UN environment

International Resource Panel

SUMMARY FOR POLICYMAKERS

ASSESSING GLOBAL RESOURCE USE

A systems approach to resource efficiency and pollution reduction

Acknowledgements

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SUMMARY FOR POLICYMAKERS

ASSESSING GLOBAL RESOURCE USE

A systems approach to resource efficiency and pollution reduction

Produced by the International Resource Panel.

This document highlights key findings from the report, and should be read in conjunction with the full report. References to research and reviews on which this report is based are listed in the full report. The full report can be downloaded at http://www.resourcepanel.org/reports/assessing-global-resource-use

Additional copies can be ordered via e-mail: resourcepanel@unep.org, or via post:
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Preface

At the Second Session of the United Nations Environment Assembly, nations not only recognized that fundamental changes in the way societies consume and produce are indispensable for achieving global sustainable development, but also acknowledged the importance of rigorous scientific evidence on the sustainable use of natural resources to inform policies to this end.

The International Resource Panel was honoured to be called upon at that session to make available information on the state, trends and outlook of sustainable consumption and production to the Assembly by 2019.[1] This interim report is the first step in responding to that request. It builds on ten years of research by the panel to reassert the centrality of natural resource management to achieving sustainable development; to reiterate the urgency and imperative to decouple economic activity and human well-being from resource use; and to provide innovative solutions based on cutting-edge data to support the transformation of our linear production and consumption systems towards efficiency and circularity.

In line with the drive for a pollution free planet at the Third Session of the United Nations Environment Assembly, the research takes a step further to look at the relationship between resource use and pollution. The amount of natural resources used is closely linked to the amount of final waste and emissions generated through their use. Effective pollution control must therefore also look to minimize raw material use, thereby decreasing final waste and emissions. This link between natural resource use and management and pollution mitigation is explored in depth at the city scale in the special feature of this report. Using a systems approach to examine resources used in developing and emerging economy cities, strategies are being put forward to reduce pollution while also advancing human well-being.

Such innovative and multi-beneficial approaches to the complex social, economic and ecological challenges of our times can be revealed by measuring and monitoring the way we extract, use and dispose of our natural resources. The scientific evidence put forward in this interim report focuses on material resources, including - for the first time - results drawn from a database spanning fifty years up to 2017. Subsequent research of the Panel, including a report to be submitted to the Fourth Session of the United Nations Environment Assembly in 2019, will expand this analysis to include water, land and fossil fuel and emission footprints.

1 Second Session of the United Nations Environment Assembly, Resolution 2/8 on ***S****ustainable Consumption and Production* available at:http://wedocs.unep.org/bitstream/handle/20.500.11822/11184/K1607179_UNEPEA2_RES8E.pdf?sequence=1&isAllowed=y.

Through continued reporting on this information at regular intervals, the International Resource Panel aims to improve the evidence base for systemic monitoring and policymaking for sustainability. It is our hope that such regularly reported data in our Global Assessment series can support the efforts of nations to monitor natural resource flows and the work of policymakers to orient socio-economic transitions toward sustainability.

We wish to sincerely thank the lead authors and the members of the International Resource Panel working group for laying the groundwork for such important research through this interim edition of the Global Assessment series. Equally, we would like to thank the members of the United Nations Environment Assembly for their confidence in the International Resource Panel to deliver this important work.

Janez Potocnik
Co-Chair
International Resource Panel

Izabella Teixeira
Co-Chair
International Resource Panel

Foreword

The more natural resources that move through our economy, the more impact - including waste, emissions and hazardous pollutants - we can expect on our environment and, in turn, our well-being. While seemingly a straightforward proposition, the links between human well-being, economic prosperity and environmental resilience are complex and varied. This means that, unless all three dimensions are taken into consideration in policymaking, any progress in achieving ambitions across them may be hampered by unintended consequences and rebound effects.

This interim report of the International Resource Panel provides a first glimpse at a new evidence base that can inform precisely this kind of integrated policymaking. It presents up-to-date information on material resources that reveals where material resources are extracted and used, for what purpose and to what effect. This information can drive targeted policy interventions and the setting of long-term goals to transform how resources are used for the benefit of people and a pollution-free planet. Seven key strategies are proposed, and existing examples from across the globe shared, to drive the transformation of consumption patterns and production systems that contribute to human well-being without putting unsustainable pressures on the environment.

The implications of this type of integrated policymaking are potentially transformative. Using data on water, fossil fuels, air pollution and greenhouse gas emissions for Delhi, India, and over 600 cities in China, case studies demonstrate how information on natural resources can help identify policy bundles that deliver a significant improvement in human well-being with a relatively small investment in resources. For developing and emerging economies, this means that delivering well-being for all citizens can be achieved with only a modest increase in the amount of resources used. For developed economies, absolute levels of resource use and impacts can be reduced while still achieving high social and economic gains.

In the case example of Delhi, a policy bundle that requires only a ten per cent increase in the city's energy and material (cement) resource demand was estimated to improve the well being of 7 million underserved homes (while decreasing greenhouse gas emissions and the fine particulate matter emissions that are a dominant risk factor in air-pollution related premature deaths). In China, a mix of compact urban design and circular economy policies could contribute up to 35 per cent towards carbon dioxide mitigation compared to single sector strategies, while also avoiding pollution-related mortalities. While every city faces its own unique challenges and circumstances, the case examples demonstrate the importance of this new evidence base in supporting impactful policy design.

The drive towards transformative, integrated approaches to sustainability must be founded on rigorous science - so that progress in one area reinforces advancements in others. Recognizing this, in Resolution 2/8 on *Sustainable Consumption and Production* the Second Session of the United Nations Environment Assembly asked the Panel to share scientific knowledge on the state, trends, and outlook of sustainable consumption and production. This report is the interim response to this request, with impressive results. I am sure you will join me in welcoming this contribution to the debates at the Third Session of the Environment Assembly, and in looking forward to the subsequent reports of this series that will expand its assessment to other natural resources including land, water and greenhouse gas emissions.

