FINANCING SUSTAINABLE, RESILIENT AND INCLUSIVE SOLUTIONS TO ATTAIN SDG 12

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Contents

Objective of the background paper is to provide expert knowledge on the theme of financing science, technology and innovation (STI) solutions for Sustainable Development Goal (SDG) 12.

Executive summary

The Sustainable Development Goals (SDGs) will only be attainable with ubiquitous deployment of resource-efficient technologies and the introduction of sustainable consumption patterns. An absolute decoupling of natural resource use and environmental pressures from economic growth and well-being improvements is a key means of implementation for the 2030 Agenda for Sustainable Development. Governments and business leaders have come to the realization that improving resource efficiency, along with inclusive and sustainable economic growth and deep cuts in drivers of environmental pressures, are essential to achieving the SDGs. Likewise, consumer awareness and changed consumption patterns have been identified as indispensable elements for sustainability.

The continuation of an economic development pathway that is based on the premise of stable and ample supplies of cheap, easily accessible materials and energy for inefficient mass consumption has become less probable. High volatility in prices and supply chain risks has already caused large macroeconomic losses, especially in the most vulnerable parts of the world. An economic approach characterized by sustainable consumption and production (SCP) follows a more robust and advanced economic paradigm in line with the SDG agenda and substantially improves the resilience of the global socioeconomic system.

This paper shows the following:

- A continuation of existing consumption and production policies is not compatible with reaching the SDGs;
- Smart SCP policy combinations targeted at impact decoupling in combination with resource efficiency typically lead to net economic gains measured in terms of gross national product.
- SCP policy changes, such as resource taxes, that shift subsidies towards resource efficiency and SCP research and development policies create asymmetries in terms of global winner and loser countries. Economic transfers combined with technology transfer mechanisms carry the potential to create net positive outcomes for all countries with ambitious SCP policy frameworks;
- Public finance systems as well as regulatory frameworks will need to undergo a substantial reform in order to trigger and maintain the momentum for an SDG transition.
- Current SCP technologies are not sufficient to attain multiple SDGs, or even ambitious formulations of single SDGs;
- Targeted large-scale science, technology and innovation (STI) programmes for breakthrough technologies requiring unprecedented amounts and modes of financing are necessary conditions to close the anticipated SCP technology gaps. Incremental technology agendas will not be sufficient;
- The uncertain success of breakthrough technologies needs to be physically hedged by preparing backstop strategies ex ante to ensure the attainability of critical targets. A particular set of risk finance instruments needs to be created to guarantee the availability of "physical backstops" when needed;
- Constructing "smart" SDG policy portfolios will require new economic thinking and analytical tools that couple the economic system with finance, technology and its respective STI sectors. Big data, citizen science and methodological advances will help in the selection of robust STI investment strategies supporting broader SDG policy portfolios.

I. Introduction

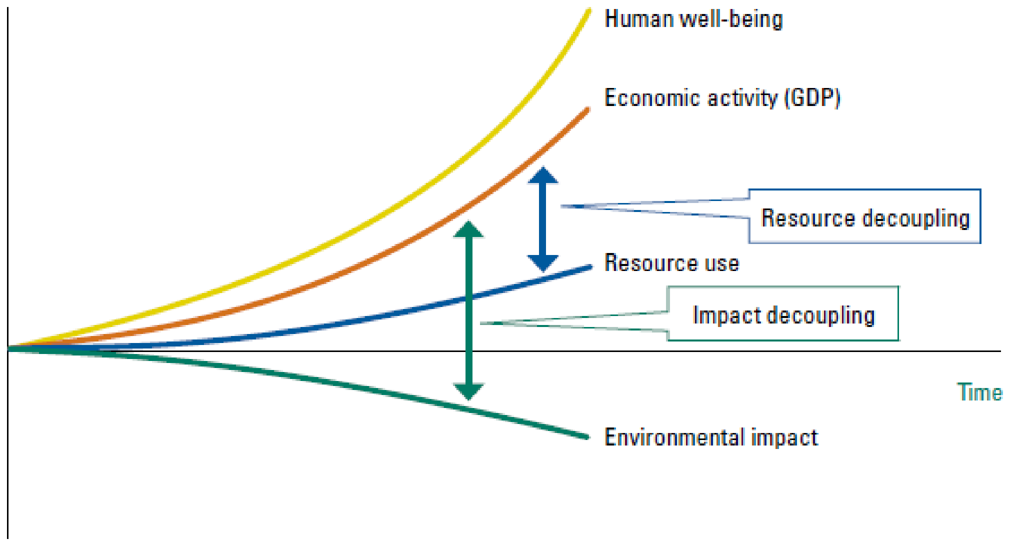
The Sustainable Development Goals (SDGs) are considered the most complete expression of the positive aspirations for human development. Among the SDGs, SDG 12—sustainable consumption and production (SCP)—is less of a goal in itself, but more a guideline for means of implementation of the aspects of the goal. Sustainable use of natural resources is referred to 12 times directly in the 17 SDGs and is considered to be a necessary building block for the attainment of all SDGs. In this sense, SDG 12 can be considered to be transversal and cross-cutting. SDG 12 is strongly associated with the notion of dual decoupling, which refers to resource and environmental impact decoupling. The degree of decoupling can serve as a metric of attaining metabolic targets of resource intensities, which are in line with the pathways towards reaching the SDGs.

An expanding human population combined with increasing individual affluence is expected to cause resource use to intensify. Given limitations on the access to and use of resources, SCP is becoming an essential requirement for development and continued human well-being. The economic system of today is surprisingly wasteful in its mode of value creation. For example, according to a study by the Ellen MacArthur Foundation, in Europe, material recycling and waste-based energy recovery captures only 5 per cent of the original raw material value.[1] Analysis has also found significant structural waste in sectors that many would consider mature and optimized. For instance, in Europe, the average car is parked 92 per cent of the time, 31 per cent of food is wasted along the value chain, and the average office is used only 35–50 per cent of the time, even during working hours. Resource efficiencies in the developed world are much higher in certain sectors (e.g., waste paper recovery); when it comes to the use of natural ecosystems, efficiencies are much lower (e.g., deforestation for extensive livestock production), mostly related to weak governance systems and institutional anchoring.

SDG 12, as illustrated in the mind map in figure AII.1, consists of roughly four blocks: (i) sustainable production; (ii) sustainable consumption; (iii) sustainable finance; and (iv) circular economy concept. SCP will lead to decoupling. The concept of decoupling is represented in figure I.1 in an idealized manner. It shows increasing trajectories for gross domestic product (GDP) and human well-being. However, figure I.1 also shows resource use increasing at a slower pace than GDP (relative resource decoupling) and environmental impacts actually declining (absolute environmental decoupling).

Figure I.1

Decoupling of resource use and environmental impacts from GDP growth



Source: UNEP (2011), Figure 1, p. xiii.

I.1 *The economic benefits of resource decoupling and its principle means of implementation*

Resource efficiency can be seen as a potential investable asset class that can generate tangible short- to me-

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[1] Ellen MacArthur Foundation (2015). Towards a circular economy: business rationale for an accelerated transition. Available from https://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation_9-Dec-2015.pdf.

dium-term benefits to economic performance. There are several benefits associated with investments in resource efficiency:

- **Price and price volatility risk**. The last decade has seen higher price volatility for metals and agricultural output than in any single decade in the twentieth century (Ellen MacArthur Foundation, 2015). The market dynamics of resource supply have produced resource and commodity prices, which have been highly volatile over time (UNEP and IRP, 2015). If resource efficiency can reduce the demand for resources and accumulate inventories in recycling and reuse pools, it will be able to dampen price volatility and the subsequent adverse effects on the economies and socioeconomic stability of many nations. Higher resource-price volatility can dampen economic growth by increasing uncertainty, discouraging businesses from investing, and increasing the cost of hedging against resource-related risks. Furthermore, continued reliance on raw material supply rather than products from recycling, reuse or remanufacturing will put more pressure on long-term prices for basic commodities.
- **Physical supply risk**. Resources, especially rare metals, are concentrated in a few countries. Thus, the rest of the world must rely on imports. For example, the European Union (EU) imports six times as much in materials and natural resources as it exports and has been identified together with Japan as a region highly vulnerable to systemic supply risks (Klimek and others, 2015). Japan imports almost all its petroleum and other liquid fuels and its natural gas, and India imports about 80 per cent and 40 per cent, respectively. Even in the area of supply of commodities for basic consumption such as food, countries are surprisingly import dependent. For example, for the supply of phosphorus, an essential component in fertilizers, India is almost completely dependent on imports (Khabarov and Obersteiner, 2017). Security of supply associated with long, elaborately optimized global supply chains appears to be decreasing. With increased resource efficiency, not only will the physical supply be available longer, but the flow of resources to satisfy the material demands of our modern societies can be kept more steady, as the resource pool is more diversified and the primary resource will be maintained for a longer period of time.
- **Intergenerational equity.** Finally, there is the moral argument to be made in favour of increased resource efficiency. In the spirit of intergenerational equity, high resource efficiency assures the availability of resources for an increased number of future generations.

There are several means of implementing resource decoupling, which can be achieved through three principle areas of intervention:

i. Increasing resource productivity through resource-efficiency gains and switching to a circular economy;

ii. Substituting resource-depleting technologies by resource-saving or resource-neutral technologies;

iii. Switching to more sustainable consumption patterns.

According to the Ellen MacArthur Foundation project's definition, a circular economy is restorative and regenerative by design, and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles. It is conceived as a continuous, positive development cycle. It preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows.[2]

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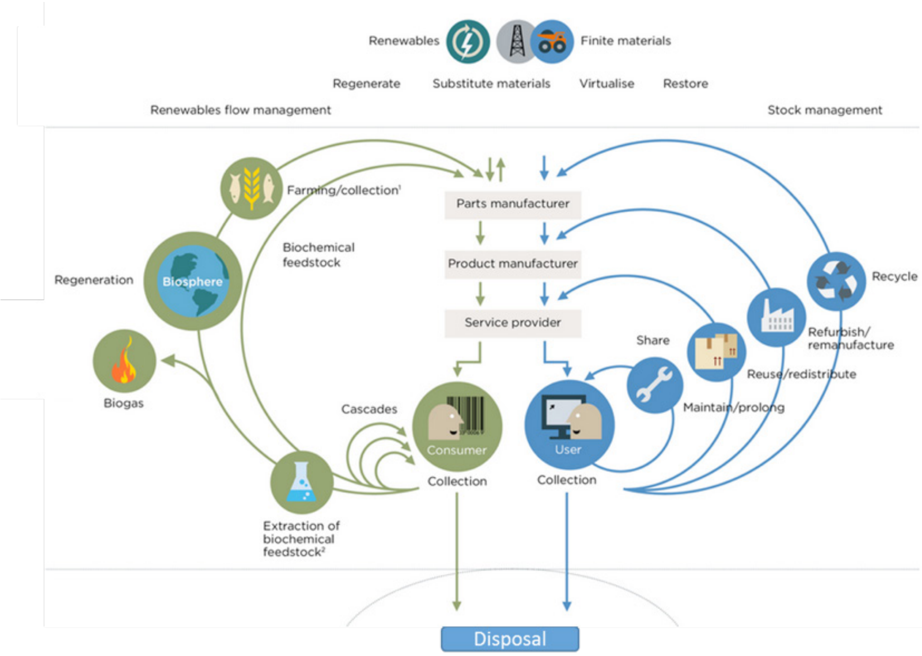
[2] Ibid., p. 5.

Figure I.1: Circular economy diagram



Source: Braungart and McDonough. Cradle to Cradle report and Ellen MacArthur Foundation (2015). Available from https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram.

Expressed in a more condensed way, a circular economy is one that is restorative and regenerative by design and aims to keep products, components, and materials at their highest utility and value at all times, distinguishing between technical and biological cycles.

I.2 *Impact decoupling through SCP in the context of the SDGs*

The degradation of the natural environment and the Earth system at large is a major concern for the global society. There is increasing evidence that further degradation will erode the fundamentals of long-term global wealth creation and human well-being. The depletion of low-cost mineral and metal reserves and the large-scale, rapid degradation of natural capital are affecting the productivity and resilience of our economies. On a global scale, the elements contributing to systemic risks to society as a whole are known as the planetary boundaries—that is, Earth system components such as climate, biodiversity, land, water, air and oceans.

While resource decoupling removes or reduces general pressure from socioeconomic systems and from the natural environment, impact decoupling in the context of the SDGs will ensure that specific environmental targets are reached. Such targets are related mostly to the dimensions of the planetary boundaries. The most iconic and most advanced area of impact decoupling is climate. SDG 13 is about impact decoupling with respect to the climate system. Substantial increases in resource efficiency in production and consumption are essential for meeting climate change targets. At the twenty-first session of the Conference of the Parties (COP 21) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris, representatives of 195 countries pledged to limit global temperature rise to 1.52.0°C above pre-industrial levels.

