UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

Implemented by

Deutsche Gesellschaft
für Internationale
Zusammenarbeit (GIZ) GmbH

EQuIP TOOL 7

INDUSTRY AND ENVIRONMENT

EQuIP

Enhancing the Quality of Industrial Policies

This publication was created by UNIDO in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH and the financial support of the German Federal Ministry of Economic Cooperation and Development (BMZ). Its content is the sole responsibility of UNIDO and does not necessarily reflect the views of GIZ or BMZ.

Deutsche Gesellschaft für Internationale
Zusammenarbeit (GIZ) GmbH
Registered offices
Bonn and Eschborn, Germany
Friedrich-Ebert-Allee 32 + 36
53113 Bonn, Germany
T +49 228 44 60-0
F +49 228 44 60-17 66
E info@giz.de
I www.giz.de/en

On behalf of
Federal Ministry
for Economic Cooperation
and Development

Acknowledgements

The new Enhancing the Quality of Industrial Policies (EQuIP) Toolkit was prepared by a team of experts from UNIDO's Directorate of Technical Cooperation and Sustainable Industrial Development (TCS) under the overall guidance of Ciyong Zou, Deputy to the Director-General of UNIDO and Managing Director of TCS, and under the direct management of Cristiano Pasini, Director of the Division of Capacity Development, Statistics, and Industrial Policy Advice (CPS).

The UNIDO EQuIP team was created by CPS's Capacity Development and Industrial Policy Advice Unit (CDA). The core group was made up of Anders Isaksson (Chief of CDA), Fernando Santiago, Christoph Hammer, Franz Brugger, Smeeta Fokeer and Frank Hartwich. The individual tools were drafted in collaboration with external experts.

This tool was written by Smeeta Fokeer, Franz Brugger, Jan Sievernich, Marco Quatrosi and Keno Haverkamp.

The revision of EQuIP received generous support from the German Development Cooperation (GIZ). We are particularly grateful to Rainer Engels and Steffen Felix of GIZ's sector project for sustainable economic development for their exceptional contributions. Additional feedback was provided by UNIDO colleagues from various Divisions and by participants of expert group meetings held at UNIDO HQ in Vienna.

The tools have undergone rigorous testing and fine-tuning through a series of expert group meetings and training workshops in – inter alia – Mauritius, The Gambia, Jamaica, Jordan and Mongolia. Niki Rodousakis (UNIDO) provided editorial support and Silvia Druml designed the layout.

Table of Contents

ACKNOWLEDGEMENTS II

LIST OF FIGURES V

LIST OF TABLES VII

INTRODUCTION 1

- Outline and objectives 2
- Key concepts 3
- Structure 8
- How to use this tool 10
- Links to other tools and possible extensions 10
- Policy implications 11
- References 13

1 WATER USE 14

- Introduction 14
- Methodology 18
- Indicators 19
- Analysis 21
- Policy options 24
- References 35

2 ENERGY AND CO_2 39

- Introduction 39
- Methodology 40
- Energy indicators 44
- CO_2 emission indicators 48
- Analysis 54
- Policy options 81
- References 88

3 WASTE 93

- Introduction 93
- Methodology 96
- Indicators 98
- Analysis 105
- Policy options 111
- References 116

4 MATERIAL 120

- Introduction 120

Methodology 123
Indicators 124
Analysis 133
Policy options 139
References 148
5 ENVIRONMENTAL GOODS (EGS) 152
Introduction 152
Methodology 153
Indicators 154
Analysis 157
Policy options 162
References 171
APPENDIX 173

List of figures

Figure 1. Concepts of a circular economy 4

Figure 2. Absolute and relative decoupling 5

Figure 3. Types of ecosystem services 7

Figure 4. Graphic visualization of this tool 9

Figure 5. Dimensions of water use 14

Figure 6. System diagram of water in the circular economy 16

Figure 7. Levels of freshwater withdrawal and water stress in example countries (2017) 22

Figure 8. Lebanon: Development of sectors' shares in total freshwater withdrawal 22

Figure 9. Level of water stress over time in example countries 23

Figure 10. Industrial water intensity and share of freshwater withdrawal for industry (change from 2002 to 2017) 24