Ligia Noronha
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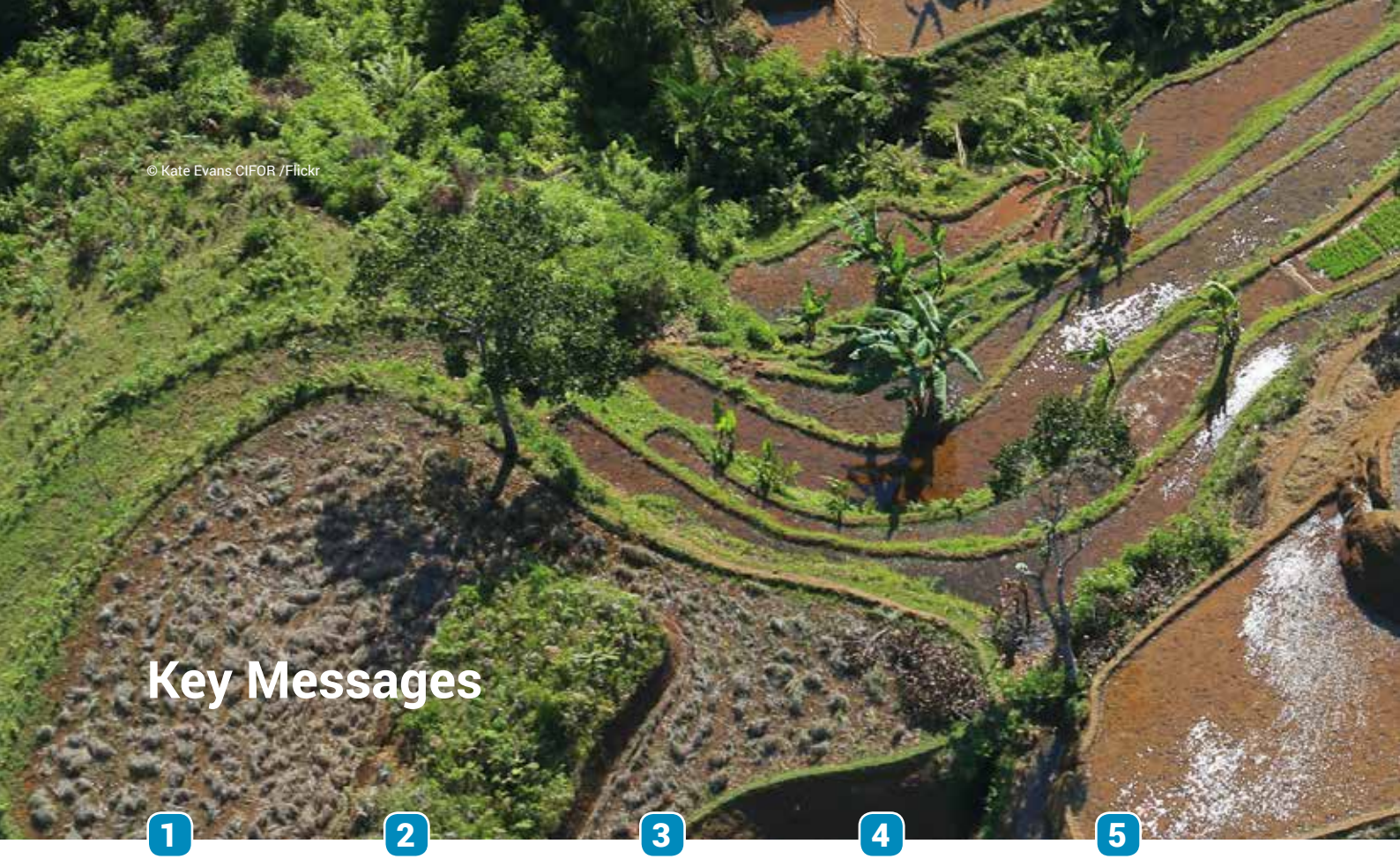


Key Messages

1

Global material resource use is expected to reach nearly 90 billion tonnes in 2017 and may more than double from 2015 to 2050, with high-income countries currently consuming 10 times more per person than low-income countries and the planetary boundaries being pushed beyond their limits.

2

Environmental impacts – including climate change and pollution – cannot be effectively mitigated by focusing on emission abatement alone. The level of resource use determines the magnitude of final waste and emissions released to the environment, making resource management and efficiency key strategies for environmental protection.

3

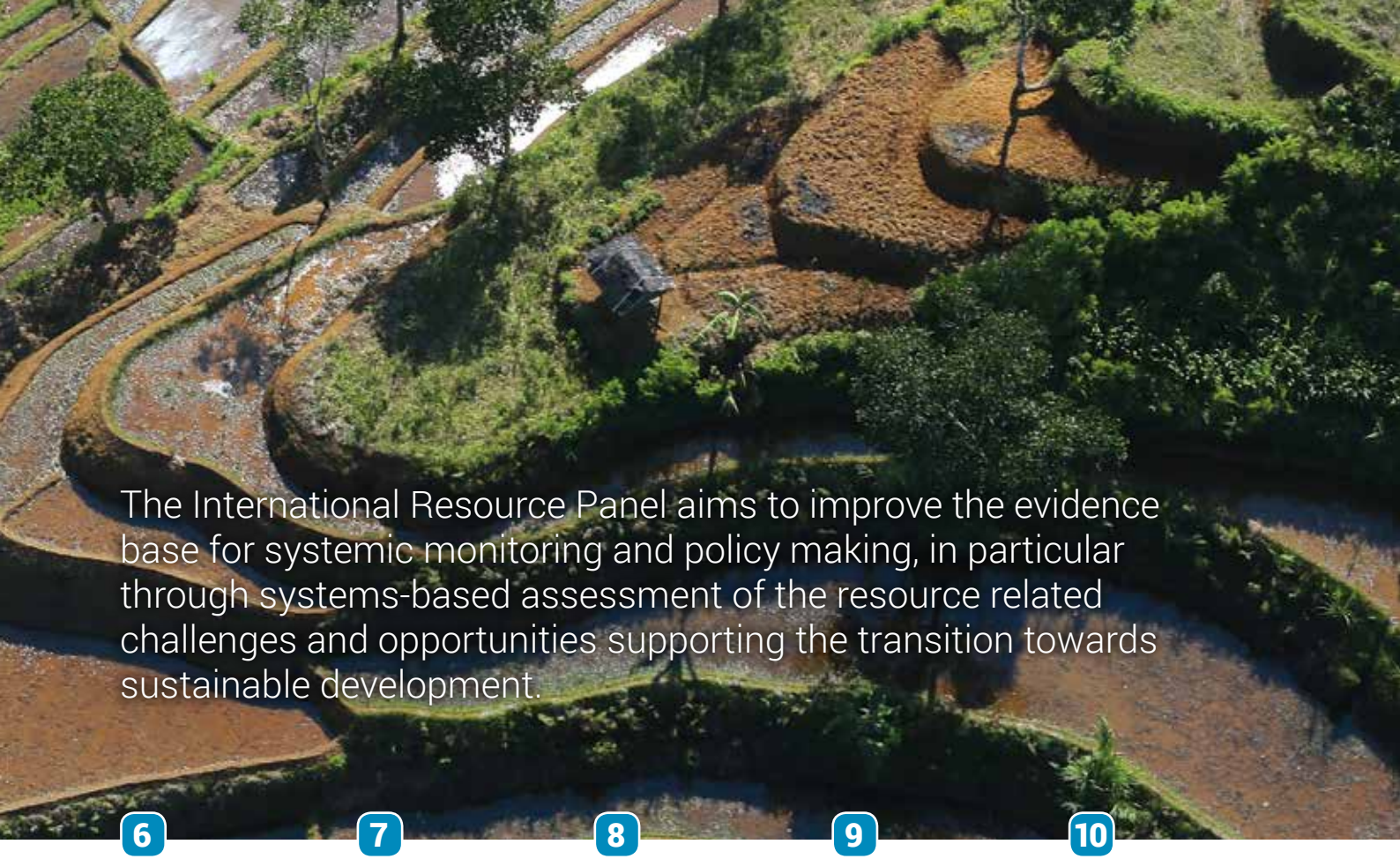
Decoupling economic activity and human well-being from resource use – i.e. enhanced resource efficiency – is necessary to achieve the Sustainable Development Goals for all.