Technological change will be critical to decarbonizing these sectors. However, demand reduction through resource efficiency will also have a crucial role. The Intergovernmental Panel on Climate Change (IPCC) states that "efficiency enhancements and behavioural changes, in order to reduce energy demand compared to baseline scenarios without compromising development, are a key mitigation strategy in scenarios reaching atmospheric CO2eq concentrations of about 450 to about 500 ppm by 2100 (robust evidence, high agreement)" (IPCC, 2014, p. 99). In the scenarios analysed by IPCC, the median levels of final energy demand reduction relative to baselines in the transport, buildings and industry sectors are about 20–30 per cent, with the high end of the ranges exceeding 60 per cent in each sector (IPCC, 2014). Increasing resource efficiency is a critical strategy to enable such necessary demand reductions to be achieved, without negatively affecting human development and well-being.

Impact decoupling with respect to the other major environmental resources, such as water, air, land and oceans, is equally important. In a vision of impact decoupling under a wider SDG framework, revenue streams from multiple ecosystem services will need to be stacked to increase the momentum for a rapid transformation towards sustainability. For example, the economics of a mixed farm will be driven by payment streams for cleaner water provisioning, carbon sequestration, soil nutrient management, biodiversity buffer strips, and crop and livestock production (given specific animal health provisions). Impact decoupling will also require significant changes in the public and private finance systems—especially in the form of ecosystem services payments, either through general budget funds or through market-based instruments.

Figure I.2.1 illustrates a stylized transitional scheme for public finance resulting from active policies to implement impact decoupling. In this case, the scheme involves impact decoupling between GDP and carbon emissions in order to align with ambitious climate stabilization targets, and results in a majority of fossil fuels remaining unexploited. While the estimates of fossil fuel reserves measured in potential emissions of some 11.000 GtCO2 are huge, the allowable budget of the additional carbon load to the atmosphere is only a small fraction of some 870-1240 GtCO2. If there were no climate changes or any other harmful effects on the Earth system functioning (e.g., ocean acidification), nations could continue to rely on relatively cheap fossil fuel reserves to propel their economies with abundant energy. Revenues from taxing the extraction and use of fossil fuels would continue to be a lucrative source of income to national budgets.

However, since the Paris Climate Agreement calls for impacts from a disturbed climate system to be avoided, national budgets need to be filled by other forms of revenue to the Government. Estimates for the EU28 show that total revenues from energy taxes amounted to €70 billion per year, while support[3] to coal and gas amount to €17 billion per year, and support for nuclear and renewables are in the order of €35 billion per year. Support to energy demand amounts to €27 billion per year while support to energy efficiency only receives some €8 billion per year. As a result, the energy sector is actually a net recipient of governmental funds. On the other hand, proceeds from the Cap-and-Trade-Auction[4] yield some €10 billion per year at a price of ~€10/t CO2, which is at least 10 times too low to provide a strong enough signal to bring the energy sector in line with the Paris Climate Agreement. Under this scenario of a much higher CO2 price, the energy sector would be a large net contributor to the national budget, making much of the support to renewable energy deployment redundant. Some of the proceeds of the EU emissions trading system (ETS) could be used to help fund energy transformations and enhancement of natural carbon sinks in other parts of the world, and help ramp up STI capacities to find new energy solutions, helping to reduce the costs of the energy transition.

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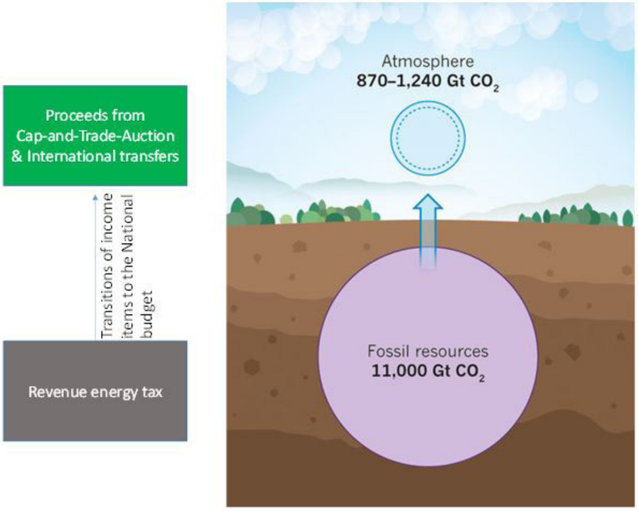
[3] See https://ec.europa.eu/energy/sites/ener/files/documents/ECOFYS%202014%20Subsidies%20and%20costs%20of%20EU%20energy_11_Nov.pdf.

[4] See https://ec.europa.eu/clima/policies/ets/auctioning_en.

Figure I.3

Transitioning of public revenue items under climate policy from tax on fossil fuels to proceeds from auctioning emission rights



II. Science, technology and innovation (STI) challenges and finance assessment of the Sustainable Development Goal (SDG) 12 system

II.1 *STI solutions and gaps to attaining SDG 12*

Significant advances in technology are required to meet the SDGs simultaneously and sufficiently early. If properly guided and resourced, technological advances can produce new solution spaces for society that were thought unattainable just a few years ago. For example, information technologies in combination with new agricultural or industrial technologies are now becoming available and can be deployed at scale, which allow for improved resource efficiency and for the creation of sustainable supply-chain management through a chain-of-custody material tracking system. A new paradigm of "block-chaining the atoms" of the material flows which propel our societal metabolisms no longer seems utopian. These advances carry the potential for more efficient collaboration and knowledge-sharing, full tracking of materials, improved forward and reverse logistics set-ups, and increased use of renewable energy and multiple-use materials (Ellen MacArthur Foundation, 2015).

Detailed technology studies are available for a myriad of sectors that are trying to address particular environmental and social challenges. Such studies typically evaluate technology potentials in terms of marginal abatement costs for additional activities of technology deployment that address a particular environmental goal, such as air pollution or climate mitigation. Studies that address the issues of resource efficiency—the narrower goal of SDG 12—are less numerous, whereas resource efficiency is an integral part of strategies in other sectors. This study will not deal with resource efficiency issues related to SDG 6 (water), SDG 7 (energy) and SDG 11 (cities and human settlements), as they will be covered by separate in-depth studies of the High-level Political Forum on Sustainable Development. For illustrative purposes, the focus of this paper is on technology and innovation options for resource-efficiency opportunities in the global food system.

Technologies and innovations boosting resource efficiency and sustainable consumption and production (SCP) in the agrifood sector

The long-term sustainability of the agrifood sector crucially depends on the sustainable management of its very basic natural resources—land, soil, water, air and climate, biodiversity—as well as the sustainable management of mineral resources, such as phosphorus, for the production of fertilizers. SDG target 12.2 requires that, by 2030, the sustainable management and efficient use of natural resources be achieved by all sectors. Currently, however, the natural resources managed directly and indirectly by the agrifood sector are often not managed sustainably or efficiently, leading to degradation or depletion of resources and natural capital.

Table II.1.1

Natural resource impacts of the agrifood sector and solutions and gaps

Facts of resource impacts of the agricultural sector	**Solutions and gaps**
• Globally, an estimated 33 per cent of soil is moderately to highly degraded owing to erosion, nutrient depletion, acidification, salinization, compaction and chemical pollution (FAO, 2015a; FAO, 2015b).	• Agronomic soil conservation practices exist; however, they typically require higher operational costs and investments and are more labour intensive.
• At least 20 per cent of the world's aquifers are overexploited for irrigation, including in important production areas such as the Upper Ganges (India) and California (United States) (Gleeson and others, 2012).	• Regulatory frameworks are either non-existent or not implemented. Technological solutions for more efficient irrigation exist, but are more costly (Sauer and others, 2010)
• The nitrogen- and phosphorus-use efficiency (from farm to field) in the global food chain is about 15-20 per cent, implying large nutrient losses to the environment (Sutton and others, 2013). Some regions have lower efficiency and higher losses (North America, East Asia), while in sub-Saharan Africa, soil nutrient depletion (where nutrient extraction is higher than input) is common (Obersteiner and others, 2013).	• Absence of stringent regulation leads to squandering of nutrient inputs. Field-scale agronomic technologies and landscape-level technologies exist to mitigate pollution. Nutrient scarcity in soils of developing countries is related to economic accessibility of fertilizers including large transaction and transportation costs for fertilizers.
• Globally, food systems account for about 24 per cent (21–28 per cent) of the global greenhouse gas emissions (FAO, 2014a; Vermeulen and others, 2012).	• Markets for climate smart agricultural solutions are at a primordial state. National-level planning initiatives are emerging.
• Globally, 29 per cent of the "commercial" fish populations are fished at a biologically unsustainable level and therefore overfished. Another 61 per cent of these populations are fully fished (FAO, 2014b).	• Effective regulatory solutions would require large-scale investments into monitoring infrastructures for enforcement. Necessary observation technologies are available.
• Food systems activities are also a major source of both terrestrial and marine biodiversity loss (Chaplin-Kramer and others, 2015; Coll and others, 2016; PBL, 2014a), while nutrient losses to ground and surface waters lead to massive algae blooms and dead zones (hypoxic) in coastal areas around the globe (Rabotyagov and others, 2014).	• Biodiversity observation systems are still poorly developed; the economic valuation of functional benefits of biodiversity is still not put in practice (IPBES, Pollination report). Regulatory mechanisms on catchment scale are only emerging (Danish nutrient credit-trading mechanism).

Source: Ekins and others (2016). Resource efficiency: Potential and economic implications.

SDG target 12.3 foresees that "by 2030, per capita global food waste at the retail and consumer levels are halved and food losses along production and supply chains, including post-harvest losses are reduced". [5]Although technologies exist to substantially reduce food wastes along the supply chain, the required reductions do not yet seem to be fully economic. Projections foresee that food wastes will be declining in the years to come. However, the rate of food waste decline under business as usual is not in line with SDG target 12.3, as illustrated in figure II.1.1. Additional measures will need to be implemented to attain SDG target 12.3; there

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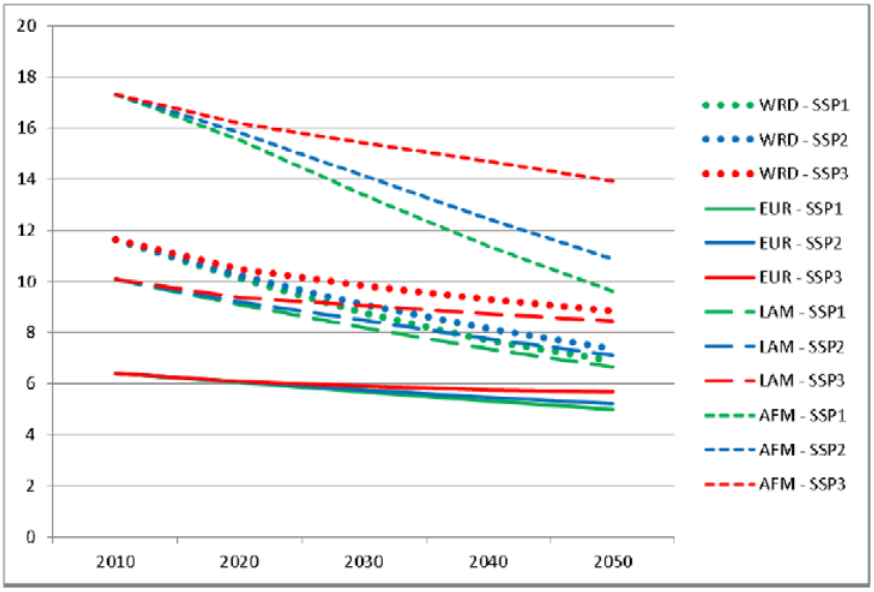
[5] See https://sustainabledevelopment.un.org/sdg12.

are many public and private sector initiatives working towards this goal, such as the FRESH initiative coordinated by the World Business Council for Sustainable Development and the activities related to the food waste resolution of the Consumer Goods Forum. The Consumer Goods Forum is an example of industry-led initiatives targeting SCP solutions through their mission of "[b]ringing together consumer goods manufacturers and retailers in pursuit of business practices for efficiency and positive change across the industry benefiting shoppers, consumers and the world without impeding competition".[6]

Figure II.1.1

Illustrative example of projected autonomous improvements of food losses and wastes according to different socio-economic development projections

Autonomous improvements of food loss and waste, by socioeconomic development projections*



*The trajectories of losses and wastes in oilseeds and pulses are based on Gustavsson and others (2011) and projected as a function of GDP for different shared socioeconomic pathway scenarios for the World (WRD), Europe (EUR), Latin America (LAM), and Africa and the Middle East region (AFM). IIASA calculations. Y-axis shows percentage loss; x-axis shows yearly loss.

Despite large losses, the food system delivers ample and safe food and is projected to maintain sufficient production capacity to provide food for all (SDG 2). However, in reality, the food system fails to deliver food security and food safety for all. Globally, more than 800 million people remain hungry, which constitutes 11 per cent of global population and a staggering 34 per cent in Eastern Africa (Food and Agriculture Organization of the United Nations and others, 2017).[7] The number of children under 5 years of age who suffer from stunted growth and wasting is currently estimated to be 155 million and 52 million, respectively. In addition to basic human suffering, these unnecessary failures in the global food system cause physical and cognitive impairments that will in turn create an ill-equipped workforce—an avoidable large-scale human resource loss. At the same time, paradoxically, the global food system yields a huge number of people who are obese—641 million adults, or 13 per cent of all adults on the planet—and 41 million children under 5 who are overweight. The rate is now about 40 per cent in France, Germany and Italy, and about 60 per cent in Canada, the United Kingdom of Great Britain and Northern Ireland and the United States of America. Only in Japan is the rate considerably lower. Another form of malnu-

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[6] See https://www.theconsumergoodsforum.com/who-we-are/overview/.

