and transportation systems for agricultural commodities. Such positive interactions should enable the targets on productivity and enhanced incomes (**2.3**) and on ending hunger and malnutrition (**2.1, 2.2**). Competition over the same resources may result in negative interactions. Food and nutrition security (**2.1, 2.2**) as well as the increase in agricultural productivity and income (**2.3**) may constrain the use of land and water at the expense of bioenergy production and overall renewable energy deployment – that is, water is needed for all types of energy production, but particularly for bioenergy, hydropower, thermal power production, coal, solar systems (**7.1, 7.2**).

In the case of hydropower production, large dam infrastructure can constrain food systems, both for fisheries and for food supply due to changes in the timing, quantity and quality of the water released for irrigation. Moreover, similar to other large-scale energy-dense agricultural commodities, large-scale biofuel production systems can adversely impact water, soil and land quality and would need to be implemented using sustainable management practices. Furthermore, raising levels of irrigation to increase agricultural productivity, but also the higher energy requirements for pumping water over long distances could exacerbate this competition and further deepen negative interactions between SDG2 and SDG7.

Those interactions are highly context dependent, and synergies or trade-offs can emerge depending on the type of the biomass, the relative shares of food and biofuel production (and subsidies), and the potential indirect spillover effects due to international trade structures and patterns. Good governance and coherence are key to mitigate negative interactions and explore the synergies between SDG2 and SDG7. In this sense, farm activities could be promoted toward maximising energy production from agricultural wastes, and reinforced synergies between **targets 2.3** and **2.4** and **targets 7.1** and **7.2**.

KEY UNCERTAINTIES

Key uncertainties remain regarding future bioenergy production levels, which are currently largely driven by subsidies and climate policies. The role of bioenergy production can both support and constrain the achievement of SDG2, and can constrain SDG2 more so than other renewable energy sources. Other critical uncertainties concern competition over natural resources between SDG2 and SDG7, many of which are driven by rapid changes in innovation, and changes in cost structures and subsidies for alternative technologies.

KEY DIMENSIONS

Time: Interactions between SDG2 and SDG7 (synergies and trade-offs), can have both immediate and longer-term impacts. For example, lack of energy availability in rural areas prevents the extraction of deep groundwater resources for irrigation until the area is electrified or diesel or solar pumps are accessible, a process that can take time. Application of energy in the form of fertilisers can quickly boost food production with results visible at the end of the growing season. Bioenergy-SDG2 linkages have both shorter-term and longer-term elements: production of energy sources can be achieved in a season (or a few years depending on the plant) while longer-term soil, land and water quality and sustainability implications might take years to materialize.

Geography: Linkages are highly location-specific, but changes in one country can also have spill-over impacts on other parts of the world given the nature of international trade structures and patterns.

Governance: Good governance, careful planning designed via inclusive and open policymaking are important. Such governance mechanisms need to study potential positive and negative linkages between SDG2 and SDG7 investments. For instance, integrative participation of local small food producers in renewable infrastructure construction (e.g. hydropower) or large-scale biofuel production is key to ensure coherence among the goals and identify a wider range of impacts.

Technology: Technological change has a significant impact on the interactions between SDG7 and SDG2. For example, continued energy-based innovation is helping to increase water, land and energy efficiency in agriculture. Climate smart agricultural practices can enhance the use of agricultural wastes (animal or plant) in support of local and sustainable energy production.

Directionality: The linkage can be bi-directional. For example, solar-powered pumps can deplete groundwater resources that are fundamental to food security; thus making energy accessible to all might compete with the sustainability of food production. But making energy accessible to all should also put more energy in the hands of the rural poor for agricultural use (such as fertilisers). Regarding biofuel, relations might be asymmetric. For example, growing bioenergy crops may undermine the eradication of hunger more than implementation of SDG2 would affect and limit the generation of renewable energy sources.

SDG 2 + SDG 13

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS – IN ADDITION TO THE COMPLEMENTARY ONES HIGHLIGHTED FOR SDG 2/SDG 7 AND SDG 6
2.4, 2.5 ⟶ 13.1	Resilient agricultural practices and maintaining and giving access to seeds/plant/animal genetic diversity should reinforce adaptation to climate change	+2	Design policies and mechanisms to foster and support agricultural action plans with triple wins for food security, adaptation and mitigation. Promote resilient strategies and practices, including market- and regulatory-based measures
2.a ⟶ 13.2, 13.3, 13.b	Enhancing international cooperation in agriculture research, science, and services should enable climate change measurements and raise awareness on climate challenges, and promote mechanisms to address them	+2	Support science and research in agricultural adaptation and mitigation. Enhance international cooperation and build scientific capacity (especially in developing countries) in agriculture research, science, and climate science and services
2.3, 2.4, 2.5 ⟵ 13.b	Positive feedback from raising awareness and capacity on climate change impacts (mitigation and adaptation) to setting up sustainable and productive agriculture practices, and maintaining biodiversity	+2	Support multi-stakeholders platform and science / society / policy interfaces: including scientists, civil society organisations, farmers, policy decision-makers
2.3 ⟶ 13.1	Unsustainable agriculture focusing solely on productivity may counteract climate adaption by increasing climate instability and extreme events	-2	

KEY POINTS

SDG2 directly affects SDG13, since today's agriculture directly accounts for about 14% of greenhouse gas emissions. Similarly, SDG13 directly affects SDG2

SDG2 targets on resilient, sustainable food production and genetic diversity reinforce resilience and adaptive capacity to climate change and risks. Under some conditions, they can also support climate mitigation

By enhancing international cooperation and building joint initiatives, SDG2 enables the integration of climate change measures into national policies, strategies and planning and awareness raising on climate mitigation and adaptation

Boosting agriculture productivity relying solely on 'business-as-usual' agricultural practices may counteract resilience and adaptive capacity to climate change. Instead, sustainability and productivity improvement within SDG2 need to be realised in tandem to ensure synergies with SDG13 targets

KEY INTERACTIONS

Agriculture accounts for about 14% of GHG emissions and 24% when forestry and other land uses are included (IPCC, 2014), a close second in global GHG emissions after electricity and heat production. Deforestation, livestock emissions, and soil and nutrient management, are some of the key drivers. At the same time, the challenge is to meet the needs of a growing world population and rising average incomes per person which implies an increase in demand for all agricultural commodities especially livestock products. SDG13 focuses mainly on climate adaptation issues, but in acknowledging the role of the United Nations Framework Convention on Climate Change, the goal also indirectly addresses climate mitigation and the main aim of the Paris Agreement signed in December 2015 to keep global temperature rise this century well below 2°C above pre-industrial levels (UN, 2015a). The Paris Agreement does not set specific parameters on climate mitigation targets for the agriculture sector which is very briefly mentioned within the Agreement preamble, but many of the country-level strategies (94%) presented through Nationally Determined Contributions (NDCs) do include mitigation action in the agricultural sector; albeit without clear benchmarks. Through the NDCs, the integration of climate change measures into national planning (**13.2**) is already underway but close follow-up work on the integration of strategies to mitigate climate change in agriculture are still needed. Overall, SDG2 targets converge with the Paris Agreement.

Beyond climate mitigation, sustainable food productions systems (**2.4**) that strengthen capacity for adaptation, and that progressively improve soil and land quality will reinforce the pursuit of resilience and adaptive capacity to climate change and risks (**13.1**). Improving soil properties such as Carbon Stock will contribute to adaption to climate variability, that is, higher Soil Carbon stock will improve water availability for crops, and crops will adapt to adverse and erratic weather. In addition, by maintaining the genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their wild species (**2.5**), and ensuring their access to farmers will offer efficient options for adaptation and resilience to climate change. Furthermore, **target 2.a** on enhancing international cooperation might facilitate the integration of climate change measures into national policies, strategies and planning (**13.2**) by providing, for example, science-based evidence. International support can also help raise awareness on climate mitigation and adaptation (**13.3**). Feedbacks from SDG13 to SDG2 are also synergetic as land food production is generally reinforced by a stable climate – in contrast to extreme weather events (droughts, floods). Food from fisheries for instance is also reinforced by protecting the climate, because that limits ocean warming and ocean acidification and, indirectly, the loss of marine biodiversity and fish resources. In this sense, the positive feedback from **target 13.3** on raising awareness and capacity on climate change mitigation is very relevant. However, going beyond awareness raising is essential to give practical effect to this synergy because agricultural productivity could fall dramatically, especially in developing countries (Cline, 2007) as well as global food production from marine ecosystems. Potential interactions from SDG2 achievement may counteract SDG13. Should **target 2.3** rely solely on 'business-as-usual' practices with conventional and unsustainable agriculture production driven by short term productivity improvements and leading to negative impacts such as soil quality decrease and/or deforestation; resilience and adaptive capacity to climate change (**13.1**) and climate mitigation efforts will be offset.

Sustainability and productivity improvement within SDG2 needs to be fully realised in tandem to ensure synergies with SDG13 targets. Solutions do exist to enable a shift from a negative to more positive interactions. For instance, 'smart and climate-sensitive agriculture approaches, such as the '4 per 1000 Initiative' launched by France on the side of COP21, or the initiative for the Adaptation of African Agriculture (AAA) launched upstream of COP22, aim at reconciling food security with climate mitigation by engaging in resilient and sustainable agriculture practices. Building capacity and awareness raising are also key to design converging actions in doubling agricultural production in a sustainable way, combat climate change, and ensure the use of well adapted natural resources for better climate resilience, such as traditional crop varieties as well as new biotechnologies.

KEY UNCERTAINTIES

The time required to bridge the gap between sustainable agriculture practices and food security worldwide is highly uncertain and cannot yet be predicted. There are also uncertainties on climate variability and its impact on current agro-ecology and adaptive agricultural practices.

KEY DIMENSIONS

Time: Conventional agriculture will impact negatively on climate mitigation and adaptation over the short, medium and long term. Bridging the gap between sustainable agriculture practices and food security worldwide will take time but can be achieved progressively.

Geography: There is strong variation in country-level approaches to climate and agriculture. China, the largest agricultural GHG emitter, is followed by India, and Brazil. Advanced economy agricultural producers such as the USA or Australia, also have large agricultural GHG emissions. Indonesia, a large emerging economy, is an important agricultural GHG emitter and the top emitter in land-use change and forestry. Other agricultural GHG emitters are much smaller, such as those in sub-Saharan Africa.

Governance: Climate Smart Agriculture and resilient strategies and practices can be promoted by a range of policy approaches, including market- and regulatory-based measures. Sustainable practices, resilient technologies and consumer preferences can be guided and supported by policymaking. Furthermore, setting a carbon price for agriculture could push forward the adoption of agricultural productivity measures.

Technology: Science and research play a major role in agriculture adaptation and mitigation. Biotechnology, and location-appropriate crop varieties that are resistant to fluctuations in temperature and precipitation are key to provide climate adaptation solutions to farmers. Land management to maintain and increase soil organic carbon stock should be promoted to reinforce synergies between adaptation and mitigation. Climate Smart Agriculture can help provide practical solutions to climate change challenges, as well as food security through the use of farming methods that match local conditions (e.g. agroecology, agroforestry, conservation agriculture, landscape management).

Directionality: Bidirectional. A change in agriculture practices is necessary to limit global climate change over the long term, and food production is reinforced by a stable climate.

SDG 2 + SDG 15

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS – IN ADDITION TO THE COMPLEMENTARY ONES HIGHLIGHTED FOR SDG 2 / SDG 13
2.4 ⟶ 15.1, 15.2, 15.3, 15.4	Agriculture impacts on the well-being of terrestrial ecosystems (sustainable food production system and agriculture practices) should reinforce the maintenance of terrestrial ecosystems and the prevention of land as well as biodiversity erosion	+2	Maintain and provide access to seeds/plant/animal genetic diversity Set up appropriate monitoring systems at the correct scales to understand how agriculture impacts on land degradation and biodiversity loss. Developed landscape-scale management approaches to address some of the trade-offs between biodiversity conservation and agriculture development
2.3, 2.4 ⟵ 15.3, 15.5, 15.8	Combatting desertification, restoring degraded land, and reducing the impact of invasive species as well as fair and better access to genetic resource enable sustainable agriculture	+1	
2.a ⟶ 15.a, 15.b	Enhancing investment in international agriculture cooperation can participate in resource mobilisation for sustainable management of ecosystems	+1	Support multi-stakeholder platforms and science / society / policy interfaces: including scientists, civil society organizations, farmers, policy decision-makers. Giving space to traditional knowledge is key in this regard
2.3 ⟶ 15.1, 15.2, 15.3, 15.5	Intense agriculture and revenue increase based solely on agricultural productivity without sustainability may counteract ecosystem protection/restoration, and increase deforestation and land degradation	-2	

KEY POINTS

Sustainable and resilient agriculture practices aligned to ecosystems protection can reinforce conservation, restoration and sustainable use of terrestrial ecosystems, sustainable forestry and arresting deforestation, and contribute to the restoration of degraded land and soils, as well as combatting desertification

Maintaining genetic diversity and its access is aligned with promoting the fair sharing of genetic resources, and slowing or preventing the extinction of endangered species

Enhancing investment in international cooperation, technology, and gene banks could facilitate the mobilisation of financial resources to conserve and sustainably use biodiversity

Extension of agricultural areas can lead to an increase in agricultural income but can also increase deforestation

If increasing agricultural productivity relies on practices and technologies that contribute to land and soil degradation and high GHG emissions, targets focused on the conservation, restoration and sustainable use of terrestrial ecosystems, forests, soils and biodiversity might not be achieved

KEY INTERACTIONS

Agriculture is one of the key drivers of change in biodiversity, ecosystems, forests, desertification, and land and soil quality. Those interactions are usually closely related to the relationship between productivity and income, with a growing need for sustainable agriculture practices. SDG2 has many direct interactions with SDG15. Any actions aiming at achieving **target** 2.4 on sustainable and resilient agriculture practices aligned to ecosystems protection, and the progressive improvement of land and soil quality would reinforce the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services (**15.1** and **15.4** on mountain ecosystems); sustainable forestry and the halt to deforestation (**15.2**); and combatting desertification and promoting restoration of degraded land and soil (**15.3**). In addition, maintaining the genetic diversity of seeds, cultivated plants, farmed and domesticated animals and their wild species and ensuring their fair access to farmers (**2.5**), is aligned with **target 15.6** on the utilisation of genetic resources, and the extinction prevention of threatened species (**15.5**). Investment in international cooperation, research and technology (**2.a**) can also provide important resources to conserve and sustainably use biodiversity and ecosystems (**15.a**, **15.b**) and restore degraded lands and soils, thus contributing to a reduction in desertification.

Similar to several SDG2 interactions with other goals, sustainability targets need to be fully integrated with food productivity and small-scale farmers' income improvement targets (i.e. **2.3**, and indirectly **2.1** and **2.2**). Access to markets (mainly via roads) can promote the extension of agricultural areas, particularly for cash crop cultivation, and might lead to an increase in agricultural productivity and income (Khandker et al., 2009). However, this could lead to deforestation – counteracting **target 15.2** on halting deforestation and increasing afforestation and reforestation globally; and other negative externalities for the environment. Furthermore, should the need for food productivity rely on practices and techniques responsible for land degradation, high GHG emission (i.e. the 'business-as-usual' scenario), and land pollution, this will counteract **targets 15.1**, **15.2**, **15.3** and **15.5**.

Intensive agricultural management with high use of agrochemicals and intense tillage, grazing or mowing, can counteract SDG15 (especially **15.5**). Animal pollination is a key regulating ecosystem service in nature – almost 90% of wild flowering plants depend on animal pollination. Intensive agricultural management, pesticide use and land-use change are key drivers of pollinator loss. Insecticides (especially neonicotinoids) have been demonstrated to have lethal and sublethal effects on pollinators. It has been estimated that 16.5% of global vertebrate pollinators and more than 40% of invertebrate pollinator species such as bees and butterflies are facing extinction (IPBES, 2016). Alternative forms of agriculture and sustainable pest control methods need to be promoted to address pollinator decline and their multiple implications on terrestrial ecosystems.

KEY UNCERTAINTIES

The appropriate scale at which to take stock and analyse interactions between SDG2 and SDG15 is a key uncertainty. Such interactions are highly context dependent and require different analytical frames and landscape-scale approaches.

KEY DIMENSIONS

Time: Restoration of degraded land might take several years to achieve lasting positive impacts.

Geography: Linkages are context dependent since the level of land degradation and biodiversity status differ from one region to another. Local and indigenous peoples' rights and livelihoods and valuable local knowledge should be considered in conservation efforts aimed at preserving and restoring biodiversity.

Governance: Governance can play a significant role in developing better interactions between SDG2 and SDG15 through programme and planning settings such as the plan for Actions launched by the UN Convention to Combat Desertification, including targets to achieve land degradation neutrality (LDN; Orr et al., 2017), and Biodiversity (IPBES) aimed at achieving food security.

Technology: Sustainable land management (i.e. the use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions; Dumanski and Smyth, 1993) should be promoted. Sustainable land management is a way to harmonize the complementary goals of providing environmental, economic, and social opportunities for the benefit of present and future generations, while maintaining and enhancing the quality of the land (soil, water and air) resource.

Innovative agroecology techniques such as ecological pest management can play an important role in reinforcing positive interaction between SDG2 and SDG15. For instance, the push-pull system – using repellent plants (push) and trap plants (pull) to control agricultural pests, or the use of key beneficial insects such as arthropod predators and parasitoids for biological control of key pest species.

Directionality: Mostly bidirectional. Unsustainable agriculture practices impact local and global ecosystems via GHG emissions. Biodiversity protection should constrain such agricultural practices and could foster new practices aligned with the sustainable use of terrestrial ecosystems.

ILLUSTRATIVE EXAMPLES OF INTERACTIONS BETWEEN SDG 2 AND THE OTHER SDGS

This box presents a summary of the more detailed country analyses of critical interactions between SDG2 and the other goals presented in Annex 1.

THE COMPOUND CHALLENGES OF DEFORESTATION, FOOD AND ENERGY PRODUCTION FOR CLIMATE MITIGATION, ECOSYSTEM PROTECTION AND HEALTH IN THE AMAZON REGION

The Amazon, the world's largest tropical rainforest, is subject to intense economic development to support agriculture, cattle ranching, large-scale hydropower generation and biofuel production, leading to deforestation and land degradation, with cascading effects and feedbacks on water availability and quality, climate change mitigation, biodiversity and human health. Thus, a large set of targets and SDGS are mutually constraining and reinforcing in this fragile ecosystem. Developing a framework and action plan to meet key SDG targets without irreversible losses to other targets will be essential for areas such as the Amazon.

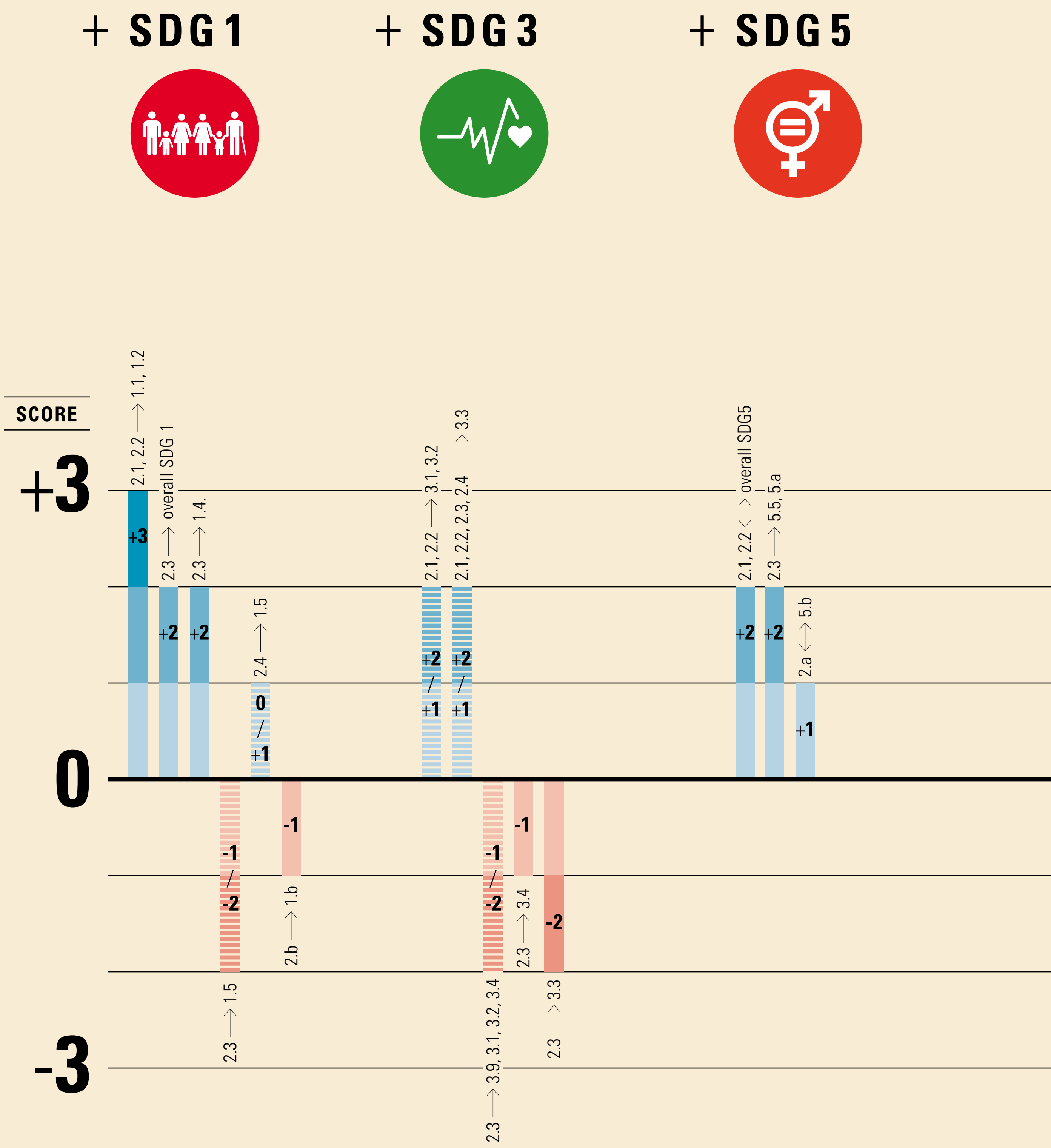
PUTTING SUSTAINABLE LAND MANAGEMENT AT THE HEART OF SENEGAL'S NATIONAL DEVELOPMENT STRATEGY

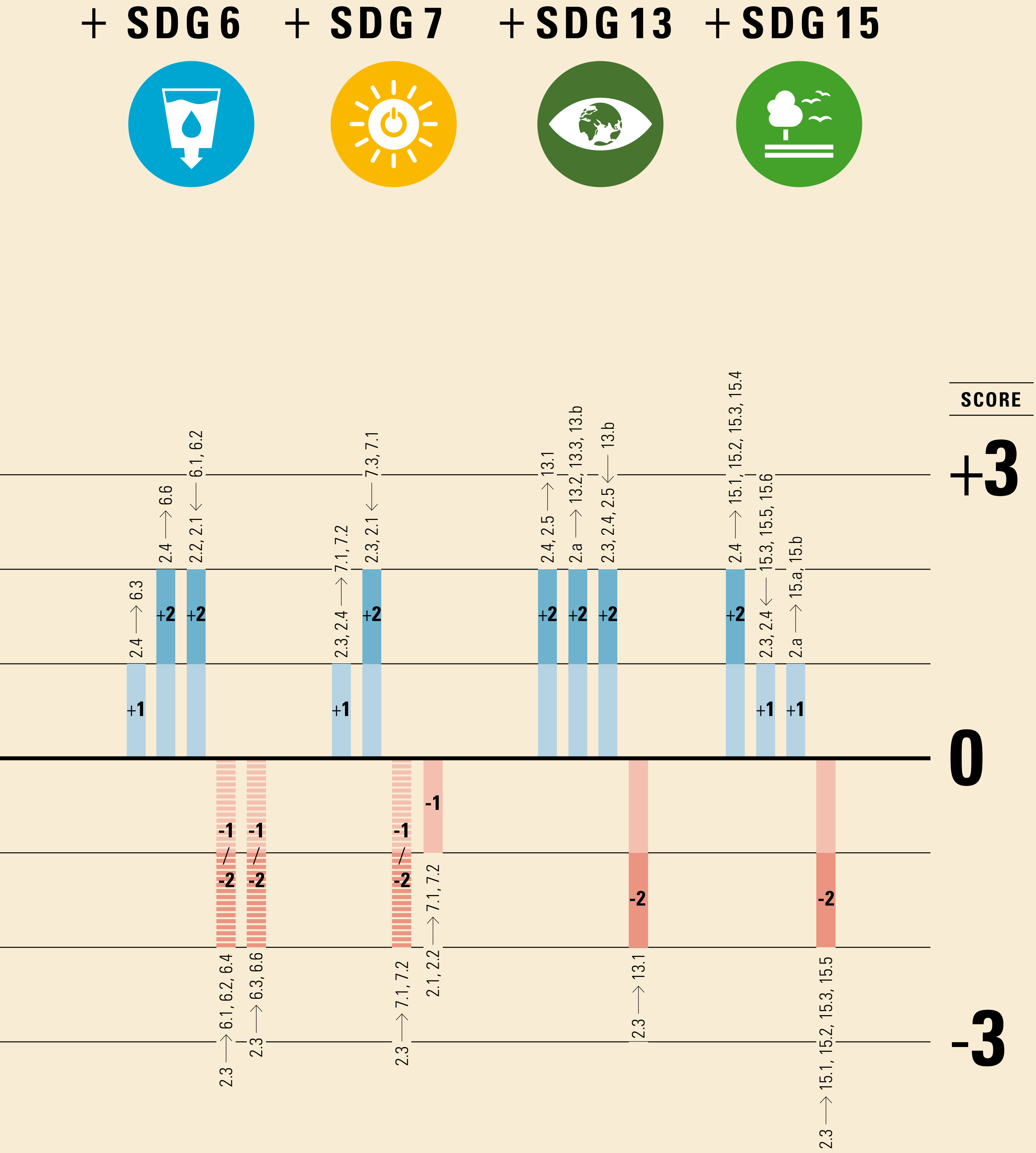
Senegal in West Africa is highly dependent on agriculture, with about 60% of the population employed in this sector. The country is also highly vulnerable to drought, and increasingly so with the onset of climate change. With growing demographic pressures and a fast-developing economy, these challenges are exacerbating. Sustainable land and water management are key areas identified by the government to ensure food production and optimal carbon sequestration.

IMPLEMENTING CLIMATE SMART AGRICULTURE TO ADDRESS CALIFORNIA'S WATER CHALLENGES

While California is best known for Silicon Valley, a dynamic, high-value agriculture sector contributes substantial nutritional diversity to the country and to national exports. However, environmental impacts, such as associated with particulates from fertilisers and dust, nitrate leaching and substantial water consumption constrain the achievement of health, water quality and availability targets. In a region prone to periodic drought, achieving Climate Smart Agriculture will be key to the achievement of SDG2 and other interlinked goals and targets.

KEY INTERACTIONS
SDG 2 WITH OTHER GOALS




+ SDG 6
+ SDG 7
+ SDG 13
+ SDG 15
SCORE
+3
0
-3
2.4 → 6.3
+1
2.4 → 6.6
+2
2.2, 2.1 ← 6.1, 6.2
+2
2.3 → 6.1, 6.2, 6.4
-1 / -2
2.3 → 6.3, 6.6
-1 / -2
2.3, 2.4 → 7.1, 7.2
+1
2.3, 2.1 ← 7.3, 7.1
+2
2.3 → 7.1, 7.2
-1 / -2
2.1, 2.2 → 7.1, 7.2
-1
2.4, 2.5 → 13.1
+2
2.a → 13.2, 13.3, 13.b
+2
2.3, 2.4, 2.5 ← 13.b
+2
2.3 → 13.1
-2
2.4 → 15.1, 15.2, 15.3, 15.4
+2
2.3, 2.4 ← 15.3, 15.5, 15.6
+1
2.a → 15.a, 15.b
+1
2.3 → 15.1, 15.2, 15.3, 15.5
-2

KNOWLEDGE GAPS

Knowledge gaps and their order of magnitude differ for various reasons, and can vary from one geographical area to another. In this context, science empowerment and capacity building on research, data collection, analysis and assessments on SDG2 and its linkages are essential to identify pathways toward meeting multiple SDGs. Investments and advances in agricultural research and development will be important for reducing negative linkages among SDG2 targets and between SDG2 targets and other SDG goals and targets. For example, global scientific cooperation (south-north, south-south, triangular) is necessary for universal science to make progress on issues such as the impact of climate change on agricultural production and nutritious quality of food produced, or the spread of pathogens and invasive species.

Building and strengthening long-term observation and information systems for sustainable development is key. To date, SDG2-related observation systems and systems that might help identify risks for related SDG goals and targets receive insufficient financial support, and are therefore subject to uneven quality and poor coverage. For example, adequate data systems are not yet in place to predict food crises with sufficient accuracy, because data are not collected at a high enough frequency or to a sufficient level of detail. Lack of standardisation of data is a further challenge. Similarly, data are not yet available to identify when and where uses of agricultural land for biofuels (to support energy and climate goals) may harm the environment or reduce food security and increase stunting. Information is insufficient concerning which agricultural lands in a watershed, as well as which agricultural technologies and practices, are most detrimental to water availability and water quality for downstream urban and industrial developments and coastal ecosystems. Access to existing data may also be an issue. Some government agencies are reluctant to share data with other agencies; this could be due to poor data quality, because the data show poor performance by the agency concerned, or because sharing the data might be perceived as losing power. These challenges are heightened in interdisciplinary and multi-agency settings.

The broad scope of the SDGs challenges research, policymakers and the development community to work across disciplines and silos – something that is easily proclaimed but remains difficult to achieve. The section provides a non-exclusive list of knowledge gaps that have been identified in relation to the goal and target interaction analysis in the previous sections.

2 + 1

The extent to which progress in SDG2 supports achievements in SDG1 is not a priority knowledge gap because achievements are largely synergetic. However, a better understanding is needed of how trade openness may impact smallholder farmers and how adverse impacts can be prevented.

2 + 2

There is a need to develop new science, technology and innovation and associated institutions to reconcile **targets 2.3** and **2.4**; these will be location-specific and will change dynamically over time. There is also a need for better understanding of which interventions work best to achieve zero malnutrition, particularly in the short SDG timeframe.

2 + 3

Insights are needed on incentives that would allow agricultural producers and processors to use their potential to contribute to more sustainable food-production practices that benefit nutritional and health outcomes.

Linkages between agro-ecological practices and food quality, as well as understanding of the impact of climate change (e.g. CO_2 concentration) on food quality are major research gaps.

There are also important knowledge gaps regarding the impact of agricultural water pollution on human health.

2 + 5

There is insufficient knowledge concerning gender equality and several SDG2 targets in many regions, given that food systems and gender equality are highly location-specific.

Agricultural research and development are generally gender-blind; that is, women's needs for innovation – such as new varieties of plant, livestock, and fish, and for new technologies are usually not addressed. Women's participation and perspectives in agricultural research and development can support social transformation. Adopting gender responsive methodologies can help in the development and introduction of new technologies.

2 + 6

Large uncertainties remain between SDG6 and SDG2 as a result of synergistic and counteracting targets, depending on geography, agricultural practice and target. Growing water variability is adding uncertainty to agricultural production systems with potentially adverse impacts for most SDG2 targets. More research is needed on how SDG2 and SDG6 targets can be achieved in tandem. In particular, more research is needed to understand how key water targets (i.e. safe drinking water) can be met through more sustainable agricultural practices.

Irrigation is essential for increasing crop productivity and even more so under climate change. Irrigation increasingly depends on groundwater sources. Groundwater depletion and the growing competition for water must be better understood and managed. Observational and spatial planning tools are needed, as are institutional innovations for more sustainable water stewardship in agriculture.

2 + 7

More analyses are needed on energy-agricultural linkages and impacts on food (and energy) systems, to help ensure that both SDGs achieve progress in tandem. This is particularly challenging because the energy sector is highly dynamic and agricultural and food systems are rapidly becoming increasingly energy dependent.

2 + 13

Rainfed agriculture continues to predominate globally and some regions, such as sub-Saharan Africa depend almost entirely on the regularity of seasonal cycles for food production. As precipitation patterns become less certain, new tools are needed for accurate, highly granular seasonal drought predictions, as well as on changes in onset of precipitation.

The effect of land use change on local and regional precipitation patterns and insights on measures to mitigate land use change in areas that affect precipitation patterns need further study.

Feedbacks between land use change and global climate must also be clarified, especially in the tropics. Additional scientific knowledge needs to be generated on agricultural science, technologies and innovations and associated institutions that meet both mitigation and adaptation targets.

Finally, the impact of climate change (CO_2) on the nutrient content of crops needs to be further studied and assessed.

2 + 15
Research, combining local knowledge with technological advances, is needed to identify technologies, practices and institutions that optimally reduce adverse impacts on terrestrial habitats and freshwater resources and avoid further deforestation and land degradation. Such research needs to be tailored to different ecologies, geographies and farm sizes, with particular support needed for smallholder farmers. Data and information at the landscape scale on the relationships between ecosystems management and provision of ecosystems services are lacking – data on long-term ecological impacts from various agricultural practices are, however, key to define the optimal allocation of management options at the landscape scale and achieve SDG2 and SDG15 concurrently.

There is a lack of wild pollinator data (species identity, distribution, abundance) in several regions. Long-term monitoring of pollinators (status and trends for most species) and pollination around the world is urgently required.

CONCLUDING COMMENTS

The SDG2 targets have multiple reinforcing and constraining linkages with the other 16 SDGs. These multiple linkages provide both challenges and substantial scope for solutions to reinforce positive and mitigate counteracting interactions. Agriculture is at the center of the food-energy-water-climate nexus and also has strong linkages to human health. Agriculture and associated changes in land-use are also key to national adaptation and climate mitigation strategies, adaptation being particularly crucial for less industrialized countries.

Policy and governance play a fundamental role: coherent and coordinated policies together with appropriate institutions can enable net environmental and development gains in complex situations and in so doing, can help ensure that adverse impacts can be reduced or avoided. However, in many geographical, political, social, economic and environmental contexts, food security targets dominate policy agendas with potentially longer-term adverse impacts on several other goals and targets such as those related to climate, health, biodiversity, water and energy security as well as to food and nutrition security itself. In such contexts, in-depth understanding of local situations will be critical to better understand interactions between SDG2 and the others goals, and provide specific management options with minimum trade-offs.

Overall, there is a need for inclusive multi-sector approaches across government departments/ministries and other stakeholders (research institutions, NGO, private sector, etc.) that fully consider environmental boundaries. Building on these general considerations, the seven summary tables in the target-level interactions section provide options for how policy could address the interactions in practice.

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SDG 3 ENSURE HEALTHY LIVES AND PROMOTE WELL-BEING FOR ALL AT ALL AGES

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INTRODUCTION

SDG3 seeks to ensure health and well-being for all, at every stage of life. In its 1948 constitution, the World Health Organization defined health as *"a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity"* and this is the definition adopted here. SDG3 is underpinned by nine targets that broadly fall into separate, but overlapping groups: reducing morbidity and mortality for vulnerable groups (mothers, newborns, the elderly and children), reducing communicable and non-communicable diseases, reducing risk factors (tobacco, substance abuse, road traffic injuries and hazardous chemicals and pollution), providing universal health coverage, and strengthening the health sector. While SDG3 targets do not specifically address the social determinants of health and well-being (CSDH, 2008; Solar and Irwin, 2010; Berkman et al., 2014), the importance of social factors, such as working conditions, income, education, and housing, is recognised within other SDGS. Waage and colleagues noted that achieving health and well-being for all relies not only on meeting the SDG3 targets, but also on ending poverty (SDG1), providing access to education (SDG4), achieving gender equity (SDG5), reducing inequality between and within countries (SDG10), and promoting peace (SDG16). Health and well-being also relies on adequate services and resources, including infrastructure (SDG9), food security and agricultural production (SDG2), decent work (SDG8), sustainable consumption (SDG12), provision of water and sanitation (SDG6), access to energy (SDG7), and resilient and inclusive cities that provide universal access to housing and transport (SDG11). Health and well-being are also critically dependent on a safe and enabling environment, supported by mitigation of climate change (SDG13) and sustainable protection and use of the oceans (SDG14) and land (SDG15) (Waage et al., 2015). The broad interdependence between environmental and human health is recognised in systems thinking and the new focus on planetary health (Whitmee et al., 2015; Gatzweiler et al., 2017).

The text that follows provides an overview of interactions at the goal level between SDG3 – the 'entry level goal' for this assessment – and the other 16 SDGs. Taking into account all the underlying targets of this entry goal, a set of key interactions is identified between the SDG3 targets and those of other SDGS, principally interactions within the range of the highest magnitude or strongest impacts based on available scientific literature and expert knowledge. The typology and seven-point scale for characterising the range of positive and negative interactions described in the opening chapter to this report is used to assess the selected target-level interactions and the context in which they *typically* occur. Illustrative examples from different world regions show how these linkages manifest in practice. Policy options are identified for how to maximise positive interactions and minimise negative interactions between now and 2030, and beyond. The chapter concludes with a list of key knowledge gaps related to the interactions studied.

KEY INTERACTIONS AT **GOAL LEVEL**

3 + 1

Poverty reduction leads to improved health and well-being, while good health is a strong enabling factor for effective poverty reduction. In fact, a healthy population is a prerequisite for development, constituting an engine for economic growth. Conversely, it is very difficult to ensure health without addressing poverty. At low income levels, rising incomes lead to health gains as basic needs are fulfilled (such as nutrition, health care, health awareness, and shelter). Increased income is likely to enable positive interaction effects, yet beyond a certain threshold, further increases may not lead to further positive health effects. Similarly, poverty reduction will have a greater effect on health in the presence of diseases associated with poverty, including AIDS, tuberculosis and malaria, as well as neglected tropical diseases, diarrheal and respiratory diseases, and the consequences of malnutrition. Where poverty reduction is most needed, governance structures are often ineffective, and great health challenges usually exist. Reducing poverty will generally result in immediate and long-term improvements in health. This relationship is highly bidirectional – ill health can constitute an inescapable poverty trap, where governmental redistribution is absent. Before conventional poverty reduction policies can be effective, the poorest of the poor often need special assistance to enable them to engage effectively with poverty reduction measures. Good governance, plus investment in health, skills, infrastructure and education, is crucial to reducing poverty.

3 + 2

Health and nutrition are inextricably linked. The relationship between food consumption and health is highly context-dependent. Under-nutrition is generally associated with poverty, whereas overconsumption can accompany either poverty or wealth and may be associated with poor nutritional intake. The relationship between food and nutrition is bidirectional: in some cases, ill health can diminish the ability of households or individuals to farm and produce food, or to work and acquire food. Fundamentally, meeting caloric and micro/macro nutrient needs is a primary requirement for health. Interruptions in food intake and quality, whether short- or long-term, can have lasting impacts on mental and physical development, impacts that begin during pre-natal growth and continue through childhood. Good health also depends on consumption of sufficient micronutrients over the life course. Reducing hunger will result in immediate improvements in health, and carries long-term implications for physical, psychological and neurological development. Increasing agricultural production may improve food security and reduce hunger; however, it also impacts on the environment, with potential implications for infectious disease transmission, and can negatively affect health through contamination of local environments with arsenic, cadmium and other pesticide residues. Technological elements of food and agricultural systems, including genetically modified organisms (GMOs), monocultural crop production, food processing, forest clearing, and irrigation, have the potential to increase production, but also to harm the environment and adversely affect future food security. There is much uncertainty about how to manage zoonotic diseases related to agricultural production. Food security will also be increasingly affected by climate-induced extreme weather events, as well as geopolitical and economic considerations.

3 + 4

Access to high-quality education is associated with better health, at both individual and community levels. Maternal and paternal education can each influence the health status of children – indeed, the favourable impact of maternal education is well known in developing countries and has also been demonstrated in the developed world. Informal education and other sources of information can also play a strong role in good or ill health: for example, misinformation can lead to poor health decisions in both developing- and developed-world contexts (as in the case of anti-vaccine sentiment). Education can affect health immediately through changed behaviour or the adoption of new technologies. It can also affect long-term health through increased income, opportunity, self-reliance and empowerment. Health benefits from education are not limited to early schooling – lifelong learning offers important opportunities in contexts of rapid change. While these relationships are universal, greater gains are possible in developing-world contexts. New technologies (such as health promotion using information and communication technologies) may increase the efficiency of health interventions and spread knowledge to more people. The relationship between health and education can be bidirectional, as poor health limits school attendance and educational achievement.

3 + 5

Improving gender equality generally enables the achievement of better health. Women's health issues are in some contexts under-prioritised and under-funded, and promoting gender equality in these cases and lead to easy health gains. Moreover, mothers make most health decisions for their children, so their empowerment leads to improved child health outcomes. Increasing participation of women in the paid work force can lead to overall economic gains and hence improved health. Health gains may be immediate (when they directly improve resources or access for women) or long-term (mediated through childcare).
The strength of the enabling interaction among these goals will be greatest where women face the greatest inequalities.
In general, gender equality has a greater effect on health than health on gender equality, although improved health of women or children can offer women more time and resources to participate in decision-making and economic activities.