4

To achieve effective decoupling, today's linear material flows must become circular through a combination of intelligent infrastructure and product design, standardization, reuse, recycling and remanufacturing.

5

Resource efficiency and circular economy create jobs and deliver better socio-economic and environmental outcomes compared to business-as-usual over the long term.



The International Resource Panel aims to improve the evidence base for systemic monitoring and policy making, in particular through systems-based assessment of the resource related challenges and opportunities supporting the transition towards sustainable development.

6

Countries face differing circumstances and therefore have varying opportunities for decoupling wealth creation and resource use, including leap frogging.

7

A systems approach that avoids burden shifting between sectors, regions, resources and impacts is needed to transform production and consumption systems toward the SDGs.

8

A systems approach can also be used to steer sustainable urban infrastructure transitions, transforming the way in which the basic needs of food, energy, water and shelter are met in order to develop inclusive, resource-efficient and low-polluting cities.

9

Targets and indicators, such as material footprints, are needed at all levels of governance to monitor material flows and steer socio-economic transitions toward the SDGs.

10

Technical, business and policy innovation across the whole product life-cycle, as well as reform of financial instruments, will be crucial for the transition to resource efficient economies, as will policy learning, capacity building and knowledge sharing.

Why a Global Assessment of Resource Use?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The way in which societies use and care for natural resources fundamentally shapes the well-being of humanity, the environment and the economy. Natural resources - that is, plants and plant-based materials, metals, minerals, fossil fuels, land and water - are the basic inputs for the goods, services and infrastructure of socio-economic systems from the local to the global scale. Research shows that, either directly or indirectly, natural resources and the environment are linked to all of the United Nations Sustainable Development Goals. Restoring and maintaining the health of the natural resource base is a necessary condition to achieving the ambitious level of well-being for current and future generations set out in these goals.

Improving the well-being of people while minimizing resource use and environmental impacts in particular through enhanced resource efficiency is an essential aspect of delivering on Sustainable Development Goal 12 on Responsible Production and Consumption, and also on almost all of the goals in a direct or indirect manner. To achieve such decoupling, today's linear material flows through the economy must become circular through intelligent design of products incorporating standardization, reuse, recycling/ remanufacturing, development of efficient and inclusive infrastructure systems, and, a focus on delivering services rather than material products. Resource efficiency is also complementary to conventional pollution-control strategies. By lowering the amount of resources used, the amount of related emissions and impacts can also be reduced, and many of them at the same time.

Viable pathways exist for society to undertake such decoupling of economic growth from natural resource use and environmental impacts. Technically feasible and commercially viable technologies can improve water and energy efficiency by 60 to 80 per cent in construction, agriculture, food, industry, transport and other sectors, while also delivering economic cost savings of between USD 2.9 and 3.7 trillion each year by 2030. Essential infrastructure (energy, buildings, transportation, water supply, sanitation and waste management) and food supply sectors significantly contribute to global resource-use pollution and environment-related impacts on human health. These sectors also shape social equity in basic provisioning and impact multiple Sustainable Development Goals. With over 60 per cent of the urban infrastructure expected to exist by 2050 yet to be built, the opportunity exists to shape the future over the long term.

In this sense, decoupling is not the domain of environmental ministries alone, but rather cuts across all ministries and

levels of government. This means that a mix of multi-level and multi-sectoral policies is needed to move beyond piecemeal changes to a profound transformation of how natural resources flow through society.

The foundation for this change is accurate information. Environmental and sustainability policy requires a solid evidence base that makes it possible to monitor the scale of the physical economy, that is - the amount of material, energy, water and land used and of emissions generated in making, using and providing goods, services and infrastructure systems. Data drawn from up-to-date information on the state, trends, and drivers of the physical economy can help to identify leverage points for targeted and effective policy intervention across sectors and geographical scales. This kind of regularly reported data, such as those drawn from a global assessment of natural resources, can inform the setting of long-term orientation goals, incentive frameworks and systems of engagement and mutual learning that will pave the way for transformational change.

Resource use and pollution

Better and more efficient production and use of natural resources can be one of the most cost-efficient and effective ways to reduce impacts on the environment and advance human well-being. Identifying efficiencies across the life cycle of natural resources means finding opportunities for improving how they are extracted, processed, used (including re-use, recovery and recycling) and disposed of to achieve the same - or greater - economic and social gains while minimizing negative environmental impacts (including pollution).

Approximately 19 million premature deaths are estimated to occur each year globally due to environmental and infrastructure-related risk factors that arise from the way societies extract and use natural resources in production and consumption systems, including essential infrastructure and food provision. About 6.5 million premature deaths (the vast majority in cities) are caused by air pollution related to energy supply and use in homes and industries, as well as transportation and construction sectors within cities.

Effective pollution control requires mitigation of substance-specific hazards and a reduction of raw material use through the economy, in order to lower the volume of final waste and emissions to air and water. Material demand has continued to shift from biomass and renewable materials to non-renewable materials, creating new waste flows and contributing to higher emissions and pollution. The global trend of moving from traditional to modern technologies, and from agriculture-based economies to urban and industrial economies (along with their fast-growing new material requirements), further accelerates global material use and creates significant challenges for sustainability policy.