[7] See http://www.fao.org/3/a-I7695e.pdf.

trition is nutrient deficiency. Globally, women of reproductive age affected by anemia number 613 million (about 33 per cent of all women of reproductive age). In total, over 2 billion people worldwide suffer from micronutrient deficiency (Food and Agriculture Organization of the United Nations and others, 2015; ICN2, 2014)—a number that also partially includes the above-mentioned hungry, overweight and obese. Nutrient deficiency is not only related to the compositions of diets, but also the nutrient content in the respective foods which are related to the health of the soils, the roots and the microbial community associated with the crops.

These aspects of soil health are still largely underexplored and thus add complexity to an adequate definition of resource efficiency and sustainable production. Significant STI effort needs to be invested both in terms of plant breeding (including symbiotic organisms) and soil science in order to develop more sustainable agricultural practices that are fully integral to a vision of healthy diets and lifestyles in line with the SDGs. The global soils are very heterogeneous, which necessitates the establishment of global big data infrastructure and analysis networks to integrate the accumulated knowledge from millions of field-scale trials to predict positive outcomes from changes in farm practices on large scales. Such infrastructures have been built with science grants for studies of the human microbiome (The Human Microbiome Project). Another example of a major data storage facility and bioinformatics infrastructure is the network of the European Bioinformatics Institute. Other STI challenges to improve the resource efficiency in agricultural production relate to the development of new high site adapted seeds, new forms of plant protection, and algorithmic decision support for farming operations ranging from traditional to robotic farming. All of these production innovations will lead to substantial efficiency improvements, from micro-dosing of fertilizers and sparing of chemicals for plant protection to reduced soil compaction due to the use of light robotic vehicles as opposed to large tractors.

SDG 12 is not only about sustainable production but also about sustainable consumption. In the case of efficiency improvements on the consumption side, there are also a number of interesting STI challenges. The principle modes of improvements in sustainable and resource-efficient consumption can also be applied to sectors other than agriculture. Shifting diets would not only be an effective solution to de-pressure the agrifood system in terms of having fewer hungry people and less environmental impact on natural resources (Obersteiner and others, 2016)equity, and inclusivity. The wide scope of the SDGs will necessitate unprecedented integration of siloed policy portfolios to work at international, regional, and national levels toward multiple goals and mitigate the conflicts that arise from competing resource demands. In this analysis, we adopt a comprehensive modeling approach to understand how coherent policy combinations can manage trade-offs among environmental conservation initiatives and food prices. Our scenario results indicate that SDG strategies constructed around Sustainable Consumption and Production policies can minimize problem-shifting, which has long placed global development and conservation agendas at odds. We conclude that Sustainable Consumption and Production policies (goal 12, but also deliver enormously valuable health and well-being benefits (EAT Lancet Commission, 2017). There are still large STI gaps in understanding how behavioural transitions can be brought about that are consistent with diet shifts towards healthier people and a healthier planet. The STI challenges are both technological (including citizen science) as well as behavioural.

Excursion; peace and sustainable production; and STI and SCP to avoid land degradation and associated conflict potential

Natural resource degradation might exacerbate conflict potentials associated with food insecurities (see box II.1). Of the 815 million hungry people on the planet, 489 million live in countries affected by conflict, underlining the importance of peace as a precondition for sustainable production patterns. People living in countries affected by protracted crises are nearly 2.5 times more likely to be undernourished than those living elsewhere (Food and Agriculture Organization of the United Nations and others, 2017). Conflicts and humanitarian crises exacerbate degradation of natural resources because of inadequate management of natural resources, especially in the periods following the crises when access to basic inputs—much less access to modern agricultural technologies and finance—is absent amid prevailing institutional instability. STI challenges for rapid reconstruction in post-conflict zones are numerous. There is insufficient time to master new information technologies that range from characterization of refugee camps using combinations of remote sensing with in-situ crowd-sourcing technologies to the diffusion of adapted "low-tech" agricultural technologies for smart food production. Challenges related to the supply of water and sanitary services also abound.

Projections of drivers of SCP in agricultural production: methods to assess gap closure

Consumption and production patterns change over time owing to autonomous technological change and consumption dynamics. Through STI investment, technological change can be pushed to accelerate. Likewise, policies can pull technological change, both through intensified deployment of best available technologies and increasing private research and development (R&D) investment to push the frontier for SCP technologies.

Box II.1.1

Climate extremes and soil degradation and conflict

There is a growing body of evidence to demonstrate how environmental stress, resource scarcity (water and food shortages in particular) and climate change can play a significant role—as proximate or underlying causes, or multipliers—in causing or exacerbating conflict.

The Arab Spring revolutions were in part triggered by food-price hikes connected to the wheat production failure in 2010 in the bread basket regions in the territory of the former Soviet Union and the subsequent interruption of otherwise affordable and reliable exports, mainly Egypt.

Drought devastated many countries in the region from 2006 to 2011. Rainfall fell below the absolute minimum needed to sustain rain-fed farming. Desperate for water, farmers began to tap aquifers with tens of thousands of new wells in the region. But, as they did, the water table quickly dropped to a level below which their pumps could lift it.

In some areas, all agriculture ceased. In others, crop failures reached 75 per cent. Generally, as much as 85 per cent of livestock died of thirst or hunger in some of the middle-eastern countries. Hundreds of thousands of farmers gave up, abandoned their farms and fled to the cities and towns in search of almost non-existent jobs and severely short food supplies. For example, it was estimated that between 2 million and 3 million of Syria's 10 million rural inhabitants were reduced to extreme poverty (living on less than $1.25 a day).

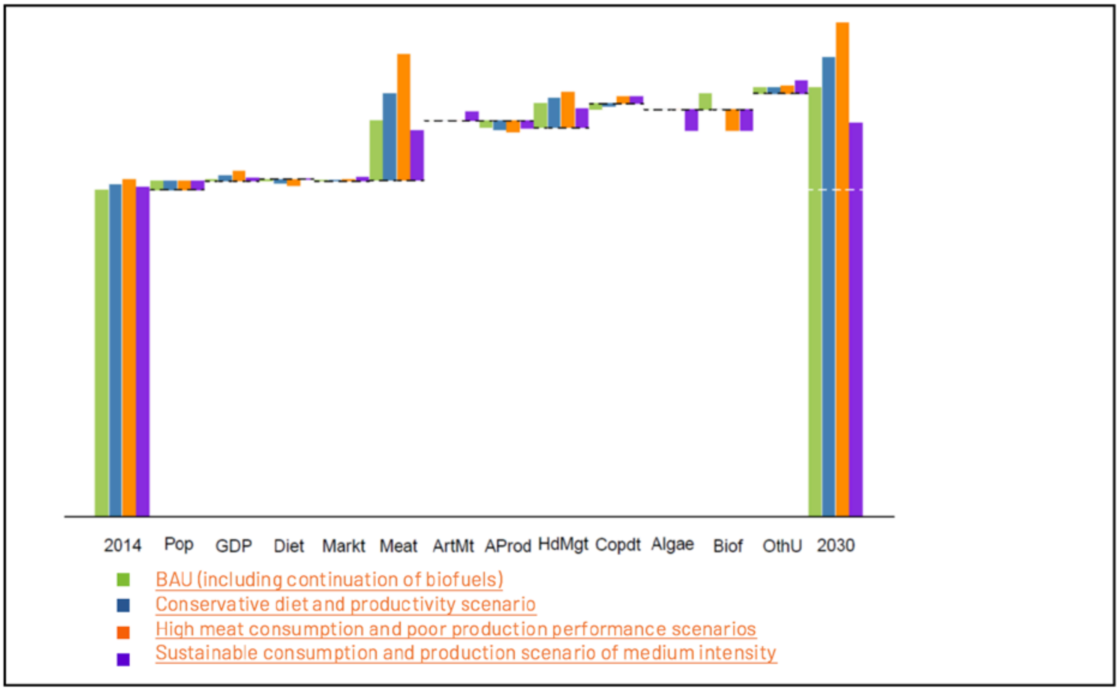
The domestic refugees in the respective countries immediately found that they had to compete not only with one another for scarce food, water and jobs, but, in a few countries, also with the already existing foreign refugee populations. Formerly prosperous farmers were lucky to get jobs at marginal wages. And in the desperation of the times, hostilities erupted among groups that were competing just to survive. What followed were civil wars and subsequent large-scale migration, mainly to Europe, shaking up its established political landscapes.

Long-term funding for sustainable reconstruction of post-conflict societies is an issue that has typically been addressed by regional development banks. Speed and quality of reconstruction could be improved (in terms of sustainability) by the injection of additional patient and ethical private funding through targeted portfolios of bonds, grants and technical cooperation.

In the agrifood sector, our illustrative case study sector for this report, there is a large potential for resource-efficiency improvement not only in terms of efficiency and productivity gains, using the natural resources of land and water, but also by improved efficiency in the food systems. This is illustrated in figure II.1.2, which shows the relative strength of the different drivers of resource efficiency.

Figure II.1.2

Decomposition of direct and indirect drivers of global corn consumption*



*Based on four SCP storylines. Drivers are population growth (Pop), increase in wealth per capita (GDP), lifestyle changes in terms of diet shifts in grains and vegetables (Diet), market feedbacks in terms of prices induced changes in demand and shifts in trade (Markt), meat production (Meat) in terms of artificial meat entering the market (ArtMt), improvements of production efficiencies (AProd), productivity shifts stemming from head management (HdMgt), use of coproducts (Copdt), use of algae as animal co-feed (Algae), corn used for biofuel consumption (Biof) and other uses such as industrial starch additive (OthU). Projections are from 2010 out to 2030.
Source: Obersteiner (own calculations).

The scenarios on the illustrative example of corn outlined in figure II.1.2 were constructed by exogenous assumptions that emulate improvements on an SCP storyline, rather than being modelled on policy reform that induces such SCP processes. What the results show is that, in terms of pushing the production efficiency frontier (in the livestock sector in particular), STI carries a large portion of the potential for resource improvements. The results suggest that a large part of the consumption of corn is avoided through improved livestock production efficiency. Likewise, the arrival of new technologies, such as the production of feed from algae sources, outcompetes corn and leads to substitution. In the case of algae, the resource-efficiency gains would be particularly large, as the algae are produced either offshore or on wastelands, such as deserts close to salt water sources. Algae will be partly or entirely fed by organic fertilizer sources or mineral fertilizer downcycled from municipal sludge and animal manures.

The food sector has created many initiatives to move towards more efficient production in SCP terms, but would benefit from more predictable policy frameworks that provide sufficiently strong direction. Interestingly, there are also many voluntary instruments active in the sector that focus on impact decoupling, such as joint agreements with the NGO community on sustainable forest management certification or deforestation-free commodity agreements (e.g., on soy, palm oil or beef).

However, in today's world, economic and regulatory incentives are not consistently pointing in the direction of more sustainable food production and consumption patterns: externalities are often unpriced; subsidies or tax exemptions are given for fossil fuels in fisheries and farming; certain agricultural sectors are protected; and consumers lack a clear insight into the environmental costs of food production. Farmers and fishermen have to produce in a very competitive market in which, typically, only price matters. This implies that they do not receive an incentive from the value chain to apply more sustainable production patterns. The food-supply-chain logic in affluent countries is largely aimed at a permanent, abundant supply of highly affordable food, which can lead to unhealthy eating patterns and also food waste. Technology road maps catering for meeting ambitious SCP targets are yet to be constructed. Gap-filling methodologies, as illustrated here for corn, are readily available to support road map exercises.

II.2. *Financing and other obstacles to the adoption and scaling of relevant technologies and innovations*

Figure AII.2 (see annex II) provides a non-exhaustive, but fairly comprehensive mind map for a large survey of literature on the barriers and solutions to the development and diffusion of technologies relevant to SCP. It is beyond the purpose of this short report to provide details on each of the subject areas outlined in this mind map. The focus here is on a selection of economic topics that appear most relevant for financing of SCP initiatives.

The principal starting point to characterize the financial viability of enhanced SCP is the profitability (cost competitiveness) of more resource-efficient (i.e., sustainable) technologies. There are three sources of cost reduction or benefit generation that justify investments to stimulate resource efficiency and sustainable resource management:

- Cost savings from more efficient use of the resource itself, and associated greater profitability and competitiveness of firms and the economy at large;
- Reduced risk as a result of using fewer resources per unit of value generated in the face of supply shocks (e.g., from depletion, mistiming of investment or geopolitical factors) and associated price volatility;
- Reduced costs related to environmental damage that is often associated with resource extraction, processing and disposal.