3 + 6

In all contexts, improving water quality and access leads to improved health – without clean water and adequate sanitation it is difficult to achieve health gains. The latter are immediate in terms of decreased water-borne infections (e.g. acute diarrheal infections, viral hepatitis) and improved nutrition; improving water quality and sanitation also leads to long-term developmental gains. The interaction between these goals is strongest in parts of the developing world where water-borne infectious disease is still prevalent, but water quality and environmental pollution issues are also widespread in many high-income contexts. This relationship is essentially unidirectional, although where health is poor, it may be that water-borne pathogens themselves are adding to the poor management of water treatment systems.

3 + 7

There are synergies and trade-offs in the relationship between energy and health. Affordable energy contributes to both economic development and the availability of other basic services like health care, transport, and heating/cooling, all of which have consequences for health. Lack of affordable energy can create or amplify health risks, such as excess-winter hospitalisation and mortality in temperate countries. However, energy development involving non-clean energy sources creates substantial short-term health issues (e.g. from direct exposure to short-lived climate pollutants or indoor air pollution from unclean cook stoves) and very large threats in the medium- to long-term (e.g. direct and indirect impacts from climate change caused by greenhouse gas emissions). Nuclear energy poses unique risks in terms of waste storage and accidental or deliberate release. Geography can modify the interactions of energy production with health – for example, urban air pollution risk is modified by local topography, modes of transport, and regional industries and agricultural activities such as burn-offs. Long-term climate-related risks are locally uncertain but modified by proximity to low-lying coastal zones and local temperature and weather patterns. The interactions between health and energy use are strongly technology-dependent. In some cases, poor health and concomitant poverty can reduce household ability to access cleaner (more expensive) energy sources where available.

3 + 8

The relationship between SDG3 and SDG8 is highly context-dependent. For example, where it reduces poverty (SDG1), economic growth leads to health gains as workers' income increases. Yet, rapid economic growth may lead to new health issues. Where it damages the environment, a variety of adverse health impacts are likely (e.g. mortality from air pollution) although often avoidable. Inequities in the distribution of wealth gains can not only exclude some from health benefits, but can also create new issues – for example, inequality may lead to a higher incidence of mental health problems and of illnesses and deaths related to violence. In industries such as manufacturing, agriculture or construction, if appropriate protections are not in place, workers' health may suffer from exposure to contaminants, heat stress, and injury. Economic growth affects health over various timescales: provision of decent work and basic income enable immediate health gains, while increases in national wealth generally lead to long-term improvements in health. However, long-term health gains are complex: for example, transitional economies often experience significant mortality related to pollution and road traffic accidents, while wealthier countries tend to experience an increase in non-communicable diseases with changed lifestyles. As well, national economic growth may mask inequalities at local level. In general, low-income countries will see greater health gains from economic growth and better working environments. The relationship between economic growth and health is strongly modified by the presence and quality of social safety nets, which mitigate the consequences of periods of unemployment or lack of wealth. In addition, the adverse impacts of growth need to be mitigated by careful social and environmental regulation. The relationship between economic growth and health is bidirectional. Ill health can constitute a major drain in low-, medium as well as high-income settings.

3 + 9

Synergies or trade-offs between health and SDG9 are strongly dependent on choices about which industries, innovations and infrastructures are favoured. Historically, development stages have been associated with typical patterns of health challenges – most prominent is the characteristic epidemiological transition from infectious to non-communicable disease, which can be exacerbated or mitigated by industrial and infrastructural decisions. Over the long-term, advances in industry, innovation and infrastructure tend to favour better health. However, there may also be negative impacts, particularly associated with land use and urbanisation, transport/mobility systems, and residential development. For example, motor vehicle-based infrastructural investment has well-established adverse unintended health consequences, including air pollution from vehicle emissions, traffic congestion, road traffic accidents and reduced physical activity from urban sprawl. However, appropriate planning, especially in cities, can minimise adverse impacts and improve health, such as through promotion of active transport. Health effects can be immediate to long-term. Due to the long timescale of infrastructure development, health consequences may be locked-in decades in advance of the completion of construction. The relationship between infrastructure and health is basically unidirectional, although poor health can influence labour participation, and therefore the ability of nations to innovate or implement various technological / infrastructural advances.

3 + 10

Reducing inequalities in income, wealth, education, health care services and access to power can contribute to the achievement of health and well-being goals. In particular, there is evidence that income and social inequalities have substantial adverse health outcomes in low-, medium- and high-income contexts. Inequalities may create health impacts through multiple pathways, including heightened psycho-social stress, higher rates of adverse health behaviours such as smoking, and poor physical environments (e.g. higher levels of air pollution). This relationship is bidirectional and can lead to feedback loops with negative consequences: for example, ill health can limit household income by directly limiting work capacity and through borrowing-related 'poverty-traps', where high interest rates force householders to sell their land to pay for medication or care, thus reducing their livelihood opportunities and further reducing their capacity to assure health. At the community level, a high burden of ill health can limit available resources and revenues and thus entrench inequalities, as in some slums/informal settlements and isolated rural areas.

3 + 11

The impact of 'place' on health is well recognised. Well-designed cities promote health and support the achievement of SDG3 while poorly designed cities create unhealthy environments, discouraging physical activity, exposing people to hazards such as air pollution and dangerous traffic, and contributing to mental illness and non-communicable diseases. In the short term, housing which is free of pollutants and hazards and which provides adequate temperatures and space supports health. In addition, transport infrastructure promotes health immediately and directly by improving access to health care and access to work and education, which supports health. Sustainable urban form and design offer some of the most cost-effective options for avoiding carbon lock-in and hence limiting or reducing carbon emissions, which supports health in the long-term. The relationship between sustainable cities and health is basically unidirectional, although ill health or disability can limit resources, labour participation and the attractiveness of active travel options and thus policy options for urban development.

3 + 12

Sustainable consumption and production is strongly connected with health over the long term; the dependence of health goals on sustainable action is strongly recognised in the new paradigm of planetary health. Short-term connections between these goals are less pronounced or may involve trade-offs. Indeed, sustainable consumption and production may require foregoing immediate economic gains. This tension has been recognised in debates over the right to development, and research is needed into mechanisms by which global financing might offset losses to enable sustainable consumption and production. The health consequences of failing to achieve this can be local (e.g. ecosystem depletion/collapse, as for some fish stocks) or global, but often are most severe in low-income contexts where regulation is weakest.

3 + 13

Many health impacts from climate change are direct, such as the effect of increasing heat stress on ability to work outside, impacts of severe weather events, especially floods and droughts, and increased frequency of intense storms. Other effects are indirect, including climatic change that promotes the spread of disease vectors (e.g. for dengue and malaria) and contributes to food insecurity and undernutrition. Such impacts may increase rapidly with the scale of climate disruption, which have the potential to precipitate local or regional conflicts, breakdown of governance or social norms, and massive flows of people. In the face of these effects, it will be very difficult to achieve health goals. Conversely, the scale of potential savings with respect to morbidity and mortality from minimising climate change is large and growing. Climate action will result in modest immediate improvements in health and well-being but major and long-lasting (multi-century) health and developmental gains. New financing mechanisms are needed to encourage poorer countries to adopt climate-friendly development trajectories and use zero-carbon energy sources.

3 + 14

The health of marine systems is directly connected to human health in coastal areas and where populations depend on marine food sources. Marine pollution and collapse of fish stocks from overfishing can have direct impacts on nutrition, and thus on health in these contexts. Reduction of marine pollution will likewise reduce morbidity and mortality. Seawater intrusion into groundwater in coastal aquifers, potentially exacerbated by extreme weather events, can contaminate freshwater resources and pose concomitant health risks. Loss of marine biodiversity can affect human health over short or long timescales, particularly as it affects the viability of marine ecosystems and thus availability of fish stocks or the potential for discovery of new pharmaceutical compounds from marine bioprospecting. Tackling marine challenges, including pollution and overfishing, requires cross-sectoral action and multi-scale integrated governance, and will take time, but should have both short- and long-term impacts on health.

3 + 15

Changes to the environment caused by human actions, including deforestation, desertification, pollution and contamination, and associated losses of biodiversity, can affect health along a number of pathways. For example, reductions in populations of bees or other pollinators resulting from environmental disruptions can affect agricultural yields and thus human health. Changes in land use, often associated with agricultural production, can expand pathogen habitats and degrade waterways, increasing the risk of infectious disease transmission. As such, achievement of health goals depends on careful management of such ecosystems. The Millennium Ecosystem Assessment categorises the role of natural ecosystems in four service areas: supporting, provisioning, regulating, and cultural services. Each has a direct or indirect connection to human health and well-being from basic functions such as nutrient cycling, provision of food and shelter, and regulation of water quality, to the spiritual and recreational components. Taken together these not only map directly to aspects of both physical and mental health but also support broader aspects necessary for human well-being such as income provision and cultural identity (Millennium Ecosystem Assessment, 2005).

3 + 16

Peace, justice and strong institutions are strong enablers of improvements in health. Conversely, their absence can impede initiatives to improve health and exacerbate inequalities. High burdens of ill health or of violence itself can limit the capacity of governments to deliver justice and implement strong institutions. In extreme cases, emerging health threats can pose challenges to peace. The impact of inter-state wars and conflicts on health are often not well recognised in the development discourse. The current crises in Libya, Syria and Iraq have promoted devastating civil strife, mass migration, and destruction of infrastructure, which have disrupted health services and may have contributed to antimicrobial resistance. Inclusion in economic life and governance processes can play an important role in maintaining trust in institutions and the preconditions for high-quality governance. This can support better health and well-being outcomes; reciprocally, good community health is likely to support stronger and more inclusive institutions.

3 + 17

Effective partnerships are critical for achieving health. It is increasingly recognised that with complex systemic problems, interventions in one sub-system are likely to lead to unintended consequences in other areas. Approaches to management and governance are often siloed, and fail to appreciate such cross-sectoral feedbacks. In contrast, adoption of systems approaches allows for the anticipation of unintended negative or positive consequences and formulation of potentially wiser interventions. Cross-sectoral, cross-spatial and multi-regional partnerships and exchange of information grounded in systems thinking are needed. This relationship is bidirectional, as ill health itself limits the capacity to participate in effective partnerships, both directly and through its impacts on education and capital. The SDGs have been criticised for not adequately emphasising the role of international trade on health. Institutionally, the majority of multilateral and some bilateral trade agreements are 'outside' the UN development agenda at present, except discussions mainly in relation to private-public partnerships. Substantively, trade contributes to health primarily through economic growth (SDG8). However, there is increasing concern about diminishing returns from trade liberalisation, and the potential adverse impacts of trade agreements, especially in low-income countries. These could be through a brain drain of qualified health workers, patents and increasing costs of medicines, and in relation to removal of trade barriers that could have adverse health impacts (e.g. easy importation of calorie dense foods to poorer countries).

KEY INTERACTIONS AT **TARGET-LEVEL**

A comprehensive assessment of all SDG interactions at target-level was beyond the scope of this chapter, but several proposed frameworks exist for integrating health and well-being across the SDGS, encompassing both health and non-health sectors and locating health and well-being as both pre-conditions and outcomes of sustainable development (Dora et al., 2015; Nunes et al., 2016). This section analyses some of these interactions in detail at the target-level. SDGS were selected based on the strength of the interlinkages and the magnitude and scale of impact in relation to the overall objective of the 2030 Agenda, while ensuring a balanced consideration of the economic, social and environmental dimensions. Target-level interactions are judged to fall within one of seven categories and are scored accordingly: indivisible (+3), reinforcing (+2), enabling (+1), consistent (0), constraining (-1), counteracting (-2), and cancelling (-3). Following a generic analysis of the selected interactions, specific examples are provided to illustrate how interactions unfold in different geographical and policy contexts.

Six targets/goals were selected for detailed analysis, with three accompanied by an illustrative example:

SDG2
Specifically target 2.3
SDG3
Illustrated using the example of improving health outcomes by improving air quality
SDG8
Illustrated using the example of the interaction between work, labour productivity and health in the context of high temperatures
SDG11
Specifically targets 11.1 and 11.2; the latter illustrated using the example of the Cheonggyecheon Stream Restoration Project, Seoul
SDG13
Specifically target 13.2

Given the comparatively large number of target-level interactions for SDG3, the focus is largely on interactions with only one target from other SDGS.

SDG 3 + SDG 2

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.1, 3.2 ⟵ 2.3	Increasing the agricultural productivity and incomes of small-scale producers will improve access to food and economic resources, which supports the health of mothers, newborns and children	+2	Implement financial and educational policies that support smallholders to increase agricultural productivity
3.3 ⟵ 2.3	Increased agricultural production, even at the small scale, can create new pathogen habitats, increase the risk of animal-human disease transmission, damage ecosystems, promote antimicrobial resistance in pathogens and insecticide resistance in vectors, and pollute drinking water, all of which can expose people to the risk of communicable disease	-1	Develop resource management regulation to prevent ecosystem degradation
3.9 ⟵ 2.3	Agriculture labour may expose people to hazardous chemicals	-1	Regulate to minimise exposure to hazardous chemicals. Provide education to agricultural workers on the safe use of chemicals
3.3 ⟶ 2.3	Ending communicable diseases will have a significant positive effect on the availability and health of the labour force to achieve the targets related to agricultural productivity and income growth	+2	Invest in healthcare services

KEY POINTS

Increasing agricultural productivity can improve nutrition, which supports health. Increased production can also lead to indirect health gains through increased economic welfare among individuals and households

Environmental and habitat changes induced by human agricultural activity can lead to ecosystem shifts which may intensify communicable disease transmission

Use of insecticides for crops and antibiotics for animals can promote antimicrobial resistance in pathogens and insecticide resistance in vectors. Intensive agricultural production can pollute drinking water through soil pollution, ground and surface water contamination, or cause direct harm to agricultural workers.

KEY INTERACTIONS

This section considers how efforts to increase agricultural productivity can interact with health. **Target 2.3** calls for a doubling, by 2030, of the agricultural productivity and incomes of small-scale food producers, especially women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment. Other SDG2 targets provide important context for this: increasing agricultural productivity (**2.3**) should occur in tandem with provision of organic, safe and nutritious food for all (**2.1**), a guarantee that food production is sustainable, resilient, adaptable and supports ecosystems (**2.4**), the maintenance of genetic diversity and traditional knowledge (**2.5**), and support for agricultural infrastructure (**2.a**), free trade (**2.b**), and the proper functioning of food commodity markets (**2.c**).

Increasing agricultural productivity (**2.3**) through cost-effective technologies at the local scale can improve nutrition, which directly supports health. Without increases in production, rapidly growing human populations will face food scarcity at both global and local scales in the coming century. There is a need for increased agricultural productivity to feed unprecedented numbers of people; moreover, promotion of small-scale production, especially among the most vulnerable, can counter the distributional inefficiencies that lead to regional scarcity and provide much-needed income and livelihoods for the poor.

At the most basic level, increased agricultural productivity (**2.3**) often increases the likelihood of uninterrupted consumption of sufficient calories; even short-term interruptions of food intake (e.g. resulting from drought, conflict, extreme climatic events or household economic shocks) can have lasting effects on health and physical and neurological development. Sufficient nutrition supports reductions in infant mortality (**3.2**), newborn/child mortality (**3.1**), and mortality associated with infectious disease (**3.3**) and cardiovascular disease (**3.4**). Variety in local agricultural production can promote consumption of the range of micronutrients essential for health. Increased production can also lead to indirect health gains through the improved economic welfare of individuals and households; in particular, high proportions of the rural and peri-urban poor are involved in agricultural work, so are well positioned to benefit from such efforts.

However, increased agricultural productivity **(2.3)** may challenge efforts to control communicable disease **(3.3)**, if contextual environmental and social factors are not accounted for, or if sustainability is not explicitly considered. At a basic level, increasing agricultural production often requires expansion of agricultural lands. Such expansion generally leads to expanded human and livestock interfaces with natural systems, and a greater opportunity for crossover of zoonotic pathogens (Institute of Medicine (US) Forum on Microbial Threats, 2008); for example, HIV, SARS, and a range of other important diseases of humans appear to have originated in humans as a result of spillover from sylvatic systems (Jones et al., 2013). In some cases, the conversion of land to agricultural uses can shift vectors or pathogen species assemblages in ways that promote disease. In Tanzania, for example, agricultural sites were found to harbour double the abundance of plague-seropositive rodents as non-agricultural sites, mediated by substantial increases in species of rodents and fleas that efficiently transmit the disease (McCauley et al., 2015). In other situations, irrigation (or other agricultural practices) can create new habitats for vectors of malaria and other diseases – this is particularly true in low-income settings (World Bank, 2008). Such risks can be countered by careful management with full awareness of ecological and social context, for example through alternation of rice with dryland crops or integrated vector management.

Increasing agricultural productivity **(2.3)** may be accompanied by increases in livestock or poultry populations and/or closer physical associations between humans and animals, which can dramatically intensify transmission of zoonotic disease. A signal case is that of H5N1 avian influenza, which has been associated with abundance of free-grazing domestic ducks, human population and rice-cropping intensity in Southeast Asia (Gilbert et al., 2008). Productivity increases in agriculture are sometimes achieved through a focus on monocultures in crop, plant and animal production. Often involving GMOs, and frequently accompanied by extensive application of fertilisers, pesticides, antibiotics or other inputs, this may increase efficiency and yield and allow increases in the scale of production, but may also lead to loss of biodiversity and increased vulnerability to plant or animal pathogens or climate change. Such systems threaten food security, with results that potentially cascade across systems to negatively affect health.

Large-scale livestock production, when accompanied by poor land management, can lead to increased effluent flows and contamination of natural environments with pathogens that cause of schistosomiasis *(bilharzia)* and taeniasis (tapeworm infection) (WHO, 2013). Where antibiotics are routinely used to promote growth and feed efficiency or prevent disease in animal stocks, livestock management can also contribute to infectious disease severity (Spellberg et al., 2011). Antibiotic use in agriculture has been linked to the emergence of antimicrobial resistance in human pathogens (WHO, 2013). Similarly, the use of insecticides in agriculture can lead to resistance in vectors; for example, a recent review found that in 23 of 25 studies across Africa, higher resistance in malaria vector mosquito populations was associated with agricultural insecticide use (Reid and McKenzie, 2016). This is such a significant issue that WHO has argued that insecticide resistance has generally been conceptually omitted as an important class of emerging infectious disease (WHO, 2013).

Increasing agricultural productivity **(2.3)** may also challenge efforts to reduce mortality and morbidity associated with air, soil and water contamination **(3.9)**. Insecticides, pesticides and fertilisers can be harmful to human health, whether through contamination of food or water or through occupational exposure. Unintentional exposure kills over a third of a million people per year (World Bank, 2008) and is associated with serious economic burdens, including direct costs and lost labour. Pesticide exposure has been associated with both acute toxicity and long-term increased risk of some cancers, neurological and respiratory disease, birth defects, and significant ecological disruptions.

The interactions between **target 2.3** and the health targets operate on both short- and long-term scales. Increases in epidemic risk through expansion of agricultural lands or ecosystem shifts can be extremely fast, especially where urban areas are in relatively close proximity to newly-cleared agricultural lands and where workers frequently travel back and forth between them. The recent West African Ebola epidemic is likely to have had its origins in agricultural borderlands, but was intensified by urban mobility patterns. The evolution of antibiotic and insecticide resistance generally operates over a timescale of several years. Contamination resulting from agriculture can follow floods or other extreme events, or can build up over longer periods, and its effects can be acute, as in unintentional poisoning, or long-term, as in the development of cancers or other health issues.

Many of the trade-offs observed between target 2.3 and health targets are more relevant in low-income settings, where larger proportions of people work in agriculture, and are therefore directly exposed to its effects. Thus, unintentional poisoning and emergence of zoonotic diseases are more likely in these contexts. Agricultural production systems in the developed world tend to be more monocultural and may involve heavier inputs of chemicals or antibiotics, promoting the evolution of resistance. Monocultures may also increase the likelihood of catastrophic disease spread, thus affecting food systems. Careful consideration must be given to regulation and technology in increasing local and small-scale agricultural productivity. In many cases, this can be achieved while avoiding negative trade-offs with health, but this requires a clear understanding of local ecology and of the likely ecological and environmental effects of agricultural technologies (e.g. irrigation systems, feed supplements, cropping practices) and crop/plant/livestock choices.

The relationship between these targets is bidirectional. Health issues can impact on agriculture through reductions in the healthy labour force or in institutional capacities and knowledge. For example, high levels of endemic malaria have been shown in some contexts to limit agricultural earnings, although labour substitution within households may mitigate these effects (Institute of Medicine (US) Committee on the Economics of Antimalarial Drugs, 2004; Audibert et al., 2012). High rates of HIV mortality have in some cases led to significant losses of skills and capacity in the agricultural sector (World Bank, 2008).

The strength of the listed trade-offs between agriculture and health vary, but are in part a function of scale. To achieve increases in throughput and efficiency, growing agricultural systems are more likely to adopt technologies that lead to negative health consequences.

KEY UNCERTAINTIES

The largest uncertainties concern how to scale up healthy small-scale production without creating ecological or direct human harm. Increased health risks should be mitigated through appropriate regulation, which will vary with context.

KEY DIMENSIONS

Time: Increased agricultural production can produce quick gains in nutrition for small-scale producers, and have long-term positive effects on food security, incomes and food supply, all supportive of long-term health. Expansion of agricultural lands or changes in agricultural techniques can produce rapid or long-term shifts in ecosystem structure and function. Resulting risks to health can thus be acute (e.g. outbreaks of new zoonotic diseases) or long-term (e.g. shifts in vector habitats). Contamination from agricul ture can also have both acute (e.g. poisoning) and long-term (e.g. cancers) effects.

Geography: In general, producers in low-income countries face higher risks and opportunities from changes in agricultural production, although specific elements of developed-world agriculture (e.g. monocultures, large-scale production) may increase some risks. The borderless nature of communicable diseases means that changes in agricultural production locally may have global impacts on diseases.

Governance: Good governance and careful planning are key to ensure that the benefits of increased agricultural production accrue to small-scale farmers and their local communities. Moreover, effective governance is key to anticipating and mitigating impacts on ecosystems from agriculture at all scales.

Technology: Technology can assist both in improving productivity (e.g. irrigation systems, feed supplements, cropping practices) and crop/plant/livestock choices and in monitoring the ecological impacts of increased productivity in order to inform appropriate regulation.

Directionality: Bidirectional. Health issues can have an impact on agriculture through reductions in the healthy labour force, and increasing agricultural productivity can expose workers to hazardous chemicals or result in ecosystems degradation that increases the risk of non-communicable disease.

SDG 3 + SDG 3

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.1 ← 3.3	Efforts to eradicate communicable disease will substantially contribute to targets to reduce newborn/infant mortality	+3	Give particular focus to the control of infectious disease in educational and medical environments
3.2 ← 3.3, 3.4	Achieving targets for non-communicable and communicable disease will assist in reducing maternal mortality	+2	Reduce prevalence of non-communicable diseases, such as diabetes and risk factors such as obesity. Eliminate smoking during pregnancy. Give particular focus to the control of infectious disease during ante-natal care and in medical environments
3.3 ← 3.5, 3.a, 3.b	Controlling tobacco, reducing substance abuse, and reducing exposure to hazardous chemicals, will assist in reducing premature mortality associated with non-communicable disease	+2	Ensure regulation prevents exposure to hazardous chemicals, and controls tobacco use
3.7 → 3.2, 3.3	Targets around reproductive and sexual healthcare provision will assist in reducing maternal mortality and help control communicable disease	+2	Support funding towards reproductive and sexual healthcare services and education
3.8 → 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.a, 3.10	Provision of universal healthcare will assist to achieve most other targets	+2	Prioritise the provision of universal healthcare
3.b, 3.c → 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9, 3.a	A strong health workforce and supportive research infrastructure support the achievement of all the other health targets	+2	Invest in the health workforce and in research infrastructure

KEY POINTS

Efforts to eradicate communicable disease will assist in targets to reduce newborn/infant mortality and maternal mortality

Controlling tobacco, reducing substance abuse, and reducing exposure to hazardous chemicals, will assist in reducing premature mortality associated with non-communicable disease

Targets around reproductive and sexual healthcare provision will assist in reducing maternal and infant mortality and help control communicable disease

Provision of universal healthcare will assist in achieving all other targets

KEY INTERACTIONS

There are several potential negative interactions among health targets. For example, there is much debate over whether and under what circumstances vertical disease-orientated health programmes can negatively affect the integrated operation of health systems, particularly in low-income settings – and thus their ability to deliver other health outcomes (Atun et al., 2008; De Maeseneer et al., 2008). Moreover, where funding is limited, efforts to achieve particular health targets could limit resources potentially applicable to achieving other targets. However, in general the health targets are mutually supportive. For example, achieving reductions in the maternal mortality rate (**3.1**) will be made easier by achieving the targets concerning sexual/reproductive health, universal health coverage, infectious disease, and non-communicable disease. This is illustrated in the following examples:

⟶ Increasing access to reproductive healthcare services (**3.7**): In Texas, United States, the rate of women who died from complications related to pregnancy doubled between 2010 and 2014 (MacDorman et al., 2016), soon after a drastic reduction in the number of women's health clinics in 2011 in response to major cuts in the state legislature's budget for family planning (Redden, 2016).

⟶ Achieving universal health coverage (**3.8**): Millions of births (more than 40% in Africa and South-East Asia) are currently not assisted by a midwife, doctor or trained nurse. Improved access to skilled attendance will significantly reduce complications and deaths (WHO, 2016).

⟶ Ending communicable disease epidemics (**3.3**): Around 25% of maternal deaths during or following pregnancy or childbirth are caused by or associated with diseases such as malaria, and AIDS during pregnancy (Say et al., 2014).

⟶ Reducing the incidence of non-communicable diseases (**3.3**): Early detection and management of diabetes in pregnancy as part of a comprehensive antenatal package was shown to reduce stillbirths by up to 45% and also to prevent maternal and newborn deaths (Pattinson et al., 2011).

Similarly, achieving reductions in newborn/infant mortality (**3.2**) will be supported by efforts to reduce infectious disease incidence (**3.3**) and to reduce exposure to toxic substances and tobacco (**3.9**).

The leading causes of death in the world in 2013 among children younger than five years of age were lower respiratory tract infections, preterm birth complications, neonatal encephalopathy following birth trauma and asphyxia, malaria, and diarrheal deaths. These accounted for 3.4 million deaths or 54% of all deaths among children younger than five years (Global Burden of Disease Pediatrics Collaboration, 2016). Providing for universal health coverage **(3.8)** and combating AIDS, malaria, and waterborne and other communicable diseases **(3.3)** will clearly play an important role in ending preventable deaths in children and infants **(3.2)**.

Protecting against toxic hazards **(3.11)** and controlling tobacco **(3.10)** each support reductions in newborn/infant mortality **(3.2)**. Smoking, exposure to second-hand smoke and indoor air pollution during pregnancy increases risk of pregnancy complications, including foetal deaths, low birth-weight and premature delivery (Lumley et al., 2004; Pope et al., 2010).

Along similar lines, achieving the target of reducing premature mortality associated with non-communicable disease **(3.4)** will be made easier by action towards targets on substance abuse **(3.5)**, tobacco control **(3.a)**, and hazardous chemical exposure **(3.9)**. Cardiovascular diseases (e.g. heart attacks and stroke), cancers, chronic respiratory diseases (e.g. chronic obstructive pulmonary disease and asthma) and diabetes account for 82% of deaths from non-communicable diseases. Tobacco use, physical inactivity, unhealthy diet and the harmful use of alcohol increase the risk of these non-communicable diseases. As such, strengthening the prevention and treatment of substance abuse, including harmful use of alcohol **(3.5)** will support the achievement of this target, as will strengthening the implementation of the World Health Organization Framework Convention on Tobacco Control **(3.a)**.

Some cancers are linked to exposure to hazardous chemicals such as particulate matter wood-smoke, lead and asbestos. As such, reducing the number of deaths and illnesses from hazardous chemicals in the air, water, and soil **(3.9)** will contribute to reductions in non-communicable disease mortality.

Achieving universal health coverage, including access at affordable prices to essential medicines and vaccines **(3.8)** will facilitate achievement of virtually all other SDG3 targets. Universal coverage allows for access to health professionals, who not only provide essential treatment, but can provide education on healthy lifestyles and disease prevention. The health of women during childbirth **(3.1)**, of newborns/infants **(3.2)**, of people suffering from communicable **(3.3)** or non-communicable disease **(3.4)** or from exposure to chemicals **(3.9)**, or of those impacted by road traffic accidents **(3.6)** all rely on affordable, effective and safe treatment by health-care professionals. A strong public health service is critical to the provision of messaging, education and resources for healthy sexual behaviour **(3.7)** and reductions in consumption of alcohol **(3.5)** and tobacco **(3.10)**. Achieving universal health coverage can be supported by the recruitment, training, development and retention of a strong workforce **(3.12)** and by research and development of essential vaccines and medicines **(3.11)**.

Many interactions between SDG3 targets are clearly bidirectional. For example, eradicating infectious disease **(3.4)** will help reach targets for maternal mortality **(3.1)** and infant mortality **(3.2)**; conversely, efforts to achieve the latter will reduce infectious disease incidence. Thus each of the health targets enables or reinforces other health targets (Nilsson et al., 2016). Many of the actions required to meet targets – investment in vaccines, medicines, health care provision, health promotion, tobacco control, hazards reduction, workforce development and research – can be achieved locally, in some cases with support from donors, and are likely to improve population health. Other actions

– such as control of infectious disease and clean air policies – require regional cooperation and long-term planning.

KEY UNCERTAINTIES

The evidence base is strong for the positive interactions between the health targets discussed. There is considerable debate over the potential conflict between vertical disease programmes and health system strengthening.

KEY DIMENSIONS

Time: Action on several targets – such as investing in maternal and newborn health – would have immediate effects. Other actions are more long-term. For example, while policies to reduce hazardous chemicals can be introduced quickly, it may take some time for air, water and soil to become safe.

Geography: While some of the targets can be managed locally, infectious diseases and environmental health issues such as clean air and water require regional co-operation. Disease burdens vary significantly depending on geographic and socio-economic context, such that efforts to achieve particular targets can imply much greater effort in certain areas.

Governance: Good governance and careful planning are key to ensure that health programmes are equitable, effective, efficient and inclusive.

Technology: Technologies – for example, to prevent infectious disease and monitor its spread – are crucial to achieving targets.

Directionality: Bidirectional. Each of the health targets support achievement of other health targets.

ILLUSTRATIVE EXAMPLE
IMPROVING HEALTH OUTCOMES BY IMPROVING AIR QUALITY: THE US CLEAN AIR ACT 1970

Policies aimed at reducing exposure to hazardous chemical substances in the water, air and soil **(3.9)** also assist countries towards meeting targets around non-communicable diseases **(3.4)** and infant health **(3.2)**, as shown by the experience of the United States' Clean Air Act of 1970.

Air pollution, including particulate matter, ozone, heavy metals and acidic gases, affects health throughout the life-course. Several studies have demonstrated a relationship between exposure to air pollution *in utero* and lower birth weight, placing babies at greater risk for the development of respiratory diseases and diminished lung function. Air pollution is associated with increased post-neonatal infant mortality, including sudden infant death syndrome. Exposure to air pollution negatively affects lung growth and places children at greater risk of development of respiratory symptoms including asthma. In adults, exposure to air pollution promotes the development of high blood pressure, heart disease and stroke; elderly people are at particular risk (Ross et al., 2012; Shah et al., 2013). Policies to reduce air pollution thus are highly supportive of health. The US Clean Air Act became law in 1970 and was strengthened in 1990, giving the Federal Government the authority to enforce regulations to limit air pollution. The reduction in particulate matter had an immediate impact on health. For example, it is estimated that 1300 fewer infants died in 1972 than would have done in the absence of the Clean Air Act (Chay and Greenstone, 2003). In 2010 alone, reductions in fine particle matter and ozone pollution resulting from the 1990 Clean Air Act amendments prevented more than 160,000 cases of premature mortality, 130,000 heart attacks, 13 million lost work days, and 1.7 million asthma attacks (US EPA, 2011).

SDG 3 + SDG 8

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.3, 3.9 ⟵ 8.1	Economic growth can be associated with adverse effects on the environment, including water, air and soil pollution and ecosystem change, which can increase the risk of communicable disease, illness and death	-1	Put in place mechanisms in relevant industries to ensure that economic growth does not degrade the environment
3.8 ⟵ 8.1	Increasing economic growth can enable governments to increase spending on healthcare, including towards providing universal health coverage	+1	Invest in education and training to lift productivity, create employment and strengthen the tax base, while moving to equal pay and an inclusive workforce
3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8, 3.9 ⟶ 8.1, 8.5, 8.6	Increased health/well-being supports people to enter the workforce and contributes to economic growth and employment	+2	Invest in healthcare and social services
3.1, 3.2, 3.3 ⟵ 8.5	Increasing the number of people employed supports people gaining access to the conditions for health, such as food, shelter, education and medical care	+2	Invest in the creation of decent jobs in social services that assist people into employment
3.8 ⟵ 8.8	Safer working environments reduce exposure to hazardous chemicals	+3	Strengthen unions and regulate to protect labour rights and health and safety in the workplace

KEY POINTS

There are many positive interactions between growth/employment/work and health/well-being. For example, higher growth can enable greater government investment in health and other social services

The interaction between growth and well-being is context dependent: the quality, nature and sustainability of growth and its relationship with the sustainability of production and consumption critically influence well-being outcomes

Growth is particularly attractive to low- or middle-income countries, but may also be associated with environmental damage and consequent loss of health/well-being; context-dependent policies must ensure appropriate conditions for growth and an appropriate allocation of its benefits

At the individual level, higher incomes are associated with greater access to the resources that help enable a healthy life: food, shelter, medical care, and education. However, stressful working conditions, poor labour rights and unsafe workplaces can put people at risk of illness and injury

KEY INTERACTIONS

Economic growth (**8.1**) and higher productivity (**8.2**) encourage job creation (**8.3**) and support full and productive employment (**8.5, 8.6**), which supports health and enables greater public investment in healthcare, education and environmental protection, which further supports well-being. Interactions are bidirectional, with increased health and well-being raising productivity and incomes (Bloom and Canning, 2001; Wagstaff, 2002). Thus, economic growth and stronger employment can be enabling or reinforcing of health/well-being goals, and vice versa (Nilsson et al., 2016). These positive links are widely understood.

It is widely accepted that greater resource efficiency – the efficiency with which resources (physical and natural) are used and allocated – increases economic growth potential and minimises ecosystem-damaging waste. Examples include ensuring that fish harvesting methods are not wasteful and avoiding the discarding of non-target species. The longer-term benefits for human populations include lower costs of marine food supplies, and availability of certain species, maintaining dietary diversity. In such a context, reducing waste can work in the direction of economic gain and better human health.

However, the gains in terms of health/well-being from economic growth are in practice not universal, nor can growth be endlessly sustainable in a finite and 'full' world (Daly and Farley, 2004). In particular, inequality in income growth across countries and across groups within countries can create difficulties such as perceived relative deprivation, which weakens the relationship between growth and health/well-being (Layard and Layard, 2005). The association is more likely to be strongly positive in low- to middle-income countries than in higher-income countries (Jackson, 2009). In the latter, growth can be 'uneconomic', namely lowering quality of life at least for some, either in rich countries themselves or owing to spillover impacts on other countries (e.g. climate change impacts). In such circumstances, gross domestic product (GDP) and gross national income (GNI) may be increasing, but indicators which more effectively measure society's well-being, such as the Genuine Progress Indicator (GPI) may be static or even declining. The GPI adapts the GDP measure so that negative outcomes such as crime and pollution count against 'progress'; and considers income distribution. The GPI is adversely affected where growth is based on undermining social and environmental capital (Kubiszewski et al., 2013; Costanza et al., 2014).

Diminishing returns to well-being arise because economic growth in high-income countries generally yields increasingly smaller gains at the margin in terms of health/welfare as indicated for example by life expectancy (Bloomberg and Aggarwala, 2008). There is also growing concern in developed countries about long work hours, work-life balance and rapid automation associated with growth. Yet growth is driven by production systems, which often have environmental impacts (e.g. carbon-emitting energy production, loss of soils/farmland to urban expansion, water use that damages aquifers) which cause damage to ecosystem or human health and constrain efforts to achieve health targets. For example, efforts to end water-borne diseases **(3.3)** and address maternal and child mortality **(3.1, 3.2)** require the availability of clean drinking water. In such cases, increasing adverse side-effects of growth can exceed growth's diminishing benefits at the margin. In short, high-income country growth may in some cases constrain or even counteract gains in health/well-being. The implication is that policies to make production and consumption significantly greener are urgently required **(8.4)**.

Even within low- or middle-income countries, where economic growth is more likely to increase well-being, growth may nevertheless be associated with environmental damage and consequent loss of health/well-being, especially in specific domains or regions where earth system processes are especially vulnerable. For example, air pollution in China is estimated to cause damage equivalent to a loss of up to 13% of GDP (Global Commission on the Economy and Climate, 2014; Stern, 2015). This potentially negative linkage ('constraining' or 'counteracting') between growth and health/well-being depends on the nature of the impacts, such as physical effects on the natural resource base, and the way these are mitigated by governments.

The path from environmentally unsustainable production to adverse health outcomes may be indirect or incremental. For example, minor inputs of polluting chemicals from agriculture may lead to cumulative effects as soil gradually becomes contaminated and contamination levels gradually rise in water supplies or food grown in a particular region (Millennium Ecosystem Assessment, 2005), leading to longer-term food shortages and health impacts, even though agricultural production may increase in the short term. The need to abandon particular regions following salination, such as in Sumeria, is a lesson from the deep history of civilisation (Diamond, 2005), but the unintended consequences of new irrigation systems that are poorly regulated are still being encountered today.

Target 3.8, which involves reducing the number of deaths and illnesses from hazardous chemicals, is closely aligned with protecting labour rights and promoting safe and secure working environments for all workers **(8.8)**. Exposure to asbestos is associated with a number of cancers (Nielsen et al., 2014); yet about 125 million people worldwide are exposed to asbestos in the workplace (Concha-Barrientos et al., 2004). In the short term, some employers may pursue economies in health and safety conditions in order to enhance profits; but in the longer term, pursuit of such savings can jeopardise not only the health and sometimes lives of employees but also – in some cases – the sustainability of the commercial enterprise itself. Economic growth and jobs that are dependent upon poor labour conditions, or the continuing abrogation of labour rights are analogous to growth secured through environmental degradation: in both cases, one goal (that of growth and jobs) is advanced at the expense of others. Governments, given sufficient resources, are typically in a better position than individual employers are to assess the preferred balance between health and safety conditions in the workplace (where better conditions enhance the quality and productivity of work) and the social costs arising if and when more costly production conditions lead to the pricing of production off the international market (diminishing the quantity of jobs in the economy). However, in some countries the level of regulation by government of labour conditions may reflect other factors such as inadequate information about risks (EU-OSHA, 2013), or even poor regard for the health and safety of migrant works and others in precarious employment. Studies on the health and safety effects of precarious employment found a negative association with occupational health and safety and that the higher the instability of employment, the more it is associated with morbidity/mortality (EU-OSHA, 2013). In such cases, joint monitoring of working conditions by labour unions and employers can lead to greater awareness of the need for improved health and safety.

As working conditions change over time, with changing technologies and the impacts of climate change, continuing globalisation and other impacts, certain sectors may be particularly affected. For example, with the increased temperatures driven by climate change in most countries – affecting especially agriculture, horticulture and forestry work, governments have a role in ensuring that regulation of health and safety conditions stays up to date (Kjellstrom and Crowe, 2011; Maloney and Forbes, 2011; UNDP, 2016). In short, context and conditions are ritical if growth is to be beneficial for well-being (van den Bergh, 2011). Where growth damages the natural resource base (biodiversity, forests, water bodies, oceans, atmosphere, bio-geochemical cycles) or crosses boundaries of the 'safe operating space' for humanity, it undermines the conditions for long-term well-being (Rockström et al., 2009; Griggs et al., 2013). Thus, a reorientation of business activity towards a green economy is essential for sustained health and well-being (Biermann et al., 2012). An understanding of this dynamic is implicit in SDG8, which includes endeavouring to decouple economic growth from environmental degradation, in accordance with the 10-year framework on sustainable consumption and production **(8.4)**. Better understanding of the specific contexts and policies where SDG3 and SDG8 conflict is important for minimising trade-offs between growth and long-term health/well-being.

KEY UNCERTAINTIES

There are uncertainties about some interactions, such as conditions under which increased income and associated spending might lead to negative health outcomes. But most interactions are positive and clear.

KEY DIMENSIONS

Time: Taking action on several targets – for example by improving occupational conditions – would have immediate effects. Many impacts are long-term: where growth contributes to growing environmental pressures it reduces health/ well-being over time.

Geography: Loss of health/well-being can be especially severe in some regions where interacting factors including topography, weather and technology mean some populations are especially vulnerable (e.g. air pollution in parts of China).

Governance: Good governance and careful planning are key to ensuring the 'right' conditions for growth and rewarding employment. Negative impacts of growth can be mitigated by governments.

Technology: Net benefits for health and well-being cannot be assumed when some technologies or their application can have adverse social and environmental impacts.

Directionality: Bidirectional. However, while growth and employment do not always contribute to health/well-being, increased health/well-being almost always contributes to economic growth and employment. More fundamentally, health and well-being is a higher-level human aspiration than growth and employment (Meadows, 1998).