Figure 11. Circular water management 25

Figure 12. Diagram of end-user reuse model 29

Figure 13. Total final consumption per capita 55

Figure 14. Share of manufacturing in country's TFC 56

Figure 15. Manufacturing energy intensity 57

Figure 16. Manufacturing sub-sectors' share in manufacturing TFC 58

Figure 17. Manufacturing energy intensity at the sub-sector level 59

Figure 18. Energy self-sufficiency 60

Figure 19. Renewable energy consumption as a share of country TFC 61

Figure 20. Renewable energy consumption in absolute terms 62

Figure 21. Renewable energy consumption in the manufacturing sector as a share of TFC 63

Figure 22. CO_2 emissions per capita 64

Figure 23. CO_2 emission intensity 65

Figure 24. CO_2 emission intensity vs CO_2 emissions per capita (2000–2018) 66

Figure 25. Share of manufacturing CO_2 emissions of total country emissions 67

Figure 26. Manufacturing CO_2 emission intensity 68

Figure 27. CO_2 intensity in the food & beverages sub-sector 69

Figure 28. CO_2 emissions per unit of GDP vs. CO_2 emissions per unit of MVA (2000–2018) 70

Figure 29. CO_2 emission decomposition analysis (2018) 72

Figure 30. CO_2 emissions per unit of energy consumption in the manufacturing sector 75

Figure 31. CO_2 emissions per unit of energy consumption in manufacturing sub-sectors 76

Figure 32. Energy vs emission intensity in manufacturing 77

Figure 33. Share of MVA in GDP vs share of manufacturing in total emissions (change from 2000 to 2018) 78

Figure 34. CO_2 decoupling in the manufacturing sector (2008–2018) 79

Figure 35. Fossil fuel subsidies per GDP 80

Figure 36. Sources of global power supply 82
Figure 37. Waste pyramid 93
Figure 38. Scope of analysis of circular production and consumption systems 94
Figure 39. Shares of waste generated 106
Figure 40. Municipal vs. industrial waste intensity (GDP/MVA) 107
Figure 41. Municipal solid waste collected per unit of GDP 108
Figure 42. Waste composition as a share of the main categories of waste flows 108
Figure 43. Waste collected as a share of treatment options 109
Figure 44. Q Index 110
Figure 45. Collection intensity vs Q Index 111
Figure 46. Building blocks of material circular economy 121
Figure 47. Product lifecycle process 122
Figure 48. Domestic extraction intensity in Latin American example countries 133
Figure 49. Share of main resource categories in domestic extraction 134
Figure 50. Material intensity vs DMC per capita in example countries (change 2000–2019) 135
Figure 51. Material decoupling: developments in DMC and GDP (CAGR 2000-2019) 136
Figure 52. Material and waste intensity (bubble size: % of MSW in DMC) 137
Figure 53. Potential species loss from forestry land use in Peru 137
Figure 54. Sub-sectors' share of manufacturing material consumption (RMC) in Colombia 138
Figure 55. The share of sub-sector in manufacturing material use (RMC) and manufacturing value added (MVA) in Colombia 139
Figure 56. Assumed benefits of an environmental fiscal reform 143
Figure 57. Share of EG exports in total manufacturing exports 157
Figure 58. Country's market share in global EG exports 158
Figure 59. Country EG market share versus EG share in the country's manufacturing exports (change from 2010 to 2020) 159
Figure 60. Country share in the most dynamic global EG exports 160
Figure 61. Historical development of inflation-adjusted world market prices for PV modules 167

List of tables

Table 1. Environmental industrial policy implication matrix 12

Table 2. Water risk financial implications for major corporations (billions USD) 15

Table 3. List of water use indicators 18

Table 4. Water policy implication matrix 33

Table 5. List of policy options: Water 34

Table 6. List of indicators – Energy 40

Table 7. List of Indicators – CO_2 emissions 41

Table 8. IEA manufacturing industries grouped according to energy intensity (ISIC Rev 3 & 4) 58

Table 9. Energy & CO_2 policy implication matrix 86

Table 10. List of policy options: Energy & CO_2 87

Table 11. List of indicators 97

Table 12. Weights per treatment option 104

Table 13. Waste policy implication matrix 114

Table 14. List of policy options: Waste 115

Table 15. List of indicators 123

Table 16. Domestic material extraction and consumption global averages across income groups 135