Deriving an appropriate estimate of the investment needs for different actors of the financial system is not a trivial task. To get a sense of the economics of resource efficiency, benefits accrued from resource efficiency, and improved resource management, activities need to be compared with the respective economic costs of policies (corporate or public) and any associated investments in research and innovation and/or equipment that are necessary to realize the resulting resource improvements. This comparison needs to be specified in monetary as well as non-monetary terms (e.g., in respect of environmental improvements) and be made attributable to the entities to which the costs accrue and who need to make their specific cost-benefit assessments. In particular, the choice of policy instrument will determine who has to carry which cost share from a resource management improvement following a policy change. For example, a resource-use tax is a cost to a producer or a regulated sector, but a tax is revenue to the government, which could recycle back to the same sector for modernization of production or to spend for other purposes. The costs to the country equal the change in GDP growth due to the economic adjustments to the policy, which would be expected to be considerably smaller than the sum of the costs flagged by the regulated entities. These considerations have important implications for who is best suited to invest (e.g., public, private, blended) and which investment instrument is recommended (see figure AII.2 for sustainability finance instruments).

Transaction cost theory and institutional economics helps us to understand why firms do not always take up existing cost-effective measures for resource efficiency. Taking measures to increase technology diffusion requires deep dives into the drivers of technology and investment inertia. A blending of government-led incentive schemes and specialized technical and management consultancies that hold valuable experience in these fields are typically used to help leverage private finance tailored to the specifics of the SCP technology, taking into account associated points of possible market failure.

There is the question of what finance and investment system is required to trigger and maintain momentum for larger transformations towards SCP. Resource efficiency requires a tailored finance approach based on who or what is targeted to achieve desired impacts. From the perspective of an individual producer, economic sector or government entity, the specific finance requirements can be assessed based on microeconomic principles. For large-scale deployment of resource-efficiency projects, de-risking investments vis-à-vis regulatory and policy uncertainty is probably the single most important issue to be tackled. This is not only because of its impact on expected implementation costs and potential impacts on revenues, but also because resource-efficiency projects usually come with evolving target setting and costly monitoring and evaluation obligations within wider sector-specific resource-efficiency or resource-management frameworks.

Traditionally, Governments have provided interest rate subsidies to capital-intensive, long-term projects to derisk and foster sector-specific sustainability resource programmes, aiming at accelerated diffusion of the best available technologies. Today, such programmes are either supplemented or gradually substituted by more private-capital-based financial instruments such as green bonds, which are typically designed, issued and guaranteed by public financial institutions (e.g., EBRD, EIB)[8] and accompanied by public-private partnership agreements. These new instruments help financial institutions to report on and comply with their own obligations on environmental and ethical performance (e.g., the Norwegian sovereign wealth fund). STI support to develop guidance for methodological support to assess sustainable resource-use projects/programmes is needed, as well as the development of (bio-)physical resource-efficiency indicator databases to inform existing and emerging financial instruments targeted at sustainable resource use.

The design and oversight of the finance system to deliver sustainable SCP outcomes in the "real" economy are important issues to be tackled. In particular, assessments are needed to determine (i) the sufficiency of capital supply to attain resource-specific targets, on both the state of resources and efficiency benchmarks; (ii) the efficiency, alignment and effectiveness of policies consisting of multiple policy instruments to deliver outcomes; and (iii) investment strategies towards specific R&D road maps, with the aim of building large-scale partnership platforms around more incremental but complex technology clusters, as well as around the generation of radical new technological solutions.

Public finance institutions are traditionally bound to be clear about the benefits that resource efficiency and sustainable resource-use investments will yield. A well-articulated investment rationale is needed that typically includes arguments regarding possible market failure. This section will therefore examine the costs of technologies and benefits of sustainable resource management, and review the literature on the benefits of reducing externalities from resource saving. The microeconomics of resource efficiency will be discussed followed by assessments of the macroeconomic benefits of resource efficiency.

Costs of technologies and benefits of increasing resource efficiency

There have been a number of estimates of the costs of increasing resource efficiency; one of the most often cited is from Dobbs and others (2011), which states that, from the perspective of a private investor, the savings in 2030 arising from implementing all the technologies considered would be $2.9 trillion per year—70 per cent of which would offer a rate of return greater that 10 per cent per year. The $900 billion investment required for implementation is estimated to have the potential of creating 9 million to 25 million jobs.

It may immediately be asked why, if there are such negative cost opportunities for investments in resource efficiency, investors do not make the necessary investments to realize these benefits.[9] This issue has been most thoroughly explored for energy efficiency, but the arguments apply equally well to other resources. Sorrell and others (2004) suggest that the failure to make cost-effective energy efficiency investments is the product of three phenomena:

- *Market failure*, normally identified as a result of incomplete property rights, positive and negative externalities, imperfect competition and asymmetric information;
- *Organizational failure*, as a result of imperfect organizational structure and policy; and
- *Non-failure*, where, because of hidden costs, organizations and individuals are in fact behaving rationally in not taking the efficiency opportunities.

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[8] For definitions and explanations of such structured finance, see http://www.eib.org/products/blending/sff/index.htm

[9] These benefits have been calculated at the market prices of resources prevailing in 2010. To the extent that resource prices have declined since 2010, and this is especially true of fossil fuels, the benefits of resource efficiency will be proportionally less.

The existence, strength and persistence of these barriers vary from issue to issue. Therefore, attempts to improve resource efficiency should seek to understand the barriers applicable in any particular case, before identifying and introducing measures to surmount them.

The benefits of reducing externalities from resource saving

The reduction of extraction and use of resources often results in negative external costs, especially in relation to the environment. Resource efficiency measures that reduce these external costs, by internalizing them into the costs of resource use or otherwise, will improve economic efficiency, over and above any other benefits (e.g., cost savings) in which they may result.

The environmental externalities of resource use, which may also be considered subsidies to that use, are very large indeed. The International Monetary Fund (Coady and others, 2015) estimated the external costs related to climate change and local air pollution from burning fossil fuels in 2015 to be about $4 billion.

Coady and others (ibid., pp. 24-25) estimate that eliminating externality-related energy subsidies through efficient pricing of fossil fuels could reduce global consumption of natural gas by 10 per cent, coal consumption by 25 per cent, and the consumption of road fuels in those regions with the highest subsidies by up to 50 per cent. The environmental benefits for human well-being include reduction in CO_2 emissions of more than 20 per cent, and reductions in premature deaths from local air pollution (mainly from coal combustion) by 55 per cent. The global gain in economic welfare from this elimination of fossil fuel subsidies is $1.4 trillion, equivalent to 2 per cent of 2013 global GDP, with most of this gain going to the more than 50 per cent of the world's population living in developing Asia, which experiences a welfare gain equivalent to 6.9 per cent of regional GDP.

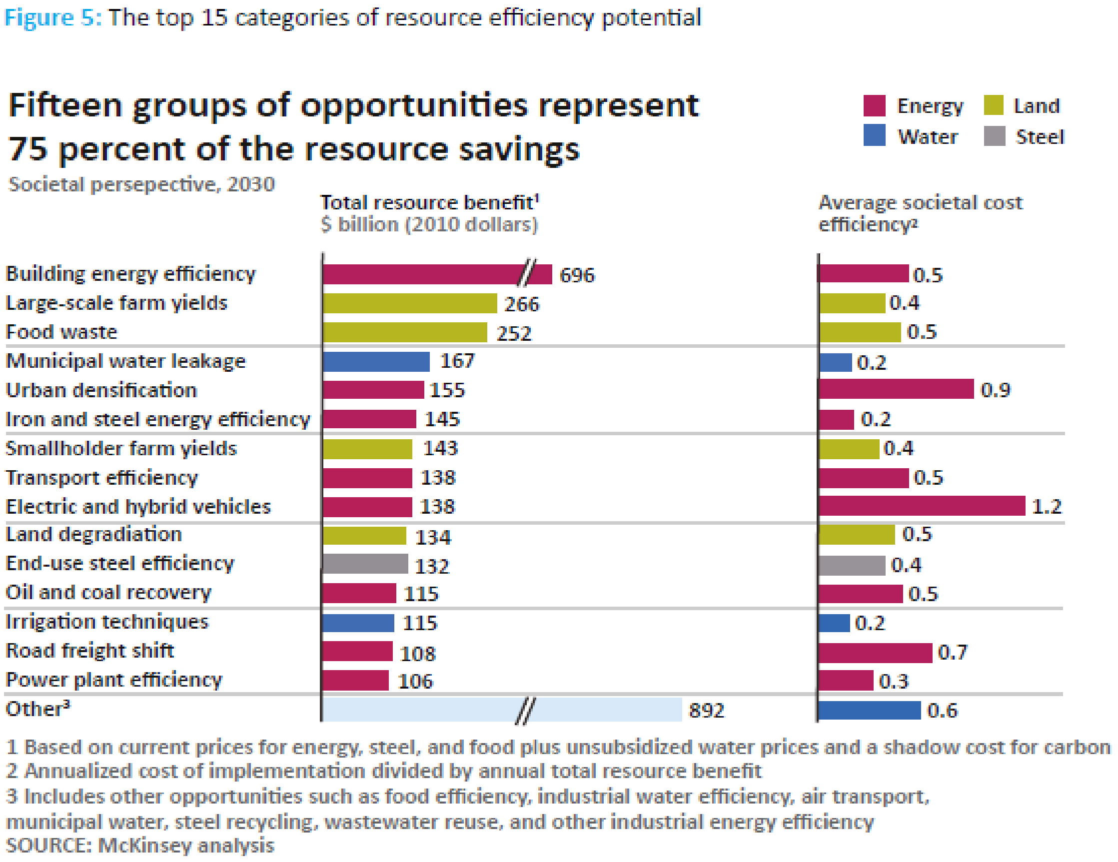
Much of this reduction in fossil fuel consumption could be achieved through increased energy efficiency, rather than reduction in energy service delivery. Thus, International Energy Agency (IEA) (2012) calculates in their Efficient World Scenario that, by 2035, "economically viable" energy-efficiency measures could reduce global coal consumption by 22 per cent, oil consumption by 13 per cent and gas consumption by 14 per cent—all below the level in the IEA New Policies Scenario, which had already achieved energy savings of about 8 per cent through energy efficiency, compared with the Current Policies Scenario (IEA, 2012).

The microeconomics of resource efficiency

Dobbs and others (2011, p.10) calculate that savings to society from resource efficiency would increase from $2.9 trillion from a private investor perspective to $3.7 trillion from a social perspective, if financial subsidies to energy, agriculture and water, and energy taxes were removed, and carbon was priced at $30 per ton. Ninety per cent of this $3.7 trillion savings would yield an investment return of more than 4 per cent (which is often taken as the social discount rate). They group their resource efficiency "opportunities" into 15 categories that capture approximately 75 per cent of this $3.7 trillion savings. These categories are shown in figure 5 from the McKinsey analysis (presented here as figure II.2.1)". Of these 15 categories, it can be seen that only electric and hybrid vehicles have a cost that is greater than the benefit. Many of these categories and opportunities will be discussed in more detail below.

Figure II.2.1

Top 15 categories of resource-efficiency potential



Another important microeconomic factor is risk management. In the case of assessing resource-efficiency projects, environmental risk assessment carries large potential to impact how large amounts of capital can be redirected towards more sustainability. Enhancing environmental risk assessment in financial decision-making is about the effective identification, pricing and management of risk and will need to become an essential feature of efficient and resilient financial markets. Physical and transition factors (including environmental externalities, trends and events) are resulting in a range of financial risks, with implications for both financial institutions and financial authorities. These factors must gain more significance in the future if the SDGs are to be attained. The G20 Green Finance Study Group has developed options for enhancing the ability of the financial system to mobilize private capital for green investments. Environmental risk analysis describes a portfolio of tools and methodologies that enable financial decision makers to integrate environmental data into the decision-making process from the risk management and asset allocation perspectives. Similar work is coordinated by the United Nations Environment Programme (UNEP) Finance Initiative with a stronger focus on climate risks.

Environmental factors are increasingly recognized as being among the most important risk factors for the global economy. The World Economic Forum's 2017 Global Risks Report, for example, concludes that four of the five top risks in terms of impact are environmentally linked: extreme weather events, water crises, major natural disasters and the failure of climate change mitigation and adaptation. These physical risks and the associated transition risks (e.g., policy action to mitigate climate change) are now recognized by some leading insurance companies, asset managers and banks as potential drivers of financial losses, increasing market volatility and sector instability. Examples from practice in several countries show that air pollution, water scarcity and natural capital degradation may also act as sources of credit, market and legal risks for financial institutions.

Stress testing in view of investment risks associated with either environmental policy changes or material risks associated with environmental change were proposed by Swart and others (2013). Such stress tests have been carried out by a number of studies—in China[10] and Germany,[11] for example—mostly focusing on assessing the microeconomic risks stemming from how government efforts in dealing with pollution (e.g., via higher levies on pollutants, carbon tax and the emissions trading system) and energy system regulation may affect borrowers' creditworthiness, profitability and company value. Detailed calculations on the impact of profit distributions as a function of policy uncertainty and optimal response in terms of investment strategies are presented in Fuss and others (2008, 2010 and 2013). Such stress testing could provide significant improvement in the assessment of relative competitiveness of SCP technologies vis-à-vis conventional technologies. However, the respective methods and banking regulations are still not fully established.