ILLUSTRATIVE EXAMPLE
THE INTERACTION BETWEEN WORK, LABOUR PRODUCTIVITY AND HEALTH IN THE CONTEXT OF HIGH TEMPERATURES

Health and work are closely related. Access to work increase incomes, which supports health. However, working in an unsafe environment **(8.8)**, harms health. For example, excessive heat in the work place represents an occupational hazard. High temperatures and dehydration place people at risk of acute heat stroke, heat exhaustion, and death. In addition, chronic heat exposure can lead to cardiovascular diseases, mental health issues and chronic kidney disease **(3.4)** (Xiang et al., 2014). Working in high temperatures increases the risk of having accidents, and impairs capacity to undertake physical and mental work (UNDP, 2016). This means that heat can limit labour productivity and economic growth. Modelling suggests that currently, worldwide, up to 10–15% of annual daylight hours are so hot that productivity is lost (UNDP, 2016). Therefore, to support both health and economic growth, labour policies should ensure that employers reduce workers' exposure to heat, through providing shade or ventilation and avoiding work in the hottest periods of the day.

The crucial connection between heat, health, productivity and economic growth is likely to be of increasing concern due to global warming. Further reductions in labour productivity associated with a warmer climate could result in reduced output in affected sectors of over 20% during the latter half of the century. The global economic cost of reduced productivity may be over US$ 2 trillion by 2030 (Dunne et al., 2013). The impacts of climate change on labour productivity as mediated by heat stress would be especially severe in tropical and subtropical environments with large primary sectors where workers carry out heavy labour for long periods at the hottest times of year (UNDP, 2016).

Climate change is associated with increasing frequency and severity of heat waves, which directly impact on health and labour productivity (Kjellstrom and Crowe, 2011). The city of Ahmedabad, India, provides an example of the devastating consequences of heat waves, and proactive policy action to reduce the impact of future heat waves. The 2010 heatwave in Ahmedabad resulted in an estimated excess 1344 deaths, with a direct impact on productivity (NRDC, 2013; Azhar et al., 2014). As a result, city officials and partners focussed on reducing the risk of heat stress by developing the Ahmedabad Heat Action Plan. This sets out an early warning system and planned response strategies to protect residents, workers, employers, and officials with strategies to reduce exposure to heat (AMC, 2013).

SDG3 + SDG11

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.2 ⟵ **11.1**	Improving access to adequate housing supports the reduction of preventable deaths of newborns and children. For example, cold housing is associated with respiratory illness in children	+2	Ensure people have access to adequate housing through a range of measures appropriate to the local context, including: slum upgrading; the provision of permanent housing to homeless people; planning, building and tax policies that ensure high-quality housing and adequate housing supply; regulation and subsidies to support the improvement of existing dwellings (including through installing insulation, clean cook-stoves, ventilation, heating or cooling systems, safety measures)
3.3 ⟵ **11.1**	Improving access to adequate housing reduces crowding and hence exposure to communicable disease	+2	
3.4 ⟵ **11.1**	Improving access to adequate housing is likely to reduce premature mortality from non-communicable diseases. For example, cold housing is associated with cardiovascular symptoms	+2	
3.9 ⟵ **11.1**	Ensuring access to adequate housing will reduce exposure to hazardous substances currently present in some housing, such as polluted air and lead	+2	

KEY POINTS

Thirty per cent of the urban population, not counting those in unaffordable housing, live in slums or are in severe housing deprivation

Deaths of newborn babies, children under five years of age and older people from respiratory and communicable diseases can be prevented by retrofitting insulation and installing effective heating and cooling. These measures are also effective in reducing cardio-vascular deaths in older people

Providing good quality housing improves mental and physical health

Providing safe and affordable housing reduces household crowding and exposure to close-contact infectious diseases

Adequate provision of social housing enables household health and well-being, social cohesion and community stability

KEY INTERACTIONS

As more people migrate to cities in search of a better life and urban populations grow, housing issues intensify. Housing in slums and informal housing poses particular risks to health. About 880 million people live in slums and informal settlements (UN, 2015b), lacking durable housing, sufficient living space, security of tenure, sanitation and infrastructure, and clean water (WHO, 2011b). In addition, many people, whether in slums or not, live in unaffordable housing (defined as costing more than 30% of total monthly household income) or in severe housing deprivation (defined as people living in crowded, poor quality, unaffordable housing, without privacy or any security of tenure) (Amore et al., 2011). Inadequate housing poses risks to health in low-, medium- and high-income countries (Haines et al., 2013). Ensuring access for all to adequate, safe and affordable housing **(11.1)** helps to end or combat communicable disease epidemics **(3.3)**. Household crowding is associated with several infectious diseases, including flu, pneumonia, typhoid, tuberculosis, and diarrhoeal and gastrointestinal diseases, as well as risk factors for water, sanitation and hygiene (Baker et al., 2013). Reducing household crowding, by building new housing, extending existing housing, or through making parts of a dwelling habitable, is likely to reduce the risk of close-contact communicable diseases (Baker et al., 2013).

Improving access to adequate housing also contributes towards **target 3.4**. Evidence connects high indoor temperatures with high blood pressure and other poor health outcomes (Kim et al., 2012a,b; Uejio et al., 2016; van Loenhout et al., 2016), and low indoor temperatures with cardiovascular and respiratory disease (Thomson et al., 2013; Maidment et al., 2014). Excess winter deaths due to cold housing were estimated at 38,200 per year (12.8/100,000) in 11 European countries (WHO, 2011a). Extreme indoor heat also increases excess summer deaths, particularly for older people (Dhainaut et al., 2003; Stedman, 2004). Improving housing temperatures, including through making housing weathertight and installing insulation, heating and ventilation, helps protect against disease (Howden-Chapman et al., 2007, 2012; Telfar Barnard et al., 2011).

Removing dangerous building materials reduces the risk of cancer (associated with asbestos; Goswami et al., 2013) and impaired brain development and cardiovascular disease (associated with lead; Lanphear et al., 2005; Navas-Acien et al., 2007; Levin et al., 2008). Modifying homes to reduce hazards reduces the risk of falls and injury (Keall et al., 2015b). Removing polluting cooking-stoves, installing ventilation, taking measures to reduce dampness and mould, and protecting against outdoor pollutants improves indoor air quality and reduces the risk of chronic respiratory disease, including asthma (WHO, 2009, 2010, 2014a). In 2012, 4.3 million people died prematurely from illnesses caused by household air pollution, closely associated with using solid fuels for cooking and heating, mainly in low-income countries (WHO, 2014b). Improving housing, through providing warm dry homes has been associated with reducing stress and contributing to improved mental health (Howden-Chapman et al., 2007). Thus efforts to improve housing **(11.1)** are likely to contribute towards reducing premature mortality from non-communicable diseases and promote mental health and well-being **(3.4)**.

Improving housing **(11.1)** will play a major role in reducing the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination **(3.9)**. Housing can be a site of exposure to hazardous substances such as lead and asbestos. These substances can also pollute water and soil. For example, lead paint degrades and mixes with dust and soil where it may be ingested by children. In the US, about 70% of childhood lead poisoning cases are associated with housing (Levin et al., 2008).

KEY UNCERTAINTIES

Associations between inadequate, unsafe and unaffordable housing and poor health outcomes are clear, although further research is needed to understand exposure-response relationships between indoor and outdoor heat and cold and cardiovascular and respiratory symptoms.

KEY DIMENSIONS

Time: Poor housing can affect health immediately (e.g. injuries sustained due to bad wiring or broken steps) or cumulatively over time (e.g. exposure to lead in paint or exposure to damp and cold housing). Some interventions to improve housing can reduce the risk of adverse health outcomes immediately (e.g. installing smoke alarms or mosquito nets or replacing lead pipes). Timing of the effects of other interventions, such as those aimed at enabling housing to be heated or cooled to a healthy temperature will depend on the season.

Geography: The risks housing poses to health depend on geography. For example, in hot countries, high indoor temperatures pose a risk to cardiovascular health, while in cold and temperate countries, cold and damp housing poses a risk to respiratory health. In low-income settings, use of solid fuel is common, which means the risks of respiratory illness associated with indoor air pollution are greater. In some places, natural disasters can damage housing and pose additional risks to health. The effectiveness of interventions to improve housing also depend on geographical context.

Governance: Several interventions to improve housing (retrofitting insulation, installing insulation, improving structural integrity) require a trained workforce, good health and safety procedures and quality control. Providing social housing requires a redistributive tax system or a strong cooperative tradition.

Technology: Technology can assist in making housing safer. For example, installing chimneys and ventilation when people use solid fuel and open cooking-stoves and lamps can reduce indoor pollution.

Directionality: Unidirectional. Better quality, affordable housing improves the health of occupants.

SDG 3 + SDG 11

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.4 ⟵ 11.2	Improving transport and particularly supporting active travel modes, promotes physical activity and helps to mitigate or prevent non-communicable diseases	+2	Ensure that transport systems connect active and public transport modes, and encourage cycling and walking through measures appropriate to the local context, such as street lighting, traffic slowing measures, footpaths, cycle lanes, shading, and pedestrian crossings
3.6 ⟵ 11.2	Improving road safety, with particular regard to vulnerable road users such as cyclists and pedestrians, will reduce harm from traffic accidents	+3	Design infrastructure that prioritises safety and protects vulnerable road users. Ensure comprehensive road safety legislation
3.8 ⟵ 11.2	Transport systems support access to healthcare, employment, family and friends, and education	+2	Ensure that public and active transport systems are integrated and well-connected to homes, jobs, and services
3.9 ⟵ 11.2	Compact cities with well-designed public transport, cycling and walking networks enable reduced car use and contribute to reductions in carbon emissions and reduce exposure to air pollution	+3	Promote policies for compact, accessible mixed-land use urban development in order to reduce car dependence and carbon intensity of urban transport and encourage physical activity

KEY POINTS

A reduction in transport emissions improves air quality and reduces the incidence of air pollution-related disease

Enhanced active travel networks support reduction in mortality from, and prevention of, non-communicable diseases

Improved road safety for vulnerable users will reduce harm from traffic accidents

Better and more affordable transport networks support access to key amenities, such as healthcare and education

Infill or brownfield development can better support improved transport networks than greenfield developments, which are more likely to rely on private motor vehicle use

KEY INTERACTIONS

Improving transport systems **(11.2)** is likely to contribute towards the health targets of reducing the incidence of non-communicable diseases **(3.4)** and the incidence of mortality and morbidity related to pollution and to road traffic **(3.6, 3.9)**, via a number of pathways: reducing exposure to harmful substances and poor air quality; encouraging physical activity; improving access to healthcare, education, and employment; and improving the safety of vulnerable road users.

Achieving target 11.2 is likely to support the positive health outcomes associated with improving housing and settlements. Affordable transport systems connect housing to employment and education opportunities, medical services, and to friends and family, all of which are associated with improved health outcomes (Hine and Mitchell, 2003; Syed et al., 2013; Sagrestano et al., 2015). Compact cities, green spaces, making roads safer for cyclists, and investing in footpaths and cycle ways that are safe and attractive, all work to encourage walking and cycling which can contribute towards reducing the risk of cardiovascular disease, cancer, obesity and obesity-related illnesses, diabetes, and mental health problems **(3.4)** (Andersen et al., 2000; Matthews et al., 2007; Boone-Heinonen et al., 2009; Lim et al., 2012; Keall et al., 2015a). Compact cities can also reduce the need for transport, avoiding the costs and adverse effects of travel, and increasing mobility options for non-drivers (Litman, 2016). There are also social benefits to compact walkable cities, with increased interactions between residents (Litman, 2006). It is estimated that for every 10% increase in urban sprawl there is a 5.7% increase in per-capita carbon dioxide emissions and a 9.6% increase in per capita hazardous pollution.

Improving transport systems **(11.2)**, particularly for vulnerable road users such as pedestrians and cyclists can also help reduce deaths and injuries from road traffic accidents **(3.6)**. Road infrastructure is mainly constructed with the needs of motorists in mind. Yet in the African region, for example, 43% of all road traffic deaths occur among pedestrians and cyclists (WHO, 2015). Most traffic crashes are predictable and preventable: the roll out of key interventions to make roads safer can prevent fatalities while encouraging more people to travel by active means (WHO, 2015).

The promotion of walking and cycling, as well as public transport, over private motorised transport can also contribute towards a reduction in transport emissions. Improving transport systems will play a major role in reducing the number of deaths and illnesses from hazardous chemicals and air, water and soils **(3.9)**.

Greenfield development in comparison to infill or brownfield developments can encourage car-orientated transport reliance. Increased reliance on private motor-vehicle transport carries environmental burdens, such as leaching of zinc and copper into soil and waterbodies (Moores et al., 2010), which carry risk for human health as well as increased cost of development (Adams and Chapman, 2016). With the right infrastructure commitments, infill and brownfield developments can facilitate a shift towards greater reliance on public transport networks, and active travel such as walking and cycling (Howden-Chapman et al., 2011; Sallis et al., 2016). Urban developments in the present will 'lock in' infrastructure possibilities for the future, contributing to a time-lag between decisions now and effects later for transport infrastructure, including the relative physical activity of affected populations and vehicle emissions. Integrating improved transport decisions into urban planning is likely to help reduce premature mortality from non-communicable disease by 2030 **(3.4)** and to help reduce the number of deaths and illnesses from hazardous air quality **(3.9)**.

KEY UNCERTAINTIES

There are few uncertainties, because the links between improved transport networks and health are well-established.

KEY DIMENSIONS

Time: Improving transport networks has immediate and long-term benefits. In the short-term, greater access is achieved for those who use transport networks. In the medium- to long-term, physical activity is improved, air quality improves, and carbon emissions are reduced. However, developing or redeveloping cities to fit this vision can take decades.

Geography: Different contexts will require different methods of improving transport networks, for example depending on the age and built environment of a city, what access exists to renewable energy networks to power (for example) electric buses, and regional, national, and international interlinks. Cultural attitudes to public transport and active transport may also require special attention.

Governance: Local governments have a strong role to play, in association with central governments. City municipalities may provide the mandate for improving the city's transport networks.

Technology: A conversion to electric-powered public transport infrastructure will be beneficial in places that have access to renewable, fossil-fuel free electricity. Technological improvements to vehicle emissions and safety will contribute to reducing mortality and morbidity related to pollution and road traffic.

Directionality: Unidirectional. Better transport systems support health goals by reducing air pollution, improving road safety, and encouraging physical activity.

ILLUSTRATIVE EXAMPLE
RESTORATION OF CHEONGGYECHEON STREAM RESTORATION PROJECT, SEOUL, REPUBLIC OF KOREA

Decision-makers often face the dilemma of having to choose between a more expensive but sustainable development path and a cheaper quick-fix solution with foreseeable future adverse repercussions. The Cheonggyecheon Stream Restoration Project provides an internationally significant example of how a metropolitan government took steps towards sustainability with a new focus on the well-being of its citizens.

Multiple factors contributed to the stream restoration. The Cheonggyecheon motorway, that covered the stream allowed easier access to the downtown area of Seoul during the mid- to late 1900s leading to rapid industrial development. However, by the early 2000s it was so dilapidated that a decision was needed on whether to demolish it completely and build a new motorway or to deculvert and restore the Cheonggyecheon stream. The worn out infrastructure in Gangbook (north of Han river) where the Cheonggyecheon stream runs, compared to the newer infrastructure of Gangnam (south of Han river) were causing an urban imbalance that was contributing to a loss of economic competitiveness in the area as a whole. The dramatic change in Seoul's priorities in favour of sustainable well-being, including cultural and historical renewal of the stream, followed the collapse of two major pieces of infrastructure in Seoul due to poor construction. These factors contributed to the Cheonggyecheon restoration becoming a major political issue during the 2002 Seoul mayoral election and led to the victory of Mayor Lee Myung Bak, who successfully advocated for the immediate restoration of the stream. Cheonggyecheon became reborn into a multipurpose public space with continuous walkways and cycleways along the length of the stream.

The motorway had previously had a daily traffic flow of around 170,000 vehicles, but after its demolition the Seoul Metropolitan Government limited car traffic to two-lane one-way streets on either side of the stream and in conjunction, invested heavily in public transport (Chung et al., 2012). Investment focused on making public transport the cheaper, easier and faster option. Bus services were improved (e.g. colour coding and reformed bus numbers) and made as fast, or faster than car trips (Seoul Development Institute, 2005). Integrated ticketing was introduced, with a standard fixed fee for trips under 10 km. Active travel networks were built with the opening of two new subways stations close to the stream, continuous pedestrian roads along the length of the stream and 22 bridges connecting the north and south side of the stream.

These efforts increased bus and subway usage and reduced daily traffic in the Cheonggyecheon area by a third, while maintaining the average speed of vehicles. The restoration also reduced fine particulate matter (PM10) and nitrogen dioxide (NO2) in air by 15% and 10% respectively between 2002 and 2005 (Jang et al., 2010). The reduction in cars and the opening of a new winding path along the continuous depressed length of the stream, reduced the heat island effect and average temperature in the Cheonggyecheon area fell by 6–9°C.

SDG 3 + SDG 13

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
3.9 ⟵ 13.2	Integrating climate change measures into national policies will support improvements in air quality	+3	Recognise the co-benefits from simultaneously mitigating climate change and reducing air pollution. Utilise systems thinking and frameworks to help structure and prioritise urban transport carbon mitigation policies
3.4 ⟵ 13.2	Integrating climate change measures into national policies has some costs. Reducing emissions may lead to job losses in some industries, which could negatively affect the economy and indirectly constrain health care	-1	Invest in renewable energy and support for retraining of workers transitioning out of fossil fuel industries

KEY POINTS

In general, a reduction in fossil fuel combustion will simultaneously mitigate climate change and reduce air pollution: both outcomes will benefit health

While the main focus remains on the long-lived greenhouse gases, short-lived climate pollutants also matter for health

On average, the co-benefits from undertaking simultaneous mitigation may be greater in low- or medium-income countries than high-income countries; however, both are necessary

Urban transport, industries, thermal plants and burning of agricultural fields is a key source of emissions and air pollution; the avoid-shift-improve framework can help structure and prioritise urban mitigation policies

While understanding the chemistry behind the interaction of air pollution and climate is important, so are considerations of available technologies, means of implementation and governance

KEY INTERACTIONS

Climate change interacts with health in many ways and the scope for climate action is very broad. The focus of this section is on the interaction between the health impacts of air, water and soil pollution **(3.9)** and the integration of climate change measures into national policies, strategies and planning **(13.2)**. Emissions, which affect both the climate and local air quality, largely derive from the combustion of fossil fuels. Therefore, reducing fossil fuel combustion will act to mitigate climate change and reduce air pollution.

Abating air pollution is a recurring international environmental policy driver with ongoing problems in cities from Paris to Beijing. Accordingly, efforts to control harmful emissions such as sulphur dioxide (SO_2) have a long history (Kanada et al., 2013) although ironically, it is now clear that the widespread abatement of sulphur is removing a (temporary) climate cooling influence (ACP, 2014). Short-lived climate pollutants include particles and aerosols such as black carbon and tropospheric ozone (UN, 2015a). Black carbon results from various domestic and industrial processes such as diesel combustion (for vehicles and electricity generation), cooking with biomass, and brick production (ACP, 2014). Each of these pollutants contributes to smog, carries a risk to human health risk when inhaled, and contributes to climate change.

Mitigating climate change as well as reducing air pollution can be achieved through action in the transport sector. There is a wide array of potential solutions for reducing carbon emissions, ranging from urban intensification that facilitates better public transport and healthy physical activity, to switching fuels for existing modes of private transport (Dalkmann et al., 2014). Well planned non-motorised transport provision can have positive impacts on greenhouse gas emissions and on local air quality. Mitigating climate change, while reducing air pollution, can also be achieved through regulation to limit emissions from electricity and heat generation, especially coal, as well as industrial and manufacturing processes. The range of strategies can be conceptualised through the avoid-shift-improve framework, which is a way of understanding the co-benefits of policies in the broader context of a sector and how it relates to technologies and behaviour when different policies have different challenges and timescales for implementation, and analysis can help structure and prioritise policy packages in a given sector (Doll and Puppim de Oliveira, 2017).

Given the alignment between climate and air pollution objectives, many studies have looked into the co-benefits of aligned policies (Howden-Chapman et al., 2007; Bell et al., 2008; Bollen et al., 2009). One review (Nemet et al., 2010) found that on average the co-benefits (valued in US$ per tonne CO_2) from undertaking simultaneous mitigation were greater in low-income countries than high-income countries. This was because there are greater marginal health benefits from reducing (initially) higher levels of air pollution, than from reducing air pollution levels in places where there is relatively low air pollution.

Understanding the atmospheric chemistry behind the interaction of air pollution and climate is an important first step in designing policies for aligning health gains from air pollution reduction with climate change mitigation. This needs to be complemented by considerations of available technologies, means of implementation, and governance, in order to minimise the risk of misaligning climate and air pollution objectives, while ensuring policy measures contribute to local municipal or regional policy goals.

The interaction between policies aimed climate change mitigation **(13.2)** and health-enhancing air pollution measures **(3.9)** is broadly enabling and potentially reinforcing. In some cases, it may be indivisible. However, within certain sectors, care must be taken to ensure that some options do not inadvertently constrain or counteract the target. Fuel switching policies in particular must be examined from the perspective of precursor emissions, and their long-term effects if deployed over a large scale. There are also impacts on air pollution from a changing climate. Seasonal effects on air pollution are well-known and a dry or cold climate may cause more severe air pollution events.

KEY UNCERTAINTIES

Uncertainties remain as to the effect/strength of some policy measures.

KEY DIMENSIONS

Time: Health benefits from consequential air quality gains will have a faster effect on health than carbon emission reduction *per se.* The latter will be a critical long-term influence on global health. Some measures with both carbon mitigating and air pollution reducing effects, such as improving vehicle fuel efficiency, are subject to 'rebound' over time. Some influential carbon reduction measures, particularly policies to alter urban form to minimise car travel and maximise active travel and use of public transport, will take decades to have full effect, as cities grow and change.

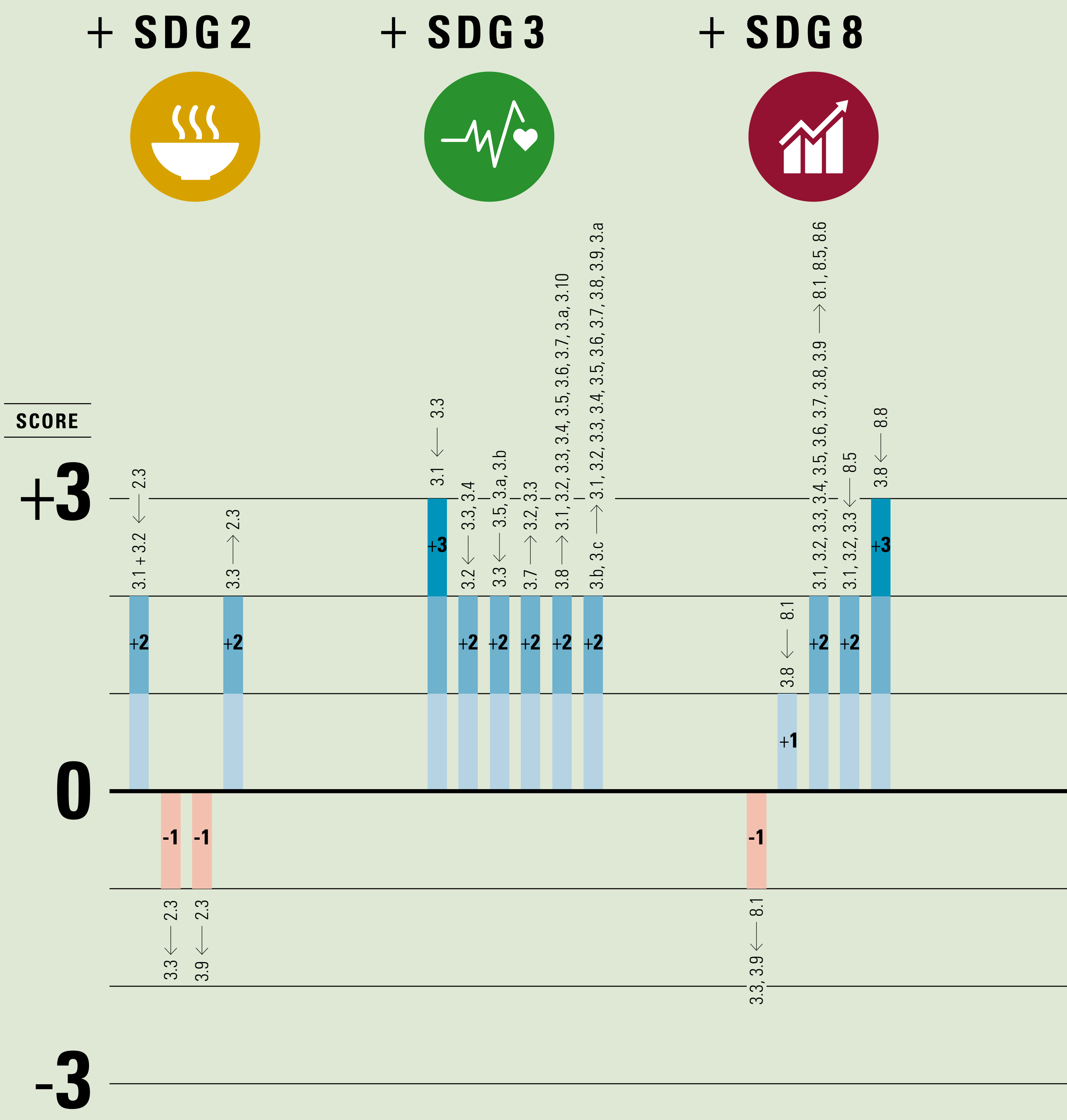
Geography: While greenhouse gas reduction measures have more global benefits, gains from air quality improvements are more local. Context influences the relative benefits and costs of policy measures, with air pollution reduction yielding higher benefits in low-income countries than high-income countries.

Governance: Attention to governance is important to minimise the risk of misaligning climate and air pollution objectives, while ensuring policy measures contribute to local municipal or regional policy goals. Coordination is vital (even internationally) as air pollution emitted in one location may be transported and have an impact on other locations.

Technology: Public policies must take into account changing technologies that impact on climate change mitigation and adaptation.

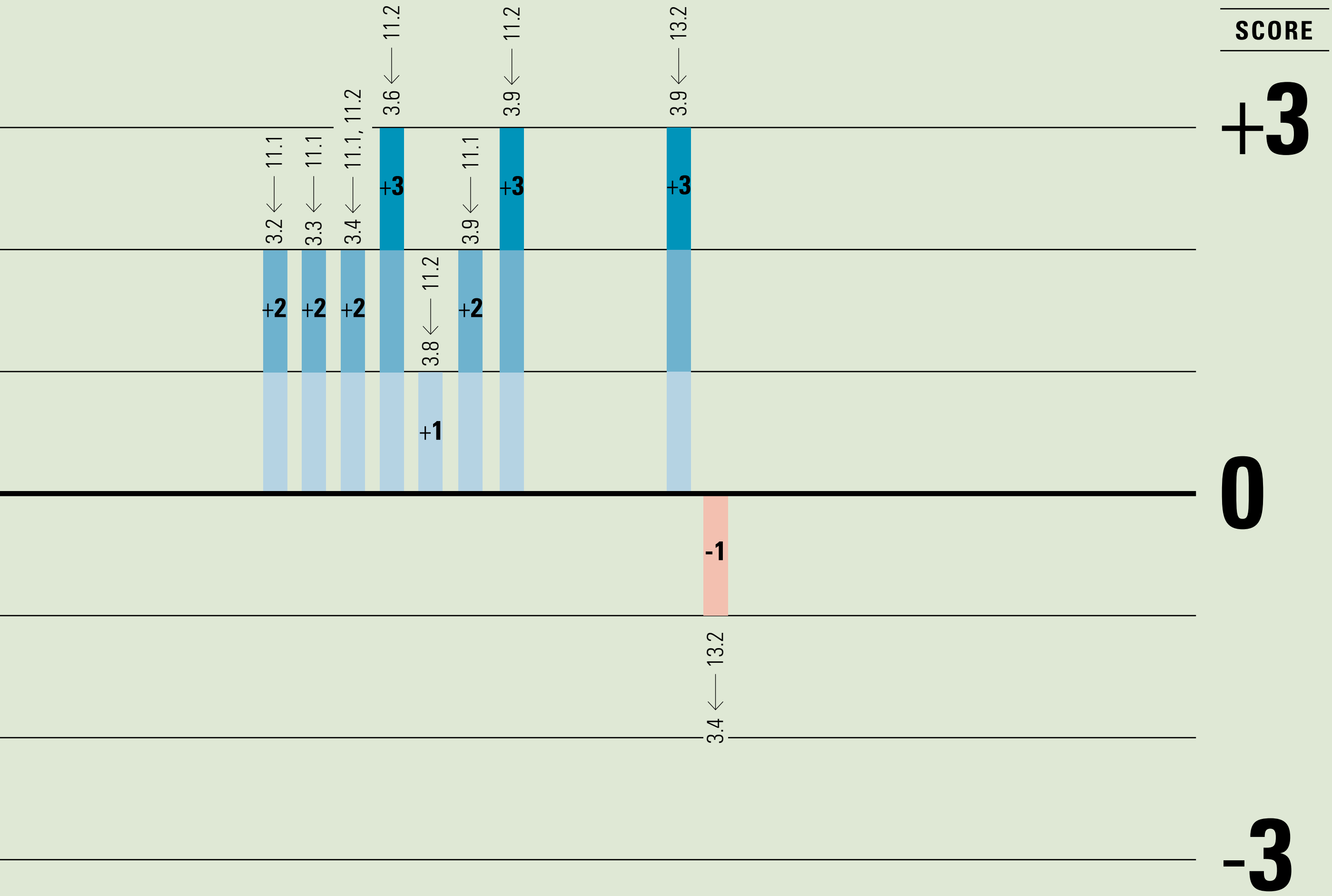
Directionality: Largely unidirectional: mitigating climate change immediately through improvements in air quality. The transition to an economy less dependent on fossil fuels may cost some jobs in the short-term, which may have knock-on effects on health and on health spending. These could be serious in areas dependent on fossil fuel extraction, although offset by job gains elsewhere; but in the long term, health gains are likely to substantially outweigh such costs.

KEY INTERACTIONS
SDG 3 WITH OTHER GOALS



+ SDG 11

+ SDG 13



SCORE
+3
0
-3
3.2 ⟵ 11.1
3.3 ⟵ 11.1
3.4 ⟵ 11.1, 11.2
3.6 ⟵ 11.2
3.8 ⟵ 11.2
3.9 ⟵ 11.1
3.9 ⟵ 11.2
3.9 ⟵ 13.2
3.4 ⟵ 13.2
+2
+2
+2
+3
+1
+2
+3
+3
-1

KNOWLEDGE GAPS

The preceding sections have illustrated some of the many interactions between SDG3 and the other SDGs. These interactions can be positive, negative, or neutral, uni- or bi-directional, short- or long-term, and often depend on geography, governance and technology. For some interactions, the state of science is not yet advanced enough to provide accurate and reliable assessments. As science advances and the evidence base grows, more comprehensive assessments should be possible, enabling significant improvements to SDG implementation strategies at regional, national and local scales. In general terms, integrated research, monitoring and data analyses will be needed in combination with targeted capacity development to fill existing knowledge gaps. The section provides a non-exclusive list of knowl edge gaps that have been identified in relation to the complex web of trade-offs involving the SDG3 target interactions described in this chapter.

3 + 2 (2.3)
Careful case-by-case analysis is needed concerning how intensifying agricultural production is expected to affect the environment, including the expansion of pathogen habitats and the degradation of waterways

3 + 3
More research is needed to strengthen the evidence base for connections between SDG3 targets; for example, the connection between air pollution and maternal mortality rates is only beginning to become clear. However, standalone programmes may detract resources from broader aspects of the health system

3 + 8
Economic growth occurs differently in different contexts: some forms of growth are environmentally and socially damaging, while others (e.g. growth in the supply of infrastructure for renewable energy) are generally not. Expanding understanding of the specific contexts and policies mediating the interdependency between growth and long-term health and well-being is important for minimising critical trade-offs. Further research is needed on the relationship between income gains, employment and health at higher levels of development, given observed diminishing returns at high levels of wealth and income for the rich and the engendering of a sense of relative social and economic deprivation among the poor

3 + 11 (11.1)
More work is needed on the health impacts of quality, compact city environments with high access to amenities and a mix of

land uses, including public spaces. Better knowledge is needed on how increasing the volume of energy efficient, quality dwellings contributes to health in various contexts, such as the quality and security of existing housing including slum dwellings in different climates

3 + 11 (11.2)
More research is needed on how new housing developments and redevelopments can best foster health-promoting transport choices, including active transport, public transport and new modes such as car sharing

3 + 13 (13.2)
Better understanding is needed about the alignment between air pollution measures and climate change mitigation measures, for example, how can such measures contribute to low-carbon urban developments including more sustainable housing, transport and urban form. Air pollution is a complex issue arising from multiple (diffuse or point) sources both locally and from surrounding areas. Better information is required on how many of these pollutants can be mitigated through climate change actions in different localities

CONCLUDING COMMENTS

With so many interactions between targets, it is clear that government-led actions and policies will be important for ensuring that positive outcomes are achieved as frequently as possible and negative outcomes are minimised or avoided. This requires the development of policy frameworks that take a systemic, integrated, holistic perspective. For example, it is helpful to focus on interlinked policy goals of cities to gain insights for policy to advance health and well-being outcomes. Governments could usefully engage in policy experimentation to address increasingly urgent climate change issues. Some governments have demonstrated the importance of linking diverse policy measures to create mutually reinforcing measures for change. It is important that planning agencies make use of systems thinking to develop a more integrated view of outcomes that increase health and well-being (Chapman et al., 2016). It may also help to understand where existing vested interests may be working against the achievement of particular targets, and where business and civil society partners can collaborate with policies of local and national governments. Pro-active engagement and enhanced coordination across government departments and ministries, as well as across different levels of government (from international to national to local), and between state and non-state actors including business and non-government organisations, will be required for this to happen effectively. Given the diverse levels of interactions, the persistent 'silo approach' to policymaking, does not serve the achievement of the health targets well.

Building on these general considerations, the six summary tables in the target-level interactions section provide options for how policy could address the specific target interactions in practice. Although addressed to specific target interactions, many of these policy options are also relevant for other interactions.

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SDG 7 ENSURE ACCESS TO AFFORDABLE, RELIABLE, SUSTAINABLE AND MODERN ENERGY FOR ALL

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INTRODUCTION

Access to affordable, reliable, sustainable and modern energy is the focus of SDG7. It is underpinned by three targets: ensuring universal access to energy services **(7.1)**, increasing the share of renewables in the energy mix **(7.2)**, and improving energy efficiency **(7.3)**. The priorities for implementing SDG7 are to enhance international cooperation and promote investment **(7.a)** and to expand infrastructure and upgrade technology in developing countries **(7.b)**.

While SDG7 contains the fewest number of targets of any SDG (along with SDG13), it is no less important a development priority. Indeed, modern energy is fundamental to human development: it launched the industrial revolution more than two centuries ago and has contributed to the near-continuous economic growth that has been achieved globally since that time. The services that energy makes possible – from mobility to manufacturing, agriculture to heating and lighting – are ubiquitous in the industrialised world, and have been around for so long that people commonly take for granted what makes these services possible. Not everyone has enjoyed the benefits that modern energy forms can provide, however. Energy resources are unevenly distributed around the world, and where they exist and are relatively easy to produce, the necessary energy extraction and conversion infrastructure (e.g. gas drilling, oil refineries, wind turbines, electricity transmission lines) requires significant sums of money to bring online. Constraints to financial and human capital often result in some among us being left out of the modern energy society.

Achieving the targets of SDG7 will impact, and be impacted by, progress along the many other SDG dimensions. Yet, while this is the focus of the current chapter, it is also important to note that there are interlinkages (some positive, others negative) between the three energy targets themselves. For example, distributed sources of renewable energy (solar, biogas) could help rural communities achieve energy access. Doing this via a more centralised, infrastructure-heavy approach would also be possible, but there is a risk that elevated energy prices could cause some households to forego access to the network. The energy efficiency target, meanwhile, is a 'win-win' strategy on essentially all accounts. Every unit of energy saved, either through technological or behavioural/conservation means, is a unit that does not need to be produced. This, in turn, lowers the energy requirements for renewables expansion and universal access provision, thereby easing the burden of attaining each.

The text that follows provides an overview of interactions at the goal level between SDG7 – the 'entry level goal' for this assessment – and the other 16 SDGs. Taking into account all the underlying targets of this entry goal, a set of key interactions is identified between the SDG7 targets and those of other SDGs, principally interactions within the range of the highest magnitude or strongest impacts based on available scientific literature and expert knowledge. The typology and seven-point scale for characterising the range of positive and negative interactions described in the opening chapter to this report is used to assess the selected target-level interactions and the context in which they typically occur. Illustrative examples from different world regions show how these linkages manifest in practice. Policy options are identified for how to maximise positive interactions and minimise negative interactions between now and 2030, and beyond. The chapter concludes with a list of key knowledge gaps related to the interactions studied. An elaborated analysis of these issues is described in McCollum et al. (2017).

KEY INTERACTIONS AT GOAL LEVEL

7 + 1

Ensuring the world's poor have access to affordable, reliable and modern energy services enables the goal of poverty eradication. However, decarbonising energy systems by promoting renewables and boosting efficiency could result in price shocks if the costs of transition to a low-carbon economy are not buffered in some way. This could prevent universal energy access, since higher energy prices would add to the challenges of improving the standard of living for the world's poorest. Investment costs for many small-scale renewable energy technologies (such as household solar photovoltaic systems) have decreased considerably in recent years, and in some areas are now the least-cost electricity supply option. If technology innovation trends continue, renewable electricity generation will become profitable in a greater number of regions. This could enable poor communities with electricity transmission access to make use of local clean energy resources, potentially allowing for revenue generation. Moreover, some of the poorer regions of the world possess some of the highest quality renewable energy supplies (e.g. biomass and solar power in Africa). Progress in making use of those potentials could help to reduce poverty, as long as the benefits accrue to local suppliers.

7 + 2

As a renewable energy source, bioenergy is likely to form an increasingly important part of the energy mix. Commercialising bioenergy production could lead to the creation of agricultural and forestry jobs, as well as to higher wages and more diversified income streams for land owners (aiding food security). However, developing agrofuels could also lead to higher global food prices (and thus reduced access to affordable food by the poor) as well as to competition between agrofuels and food crops over scarce agricultural land, water and energy for agrofuels production. Another key interaction is energy for agricultural operations. Providing energy to impoverished farmers is likely to make it easier for them to pump groundwater and mechanise their farm equipment to increase food crop yields, and will enable easier maintenance of cold chains (temperature-controlled supply chains) for marketing produce and thus improving regional diet diversity. Some forms of bioenergy – such as fuels produced from domestic wastes – do not compete with food production, although transportation of waste residues and operation of agrofuel processing plants can be energy-intensive.

7 + 3

The SDG7 targets are directly linked to achieving major reductions in air pollution. Improving air quality, and by extension human health, is especially important for those living in the dense urban centres of both developed and rapidly developing countries. Thermal comfort (heating and cooling) and cooking are key to good health, which highlights the need to ensure access to affordable and reliable energy. Use of energy-efficient appliances such as clean cook-stoves is fundamental to improving indoor air quality. Energy is also essential for refrigeration, which contributes to food conservation along the supply chain and helps avoid the health risks associated with bacterial contamination. Refrigeration enables rural populations to store the medicines and vaccines necessary for ensuring community health. Energy-saving measures related to 'active travel' (cycling and walking) can help improve health and well-being by lowering rates of diabetes, heart disease, dementia, and some cancers; but at the same time can offset efforts to reduce deaths and injuries from road traffic accidents if the infrastructure provided is unsatisfactory.

7 + 4

Well-lit, well-heated, and well-cooled schools and households are essential for creating comfortable learning spaces for children and adults and reduce dependency on natural variations in daylight. The information and communication technologies on which modern learning is based also require energy input. Ensuring energy access in countries where access to reliable energy services may be lacking can therefore reinforce education goals. The level of educational attainment within a society can influence its collective awareness about sustainable development and sustainable lifestyles, including an understanding of why transformative changes in the energy system are necessary. Knowledge and skills in the area of energy sustainability may then influence which technological, financial and political solutions are feasible to implement. Thus, quality education is an enabling factor in achieving SDG7. Energy is also a key element of science education; and better inclusion of energy in school curricula may foster better science literacy at all levels of society.

7 + 5

Access to energy would expand the number and range of opportunities for women, for example enabling women to work from home and thereby generate an independent source of income. Impacts will initially be greatest at the household level, with society-wide implications emerging over time. The more empowered women become, the more likely they are to push local initiatives that directly benefit them from an energy-access perspective, since they are often the ones to gain most from the use of cleaner, easier-to-obtain fuels for cooking and lighting. Access to energy reduces the importance of physical gender differences in the labour force, increasing access to the professions for women. Public outdoor lighting would increase security for women and girls, potentially allowing them to continue autonomous activities outside their households after dark.

7 + 6

Thermal cooling and resource extraction require vast amounts of water; while wastewater from the energy sector releases large quantities of thermal and chemical pollution into aquatic ecosystems. In most cases, a shift from fossil energy technology to renewables and boosting energy efficiency would reinforce the achievement of sustainability objectives related to water access, scarcity, management and pollution. However, some renewable energy sources (including bioenergy and hydropower) could, if not managed correctly, have counteracting effects that compound existing water-related problems. Installing and operating water extraction, transport and treatment systems requires a considerable amount of energy ('energy-for-water'). Expanding these services to poorer populations will be enabled by universal energy access. A shift toward unconventional water supply options (e.g. desalination) in the world's water-stressed regions will generally increase energy demand. This may benefit renewables: if water-related infrastructure and equipment can be used for real-time demand-side power management, developing water and sanitation systems could help grid integration of intermittent electricity sources. However, water-related energy demand increases could be challenging if there are constraints to up-scaling renewables quickly.