Metal-ore extraction and metal production increased threefold from 1970 to 2010. The steepest increase occurred from 2000 to 2010, driven mainly by the industrialization and urbanization of emerging economies. Environmental impacts have increased over time, mainly as a result of increased production. Decreasing material and energy productivity is bad economically – it means reduction of potential economic growth – and also bad environmentally (as pressures and impacts upon the environment, including pollution, grow disproportionally faster than the production of goods and services). Investing in material and energy productivity is therefore a key area for improving the integration of economic and environmental objectives and reducing pollution. This is integral to SDG 12, which aims to reshape consumption and production patterns by transforming resource use in a way that reduces pressures on the environment and climate while promoting human and economic development.

What can a systems approach to natural resources tell us?


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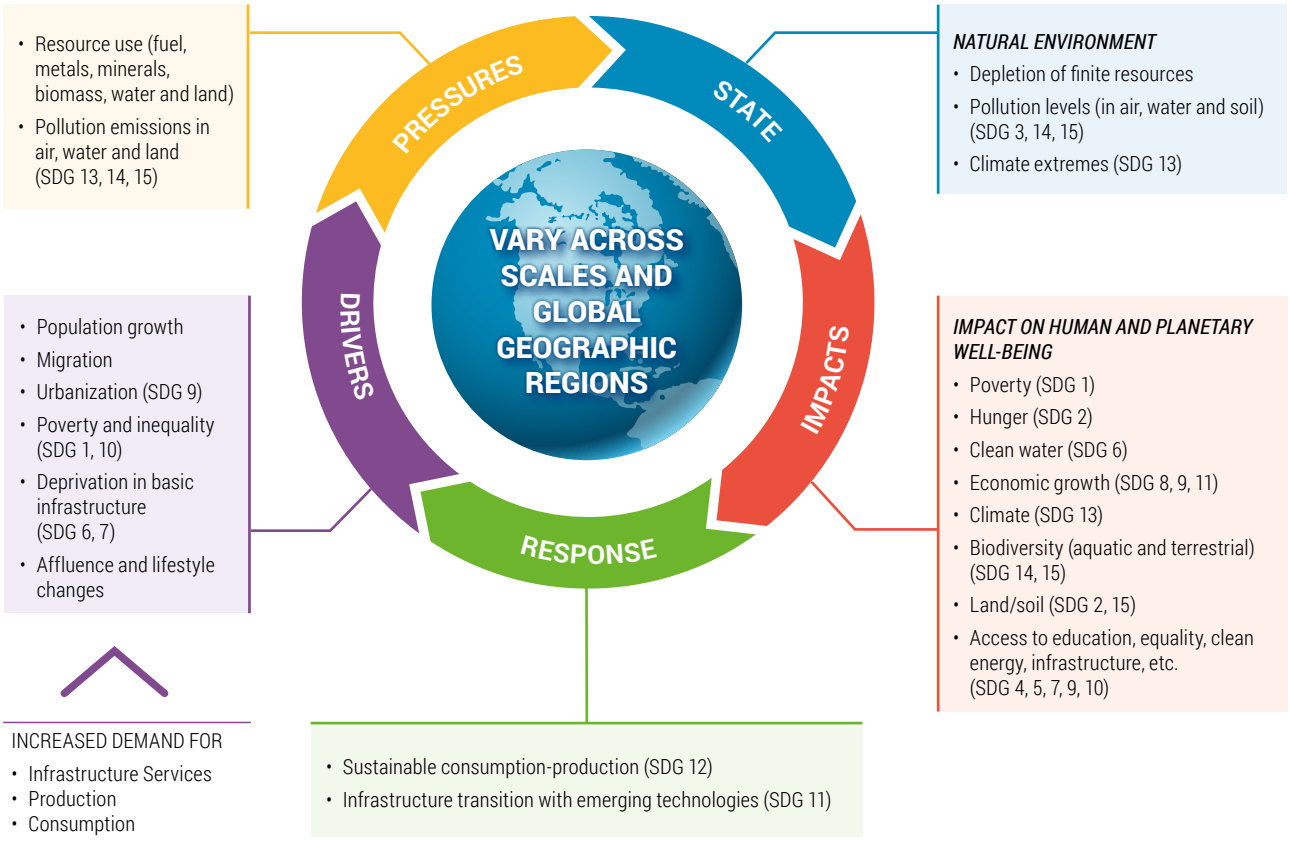
Focusing on single resources, single economic sectors or single environmental and health impacts will not achieve the collective vision of the Sustainable Development Goals, and may instead cause harm if the interactions between each of the goals are not considered. Analysis linking the way natural resources are used in the economy to their impacts on the environment (pollution, deforestation, biodiversity loss and water depletion) and people (health, well-being, wealth and so on) across time requires the adoption of a systems approach. A systems approach connects the flow of resources - from extraction through to final waste disposal - with their use and impact on the environment, economies and societies at each stage of the life-cycle. The approach can be used to identify key leverage points; develop resource targets; design multi-beneficial policies that take into account trade-offs and synergies; and steer a transition toward sustainable consumption and production and infrastructure systems.

The International Resource Panel assesses natural resources from a systems perspective in keeping with the **DPSIR** analytical framework for human-nature interactions. The framework looks at multiple **drivers** of resource use and resulting **pressures** on the natural environment as determinants of the **state** of the environment. The state of the environment in turn **impacts** human wellbeing and socio-economic systems that rely on it, thus requiring a **response** strategy to influence key drivers, and direct the resulting pressure, state and impacts to desired levels through an iterative and continuous process.

The use of natural resources, and their related impacts, are increasingly transboundary, largely due to trade and globalization. As a result, national accounting metrics that focus solely on a nation's direct natural resource use do not fully represent the resources and associated impacts that contribute to economic activity. The concept of footprints that captures resource use across borders is therefore a critical tool in a systems approach. Footprints can measure different types of pressures, including resource use, pollution emissions and environmental impacts. Four footprints on resource use (materials, land, water and fossil energy) have been identified as determining the magnitude of most specific environmental impacts.

FIGURE 1 Natural resource use linked to the Sustainable Development Goals via the Drivers-Pressures-State-Impact-Response Framework.



DPSIR = Drivers, Pressures, State, Impacts and Response

A Global Assessment of Material Resources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While subsequent reports of this series will assess footprints of all resources (materials, land, water and greenhouse gas emissions), the focus of this report is on material resources. Material resources are the biomass (such as wood and crops for food, energy and plant-based materials), fossil fuels (such as coal, gas and oil), metals (such as iron, aluminum and copper) and non-metallic minerals (including sand, gravel and limestone) that are used in the economy. Strong growth in the extraction of material resources continues to support the global economy, and also adds to global environmental pressures and impacts. Based on a material resources database that covers almost five decades (1970 to 2017) and 191 countries, existing trends forecast global material use to reach 88.6 billion tonnes in 2017 – more than three times the amount used in 1970. This is significant because, all else being equal, growing material extraction with subsequent material flows would lead to growing environmental pressures and impacts across the globe.