II.3 *Existing and novel approaches for addressing financing and economic challenges: a global and national assessment*

The 2030 Agenda for Sustainable Development defines a broad and comprehensive road map for global transformation towards a better and more sustainable future for all. Sustainable consumption and production and the decoupling agenda is not only found in SDG 12, but also in SDG target 8.4: "Improve progressively through 2030 global resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation, in accordance with the 10-year framework of programmes on sustainable consumption and production, with developed countries taking the lead."[12]

It is important to understand that there will be both synergies and trade-offs across the SDGs, and that SCP plays a crucial role in supporting achievement of multiple specific SDGs and the set of SDGs as a whole (IRP, 2015; Obersteiner and others, 2016). Monitoring and implementing the SDGs thus requires a nexus approach that accounts for multiple interactions. For financing in particular, it is important to understand that investment can only operate effectively in harmony with a much wider policy framework. Results are provided from a modelling exercise that draws together many of the elements required to guide the implementation efforts—financing in particular. Achieving progress on understanding particular finance implications requires robust evidence and advice that is trusted by a wide range of stakeholders.

Scientific capacity needs to provide insights relevant to public policy and private decision-making and thorough analysis must account for and integrate across current and future technology options, socioeconomic drivers, natural resource constraints, environmental impacts, and a wide range of factors influencing human well-being. It should provide robust analysis of policy options across different contexts and specific topics and agendas including sustainable resource management, resource efficiency, waste minimization, pollution reduction, and the circular economy. Only in the frame of such comprehensive economic assessments it is possible to address the issues of financial shortfalls and financing requirements—in particular those related to environmental risk accounting.

Assessing global resource use and greenhouse emissions to 2050, with ambitious resource efficiency and climate mitigation policies

Achieving sustainable development requires natural resource use and environmental pressures to be decoupled from economic growth and improvements in living standards (IRP, 2015), so that the impacts of socioeconomic activity are maintained within planetary boundaries (Steffen and others, 2015).

As illustrated in table II.3.1, Hatfield-Dodds and other (2017) use a novel global multimodel framework to develop projections of natural resource use to 2050 (see the " existing trends" scenario in table II.3.1) and three policy scenarios, incorporating detailed analysis of economic dynamics and incentive effects, including changes in the supply and demand of different types of goods and services. Each of the four scenarios represents a specif-

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[10] http://www.greenfinance.org.cn/upfile/upfile/filet/ICBC环境压力测试论文_2016-03-19_08-49-24.pdf

[11] University of Cambridge Institute for Sustainability Leadership (CISL). (2016). Feeling the heat: an investors' guide to measuring business risk from carbon and energy regulation. Cambridge, UK: Cambridge Institute for Sustainability Leadership. May

[12] See https://sustainabledevelopment.un.org/sdg8.

ic combination of potential future resource-use trends and future greenhouse gas emissions pathways.

Existing trends (H3) is calibrated to historical natural-resource-use trends (H) and greenhouse policies that would see a 3°C increase (3) in temperatures by the end of the century, rising to about 4°C after that. Natural-resource-use trends are applied across major world regions, accounting for changes in GDP per capita. Existing trends are aligned with the "middle-of-the-road" Shared Socio-economic Pathway (SSP2) (O'Neil and others, 2015; IIASA, 2015) and greenhouse emissions match the trajectory for Representative Concentration Pathway 6.0 (RCP6.0) (Rogelj, 2012), a little lower than most interpretations of the Paris Climate Agreement pledges (Intended Nationally Determined Contributions) to 2030.

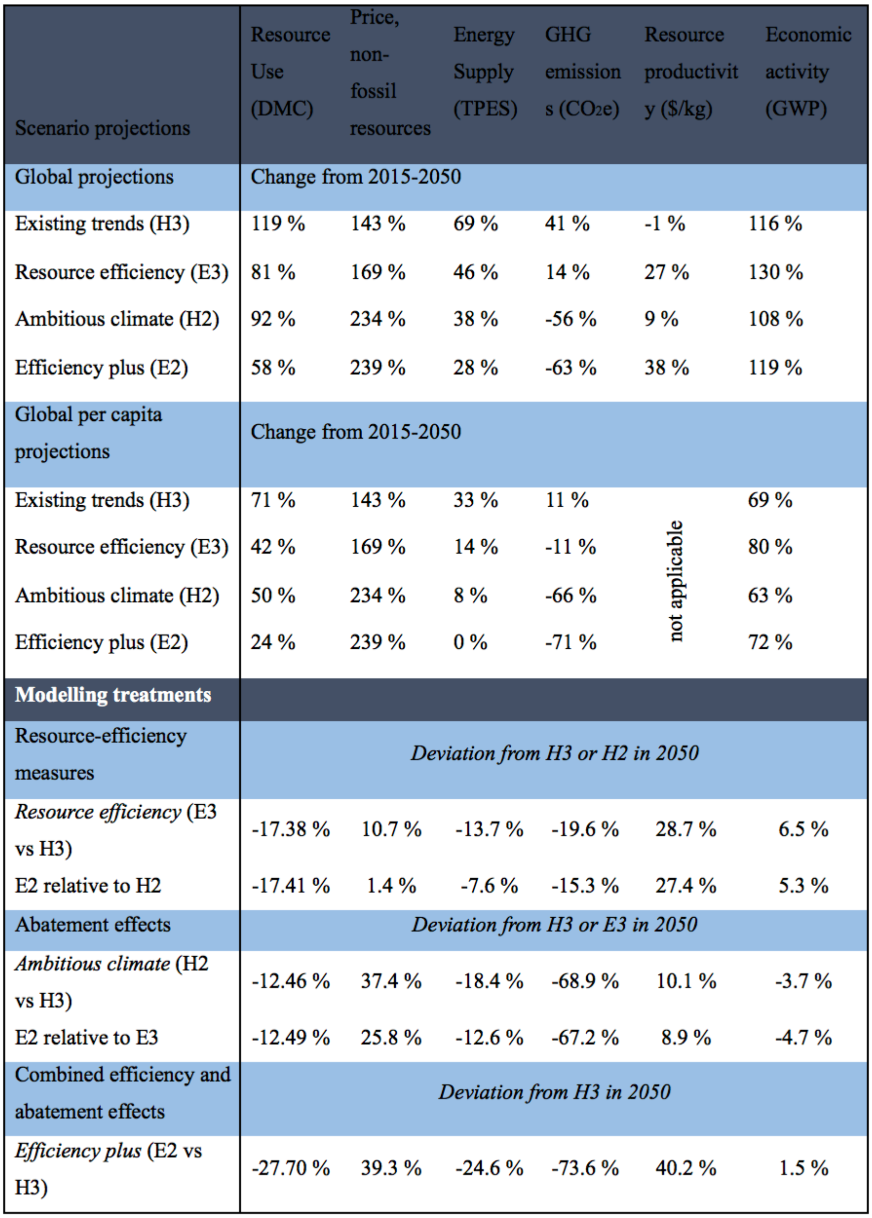
Resource efficiency (E3) assumes a package of stylized measures that drives improvements in resource efficiency (E) from 2020 (described in methods below), with the same greenhouse policies (3) as existing trends.

Ambitious climate (H2) assumes the same natural-resource-use policies (H) as existing trends, but also assumes that the world adopts ambitious greenhouse gas abatement policies capable of limiting likely global temperature increases to 2°C (2) above pre-industrial levels. This represents the increasingly ambitious action required to limit emissions to well below 2°C, going beyond the specific pledges made for 2025-2030, with global greenhouse emissions to 2050 calibrated to match RCP2.6.

Efficiency plus (E2) combines the resource-efficiency settings (E) for the resource-efficiency scenario and greenhouse gas abatement settings (2) for the ambitious climate scenario to explore potential policy interactions. Greenhouse emissions are lower than the RCP2.6 trajectory, implying this scenario has a higher chance of limiting climate change to 2°C than the ambitious climate scenario.

Table II.3.1

Summary of global natural resource use, energy supply, greenhouse gas emissions, resource productivity and economic activity (change from 2015-2050 and impacts in 2050)



Scenario projections	Resource Use (DMC)	Price, non-fossil resources	Energy Supply (TPES)	GHG emissions (CO_2e)	Resource productivity ($/kg)	Economic activity (GWP)
Global projections	Change from 2015-2050					
Existing trends (H3)	119 %	143 %	69 %	41 %	-1 %	116 %
Resource efficiency (E3)	81 %	169 %	46 %	14 %	27 %	130 %
Ambitious climate (H2)	92 %	234 %	38 %	-56 %	9 %	108 %
Efficiency plus (E2)	58 %	239 %	28 %	-63 %	38 %	119 %
Global per capita projections	Change from 2015-2050					
Existing trends (H3)	71 %	143 %	33 %	11 %	not applicable	69 %
Resource efficiency (E3)	42 %	169 %	14 %	-11 %		80 %
Ambitious climate (H2)	50 %	234 %	8 %	-66 %		63 %
Efficiency plus (E2)	24 %	239 %	0 %	-71 %		72 %
Modelling treatments						
Resource-efficiency measures	*Deviation from H3 or H2 in 2050*					
Resource efficiency (E3 vs H3)	-17.38 %	10.7 %	-13.7 %	-19.6 %	28.7 %	6.5 %
E2 relative to H2	-17.41 %	1.4 %	-7.6 %	-15.3 %	27.4 %	5.3 %
Abatement effects	*Deviation from H3 or E3 in 2050*					
Ambitious climate (H2 vs H3)	-12.46 %	37.4 %	-18.4 %	-68.9 %	10.1 %	-3.7 %
E2 relative to E3	-12.49 %	25.8 %	-12.6 %	-67.2 %	8.9 %	-4.7 %
Combined efficiency and abatement effects	*Deviation from H3 in 2050*					
Efficiency plus (E2 vs H3)	-27.70 %	39.3 %	-24.6 %	-73.6 %	40.2 %	1.5 %

Geopolitics and the distribution of impacts across nations

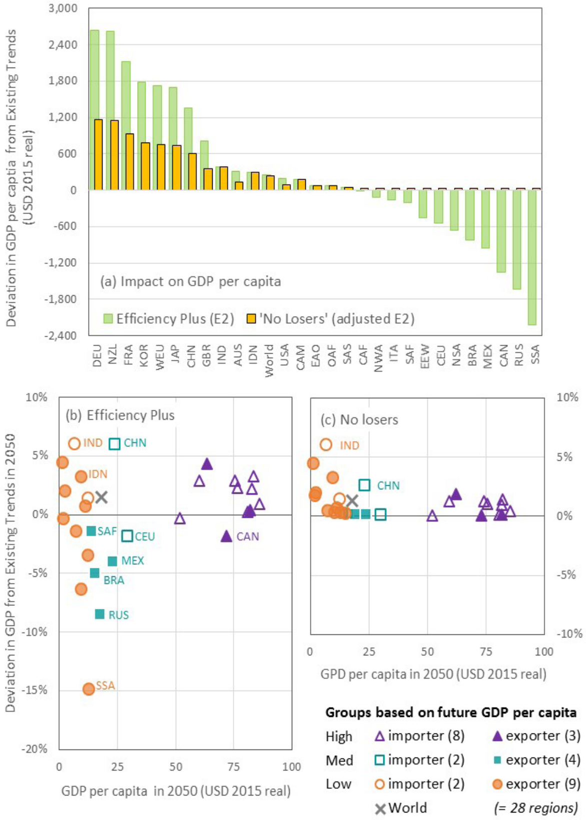
The political economy of resource efficiency and greenhouse abatement are fundamentally different. Resource efficiency can be effectively implemented on a national scale, with well-designed measures providing near-term economic gains to implementing firms and nations in the absence of global action. By contrast, greenhouse abatement is a global public good, with very long lag times between nations incurring the incremental costs of emissions reductions and receiving the non-excludable shared benefits of avoided climate damages.

Hatfield-Dodds and others (2017) find that the efficiency plus scenario would provide net economic gains to 17 of 28 regions, accounting for two thirds (66 per cent) of global population in 2050, and losses to the other 12 regions. (These economic gains and losses do not include the benefits of avoided climate change associated with ambitious abatement in the efficiency plus scenario.) Regions that benefit are largely high-income nations and/or net resource importers (13 of 17), with five of nine low-income net exporters also benefiting (see Figure II.3.1). Benefiting nations include China, India, Indonesia and most Group of Seven nations. Disadvantaged regions include Central Europe, Eastern Europe, South Africa, South America and West Asia. Total net losses are equivalent to 30 per cent of total net gains, or 40 per cent of net gains by high- and medium-income nations. Adding a safety margin of $34 per capita on top of these net losses (recognizing perfect targeting within regions is impractical) would require 50 per cent of net gains by high- and medium-income nations.