Table 17. Material policy implication matrix 147

Table 18. List of policy options: Material 147

Table 19. List of indicators 154

Table 20. List of 25 most dynamic EGs between 2007 and 2013 (APEC & WB lists) 160

Table 21. List of 25 most dynamic EGs between 2014 and 2020 (APEC & WB lists) 161

Table 22. Environmental goods policy implication matrix 169

Table 23. List of policy options: Environmental goods 170

Introduction

Industry has long been characterized as “the main engine of growth” (Kaldor, 1967). Industrialization typically leads to rapid and sustained economic growth (Felipe et al., 2014, Commission on Growth and Development, 2008), and subsequently to shared prosperity. Industry, by its very nature, converts raw materials, components, or parts into finished goods. It therefore plays a key role in how resources are transformed and managed.

The global economy as we know it has increased pressure on the environment. Resource scarcity is intensifying, and water, land, biodiversity, materials, energy, fibre, and other natural resources are being degraded and liquidated. Any further delay in addressing these issues increases the costs of preventing irreparable damage and safeguarding the basis of human prosperity. Every decade of inaction could increase the mitigation expenditure needed to meet climate targets by 40 per cent (GAO, 2014). A rise in temperature of a mere 2 degrees Celsius from pre-industrial levels could lead to economic damages of around 0.9 per cent of global output annually (Sanderson and O’Neill, 2020). The urgency of delivering on climate change has been recognized by global leaders and translated into treaties with the aim of protecting our environment. Within the pledge of Nationally Determined Contributions (NDCs) of the Paris Agreement, a large number of countries have established emission mitigation targets for 2030 as part of a coordinated effort to keep the rise of the global temperature well below 2 degrees Celsius above pre-industrial levels. Similarly, through the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs), world leaders affirmed that they are: “Determined to protect the planet from degradation, including through sustainable consumption and production, sustainably managing its natural resources and taking urgent action on climate change, so that it can support the needs of the present and future generations.”

At the same time, the global manufacturing landscape is rapidly changing. We have entered a new industrial age – the age of clean technology manufacturing. Industries that were still in their infancies only 20 years ago, such as solar PV and wind, or even only ten years ago, such as electric vehicles and batteries, have developed into large manufacturing sectors globally. The scale and significance of these and other green industries are set for further rapid growth. Countries around the world are stepping up efforts to expand their green manufacturing sectors with the overlapping aims of advancing net zero transitions, strengthening energy and material self-sufficiency and security, and competing in the new global green economy (IEA, 2023).

The political climate is also changing in favour of an economic transformation and green transition. The Inflation Reduction Act in the United States, the European Union’s Fit for 55 package and its Green Deal or the recently announced Net Zero Industry Act, Japan’s Green Transformation programme, the Production Linked Incentive scheme in India and China’s most recent Five-Year-Plan are all pointing towards the same direction. Governments around the world are increasingly adopting policies that promote sustainable production based on the reduction, reuse and recovery of materials and the decarbonization of energy-intensive yet essential industrial sectors, thereby, promoting more sustainable consumption and the concept of green growth (creating economic growth while reducing greenhouse gas emissions and achieving higher environmental sustainability).

These developments offer major opportunities for growth and employment in new and expanding industries. According to the International Energy Agency (IEA), there are global market opportunities in clean energy technologies alone valued at around USD 650 billion a year by 2030 – more than three times today's level and more than doubling the number of related jobs in manufacturing (IEA, 2023).

Developing countries need appropriate industrial strategies to cut their share in these emerging markets. Effective policies can help attract new projects and investments – relatively short lead times to bring new manufacturing facilities online makes shifting them to other countries with more conducive environments easier. Industrial strategies for green manufacturing require a concerted government approach, and a close coordination of environmental, energy and material resource security with economic opportunities. Countries need to re-examine their domestic competitive advantages, conduct comprehensive supply chain risk assessments, cut red tape for green manufacturing, mobilize investment and financing, promote the development of the workforce's skills and capabilities, and accelerate innovation and the adoption of new technologies.

The green transformation of industry will require a concerted effort to achieve resource and energy efficiency, pollution reduction, waste treatment and an increase in environment friendly products. It requires sustainable designs, the development and adoption of green technologies, and a maximization of resource efficiency while minimizing waste.