Growing material use is driven by expanding populations, consumption trends in mainly developed economies and the transformation of developing economies. Demand for materials has shifted from renewable to non-renewable resources, reflecting the global trend away from traditional towards modern technologies, and from agriculture-based economies to urban and industrial economies. This creates new waste flows - thereby increasing emissions and pollution. For example, data show that the steep increases in demand for metal ores, like iron, have contributed to sharp rises in greenhouse gas emissions, acidification, aquatic ecotoxicity and emissions of smog-forming substances.

New analytical tools provide insight into the amount of primary raw materials required along the entire supply chain of commodities.[2] For imports, and measured on a per capita basis, the use of primary raw materials is four times the world average in Europe and North America. Global materials have historically been sourced from low-income and middle-income regions that bear the burden of local impacts of resource extraction, often for the sake of producing primary exports to high-income countries. Until the year 2000, high-income countries were net importers of materials while all other regions were net exporters. This has changed dramatically in 2017. High-income countries now export one billion tonnes of materials, mainly driven

2 The raw material equivalents (RME) of trade flows, that is, the amount of primary raw materials required along the supply chain to produce commodities.

by the United States and Australia's fast growing exports, while upper-middle-income countries import around 750 million tonnes.

Material footprints add further depth to the picture of global materials use. In 2017, despite more than half of global material use being directed to final demand in Asia and the Pacific, the material footprint of the region is estimated at 11.4 tonnes per capita. North America recorded 30 tonnes of material per capita for final demand, Europe 20.6 tonnes and all other regions measured under 10 tonnes per capita. On a per capita basis, high-income countries continue to consume 10 times more materials than low-income countries.

The full report provides in-depth analysis of material resources to illustrate where materials are extracted, where they are used, what the impacts are and what has driven material use. Understanding these interactions facilitates the development of appropriate policy responses. Reigning in the total physical scale of the economy is one essential first step to reduce waste and emissions and to mitigate overall environmental impacts. A new economic paradigm is needed to improve resource productivity and allow for production and consumption systems to be run with lower material and energy requirements, as well as reducing waste and emissions while providing all services needed.

How resource efficiency can transform economies

The International Resource Panel modelled the combined economic and environmental consequences of ambitious resource efficiency and greenhouse gas abatement policies (UNEP, 2017) and found that there is substantial potential to achieve win-win outcomes that reduce environmental pressure while improving income and boosting economic growth.

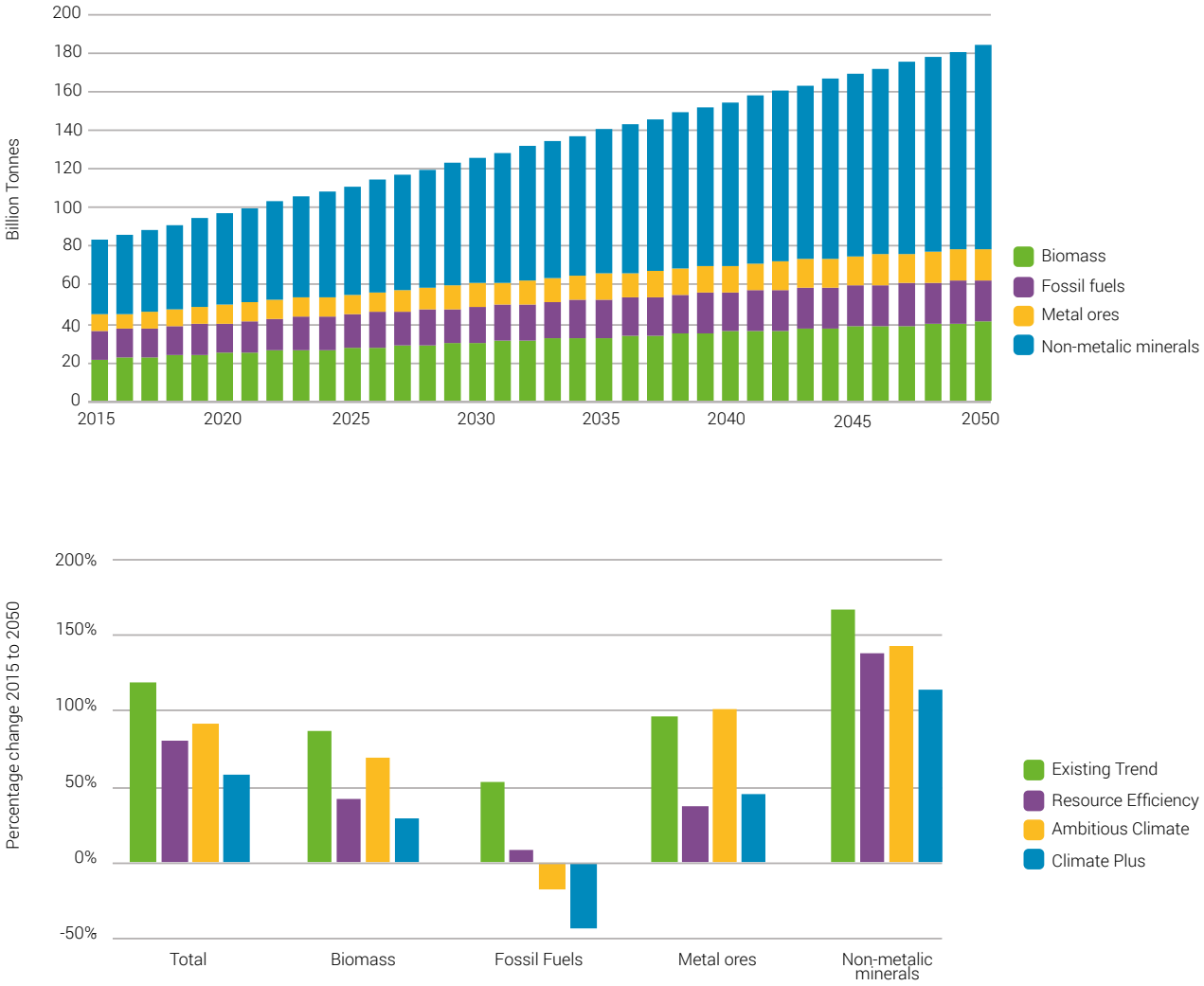
By 2050, ambitious polices for resource efficiency could reduce global resource requirements by about a quarter and deliver global economic growth of 3 to 5 per cent above the existing trend. This would also have considerable co-benefits for climate mitigation efforts.