Figure shows the impact of an illustrative "no loser" approach in which a grand global deal is struck to deliver both resource efficiency and a 2°C emission trajectory, involving sharing 50 per cent of the potential net economic benefits to high- and middle-income nations to ensure that no region is worse off than they would be under existing trends. This imagines that high- and middle-income nations are willing to forgo some potential gains on the grounds that they are unlikely to be realized in practice without some benefit-sharing. The illustrative deal would address the economic disadvantages of global resource efficiency to resource-exporting nations and the associated geopolitical impediments, and all nations would therefore be better off once the real (but hard to quantify) long-run benefits of avoided climate change are accounted for. It also redresses, at least in part, the lack of formal representation of differentiated emissions targets and associated global emissions trading in the ambitious climate scenario.

Figure II.3.1

Impact on economic activity (GDP per capita) for 28 regions in 2050: 3 scenarios



Source: Hatfield-Dodds et al. (2017)

Assessing the economics of resource-efficiency measures

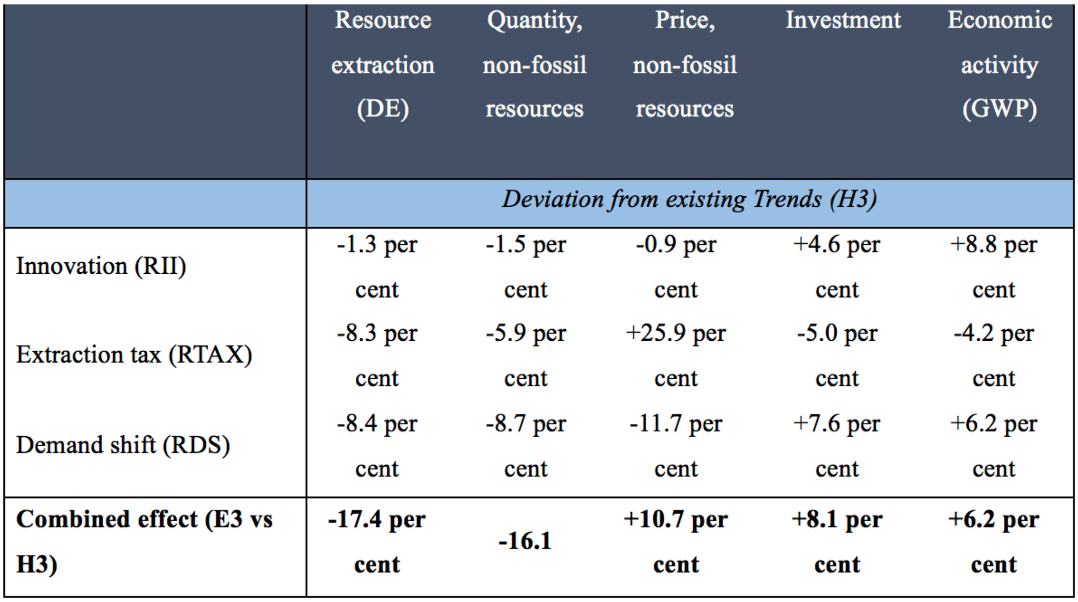
The modelling explored potential improvements in resource efficiency through a combination of three measures, reflecting the main ways in which reductions in resource intensity and slower growth in natural resource extraction can be achieved in computable general equilibrium (CGE) and similar economic models: technical resource innovation and improvements (RII) reduce the quantity of resource input required for a given volume of output; a resource extraction tax (RTAX) increases the price of natural resources relative to other inputs; and an exogenous resource demand shift (RDS) shifts the demand curve towards the origin, mimicking the effect of changes to regulations, planning and procurement policies that seek to maintain or improve the services or amenity provided through natural resource use (such as the space and comfort provided by buildings) with progressively lower resource intensity over time.

The three types of measures have very different impacts on natural resource extraction, resource prices, investment and overall economic activity, as shown in Table 2.2. Innovation (RII) reduces prices and boosts economic growth, but has only very modest impacts on extraction volumes, due to the rebound effect, where lower unit costs induce higher direct and indirect natural resource use. The extraction tax (RTAX) increases prices and slows the growth of natural resource use, and also lowers the rate of economic growth. The resource demand shift (RDS) reduces prices and the volume of extractions modestly, and relatively evenly, with a positive second round impact on economic activity through increased investment (due to reduced expenditure on consumption of materials-based goods and services). The measures also impact differently across natural resource categories (biomass, fossil fuels, metal ores and non-metallic minerals).

Crucially, the different patterns of impacts associated with these stylized measures implies that the physical effectiveness and economic impacts of real-world resource efficiency initiatives will depend on the mix and detailed design of the measures employed. While we find here that resource efficiency boosts economic growth and provides net economic benefits, it is possible that resource efficiency strategies could slow growth and result in net economic costs in some circumstances.

Table 2.2

Impacts of resource efficiency components on global resource extraction (DE), resource prices, investment and economic activity (GWP) in 2050. Deviation from Existing Trends (H3).



	Resource extraction (DE)	Quantity, non-fossil resources	Price, non-fossil resources	Investment	Economic activity (GWP)
	Deviation from existing Trends (H3)				
Innovation (RII)	-1.3 per cent	-1.5 per cent	-0.9 per cent	+4.6 per cent	+8.8 per cent
Extraction tax (RTAX)	-8.3 per cent	-5.9 per cent	+25.9 per cent	-5.0 per cent	-4.2 per cent
Demand shift (RDS)	-8.4 per cent	-8.7 per cent	-11.7 per cent	+7.6 per cent	+6.2 per cent
Combined effect (E3 vs H3)	**-17.4 per cent**	**-16.1**	**+10.7 per cent**	**+8.1 per cent**	**+6.2 per cent**

II.4 *The potential for STI road maps to facilitate necessary investments*

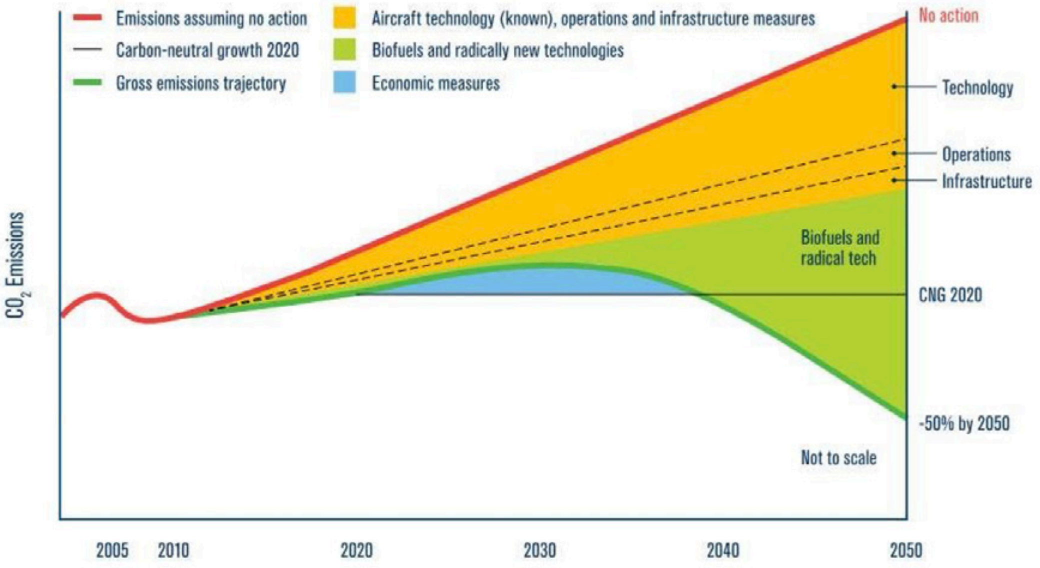
In view of climate mitigation, STI road maps exist for many sectors (e.g., energy, building, transport, pulp and paper) on the global level. Typically, they provide a vision of what the particular sectors could do by applying Best Available Technologies (BAT) or known and proven technologies on larger scales. This section takes a deeper look into the road map of the aviation industry—one that stands out by proposing a technology wedge of "radical tech," which is currently not fully defined and is yet to be created by targeted STI efforts.

Incremental and radical STI investments in the aviation industry towards its 2050 climate target

There are many road maps on climate mitigation by countries or global and regional sectors. However, there are hardly any road maps that explicitly count on outcomes of new radical technologies because of particular STI investment strategies. The aviation industry represents a notable exception in the sense that it is counting on radical technological solutions in its sector to appear (mostly) two decades from now, which would allow the industry to meet its ambitious mid-century climate mitigation target.

Figure II.4.1

Schematic climate mitigation technology road map



Source: IATA The IATA Technology Roadmap is intended to assist airlines, and the aviation industry in general, in assessing the effect of different technologies, and to monitor how technology measures help achieve the high-level industry goals for emissions reduction by providing an overview of fuel-efficient green technologies and their impacts at both single-aircraft and world-fleet levels.

The aviation industry pledged a commitment to taking a global approach to mitigating aviation greenhouse gas emissions, adopting three high-level goals as illustrated in figure II.4.1:

i. An average improvement in fuel efficiency of 1.5 per cent per year from 2009 to 2020;

ii. A cap on net aviation CO_2 emissions from 2020 (carbon-neutral growth);

iii. A reduction in net CO_2 emissions of 50 per cent by 2050 relative to 2005 levels.

These collective goals were endorsed by the whole aviation industry (airlines, manufacturers, airports and air navigation service providers) in the joint industry submission to the International Civil Aviation Organization (ICAO) in 2009. Governments meeting at ICAO in October 2010 then set out a fuel efficiency goal to 2 per cent per year and made carbon-neutral growth an aspirational goal from 2020. In order to achieve these high-level goals, the aviation industry established a four-pillar strategy comprising

i. Investment in new technology (more efficient airframe, engines and equipment; sustainable biofuels; new energy sources)

ii. Efficient operations (drive for maximum efficiency and minimum weight)

iii. Effective infrastructure (improve air routes, air traffic management and airport procedures)

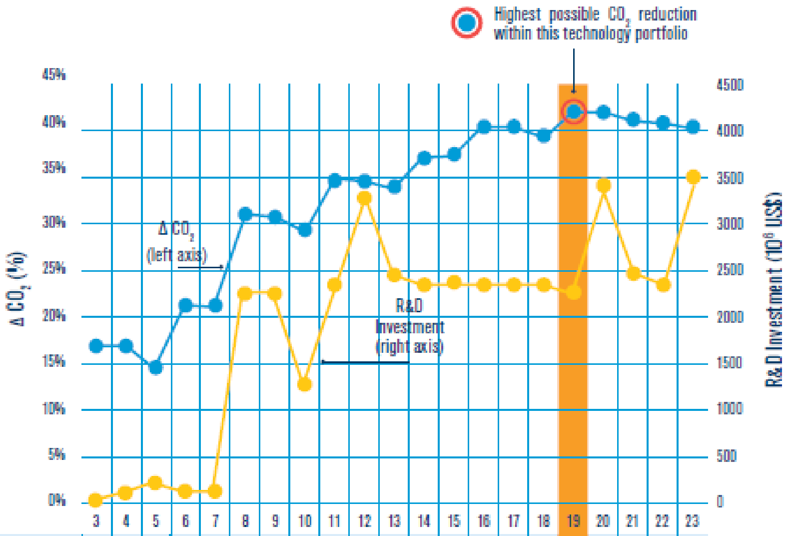
iv. Positive economic measures (carbon offsets, global emissions trading)

The first of these four pillars—new technology—holds the great potential so critical to achieving the desired objectives in emission reduction. This pillar will also require specific, large-scale and long-term funding which the industry, in cooperation with actors from the public STI sector, has yet to raise. Their achievement largely depends on the development and implementation of new technologies by aircraft, engine and equipment manufacturers. The environmental benefits of these technologies (through better fuel efficiency and, thus, lower carbon emissions) will become effective through airline fleet modernization and, to a minor degree, retrofits to in-service aircraft. There is an underlying challenge to selecting the appropriate technologies, as this selection is driven by sometimes uncertain factors, such as current development status, benefits, risk, and R&D costs. IATA (2013) provides an example of technology portfolios and their respective estimates of CO_2 savings and R&D investment requirements. The very dynamically developing area of aviation biofuel technologies can be considered independently from aircraft technologies as long as only drop-in fuels are used, which is expected to be the case for the next few decades. Progress in this area is reviewed on a continuous basis in the IATA Report on Alternative Fuels, which appears annually.

For a long time, fuel costs, which usually represent the largest single item in an airline's operational costs, have been considered to be a sufficient driver for improving fuel and CO_2 efficiency and the related technology developments. In view of its ambitious climate targets the industry has decided to develop an ICAO aircraft certification standard for CO_2 emissions, similar to the existing standards for noise and engine emissions (nitrogen oxides, carbon monoxide, unburned hydrocarbons, smoke). The aim of the CO_2 standard is to foster the development and use of fuel-efficient technologies and designs by aircraft and engines manufacturers. Effective infrastructure measures constitute another straightforward efficiency wedge for CO_2 mitigation and resource sparing.