7 + 8

Deploying renewables and energy-efficient technologies can spur innovation and reinforce local, regional and national industrial and employment objectives. Active measures may need to be taken to minimise the negative impacts of a large-scale switch to renewable energy on those currently working in the fossil fuels sector: government support may be needed to help businesses re-tool and workers retrain. Workforce migration may also be needed because fossil fuel development is highly concentrated whereas renewable energy projects are distributed across wide geographic areas. To support clean energy efforts, strengthened financial institutions in all countries are necessary for providing capital, credit and insurance to local entrepreneurs attempting to enact change. Decarbonising energy systems through an up-scaling of renewables and energy efficiency could potentially constrain countries' economic growth; but strong growth decoupled from environmental degradation and job growth from installing and maintaining renewable energy and energy efficiency technologies that could more than compensate for economic costs associated with these changes means this interaction seems only mildly counteracting. Decarbonising fossil-fuel based energy sources by technologies such as carbon capture and storage can increase demand for a skilled workforce and create economic growth, although higher energy prices may stimulate energy efficiency related job creation.

7 + 9

Building resilient infrastructure, promoting inclusive and sustainable industrialisation and fostering innovation are a necessary pre-condition for, and indivisible from, achieving the SDG7 targets on access to energy services, increasing the share of renewables in the energy mix, and increasing energy efficiency. Upgrading and retrofitting infrastructure to make it more reliable and sustainable; providing financial and technical support to promote technological development; and encouraging innovation through scientific research funding – will each directly benefit countries' energy industries. Eco nomic, social and environmental benefits could accrue to individuals and firms in urban areas, since this is where most innovation and industrial activity tends to occur, and where recycling and reuse is highly-efficient. One concern could be the early retirement of fossil energy infrastructure (power plants, refineries, pipelines), which may be needed to mitigate related sustainability challenges. Unless targeted policies are used to help alleviate the burden on industry, the economic implications could in some cases be negative. Carbon pricing through a carbon tax or cap-and-trade market mechanism may be used to reduce carbon intensity in industrial processes and provide states with funds to help innovation and compliance in the industrial sector.

7 + 10

Ensuring energy access and increasing the share of some types of renewable energy (such as agriculture and forest-based bioenergy) can enable educational, health and employment opportunities for the rural poor, with positive effects on income and equality. Universal access to energy is key to achieving equality, where all are free to exercise their development options. Good governance will help to avoid clashes between objectives. For example, policymakers must be careful to ensure that energy remains affordable to the poorest, especially if higher-cost renewables are deployed. Ideally, institutional and financial capacity should be locally sourced, although foreign investment and development funding (from rich to poor countries) is also important. Both can foster socio-economic development and help reduce inequalities between countries, as well as within them (across different social, gender, economic, ethnic, religious and racial groups). Locally available sources of renewable energy may also reduce inequalities due to international fossil fuel market variations that could result from political or speculative pressures.

7 + 11

Energy is central to urbanisation; energy allows cities to grow and perform. Clean, efficient energy systems, in particular, create the conditions for cities and human settlements to be inclusive, safe, resilient, less-polluting, and more sustainable. An up-scaling of renewable energy and energy-efficient technologies and infrastructure systems (such as transit-orientated, mixed-use developments) can have a large impact on the sustainability of a given city or community. Similarly, if cities move in a more sustainable direction in terms of transport, housing and urban planning, air quality, resource efficiency, and/or climate change mitigation, then this will create the necessary enabling conditions for achieving SDG7, because renewables and efficiency will need to feature in the portfolio of solutions. Smart grids in cities will improve energy efficiency and facilitate the development of renewable energy at the domestic or neighbourhood scale.

7 + 12

Efforts to reduce waste and pollution, improve resource efficiencies, increase recycling and reuse and promote awareness about more sustainable lifestyles coincide with the requirement for more efficient use of natural resources (fossil and renewable). For example, phasing out inefficient, wasteful, and market-distorting fossil fuel subsidies – in a way that minimises counteracting adverse side-effects on the poor – could reinforce attempts to deploy renewables and energy-efficient technologies and consumption patterns. Responsible consumption triggers responsible production and minimises waste, in turn minimising the amount of energy associated with waste handling and management.

7 + 13

An immediate up-scaling of renewables and energy efficiency is strongly linked to keeping global warming to well below 2°C above pre-industrial levels, the legally binding objective of the Paris Agreement. Achieving SDG7 could put the world on track for meeting this challenge, though it would not be entirely sufficient given the scale of the decarbonisation challenge. In the reverse direction, better integrating climate change measures into national planning, improving education, awareness, and capacity on climate issues, and mobilising funds for mitigation will all go a long way in furthering targets for renewables and energy efficiency. Under certain conditions, providing universal access to modern energy services by 2030 is fully consistent with the Paris Agreement, because it is not expected to have more than a minor effect on global carbon emissions.

7 + 14

Renewable energy generated from offshore wind, wave and tidal power farms is a good resource base for coastal communities. Conserving and sustainably using marine resources (including fossil fuel reserves – much of which are located offshore), calls for increased scientific knowledge of the impacts of their exploitation on aquatic habitats, and for increased research, human and institutional capacity to mitigate the adverse effects of these energy-related activities. Upscaling of renewables and energy-efficient technologies and consumption patterns will help decrease ocean acidification (via lower carbon emissions), accidental impacts from energy-production and transport activities on aquatic habitats, and marine thermal pollution from cooling at coastal power plants. Adverse side-effects of ocean-based energy installations include spatial competition with other marine activities (such as tourism, shipping, resource exploitation) and with marine and coastal habitats and protected areas. Geoengineering projects such as ocean fertilisation may have additional energy impacts, either positive or negative as the need for fertilisers and biomass harvesting are considered.

7 + 15

Ensuring that the world's poor have access to modern energy services would reinforce the objective of halting deforestation, since firewood taken from forests is a commonly used energy resource among the poor. On the other hand, protecting terrestrial ecosystems, sustainably managing forests, halting deforestation, preventing biodiversity loss and controlling invasive alien species could potentially clash with efforts to expand renewables, if that would mean constraining large-scale use of bioenergy. Land-use changes involved in extensive renewable energy production such as hydroelectric dams may conflict with SDG15. Good governance and sound implementation practices are critical in all such cases. For example, policies could ensure that bioenergy crops are primarily grown on degraded lands, which might mean they have little impact on global agricultural markets and could simultaneously improve soil carbon and terrestrial biodiversity. International coordination is of particular relevance, especially because bioenergy deployment in one country can have indirect land-use change impacts elsewhere in the world.

7 + 16

Effective, accountable and transparent institutions are needed at all levels of government (local, national, international) for creating the conditions necessary to be able to ensure universal energy access, increase the share of renewables and increase energy efficiency. Strengthening the capacity of developing countries to participate at the international level (such as within United Nations agencies, the World Trade Organization, regional development banks and beyond) will be important for issues concerning trade, foreign direct investment, labour migration, policy and institutional arrangements, and technology transfer. Reducing corruption, where it exists, will help these bodies and related domestic institutions maximise their societal impacts and ensure that the optimal mixes of measures for energy access provision, renewable energy and energy efficiency are implemented effectively. Eliminating perverse subsidies for unsustainable energy sources could help to achieve both better governance and sustainable energy goals.

7 + 17

This goal is about strengthening the means of implementation for achieving all SDGs. However, to ensure access to affordable, reliable, sustainable and modern energy for all, it is critical that all countries are able to mobilise the necessary financial resources (such as via taxes on fossil energy, sustainable financing, foreign direct investment, financial transfers from industrialised to developing countries); are willing to disseminate knowledge and share innovative technologies; follow recognised international trade rules while at the same time ensuring that LDCs are able to take part in that trade; respect each other's policy space and decisions; forge new partnerships between their public and private entities and within civil society; and support the collection of high-quality, timely, and reliable data relevant to the furthering of their aims.

KEY INTERACTIONS AT **TARGET-LEVEL**

In terms of its three main elements – ensuring energy access (7.1), increasing the share of renewables (7.2), and speeding up the rate of energy efficiency improvement (7.3) – SDG7 has links with all 16 other sdgs. This section analyses some of these interactions in detail at the target-level for a subset of the SDGS. This selection was based on the strength of the interlinkages and the magnitude and scale of impact in relation to the overall objective of the 2030 Agenda, while ensuring a balanced consideration of the economic, social and environmental dimensions. Target-level interactions are judged to fall within one of seven categories and are scored accordingly: indivisible (+3), reinforcing (+2), enabling (+1), consistent (0), constraining (-1), counteracting (-2), and cancelling (-3). Following a general analysis of the selected interactions, specific examples are provided to illustrate how interactions unfold in different geographical and policy contexts.

Six goals were selected for detailed analysis, with three accompanied by an illustrative example (as noted):

SDG1
SDG2
SDG3
Improving air quality and health for the rural poor in India
SDG6
Groundwater depletion and renewables in Saudi Arabia
SDG8
Renewables and job creation in Germany
SDG13

SDG 7 + SDG 1

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.1 ⟶ 1.4	Energy is a basic service, therefore universal energy access reinforces the achievement of 1.4	+2	Develop energy access policies that support clean cooking-stove purchases and lower fuel bills Institute capacity building and education programs to support individuals in the energy industry at the local level
7.2, 7.3 ⟶ 1.4	Decarbonising the energy system through renewables and efficiency is consistent with the provision of basic energy services as long as policies help to shield the poor from any fuel price increases that may result. Lacking such policies, 7.2 and 7.3 could constrain the options for achieving 1.4	0/-1	Where necessary, put in place compensation mechanisms that could be required to protect the poor from energy price shocks resulting from efforts to boost the deployment of renewables and energy efficiency
7.2, 7.3 ⟶ 1.5	Renewables and energy efficiency are a necessary pre-condition for limiting global climate change; in turn, exposure of the poor to climate-related extreme events will be reduced	+2	Policies ensuring that the energy system is decarbonised through an upscaling of renewable energy technologies and energy efficiency efforts are critical for limiting the extent of global climate change and, in turn, exposure of the poor to climate-related extreme events

KEY POINTS

SDG7 affects SDG1 through the dimension of energy poverty and the need to provide the world's poor with access to affordable, reliable and modern services

Decarbonising the global energy system by promoting renewables and boosting energy efficiency can lead to major reductions in greenhouse gas (GHG) emissions over the longer term, which may help reduce the exposure of the poor to climate-related extreme events and other environmental disasters

If policy interventions are not managed properly, the poor could experience economic shocks in the form of higher energy prices, thus increasing rather than reducing poverty and impairing the transition to universal energy access to modern fuels

The lack of modern energy services contributes to poverty, not only in absolute terms, but also in terms of GDP (because the energy, personnel and tools involved are often from the 'informal economy'). Thus, accessing modern energy services will improve economic exchanges locally and raise per-capita economic activity and productivity

KEY INTERACTIONS

The principal interactions between SDG7 and SDG1 concern targets **1.4** and **1.5**. Access to modern energy forms (electricity, clean cooking-stoves, high-quality lighting, and sustainable fuels) **(7.1)** is fundamental to human development since the energy services made possible by modern energy forms can provide a solid foundation for escaping the poverty trap, particularly in the poorest parts of developing countries: namely rural and urban communities in South Asia, Southeast Asia, and Sub-Saharan Africa (Pachauri et al., 2012) **(1.4, 1.5).** Too many people in these locations still rely on polluting and unhealthy fuels (charcoal, firewood, animal dung) for cooking, heating and lighting: roughly 3 billion people, or 40% of the world's population lack modern fuels for cooking while an estimated 1.1 billion people live without electricity (UN, 2016). Clear progress is being made to provide access to these individuals, but in the meantime their health continues to suffer (from the harmful effects of burning 'traditional' fuels indoors), and they are forced to spend too much time acquiring fuel, preparing meals, and/or keeping the lights on. Modern fuels and technologies (such as delivered gas powering a clean cooking-stove), whether made available in a centralised or distributed way, can alleviate these burdens, which often fall disproportionately to women and children. Impacts can be substantial: time is freed up, which may be used to pursue employment, educational, and leisure and wellness opportunities (Pachauri et al., 2012).

Decarbonisation of the global energy system through a major up-scaling of renewables **(7.2)** and energy efficiency **(7.3)** efforts is needed to dramatically cut GHG emissions (Clarke et al., 2014). Such actions are unavoidable if the exposure of the world's poor to increased climate-related extreme events and other environmental disasters is to be significantly reduced

(IPCC, 2014) **(1.5)**. An acknowledged risk of transitioning the energy system away from fossil fuels toward renewables is that energy services could become less affordable for those who need them most. In other words, higher energy prices could hinder the goal of universal energy access and slow down some structural and infrastructural changes among the lesser developed economies (Jakob and Steckel, 2014). Policies must be designed such that they take an integrated and holistic perspective of multiple policy objectives. For example, Cameron et al. (2016) found that poorer populations can be shielded from fuel price rises through access policies (e.g. subsidies) that support clean cooking-stove purchases and lower fuel bills. Funding support for these policies could be derived from carbon tax revenues or financial flows from carbon trading – leveraging the same carbon pricing mechanisms being simultaneously used to incentivise renewables deployment and energy efficiency efforts. In addition, the local production of renewable energy (biomass, solar, wind) could lead to new income streams, which could counterbalance any system-wide energy price rises.

KEY UNCERTAINTIES

(1) The level of local skills and knowledge (technological, business, or otherwise) that will exist within the individual communities in 10 to 15 years, especially concerning the capacity to ensure that energy access provision remains adequate, reliable and affordable. This depends strongly on educational attainment, which itself is affected by energy access in a continuous loop. (2) Exact quantifications for what a proper, decent level of energy access actually entails, in terms of the full range of services required to escape the poverty trap.

KEY DIMENSIONS

Time: Major structural and infrastructural changes will be needed to achieve energy access targets throughout the world, often in hard-to-reach rural areas. Achieving these goals may need a redefinition of strategies and policies in urban capitals, and this could take time given the lack of sufficient resources in many poor countries and the rigidity of the political systems in some nations.

Geography: (1) Lack of energy access is both a rural and an urban problem, and is most acute in the poorest parts of South Asia, Southeast Asia and Sub-Saharan Africa. Modernising the lives of these people, in terms of energy service provision, could have global economic consequences (due to newly created employment and educational opportunities). (2) Increasing energy efficiency and substituting fossil fuel energy by renewables in any country of the world, whether rich or poor, will benefit those in poverty by reducing their exposure to climate-related extreme events and other environmental disasters. However, reducing exposure to climate change-related extreme events is a complex issue where decarbonisation of the energy supply plays a minor role in the short term compared to other land use policies and local governance.

Governance: (1) The supposed trade-off between energy system decarbonisation (renewables / efficiency) and energy access is non-genuine. The trade-off is not intrinsic to the decarbonisation measures themselves, but to poorly designed policies. Compensation mechanisms can be designed to ensure that the poor are shielded from energy price shocks. However renewable energy prices are generally locally determined and tend to decline with technological advancement. This protects the poorest from the highly speculative prices associated with fossil fuel energy. (2) Enabling policies are key to mobilising transformational change in energy systems, with respect to technology investments and infrastructure changes.

Technology: (1) Continued improvements in the design, efficiency, and cost of efficient, portable cooking-stoves and lighting devices are needed, particularly because the up-front capital costs of these technologies can often account for weeks/months of income for the poorest households. If costs are too high, then this could prevent individuals from putting their limited funds toward other useful purposes (such as educational and business opportunities, healthcare, internet and communications tools). However, technical advancement in renewable energy technology (e.g. wind turbines, solar panels, heat exchange devices) drives lower prices for sustainable energy services. (2) Whether new energy systems for the poor are centralised (national grids) or decentralised (local level only) will depend on each country's geographical and governance context, as well as on the existing state of infrastructure in the region.

Directionality: Unidirectional. Energy access provision is necessary (but not sufficient) for delivering the types of service required for escaping the poverty trap (education, employment, healthcare). Yet, in the reverse direction, provision of those services by some other means (such as programmes to regularly transport disadvantaged individuals to more affluent communities for those services) does not guarantee that energy access will be achieved in those communities where it is most needed. Furthermore, demographic pressure is a key issue for energy supply in rural areas as well as urban communities. Without a clear indication of future demand, the supply may never be adequate.

SDG 7 + SDG 2

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.2 ⟶ 2.1	If not restricted to degraded lands, large-scale global production of purpose-grown energy crops could drive up food prices and so constrain the achievement of ending hunger for the poor	0/-1	Design legislation so that competition of bioenergy crops with land use for other purposes is avoided. This can be done by prioritising bioenergy production on degraded land; maximising energy production from agricultural wastes (from non-bioenergy crops), and investing in research and technologies that lead to higher crop yields
7.2 ⟶ 2.3	Bioenergy production could reinforce initiatives pursuing agricultural jobs creation and higher farm wages. Bioenergy from agricultural wastes also provides higher returns for job creation	+2	Structure policies should be designed so that they promote the creation of bioenergy-related jobs and diversified income streams for farmers, particularly for women, indigenous groups, family farmers and fishers. Policies should favour waste-to-energy projects for bioenergy
7.2, 7.3 ⟷ 2.3, 2.4	Greater agricultural productivities for all types of crops, particularly bioenergy, can aid the achievement of the renewable energy target by allowing as much bioenergy to be produced on as little land as possible, thereby minimising land use competition. Energy efficiency improvements can also reinforce agricultural productivity by reducing the energy inputs needed. Bioenergy production from agricultural and forest wastes could increase productivity and efficiency in rural areas	+2	Put in place mechanisms to manage the energy, land, fertiliser and water inputs to agriculture, thereby helping to mitigate any negative effects on the environment as well as on agricultural prices (and thus on food security)

KEY POINTS

Basic energy availability is a key component in food systems that have the potential to achieve the goal of zero hunger. Energy is also a prerequisite to reduce and recycle food waste, and to preserve the long-term value of edible items.

Interactions could become stronger if bioenergy (especially from agro-fuels) is deployed on a large scale in order to meet the renewable energy targets

If policy interventions are not managed properly, food production could decrease and food prices could increase, thereby reducing access to affordable food. Access to affordable food may also be jeopardised due to long-term soil depletion associated with monocropping of agrofuels, and to hydrological changes or topsoil loss associated with the cultivation of marginal or degraded croplands for agrofuels or to replace food production lost to agrofuel farming

While agricultural productivity can be increased by raising levels of energy inputs into agriculture (fertiliser, agrochemicals, pumped irrigation, machinery, fossil fuels for cultivation and transportation, post-harvest storage), the potential trade-off is higher energy requirements for the sector

Second- and third-generation waste-to-energy technologies are attractive because agricultural, forest and domestic wastes can be used as stockpiles for energy services. These do not require supplemental crop production or forest harvest and provide room for manoeuvring in existing productions. Moreover, fuels from domestic wastes do not depend on prevailing weather conditions and so are resilient to climate change

KEY INTERACTIONS

More mechanised, modern farm practices can have a strong impact on farm yields, and thus livelihoods (**2.3**). Large-scale bioenergy production could play an increasingly important role as renewable energy (**7.2**) is ramped up in scale toward 2030 and beyond. Because of open questions surrounding bioenergy, the following discussion focuses on its benefits and consequences. Most closely interacting with SDG7 are targets **2.1** and **2.3/2.4**, the latter supported by increasing the speed of energy efficiency improvements in the agriculture sector.

The impacts of increased bioenergy utilisation on food and agriculture systems are complex and context-dependent. The effects may be positive or negative, depending on the type of bioenergy supplied, its source, and the size of the operation (Smith et al., 2014). Creutzig et al. (2013) and others have shown that producing bioenergy crops can contribute positively to local economies, for example by creating jobs in rural areas. Higher wages, and more diversified income streams for farmers, are additional benefits (Gohin, 2008). This is true, for instance, of the Brazilian sugarcane ethanol industry, where average farm incomes are greater than in most other agricultural sectors in the country (de Moraes et al., 2010; Satolo and Bacchi, 2013). Good governance and careful planning are key to ensuring that the benefits go to those that deserve them. If poorly regulated, large-scale bioenergy deployment could end up harming the very farmers that SDG2 attempts to support, particularly if the revenues accruing from the sale of bioenergy go to company owners and investors rather than to small-scale, local landowners and tenants, or if the revenues are not shared equally between parties (van der Horst and Vermeylen, 2011). In the worst case, small-scale farmers could even be displaced, either from their lands or in local business networks, or both. In other words, the distributional impacts of bioenergy deployment – while still uncertain, given their situational dependencies – could be non-trivial (Davis et al., 2013; Muys et al., 2014). The topic requires future study, at the empirical/case-study level and by national- and global-scale integrated modelling frameworks.

A potential risk of large-scale bioenergy deployment is that crops grown for energy purposes could compete with existing crops grown for other purposes, such as food production (Smith et al., 2014). Such concerns are often captured in the 'food versus fuel' debate; more specifically, concerning food security (higher or more volatile food prices) and the displacement of communities and their agro-economic activities. While impacts are felt most acutely locally, global market dynamics may be the ultimate driver, with bioenergy deployment in one country creating ripple effects that propagate worldwide (so-called 'indirect land-use change'). In fact, bioenergy deployment could lead to co-benefits in one country, but adverse side-effects elsewhere. Good governance, in the form of well-designed policies, is key to avoiding adverse impacts, or at least minimising them to the extent possible. Certain types of crops, either for energy or food production, are more land-intensive than others. Hence, decreasing the area needed for growing crops also decreases the risk of land competition, and by extension the threat of food insecurity and community displacement, as well as deforestation. Policies, agricultural research, and extension programmes that incentivise and promote greater agricultural productivities (improved and sustainable crop yields, that do not sacrifice long-term productivity for short-term yields) can all help. They can also direct farmers toward producing bioenergy on degraded and marginal land. Another key approach is to maximise energetic valorisation of agricultural residues and organic wastes. Both strategies would largely avoid competition between bioenergy and other land-use purposes, although there are limits to how much bioenergy can be produced by these means. Food prices may still rise even if care is taken to avoid such an outcome; yet, according to several integrated models, the potential price effects induced by unconstrained levels of climate change and the resultant water and temperature impacts are far greater than the bioenergy-induced effects (Lotze-Campen et al., 2014). While bioenergy, strictly speaking, is not necessary to meet **target 7.2**, its availability could help in certain dimensions, such as for reducing the global aggregate costs of climate mitigation (Clarke et al., 2014).

KEY UNCERTAINTIES

(1) It is not yet clear how quickly traditional food systems can be modernised and mechanised, or what the energy use implications of this would be (such as for food conservation via different energy-related processes, drying facilities for harvests, establishing cold chains during transport and distribution, and refrigeration at the household level, among others). (2) There are large uncer-

tainties in terms of the type of indirect land-use change impacts that might arise through deployment of bioenergy in a given country context (that is, which types of agricultural lands throughout the world are converted to other purposes in response to changing food/crop prices).

KEY DIMENSIONS

Time: Some impacts may be short-term in nature (i.e., over a few years or crop cycles), with a sustainable equilibrium then again be reached. Other impacts may be longer term in nature, perhaps even irreversible over the course of a generation (such as if forests are cleared for crop production).

Geography: (1) Some areas could benefit while others are, simultaneously, negatively impacted. For example, in Scandinavia farmers and foresters have benefitted from bioenergy production through the diversification of markets. However, to the extent these producers have changed food export patterns, or do so in the future, then food security globally could be affected. (2) While the impacts of large-scale bioenergy production are felt most acutely locally, global market dynamics may be the ultimate driver, with bioenergy deployment in one country creating ripple effects that propagate worldwide. In such situations, it is likely that the most benefits will be obtained when bioenergy is obtained from waste, rather than primary agricultural production.

Governance: (1) Good governance and careful planning are key to ensuring the benefits of bioenergy production accrue to small-scale farmers and their local communities. Well-designed policies are also needed to ensure that adverse side-effects of large-scale bioenergy utilisation are minimised or avoided, including incentives and support mechanisms that (i) promote greater agricultural productivities (improved and sustainable crop yields) and (ii) direct farmers toward producing bioenergy on degraded lands and maximising energy production from agricultural wastes (from non-bioenergy crops). (2) Adverse effects of demand-side driven policies (such as a mandatory percentage of ethanol or biodiesel in fuels) may be more important than their energy security or climate change mitigation effects.

Technology: Greater agricultural productivities (improved and sustainable crop yields), both for bioenergy and food crops can help minimise or avoid direct competition of different crop types for land in different countries. Waste-to-energy technologies and biorefineries are also important options and would benefit from increased R&D effort.

Directionality: Bidirectional. Large-scale utilisation of agrofuels can affect food production, and thus the goal of ending hunger. In the reverse direction, ending hunger may impose limits as to how much cropland is available for bioenergy production; greater agricultural productivities for all types of crops can minimise or avoid land competition and degradation.

SDG 7 + SDG 3

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.1 ⟶ 3.8	Universal energy access enables the provision of food, medicines and vaccines because mechanised refrigeration is essential for effective storage	+1	Develop energy access policies to facilitate the spread of refrigeration in rural areas, which will be beneficial for food preservation (to reduce the amounts of food that normally go to waste) and the storage of life-saving medicines and vaccines
7.1, 7.2, 7.3 ⟶ 3.9	In most cases, efforts to provide energy access, expand renewables, and promote energy efficiency will lead to simultaneous reductions in air pollutant emissions; thus the targets are reinforcing	+2	Draw up legislation promoting renewable energy and energy efficiency across multiple sectors to reduce negative impacts on the health of rural and urban populations. Pay particular attention to those sectors that are currently the most energy-intensive and energy-polluting, such as buildings, industry and transport in densely populated urban areas, as well as those rural areas with a high use of chemicals for agricultural production Energy access policies that promote the use of cleaner energy and which are less-polluting can significantly reduce premature mortality. Policies targeting those sectors of the population with highest exposure to indoor and outdoor pollution will be most beneficial
7.3 ⟶ 3.4	Energy-saving measures related to ‘active travel’ (cycling and walking) can lead to improved health and well-being by lowering rates of diabetes, heart disease, dementia, and some cancers	+1	Where possible, ensure urban planning and land use management policies encourage energy-saving ‘active travel’ modes (cycling and walking). This will benefit community health, in terms of lower rates of diabetes, heart disease, dementia, and some cancers
7.3 ⟶ 3.6	Energy-saving measures related to ‘active travel’ (cycling and walking) can constrain efforts to reduce deaths and injuries from road traffic accidents, if the provided infrastructure is unsatisfactory and if higher air quality standards are not required	0/-1	Build cycling and walking infrastructure that is safe for all, to reduce deaths and injuries from road traffic accidents

KEY POINTS

Providing energy access, promoting renewables and boosting efficiency can lead to major reductions in air pollution, and by extension significant improvements in air quality and human health, particularly in the dense urban centres of the rapidly developing world

Elevating levels of walking and cycling ('active travel') in cities can also lead to better health and well-being among the local population

Energy is vital to providing thermal comfort in buildings. Energy access is also needed for refrigeration, which is essential for maintaining food quality along the supply chain for providing city markets with healthy products. Refrigeration is also critical for rural populations; for storing food, medicines and vaccines

KEY INTERACTIONS

The principal interactions between SDG7 and SDG3 concern target **3.9**. Present-day fossil energy extraction, conversion, and end-use activities emit a range of air pollutants, as do some traditional bio-fuels (dung, wood, waste, and peat or charcoal prepared and burned in traditional ways) many of which are harmful to humans, leading to respiratory and cardiovascular diseases and even cancer. Thus, increased efforts to move the world's poor towards clean renewables and to significantly increase energy efficiency (i.e. lower the requirements for energy of all types) would drive major reductions in emissions of sulphur dioxide (SO_2), nitrogen oxides (NO_X), black carbon (BC), fine particulate matter (PM2.5), and mercury, among others. Targets **7.2** and **7.3** primarily affect outdoor (ambient) air pollution, whereas target **7.1** would most affect indoor (household) pollution. The level of exposure of a given population to energy-consuming activities (power plants, factories, cars, kilns) significantly influences the human health effects of air pollution – and, by extension, the improvements that can be attained by meeting or exceeding the three energy targets. The dense cities of the rapidly developing world (Beijing, Delhi, and many others) have the most to gain; large metropolitan centres in the industrialised world (London, Los Angeles) could also benefit substantially.

Several forward-looking, integrated scenario studies have estimated the air quality co-benefits that could be achieved – in diverse contexts – by providing energy access, promoting renewables, and boosting efficiency. For example, Rose et al. (2014) found that in China strong efficiency and decarbonisation efforts could result in SO_2 emissions reductions of 15–75% below reference levels by 2030 and 40–80% by 2050. Chaturvedi and Shukla (2014) drew similar conclusions for India: reductions of 10–80% in the long term, depending on the scenario and pollutant under consideration. At the global level, Rafaj et al. (2013) found reductions of 40% (SO_2), 30% (NO_X), and 5% (PM2.5), relative to a baseline scenario, are possible by 2030. Meanwhile, Riahi et al. (2012) showed the importance of providing modern energy access (fuels, electricity, clean cooking-stoves) for improving indoor air quality in the developing world. They estimated global reductions of 50% (SO_2), 35% (NO_X) and 30% (PM2.5) by 2030 in scenarios that include a rapid up-scaling of renewables and energy efficiency measures. This could help reduce globally-aggregated disability-adjusted life years (DALYS) by more than 10 million over the next one and a half decades, mostly in developing countries. Similar conclusions were reached by the IEA (2016). It should be noted, however, that not all energy-saving measures are beneficial for air quality: such as when switching from gasoline to diesel vehicles. Similarly, although biofuels are a form of renewable energy, they are not necessarily low-polluting in their life cycle.

There has been some attempt to monetise the air quality co-benefits of energy efficiency and decarbonising the energy system (Nemet et al., 2010). West et al. (2013) estimated the co-benefits of avoided mortality to be USD 50–380 per tonne CO_2 globally (70–840 for China and 20–400 for India). Benefits of this magnitude are similar to the costs of ramping up renewables and energy efficiency over the coming decades (Clarke et al., 2014).

Energy-saving measures, such as integrated transport and urban planning strategies that promote 'active travel', can also lead to better health and well-being, including lower rates of diabetes, heart disease, dementia, and some cancers (Woodcock et al., 2009; Haines, 2012; Shaw et al., 2014) **(3.4)**. However, if the provided infrastructure is unsatisfactory, increased 'active travel' could increase risk of death and injuries from road traffic accidents **(3.6)**.

Moreover, though not well researched up to this point in time, a potential risk of certain forms of clean energy is that some pathways may create new health issues, either within the region of production or elsewhere (e.g. siloxane emissions from biogas plants, growing hazardous waste flow due to photovoltaics or battery production and disposal).

KEY UNCERTAINTIES

(1) The future climate impacts on local atmospheric conditions affects are a key uncertainty affecting ambient concentrations of harmful pollutants. (2) The long-term effects of current/recent investments in dirty fossil energy infrastructure and vehicles, and the possibilities for retrofitting those facilities to make them less polluting are also unknown. (3) How consumer behaviour and preferences might change over time is unclear, especially with respect to adopting more active lifestyles that are less dependent on motorised transport. (4) Some forms of clean energy production could potentially create new health issues.

KEY DIMENSIONS

Time: Transformational changes in energy systems take a considerable amount of time to effect, given the long-lived infrastructure. While vehicles and other consumer appliances may have lives of 5 to 15 years, power plants and factories can last for 50 years or more. This influences how quickly existing infrastructure can replaced and how quickly air quality levels can be improved.

Geography: (1) Dense urban areas in both developing and industrialised countries stand to gain the most from renewable energy and energy efficiency policies that improve outdoor air quality, while providing energy access (upgrading to modern fuels and clean cook-stoves) would most benefit the indoor air quality of rural households in the least-developed countries (LDCs). (2) Air quality is principally a local/regional problem, although air pollutant emissions can travel across city/state/country borders and affect other populations. (3) The potential for renewables differs widely, which means different renewable energy technologies will be the focus of air pollution mitigation strategy in different regions.

Governance: (1) Air quality is principally a local/regional problem, although national energy policies can help or hinder the situation. (2) Enabling policies are central to transformational change in energy systems, especially for changes in technology investment (efficiency and reduced emissions) and infrastructure.

Technology: (1) Technological change is a critical enabler for improved air quality via energy access provision, renewables deployment, and efficient devices. (2) Behavioural change is also important if societies are to adopt more active lifestyles that are less dependent on motorised transport and to embrace the latest technological advances in equipment and appliances.

Directionality: Bidirectional, but asymmetric. Energy use impacts health and well-being. And in the reverse, the collective health and well-being of a society could potentially influence what transformational changes in the energy system they have an appetite to pursue. The former causality is stronger than the latter and is therefore focused upon in this report.

ILLUSTRATIVE EXAMPLE
IMPROVING AIR QUALITY AND THE HEALTH OF THE RURAL POOR IN INDIA

India is the third largest economy in the world, with its 1.3 billion people making up nearly 20% of the global population. Yet, in terms of energy use, it consumes only 6% of the world's primary energy. Meanwhile, some 240 million Indians lack access to electricity (IEA, 2015). Recent commitments to address climate change and the prospects for rapidly increasing energy demand, which is expected to double in India within the next two decades, have triggered a wave of planned reforms of the energy system. These include boosting the share of renewables in the country's energy mix **(7.2)** and expanding efforts to provide universal access to modern energy forms **(7.1)**, particularly to those in rural areas relying on traditional and dirty fuels (firewood, charcoal, crop residues, and dung; Bonjour et al., 2013) for cooking and heating. The number of premature deaths in India due to indoor and near-household air pollution from the use of traditional solid fuels is around 1 million annually, the highest of any country in the world (IHME, 2015). Globally, the figure is around 3.9 million (Smith and Sagar, 2014). The main cause is exposure to poor combustion of solid fuels in inefficient cooking-stoves.

India has tried to address this issue by providing subsidised LPG (liquefied petroleum gas) as an interim cleaner substitute for traditional solid fuels. This programme has recently accelerated, making India one of the world leaders in a 'health-centred strategy for air pollution' (Sagar et al., 2016). Three national initiatives were launched in 2014 to provide LPG to 50 million more families by March 2019 (Smith, 2016). This major new campaign could ultimately contribute to India reaching its SDG goals for health and energy simultaneously. Elements include over US$ 1 billion committed directly by the national government, with much more provided to state governments from alternative sources, a large share of the middle class population voluntarily giving up subsidies to contribute to the programme, wide-scale use of information technology, use of social marketing and social media, and support for the programme at the highest levels of Indian decision-making, ranging from the Prime Minister to the private sector, community groups and major agencies.

SDG 7 + SDG 6

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.2 ← 6.1, 6.4	Increased utilisation of unconventional water supply options to satisfy growing demands for safe, affordable freshwater supplies could constrain renewable energy deployment if those options (e.g. desalination) are highly energy-intensive	-1	Ensure that unconventional water supply options (e.g. desalination, wastewater recycling and inter-basin water transfers) do not generate excessively high loads on regional power systems, particularly if the goal is to integrate high shares of renewables into those systems
7.2, 7.3 ← 6.1, 6.4	Increased electricity demands from the water sector could enable the integration of variable wind and solar resources, if developed in combination with real-time demand-side power management of water-related infrastructure and equipment	+1	Better integrate water and energy systems development planning in order to capture the benefits of real-time demand-side power management of water process equipment for the integration of intermittent solar and wind resources. Coupling water and energy markets, which have historically managed their operations separately, could also be potentially beneficial
7.2, 7.3 → 6.1, 6.4, 6.5	Renewables and energy efficiency will, in most instances, reinforce targets related to water access, scarcity and management by lowering water demands for energy production (compared to a less-efficient fossil energy supply system)	+2	Ensure that energy policies and water resource management plans for renewable energy options, such as bioenergy and hydropower, do not result in adverse side effects either nationally or beyond national borders, particularly in water-scarce regions Take care that policies promoting energy efficiency in the electricity generation, buildings, transport agriculture and industry sectors do not temper growth in water demand. Pay particular attention to energy-intensive operations with significant lighting, heating and cooling loads
7.2, 7.3 → 6.3, 6.6	Renewables and energy efficiency will, in most instances, reinforce targets related to water pollution and aquatic ecosystems by reducing levels of chemical and thermal pollution (compared to a less-efficient fossil energy supply system)	+2	Align energy and water-management policies so that negative effects on aquatic ecosystems are minimised (such as thermal and chemical pollution). Policies limiting once-through cooling offer an example

KEY POINTS

Ramping up renewables and boosting energy efficiency can help ensure water availability for all, reduce the number of people suffering from water scarcity, minimise water pollution, and protect water-related ecosystems. Exceptions could be the large-scale deployment of agrofuels and hydropower, if not managed properly, and the use of solar or wind pumps for groundwater irrigation, as these can accelerate groundwater depletion

Shifts toward unconventional water supply options in water-stressed regions will generally increase energy demand; this may be challenging to accommodate in low-carbon energy systems. On the other hand, increased electricity demands from the water sector may present opportunities for real-time demand-side power management, which would benefit the integration of variable wind and solar resources, as well as energy efficiency measures

KEY INTERACTIONS

Freshwater resources throughout the world are facing increased pressures, with four billion people living in regions of water scarcity (Mekonnen and Hoekstra, 2016). The global energy system currently requires a large amount of water ('water-for-energy'); it also releases a large amount of pollution (thermal and chemical) **(6.3)** back into freshwater and marine systems **(6.6)** (Chuang et al., 2009; Stewart et al., 2013). If these water demands and pollution impacts increase, then existing ecosystem problems could be exacerbated, particularly in areas that are already stressed and where demand growth is likely to be high, such as countries in the Middle East, South Asia, and Sub-Saharan Africa (Luo et al., 2015). Fossil energy extraction (e.g. hydraulic fracturing for oil and natural gas) often demands significant water inputs. So too do fossil (coal, gas, oil) and nuclear power plants, which use freshwater for thermal cooling. In fact, about half of all water withdrawals in the United States and Western Europe in 2009 were for power-plant cooling (EEA, 2009; Maupin et al., 2010). Coal-fired plants are of particular concern because their numbers have been increasing rapidly in developing countries, with consequent demands for water. Retrofitting thermal cooling technologies to be more water-efficient **(6.4)** can provide significant reductions in energy sector water use (Davies et al., 2013; Byers et al., 2014; Fricko et al., 2016) and vulnerability of the power sector to water scarcity and climate change (van Vliet et al., 2016). Potential measures include minimising on-site losses (such as from storage tanks and pipes), increasing the amount of water recycled internally, moving towards air-cooling technology, and improving the efficiency of the inherent energy conversion processes. However, there are trade-offs with alternative cooling technologies, including increased water consumption and investment costs, as well as reduced operating efficiency (Webster et al., 2013).

In general, renewable electricity generation, particularly solar photovoltaic and wind, impacts local/regional water supplies less than fossil and nuclear plants. Thus, ramping up these forms of renewable energy by 2030 **(7.2)** should ease pressures on local water availability **(6.1)** and contribute to improved water quality **(6.3)** (Davies et al., 2013; Fricko et al., 2016). The effects are less clear-cut for some other types of renewable energy, namely bioenergy and hydropower.

Depending on water management practices, freshwater withdrawal and consumption could be significantly higher, especially for the latter two options. For bioenergy from agrofuels, the effects depend on the type of crop being grown, how much water it requires for growth, and where that water comes from (rainwater vs. irrigated water from a river, lake or underground aquifer) (Gerbens-Leenes and Hoekstra, 2009; Smith et al., 2014; Hejazi et al., 2015). For hydropower, the main concern is evaporation from the surface of the contained reservoir, as any water lost to the atmosphere is no longer available for downstream use (whether for municipal, industrial, or agricultural use). Energy efficiency **(7.3)** at the end-use level can also have major implications for water demand: any unit of fossil energy, bioenergy, or electricity that does not need to be supplied means a certain quantity of water that can be saved **(6.4)** or a given amount of thermal/chemical pollution that can be avoided **(6.3)** (Vidic et al., 2013; Miara et al., 2014; Fricko et al., 2016).

In the reverse direction ('energy-for-water'), reliable access to energy **(7.1)** is essential for the supply and treatment of water. A future shift toward unconventional water supply options **(6.1, 6.4)** (e.g. desalination, wastewater recycling, interbasin water transfer) in water-stressed regions will generally increase energy demand, because the associated technologies are more energy-intensive than conventional supply options (i.e. pumping from local surface and groundwater resources). These increased demands could be additionally challenging to accommodate from the perspective of climate change and air pollution objectives. Greater energy demand will necessitate lower emissions per unit of energy supplied in order to achieve emission levels anticipated prior to water sector transformations. This means that different combinations of energy technologies are likely to be required to achieve climate and air pollution targets under concurrent water SDGs (Parkinson et al., 2016).

Nevertheless, increased energy demand from expansion of unconventional water supply options **(6.1, 6.4)** can potentially support the integration of intermittent wind and solar energy resources **(7.2)**. Operational schedules for water pumps and processes are relatively flexible, and these scheduling features could allow water sector demand to absorb wind and solar variability in real-time (Strbac, 2008). Providing this service in line with demand could displace the need to develop costly dedicated energy-storage technologies, such as batteries. Likewise, waste-heat from thermal power plants can be used in some desalination processes, thereby reducing water sector energy requirements and, by extension, power plant cooling loads. Critical to achieving these efficiency gains will be (i) the integration of water and energy systems development planning, and (ii) the coupling of water and energy markets, which have historically managed their operations separately. Whether tapping into these synergies can outweigh the trade-offs associated with increased water-related energy demand remains an open research question.