Resource efficiency policies and initiatives could:

- reduce natural resource use globally by 26 per cent by 2050, in combination with ambitious global action on climate change, as well as stabilizing per capita resource use at current levels in high-income countries;
- reduce greenhouse gas emissions by an additional 15 to 20 per cent by 2050 (for a given set of greenhouse policies), with global emissions in 2050 falling to 63 per cent below 2010 levels, and emissions in high-income countries in 2050 falling to 74 per cent below 2010 levels;
- more than offset the economic costs of ambitious climate action, so that income is higher and economic growth is stronger than in the 'existing trends' scenario;
- deliver annual economic benefits of USD 2 trillion globally by 2050 relative to existing trends, including benefits of USD 520 billion in high-income nations, while also helping put the world on track to limit climate change to 2°C or lower.

These projections can be treated as a reasonable minimum estimate of economically attractive physical resource efficiency potential. Further reports of this series will present in-depth scenario modelling to support informed policy and decision making. The level and mix of economic and environmental benefits achieved will depend, however, on the design of the policies and approaches implemented – suggesting that attention will be required to develop and test a smart and practical package of resource-efficiency measures.

FIGURE 2 Global resource extractions by four categories (biomass, fossil fuels, metal ores and non-metallic minerals) (a) 2010–2050 for Existing Trends, and (b) change from 2015 to 2050 for four scenarios.



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Driving a profound resource efficiency transition


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Efficiency in the way resources are extracted and manufactured by industry, used and re-used by people and recycled and disposed of by all is essential to efforts toward a sustainable and pollution-free planet. A long-term vision underpinned by evidence-based targets and incremental policy signals can combine to produce a profound transformation of the physical economy. It is crucial to ensure a coordinated and coherent approach to policymaking across ministries, as well as the participation of stakeholders capable of turning shared visions into reality and managing resistance to change by clarifying multiple benefits for the actors. This implies not only bottom-up changes in the way businesses create value and citizens access, use and dispose of resources, but also top-down changes in the way that policies steer the markets where businesses operate and build the social infrastructure in which citizens live.

To steer long-term and profound changes, four iterative steps across all levels of governance are required: (1) monitor current performance and use; (2) set targets and define future objectives in the light of international agreements; (3) test and innovate targets, regulation and voluntary approaches, subsidies and taxes for resource efficiency and integrated resource management; and (4) evaluate, learn and adapt.

At the national level, a bundle of strategies and tools is available to public authorities to support the shift towards inclusive, resource-efficient and pollution-free economies. The overarching strategies manifest differently in terms of possible pathways depending on a country's level of natural resource endowment and its socio-economic context. **Absolute decoupling** is recommended as an aim for high-income nations, with the need to lower average resource-consumption levels, distribute prosperity equally (including for gender equality) and maintain a high quality of life. Strategies toward waste prevention, high-value resource recovery, circular resource flows and adjusting social norms are particularly relevant. **Relative decoupling** is a key strategy well-suited to developing economies and economies in transition to raise average income levels and eliminate poverty. These countries should strive to improve their resource efficiency even as their net consumption increases until a societally acceptable quality of life is achieved. There is an opportunity to fast-track sustainable development in such countries by learning from and leapfrogging traditional pathways.

Resource efficiency alone is not enough. Productivity gains in today's linear production system are likely to lead to increased material demand through a combination of economic growth and rebound effects. What is needed is a move from linear to circular material flows through a combination of extended product life cycles, intelligent product design and standardization, reuse, recycling and remanufacturing. Business models aiming at offering high-quality services as an alternative to selling more products would be another important component.

FIGURE 3 Transition cycle toward sustainable resource use.

Seven policy strategies for multi-beneficial policymaking

Many policy tools have been successfully used for tackling aspects of the resource efficiency challenge in different parts of the world. This report proposes seven strategies for consumption patterns and production systems that contribute to human well-being without putting unsustainable pressures on the environment.

1. Set targets and measure progress

A set of resource efficiency targets for the use of key resources (materials, land and water, as well as greenhouse gas emissions) can guide policy development and inform a progress-monitoring framework. Targets should preferably be footprint-based to consider transboundary effects of product use and minimize the risk of shifting problems to other regions. Reporting on harmonized metrics of resource use and efficiencies at regular intervals across and within countries could raise the profile of resource efficiency and drive ambitions to increase it. Resource-efficiency targets are the first step forward, while national and international targets for sustainable levels of global resource consumption will also be needed.

2. Act on key leverage points across all levels of governance

To identify "hot spots" for policy action, national and international resource efficiency programmes could play a strategic role in the coordination of monitoring to streamline institutional arrangements and promote synergies in national – and cross-sectoral – policy interventions.

3. Take advantage of leapfrogging opportunities

Many fast-growing cities and developing economies are not locked into current design and business models. They can benefit from a weaker bias[3] against resource efficient investments, and the opportunity to avoid the resource- and energy-intensive design for new infrastructure. Taking advantage of these opportunities requires access to finance and international cooperation, in particular for low-income economies.

4. Implement a policy mix that builds incentives and corrects market failures

Aligning price signals and fiscal policies with the strategic goals of society can adjust the behaviour of firms and individuals, so that their investment and purchase decisions reflect those of society as a whole. Implementing a policy mix that builds incentives and corrects market failures for resource efficiency, including slowly shifting taxes from labour to materials in line with the pace of decoupling success, can have a strong steering effect and help to avoid rebounds.

5. Promote innovations toward a circular economy

A switch from consumption of finite resources to recycled materials and renewable resources (such as sunlight, wind and sustainably managed biomass) opens up the possibility of meeting the needs of more people over the long term. Before recycling, extending the lifetime of material resources through direct reuse, repair, refurbishing or remanufacture, as well as policies that encourage recycling to be considered as part of product design, are crucial to breaking through infrastructural lock-in of existing production and consumption systems.

6. Enable people to develop resource-efficient solutions

New types of alliances to collaborate, experiment and learn are critical to a successful transition. Initiating and participating in multi-stakeholder platforms, cross-cutting and expert networks and private-public partnerships will help promote cooperation and collaboration. Governments can provide skills training, improve education programmes and provide financial support to spread risk associated with potential breakthrough innovations.