Figure II.4.2

Technology portfolios to increase carbon efficiency and their estimated R&D investment requirements



			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Aerodynamics	T1	Natural Laminar Flow Control								■	■		■	■	■	■	■	■	■		■	■	
	T2	Hybrid Laminar Flow Control						■	■			■								■			■
	T3	Active Load Alleviation	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	T4	Variable Chamber				■	■							■	■				■	■	■	■	■
	T5	Fuel Cells									■	■	■	■	■	■	■	■	■	■	■	■	■
	T6	Lightweight Cabin Interiors	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	T7	Riblets				■	■							■	■				■	■	■	■	■
	T8	Laminar Flow Drag Coatings						■	■	■	■	■	■			■	■	■					
Wing	T9	CentrAL								■								■				■	■
	T10	Composite Primary	■	■	■	■	■	■	■		■	■	■	■	■	■	■		■	■	■		
	T11	Advanced Aluminum																					
	T12	Al-Li Alloys																					
	T13	CentrAL																					
Fuselage	T14	Composite Primary	■	■		■	■	■	■	■	■	■		■	■	■	■	■	■	■		■	
	T15	Advanced Aluminum			■								■								■		■
	T16	Al-Li Alloys																					
Empennage	T17	CentrAL																					
	T18	Composite Primary	■																■				
	T19	Advanced Aluminum		■	■		■		■			■	■		■		■			■	■	■	■
	T20	Al-Li Alloys				■		■		■	■			■		■		■					
Engine	T21	Advanced Turbofan														■	■	■	■	■	■	■	■
	T22	Geared Turbofan						■	■	■	■	■	■	■	■								
	T23	Winglet	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	T24	Structural Health Monitoring	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Source: IATA (2013)

The fourth pillar proposed by the industry refers to the implementation of market-based offsetting measures in international aviation. While a single market-based measure for aviation may be necessary as a gap filler to achieve the industry's climate change targets, including capping net emissions at 2020 levels (carbon neutral growth 2020), market-based measures are not expected to drive technological developments. They act more as a kind of insurance in cases where certain STI developments are not delivered in time or fail to be delivered, ensuring that the industry is still able to comply with its three climate mitigation targets at any point in time.

The flexibility gained through the availability of market-based instruments has several advantages:

- It allows the industry to commit itself early on to ambitious climate mitigation targets;
- It allows the industry to engage in a long-term STI-based investment strategy to develop game-changing new radical technologies that will transform the industry in the long run into a low-carbon transport sector. Also, incremental innovations can be developed according to feasible time plans without endangering the high safety standards of the industry;
- It allows compliance with short-term targets, which would otherwise be infeasible due to the vintage structure of the airplane fleet and avoids situations of early retirement of aviation assets characterized by large early sunk costs.

As a consequence of the availability of market-based instruments, STI investment can be planned according to the envisaged road map. Investment instruments can, thus, be tailored towards the necessities of the respective STI project depending on the required investment amounts, level of technology readiness, and public or private interest. The instruments can vary from classical public research grants with or without private co-financing obligations to industry-wide breakthrough technology bonds modelled after catastrophe (CAT) bond structures.

III. Conclusion and suggestions for a way forward

There are a number of high-level points that can be taken away from the analysis presented above.

- **Investments into resource efficiency**, sustainable consumption and production (SCP) are **key** for the attainability of the SDGs in their entirety. However, finance for incremental research and development and deployment of **best available technologies (BAT) will not be sufficient** to meet the ambitions of the Sustainable Development Goals (SDGs).
- A systemic transformation towards sustainability will require significant **additional science, technology and innovation (STI) investments to generate radically new technologies,** which also complement no-regret deployment of BATs (including offsets) together ensuring that the SDGs are attainable.
- **STI investments** are more likely to be **economically superior** to classical technology-diffusion-enhancing policies. Communication of long-term commitments to **large-scale STI programmes** based on adaptively developed technology road maps will provide the necessary market signals for **avoiding** sinking large amounts of investments in **technological lock-ins**.
- The multiple goals of the SDGs need to be addressed by **smart portfolios of regulatory and economic policy instruments, creating a stable investment environment** with the aim of triggering and continuously supporting transformational change towards sustainability. Public finance systems, in particular for STI investments, need to be consistent with societal and technological road maps towards sustainability that are characterized by ambitious goals.
- **New blended finance instruments** will be necessary to **bring international STI programmes to scale**. Cross-border risk sharing in public-private partnership/STI finance constructions will provide strong directional signals and reinforce commitments towards adaptive technology road maps.
- **International STI investment programmes** creating SCP technology clusters of excellence need to be designed such that, from inception, **no one is left behind**. Supplementary international (public) STI finance programmes are necessary for building critical capacity more ubiquitously through open funding calls with minimum participation criteria for developing countries.

IV. A narrative of a way forward: from a business-as-usual transition economy to the SDG economy

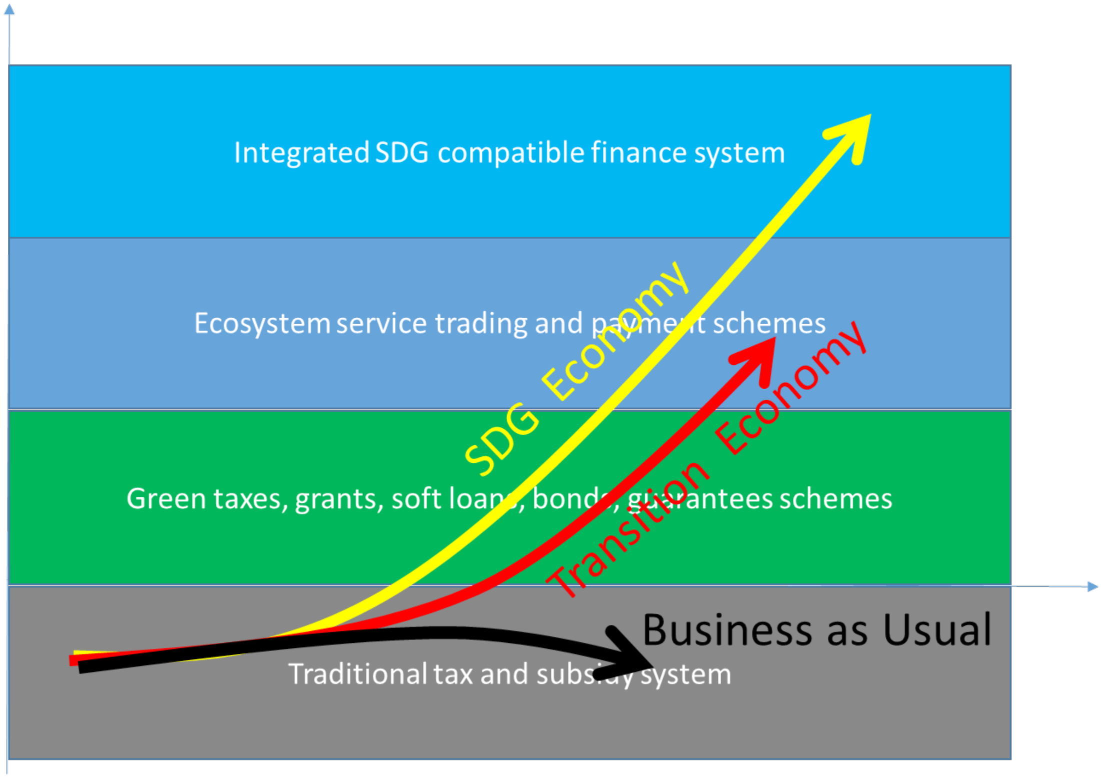
The transition to an economy which is consistent with timely delivery of the Sustainable Development Goals (SDGs) can be conceptualized according to the three horizons framework (Sharpe and others, 2016). As illustrated in Figure IV.1 during the first implementation wave, there is a phasing out of business-as-usual modes of operation. In this phase, the functioning of the economy needs to be increasingly informed by stacking up new policy instruments that first help to push deployment of best available technologies (BAT) technologies through financial incentives, such as tax breaks, green bonds, and public resource efficiency investment guarantee schemes that back private-sector-led soft loan schemes. Green taxes provide economic incentive to reduce extraction, consumption and waste disposal. New technology initiatives are not only pushed by conventional research grant schemes, but are also increasingly combined with incubator funding. Technology road maps that are co-created in technology platforms provide inputs to science, technology and innovation (STI) policy planning and prioritization.

The ***transition economy*** also starts with experiments and scales up markets for ecosystem services. Trading systems and ecosystem service payment schemes such as carbon markets are currently approaching 20 per cent coverage of global power plant emissions at prices not yet compatible with the Paris Climate Agreement. Sector-specific global alliances are emerging and engaging in joint target-setting and technology road-mapping as illustrated by the example of the aviation industry: Public-private partnership arrangements emerge to finance large-scale STI programmes with the purpose of developing radically new technologies necessary for attaining ambitious sector-wide sustainability targets by mid-century. The economy becomes increasingly circular and resource decoupling is observable and intensifies. Signs of impact decoupling become visible.

The ***SDG economy*** starts to rise when some of the breakthrough technologies emerge on the markets and lead to fast transitions. Breakthrough technologies are crowding out other technologies that are not compatible with SDG pathways. There is a constant STI pull as regulatory and economic incentives follow the pressure to achieve impact decoupling through not only creative destruction of obsolete old economy assets, but also smarter consumer behaviour and an integrated public and private financial system guided by Environmental and Social Risk Assessment methodologies. The SDG-compatible finance system rewards risk taking for sustainability solutions and discourages investments that are not in line with the principles of the circular economy and that fail to deliver large enough marginal impact avoidance. STI finance systems allow for participation of developing countries, ensuring the presence of critical STI capacities in large-scale globally distributed STI clusters of excellence and that STI solutions are also locally adapted and can be rolled out on a global scale. Breakthrough technology initiatives are funded by traditional public granting mechanisms, but new financial instruments (e.g., those modelled after catastrophe (CAT) bonds) also become available to accelerate the production and diffusion of hard and soft technologies in service of a resource-efficient circular economy attaining levels of impact decoupling. For some resources, impact decoupling can even become regenerative. Economic tools that served the old economy diminish in their relative importance.

Figure IV.1

Conceptual framework of economic levers to enable sustainable economic transition with respect to SDG 12*

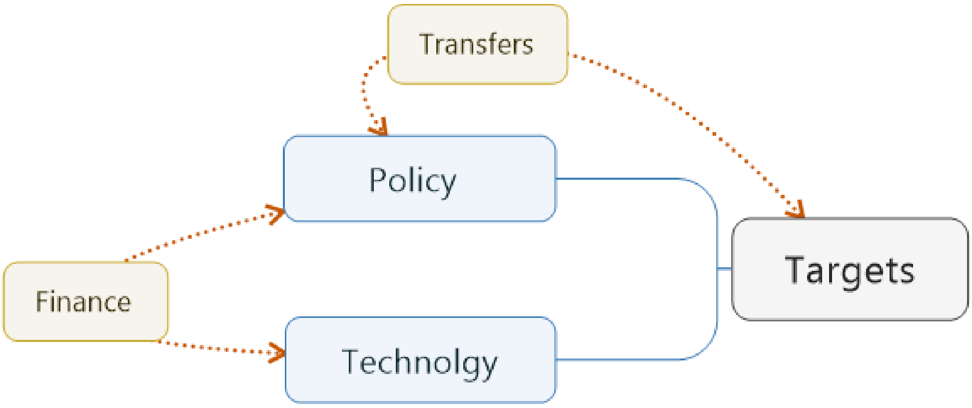


*Economic levers were selected to match the goal of achieving the sustainable management and efficient use of natural resources in a wider SDG framework. Three pathways of development of the economic system are distinguished: (i) business as usual; (ii) emerging economy; and (iii) SDG compatible economy. The stacked blocks indicate the elements of economic instruments to be bundled to attain advanced states of SDG compatibility.

Finally, as depicted in , a consistent STI finance framework needs to be embedded in a wider SDG policy process, where clear and quantitative targets are set on global, national and subnational levels. Pathways to reach these goals are investigated and translated into tangible policy and technology road maps, which are sufficiently adaptive to absorb exogenous shocks. These road maps are the outcome of adaptive multi-stakeholder consultation processes involving public, private and civil society entities. Road maps are differentiated by geography, sectors and timelines. The elaboration of globally consistent national/regional plans will only become politically feasible if they are enabled by transfers from the global North to the global South, following the principle of common but differentiated responsibilities. Public and private sources of finance provide the capital and, therefore, the coordination function to deploy technologies and create behavioural changes through price incentives. Early retirement of capital that has become obsolete sooner than expected is properly priced and technically hedged. Finally, STI finance also serves the function of promoting the radical new technologies necessary to attaining the ambitious SDG goals—which currently seem out of reach, but their fulfilment is essential to avoiding transgressing planetary boundaries and ensuring well-being for all.

Figure IV.2

Simplified process diagram of the SDG delivery system in relation to targets for sustainable resource management



Source: Obersteiner.