Every country is characterized by different conditions and strengths and must therefore develop their own distinct strategies. While keeping in mind that many environmental problems can only be collectively addressed by international cooperation, this tool aims to help countries build a resilient foundation for the industries of tomorrow.

Outline and objectives

This tool aims to introduce policymakers to a range of indicators and methods that can be used to measure, design, and evaluate the green transition of their manufacturing industries. These are organised along five key thematic areas:

- Energy & CO_2
- Water use
- Material use
- Waste management
- Environmental goods

While the first four thematic areas prioritize limiting the impact of the manufacturing sector and its sub-sectors on the environment, the last one focuses on countries' economic opportunities. To emphasize the urgency of action, the analysis is complemented by indicators that can be used for "hotspot assessments", which are highlighted in red. In the climate change literature, "hotspots" refer to areas where strong climate signal and high concentrations of vulnerable people are present (De Souza et al., 2015). We adopt this concept for the industrial sector and use it to identify and assess countries in which industry represents a particularly strong threat to the environment, for instance, through biodiversity loss, sea level rise, flood risk, or water stress.

By engaging with the key concepts and indicators, policymakers will learn how to benchmark their country against others and identify successful comparators and failures. In addition, the tool aims to provide practical advice by introducing industrial policy options through the presentation of case studies. Different sets of questions are addressed: how does the country fare in terms of its greenhouse gas emission from industry or its water and material efficiency? What is the country's level of waste production and how has this changed over time? Which sectors perform well or poorly in terms of greenhouse gas emission intensity? What economic opportunities can a country benefit from by expanding its green sectors?

Key concepts

Two central themes are essential to sustainable industrial policymaking:

(i) circular economy and

(ii) environmental-economic decoupling.

Another concept that can help us understand the intrinsic value of nature in all human activities, including industry, is ecosystem services, outlined in **Box 1**.

Circular economy

The circular economy can spur growth and generate jobs without compromising the natural environment, and thus represents a cornerstone for a resilient and low-carbon economic growth. It is a systems solutions framework for economic development that addresses the root causes of many grand challenges we currently face such as climate change, biodiversity loss, waste, and pollution while at the same time generating better growth opportunities (Albaladejo et al., 2021). This approach rests on three core principles:

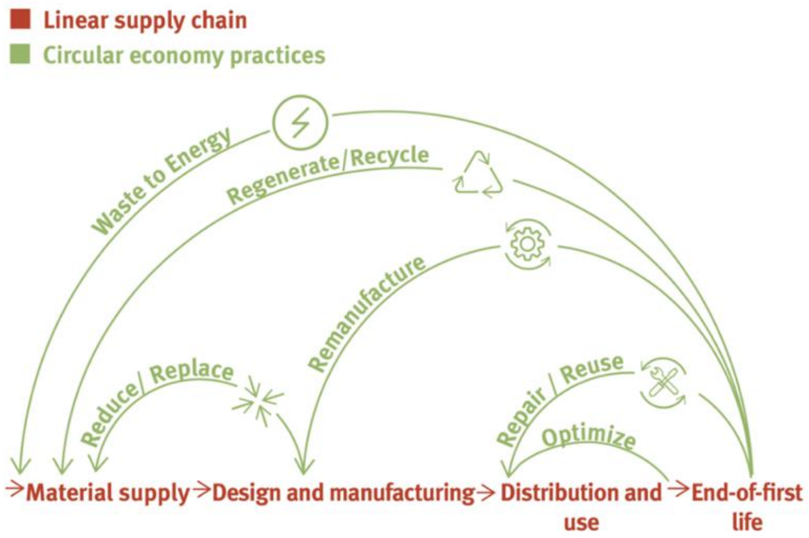
(i) designing out waste externalities,

(ii) keeping resources in use and

(iii) regenerating natural capital.

The circular economy can help better align industrial production with the planetary boundaries and the ongoing environmental crisis.

Figure 1. Concepts of a circular economy



Source: UNIDO

Figure 1 provides an illustrative introduction to the concept of the circular economy in comparison with traditional linear supply chains. The following measures are examples of how circular economy can help us achieve this:

1) significantly reduce use by rethinking products and eliminating energy intensive activities that rely heavily on fossil fuels;
2) reduce use, by continuously improving production processes and ensuring better allocation of resources;
3) reuse of products, waste and water within operations or through external use within the community;
4) recycle products at the end of their life-cycle; and
5) replenish by restoring natural resources such as forestland and biodiversity.