7. Unlock the resistance to change

Any reduced revenues and job losses occurring during transformations to a resource-efficient and sustainable global economy must be addressed to overcome resistance to change and to support workers and businesses that are impacted. Upskilling training and education, recycling tax revenues back to affected industries and businesses to support transformation and protecting the very poor and vulnerable through policy packages that take their needs into account are some of the ways resistance to change can be mitigated.

3 This relates to the fact that vested interests may not be as set on defending the status quo, and that consumption habits may not yet be as tied to mass consumption with rapid obsolescence, thereby providing greater scope for new forms of consumption and leasing (Swilling and Annecke, 2012; Boston Consulting Group, 2010).

Special feature: mitigating air pollution and achieving SDGs in cities through a systems focus on natural resources and infrastructure

Air pollution has emerged as one of the primary risk factors for premature mortality in the 21st century, linked with 6.5 million premature deaths annually, the majority of which are in global cities. Indoor and ambient air pollution in the form of fine particulate matter (PM2.5) is the dominant risk factor (accounting for 96 per cent of health impacts).

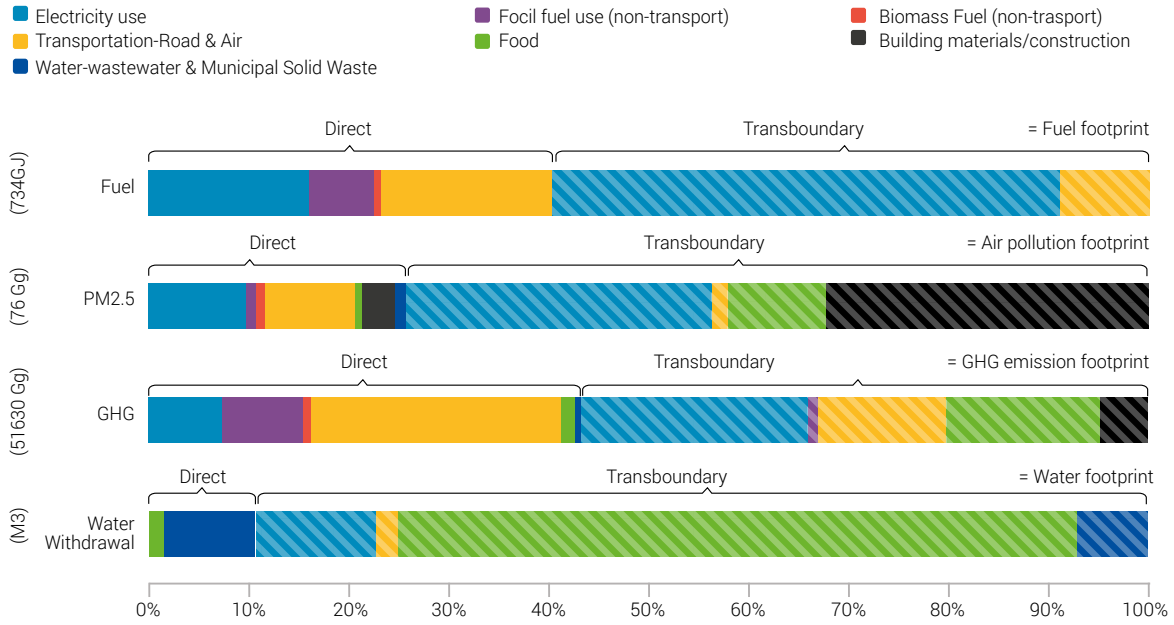
Addressing PM2.5 air pollution is challenging because it arises from multiple sectors within the city boundary (industry, transportation, household cook stoves, waste burning, construction and road dust) and outside city boundaries (agricultural burning, industrial emissions and natural sources). Furthermore, PM2.5 concentrations in air are influenced by local weather patterns in complex ways and exacerbated by climate change (particularly extreme heat and drought events).

Lessons learned from air-quality management experiences indicate that systems-based approaches complemented by end-of-pipe control strategies are important in addressing the multi-faceted sources of PM2.5. The Special Feature presents a systems approach anchored in the use of natural resources, with a focus on essential infrastructures and food supply in cities. The findings suggest pathways for reducing pollution while also providing multiple co-benefits that advance Sustainable Development Goals for economies at differing stages of development.

For developing economies, strategic pathways are identified for transforming cities with underserved populations, high inequality and high pollution-levels to become inclusive, resource efficient and cleaner, thereby advancing the well-being of large urban populations. A case study of Delhi, India, demonstrates how a bundle of strategies (provision of transit services, in situ slum rehabilitation within the urban fabric, resource-efficient multi-storey building construction with low-polluting materials, energy efficiency among high consumers and replacement of dirty cooking fuels) can deliver basic services to about 7 million additional people while consuming a small fraction (less than 5 per cent) of the total amount of cement and electricity used in the city today, while avoiding over 22 per cent of greenhouse gas emissions and air pollution (PM2.5) emissions and preventing more than 2,500 premature deaths from dirty cooking fuel use alone. This case study indicates a significant improvement in human well-being, with a relatively small investment in resources, as a good example of the concept of decoupling.

For **emerging economies** undergoing rapid urbanization and industrialization, circular economy policies combined with urban planning that enables beneficial exchange of materials and energy across different industry and infrastructure sectors in cities are found to yield economic gains, natural resource conservation, greenhouse gas mitigation and air-pollution reductions. Using modelled energy use in different sectors (residential, commercial and industrial) in more than 630 Chinese cities, circular economy strategies in cities had a demonstrated collective impact on national sustainability and greenhouse gas emissions targets, while also showing local health co-benefits specific to each city's context. The models show that circular economy strategies

FIGURE 4 Case example of resource use (water and fossil fuels) footprints, and, air pollution and greenhouse gas emission footprints of infrastructure provision and food supply in New Delhi, India (data from Ramaswami et al., 2017a; Nagpure et al., 2017a)



applied in cities can collectively contribute an additional 15 per cent to 36 per cent towards national greenhouse gas mitigation compared to conventional single-sector strategies. Co-beneficially, about 47,000 (range 25,500 - 57,500) premature deaths are estimated to be avoided annually through air-pollution reduction.