5. Annotated Bibliography

REFERENCE	COMMENT
UNEP (2017) Resource Efficiency: Potential and Economic Implications. A report of the International Resource Panel. Ekins, P., Hughes, N., and others.	Comprehensive report on the economics of resource efficiency, impact decoupling and circular economy; There are many relevant case studies for resource efficiency presented in this report
The 10-year framework of programmes on sustainable consumption and production patterns (10YFP)	The 10YFP also fosters knowledge and experience sharing, and facilitates access to technical and financial resources for developing countries. 10YFP Trustfund (18 small scale projects funded)
Ellen MacArthur Foundation (2017) "Achieving growth within"	A €320-BILLION CIRCULAR ECONOMY INVESTMENT OPPORTUNITY AVAILABLE TO EUROPE UP TO 2025
Ellen MacArthur Foundation (2015) Towards a Circular Economy: Business rational for an accelerated transition	Presents a vision and concrete steps and investment potential for business to implement a circular economy. The report has a strong focus on Europe.
OECD (2015), Material Resources, Productivity and the Environment, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264190504-en	Gives a good understanding of how minerals, metals, timber or other materials flow through the economy throughout their life cycle, and of how this affects the productivity of the economy and the quality of the environment. Report considers the production and consumption of materials, as well as their international flows and available stocks, and the environmental implications associated with their use. It also describes some of the challenges and opportunities associated with selected materials and products that are internationally-significant, both in economic and environmental terms (aluminum, copper, iron and steel, paper, phosphate rock and rare earth elements).
EAT Lancet Commission (2017)	Understanding what constitutes a healthy diet and how to produce it sustainably for 9 billion people by 2050 is arguably the greatest challenge facing humanity. The EAT-Lancet Commission on Food, Planet, Health is developing science-based targets that define what is a healthy diet from a sustainable food system – and showing how to take action for a better food future.
(Obersteiner and others, 2016)	SCP in the food sector act as depressor elements to attain SDG 15 goals in the overall land system
IATA (2013). IATA Technology Roadmap, 4th edition, June 2013. https://www.iata.org/whatwedo/environment/Documents/technology-roadmap-2013.pdf	In this publication the global airline industry provides an ambitious and detailed technology roadmap for low to no GHG emissions fuels and practices.
(Lemoine and others, 2010)	Portfolio approach to investment in R&D for incremental resource efficiency in energy technologies and R&D investment to produce radical new technologies to attain ambitious climate targets.

OECD (2016), Policy Guidance on Resource Efficiency, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264257344-en	Improving resource efficiency by putting in place policies that implement the principles of reduce, reuse, recycle (the 3Rs) is crucial to improving resource use, security and competitiveness while diminishing the associated environmental impacts.
(Klimek and others, 2015)	Paper illustrates that for risk reduction in supply of key minerals and metals SDP and circular economy concepts can help mitigate risk exposure.
UNEP (2011) Decoupling natural resource use and environmental impacts from economic growth, A Report of the Working Group on Decoupling to the International Resource Panel. Fischer-Kowalski, M., Swilling, M., vvon Weizsacker, E.U., Ren, Y., Moriguchi, Y., Cran, W., Krausmann, F., Eisenmenger, N., Giljum, S., Hennicke, P., Romero Lankao, P., Siriban Manalang, A.	
UNEP-FI Guide to Banking and Sustainability (2016)	Through these pages, three key messages emerge on what defines a sustainable bank: • First, addressing sustainability issues requires responsibilities and actions to be taken at all levels and across all the key functions of banks. • Second, a sustainable bank is one that not only understands and manages the risks that arise because of sustainability issues, but also perceives the strategic dimension of these issues. • Third, communicating and engaging—within the bank, with peers and with stakeholders—is critical to embracing something as complex and as vital as sustainability issues.

Food and Agriculture Organization of the United Nations, International Fund for Agricultural Development, UNICEF, World Food Programme, World Health Organization, 2017. The state of food security and nutrition in the world 2017: building resilience for peace and food 25 security.

Hatfield-Dodds, S., Schandl, H., Newth, D., Obersteiner, M., Cai, Y., Baynes, T., West, J., Havlik, P., 2017. Assessing global resource use and greenhouse emissions to 2050, with ambitious resource efficiency and climate mitigation policies. Journal of Cleaner Production 144, 403– 414. https://doi.org/10.1016/j.jclepro.2016.12.170

Klimek, P., Obersteiner, M., Thurner, S., 2015. Systemic trade risk of critical resources. Science Advances 1, e1500522. https://doi.org/10.1126/sciadv.1500522

Lemoine, D.M., Fuss, S., Szolgayova, J., Obersteiner, M., Kammen, D.M., 2010. The optimal portfolio of emissions abatement and low-carbon R&D depends on the expected availability of negative emission technologies.

Obersteiner, M., Peñuelas, J., Ciais, P., van der Velde, M., Janssens, I.A., 2013. The phosphorus trilemma. Nature Geoscience 6, 897–898. https://doi.org/10.1038/ngeo1990 Obersteiner, M., Walsh, B., Frank, S., Havlik, P., Cantele, M., Liu, J., Palazzo, A., Herrero, M., Lu, Y., Mosnier, A., Valin, H., Riahi, K., Kraxner, F., Fritz, S., Vuuren, D. van, 2016. Assessing the land resource-food price nexus of the Sustainable Development Goals.

Science Advances 2, e1501499. https://doi.org/10.1126/sciadv.1501499

Sauer, T., Havlík, P., Schneider, U.A., Schmid, E., Kindermann, G., Obersteiner, M., 2010. Agriculture and resource availability in a changing world: The role of irrigation. Water Resour. Res. 46. https://doi.org/10.1029/2009WR007729

Sharpe, B., Hodgson, A., Leicester, G., Lyon, A., Fazey, I., 2016. Three horizons: a pathways practice for transformation. Ecology and Society 21. https://doi.org/10.5751/ES-08388-210247

Annex I

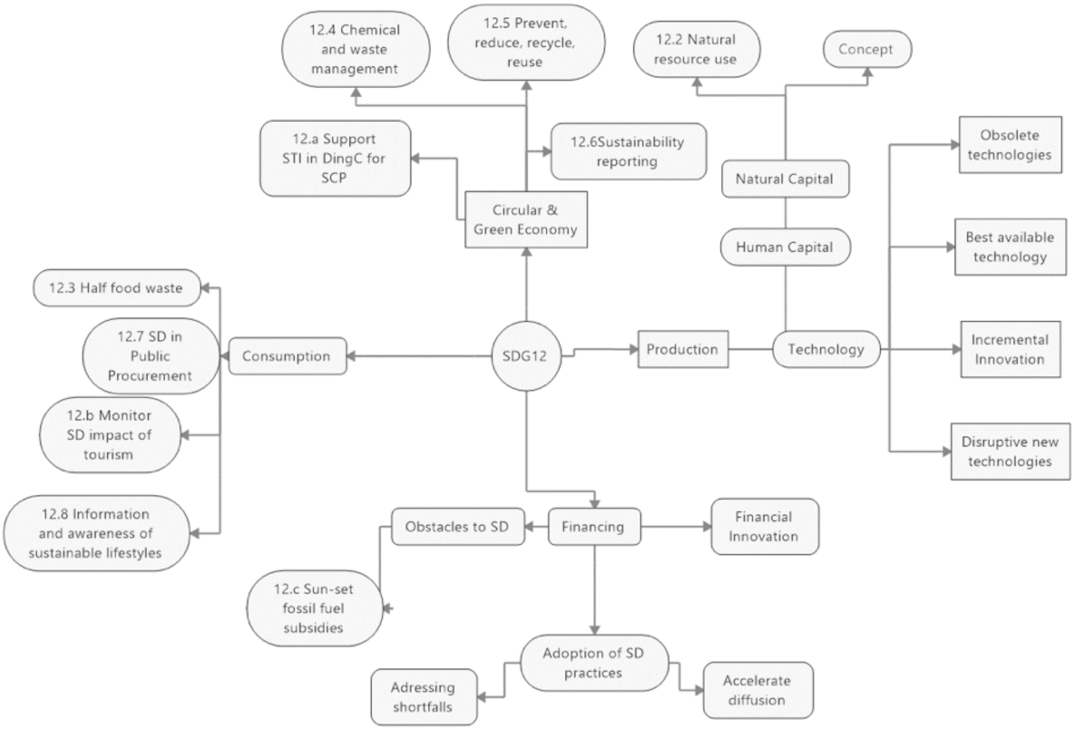
SDG 12 and its targets

SDGs	Targets
12: Ensure sustainable consumption and production patterns	12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns, all countries taking action, with developed countries taking the lead, taking into account the development and capabilities of developing countries
	12.2 By 2030, achieve the sustainable management and efficient use of natural resources
	12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses
	12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
	12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
	12.6 Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle
	12.7 Promote public procurement practices that are sustainable, in accordance with national policies and priorities
	12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature
	12.a Support developing countries to strengthen their scientific and technological capacity to move towards more sustainable patterns of consumption and production
	12.b Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products
	12.c Rationalize inefficient fossil-fuel subsidies that encourage wasteful consumption by removing market distortions, in accordance with national circumstances, including by restructuring taxation and phasing out those harmful subsidies, where they exist, to reflect their environmental impacts, taking fully into account the specific needs and conditions of developing countries and minimizing the possible adverse impacts on their development in a manner that protects the poor and the affected communities

Annex 2

Figure AII.1

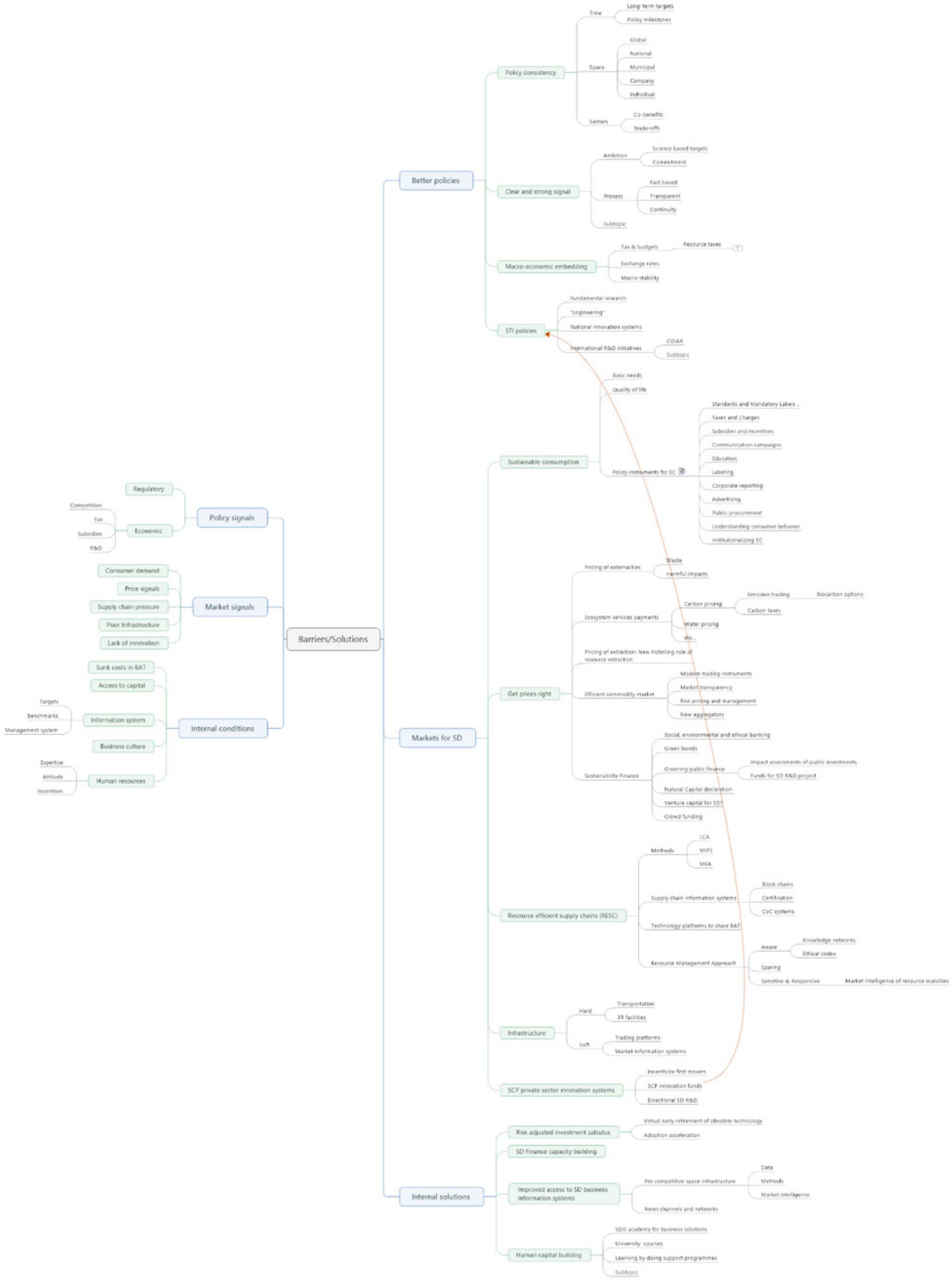
Mind map of SDG 12



Source: Obersteiner

Figure AII.2

Mind map of barriers and solutions related to STI development and deployment issues in the context of SDG 12.



Source: Obersteiner