A few scenario studies utilising integrated modelling frameworks have recently studied the water-energy nexus, with an eye toward how a rapid up-scaling of renewables and energy efficiency could impact future water demands. The PBL Netherlands Environmental Assessment Agency (2012), for instance, showed that total global water demands **(6.4)** could be reduced by around 25% by 2050, relative to a baseline scenario, if renewable **(7.2)** and efficient technologies **(7.3)** were to be widely deployed. The number of people living in severely water-stressed regions worldwide was estimated to decline from 3.7 to 3.4 billion in this case. Hanasaki et al. (2013) and Hejazi et al. (2013) arrived at similar conclusions using other integrated models.

KEY UNCERTAINTIES

(1) The magnitude of future water demands for non-energy purposes (i.e. municipal, industrial, agricultural) can be difficult to predict. (2) Major uncertainties surround the impacts of the future climate on local hydrological conditions, and this affects water availability. (3) The quality of local governance on water management issues is uncertain, particularly in developing countries that may have a short history with these institutions. Good governance is itself dependent on local skills and capacities.

KEY DIMENSIONS

Time: Water and energy supply technologies have long lifetimes. Thus, the demands of these technologies, once built, can persist far into the future. Retrofits and adapted management practices are possible, but this becomes more difficult after the technologies have been installed.

Geography: (1) Water demands are mostly of local/regional concern (water basin level). Areas already under water-stress, and where demand growth is likely to be high, include countries in the Middle East, South Asia, and Sub-Saharan Africa. (2) Exporting freshwater from distant areas is energy intensive and will limit the potential of distant basin transfers. (3) Not coordinating management of transboundary flows can lead to conflict between countries.

Governance: (1) Strong local institutions are crucial for successful water resource policies and regulatory practices. In industrialised countries, such institutions largely exist, but this may not be the case in many developing countries. (2) Integrated planning of water and energy supply is needed to ensure that cross-sector impacts are not adverse.

Technology: (1) Water demands from renewable energy depend strongly on the type of technology employed. Solar and wind power can cut local water demands and drastically reduce thermal pollution in surrounding aquatic ecosystems. Bioenergy and hydropower, on the other hand, if not managed properly could drive up water demand. (2) Energy efficiency at all parts of the product chain, but especially at the end-use level, is a win-win strategy: if less energy needs to be supplied to consumers, then water demand can be reduced in upstream energy conversion processes. (3) Water supply technologies can be combined with emerging real-time energy demand management technologies to enable increased operational flexibility in the electricity system.

Directionality: Bidirectional. Energy conversion activities require freshwater for cooling (more or less depending on the technology) and can damage local aquatic ecosystems through thermal and/or chemical pollution ('water-for-energy'). In the reverse direction ('energy-for-water'), a future shift toward unconventional water supply options (e.g. desalination, wastewater recycling, interbasin water transfer) in water-stressed regions will generally increase energy demand, because the associated technologies are more energy-intensive than conventional supply options (i.e. pumping from local surface and groundwater resources).

ILLUSTRATIVE EXAMPLE
RENEWABLE ENERGY DEPLOYMENT AND GROUNDWATER DEPLETION IN SAUDI ARABIA

The Kingdom of Saudi Arabia (KSA) boasts some of the highest quality solar energy resources on the planet. As solar technology costs are anticipated to improve significantly in the coming decades, KSA is planning to exploit its abundant solar potential in a big way **(7.2)**: more than 40 GW of new installed solar energy capacity are planned for development by 2030 (KACARE, 2013). The aim is to supply increasing electricity demands for a rapidly expanding urban population and industrial sector while simultaneously displacing the current electricity generation fleet. This consists mainly of oil-burning power plants, which are extremely carbon-intensive and can require considerable amounts of water for cooling.

The abundance of renewable energy is contrasted, however, by extreme water scarcity **(6.1, 6.4)**. The region can be classified almost entirely as a desert environment and receives very little precipitation annually. Implications for water availability are substantial: on average there are less than 50 m³ of surface water available on a per capita basis each year (FAO, 2008). For perspective, the historical per capita demand for freshwater across all sectors is more than 900 m³ annually (FAO, 2008). To make up this massive shortfall, KSA relies heavily on alternative water resources, of which pumping water from underground aquifers is most prevalent (FAO, 2008). Extracted groundwater in KSA can be classified as 'fossil' groundwater, due to the very slow recharge rates that accompany negligible annual precipitation. The non-renewable nature of fossil groundwater means that current extraction rates are rapidly depleting the available groundwater resource. The estimated rate of groundwater depletion is alarming: more than 20 times the estimated recharge is currently extracted from the region's most important aquifers each year (Gleeson et al., 2012). Unless measures are taken to significantly reduce groundwater use in KSA, severe shortages are likely to develop over the coming decades.

Water conservation at end-use is acknowledged as the best way to avoid groundwater shortages **(6.4, 6.5)**; however, such measures can only go so far. Thus, expansion of unconventional water resources will probably be needed to support future growth in urban and industrial water demand, even if existing water-intensive agricultural practices are eventually outsourced to other counties. Desalination of water extracted from the adjacent Red Sea and Persian Gulf has already emerged as a key technology in KSA's water supply portfolio. The national fleet of desalination plants is the largest in the world, and includes an interprovincial water conveyance network that transfers treated water to major inland urban areas. Industrial and municipal wastewater recycling also plays an increasingly important role in managing increased water demand, especially where lower quality water can be used in place of water treated to potable standards.

Wastewater recycling, desalination, and long-distance water transport all require more energy than conventional surface and groundwater supply systems for providing the same amount of freshwater to end-users. Thus, widespread use of these technologies to mitigate groundwater depletion is likely to increase energy demand, which could in turn lead to higher levels of GHG emissions if the additional water supply requirements are met by the existing fossil fuel-intensive national energy mix. Recent analysis suggests that a transition away from non-renewable groundwater use by 2050 could increase electricity demands by more than 40% relative to 2010 conditions, and would require investment of a similar magnitude to a transition away from fossil fuel electricity generation in support of the country's renewable energy goals (Parkinson et al., 2016). Thus, a key challenge facing KSA over the coming decades will be identifying a healthy balance of trade-offs across its objectives for water supply and sustainable energy. Alternatively, KSA will need a suitable financing scheme for the massive infrastructure investment costs that accompany fulfilment of multiple sustainable development objectives concurrently.

Potential synergies between KSA's water and energy sustainability objectives can be expected in future scenarios that include a rapid up-scaling of solar photovoltaic (PV) and wind energy (7.2). Transitioning to a national power system based largely on these generation technologies will avoid thermal water pollution released from existing fossil-fuelled power plants, which typically use seawater for cooling. Moreover, increased energy demand from expansion of unconventional water supply technologies can potentially support KSA in the large-scale integration of intermittent wind- and solar-energy resources. Real-time demand-side power management technologies will provide electricity system operators with increased flexibility to accommodate variable generation sources, and many of the processes in KSA's existing and future water supply systems are ideal candidates for this type of technology application (Al-Nory and El-Beltagy, 2014).

SDG 7 + SDG 8

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.1 ⟶ 8.3, 8.5, 8.6	Having access to modern energy services allows individuals in poorer communities, particularly women and children, to spend more time at work and school, thus enabling employment and education opportunities	+1	[8.5/8.6] Undertake assessments to determine the areas where lack of energy access limits educational attainment, employment acquisition, and economic growth. Where this is the case, design policies to remove these obstacles, such as by providing the necessary energy access, promoting greater equality in per capita income, and supporting small businesses [8.5/8.6] Design energy access policies in such a way that they are equitable and inclusive, thereby increasing employment for all without regard to gender, age or ability
7.2, 7.3 ⟶ 8.1, 8.4	Decarbonising energy systems through an up-scaling of renewables and energy efficiency could constrain countries' economic growth, if only slightly. However, strong growth decoupled from environmental degradation is possible	0/-1	Changes in tax codes could help to ensure that household consumption and economic growth is minimally affected by policies attempting to decouple environmental degradation (e.g. GHG emissions production) from these growth metrics. For instance, income taxes could be reduced if the same revenue streams can be sourced from carbon taxation
7.2, 7.3 ⟷ 8.2, 8.3, 8.5, 8.6, 8.10	Design, manufacture, and installation of renewables and energy efficient technologies can create conditions for new and higher-paying jobs; although some businesses will need to re-tool, and some workers will need to re-train. Strengthened financial institutions in developing country communities are necessary for providing capital, credit, and insurance to local entrepreneurs attempting to enact change	+1	[8.2/8.3/8.10] Policies promoting the deployment of renewable energy and energy-efficient technologies can help spur innovation, economic diversification, and new and higher-paying jobs. Governments can assist businesses that need to re-tool and workers that need to re-train. Support of small- and medium-sized enterprises, particularly new business ventures, is critical [8.2/8.3/8.10] Stable legislation that fosters strengthened financial institutions at the community level, especially in developing countries, is also key, as these institutions provide the means for local entrepreneurs to access capital, credit, and insurance. Capacity-building would assist these local financial institutions in undertaking assessments of climate change impacts and high-impact actions in order not only to assess financial and other risks but also to mobilise funding for projects to address climate change
7.2, 7.3 ⟷ 8.5	Phase-out of fossil fuels especially coal and tar sands may represent a permanent loss of jobs in mining regions. What these jobs are replaced by will determine the net impact.	0/-1	

KEY POINTS

SDG7 and SDG8 are closely interlinked through employment and education (particularly among the poor), innovation and jobs, and environmentally sustainable economic growth

Achieving universal energy access will create opportunities for many employment and educational opportunities in the world's poorest communities

Deploying renewables and energy-efficient technologies/consumption patterns can spur innovation and have an impact on local, regional and national employment; indications are that the net impacts could be slightly positive

Carefully designed policies can help decouple economic growth from environmental degradation in the coming decades; reductions in annualised GDP/consumption growth rates are expected to be small

Energy-related curricula can improve science literacy in populations, especially for the poorest, giving access to better, more skilled jobs

KEY INTERACTIONS

The energy sector is a major contributor to the economy for many countries. Energy also accounts for a significant amount of consumer (household and business) expenditure: more in some countries than others and more in some parts of society than others (namely the urban and rural poor in developing countries). Hence, transformative change in the ways that societies produce and consume energy over the period to 2030 will touch upon every financial and monetary aspect of daily life. In this sense, SDG7 and SDG8 are closely interlinked, with the interactions falling into three main groups: full and productive employment, and number of youth in employment, education, and training **(8.5, 8.6)**; high levels of economic productivity, innovation, and job creation **(8.2, 8.3, 8.10)**; and sustained economic growth globally, but especially in LDCs, while at the same time decoupling growth from environmental degradation **(8.1, 8.4)**.

Provision of universal access to affordable, reliable, and modern energy services can enable the achievement of targets **8.5** and **8.6**. Some of the poorest individuals in society (primarily in parts of South Asia, Southeast Asia, and Sub-Saharan Africa) are forced to spend a significant amount of time acquiring fuel for cooking and keeping the lights on. Modern fuels and technologies (such as delivered gas powering a clean cooking-stove), whether made available in a centralised or distributed way, can alleviate these burdens, which often fall disproportionately to women and children. Impacts can be substantial as time is freed up, which may be used to pursue employment, educational, and leisure and wellness opportunities (Anenberg et al., 2012; Pachauri et al., 2012; Raji et al., 2015). Access to modern energy means children can attend school without having to make a sacrifice for the household (as their labour is often needed on the family farm, etc.), and electric lighting makes it easier to complete homework at home outside daylight hours. Information and communication technologies (e.g. computers and internet servers) can be used to enhance the learning process. Street lighting via electrification can enhance safety, allowing women to attend adult-education classes after dark where they might otherwise feel it is unsafe to do so. In all cases, local economies would benefit over the short and long term, as resident knowledge and capacity can be built up and institutionalised within communities.

Ramping up renewables and boosting energy efficiency efforts (with new technologies or via structural changes) can directly benefit certain segments of local, regional, and national economies. Solar and wind power, in particular, can be key to boosting economic growth in developing regions where the resource potentials are high (e.g. Northern Africa). At the same time, strengthened financial institutions in developing country communities are necessary for providing capital, credit, and insurance to local entrepreneurs attempting to enact change. Innovative technologies like solar and wind power, biofuels, and other renewable energy technologies have the potential to raise wages and create new jobs, either directly or indirectly, in the countries where they are installed and/or manufactured (Gohin, 2008; Creutzig et al., 2013; IRENA, 2016). Yet, if fossil fuel sectors contract as a result, then some businesses will need to re-tool and some workers will need re-training. Thus, it is important to consider the net employment impacts of an expansion in renewable energy and energy-efficient technologies/consumption patterns. Complicating factors include (i) the cost of the jobs created and how this may displace other jobs in capital-constrained environments (Frondel et al., 2010); (ii) the share of the technologies that are designed, engineered, or manufactured within a country versus imported from abroad, because this affects the trade balance; (iii) the existing skills in the local labour force and the capacity of individuals to be re-trained, as this has an impact on real wages (Babiker and Eckaus, 2007; Fankhauser et al., 2008; Guivarch et al., 2011); and (iv) the influence of subsidies and tax revenue re-distribution (such as from carbon pricing in an effort to reduce labour taxes) on the fuel and technology choices of businesses and individuals, especially for labour- vs. energy-intensive goods and services (Clarke et al., 2014). In today's solar power industry, for instance, solar panels are largely produced in developing countries (e.g. China) but are widely purchased and installed by households and businesses in wealthier nations (e.g. Japan, North America, Western Europe, Australia/New Zealand). It still takes local expertise to install such devices, however; and that can provide much local benefit. The same may be the case for energy-efficiency measures, such as building retrofits or operating public transit, even if the materials and vehicles are manufactured elsewhere (Aether, 2016). With these context dependencies in mind, an analysis and review of the literature by Blyth et al. (2014) showed a small increase in net employment as renewable energy and energy efficiency are ramped up over time, primarily because these are generally more labour-intensive (in terms of electricity produced) than the fossil electricity systems they replace. However, any stranding of fossil assets during the transition process could hamper the competitiveness of energy providers, at least for a time (Bertram et al., 2015; Johnson et al., 2015). At the macro-level, global context, it is not clear whether scaling up renewables and energy efficiency (or more generally, strengthening environmental regulations) will adversely affect a given country's international competitiveness: although empirical evidence of past and existing regulations suggests competitiveness impacts may be fairly small, at least compared to other factors such as prevailing market conditions or the quality of the local workforce (Dechezleprêtre and Sato, 2014).

Long-term scenario studies using forward-looking energy-economic modelling tools indicate that economies can continue to grow while simultaneously decarbonising their energy systems through an up-scaling of renewables and energy efficiency (Clarke et al., 2014). Essentially all of these analyses have focused their attention either at the global level or on individual countries that are either already industrialised or are rapidly developing; none have done the same for LDCs, for which **target 8.1** aims to achieve an annual growth of at least 7% of GDP. The global studies are nevertheless useful for providing context, as they take into account all countries simultaneously, and consider trade and spill-over effects between them. As stated in its Fifth Assessment Report, the Intergovernmental Panel on Climate Change concluded (Clarke et al., 2014) that in the most stringent climate change mitigation pathways, where the expansion of renewables and efficiency measures is largely consistent with the SDG7 targets, global consumption losses amount to 1–4% in 2030 (median: 1.7%) and 2–6% in 2050 (median: 3.4%), relative to scenarios without substantial action to decarbonise the economy. Such losses correspond to an annual average reduction in household consumption growth of 0.06–0.20%-points between now and 2030 (median: 0.09) and 0.06–0.17%-points through 2050 (median: 0.09). In other words, annual reductions in growth are miniscule compared to the 7% per year growth target for LDCs, or the lower growth rates characteristic of more developed economies (e.g. 1–5% per year).

KEY UNCERTAINTIES

The distributional effects of the energy system transformation, both within and across countries are unknown. These are important for understanding which populations benefit more or less, in terms of employment opportunities and income.

KEY DIMENSIONS

Time: (1) In LDCs, well-targeted policies and measures may take time to implement, but once established the effects are long-lasting. (2) For employment, the impacts of an energy system transformation may be more pronounced in the short term, before macro-economic adjustments (geographical and sectoral reallocations) have time to once again reach a stable equilibrium.

Geography: (1) Individuals in poor urban and rural areas of LDCs will derive the most benefit from energy access provision, in terms of increased educational and employment opportunities. (2) The employment impacts from deploying renewables and energy-efficiency measures are most likely to be felt in those countries that have the capacity to design, engineer, and manufacture them (i.e. more advanced economies). (3) Potentials of renewables vary throughout the regions of the world, and these differences will affect employment options.

Governance: (1) Governments (at local, regional, and national levels) can create incentives for innovative businesses to establish operations in their respective jurisdictions. (2) Governments may need to support businesses and workers during the energy transition. Policies that facilitate labour mobility (e.g. flexible labour markets, reasonably priced housing, and targeted re-training) can help minimise negative effects for those workers who are displaced. The removal of fossil fuel subsidies can allow renewables to compete in the market more fairly.

Technology: Different renewable and energy-efficient technologies/consumption patterns will have different local impacts on jobs and the economy. An important consideration is what shares of a given technology are designed, engineered, or manufactured within a country/region versus imported from abroad. This depends entirely on the decisions of countless business leaders and is effectively impossible to predict from the outset.

Directionality: Bidirectional. The up-scaling of renewables and energy-efficient technologies/consumption patterns can spur innovation and influence local, regional, and national employment. At the same time, the countries and cities likely to attract these industries will need to have strong economies and pre-existing skills and capacity within the labour force; a strengthening of financial institutions in lesser developed countries can aid such efforts.

ILLUSTRATIVE EXAMPLE **RENEWABLE ENERGY DEPLOYMENT AND JOB CREATION IN GERMANY**

Germany is one of the most advanced countries in the world in terms of renewable energy. Over the past few decades, it has seen some of the greatest deployment of wind, solar, bioenergy, and other forms of renewables of any major economy **(7.2)**, and is a major producer of renewable energy technologies **(8.2, 8.3)**. The so-called 'Energiewende', has also had a marked impact on employment within Germany – in most ways positive.

Germany was the first country to enact a green electricity feed-in tariff (FIT) scheme when it did so in 1991 with the Electricity Feed-in Act. This was later followed by the Renewable Energy Sources Act in 2000; several incarnations of this Act ('Erneuerbare-Energien-Gesetz' in German) have since followed, each preserving the aim of promoting renewable electricity generation, even if the FIT approach is currently being phased out.

These key pieces of energy legislation have led to considerable job creation in Germany **(8.2, 8.3, 8.5, 8.6)**. The gross employment effects within the renewable energy sector have been estimated at 160,500 new jobs (2004), 277,300 (2007), 399,800 (2012), and 371,400 (2013) (Lehr et al., 2015) – for reference, Germany's total workforce over this period was around 40 million. Wind power and bioenergy have been the biggest contributors to job growth, with hydropower and geothermal energy playing relatively small roles. In all cases, the number of jobs has grown fairly consistently over time. Solar power is a notable exception: employment in this sector rose quickly until 2011/2012 but has since declined.

The rise and fall of Germany's solar power industry is well known, often held up as an example of how an industry can fail before reaching self-sufficiency. However, this telling of the story masks important details underlying the macro-level dynamics (Pahle et al., 2016). The explanations typically given are that solar companies were too optimistic about future demand, leading to an overcapacity in production, and that strong competition from low-cost producers in other parts of the world, notably China, made it difficult for German firms to compete (BMWi, 2012; Lehr et al., 2015). Yet, what is often forgotten is that other sub-sectors of Germany's solar industry have performed well over the past decade. German PV equipment producers, for instance, achieved a 50% share of the world market as recently as 2015 (VDMA, 2015).

The German wind energy industry, which has had sustained success in recent years, provides a counterexample to the broader solar industry dynamics. Why is this sector different? As Claudy et al. (2010) noted, German companies responsible for manufacturing wind turbines and related equipment (e.g. Siemens and ENERCON) have long been established worldwide; they also have strong comparative advantages vis-à-vis their global rivals. This was generally not the case for Germany's solar industry as a whole. The critical question is whether Germany's comparative advantages can be sustained over the long term and this depends on the skills of the work force and the ability of domestic firms to innovate technologically. Estimates of the net employment effects of renewable energy deployment in Germany provide a less clear-cut picture than for gross employment. Different assessments yield different answers: overall job creation (net of jobs lost in other sectors outside of renewable energy) may have been either positive or negative over the past decade (Blazejczak et al., 2013; Lutz et al., 2014). Job creation has been described as a 'welcome side effect' of Germany's major policies to support renewable energy deployment (Pahle et al., 2016). Employment was never the express intent of those policies; the main objective has always been environmental concerns (such as reducing emissions causing climate change) and this continues to be the case. Nevertheless, employment aspects are thought to have played a role in creating political support for the 'Energiewende', especially with organised labour (e.g. trade groups) (Joas et al., 2016). Federal and state policies that attempt to nurture domestic job growth and industrial development are now emerging, either explicitly or implicitly, including financial tax incentives, favourable customs duties, export credit assistance, quality certification, and special loan structures (Lewis and Wiser, 2007; Kuntze and Moerenhout, 2012; Pahle et al., 2016).

SDG 7 + SDG 13

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
7.1 ⟶ SDG13*	The universal energy access target is fully consistent with the goal of combatting climate change, as it is likely to have only a minor effect on global carbon emissions	0	
7.2, 7.3 ⟶ SDG13*	Decarbonising energy systems through an up-scaling of renewables and energy efficiency is a necessary but not sufficient condition for combatting climate change, since less fossil energy means lower GHG emissions	+2	To achieve the temperature targets outlined in the Paris Agreement, all countries will need to decarbonise their energy systems through an up-scaling of renewables and energy efficiency. The pledged Nationally Determined Contributions (NDCs) provide a good start, but these will need to be strengthened considerably over time
7.2, 7.3 ⟵ 13.2, 13.3, 13.a	To aid the rapid deployment of renewables and energy-efficiency measures, countries will benefit from integrating climate change measures such as carbon pricing into national planning, improving relevant education and awareness, and mobilising funds for mitigation	+2	[13.2] Sponsor careful assessments of high-impact areas for climate action and identify where the use of renewable energy and energy efficiency can make the most cost-effective interventions. Policies should then be designed to promote the incorporation of this knowledge into national and regional strategies and planning. Energy and climate policies must be interlinked and must consider the entire lifecycle of energy services in order to avoid policy inconsistencies between reaching NDCs [13.3] Provide funding for education, training and public-awareness programmes to help in informing local communities, in both industrialised and developing countries, about the importance of climate change mitigation and the positive contributions that renewable energy and energy efficiency efforts can make. This should be done within the broader context of national development strategies, considering all other SDGs [13.a] Developing countries should design their climate action programmes such that they attract and use available international funding sources (e.g. from the Green Climate Funds). By strengthening their institutions and capacities to ensure their domestic programmes are financially viable and transparent, these countries should be able to increase the likelihood of obtaining funding support

**The 2030 Agenda text on SDG13 does not specifically mention a long-term temperature goal, but it does refer to the United Nations Framework Convention on Climate Change (UNFCCC) process, and the stated objective of the 2015 Paris Agreement is "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C".*

KEY POINTS

Replacing a fossil-dominated energy system by a cleaner, more efficient system would contribute to major reductions in GHG emissions globally

A dramatic, essentially immediate up-scaling of renewables and energy efficiency is necessary to limit global climate change to 2°C, or well below, over the long term, the stated goal of the Paris Agreement. If achieved by all countries, the SDG7 targets could put the world on track to meeting this challenge

Pursuing the SDG13 targets for better integrating climate change measures into national planning, improving education, awareness, and capacity on climate issues, and mobilising funds for mitigation will help ensure that the SDG7 targets for renewables and energy efficiency are achieved

Achieving universal access to modern energy services by 2030 will not exacerbate climate change

KEY INTERACTIONS

SDG7 has a direct interaction with SDG13, since today's fossil-dominated energy system is the main contributor to global GHG emissions. While the SDG13 targets do not mention specific goals for stabilising global climate, they do acknowledge that the United Nations Framework Convention on Climate Change (UNFCCC) is the primary international, intergovernmental forum for negotiating the global response to climate change. That forum has of course already taken action, with the result being the Paris Agreement of December 2015 (UNFCCC, 2015), which endeavours to hold "the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change" (Art. 2). Informing that debate were many scientific studies considered by the Intergovernmental Panel on Climate Change in its latest assessment (Clarke et al., 2014). The IPCC concluded that a dramatic, essentially immediate up-scaling of renewables and energy efficiency is necessary to limit global climate change to below 2°C over the long term. To achieve this, the vast majority of the world's countries have pledged Nationally Determined Contributions (NDCs) – individualised plans for how each nation intends to reduce its emissions over the next few years. Renewables (7.2) and energy efficiency (7.3) are essential elements in nearly all cases. Hence, from this standpoint target 13.2 is already on its way to being achieved; and this will help underpin the SDG7 targets. Similarly, targets 13.3 and 13.a are also critical for enabling the successful, rapid deployment of renewable and energy-efficient technologies and consumption patterns, especially in developing countries where financial capital may be in short supply, institutions weaker, and information about climate solutions scarcer.

Of particular importance to the poor in developing countries (in South Asia, Southeast Asia, and Sub-Saharan Africa), the scientific literature indicates that ensuring universal access to modern energy services by 2030 **(7.1)** is fully consistent with the SDG13 and Paris Agreement climate goals. In other words, energy access provision will not exacerbate climate change, as it is likely to have only a minor effect on global carbon emissions, even if the modern fuels being supplied are still fossil fuels (e.g. natural gas, kerosene, LPG) (PBL Netherlands Environmental Assessment Agency, 2012; Riahi et al., 2012; Rogelj et al, 2013). Although this may seem counter-intuitive, it should be remembered that, for instance, advanced (fossil) cooking-stoves are many times more efficient than the outdated (renewable) biomass cooking-stoves they replace. Decentralised renewable systems (e.g. solar panels, small-scale wind, micro-hydro) offer additional low-carbon possibilities (Kaundinya et al., 2009; Reddy et al., 2009). In discussing energy access for the world's poorest **(7.1)**, it is important to distinguish this target from the broader goal of sustained economic growth (SDG8). Unless economic growth is decoupled from carbon emissions, which the scientific literature shows is feasible, then emissions are likely to rise considerably as the wealth and livelihoods of developing country households improve. The concern is that the world's rural and urban poor – those living on less than US$ 1.25 per day – could fail to join this wave of welfare improvement. And for this reason, dedicated energy access policies are critical for ensuring that, at the very least, their basic needs for energy services are met.

KEY UNCERTAINTIES

(1) The speed with which countries are willing to decarbonise their energy systems through a rapid up-scaling of renewables and energy-efficient technologies/ consumption patterns is unknown, as is the ambition of such actions post-2030. It is the latter that will ensure that long-term climate goals are met. (2) Also unknown are the exact quantifications for what a proper, decent level of energy access actually entails, in terms of the full range of services required to escape the poverty trap. These threshold levels, in combination with fuel and technology choices, will determine the carbon emissions of the world's poorest.

KEY DIMENSIONS

Time: While transforming the global energy system will be a decades-long process, near-term and immediate actions promoting renewables and boosting energy efficiency are critical, given tight cumulative budgets for GHG emissions for staying well below the 2°C threshold. A unit of carbon released into the atmosphere by the energy system between now and 2030 will still be there next century and beyond.

Geography: Actions to promote renewables and boost energy efficiency in one part of the world are just as important as in any other, since climate change is a global problem. But some countries have bigger energy systems than others, some have more carbon-intensive energy systems, and some rely more on transportation of goods for their GDP; while some counties have two or all three of these conditions. Such countries can have a larger impact on mitigating climate change through their national actions (e.g. China, India, USA, Europe, Brazil, Russia, Australia, Canada).

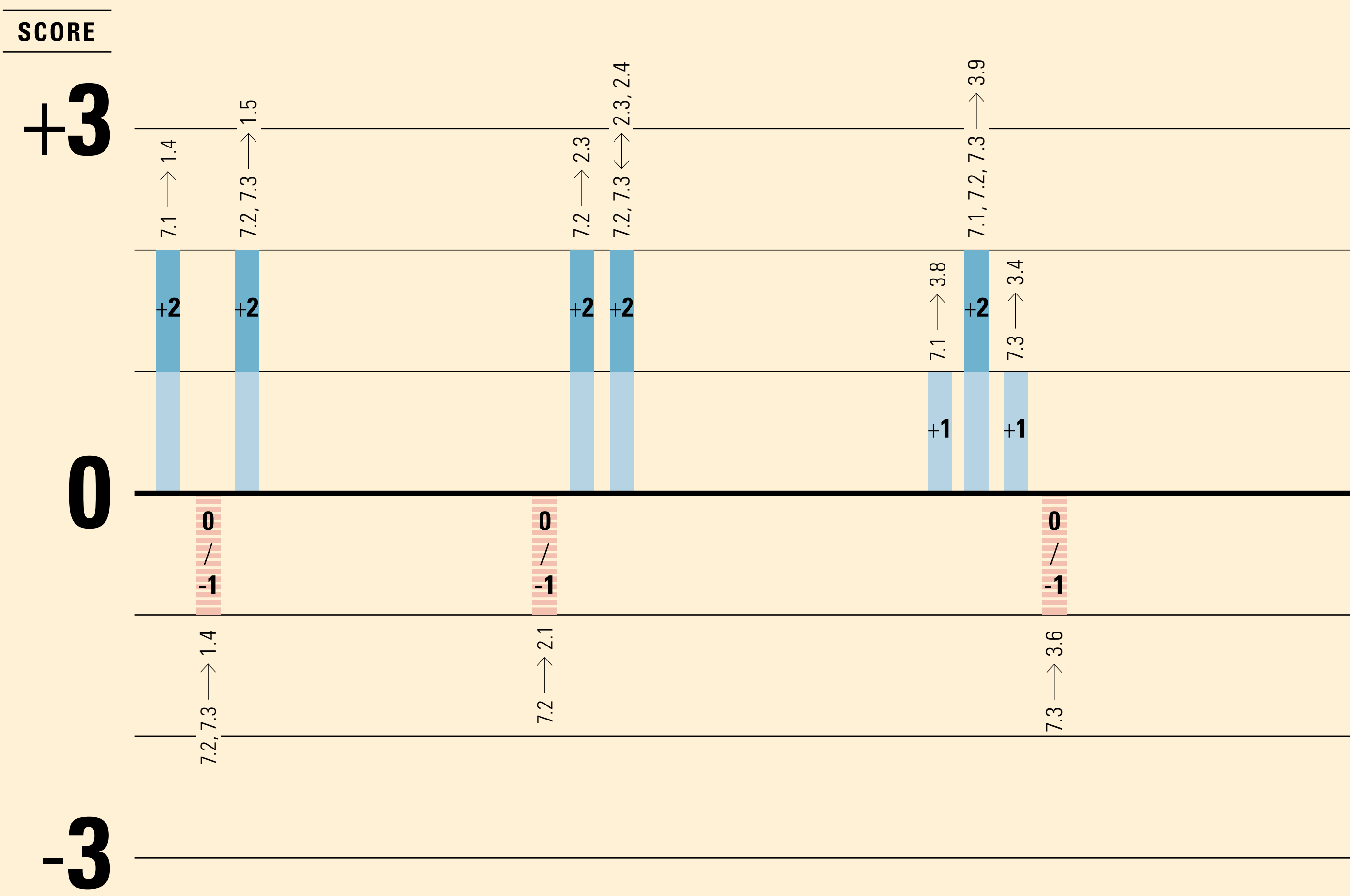
Governance: (1) Renewables and energy efficiency can be fostered and incentivised by a range of policy approaches, including market- and policy-based measures. Many measures have already been tested at local, regional, and national level. Experience gained in one jurisdiction can help to inform policy in another. Moreover, energy and climate policy must be accorded to phase out fossil fuels. Fossil fuel producing states must acknowledge their climate responsibility over the full lifecycle of their resources and act accordingly. (2) With regard to energy access provision, well-designed policies are needed to influence consumer preferences and ensure that households make fuel- and technology-purchasing decisions that are optimal both for them and for society as a whole.

Technology: (1) Advancements in technology are critical for decarbonising the global energy system, namely in the adoption of renewables on the supply side (solar, wind, hydro, geothermal electricity generation; biofuels). Carbon capture and storage technologies must be deployed on fossil fuel plants as well as on biomass-to-energy plants in order to provide opportunity for negative emissions capacity worldwide. The demand side is more complex: designing more energy-efficient devices is necessary, but just as importantly technology adoption depends heavily on human behaviour and consumer preferences. However, it is the sector where some of the most important abatement on emissions can be achieved. (2) Similarly, for the provision of energy access, poverty largely determines the willingness and likelihood of low-income households to adopt modern fuels, cooking-stoves, and lighting technologies.

Directionality: Bidirectional. A dramatic, essentially immediate up-scaling of renewables and energy efficiency is necessary to limit global climate change to well below 2°C over the long term, the stated goal of the Paris Agreement. The SDG7 targets, if achieved by all countries, could put the world on track to meeting this challenge. In the reverse direction, pursuing the SDG13 targets for better integrating climate change measures into national planning; improving education, awareness, and capacity on climate issues; and mobilising funds for mitigation will go a long way in ensuring that the SDG7 targets for renewables and energy efficiency are achieved.

KEY INTERACTIONS
SDG 7 WITH OTHER GOALS

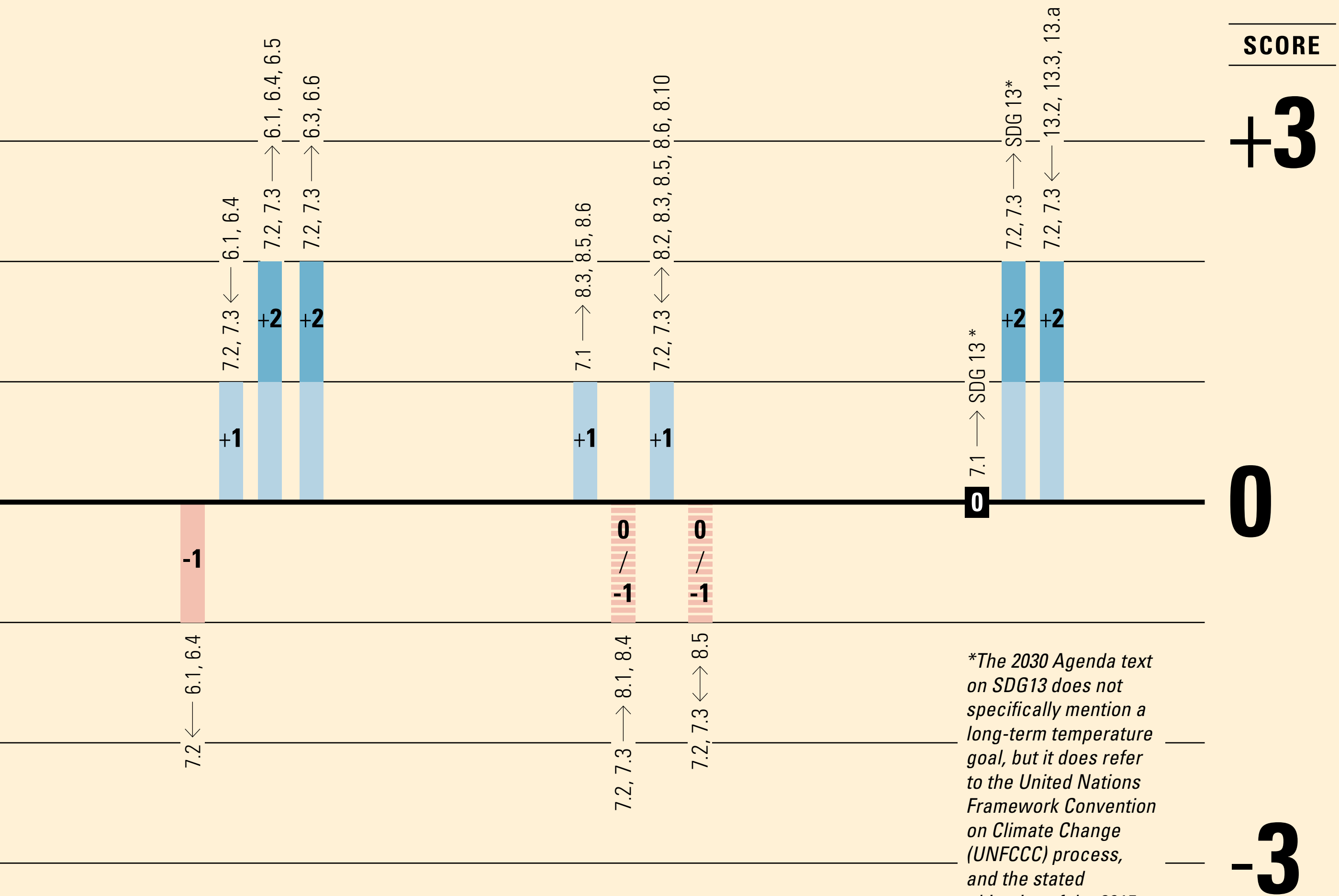
+ SDG 1 + SDG 2 + SDG 3



+ SDG 6

+ SDG 8

+ SDG 13



The 2030 Agenda text on SDG13 does not specifically mention a long-term temperature goal, but it does refer to the United Nations Framework Convention on Climate Change (UNFCCC) process, and the stated objective of the 2015 Paris Agreement is "well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C".

KNOWLEDGE GAPS

The state of science is not yet robust enough to score some target-level interactions or identify their particular dependencies (i.e. with respect to time, geography, governance, technology, and direction). As the science advances and the evidence base grows, a more comprehensive assessment should be possible. This also implies, by extension, that the target-level interaction scores reported here could change in the future as the evidence base advances.

To provide decision-makers with a more holistic view of the complex web of interactions affected by SDG7, this section identifies a number of knowledge gaps where scientists should focus their analytical attention in the coming years. This list is not intended to be exhaustive as it draws only from the target-level interactions considered in the previous section. Moreover, transcending these SDG-specific knowledge gaps are the more general uncertainties related to a number of transformational driving forces that are already shaping the future, such as 'big data', the Internet of Things, and 3D printing, among others. Real questions remain regarding the knowledge gaps that will arise from such innovations.

Filling the gaps in knowledge summarised here will require collaborative work between scientists across multiple disciplines, especially in the social sciences (sociology, anthropology, demography, human geography, education, political science, law, communication studies, economics), natural sciences (climate sciences, agricultural sciences, hydrology, atmospheric chemistry, health sciences), engineering, and integrated systems modelling.

7 + 1

Researchers and analysts still have some work to do in determining what a proper, decent level of energy access actually entails, in terms of the full range of services required to escape the poverty trap.

7 + 2

The indirect land-use change impacts of large-scale bioenergy utilisation, and the resultant impacts on food prices, access to food, and farm incomes. Research should include empirical studies (for past and existing policy) and national- and global-scale integrated modelling frameworks (for future policy).

7 + 3

The distributional impacts of air quality co-benefits of renewables and energy efficiency (for different socio-economic groups in different parts of cities/regions).

The impacts of 'active travel' (walking and cycling) on health and well-being. Research should focus on observational/empirical studies.

7 + 6

The magnitude of future water demands for non-energy purposes: municipal, industrial, agricultural. It is especially difficult to predict the future water consumption 'needs' of developing country households.

The impacts of the future climate on local hydrological conditions, as this affects water availability.

The potential benefits of real-time demand-side power management of water process equipment for integrating intermittent solar and wind resources into the energy grid.

7 + 8

The net employment and competitiveness impacts of the energy system transformation on local, regional and national economies, particularly over the near term. The distributional effects of the energy system transformation, within and across countries. This is important for understanding who benefits more and who benefits less, for instance in terms of employment opportunities and incomes. What empirical case studies of past and existing energy policy interventions show about the net impacts on local, regional and national employment and competitiveness

The lack a welfare metric that goes beyond the strictly economic formulation of GDP.

How energy related curricula can help science literacy and promote better employment and competitiveness?

How to minimise adverse side-effects on those that may lose from the energy system transformation (principally businesses and workers in fossil energy extraction and conversion).

The role of social innovation in decoupling of energy consumption from economic growth.

7 + 13

The role of human behaviour in the adoption of energy-efficient, low-carbon technologies/consumption patterns and how policies can influence consumer preferences toward choices that are beneficial for both individuals and wider society.

How best to increase awareness and capacity about solutions to climate change. The potential for the democratisation of the low-carbon energy system, including greater decentralisation, such as energy cooperatives and other community-based energy initiatives, bioenergy villages and renewable energy municipalities.

CONCLUDING COMMENTS

With so many interactions between the various SDG targets, it is clear that government-led actions and policies will be important for ensuring that the positive outcomes are achieved as frequently as possible and negative outcomes are minimised or avoided. More than ever, this requires policy frameworks that take an integrated, holistic perspective. Pro-active engagement and enhanced coordination across government departments and ministries, as well as across different levels of government (from international to national to local) will be required for this to happen effectively. Otherwise, the 'silo approach' to policymaking could persist indefinitely. This would not serve the achievement of the SDGs well.

The six summary tables in the target-level interactions section provide options for how policy could address the specific target interactions in practice, in such a way that the targets of the various SDGs are pursued in concert, with potential conflicts avoided or minimised as far as possible. Although addressed to specific target interactions, many of these policy options are also relevant for other interactions.