More in-depth insights and applications of the circular economy concept will be discussed in the different thematic chapters, notably water, waste, and material.

Decoupling

Decoupling aims to increase economic output (in our case the manufacturing sector's output) while simultaneously slowing the increase or ideally decreasing negative environmental effects such as CO_2 emission, material use or waste production. A country is considered to have successfully decoupled if the economy's growth rate is higher than that of its environmental impact, for instance, CO_2 emission.

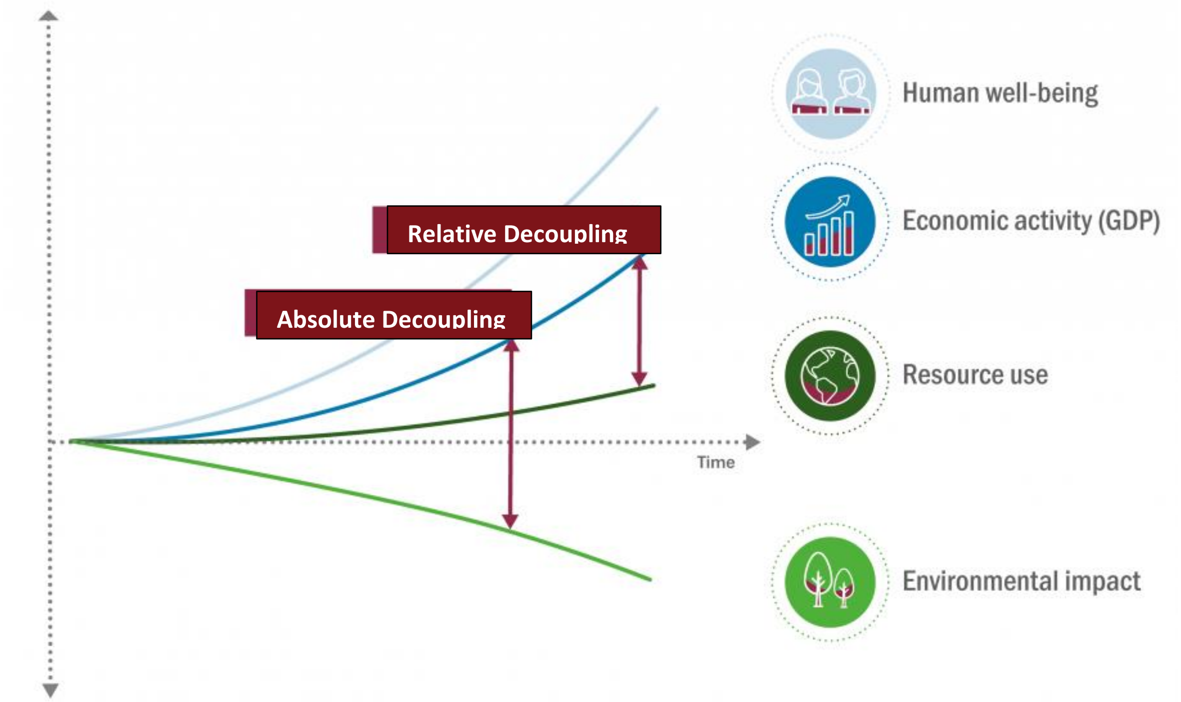
Different levels of dissociations between the environmental 'bads' and the economic 'goods' exist. **Figure 2** presents the classifications of decoupling that result from various possible combinations of manufacturing value added (MVA) and industrial energy consumption. These classifications have traditionally been grouped into two main categories: absolute or relative decoupling. From the perspective of an environmentally sustainable development, it is crucial to distinguish between the two.

Absolute decoupling is achieved when industry's impact on the environment is stable in a growing economy or decreases at a higher rate than the economic growth rate (OECD, 2002; Spangenberg et al., 2002), i.e. when MVA displays a positive growth while the growth rate of industrial resource use or emission is zero or negative. The generation of MVA is thus absolutely decoupled from environmental impact. Consequently, absolute decoupling is highly desirable for environmentally sustainable development.