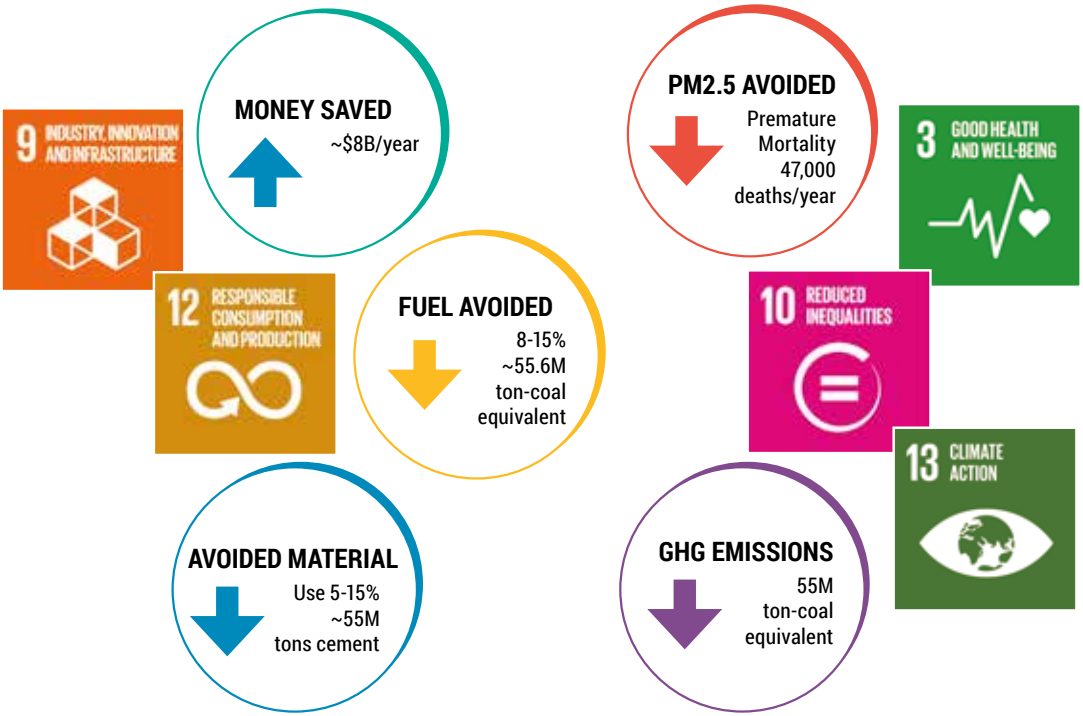
Developed economies also benefit from a systems approach that systemically integrates resource efficiency in multiple sectors with air-pollution control, as has been demonstrated from experiences in air-quality management in countries including the United States. Air pollution is a worldwide challenge requiring a systems approach anchored in resource use and efficiencies, particularly in the infrastructure and food supply sectors.

For cities, the bundle of policy strategies listed below, when implemented together, can simultaneously reduce air pollution and advance human well-being, achieving multiple benefits in diverse world regions.

- Develop urban-rural market mechanisms and avoid urban area expansion to agricultural lands and lands that provide high-value ecosystem services to ensure preservation of lands and reduction of dust/air pollution emissions;

- Undertake strategic urban land-use and infrastructure planning within cities and urban areas to reduce travel demand;
- Invest in efficient transit systems to reduce vehicular emissions and congestion;
- Undertake inclusive development and in situ slum rehabilitation in multi-storey buildings within dense city areas that provide essential services and access to livelihoods while reducing the travel burden on the poor;
- Promote multi-storey resource-efficient building construction and energy efficiency for all buildings;
- Promote culturally-sensitive behavioural change strategies to reduce resource use, including a focus on resource substitutions for dirty cooking fuels and construction materials;
- Implement electricity grid transformations with high levels of renewable energy;
- Encourage business innovations to reduce agricultural and solid-waste burning.

FIGURE 5 Environment, human well-being and economic co-benefits estimated across 637 Chinese cities in a resource efficiency and symbiosis scenario compared to the year 2010 baseline.



Source: Ramaswami et al. 2017b

Where to from here?

Sustaining and managing resource use is a cornerstone of sustainable development, particularly in terms of achieving environmental ***and*** socio-economic goals. A systems approach considering all phases of natural resources life cycles – from extraction through production, consumption, recycling and final disposal – has been shown to foster a better understanding of the physical basis of societies. This improved understanding can, in turn, inform the design of effective policy measures across all sectors and levels of the economy to promote resource efficiency and reduce pollution.

The twin issues of reducing overconsumption and waste of natural resources on the one hand, and providing secure access to natural resources and food on the other, must be addressed simultaneously to ensure that neither surpasses the thresholds of a global "safe operating space". Strategies and solutions should therefore be designed according to national circumstances, but in a globally consistent manner by approaching the Sustainable Development Goals without compromising other regions' progress towards this end.

Conventional pollution control by add-on technologies is bound to shift environmental problems and increase resource consumption. Keeping natural resource use and associated impacts within safe limits can only be achieved by significant increases in resource efficiency within production and consumption systems and infrastructure provision. Transformations toward resource-efficient urban infrastructures also have the co-benefit of increasing progress related to human health and well-being.

Overall, transformational policies are needed to enhance resource efficiency and sustainable resource use throughout the economy. There has been initial progress in establishing instruments that foster a more sustainable use of natural resources in production and consumption systems, including infrastructure management. Nevertheless, there remain huge opportunities for the future.

Improved information and scenario analysis on the state, trends and outlook of natural resource use, reported on a regular basis, can support effective and targeted policy design and evaluation. The Global Assessment of Natural Resource Use and Management series of the International Resource Panel aims to provide this knowledge base. All in all, this report can be taken as a pilot, providing strategic elements for regular reporting based on a new and authoritative database of the International Resource Panel on material flows. A report covering natural resources (water and land) and greenhouse gas emissions is expected to be released in 2019.

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SUMMARY FOR POLICYMAKERS

ASSESSING GLOBAL RESOURCE USE

A systems approach to resource efficiency and pollution reduction

The way in which societies use and care for natural resources fundamentally shapes the well-being of humanity, the environment and the economy. Better and more efficient use of natural resources can be one of the most cost-efficient and effective ways to reduce impacts on the environment, while also achieving the socio-economic objectives of international sustainable development and climate goals. Viable pathways exist for society to undertake such decoupling of economic growth from natural resource use and environmental impacts. But how can we get there?

Environmental and sustainability policies require a new evidence base that makes it possible to monitor the scale of the physical economy, that is - the amount of material, energy, water and land used and emissions generated in making, using and providing goods, services and infrastructure systems. This publication provides an assessment of the state, trends and outlook of global natural resource use, with a focus on material resources as part of the evidence base for policymaking for sustainable consumption and production. The report pinpoints seven strategies for system-wide pollution reduction and more sustainable resource use throughout the economy, including consideration of appropriate policy instruments and good practice examples from cities and countries around the world. A special feature on the link between resource use, infrastructure, air pollution and human health in cities is included.

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