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SDG14 CONSERVE AND SUSTAINABLY USE THE OCEANS, SEAS AND MARINE RESOURCES FOR SUSTAINABLE DEVELOPMENT

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INTRODUCTION

SDG14 focuses on human interactions with the ocean, seas and marine resources. It is underpinned by targets addressing conservation and sustainable use of the ocean, seas and marine resources including coastal zones, and targets referring to capacity building and ocean governance. Oceans cover more than 70% of the planet's surface and play a crucial role in planetary resilience and the provision of vital ecosystem services. The status of the ocean and several of its resources and functions have been deteriorating over the past century. Oceans, seas and coastal zones are subject to pollution, overexploitation and climate change impacts such as warming, coastal erosion, sea-level rise, ocean acidification and deoxygenation. Several coastal regimes are under noticeable stress, compromising the services they provide. SDG14 and its seven targets and three means of implementation are aimed at an urgent need to transform human behaviour toward sustainable practices when exploiting marine resources, and to taking action to preserve productive and resilient oceans and seas. The seven targets largely reflect commitments under other international frameworks such as the commitment to maintain or restore fish stocks to levels that can produce maximum sustainable yields (made in 2002 under the Johannesburg Plan) or the commitment to conserve at least 10% of marine and coastal areas (provided under the CBD Aichi Target 11). However, the 2030 Agenda for Sustainable Development puts use and conservation of the ocean and its resources, including coastal areas, into the wider sustainable development context for the first time. The ocean space in general and SDG14 in particular have a cross-cutting role in the 2030 Agenda, and SDG14 interacts with all 16 other SDGS. The nature and intensity of these interactions is highly context-specific and differs across the SDGS and their associated targets.

The text that follows provides an overview of interactions at the goal level between SDG14 – the 'entry level goal' for this assessment – and the other 16 SDGS. Taking into account all the underlying targets of this entry goal, a set of key interactions is identified between the SDG14 targets and those of other SDGS, principally interactions within the range of the highest magnitude or strongest impacts based on available scientific literature and expert knowledge. The typology and seven-point scale for characterising the range of positive and negative interactions described in the opening chapter to this report is used to assess the selected target-level interactions and the context in which they *typically* occur. Illustrative examples from different world regions show how these linkages manifest themselves in practice. Policy options are identified for how to maximise positive interactions and minimise negative interactions between now and 2030, and beyond. The chapter concludes with a list of key knowledge gaps related to the interactions studied.

KEY INTERACTIONS AT **GOAL LEVEL**

14 + 1
SDG14 is a critical enabler of poverty alleviation, and environmentally sustainable economic growth and social well-being ('blue growth'), particularly in Small Island Developing States (SIDS) and Least Developed Countries (LDCs). Sustained incomes and economic benefits from fisheries, aquaculture and tourism sectors depend heavily on the health of oceans and coasts. Strengthening the resilience of oceans and coasts, for example through conservation and protection of coastal wetlands, will help reduce shock exposure and enhance the resilience of poor coastal populations to extreme climate-related events. However, blue growth policy interventions aimed at achieving rapid economic growth to lift people out of poverty might impair ocean health and promote overexploitation of marine resources. Also, creating marine protected areas (MPAS) can constrain access to resources and ecosystem services necessary for poverty alleviation. Similarly, prohibiting certain subsidies could limit options for developing fisheries sectors.

14 + 2
Seafood, whether farmed or caught in the wild, is globally important as a source of protein, omega-3 fatty acids, vitamins, calcium, zinc, and iron for one billion people. Sustainable fisheries and aquaculture backed by healthy oceans and coasts are a necessary prerequisite to achieve food security and improved nutrition, and to establish sustainable food production systems in islands and coastal regions, particularly in SIDS and LDCs. However, most stocks are already fished at or beyond sustainable limits and are often subject to wasteful fishing practices. Reducing fishing effort on wild stocks to sustainable levels will improve fish stocks and provide a reliable food source in the long-term. Technology transfer and research capacity building in aquaculture and selective fishing can help enhance productive capacity and income generation for small-scale food producers. Creating MPAS can provide fishery benefits and remove pressure from key fishing areas such as spawning grounds and nurseries, and can enable fish stocks in adjacent areas to rebound. A potential negative side-effect of MPAS however could be that access to fishery resources and areas for aquaculture is limited. Increasing agriculture productivity and production for enhanced food security might also impair ocean health through increased pollution and nutrient run-off.

14 + 3
Many people live in coastal areas and depend on the food resources that the oceans and seas provide. Contamination of coastal zones or seafood with pollutants can cause health problems. Reducing and preventing marine pollution will thus help reduce pollution related deaths and illnesses. In addition, healthy seas and coasts can contribute to the overall health and well-being of coastal communities and tourists. The ocean is a biodiversity hotspot, home to a wide range of animals, plants (algae) and bacteria that are potentially relevant for the research and development of vaccines and medicines. However, exploring marine biodiversity for genetic and biochemical resources ('bioprospecting') as part of marine pharmacology may have negative effects

on ocean sustainability in cases where this causes disturbance or pollution, or triggers overexploitation.

14 + 4

Knowledge and capacity building, and training and awareness programmes on ocean and sea services will positively affect conservation and sustainable use of the oceans, seas and marine resources. This will support the achievement of targets under SDG14, especially those addressing marine pollution, ocean acidification, and resource use including fisheries, as well as ocean governance. Thus, introducing ocean literacy into the curricula of education programmes early and through all levels of education is important to ensure global understanding of ocean issues. Likewise, trained and skilled people are required to support and contribute to sustainable ocean development in all sectors, including the education sector, and across policymaking, society, economy (e.g. in the context of blue growth) and environmental affairs. Investment in capacity building and transfer of knowledge and technology in the marine field, and action taken on quality education and training under SDG4 (essentially all targets) will be especially important for developing countries and SIDS. In return, healthy oceans, sustainable resource use and conservation can contribute to building a culture of sustainable development, globally.

14 + 5

Equal opportunities are an issue in many marine and maritime economy sectors. Activities 'at sea' and leadership positions in fisheries or shipping are traditionally male-dominated, limiting access to opportunities and resources for women. Despite, a significant contribution made by women in some sectors (for example, roughly 50% of employees in the seafood industry are women) their role is often overlooked and underpaid. Sustainable development of marine and maritime sectors can create new opportunities for income and employment opportunities for women. Gender mainstreaming of policies and measures on access to marine resources, seafood markets or maritime sectors can contribute to ensure equal rights to natural and economic resources. Likewise, promoting knowledge, capacity building and technology transfer can contribute to the empowerment of women where attention is paid to related gender issues.

14 + 6

Oceans and seas are major sources of water in the hydrological cycle and therefore require sustainable management through integrated water management that addresses the multiplicity and diversity of water actors. Ocean sustainability directly links to sustainable water management. Preventing marine pollution contributes to improving water quality and vice versa. Conservation of marine and coastal areas can support integrated water resource management and contribute to protecting and restoring water-related ecosystems. Sustainable aquaculture can contribute to water-use efficiency and local water and sanitation management. In return, increasing water-use efficiency may have positive feedbacks on marine and coastal ecosystems and support their conservation and sustainable use. For example, replacing open by closed recirculation systems to reduce water demand would also limit waste water flow to the environment. A potential negative side-effect of strengthening coastal tourism or aquaculture as part of blue growth might be the resulting impact on water quality and availability.

14 + 7

Increasing the share of renewable energy in the global energy mix and improving energy efficiency, reliability and affordability will enhance sustainability and help reduce ocean acidification through reduced carbon dioxide emissions. Different types of ocean energy already contribute to the global renewable energy supply and have the potential to expand further in the future, particularly in island states and coastal regions. Strengthening marine research and transfer of marine technology in this field could support this expansion and help increase the share of renewable energy in the global energy mix. On the other hand, more energy infrastructure in coastal and marine areas may have negative impacts; for example by increasing spatial competition with other uses (coastal and marine protected areas, fisheries, aquaculture, tourism). But synergies with other uses are also possible, for example by integrating aquaculture and wind farming.

14 + 8

Conservation and sustainable use of oceans, seas and marine resources can directly contribute to promoting sustainable economic growth and opportunities for decent work, particularly in island states and coastal regions. Sustainable growth of marine and maritime sectors such as fisheries, aquaculture and tourism supports employment and economic growth. Capacity building and transfer of marine technology will help create the strengthened professional skills and competences necessary for achieving the SDG14 targets, and will also support youth employment, education and training, job creation and innovation, and enable sustained long-term economic growth. Striving for healthy oceans, coasts and marine resources and the improvement of global resource efficiency in consumption and production and decoupling economic growth from environmental degradation, are mutually supportive. However, trade-offs are possible where conservation and restoration measures limit economic growth, which can in turn impact ocean health.

14 + 9

Sustainable use of marine and coastal ecosystem services for the development of marine and maritime activities (i.e. blue-growth) and equal access to marine resources and trade options can support industrialisation efforts and promote innovation, especially in island states and coastal regions. Likewise, fostering sustainable infrastructure, industrialisation, and research and technologies may support the achievement of conservation and sustainable use of the oceans. Trade-offs may occur where a balance must be found between ocean conservation and restoration measures. For example, reducing pollution or the establishment of MPAs can constrain industrialisation and infrastructure development in coastal regions.

14 + 10

Healthy oceans and coasts provide a sustainable resource base for income growth in low-income populations. For example, blue growth will help achieve greater in-country equality over the long-term when supported by fiscal, wage, and social protection policies. Moreover, providing small-scale artisanal fishers with access to marine resources and markets helps achieve socio- and economic inclusion. Restoring and maintaining ocean health also fosters the achievement of other SDGs aimed at improving livelihoods and well-being, and eliminating extreme poverty which all help to reduce inequalities. However, improving ocean health and conserving coastal and marine resources also has the potential to limit options for economic and income growth. Promoting the representation of developing countries in decision-making within global economic and financial institutions can help strengthen the engagement of LDCs and SIDS in the World Trade Organization fisheries subsidies negotiations, which may support the elimination of certain fisheries subsidies. Directing official development assistance, and foreign direct investment towards the sustainable use of marine resources can also provide greater economic benefits especially for SIDS that rely on these resources for their economic growth.

14 + 11

Coasts are an attractive zone for human settlement and urban development, often driven by the opportunities for economic activities and natural resources provided by coasts and coastal zones. About 65% of all megacities worldwide are located in coastal areas, and as a result coastal areas generally show higher population densities, growth and urbanisation trends than inland areas, which implies a direct relation between ocean sustainability and sustainable cities and communities. This expansive and intensified utilisation and change in coastal areas, which is also related to new uses such as aquaculture, coastal protection infrastructure or port construction, has many negative impacts on coastal ecosystems. Synergies are likely between the reduction in marine pollution and the development of safe housing and environmentally friendly cities that aim at reducing energy consumption, improving sewer management and minimising the degradation of oceans and seas at large. Similar bi-directional benefits occur between sustainable management practices and conservation efforts in the coastal and marine environment and the development of safe, resilient and sustainable settlements. Conflicts may occur where ocean and coastal conservation and restoration limit options for urbanisation, housing, infrastructure or transport upgrading. Promoting the construction of new buildings using local materials may have negative impacts on coastal ecosystems from which the building materials are removed, and on their conservation and restoration.

14 + 12

Sustainable consumption and production, such as sustainable management of natural resources or the reduction of wastes, are critical for ending overfishing, sustainably managing marine and coastal ecosystems and reducing marine pollution. Halving per capita global food waste at the retail and consumer level, for example, will have positive impacts on ecosystem protection, sustainable fisheries, and marine pollution through reduced nutrient inputs from agriculture. Achieving sound management of chemicals throughout their lifecycle will also help minimise marine pollution; from land-based and offshore industries. Recycling and prevention of waste from land-based sources is a prerequisite for reducing marine litter. Improving ocean literacy and understanding of the drivers of ocean decline could support transformations towards sustainable consumption and production. More directly, conserving and sustainably using the oceans, seas and marine resources has the potential to support sustainable consumption and production patterns in ocean-based industries (fisheries, tourism, maritime transportation, among others).

14 + 13

Ocean and coastal ecosystems are essential climate regulators, but are also directly affected by climate change. Restoring and protecting the health of oceans, coasts and marine resources contributes to strengthening the resilience and adaptive capacity of both the natural and human systems to climate change. Coastal ecosystems such as mangroves, saltmarshes and seagrass meadows contribute both to climate adaptation (e.g. protection from coastal hazards) and climate mitigation (through carbon sequestration). Further co-benefits arise from reducing risks and vulnerabilities and strengthening the resilience of coastal communities to climate-related hazards (such as by promoting poverty eradication, food security, sustainable livelihoods, capacity building or biodiversity). Where sustainable ocean management is included as a topic in education, training and technology transfer in relation to climate change, it will contribute to raising capacity on climate change adaptation and mitigation and ensure more effective climate change planning and management. In turn, achieving action on climate change will help limit ocean acidification, already well underway owing to increased levels of carbon dioxide in seawater, and will positively affect ocean management and conservation efforts. The potential for trade-offs is limited but possible. Offshore installations for renewable energy production may have negative impacts on the marine environment, particularly on marine mammals. On the other hand, failing to mitigate climate change and reduce global warming will increase climate related impacts on coastal ecosystems, such as through warming and ocean acidification, but also through sea-level rise and related effects. This may further constrain the protection and restoration of coastal ecosystems and reduce resilience and adaptive capacity towards climate change.

14 + 15

Ocean and coastal systems are hotspots for biodiversity, both in areas within and beyond national jurisdiction. Halting loss of biodiversity improves the resilience of ecosystems and supports healthy and productive oceans. Issues such as wildlife trafficking, benefit sharing of genetic resources or invasive species also concern marine and coastal habitats and species, while ocean conservation and sustainable use of marine resources contributes to the reduction of habitat degradation, biodiversity loss and species protection. Conservation, restoration and protection of terrestrial and freshwater ecosystems will also benefit the health of oceans and seas: benefits derived through reduced impacts from land-based sources, such as non-point source pollution, erosion and sedimentation.

14 + 16

Ocean governance, building on effective, accountable and transparent institutions and responsive, inclusive, participatory and representative decision-making, will be essential to achieve SDG14. Likewise, it will contribute to delivering peace, justice and strong institutions. Specific synergies exist between tackling illegal, unregulated and unreported (IUU) fisheries and the reduction of corruption and bribery. Implementing international law as reflected by the UN Convention on the Law of the Sea (UNCLOS) and related agreements, such as the UN Fish Stocks Agreement, would enhance the conservation and sustainable use of oceans and their resources. Aiming for accountable and transparent institutions, as well as inclusive, participatory and representative decision-making is fully consistent with aiming to improve capacities of marine management organisations to end unsustainable fishing practices or to protect marine ecosystems. In the reverse direction, improving ocean governance for sustainability will be important to achieve SDG16 with regard to the oceans.

14 + 17

SDG17 is an important building block for the 2030 Agenda, aiming at strengthening the means of implementation for all SDGs. Global partnerships for sustainable development are especially important in the context of oceans, seas and marine resources, owing to the global connectivity of marine ecosystems and the cross-cutting and often far-reaching effects of marine resource use. Achievement of SDG14 will benefit particularly from the mobilisation of financial aid, strengthened technology exchange, capacity building, better policy coherence and multi-stakeholder partnerships.

KEY INTERACTIONS AT **TARGET-LEVEL**

SDG14 is an integral part of the 2030 Agenda, linking to all 16 other SDGS. This section analyses some of these interactions with a selected set of SDGS in detail at the target-level. SDGS were selected based on the strength of their interlinkages with SDG14 and the magnitude and scale of impact in relation to the overall objective of the 2030 Agenda, while ensuring a balanced consideration of the economic, social and environmental dimensions. Target-level interactions are judged to fall within one of seven categories and are scored accordingly: indivisible (+3), reinforcing (+2), enabling (+1), consistent (0), constraining (-1), counteracting (-2), and cancelling (-3). Following a generic analysis of the selected interactions, specific examples are provided to illustrate how interactions unfold in different geographical and policy contexts. As oceans are highly interconnected ecosystems not confined by national boundaries, national, regional and global examples are provided.

Six goals were selected for detailed analysis, each accompanied by an illustrative example:

SDG1
Western Indian Ocean
SDG2
Kenya and Tanzania
SDG8
Baltic Sea
SDG11
Australia
SDG12
G7 Action Plan to combat Marine Litter
SDG13
Paris Agreement

SDG 14 + SDG 1

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.2 → 1.1, 1.2	Healthy and productive oceans benefit small-scale fishers, improve tourism revenue and increase potential for blue carbon markets	+2	Raise awareness of local communities on the importance of healthy oceans, and sustainable use of coastal and marine resources for their livelihoods and sustained income
14.2 → 1.5	Healthy oceans and coasts help reduce vulnerability to climate hazards	+2	Strengthen the role of marine and coastal ecosystems in climate change adaptation in national and regional adaptation strategies and policies
14.3 → 1.1, 1.2	Minimising and addressing the impacts of ocean acidification will improve fish stocks, livelihoods and incomes	+2	
14.4 → 1.1, 1.2	Sustainable fisheries stabilise income and create opportunities for value-addition	+2	Invest proceeds from fishing in produced capital (e.g. fishing and transport vessels, ports, roads) and human and institutional capacities Develop recording and reporting methods whereby artisanal and recreational fishers are engaged in data collection and assessment of catch trends
14.4 → 1.1, 1.2	Higher value-added economic activities may displace livelihoods and increase poverty	-1	
14.4 → 1.4	Sustainable fisheries stabilise income and create opportunities for value-addition	+2	
14.5 → 1.1, 1.2	MPAs restrict access and can create competition for scarce resources and so constrain poverty reduction efforts	-1	
14.7 → 1.1, 1.2	Sustainable tourism, fisheries, coastal agriculture, mining, and mariculture can create jobs and reduce income poverty	+3	Establish the social, economic and environmental baselines for blue growth and develop roadmaps for key sectors with trackable milestones backed with environmental protection goals
14.7 → 1.1, 1.2	Increased economic activity creates more pressure on coastal and marine resources and more environmental harm	-1	Designate marine spaces for different social, economic and environmental uses and objectives and identify the trade-offs between competing uses Create sovereign wealth funds to ensure flow of benefits after non-renewable resources are exhausted, avoid crowding out other economic sectors, and develop measures to avoid the impacts of inflation on the poor and vulnerable
14.7 → 1.3	Creating jobs in sustainable tourism, fisheries, coastal agriculture, mining, and mariculture can enable social protection programmes	+2	Develop social protection policies and invest proceeds from blue growth in social protection programmes for the poor and most vulnerable. For example, old-age pensions, health insurance, and unemployment insurance

KEY POINTS

Poor coastal communities in low income countries are likely to suffer the most from changes in the coastal and marine environments that directly and indirectly support their livelihoods. Protection, restoration and management of critical coastal and marine habitats have the most direct links to poverty eradication, improving their livelihoods and reducing their vulnerability related to extreme climate events

Sustainable tourism, fisheries and coastal agriculture in SIDS and LDCS can create decent jobs that reduce income poverty. To promote a more inclusive pattern of growth and development, simultaneous expansion and development of social protection programmes for the poor and most vulnerable is necessary

Higher economic activities aimed at poverty alleviation can create more pressure on coastal and marine resources and environmental harms and can lead to long-term costs to the local economy

KEY INTERACTIONS

SDG14 targets interact with SDG1 targets in the context of ending income poverty and multidimensional poverty (deprivation of non-monetary factors including ecosystem services, education, training, sanitation and health) (Liu et al., 2015; ILO, 2016). Protection, restoration and management of critical coastal and marine habitats **(14.2)** maintain biodiversity and rebuild fish stocks and are therefore inextricably linked to improved livelihoods and eradicating poverty **(1.1, 1.2)**. The net benefits of **target 14.2** include improved revenue from tourism, enhanced biodiversity and fish stocks, and increased potential for income from blue carbon markets. At the same time, coastal habitats protect homes, communities, and businesses from extreme climate-related events such as coastal flooding and storm surges, and can help reduce the vulnerability of poor people (often with no insurance) **(1.5)** and the associated economic impacts **(1.1, 1.2)**.

Adapting fisheries to sustainable levels and eradicating IUU fisheries **(14.4)** has a direct link to stabilising and/or increasing productivity, profitability, and net economic benefits from fisheries (World Bank, 2009), and to reducing poverty **(1.1, 1.2)**. For example, addressing IUU fishing will provide up to US$ 1.5–2 billion per year for Sub-Saharan African countries. However, certain fish stocks may recover slowly and this may delay poverty reduction efforts. Increasing value-addition also has a direct link to reducing fishing effort (Kelleher, 2015) **(14.4)** and can create jobs in the post-harvest sectors (processing and marketing) for women in Africa who have little or no access to natural and economic resources (UNECA, 2016) **(1.4)**. Value-addition also has potential to create business opportunities in expanding access to credit, processing technology, storage facilities, and training **(1.4)**. However, replacing indigenous technologies by imported technologies, and deploying newer advanced technologies from higher value-added economic activities may threaten livelihoods and increase poverty.

The creation of MPAS **(14.5)** in order to conserve degraded and threatened species, ecosystems, habitats and biodiversity is an important factor in the alleviation of long-term poverty (Fisher and Christopher, 2007) **(1.1, 1.2)**. However, MPAS can conflict with the social and economic objectives of populations who may lose access to the resources therein and can thus constrain poverty reduction goals. Their success therefore depends on how they are developed and managed and how the costs and benefits of lost fishing opportunities are shared, for example.

There are many linkages between **target 14.7** and poverty eradication in SIDS and LDCs, which are highly dependent on coastal and marine resources for economic development. Sustainable development of tourism, fisheries, coastal agriculture, mining, and mariculture can create jobs for many coastal populations **(1.1, 1.2)**. While these sectors have the potential to increase income, maximising synergies requires the simultaneous development and expansion of social protection programmes. Depending on the available resources in each country, design options can include social insurance, old-age pensions, disability pensions, unemployment insurance and skills training **(1.3)**. However, increased economic activity can create more pressure on coastal and marine resources and more environmental harm from pollution, and can lead to decreased economic activity, job losses and long-term costs to the local economy (Kelleher, 2015).

While climate change impacts on the health of marine ecosystems, habitats and species are not fully understood, minimising and addressing the impacts of ocean acidification **(14.3)** will reduce the negative consequences on commercial species like shellfish, loss of coral reefs, and on the size, productivity and stability of fish stocks and associated livelihoods and incomes **(1.1, 1.2)**. On the other hand, significant changes in local weather patterns and sea-level rise may make poverty reduction more difficult; prolonging existing poverty and creating new poverty traps (Olsson et al., 2014).

KEY UNCERTAINTIES

(1) The main uncertainty relates to maintaining fish biomass and fishing effort to levels that can produce maximum sustainable yield and at the same time ensure profitability to support livelihoods. (2) The overall effects of MPAs are difficult to establish: while limiting access to resources, protected areas support the regeneration of degraded habitats and stocks, which could in turn benefit coastal livelihoods. (3) The impact of ocean acidification it is highly species specific which makes it difficult to extrapolate from one species, habitat or area to another.

KEY DIMENSIONS

Time: The time needed to restore natural resources and ecosystems depends on their status and dynamics. Building infrastructure and establishing support programmes takes time, as does restoration of degraded habitats or fish stocks.

Geography: (1) Geographical context is mainly a concern for rural island and coastal communities, but also for urban areas and informal settlements of coastal cities in less developed regions. (2) There may be spill-over effects to adjacent hinterland communities through trading of fish or other coastal and marine products.

Governance: (1) Policies and strategies are needed to ensure that investments are made with a focus on addressing the needs of the poor and to tackle spatial competition. Policies and strategies directed at reducing poverty should acknowledge the importance of natural capital for poverty alleviation and promote sustainable use of natural coastal and marine resources. Integrated governance across scales and sectors is essential. (2) As the transition to a blue economy may lead to job losses in some traditional sectors and the replacement of indigenous technologies by imported technologies, policy measures aimed at job creation in other non-marine sectors may be needed to provide alternative livelihoods.

Technology: Building sustainable fisheries, aquaculture and tourism may need context specific innovations in gear, monitoring, control and facility technology.

Directionality: Interlinkages are bi-directional. Healthy oceans and sustainable use of marine resources are a prerequisite for ocean ecosystem services to contribute to poverty alleviation. At the same time, poverty alleviation will strengthen capacities and possibilities to conserve and sustainably use ocean and coasts.

ILLUSTRATIVE EXAMPLE
THE WESTERN INDIAN OCEAN REGION

The Western Indian Ocean region includes Somalia, Kenya, Tanzania, Mozambique, South Africa and the island states of Mauritius, Comoros, Seychelles, Madagascar and Réunion (France). It has a combined coastline exceeding 15,000 km (including island states) and a total continental shelf area of about 450,000 km² (UNEP/Nairobi Convention Secretariat, 2009). Except for the Seychelles, Mauritius and South Africa, over 50% of coastal populations have low Human Development Index (HDI) values and live below the poverty line (Gössling, 2006; UNDP, 2006). Ensuring that the regions' critical habitats (coastal lowland forests, mangroves, seagrass beds and coral reefs) are protected, restored and managed **(14.1, 14.2, 14.5)** is crucial to reducing poverty and increasing income for the 65 million people that live within 10 km of the coast (Burke et al., 2011).

Sustainable fisheries **(14.4)** are crucial for sustainable economic development of the countries that together generate about 4.8% of the global fish catch; equivalent to about 4.5 million tonnes of fish per year (FAO, 2009). Failure to address IUU fishing for example, which is common in artisanal (nearshore) and industrial (further offshore) fisheries (UNEP/Nairobi Convention Secretariat and WIOMSA, 2015) is expected to cost the South-West Indian Ocean region around US$ 400 million per year (Harris and Gove, 2005).

An estimated US$ 25 billion per year is derived from the coastal and marine resources in this region (UNEP/Nairobi Convention Secretariat, 2009), mainly from tourism, fisheries, coastal agriculture, mining, mariculture, and ports and coastal transport. There is enormous potential to grow these sectors and to create jobs, including within associated non-marine sectors **(14.7)**, with the value of Western Indian Ocean assets estimated at US$ 333.8 billion (Obura et al., 2017). For example, tourism – the largest contributor to GDP at over US$ 11 billion per year, equivalent to 40% of the total from marine and coastal resources (UNEP/Nairobi Convention Secretariat and WIOMSA, 2015) – can create jobs in hotels, restaurants, housing and residential activities, agriculture and fisheries and so provide quick revenue to alleviate poverty **(1.1, 1.2)**. Investment in infrastructure such as road networks, airport facilities, amenities in the coastal and beach zones, and ports for cruise tourism can also provide high revenue for the economy and so benefit poor populations **(1.1, 1.2)**.

Marine extractive industries are expanding, with Kenya, Tanzania and Mozambique beginning to explore for offshore oil and gas which could provide economic benefits from income and saving on fuel imports that could be directed to poverty reduction programmes. Investing the proceeds from these non-renewable resources into long-term sustainable economic opportunities for poor populations, creating sovereign wealth funds, and building human and institutional capacities will reduce long-term poverty **(1.2)**.

There are currently 83 MPAs in the region. Enhanced conservation measures in existing MPAs, and the creation of new MPAs (14.5) can encourage fee increases in marine parks and reserves and for licences (where they exist) and can increase revenue from the tourism industry to coastal communities **(1.1, 1.2)** (UNEP/Nairobi Convention Secretariat and WIOMSA, 2015). Some countries have already set ambitious targets in this regard: Seychelles aims to establish MPAs covering 30% of its 1.4 million km² of its exclusive economic zone (EEZ) by 2020 and Zanzibar aims to establish 15% of its coastal and marine ecosystems as MPAs.

Investment in climate change adaptation **(14.3)** has great potential to reduce poverty in coastal populations **(1.1, 1.2)** while also reducing their vulnerability to natural disasters **(1.5)**. In Kenya and Madagascar, blue carbon projects have been developed to generate revenue from carbon credits to coastal communities from the sustainable management of mangroves.

SDG 14 + SDG 2

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.2 ⟶ 2.1	Healthy oceans will enhance fisheries yields	+1	Raise awareness of artisanal fishers and local communities to the importance of critical habitats and ecosystems for their food security and nutrition
14.4 ⟶ 2.1	Sustainable fisheries are inextricably linked to fish availability and food security	+3	Strengthen and implement existing laws and policies to ensure responsible and sustainable fisheries and where possible develop co-management approaches with local communities
14.4 ⟶ 2.2	Fish and fishery products directly enable the provision of micronutrients	+2	Strengthen and implement existing laws and policies to ensure responsible and sustainable fisheries and where possible develop co-management approaches with local communities Encourage the use of voluntary mechanisms such as ecolabels to encourage safety of fish and long-term sustainability
14.5 ⟶ 2.1, 2.2	MPAs enhance fish recruitment in areas adjacent to them	+1	
14.5 ⟶ 2.1, 2.2	MPAs may limit access to food resources and areas for aquaculture	-1	
14.5 ⟶ 2.5	Depending on their size, MPAs can maintain genetic diversity within species	+1	

KEY POINTS

Sustainable fishing and aquaculture and healthy ocean ecosystems and habitats are key to providing food security and meeting nutritional needs in many developing and developed countries

Increased agricultural productivity to provide food might constrain efforts to reduce marine pollution from agricultural run-off and nutrients

KEY INTERACTIONS

SDG14 is inextricably linked with enhancing food security **(2.1)** and nutritional needs **(2.2)** in developed and developing countries (Thilsted et al., 2016), and mainly interacts with SDG2 through sustainable fishing and aquaculture **(14.4, 14.6)**, safeguarding the health of ocean ecosystems and habitats **(14.1, 14.2, 14.3)**, and the creation of MPAS **(14.5)**. In 2010, fish provided more than 2.9 billion people with almost 20% of their average per capita intake of animal protein and 4.3 billion people with about 15% (FAO, 2014). A significant proportion of the food security of nutritionally vulnerable people **(2.1)** comes from fish and exceeds that of most of terrestrial animal foods (Béné et al., 2016). However, stocks of the most important species are fully fished and/or overfished and rebuilding them to biologically sustainable levels **(14.4)** could increase fisheries yields **(2.1)** by 16.5 million tonnes (FAO, 2014) to meet the global demand for fish and fishery products.

Responsible and sustainable fisheries (14.4) also reinforce target 2.2 by providing long-chain polyunsaturated fatty acids and essential micronutrients – vitamins D and B and a range of minerals (calcium, phosphorus, iodine, zinc, iron, selenium) (Thilsted et al., 2016) for more than 10% of the global population, especially in developing nations in the equatorial region **(2.2)** (Golden, 2016). If the degradation of ocean ecosystems **(14.1, 14.2, 14.3)** and decline in fish catches are not addressed **(14.4, 14.6)** 845 million people (11% of the current global population) may become micronutrient deficient (Golden, 2016). Fish is also essential for growth, brain function and maintaining the nervous system (Thilsted et al., 2016). This can play a critical enabling role for brain development and growth in children **(2.2)** and the nutrition of the nearly one-fifth of pregnant women worldwide that have iron-deficiency anaemia and the one-third that are vitamin-A deficient **(2.2)** (Golden, 2016). Protein and trace elements derived from aquatic sources are added to animal feeds to enhance agricultural productivity **(2.3, 2.4)** and can increase income for small-scale food producers. However, without adequate pollution prevention measures, marine pollution **(14.1)** from agricultural run-off of nutrients (nitrogen, phosphorus) can adversely affect fish availability **(2.1, 2.2)**. While creating MPAS **(14.5)** can enhance fish recruitment and productivity for better food security and nutrition, and can increase fish production in adjacent areas **(2.1, 2.2)**, they may limit access to food resources for coastal communities and may limit areas available for aquaculture **(1.1, 1.2)**. Depending on their size (large or isolated), MPAS can preserve genetic diversity within species (Munguía-Vega et al., 2015) **(2.5)**.

KEY UNCERTAINTIES

(1) While the link between fisheries and aquaculture and food security is well established, long-term food security and nutrition depends on the status of stocks, and the health of the associated ecosystem.
(2) A key uncertainty relates to achieving total food security where access and distribution of harvested fish is limited due to post-harvest losses.

KEY DIMENSIONS

Time: (1) The period required for wild stocks to recover depends on the stock status after collapse. (2) Building infrastructure and establishing support programmes takes time.

Geography: (1) It is mainly rural island and coastal communities that are affected, and urban areas and informal settlements of coastal cities in less developed regions. (2) There may be spill-over effects to adjacent hinterland communities through trading of fish or other coastal and marine products.

Governance: Adopting a nexus approach to fisheries management, marine ecosystem conservation and agriculture can help overcome trade-offs and maximise synergies.

Technology: Ensuring sustainable fisheries and aquaculture may need context specific innovations for monitoring and control of activities, among others.

Directionality: Bi-directional. Sustainable seafood is essential to ensure food security, especially in coastal areas and islands. At the same time, establishing food security risks increasing pressure on fish stocks and marine ecosystems beyond sustainability.

ILLUSTRATIVE EXAMPLE
BEACH MANAGEMENT UNITS IN KENYA AND TANZANIA

Coastal communities in Kenya and Tanzania rely heavily on fisheries for food security **(2.1)** and nutrition **(2.2).** In Tanzania, 70% of the population relies on fish (freshwater and marine) for protein (UNEP/Nairobi Convention Secretariat and WIOMSA, 2015). For the last ten years, beach management units (BMUS) have been established in Kenya and Tanzania as a co-management approach between government and local communities to share responsibilities for resource management and the conservation of fish stocks **(14.4)** for enhanced food security **(2.1)** and sustainable livelihoods. BMUS are currently governed by the Kenya Fisheries Management and Development Act 2016 and the Tanzania Fisheries Act 2003 and Fisheries Regulations 2009, and draw their membership from a wide range of sources (fishers, boat owners, boat crew, traders, processors, boat builders and repairers, net repairers) with jurisdiction over distinct geographical areas to manage fish landing stations on behalf of fisheries departments and are empowered to levy fees (UNEP/Nairobi Convention Secretariat and WIOMSA, 2015). BMUS are now considered a central element of artisanal fisheries co-management in Tanzania (over 170 BMUS) and Kenya (73 BMUS) (Kanyange et al., 2014). The shift from a top-down centralised fisheries governance approach has also proved useful for addressing the lack of government staff to manage fisheries and continued budget cuts (Kanyange et al., 2014), as well as to reduce conflict between and among stakeholders. The BMU approach can play a critical enabling role to address threats from deteriorating aquatic habitats **(14.2)** and declining fish stocks **(14.4)** and to enhance food security.

SDG 14 + SDG 8

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.1, 14.3, 14.4 ⟶ 8.4	Tackling marine pollution, ocean acidification and unsustainable fisheries all reinforce the efficient and sustainable consumption and production of resources	+2	Establish product lifecycle monitoring schemes to identify opportunities to improve resource efficiency and provide incentives and support for respective innovation Identify sources and pathways for marine pollution and improve production policies and waste management accordingly
14.2, 14.5 ⟷ 8.1, 8.3	Taking measures to protect and restore marine and coastal ecosystems (e.g. establishing MPAs) might entail restrictions for economic activities and therefore limit opportunities for economic growth and job creation and vice versa	-2	Develop and adopt regional/sea-basin based marine spatial plans to coordinate conservation, economic uses and impacts in line with sustainable development criteria
14.4, 14.7 ⟷ 8.1, 8.5	Sustainable fisheries, aqua-culture and tourism will contribute to economic growth and to achieving full employ-ment and vice versa	+2	Ensure policies for marine resource uses like fisheries include sustainable exploitation limits and that these are implemented, followed-up and reviewed Promote job diversification and development in green/blue growth sectors in coastal areas
14.7 ⟷ 8.9.	Increasing economic benefits through sustainable coastal and marine tourism forms part of promoting sustainable tourism as such	-1/ +1	Ensure policies to manage and develop tourism include provisions on pollution and waste management and respect conservation needs of sensitive habitats and species Build capacities and raise awareness among actors and stakeholders on sustainable practices Create incentives for sustainable tourism development

KEY POINTS

Protection and restoration of marine ecosystems and fisheries resources and options for short-term economic growth, productivity and job creation policies and measures might constrain each other

Healthy oceans and fisheries resources provide the necessary basis for sustainable job and growth policies for maritime sectors and coastal areas

Coastal tourism is a key contributor to promoting sustainable tourism as a driver for local employment, cultures and products

KEY INTERACTIONS

SDG14 and SDG8 mostly interact through their targets for conservation and sustainable resource use with the nature of the interaction highly context-specific. In general terms, oceans are important for the global economy and employment; among others, they provide natural resources and space for business development and are essential for climate regulation. About 30% of mineral oil is extracted from the ocean, and shipping routes are the most important transport lanes for global trade (Maribus, 2015). Ocean-based activities are estimated to generate global revenue in the range US$ 3–5 trillion per year (FAO, 2014). While designating parts of marine and coastal areas for protection might constrain options for growth and jobs in some cases, they may help generate jobs and growth opportunities in others. Tackling marine pollution through improving waste management and increasing recycling can enable a shift to circular economies, create 'green' jobs, and improve tourism. However, measures such as taxes and levies on plastic bags and fertilisers, may conflict with other important poverty-reduction sectors, such as coastal agriculture.

Although economic growth and job creation focused on short-term developments or entailing negative environmental impacts might be restricted by conservation policies and measures aimed at maintaining marine ecosystem health and resources, Russi et al. (2016) demonstrated that protecting marine and coastal ecosystems is vital for a sustainable blue-green economy in Europe, providing livelihood and income opportunities and helping climate change adaptation in coastal communities.

Ensuring sustainable exploitation of marine resources and restoring ocean health will lead to an overall benefit for sustainable economic development and employment. For example, it is estimated that ending overfishing and achieving sustainable fisheries **(14.4)** would generate EUR 3188 billion annually, which could support the equivalent of 32,000 full-time fishing jobs and 69,000 (full- and part-time) processing jobs every year in the EU alone (NEF, 2012). Increasing economic benefits through sustainable use of marine resources to reinforce economic growth and employment development **(8.1, 8.5)** can be especially important in SIDS and LDCS **(14.7)**. For example, capture fisheries and aquaculture often play a major role in national economies of SIDS, particularly in the Pacific where they can contribute as much as 10% of GDP. Fisheries and aquaculture production in this region were valued at US$ 3.2 billion in 2014 (Gillett, 2016). Deep-sea mining for minerals is an emerging economic activity that could provide new income sources to SIDS and LDCS, and generate jobs and growth in the domestic private sector (UNEP, 2012). However, guidelines and policies for their sustainable extraction must first be adopted. Increasing economic benefits through sustainable marine and coastal tourism **(14.7)** forms part of promoting sustainable tourism **(8.9)** in coastal areas and islands. Tourism has increased over the past 40 years with coastal tourism now one of the main components in some areas, especially small island states (United Nations, 2016). Tourism represents 5% of world GDP and contributes up to 7% to employment (UNEP, 2012). Almost half of all international tourists travel to coastal areas, in some SIDS accounting for up to 25% of GDP (Ramsar and UNWTO, 2012). The oceanic island characteristics of SIDS provide large potential for marine tourism development, as demonstrated in Fiji where tourist resort development has been combined with traditional coastal fishing villages (FAO, 2014). In Europe, coastal and marine tourism is the largest maritime activity, employing almost 3.2 million people and generating EUR 183 billion in gross value added in 2011 (ECORYS, 2013). However, coastal tourism can also have negative effects on ocean health and sustainable resource use that need to be addressed to ensure sustainable development and to avoid conflict with other SDG targets **(14.1, 14.2, 14.4)**. These include: seasonal increase in consumption, pollution and waste; development of infrastructure such as hotels or airports often in or near sensitive habitats like coral reefs; malpractice in recreational activities such as diving, snorkelling or wildlife watching (WWF, no date); and modifications of beaches and coastal waters to increase their attractiveness (United Nations, 2016).

KEY UNCERTAINTIES

Interactions are context-specific and depend on national and local conditions, cultures and policies.

KEY DIMENSIONS

Time: Short-term growth and employment opportunities risk being unsustainable and thus undermining the achievement of SDG14 and SDG8. Generating sustainable growth and employment opportunities will be a long-term investment and in most cases will depend on a comprehensive strategic approach to sustainability of economic development, natural resource productivity and maintenance of ecosystem services.

Geography: Concerns mainly island and coastal communities. There may be spill-over effects into the coastal hinterland.

Governance: Cross-sectoral coordination in regulatory and enabling policies and programmes is needed. Integrated governance across scales and sectors is essential, especially to ensure synergies are utilised. For example, the success of MPAs can depend on how the costs and benefits of lost fishing opportunities and MPA effects are shared.

Technology: Technology and its transfer are central to various aspects of ocean sustainability. For example to improve selectivity of fishing gear or minimise marine pollution from land and sea-based sources in order to contribute to sustainable economic growth and employment.

Directionality: Bi-directional. Sustainability of policies and measures to promote economic growth and employment will be directly relevant for conservation and sustainable use of oceans, seas, and marine resources while their health status will affect growth and job opportunities.