Relative decoupling occurs when economic growth is accompanied by an equal or lower growth in environmental impacts, i.e. the MVA growth rate is higher than that of its negative externalities. In this case, MVA growth is achieved at the expense of a simultaneous, yet lower rise in environmental impacts. Relative decoupling is thus less desirable for environmentally sustainable development than absolute decoupling.

No decoupling takes place when the growth rate of the environmental impact of industry exceeds that of MVA. In this case, the same amount, or a lower level of MVA is being generated despite a rising use of resources. This is clearly undesirable from an environmentally sustainable development perspective. However, gradual reductions in resource intensity (discussed below) may still lead to a future shift towards environmental decoupling.

Figure 2. Absolute and relative decoupling



Source: Adopted from UNEP (2011)

Achieving decoupling entails significant changes in production and consumption patterns supported by policies that adapt economic activities to Earth's environmental boundaries. As a major resource user and polluter, achieving decoupling in industry translates into doing more with less (Albaladejo et al., 2021). Successful decoupling also depends on the implementation of a solid circular economy. This tool thus promotes circular economy and decoupling as key industrial policy outcomes.

We use the concept of intensity to assess the need for more circularity and greater decoupling. Intensity is similar to efficiency. Mathematically, both concepts are the same indicator, namely how much total resources (energy, materials, water, waste, or CO_2 emissions) are needed to produce USD 1 worth of MVA. Conceptually, however, the two terms are the inverse of each other and describe two different sides of the same coin. While greater efficiency is desirable (achieving higher value added using fewer resources), higher intensity is undesirable (lower value added despite using a higher amount of resources). To highlight the need for action, we use intensity as an indicator calculation in this tool.

It is important to note, however, that improvements in intensity may also result in so-called rebound effects by lowering production costs and thus stimulating growth and demand. Whether an absolute reduction of environmental pressures can be realized therefore depends on other factors as well, such as the implementation of policy instruments that limit such rebound effects. We address this aspect by providing examples of policy instruments in each section.

Box 1. Ecosystem services

The Millennium Ecosystem Assessment defines ecosystem services as “the benefits people obtain from ecosystems” (Chopra, 2005). These include provisioning services, regulating services, cultural services, and supporting services (see **Figure 3**). Humanity, while buffered against environmental changes through culture and technology, is fundamentally dependent on these ecosystem services. The concept thus provides a framework linking the biophysical structure, functions and processes to the social and economic benefits for humans (Austen et al. 2019).

To help inform decision-makers about current versus future costs and benefits, many ecosystem services are valuated to draw equivalent comparisons with human-engineered infrastructure and services. The economic (i.e. monetary) value of such services can either be estimated based on directly consumed resources (e.g. fishery, timber, water, food) or benefits, which are indirectly provided (i.e. climate regulation, flood prevention, waste absorption). Some ecosystem services are *non-consumptive* as they provide non-material benefits (e.g. recreational, spiritual benefits) or might generate potential benefits in the future (e.g. new antibiotics or therapeutic applications).

Ecosystem services are highly dependent on the diversity of genes, species and ecosystems found in nature (i.e. on biodiversity). Nearly all enterprises have a direct (through operations) or indirect (through their supply chain or investment decisions) impact on ecosystems, while simultaneously depending on the services those ecosystems provide as inputs for their products and production processes.

For instance, the majority of industrial processes depend on freshwater provision as a critical input (TEEB, 2010). Pharmaceutical industries rely on wild genetic resources that are present in nature to identify new compounds. Ecosystems such as wetlands and mangroves can reduce damage from storms and flooding. One policy measure that directly relates to this concept is *payments for ecosystem services* (PES), which is outlined in the Policy options of the material chapter.

Figure 3. Types of ecosystem services

Source: Adapted from WWF in Roe et al. (2018)

Structure

As mentioned in the outline, this tool is structured across the five thematic areas of

(i) energy and CO_2,

(ii) material use,

(iii) water use,

(iv) waste management, and

(v) environmental goods.

Each section provides a brief introduction of the topic, discusses why it is relevant and how policymakers can use the proposed indicators and analyses. Key concepts for each thematic area will also be presented in every introductory section.