ILLUSTRATIVE EXAMPLE
THE BALTIC SEA

The Baltic Sea is a semi-enclosed inland sea with around 85 million people within its catchment area (Ahtiainen et al., 2013). Its resources provide multiple ecosystem services that can contribute to economic growth, and to increasing and diversifying employment in many sectors including seafood, sand and gravel extraction, shipping, recreation and tourism (Ahtiainen and Öhman, 2014). The three largest maritime economic activities – fisheries for human consumption, shipping and ship-building – provided 360,000 jobs and EUR 16.6 billion gross value added in 2010 (EUNETMAR, 2013). The maritime sector is central to the economy and employment in the coastal regions of all Baltic States. Several segments of the maritime sector have potential to help develop economic productivity **(8.2)** and full employment **(8.5)**, and to reduce youth unemployment **(8.6)**. In the period 2008–2010, energy generation by offshore wind farming in the region increased by 20%, cruise tourism by 11% and marine aquaculture by 13%. Short-sea shipping, coastal tourism, yachting and marinas, and environmental monitoring are considered to have high growth potential in the Baltic Sea (Brodzicki and Zaucha, 2013). Tourism and fisheries are the two most important sectors for employment, providing 244,000 of 360,000 jobs in the EU maritime sectors (Brodzicki and Zaucha, 2013). However, the potential of the blue economy, especially sectors such as tourism or marine aquaculture, depends on healthy oceans and marine resources. The Baltic Sea is severely affected by eutrophication, pollution and unsustainable fishing practices, which threaten ecosystems and ecosystem services and associated economic activities such as fisheries and tourism (HELCOM, 2010). Failing to restore the Baltic Sea to good ecological health will impair its ability by 2030 to add an additional 550,000 jobs and EUR 32 billion in annual value in tourism, agriculture and fisheries alone (BCG, 2013). Building on these findings, the EU has launched a Baltic Sea agenda identifying options and instruments for the support of sustainable blue growth in the region (European Commission, 2014).

SDG 14 + SDG 11

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.1 ⟷ 11.1, 11.3, 11.6	Tackling marine pollution reinforces the provisioning of safe housing and quality of basic services, sustainable urbanisation and integrated settlement planning and management, and reducing the environmental impact of cities such as in the context of waste management, and vice versa	+2	Ensure integrated planning and management in coastal areas; include integrated coastal management, marine spatial planning and harmonise with urban planning and regional development policies; ensure coherent policymaking across administrative boundaries including upstream catchment areas (applies to all target interactions) Develop and monitor implementation of effluent discharge and waste management standards and of litter control and litter prevention measures in coastal areas as well as in upstream catchment areas Ensure participation of societal actors and stakeholders from different groups in planning and decision-making together with coastal and marine managers, where relevant (applies to all target interactions) Increase public awareness of the role and importance of coastal and marine ecosystems (applies to all target interactions) and sensitise stakeholders on pollution prevention Provide training and capacity building for practitioners on integrated planning and management (applies to all target interactions
14.2 ⟷ 11.1, 11.3, 11.4, 11.5, 11.6	Sustainable coastal zone management and protection of coastal ecosystems reinforces the achievement of various SDG11 targets, including the safeguarding of coastal natural heritage (e.g. coastal wetlands), and vice versa	+2	Ensure that coastal ecosystems are sustainably managed, protected or restored, within as well as around coastal settlements

14.2 ⟷ 11.1, 11.2, 11.3	Fostering sustainable coastal zone management and increased protection efforts for coastal ecosystems may result in constraints for or even counteract the achievement of several SDG11 targets, depending on the strength of integration of approaches and policies. Interactions may also work in the opposite direction	-1/ -2	Ensure ecological connectivity between offshore ecosystems, coastal ecosystems and coastal urban ecosystems and ensure their protection Promote nature-based solutions to integrate coastal protection, urban development and coastal conservation
14.2, 14.5 ⟷ 11.c	The construction of new buildings using local materials possibly receives constraints, counteracting or even cancelling from sustainable ecosystem management and conservation depending on the strategies and measures taken under these, and vice versa	-1/ -2/ -3	Ensure that construction recommendations and policies do not counteract policies set up to sustainably manage, protect, restore and conserve coastal ecosystems
14.3 ⟶ 11.4	Tackling ocean acidification reinforces the protection and safeguarding of coastal natural heritage such as coral reefs	+2	Enforce climate mitigation and adaptation measures Ensure conservation of critical coastal ecosystems and integrated coastal management to build resilience
14.5 ⟷ 11.1, 11.2, 11.3	Constraints or counteracting of SDG11 targets concerning settlements and transport systems in the coastal zone could arise from increased conservation efforts in the coastal zone, depending on the conservation status applied or of measures intended	-1/ -2	Ensure that sufficient representative coastal ecosystems are conserved and protected from human influence Improve education and increase awareness of the role and importance of coastal and marine ecosystems and the multiple benefits from sustainable use and conservation

KEY POINTS

The key linkages are through pollution, coastal and marine management including settlement planning and infrastructure development (onshore and offshore), and restoration and conservation of coastal ecosystems

Conservation is explicitly addressed in both SDGS

The strong land-sea nexus of interactions is especially relevant for settlement planning, development and infrastructure, due to a potentially long reach between upstream catchments and downstream coastal areas and marine waters

Most linkages have potential for bi-directional effects and include synergies and trade-offs. Avoiding negative effects requires integrated approaches cognisant of the transboundary nature of interactions in coastal zones

Coordinated actions and integrated approaches have potential to support both SDGS

KEY INTERACTIONS

Geographically, most interactions between SDG14 and SDG11 occur in coastal areas (Agardy et al., 2005; Duxbury and Dickinson, 2007; Stojanovic and Farmer, 2013; Barragán and de Andrés, 2015) but due to the land-sea nexus and long reach of land-based activities, interactions may span from upstream catchment areas out into marine waters, especially for pollution (Agardy et al., 2005; Crossland et al., 2005). A strong land-sea nexus around human settlements and urban areas creates potential for benefits to local communities and coastal and marine ecosystems as well as trade-offs. For instance, protecting and conserving the coastal environment **(14.2, 14.5)** around urban areas will necessarily impose urbanisation constraints (Xu et al., 2008), potentially limiting options for ensuring housing and services for all **(11.1)**, access to transport **(11.2)** and inclusive urbanisation **(11.3)**. But tackling marine pollution under **target 14.1** reinforces and contributes synergistically to ensuring safe housing, basic services and upgrading slums **(11.1)**, enhancing sustainable urbanisation **(11.3)** and reducing the environmental impact of cities **(11.6)** (Nunes et al., 2016). The policy and management measures required to reduce coastal and marine pollution (especially that originating from urban centres) include upgrading sewage and wastewater management systems and improved urban planning. Furthermore, action on ocean acidification **(14.3)** will also benefit the safeguarding of natural heritage of coastal areas **(11.4)**; coastal ecosystems such as coral reefs provide a wide range of benefits from livelihoods to biodiversity but can be severely affected by ocean acidification.

Trade-offs are possible, depending on whether policies and management are approached in an integrative manner and across sectors as well as administrative or jurisdictional boundaries. Sustainable management of coastal areas **(14.2)** can enable better human settlement planning and management **(11.3)**, including the provisioning of safe housing or upgrading of slums located in the coastal zone **(1.1)**, can safeguard natural heritage **(11.4)** by ensuring the inclusion of coastal, catchment, and wetland protected areas, can contribute to disaster management **(11.5)** such as the reduction of flooding or erosion, and can reduce the environmental impacts of cities **(11.6)**. Here also, trade-offs are possible depending on how the policies and measures adopted integrate these targets. Promoting the construction of new buildings utilising local materials **(11.c)** may have negative impacts on coastal ecosystems and hinder the restoration and protection of marine and coastal areas **(14.2, 14.5)**. Although some countries like the Maldives (Jaleel, 2013) have established strict regulations, mining of corals for construction material is an issue in many coastal countries and island states, such as the Solomon Islands (Albert et al., 2015) and Kiribati (Babinard et al., 2014). This is also the case for timber extraction from mangroves and sand mining from coastal systems (Masalu, 2002; Agardy et al., 2005; Babinard et al., 2014). In the other direction, **target 11.c** may encounter constraints due to protection and conservation measures taken under **targets 14.2** and **14.5**.

Overall, implementing SDG14 will provide opportunities for sustainable coastal development and urbanisation, and for the protection of cultural and natural heritage in coastal areas; and sustainable and integrative settlement planning and development as promoted under SDG 11 will support the achievement of SDG14 targets aiming at protection and conservation of coastal and marine areas. Planning and management across scales and sectors, cognisant of the land-sea nexus is therefore essential to reach targets from both SDGs and minimise possible trade-offs. In this context, it is important to note that coastal zones show on average higher population densities and experience stronger population growth and urbanisation rates than their hinterland, a trend that is regionally modified in terms of extent and drivers but which is generally expected to continue (Barragán and de Andrés, 2015; Neumann et al., 2015; Merkens et al., 2016). About 65% of all megacities are located in coastal areas, and population projections suggest the number of megacities will increase from 20 in 2010 to 25 by 2025 (Brown et al., 2013). Population growth, urbanisation trends and increasing demand and competition for resources, transport and energy are increasing pressure on coastal zones and their ecosystems, and in turn on the capacity to provide resources in a sustainable way (Sekovski et al., 2012; Barragán and de Andrés, 2015).

KEY UNCERTAINTIES

(1) The main uncertainties concern the lock-in effects that infrastructure brings to cities, and policy and governance decisions on urban development. (2) Further uncertainties concern the socio-economic impacts due to degradation of coastal habitats and ecosystems, and to the overall complexity of interactions within the coastal social-ecological system.

KEY DIMENSIONS

Time: Decisions are generally of a long-term nature because they tend to lock-in technologies and infrastructure with long lifecycles.

Geography: Interactions between SDG14 and SDG11 mainly concern urban settlements in coastal zones, with some effects especially pronounced in low-lying coastal areas, but may also apply to smaller coastal settlement structures and regions neighbouring coastal settlements, as well as to urban areas further upstream within the catchment (land-sea nexus).

Governance: Strong local governments and urban institutions as well as coherent policymaking and governance across administrative and jurisdictional boundaries are essential for formulating integrated solutions and effective implementation (i.e. coordination).

Technology: Technology is central to some ocean/coast impacts from cities and human settlements. It is essential for pollution management and relevant for disaster reduction. Destructive technologies such as breakwater construction can negatively influence coastal and marine ecosystems, accelerate coastal erosion or cause coastal squeeze, and so require cautious and integrative planning.

Directionality: Most of the identified synergies and trade-offs have potential for bi-directional effects.

ILLUSTRATIVE EXAMPLE **EXPLORING LINKAGES BETWEEN URBANISATION AND THE OCEANS AND COASTS IN AUSTRALIA**

Being a continent nation, Australia has an exceptionally long coastline (35,900 km without islands), an extensive maritime offshore area connected to large ocean basins and seas, and over 8200 islands (Short and Woodroffe, 2009; Australian Government - Geoscience Australia, 2016). Owing to their length and extent, Australia's coasts and marine waters contain a wide range of ecosystems.

Challenges in ensuring sustainable coastal management **(14.2)**, pollution management **(14.1)**, and a reduction in urban footprint **(11.6)**, together with the need for sustainable urban development **(11.3)**, safe and sustainable transport systems **(11.2)** and disaster risk reduction **(11.5)**, result from a combination of both human and environmental pressures (Stocker et al., 2012). Although the Australian coastline has many remote sections, about 85% of the population lives within 50 km of the coast; mostly along the east, south-east and south-west coast (Australian Bureau of Statistics, 2004, 2012, 2016). In contrast to regional inland areas which experience strong population decline, population growth is high in capital cities, most of which occur along the coast, and in non-metropolitan coastal areas (Australian Bureau of Statistics, 2016). This coastal migration trend, often referred to as the 'sea change' phenomenon and manifesting in increasing urbanisation of the Australian coastline with coast-specific developments such as 'canal estates' and waterfront housing (Harvey and Stocker, 2015), has been attributed to lifestyle decisions by residents as well as to financial interests of developers and to State government policies (Gurran and Blakely, 2007; Danaher, 2008). Leading to further coastal sprawl, these changes place many pressures on coastal systems (habitat degradation, pollution, changes in hydrology) as well as on social and community structures (Green, 2010; Harvey and Caton, 2010; Stocker, 2012). They also create demand for infrastructure developments **(11.2)** and challenges for coastal planning and management **(11.3, 14.2)** and climate change adaptation **(11.5)**, especially since most of these developments occur in low-lying coastal areas (Harvey and Stocker, 2015).

As in many other countries, the combination of pressures from urban development, flood mitigation measures, and the use of land and water in and around catchment areas and coastlines has changed enormously and even destroyed some Australian coastal ecosystems **(14.2)** (Australian Government, 2011; McDonald and Foerster, 2016). Low-lying coastal areas are frequently exposed to flood hazards and coastal erosion **(11.5)**, with climate change through sea-level rise increasing exposure and vulnerability to coastal hazards for metropolitan populations as well as for remote coastal areas (Harvey and Woodroffe, 2008; Australian Government, 2011). Australian coastal waters also contain important shipping routes (Harvey and Caton, 2010). Commercial and recreational fishing, and aquaculture are other coastal activities that create environmental concern (Harvey and Caton, 2010; Australian Government, 2011), with recreational fishing rated as more significant than commercial fishing in some regions (McPhee et al., 2002; Cooke and Cowx, 2006).

Protecting coastal environments and critical aquatic habitats **(14.2)** has been designated one of Australia's six national priorities under its 'Caring for our Country' programme (Australian Government, 2013). Important steps were taken on the protection and rehabilitation of coastal and aquatic ecosystems through increased community participation, the improvement of water quality, and the protection of Ramsar wetlands and highly valued ecosystems such as the Great Barrier Reef. This included efforts to address key threats to wetlands, to clean up estuaries and coastal hotspot areas, and to protect habitats for biodiversity and ecosystem services. Australia has also designated 36 marine and coastal wetlands under the 1971 Ramsar Convention, six marine and coastal World Heritage sites under UNESCO, and several small and large-scale coastal and marine protected areas **(14.5)**. Despite these achievements and recent efforts towards more systematic conservation planning, Barr and Possingham (2013) found marine conservation in Australia is lacking representation of the full range of ecosystems and their diversity. Conservation of coastal ecosystems is further challenged by conflicting interests and jurisdictional issues arising from multiple land-sea interactions and transboundary effects, calling for integrated land-sea conservation planning and management to tackle these challenges (Álvarez-Romero et al., 2011; Kenchington, 2016).

SDG 14 + SDG 12

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.1 ⟷ 12.1, 12.2, 12.3, 12.4, 12.5	Sustainable production and consumption, sustainable management of natural resources, recycling, and sound management of chemicals and wastes will help prevent marine pollution	+3	Develop integrated policies and action plans on marine litter Promote circular economies and improve recycling along the entire value chain, including streamlining the prevention of marine litter into policies related to consumption and production
14.4 ⟷ 12.2, 12.3	Sustainable fisheries contribute to sustainable management of natural resources. Specific management measures, such as discard bans or selective fishing methods reduce food losses along the production chain	+3	Develop fisheries policies based on maximum sustainable yield, promote the adoption of sustainability and discard elimination targets for all fish stocks and support context-specific technical innovation for resource efficiency
14.4 ⟷ 12.6	Adoption of labelling schemes and voluntary codes of conduct by companies by the fishing industry will help support sustainable fisheries	+1	Promote and establish sound seafood eco-labelling
14.7 ⟶ 12.2, 12.3, 12.a	Increase in benefits for SIDS from sustainable use of marine resources can enable sustainable management and efficient use of natural resources, a reduction in food wastes, and strengthened scientific and technological capacity	+3	Strengthen capacities for impact assessment and sustainable management of fisheries and aquaculture Establish incentives for sustainable and resource-efficient use of marine resources and coastal areas

KEY POINTS

Many close synergies between SDG14 and SDG12 with some targets inextricably linked in both directions

Sustainable management and protection of marine and coastal ecosystems, and sustainable fishing practices can lead to more efficient use of natural resources and less food waste and loss

Sustainable consumption and production patterns (in agriculture, industry, private households) can help prevent and reduce marine pollution, minimise the effects of ocean acidification, and protect marine and coastal ecosystems

KEY INTERACTIONS

SDG14 has close synergistic positive links with SDG12 (ranging from 'enabling' over 'reinforcing' towards 'indivisible' interactions at the target-level). Achieving sustainable fisheries, restoring stocks and ending IUU fisheries **(14.4)** will contribute to sustainable management and efficient use of natural resources and is therefore indivisible for reaching **target 12.2** and reducing food waste **(12.3)**. Likewise, increasing economic benefits to SIDS from sustainable natural resources **(14.7)** reinforces the achievement of **targets 12.2** and **12.3**. The marine environment is at the receiving and accumulating end of consumption and production chains. Land-based pollution, such as nutrients from agriculture and input of wastes, is among the key impacts on the marine environment. Tackling marine pollution **(14.1)** (especially from land-based sources) to protect marine ecosystems, habitats and species from harmful effluents and discharges, involves better waste management and sustainable chemical policies, and will enable the achievement of environmentally sound management of chemicals and wastes **(12.4)** and a move towards a circular economy **(12.5)**.

A reduction in food waste at the retail and consumer level will support more sustainable, less output-orientated forms of agriculture (e.g. organic or small holder farming) and so reduce land-based pollution, such as from nutrients. Sustainable and efficient use of natural resources and recycling will decrease fossil fuel use (e.g. from smelting or maritime transportation), and so help reduce ocean acidification. Tackling marine pollution requires a transformation of production chains which will encourage companies to develop and improve their sustainability policies **(12.6)**. Increasing the role of ecolabels as a tool to drive sustainable fisheries **(14.4)** is an additional enabling factor.

KEY UNCERTAINTIES

(1) The effects of land-based pollution and the sources of pollutants have been well studied in many parts of the world. Nevertheless, monitoring data for specific types, amounts and sources are lacking for many regions. (2) There are also uncertainties concerning links with ecosystem dynamics as well as with management and governance across sectors to address land-ocean interactions.

KEY DIMENSIONS

Time: The necessary transformational changes will require substantial efforts and time. Achieving sustainable management and protection of marine and coastal ecosystems by 2020 seems unrealistic in light of the time frame for **target 12.3** (sustainable management of natural resources by 2030). Achieving sustainable fisheries by 2020 will contribute to achieving sustainable natural resource use by 2030. Also, pollutants such as plastic debris, remain long-term in the environment if not removed, leading to considerable time lags for environmental responses to measures with regard to sustainable consumption and production patterns.

Geography: Over 70% of the planet's surface is covered by oceans, and 20 of 31 megacities with more than 8 million people are within the low-elevation coastal zones (Brown et al., 2013). Consumption and production patterns in coastal communities and megacities will greatly affect ocean sustainability. At the same time, development in SIDS will be crucial given their large proportion of ocean space.

Governance: Ocean governance is based on the legal and institutional framework established under UNCLOS. Many pressures and drivers of ocean decline are located on land, outside the mandates of marine management organisations. Greater integration between legal governance regimes for land, air/climate and the ocean will create synergies for SDG14 and SDG12. Voluntary or market-based policy approaches can foster better goal achievement.

Technology: Technology is central to sustainable aquaculture, resource efficiency and a circular economy.

Directionality: Bi-directional, but asymmetric for some targets. Sustainable fisheries will directly support sustainable management and efficient use of natural resources. For many pressures, the marine environment is the end point for pollutants from unsustainable production and consumption patterns on land.

ILLUSTRATIVE EXAMPLE
G7 ACTION PLAN TO COMBAT MARINE LITTER

Marine litter is one of the main contributors to marine pollution. Plastics are of growing concern owing to their persistence in the marine environment and to their impacts on wildlife and potentially, humans consuming marine proteins. In 2010, 275 million tonnes of plastic waste were estimated to have been generated by 192 coastal countries, with 4.8–12.7 million tonnes of this entering the ocean (Jambeck et al., 2015). Key factors for the largest amounts of marine litter from countries were population size and the quality of waste management. Under a business-as-usual scenario, the cumulative amount of plastic waste entering the ocean from land-based sources could increase by an order of magnitude by 2025 (Jambeck et al., 2015). The input is not expected to peak before 2100, and without drastic transformative action in line with SDG12 the amount of waste generated will continue to grow with increased population and increased per capita consumption associated with economic growth (Hoornweg et al., 2013, 2015).

Growing public awareness has led to widespread action at different scales and by different actors, including 'fishing for litter' initiatives by civil society organisations, scientific research programmes, national strategies and measures by governments or action plans by international organisations such as the Regional Seas Conventions. The impacts of marine litter on ocean sustainability were recognised by the 2030 Agenda. Namely, pollution from land-based activities, including marine debris and nutrient pollution **(14.1)** and floating plastic debris **(14.1.1)**. Recent studies have also shown the toxicity of microplastics, for example leading to reduced fertility of marine organisms (Cressey, 2016).

In 2015, the Heads of State and Government of the seven strongest economic countries addressed the effects of marine pollution from litter and adopted the G7 Action Plan to Combat Marine Litter. The Action Plan includes several actions that enable the achievement of **target 14.1** through addressing sustainable consumption and production patterns. It reflects the need to take action outside the traditional regulatory scope of regional seas conventions or other ocean governance bodies and supports an integrated, cross-sectoral approach to reducing marine pollution. Although primarily aimed at reducing marine litter there are strong interdependencies with SDG12 and reinforcing feedbacks can be expected if implemented coherently, particular for **targets 12.1, 12.4, 12.5, 12.6, 12.8** and **12.a**. Actions that support **target 14.1** and at the same time directly contribute to SDG12 include: improving countries' systems for waste management, reducing waste generation, and encouraging reuse and recycling (**12.1, 12.4. 12.5**); incorporating waste management activities into international development assistance and investments and supporting the implementation of pilot projects where appropriate (**12.1, 12.a**); investigating sustainable and cost-effective solutions to reduce and prevent sewage and stormwater-related waste, including microplastics entering the marine environment (**12.1, 12.4**); promoting relevant regulations and incentives to reduce the use of disposable single-use and other items, which impact the marine environment (**12.1, 12.4, 12.5**); encouraging industry to develop sustainable packaging and remove ingredients from products to gain environmental benefits, such as by voluntary phase-out of microbeads (**12.1, 12.5, 12.6**); promoting best practice along the whole plastics manufacturing and value chain from production to transport, such as aiming for zero pellet loss (**12.1, 12.6**); assessing and analysing removal data to support and target outreach efforts, potential policy options, and other means of preventing litter (**12.1, 12.8**); promoting outreach and education activities leading to individual behaviour change that can reduce the amount of litter entering the environment, internal waters and the seas (**12.1, 12.8**); supporting the initiation of a harmonised global marine litter monitoring effort and the standardisation of methods, data and evaluation (**12.b**); supporting efforts by the United Nations Environment Programme and other organisations to help understand the sources, pathways and impacts of marine litter (**12.1, 12.8**); and supporting and calling for additional research initiatives to address marine litter (**12.a**).

SDG 14 + SDG 13

TARGETS	KEY INTERACTIONS	SCORE	POLICY OPTIONS
14.1, 14.2, 14.3, 14.4, 14.5, 14.6 ⟷ 13.1	Action taken to strengthen the health of coastal and marine ecosystems including fish stocks will reinforce the strengthening of environmental and societal resilience and adaptive capacities to climate change, and vice versa	+2	Enforce climate mitigation measures Take action to protect, restore and strengthen the mitigation and adaptation potential and resilience of coastal and marine ecosystems to climate change Ensure the adequate sharing of information, data and technologies Improve education and build awareness of the benefits arising from sustainable management and conservation of marine and coastal ecosystems for climate change mitigation and adaptation
14.2, 14.3, 14.5 ⟷ 13.2, 13.a, 13.b	Action taken for promoting healthy oceans and coastal systems will also enable or even reinforce the development and integration of climate change measures into policies, planning and management, such as by promoting coastal ecosystems serving as blue carbon systems, and vice versa	+1/ +2	Promote coastal ecosystems as blue carbon systems for climate change mitigation where appropriate Provide and sustain capacity building and support to LDCs and SIDS in developing and implementing sustainable projects for mitigation, adaptation and resilience building Ensure the adequate sharing of information, data and technologies
14.2, 14.3, 14.4, 14.5, 14.6 ⟵ 13.1, 13.2, 13.3	Policies and measure taken to adapt to climate change may counteract or even cancel SDG14 targets aiming at the protection and conservation of coastal ecosystems, such as if technical protection measures fail to provide enough space for saltmarshes to keep up with sea-level rise (coastal squeeze)	-2/ -3	Ensure coherent and integrated coastal zone management and coastal protection management Develop nature-based solutions that promote both coastal and marine conservation and sustainable urban development in an integrated way
14.a ⟷ 13.3, 13.b	Increasing marine scientific knowledge, research capacities and technologies will enable or even reinforce awareness raising and capacity building for climate change mitigation measures, planning and management, and vice versa	+1/ +2	Build human and institutional capacity and ensure participation of relevant stakeholders and societal actors in policymaking and management Build transdisciplinary partnerships for climate change action and programmes Develop, maintain and support early warning systems on coastal and marine hazards

KEY POINTS

Oceans and coasts are closely linked with mitigation and adaptation action on climate change and related hazards, resulting in strong synergistic and bi-directional links between SDG14 and SDG13 over various targets

Strong synergies exist between SDG14 and SDG13 in terms of capacity building, knowledge exchange and technological innovation. Investment in these areas under either goal will support the achievement of targets under both, as well as the achievement of targets relevant to building resilience and adaptive capacity

Failing to tackle SDG13 will have major consequences for oceans and coasts; however, sustainable use and conservation of oceans and coasts and their resources can contribute to climate change mitigation and adaptation

KEY INTERACTIONS

Oceans and coastal ecosystems are essential elements of the Earth system, and have an important role in climate regulation (Heckbert et al., 2011; Visbeck et al., 2014). Coastal ecosystems such as mangroves have great potential for climate mitigation through carbon sequestration (Luisetti et al., 2013; Warner et al., 2016) and for adaptation by providing protection from coastal hazards and climate change impacts such as sea-level rise and increased storminess (Agardy et al., 2005; Spalding et al., 2014). They also deliver important maintenance services for fisheries, such as by providing nursery grounds for fish (Brander et al., 2012). These processes and services contribute to building resilience to climate change both for the human and environmental components of this tightly coupled system.

But marine and coastal ecosystems and coastal regions are also directly affected by climate change (Rhein et al., 2013; Pörtner et al., 2014; Wong et al., 2014; Stocker, 2015). Ocean warming and ocean acidification or changes in ocean circulation patterns will have potentially large impacts on marine and coastal ecosystems. These range from degradation of coral reefs to changes in species composition and distribution, with potentially critical effects for fish stocks and fisheries (Pörtner et al., 2014; Visbeck et al., 2014; Wong et al., 2014). Coastal ecosystems and human coastal communities are increasingly exposed to the effects of sea-level rise and extreme events, especially through coastal flooding and erosion or saltwater intrusion into coastal aquifers. Coastal ecosystems may be unable to cope with the rate at which sea-level is rising and changes in light availability, salinity or circulation patterns are occurring, risking degradation or even ecosystem loss and possibly reducing the protection and mitigation potential of coastal ecosystems (Wong et al., 2014).

Cumulative impacts from direct and indirect (via climate change) human pressures on marine and coastal ecosystems are potentially large and require concerted action in both directions of SDG14 and SDG13. Strengthening the resilience of ocean and coastal ecosystems by reducing pollution **(14.1)**, restoring their health **(14.2)**, tackling ocean acidification **(14.3)**, managing fish stocks sustainably **(14.4, 14.6)** and protecting coastal and marine areas and biodiversity **(14.5)** helps strengthen the overall resilience and adaptive capacity of coastal systems to climate change **(13.1)**. It will also co-facilitate the integration of climate change measures into policies and planning **(13.2)**, the promotion of mechanisms for raising capacity to climate change-related planning and management **(13.b)**, and the implementation of commitments on climate mitigation taken under the United Nations Framework Convention on Climate Change (UNFCCC) **(13.a)**. Increasing research capacity, scientific knowledge and marine technology **(14.a)** can contribute to developing capacity on climate change adaptation and mitigation **(13.3)** and to effective climate change planning and management **(13.b)**, especially in coastal LDCs and SIDS. In turn, targets under SDG13 that aim at building resilience to climate-related hazards **(13.1)**, integrating climate change measures into policies **(13.2)**, improving education, awareness and institutional capacity **(13.3)** and addressing the needs of developing countries under the UNFCCC **(13.a)**, for example with regard to adaptation measures, may support sustainable ocean management and conservation **(14.2, 14.5)**. Targets under SDG13 may also help reduce ocean acidification **(14.3)**, and have positive impacts on fisheries **(14.4, 14.6)** and economic benefits for SIDS and LDCs **(14.7)**. Trade-off are possible depending on how measures are aligned between SDG14 and SDG13.

KEY UNCERTAINTIES

There are uncertainties linked to natural dynamics, the complexity of interlinkages within the natural system and between the natural and the human systems, and to management and good governance.

KEY DIMENSIONS

Time: (1) The timing of ocean and coastal restoration and conservation depends on natural dynamics and the level of degradation. Building capacity takes time but has a long-term effect. (2) Climate change-related planning and management, and adaptation and mitigation measures, have different time scales of implementation and effect and should thus always complement each other.

Geography: Interactions primarily concern island and coastal zones, but are also of global importance owing to the relevance of marine and coastal systems for global climate regulation.

Governance: Ocean sustainability needs integrated governance such as coordination of regulatory measures and incentives among different sectors and across different scales. Besides climate change adaptation and mitigation and the overall strengthening of the health and resilience of coastal and marine systems in the context of climate change, this also includes energy and technology or consumption and production patterns.

Technology: Outcomes depend on technology transfer for capacity building, but also on the development of technologies and measures in consideration of the complexity of the system.

Directionality: While positive synergistic and bi-directional interactions occur between SDG14 and SDG13, there is also potential for negative interactions. The strength of impacts, synergies and trade-offs often depends on the degree of policy and management integration between both goals.

ILLUSTRATIVE EXAMPLE **THE PARIS AGREEMENT**

The fundamental global agenda for combating climate change is the United Nations Framework Convention on Climate Change (UNFCCC, 1992). The most recent agreement under the UNFCCC, the Paris Agreement, entered into force on 4 November 2016. This agreement "aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" (UNFCCC, 2015). Key elements of the Paris Agreement of relevance to oceans and coasts, their contributions to SDG13 and the achievement of SDG14 include the following.

Holding the increase in global temperature to below 2°C and aiming for a maximum of 1.5°C above pre-industrial levels (Art. 2). This long-term temperature goal will support the achievement of targets that aim at healthy and resilient marine and coastal ecosystems **(14.2, 14.5)** and those that promote sustainable fisheries management **(14.4, 14.6)** and economic benefits for SIDS and LDCS **(14.7)**. Although science has issued warnings that the agreed temperature limits could have critical effects on the Earth system (Knutti et al., 2016), slowing global warming will support the overall strengthening of resilience and adaptive capacity of the natural system and the human system towards climate change **(13.1)**.

Targeted reduction of emissions and achieving of a balance between greenhouse gas emissions and sinks in the latter half of the 21st century, including successful preparation, communication and maintenance of Intended Nationally Determined Contributions (INDCS) as established under Art. 4. Reducing greenhouse gas emissions and concentrations in the atmosphere is fundamental for minimising ocean acidification **(14.3)**, and the required INDCS relate directly to **targets 13.2** and **13.3**.

Conserving and enhancing sinks and reservoirs of greenhouse gases (Art. 5) and establishing mechanisms to contribute to the mitigation of greenhouse gas emissions and to support sustainable development (Art. 6). These elements have synergistic links to **targets 14.2** and **14.5** when considering the carbon sink potential of coastal ecosystems and the need to protect, conserve or restore this potential. Such mechanisms could also be established under **target 13.b**.

Strengthening adaptation options and "enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change, with a view to contributing to sustainable development" (Art. 7). This is a direct link to **target 13.1**, but also contains an indirect and synergistic link to SDG14 targets working towards healthy and resilient marine and coastal ecosystems **(14.1, 14.2, 14.5, 14.4, 14.6)**.

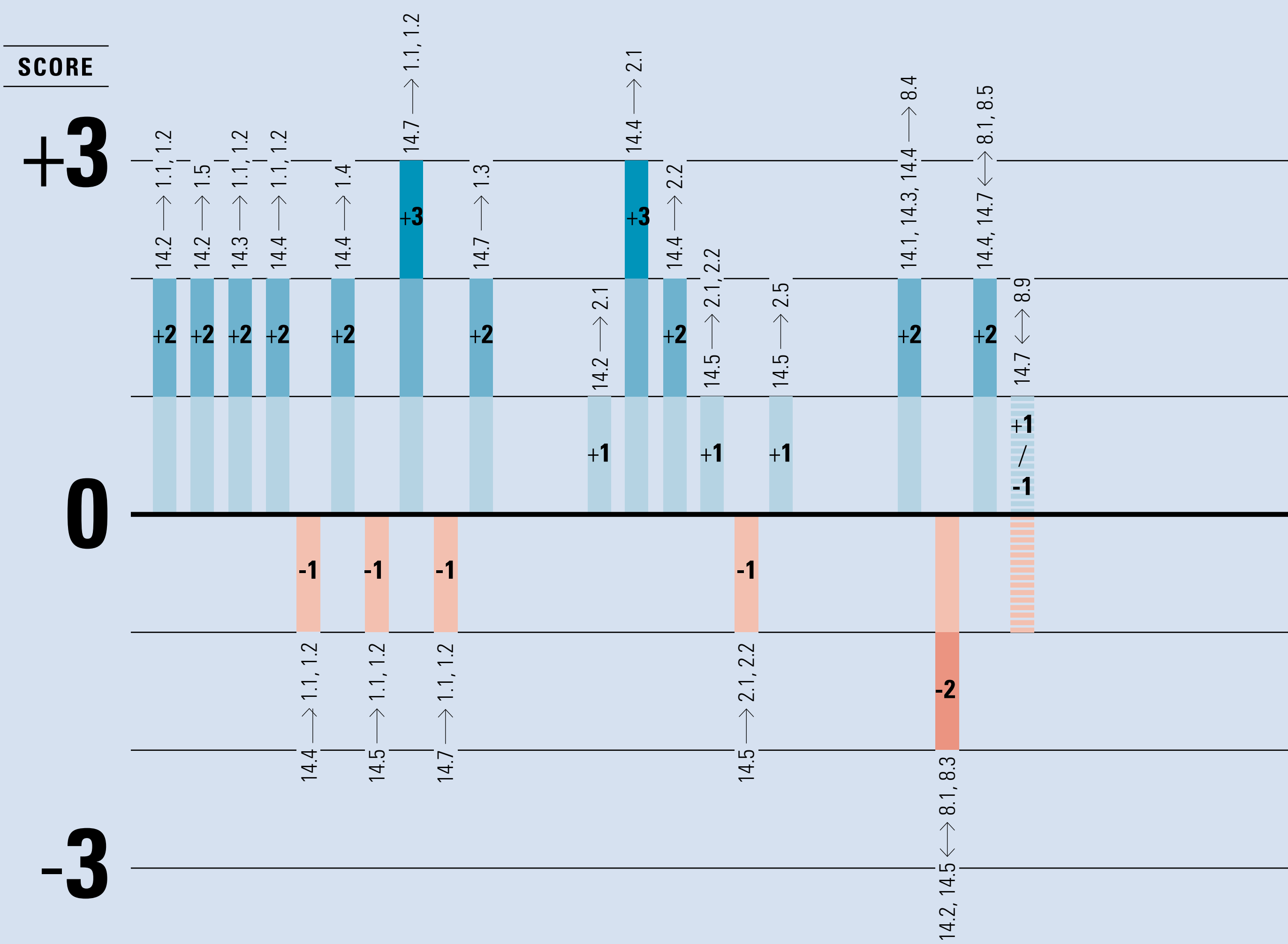
Addressing loss and damage "associated with the adverse effects of climate change, including extreme weather events and slow onset events, and the role of sustainable development in reducing the risk of loss and damage" (Art. 8). This directly links to both SDGS by addressing the protective potential and mitigation potential of coastal ecosystems **(13.1, 14.2, 14.5)**.

Reaffirming the obligations of developed countries for supporting developing Parties in their efforts on mitigation and adaptation to climate change through finance and voluntary support, technology transfer and capacity building (Arts. 9, 10, 11). These goals directly link to all targets under SDG13 but measures taken here will also benefit the achievement of SDG14 due to the central role that oceans and coasts play in the climate system.

Implementing the Paris Agreement will thus support achieving SDG13 and SDG14 and the 2030 Agenda as such. However, aligning policies and developing integrated approaches will be essential for ensuring the best possible outcomes and for minimising potential trade-offs.

KEY INTERACTIONS
SDG 14 WITH OTHER GOALS

+ SDG 1 + SDG 2 + SDG 8



+ SDG 11
+ SDG 12
+ SDG 13
SCORE
+3
0
-3
14.1 ⟷ 11.1, 11.3, 11.6
14.2 ⟷ 11.1, 11.3, 11.4, 11.5, 11.6
14.3 ⟶ 11.4
14.2 ⟷ 11.1, 11.2, 11.3
14.2, 14.5 ⟷ 11.c
14.5 ⟷ 11.1, 11.2, 11.3
14.1 ⟷ 12.1, 12.2, 12.3, 12.4, 12.5
14.4 ⟷ 12.2, 12.3
14.4 ⟷ 12.6
14.7 ⟶ 12.2, 12.3, 12.a
14.1, 14.2, 14.3, 14.4, 14.5, 14.6 ⟷ 13.1
14.2, 14.3, 14.5 ⟷ 13.2, 13.a, 13.b
14.a ⟷ 13.3, 13.b
14.2, 14.3, 14.4, 14.5, 14.6 ⟵ 13.1, 13.2, 13.3
+2
+2
+2
-1 / -2
-1 / -3
-1 / -2
+3
+3
+1
+3
+2
+2 / +1
+2 / +1
-2 / -3

KNOWLEDGE GAPS

Knowledge gaps exist in relation to all SDG14 targets and their interactions with other targets in the 2030 Agenda. The reasons for these gaps and their dimensions vary. In some cases (such as food security and sustainable fisheries, or maritime industries and job creation), interactions have already been analysed and are regularly monitored in many marine regions and countries. In contrast, for example in the relation between marine conservation and poverty alleviation or between marine ecosystems and climate change, knowledge is limited, fragmented or exists only in generic terms often not updated on a regular basis. The knowledge gaps that exist are not always caused by lack of data or information but also access restrictions, lack of standardised data collection protocols, lack of coordination across political or sectoral boundaries, or by capacity limitations for the analysis and translation of data and other types of information into policy advice.

In general terms, integrated research, monitoring and data analyses will be needed in combination with targeted capacity development to fill existing knowledge gaps. Having regard to limited resources especially in SIDS and LDCs, consideration should also be given to the development and applicability of data-poor assessment approaches and models. Sea-basin based open-access platforms to marine data should be created. They could for example be developed based on existing platforms or as joint initiatives by member states and existing regional organisations. They should be interoperable and free of restrictions on use, with the specific target of developing an integrated information base on oceans, seabed resources, marine life, and risks to habitats and ecosystems. The table provides a non-exclusive list of knowledge gaps that have been identified in relation to the target-level interaction analysis provided in this chapter.

14 + 1

The social and economic value of oceans, ecosystem services, and risk analysis (in relation to extractive industries) in low-income countries within their coastal waters and EEZs

The impact of an expansion in blue jobs, value addition, and new technologies on jobs in traditional sectors

Options to maintain fish stocks at biologically sustainable levels by limiting fishing effort while ensuring profitability
Human and institutional capacity gaps in low-income countries

14 + 2

Under- or misreporting of landings of artisanal catches in low income countries
Stock assessments in artisanal fisheries in low-income countries

14 + 8

How marine ecosystem services link to economic and social development in concrete terms and how this changes over time. Especially in developing countries, this links to limited expertise on valuation techniques, their application and collection of the necessary data

How to minimise negative effects of economic and social development on marine ecosystems

The potential for sustainable blue growth in individual marine regions, sea basins and countries

The value of ecosystem services (especially non-marketed ones) and how to integrate monetised and non-monetisable values for policy analysis and reporting

14 + 11

How increased coastal development, urbanisation and coastal environments interact and influence each other
How urban and regional planning and fiscal policies influence the coastal environment and vice versa, and how to develop integrated cross-boundary governance (i.e. across the land-sea nexus) and across administrative boundaries and jurisdictions

Gaps in capacity, especially in developing countries, for ensuring sustainable human settlement planning and regional development

14 + 12

The status of stocks and fisheries including the level of discards and how they should be managed to provide for maximum sustainable yield

How aquaculture affects marine systems in specific contexts, particularly with regard to inputs of chemicals and nutrients to the marine environment and to effects on wild fish stocks and how these can be reduced

How to minimise post-harvest loss in seafood production and supply chains, especially through small-scale artisanal fisheries

How to achieve better waste management, recycling and reduce marine pollution of all kinds, including marine debris

How human health is affected by the release of microplastics to the marine ecosystems

14 + 13

What are the effects and impacts of the long-term temperature targets established under the Paris Agreement, on oceans, seas, coasts and their ecosystems

What are the impacts of climate change on the health of marine ecosystems, habitats and species in low-income countries, and how can these be mitigated or reduced

How resilient are marine and coastal ecosystems to climate change, and what are suitable and effective conservation and management measures to provide climate mitigation, nature-based adaptation and the reversion of negative effects such as coral bleaching

The influence of climate change on fish stocks

CONCLUDING COMMENTS

SDG14 plays a cross-cutting role in the 2030 Agenda, interacting with many other SDGs. Transformation towards more integrated and aligned policies and measures in response to these interactions, backed by tailor-made capacity building and strengthened institutions, is a prerequisite for achieving the 2030 Agenda.

Progress has been made towards more integrated governance of the ocean. However, silo-based decision-making often irrespective of ecosystem-dynamics and meaningful ecological boundaries still prevails in many cases. Decision-making needs to take due account of the environmental dimension as an indispensable enabler for sustainable development and ensure that this dimension is not lost when negotiating between conflicting goals and targets, especially in relation to potential trade-offs and conflicts. To date, degradation of the marine environment has outpaced development of the international ocean governance landscape. Achieving SDG14 and its associated targets, and other SDGs where the ocean plays a crucial role will thus depend on a robust implementation framework, including mechanisms for tracking commitments, regional cooperation and integrated thematic assessments (Unger et al., 2017).

Building on these general considerations, the six summary tables in the target-level interactions section provide options for how policy could address the specific target interactions in practice. Although addressed to specific target interactions, many of these policy options are also relevant for other interactions.

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LOOKING AHEAD

NEXT STEPS

The conceptual framework and assessment of key interactions of the four goals presented in this report are intended as a starting point for further work towards a more complete understanding of how the sustainable development goals (SDGs) fit together. The proposed framework guides a more detailed analysis and enables structured deliberations on how to implement the 2030 Agenda coherently, in order to maximise development outcomes. Making interactions explicit and understanding the full impacts of policies and actions across goals stimulates important knowledge gathering and learning processes, and has very concrete and tangible value for achieving efficiency and effectiveness in SDG implementation, for driving meaningful multi-stakeholder partnerships, and for country level monitoring, evaluation and review. The SDGs as an internationally-agreed single agenda with a 2030 time horizon integrating many policy dimensions provides a convergence point to support collaboration across scientific, policy and practitioner communities.

REFLECTIONS ON THE SEVEN-POINT SCALE AND METHODOLOGY

The report presents a typology and an approach to scoring SDG interactions that can be replicated and refined for each and every goal, and importantly, at different geographical scales, whether global, regional, national or sub-national, with varying data and evidence availability.

The framework on which this work is based identifies causal and functional relations underlying progress or achievement of the sustainable development goals and targets: positive interactions are assigned scores of +1 ('enabling'), +2 ('reinforcing') or +3 ('indivisible'), while interactions characterised by trade-offs are scored with -1 ('constraining'), -2 ('counteracting'), or -3 ('cancelling'). By systematically assessing the interactions and relationships between goals and targets, this report supports horizontal coherence across sectors.

The approach taken relied on an interpretive analytical process whereby research teams combine their knowledge and expert judgment with seeking of new evidence in the scientific literature and extensive deliberations about the character of different specific interactions. A potential caveat emerged in that even when starting from similar understandings about interactions and the main conceptual underpinnings of the framework, the different teams landed in somewhat varying interpretations of how to apply the framework and score interactions. This poses a challenge in terms of replicating the study.

Nevertheless, a strength of the approach was that it generated a highly iterative process for deepening the understanding of target interactions. Each team had valuable debates about the terms of the scale and several revisions were made to scores in different chapters over the course of the work. In fact, in many respects it could be argued that the process of deciding on the score was possibly more valuable than the final result, since it required a detailed study of the literature, a consideration of the issues and potential context dependencies, a review of limitations and gaps in current knowledge, and discussion with others. To this extent, the assessment becomes a vehicle for triggering dialogue interpretation and learning process.

Based on this assessment, there should be ample potential for carrying out similar interaction assessment exercises among governments and other societal stakeholders concerned with SDG implementation, as well as in the country or regional contexts where there are limited data and evidence.

RECOMMENDATIONS TO POLICYMAKERS

Based on the analysis, four recommendations to better identify and manage interactions across SDGs to inform planning and implementation stand out:

1. SYSTEMATICALLY IDENTIFY THE INTERACTIONS BETWEEN AND AMONG THE 17 GOALS TO INFORM PRIORITY-SETTING IN A GIVEN CONTEXT

This could take the form of a matrix including the 17 goals where at each intersection the most significant interactions at target-level are identified and scored using the seven-point scale. Identifying *a priori* the most relevant interactions requires bringing together a wide range of expertise spanning goals, disciplines and sectors.

Building such an exercise into the planning for national implementation of the SDGs would provide a useful overview of key interfaces between goals, and support the management of interactions across government departments, for example, through early identification of potential conflicts. Key interlinking targets that operate as connectors or enablers can also be identified – even if they may not be singled out initially as key priorities in a particular context – thus helping to develop a more joined-up narrative of what it will take to achieve the SDGs as a whole.

It would help governments in their priority-setting by emphasising where the achievement of one objective will not be possible without simultaneous or even preliminary action on others, thus informing how to plan sequencing of actions for optimal impact, and highlighting needs for integration between policy areas or jurisdictions. For instance, tackling urban air pollution requires determined action to move away from fossil fuels as well as achieving energy efficiency targets in the transport, housing and industrial sectors.

Beyond the particular scores determined in such an assessment exercise, the *process* of collectively mapping interactions and scoring the degree of interdependency is valuable in itself. By providing a common terminology and methodology, it encourages cross-sectoral and cross-disciplinary conversations that go beyond a traditional, siloed approach.

2. MAP EXISTING INSTITUTIONS AND ACTORS TO ASSESS STRENGTHS AND WEAKNESSES OF STATUS QUO FOR DELIVERING THE SDGS

Mapping the existing institutional landscape in a particular country/context and identifying key actors for implementing the SDGs is needed to assess the extent to which the existing institutional set-up is fit for purpose to deliver on the SDGs and address their interactions. If certain targets are in conflict with progress in targets under other goals, then governance mechanisms must be put in place to manage these interactions and address potential tensions and conflicts. For example, if the Ministry of Agriculture puts food security through agricultural intensification as its key SDG2 target, while the Ministry of Water's target is to dramatically reduce agricultural water pollution under SDG6 and SDG14, and the Ministry of Environment's target is to reduce biodiversity loss and expand conservation zones under SDG15, then mechanisms must be put in place to negotiate how the sets of targets should be moved forward.

Moreover, it is widely recognised that while the responsibility of achieving the 2030 Agenda lies with countries, non-state actors have a key role to play. Understanding how the SDGs interact with one another can enable a better understanding of the roles stakeholders can play and harness meaningful partnerships for delivering on the SDGs. Based on key intervention points identified through the assessment of interactions, clusters of issues can be identified and provide a framework for cross-sectoral collaboration around a set of common priority issues.

Governments focus on multiple concurrent 'public good' goals, for which there are multiple beneficiaries and where the goods or services are not adequately provided by the private sector or non-profit sector. This is even more true of international goals, for example those designed to address global problems such as climate change and conflict. For example, when the United Nations Framework Convention on Climate Change works together with other international agencies such as the World Trade Organization, this global level of governance can be used for setting priorities based on critical global outcomes and provide a framework for nested and subsidiary levels of governance and policy.

3. ENACT CHANGE TO ENABLE HORIZONTAL MANAGEMENT OF SDGS

The SDGs' ambition and emphasis on integration, challenge current institutional and governance arrangements and require new mechanisms for driving policy integration and coherence. Leadership and the development of cross-cutting coordination mechanisms will be key to achieving this in practice. Some countries have already developed cross-ministerial and consultative mechanisms such as in Germany, Colombia or Finland. But this also needs to be aligned with decision-making and implementation processes, whether for resource allocation, data and information collection and sharing, support for research and innovation, or institutional and individual capacity development. How these processes develop will be country-specific.

4. APPLY AN INTEGRATED PERSPECTIVE TO MONITORING, EVALUATION AND REVIEW

Beyond the monitoring of individual targets and goals, what is needed is an integrated perspective to monitor progress towards achievement of the SDGs. At the outset, it is recommended to draw up an initial matrix of interactions to serve as a baseline. Data and information systems should be integrated in order to monitor interactions between targets. Ideally, there should be a definition of headline indicators to monitor progress across various SDG domains.

Assessment and scoring of interactions should be conducted at various stages in the planning and implementation of policies, as well as in the evaluation of policy outcomes. Using the initial matrix of interactions as a baseline, comparisons should be made in order to identify synergies and trade-offs within the implementation processes and to establish the extent to which it was possible to minimise trade-offs and maximise synergies.

The seven-point scale can therefore provide a basis for review and impact assessment, and makes it possible to identify important cross-cutting gaps in data and knowledge.

NEXT STEPS FOR THE SCIENTIFIC COMMUNITY

The scientific community has been focusing for a long time on deepening its understanding of social and ecological systems, and their interlinkages. This report represents a contribution towards this broad array of scholarly work. The following sections outline possible next steps and a few examples of ongoing initiatives that seek to develop the knowledge and solutions for addressing the SDGs in an integrated way.

1. CONTINUE TO GROW THE SCIENTIFIC EVIDENCE BASE

The SDGs highlight the need for more integrated research for sustainable development across natural, social, health sciences, economics and engineering. They also require a stronger drive towards transdisciplinary research. This report draws on the scientific literature on interactions related to the four SDGs explored in detail, and identifies a number of knowledge gaps. An important contribution that could be made by the scientific community is to continue growing and critically assessing new knowledge on individual or clusters of SDGs through observations, data sharing and integration, empirical research and context-sensitive analysis, theory development, modelling, and scenario development.

One way that scientists are organising themselves is through Future Earth, a ten-year international research initiative that aims to develop the knowledge for responding effectively to the risks and opportunities of global environmental change and for supporting transformation towards global sustainability in the coming decades. Future Earth mobilises the global scientific community while strengthening partnerships with policy-makers and other societal actors to co-design and co-produce new knowledge and solutions.

The growing body of sustainability science literature poses a challenge in itself in bringing synthetic, authoritative, timely and policy-relevant insights. The SDGs could be used as a knowledge management framework to mobilise and structure key scientific evidence in support of the SDGs. This could also take the form of thematic assessments, to support the implementation of all SDGs and make the scientific literature on interactions more accessible.

The scoring approach and synthesis work undertaken within this report points also to a need for a broad-based assessment of scientific knowledge on the SDGs and their interactions. Such comprehensive synthesis could build on the Global Sustainable Development Report, a United Nations report published every four years with the contributions of the scientific community.

2. APPLY A SYSTEMS APPROACH

This report has mostly focused on an examination of binary interactions. In other words, interactions between target A and target B, recognising that interactions can be far more complex, multidimensional and dynamic with feedbacks and unforeseen consequences. Further work on interactions could usefully apply a systems-approach.

A systems approach can be taken at various organisational levels depending on the goals and targets and the spillover to other goals and targets. For example, where policies such as agricultural intensification can have unintended consequences, such as nitrate or *E. coli* pollution of freshwaters, national governments then need to consider appropriate policy instruments.

One project that seeks to address the full spectrum of transformational challenges related to achieving the 17 SDGs in an integrated manner so as to minimise trade-offs and maximise benefits, is The World in 2050 (TWI2050). This global research initiative brings together a large consortium of researchers, modelling teams, and policymakers around the world to explore science-based transformational and equitable pathways to sustainable development combining quantitative and qualitative analysis.

Strengthening integrated science to deliver the knowledge and implementation pathways will require capacity building to work across disciplines and include non-scientists in research processes. It will also mean that scientists will need to work harder to bridge disciplines, knowledge systems, and find efficient ways to link and share datasets from diverse sources.

3. EMBED INTERACTIONS IN MONITORING AND REVIEW

Throughout the development process of the Sustainable Development Goals in the UN's Open Working Group, the importance of considering the SDGs as a whole rather than in isolation was emphasised. The Inter-Agency and Expert Group on Sustainable Development Goals Indicators tasked with providing a proposal for a global indicator framework for the follow-up and review of the 2030 Agenda highlighted the new data requirements for the monitoring of the SDGs and their 230 indicators agreed in March 2016 as well as the importance of interlinkages. Subsequently a working group has been established to look at interlinkages between goals and targets, and within the statistics underlying the indicators with a view to build a more integrated analysis of the economic, social and environmental developments related to the SDGs. The working group will conduct its work between 2016 and 2018.

One approach towards more integrated reporting is the proposal to develop a set of Essential Sustainability Variables (ESVs). The aim of these ESVs would be to provide a minimum set of integrated, headline indicators in which the indicators themselves focus on interactions between SDG goals and targets to ensure that they are addressed in an integrated fashion.

4. STRENGTHEN THE SCIENCE-POLICY INTERFACE

The scope of the ambition set by the 2030 Agenda calls for a wide mobilisation of expertise, resources, competences, and enthusiasm from the global to the national and local levels. One important dimension of this much-needed science-policy-society interface is the need to strengthen science advisory mechanisms to decision-makers at both the global and the national-level to support evidence-based decision-making and solution-building. Strengthening science systems at the national level and connecting scientists to decision-makers as well as strengthening capacities of scientists to engage in a timely and adequate manner to allow scientific evidence to be effectively used will be a critical enabler to navigate the complexity and the urgency of the SDGs.

ANNEX
THREE ILLUSTRATIVE EXAMPLES OF INTERACTIONS BETWEEN SDG 2 AND THE OTHER SDGS

Literature referred to in the texts may be found within the References section to the chapter on SDG2

THE COMPOUND CHALLENGES OF DEFORESTATION, FOOD AND ENERGY PRODUCTION FOR CLIMATE MITIGATION, ECOSYSTEM PROTECTION AND HEALTH IN THE AMAZON REGION

SUMMARY OF KEY TRADE-OFFS

Land use conversion for agriculture purposes such as cattle ranching or soybean production (2.3) **or biofuel production** (7.2) **may counteract the maintaining of ecosystems and forest conservation/protection** (15.1, 15.2, 15.5, 2.4)

Hydroelectric power generation (7.2), **can lead to the flooding of forested areas (especially constraining** 15.2) **and a decrease in agricultural productivity in the lowland Amazon floodplains (SDG2)**

Deforestation due to intense agriculture/pasture expansion, can counteract efforts to combat climate change (SDG13) and constrain climate adaption by increasing climate instability and extreme events (13.1). **Such a trend may be exacerbated by dams which also lead to an increase in greenhouse gas emissions**

Land use conversion for agricultural purposes (2.3) may constrain SDG3 due to an increase in exposure to malaria risk (3.3) **and/or mercury contamination of soil** (3.4, 3.9)

The Amazon is a typical example of a 'frontier economy' (Boulding, 1966) where economic growth, based on the perpetual conquest of land and resources, is sometimes seen as infinite (Becker, 2005). Deforestation to provide land for agriculture, cattle ranching and large-scale hydropower generation has been the prevailing model for rural development over the last 50 years (Nobre et al., 2016). In Amazonia, smallholder farmers play a critical role in the maintenance of global agrobiodiversity, and generally use few agro-chemicals (Kawa et al., 2015), but were responsible for up to 69% of Amazon deforestation between 2006 and 2011. Deforestation declined between 2004 and 2012, but increased sharply in 2016.

THE NEXUS FOOD-WATER-ENERGY-DEFORESTATION

Much of the total deforested area in the Brazilian Amazon (legal Amazonia) has been converted to pasture for cattle ranching, approximately 70–88% in 1995 (Margulis, 2004) and 62% in 2008 (Almeida et al., 2016). For Mato Grosso State, increased soybean production between 2000 and 2007 accounted for 12% of the deforestation, with 71% of newly cultivated soybean fields planted in formerly deforested areas. Since 2009, 46% of the increase in agricultural production was achieved through changes in agricultural management practices (Arvor, 2009). The effect of biofuel production on deforestation has not been assessed globally, but biodiesel from soybean in Mato Grosso may have been responsible for up to 5.9% of the direct annual deforestation over the past few years (Gao et al., 2011). On 24 July 2006, the Soybean Moratorium was signed, which effectively reduced the deforested land for soybean production. Since first agreed, the moratorium has been renewed every year, and it is currently renewed without end date (Greenpeace, 2016). Land use change pressures can be further reduced by investing in second generation biofuels and public transport, with positive impacts for the Brazilian economy (Obermaier M., pers. comm.). Large parts of the Amazon are suitable for palm oil production and profitable (Englund et al., 2015). Lack of interest in sustainability criteria in key consumer markets may worsen production standards in Brazil, including social sustainability of rural workers on the plantations. This illustrates the competition over land use and trade-offs between SDG2 (mainly the targets emphasising agriculture productivity improvement, such as 2.3) and the need to halt deforestation (**15.1, 15.2, 15.5**).

Intense agriculture based solely on short-term productivity without sustainability may counteract SDG targets related to forest conservation/protection. This negative interaction also illustrates the potential conflicts between the various SDG2 targets, where unsustainable agriculture productivity (**2.3**) may constrain the maintenance of ecosystems (**2.4**). Negative interactions of this type are exacerbated by biofuel production as a means of increasing the share of renewable energy in the energy mix (**7.2**).

Biofuel production is one of the strongest links between agriculture, deforestation and green energy (Kahn et al., 2014). Hydroelectric power generation is another. The Brazilian plan calls for 30 new large dams in the next 30 years (Brazil MME, 2011). This would cause the flooding of 12,000 km² of forested area (Fearnside, 2000). Apart from a significant increase in GHG emissions, well known in tropical countries (Kemenes et al., 2007), one of the consequences will be decreased productivity in the lowland Amazon floodplains due to the retention of nutrients by reservoirs. This endangers food production, because floodplains contain most of the traditional agriculture, coupled with fishing livelihoods (fish disappear after dam construction), hunting and forest product gathering, with major seasonal variations driven by the annual flood cycle, also affected by the dams (Barham et al., 1999).

In this case, water use to increase the share of renewable energy (**7.2**) via hydroelectricity, may also counteract the maintaining of ecosystems (**2.4**) and the pursuit of forest conservation/protection (**15.1, 15.2, 15.5**) and also constrain the capacity to reach food and nutrition security (**2.1, 2.2**) as well as the capacity for small-scale food producers to increase their food production and revenues (**2.3**).

CONSEQUENCES FOR CLIMATE CHANGE

Converting forest to pasture is estimated to result in an average temperature increase of 1.0–1.5°C in deforested area during the dry season due to the change in surface energy budget (Gash et al., 1996). Deforestation due to intense agricultural expansion highlights how **target 2.3** can counteract combatting climate change and can constrain climate adaption by increasing climate instability and disasters (**13.1**).

The impact of land use change on precipitation is not clear and needs further study. A possible explanation for the precipitation reductions observed in the last two decades over the southern and south-eastern Amazon could be the change in albedo between forests and pasture. In all countries with a large part of territory belonging to the Amazon (Brazil, Columbia, Peru, Bolivia, Ecuador), agriculture, forest and land use change account for over 83% of total GHG emissions. These countries rely heavily on agriculture and forestry for climate change mitigation (Börner and Wunder, 2012). However, mitigation solutions in these sectors imply a high level of technological complexity. Less demanding technology solutions to mitigate GHG emissions such as land retirement and primary forest conservation do exist but involve higher implementation costs for smallholdings than for medium to large farms.

CONSEQUENCES ON BIODIVERSITY STOCK DEPLETION

A study in the southwestern Amazon, indicates that post-logging timber species composition and the total value of forest stands do not recover beyond the first-cut, suggesting that the most valuable (in commercial terms) timber species become rare or even disappear in old logging frontiers (Richardson and Peres, 2016).

Intense agriculture expansion may thus constrain the achievement of SDG15 on biodiversity, and may in particular counteract **target 15.5** on the reduction of habitat degradation, halting the loss of biodiversity and the extinction of threatened species.

Aquatic biodiversity will decline as a direct result of Amazonian dam projects due to the loss, fragmentation and degradation of riparian and terrestrial habitats (Lees et al., 2016).

IMPACTS ON HEALTH

In the Tapajos Amazon region, conversion of forest to pasture results in soil erosion and the transfer of soil sediments into waterways, causing mercury pollution. Inorganic mercury, which is naturally present in the soil, is then transformed into methylmercury through bacterial activity and enters the aquatic food web, with the highest mercury concentrations occurring in the top predators at the ends of food chains. The majority of riverside dwellers eat fish several times per week. Methylmercury is a neurotoxin, and various studies have reported nervous system dysfunction associated with mercury exposure among these communities (Fillion et al., 2009). This example shows how land conversion for agriculture purposes aligned with t**arget 2.3** may constrain health, particularly the reduction of deaths and illness caused by hazardous chemicals **(3.9)** and the fight against non-communicable diseases **(3.4)**. A recent study on the border between Brazil and French Guiana summarised the links between land use change and an increase in exposure to malaria risk: deforested areas provide favourable conditions for malaria vector breeding and feeding, while forest and secondary forest can provide resting sites for adult mosquitoes after feeding. Consequently, the more the forest and secondary forest patches interact with deforested patches, the more the landscape is favourable to vectors and vector-human encounters (Li et al., 2016). This trend illustrates how deforestation for the purposes of conversion to another type of land use such as agriculture can counteract the ending of communicable diseases such as malaria **(3.3)**.

PUTTING SUSTAINABLE LAND MANAGEMENT AT THE HEART OF SENEGAL'S NATIONAL DEVELOPMENT STRATEGY

SUMMARY OF KEY SYNERGIES

Sustainable land management and improving land and soil quality (SDG2) can:

Reduce land degradation/ desertification and increase fertility and biodiversity protection (15.3)

Reduce soil erosion and maintain the physical structure of the soils and thus their water-holding capacity as well as regulating soil quality (6.6)

Sequester carbon and mitigate climate change (SDG13). Such co-benefit impact contribute to SDG2 food security targets as sequestered carbon, when mineralised, releases nutrients for plants

Play a major role in food security and poverty alleviation in urban and peri-urban areas (1.1, 1.2)

Summary of key trade-offs

Depending on soil quality, improving plant production may counteract action on climate change (SDG13)

Some agriculture practices can have adverse impacts on terrestrial ecosystems (SDG15). Strong international partnerships and capacity-building are key to mitigating such trade-offs (SDG17)

Intensive peri-urban agriculture using fertilisers and pesticides to increase productivity and therefore farming revenue (2.3) **constrains water quality** (6.1, 6.3) **and increases associated diseases** (3.9)

BACKGROUND

As is the case in many African countries, the population of Senegal is growing rapidly. Population is expected to triple between 2013 and 2050. This rapid growth is indicative of a marked demographic transition that is increasing demand for goods and services, and increasing pressure on natural resources and the environment.

Senegal is currently the second fastest growing economy in West Africa, behind Côte d'Ivoire (World Bank, 2017). In 2015, GDP grew by 6.5%, which had not been achieved since 2003. The fastest growing sector is the primary sector, boosted by growth in extractives, fishing, and agriculture. Exports from the primary sector are increasing rapidly.

West Africa suffered a long period of low annual rainfall between 1968 and 1998. This significantly reduced the availability of surface water and the recharge of groundwater, resulting in saltwater intrusion in the main coastal basins. However, the situation has now reversed, and average rainfall for the period since 2006 is greater than the average recorded for the period 1940–2012. According to the Senegalese Directorate of Management and Planning of Water Resources, water resources are now adequate in rivers, watercourses and underground. However, distribution and management of these resources are unsatisfactory. Less than 50% of the water available in the Senegal

River is estimated to be used for irrigated agriculture.

Climate models project that by 2050 average temperature in Senegal will have increased by 3–4°C. The greatest changes in rainfall are projected to occur in semi-arid regions. Rainfall during the cropping season is projected to drop by 20%, with the rainy season ending earlier (Sultan and Gaetani, 2014).

AGRICULTURE

Agriculture plays an important role in the national economy. It is the main economic activity in rural areas of Senegal. In the country as a whole, 60% of the working population is employed in agriculture. However, agriculture accounts for only a small proportion of GDP (8%).

LAND DEGRADATION

By ratifying the United Nations Convention to Combat Desertification in 1994, Senegal undertook to implement a National Action Plan (NAP). In its third report, the Ministry for the Environment and Nature Protection (Ministère de l'environnement et de la protection de la nature, 2004) assessed land degradation in Senegal, and showed that almost 60% of arable land was subject to degradation, mainly related to water scarcity and water erosion. Despite considerable investment efforts to implement the NAP, the report revealed that degradation had continued, increasing poverty.

NEXUS OF LAND DEGRADATION, FOOD SECURITY, CLIMATE AND WATER CHALLENGES

In 2014, Senegal adopted "a new development model to accelerate its progress toward emerging market status [which] constitutes the reference for economic and social policy […]" (Ministry of Economy, Finance and Planning, 2014: Executive Summary). In the agricultural sector, the successful implementation of priority actions, such as water management, improving soil quality and land reform depends on several factors. At the same time, by ratifying the Paris Agreement within the United Nations Framework Convention on Climate Change, Senegal undertook to reduce its global GHG emissions, some of which were generated by the agriculture sector, and to implement adaptation measures such as technologies to combat land degradation and access to drinking water.

SUSTAINABLE LAND MANAGEMENT: THE MANY BENEFITS PROVIDED BY SOIL ORGANIC MATTER

Soils provide many ecosystem services that are essential to communities and their environment. The role played by organic matter in soil functioning has now been clearly established (Feller et al., 2012; Banwart et al., 2014): it maintains fertility, assures primary production and maintains the physical structure of the soils and thus their water-holding capacity as well as regulating soil quality (SDG6). As the main carbon sink of terrestrial ecosystems, soils also regulate the exchanges of carbon dioxide and other GHGs between the soil and the atmosphere. Increasing organic matter stocks, therefore, helps to mitigate climate change (SDG13). However, it is also important that some of the organic matter stored in soils should be mineralised to ensure the release of nutrients, such as nitrogen, for plants, thus improving productivity (SDG2). Recent research (e.g. Wood et al., 2016) showed that different forms of soil organic matter do not have the same magnitude of effects on climate change mitigation or crop yield. There is, therefore, a trade-off between actions required to mitigate climate change (SDG13) and actions required to improve plant production (SDG2). Anticipating the impact of action plans on the targets associated with these two goals requires a detailed knowledge of the processes that determine soil organic carbon dynamics. Such knowledge can help to reinforce synergies within the nexus and mitigate or even overcome some constraints and trade-offs between the goals.

In West Africa and Senegal, sustainable land management is the core issue of action plans to combat land degradation. These plans focus on water management (SDG6), fertility and biodiversity (SDG15) (Liniger et al., 2011). In these regions, the viability of production systems depends to a great extent on the management of organic residues (crop residues, manure, etc). In savanna regions, production systems are organised as a ring around the villages (Manlay et al., 2004) with a gradual increase in intensification from the savanna area towards the centre of the village. This spatial organisation and the recycling of organic residues are key for soil organic matter stocks (Manlay et al., 2004). Because regions with sandy soils have a low storage capacity, increasing productivity should be the priority target of agricultural action plans. In 2010, the Senegal Ecological Monitoring Centre, together with its partners, published a set of best practices for sustainable land management in Senegal (CSE, 2010). This showed the diversity of existing practices, highlighting the potentially harmful effects of some practices on other aspects such as biodiversity (SDG15). Although these best practices exist, Botoni and Reij (2009) stressed that upscaling them requires a strong international commitment (SDG17: Strengthen the means of implementation and revitalise the global partnership for sustainable development) and the use of dedicated funds to fully meet the multiple challenges of combating land degradation, ensuring food security, water management and mitigation of, and adaptation to, climate change.

GOVERNANCE OF LAND TENURE: A SAFEGUARD TO AVOID HARMFUL IMPACTS

According to the FAO, "The eradication of hunger and poverty, and the sustainable use of the environment, depend in large measure on how people, communities and others gain access to land, fisheries and forests" (FAO, 2012: Preface). De Schutter (2011) pointed to the need for security of land tenure to ensure national food security, and stressed the importance of not transposing the Western model of property rights to resolve competition for land between local communities and companies willing to invest in agriculture in developing countries.

To meet this challenge of rational land governance, Senegal has drawn up Land Occupation and Use Plans, for example for the Lac du Guiers region (see http://ppr-srec.org/fiches-actions/observatoire-participatif-de-veille-sur-le-foncier-opvf-phase-pilote-dans-la-zone-du-lac-de-guiers-au-senegal.html).

SOCIAL AND ENVIRONMENTAL LINKS BETWEEN URBAN, PERI-URBAN AND RURAL AREAS

In 1976, 34% of the population in Senegal lived in cities (République du Sénégal, 2014). By 2013, this had increased to 49%, with around 50% of this urban population concentrated in Dakar. Urbanisation has thus accelerated during recent decades. There are many complex factors explaining the increased number of people living in cities in Senegal. However, Gueye et al. (2015) showed that drought has had a major impact on migration to cities. Successive droughts (1970–1973, 1976–1977, 1983–1984) had an almost immediate effect on the economy of Senegal, which is largely based on agriculture (peanuts, millet, rice, cowpea, manioc, etc), with the migration of rural populations to cities which were forced to accommodate these new inhabitants in a short space of time. Farmers, accounting for a very high proportion of these new arrivals, helped to develop peri-urban agriculture, thus meeting the increased food demand in cities. Peri-urban agriculture is a source of revenue for the poorest households in urban areas (Golhore, 1995). It therefore plays a major role in action to end poverty (**1.2**). In Senegal, a 250% increase in production is forecast with an increase in the area under cultivation (Gueye et al., 2015). However, this peri-urban agriculture model has a detrimental effect on population and human health (Ba et al., 2016). Research undertaken in the large metropolis of Dakar (in Pikine and Niayes) showed that developing intensive peri-urban agriculture using fertilisers and pesticides to increase productivity and, thus revenue from farming **(2.3)**, had a detrimental effect on water quality **(6.3)** and drinking water **(6.1)**. In a study of more than 100 wells in the Niayes area, Sall and Vanclooster (2009) found the water was severely polluted by nitrates and so called for the rapid implementation of environmentally-friendly farming practices to ensure sustainable production (SGD12). In these peri-urban farming systems, efforts to increase production currently tend to degrade water quality. This harmful interaction constrains the achievement of **target 3.9**. A survey of the market-gardening systems in Pikine (a suburb of Dakar) showed that nearly 7% of produce (lettuce) was contaminated by Salmonella, a human pathogen (Ndiaye et al., 2011).

IMPLEMENTING CLIMATE SMART AGRICULTURE TO ADDRESS CALIFORNIA'S WATER CHALLENGES

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SUMMARY OF KEY SYNERGIES

Access to nutritious food (2.1) **contributes to ending malnutrition** (2.2)

SUMMARY OF KEY TRADE-OFFS

Agricultural production can reduce air quality (3.9)

Nitrate leaching from fertiliser use and animal production contaminates drinking water (6.1)

Fertilisers and animal waste run-off may pollute surface water (6.3)

Agriculture is a major user of freshwater, challenging sustainable water withdrawal and supply (6.4)

California is among the top ten agricultural economies globally and the largest in the USA, with an estimated US$ 50 billion per year in farm-gate revenue. While agriculture, together with food and beverage processing, accounts for less than 5% of the overall state economy, it continues to play a significant role in rural incomes. California agriculture is highly market-orientated, with continued shifts toward high value products that take advantage of the Mediterranean climate and can compete globally on quality and safety, which is evident through its 23% share in total export revenue.

With over 76,000 farms ranging from small, organic to large commercial operations, producing over 400 different agricultural commodities, California plays an important role in providing access to safe and nutritious food to end malnutrition in all forms **(2.1, 2.2)** and ensuring sustainable and resilient food systems **(2.4)**. Achieving these, presents both synergies (reinforcing) and trade-offs (constraints) to meeting other SDGs. As California has one of the strongest records on environmental regulation in the USA, its policy approaches to minimising trade-offs between agriculture and environmental objectives may be instructive.

NUTRITION AND HEALTH: SDG2 & SDG3

California is responsible for almost half the U.S. production of vegetables, fruits, and nuts, and 20% of dairy products. Thus, California's agriculture plays a very significant role in the nutritional quality of the U.S. diet, reinforcing access to safe and nutritious food **(2.1)** and ending malnutrition **(2.2)**. However, Californian agriculture also poses constraints on other health targets. Farm activities account for 21% of ozone-forming gases and more than half of particulate emissions (from fertilisers and dust) in the San Joaquin Valley (Cowan, 2005; ARB, 2008). This constrains reducing the number of deaths and illness from hazardous chemicals and air, water, and soil pollution and contamination **(3.9)**. Californian air pollution laws had exempted farms from permitting requirements until 2004, when a series of new regulations on farms, wine fermentation, and large cattle and dairy operations began requiring state pollution permits to address this trade-off. Finally, agriculture constrains access to clean drinking water, a health concern being addressed through regulatory measures.

SUSTAINABLE & RESILIENT AGRICULTURE: SDG6 - WATER

With a dry climate, water is an essential resource for agricultural productivity and climate resilience in California. During the current five-year drought, agriculture has received no or greatly reduced surface water allocations, leading to a negative economic impact on the agriculture sector amounting to US$ 2.2 billion in 2014 (Howitt et al., 2014; Medellin-Azuara et al., 2016).

With the Poter-Cologne Act of 1969, California began regulating water quality prior to the passage of the national Clean Water Act. State water quality regulations were further strengthened to reduce run-off from irrigated lands (in 2003) and improve groundwater quality (in 2001). However, nitrate leaching into groundwater in regions with intensive agricultural crop and livestock production leads to groundwaters that exceed drinking water quality standards (Harter et al., 2012). As many people outside large urban centres depend on wells for drinking water, agricultural practices constrain access to safe and clean drinking water **(6.1)** and improving water quality through reducing pollution **(6.3)**. To reduce nitrate leaching from fertiliser use, policy responses being considered include increasing taxes on nitrogen fertilisers and increased regulatory measures in the form of grower nutrient management plans. To offset the impact of these measures on the economic sustainability of Californian agriculture, funding from taxes on fertiliser sales have been used since 1990 for research to assist farmers in reducing the environmental impact of fertiliser use. This research has resulted in recommendations and tools used by growers to sustain productivity and facilitate compliance with water quality regulations.

Competition across urban, environmental, and agricultural sectors has intensified with increased environmental priorities and the needs of growing urban populations, along with periodic droughts. Of the total estimated surface water available, from runoff stored in reservoirs and from stream flow, agriculture withdraws 40%, while the environment accounts for 50%, with the urban sector accounting for the remaining balance (California Department of Water Resources, 2013). In normal water years, about 70% of developed water use (surface + groundwater) is for irrigated agriculture. However, in periods of drought, less water is allocated to irrigation districts and the share of irrigation water declines to 50% or less. In normal years, about one third of total developed water is from groundwater; the level increases to 50% or more in periods of drought such as in the last few years. Increased reliance on groundwater constrains ensuring sustainable withdrawals and supply of freshwater to address water scarcity **(6.4)**. It also constrains access to clean drinking water **(6.1)**. In 2016, the State was forced to allocate US$ 19 million to provide emergency drinking water to thousands of people, largely in agricultural regions, due to overdraft of groundwater wells. To address concerns over the sustainability of groundwater for both agricultural and drinking water needs, California passed the Sustainable Groundwater Management Act in 2014 to regulate groundwater pumping. The impact of this new law is not yet clear, but will clearly constrain agriculture in regions of the state that rely entirely on groundwater for irrigation. Thus, a potential impact is a reduction in state-wide crop acreage.

The relationship between agriculture and water resources is complex and requires action at both the farm and basin scale. During the past 50 years, the water use efficiency of California agriculture has increased: total agricultural water use has declined while at the same time, the shift toward higher value crops has significantly increased the productive use of that water. However, the shift toward more efficient drip and micro sprinkler irrigation systems which contributes to this efficiency gain, has simultaneously constrained sustainable groundwater management. Drip irrigation significantly reduces groundwater recharge rates, and the number of irrigated acres expanded as farmers shifted to groundwater supported drip and thus independence from canal infrastructure providing surface water. Research, funded by agricultural producer organisations such as the Almond Board of California, along with public sources, is examining the possibility of deliberately flooding agricultural lands in the rainy winter months to increase groundwater recharge, advancing new solutions to reinforce sustainable management of this critical resource.

SUSTAINABLE & RESILIENT AGRICULTURE: CLIMATE CHANGE - SDG13

The concept of Climate Smart Agriculture – balancing mitigation, adaptation, and productivity – is increasingly integrated into California's agricultural policy framework. While agriculture accounts for only 8% of state GHG emissions, it will, in turn, be significantly impacted by climate change. The projected reductions in precipitation and more frequent periods of drought are a major driver for adaptation. Furthermore, rising temperatures will significantly impact major crops: almonds and stone fruits require winter chilling, and wine grapes have climatic specificity for different varieties. The state passed a comprehensive climate change law in 2006 that called for reducing GHG emissions through the use of a cap and trade system. This policy has since been strengthened by additional regulations and investments in a low carbon economy, including in the area of agriculture. While the original policy did not set GHG emission caps on agriculture, it does regulate emissions from food and beverage processing in the state, thus connecting SDG13 with SDG2. In September 2016, the state enacted new regulations on short-lived climate pollutants to meet more ambitious climate mitigation goals. This regulation calls for methane reductions in the dairy production sector. Livestock production accounts for about half of California's agricultural emissions, with the majority of dairy production in large, confined operations. It is expected that the new methane emissions regulations could significantly constrain the economic viability of the dairy industry through very significant increases in costs associated with changing manure management practices (Lee, 2016). At the same time, the priority given to climate change in state policy has provided a framework for synergies with agricultural productivity and adaptation through public investments in incentives for growers to adopt climate mitigating practices. Funds from carbon credit auctions support incentives (subsidies) for growers in the areas of healthy soils, more water and energy efficient irrigation systems, and installation of dairy digesters. A recent review of research in California demonstrates that these technologies and management practices offer co-benefits for both GHG emission reductions and either productivity or climate resilience benefits (Byrnes et al., 2016), reinforcing the economic and environmental sustainability of agriculture. Thus, while the climate mitigation policy framework in the state may have some constraining impacts on agriculture, it also provides reinforcing investments in the productivity, sustainability, and resilience of the sector.

The case of California illustrates some of the approaches to reconciling across goals for an economically viable, highly diverse food system and a sustainable environment. Increased regulation for health and environmental concerns, more limited allocation of water for agriculture, and international trade competition constrain California agriculture and will continue to drive changes in the amount and types of agriculture produced. At the same time, investments by the state and national governments and agricultural producer organisations are providing incentives and new tools and technologies that are driving continuous improvement in the agriculture sector to reconcile these constraints between goals. This is evident in the continued growth in economic value of the sector and the increasing evidence of improvements against environmental measures.

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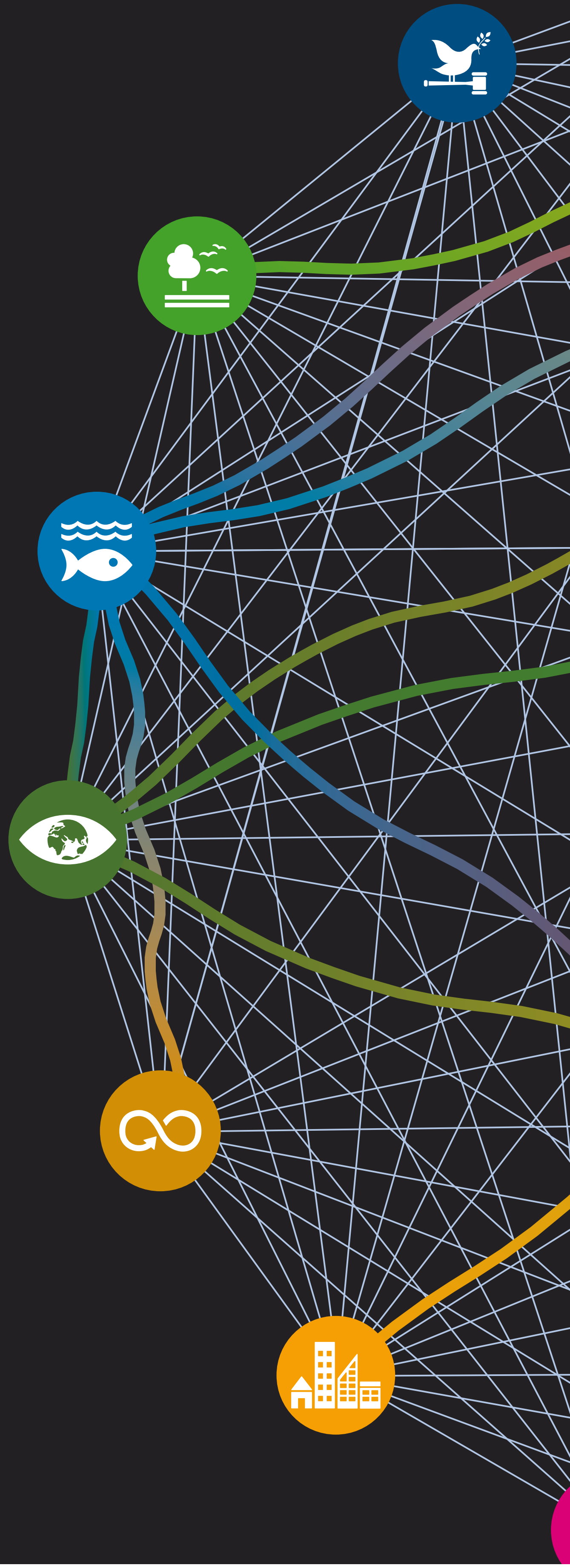

The United Nations' 2030 Agenda for Sustainable Development was adopted in September 2015. It is underpinned by 17 Sustainable Development Goals (SDGs) and 169 targets. National policy-makers now face the challenge of implementing this indivisible agenda and achieving progress across the economic, social and environmental dimensions of sustainable development worldwide.

For this report, a team of scientists evaluated the key target-level interactions between an 'entry goal' and all other goals, and attributed a score to these interactions based on their expert judgment and as justified through the scientific literature. For their work, they used the 7-point scale pictured below.

The report is based on the premise that understanding the range of positive and negative interactions among SDGs is key to unlocking their full potential at any scale, as well as to ensuring that progress made in some areas is not made at the expense of progress in others. The nature, strengths and potential impact of these interactions are largely context-specific and depend on the policy options and strategies chosen to pursue them.

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