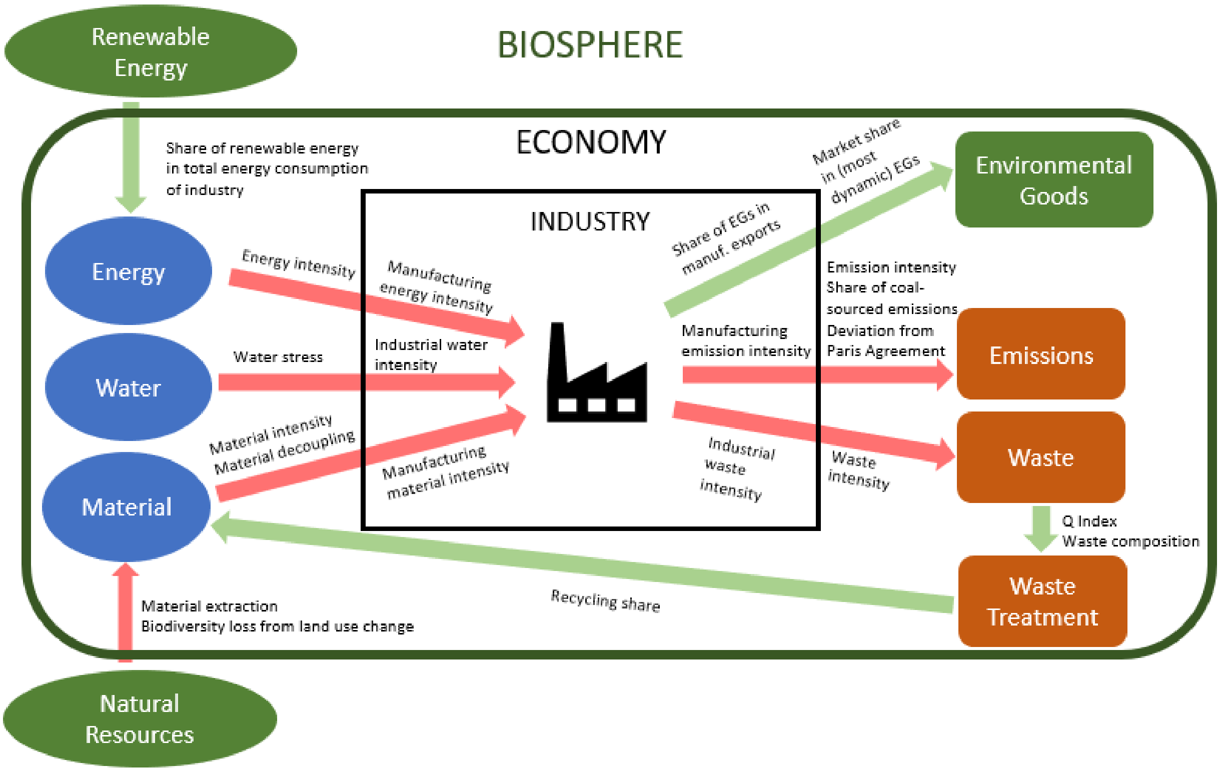
The methodology section gives an overview of the indicators that are used in each section, an analysis of these indicators as well as the data sources. The rationale and main questions associated with each indicator describe why they were selected for this tool. *Direct inferences* are questions that can be immediately answered by using the respective indicator, creating the groundwork for the proposed *follow-up questions,* which require more detailed investigation and provide more specific policy insights.

In the analysis section of each thematic area, the indicators are used to analyse a country against their comparators. This often involves the combination of two or more indicators to create graphs that are subsequently explained as an example of analysis. In each of these example analyses, we showcase the key indicators of the respective thematic chapter with a chosen group of comparator countries. The selected country groups for each section are as homogenous as possible in terms of geographical location (each chapter focuses on a different region), income level, population size, and stage of industrial development. Benchmarking their performance and progress against one another highlights the differences in the countries' trajectories. Please note that data availability differs greatly between countries, with an impact on the ideal indicator and comparator choice as well as the analytic narrative.

Lastly, each thematic area includes a section that lists various *policy instruments*. These are not exhaustive but intend to give policymakers a better understanding of how certain aspects of the green transition can be encouraged and supported. The policy instruments are further exemplified by short case studies. These examples can also be used in cases where the lack of data availability impedes an in-depth country analysis.

Figure 4 presents a visual representation of this tool. The components energy, water, and material (on the left in blue) cover various inputs into a country's economic- and industrial activities. These activities result in both negative outputs, such as CO_2 emission and waste, which should be minimized as much as possible, as well as in positive outputs, e.g. environmental goods. The negative consequences of waste can be addressed by adopting appropriate waste treatment. Renewable energy and natural resources are considered to lie outside the economic sphere and belong to the biosphere but have an impact on energy and material consumption. The arrows between each component represent some of the main indicators used in this tool to analyse the relationships between different inputs against outputs.

Figure 4. Graphic visualization of this tool



Source: Own elaborations

The analysis, where possible, is at the level of manufacturing and the manufacturing sub-sector level of aggregation. We refer to the former as the ‘aggregated manufacturing sector’, and the latter as the ‘different sectors’, such as food and beverages, chemicals, basic metals, or electrical machinery, etc., which together represent overall manufacturing. Unfortunately, such disaggregated data are often difficult to obtain for the majority of non-OECD countries. Where available, the indicators will help analysists understand the performance of their country’s manufacturing sector compared to suitable benchmark countries. Where this is not possible due to the lack of sub-sectoral data, national-level comparisons can be conducted.

The types of graphs used in this tool are predominantly bar or line charts and scatterplots. While bar charts present a snapshot analysis of an individual indicator, line graphs allow for the inclusion of a temporal dimension. Scatterplots are used when two indicators are combined to assess their relationship. This is particularly relevant for the concept of decoupling.

Data for this tool are derived from a wide range of sources. The main databases are UNIDO’s INDSTAT, the World Bank’s WDI, the IEA’s world energy balances, the IEA’s emissions in fuel combustion, FAO’s AQUASTAT and WITS’s UN Comtrade, and several other sources. One main consideration in the choice of data sources was that they are openly accessible for the participants of a training session. Additional data from national statistics offices or other specialized sources may enhance the analytic depth of the presented indicators.

How to use this tool

This tool presents data in each section for a different set of sample countries to illustrate how the indicators can be used for analysis and benchmarking. When using the indicators, users should keep some considerations in mind when selecting comparator countries. Geographical proximity is a useful measure for benchmarking several countries, as environmental dimensions within a region with similar ecosystems are generally comparable. In terms of socio-economic aspects, such as level of income, the choice of indicator depends on the desired perspective: comparisons are often made between countries that are at a similar stage of development to highlight different environmental performances under comparable socio-economic conditions, but so-called ‘role models’ at more advanced stages of development can be included to highlight aspirational goals. It should be kept in mind that the use of the environment (expressed in terms of intensity) is essentially a function of a country’s stage of development. Hence, the economy’s size and structure (industry vs services, etc.) play a significant role in terms of how intensively the environment is used.

Each chapter can be analysed in relation to other sections as well as individually. Policymakers may opt for a specific section based on relevance for their specific country, or simply out of interest. Such modular application is possible as each thematic section is constructed in a way to fully function on its own. The indicators are generally arranged to first paint a broad, country-level picture and to then gradually narrow their focus in relation to various socio-economic measures and shifting to levels of increased sectoral disaggregation. The context-based potential of manufacturing to contribute to the abatement of environmental impacts and the implementation of the circular economy can thereby be established.

The indicators generally deliver the most meaningful insights when analysed in the context of other indicators of the same chapter, e.g. the development of industrial resource use vis-à-vis intensities. Some indicators can furthermore be related to others that are outside their thematic chapter if they are on the same level of analysis. This is particularly true for the material and waste chapters, as exemplified in the material analysis, but could also be applicable to the water and energy and CO_2 chapters. This approach may shed light on country-specific patterns and the environmental impact of their production. Still, not all correlations necessarily constitute a causal relationship. Establishing such a conditional link usually requires more specific and in-depth topical research.

Links to other tools and possible extensions

Environmental concerns—and hence policy action—are not limited to one specific aspect of industrial production but cover all dimensions of manufacturing. This tool therefore has a wealth of thematic links to the other EQuIP tools that explore these dimensions.

Reducing the use intensity of materials, energy and water increases the economy’s competitiveness by reducing production costs, particularly in terms of the rising costs of such inputs and the associated competition to acquire them on the market. This establishes a link to Tool 1 on *Industrial Performance*. Reducing material intensity also supports the transition from resource-intensive primary processing activities towards producing high value-added goods, a key objective of many developing countries and connects to Tool 3 on *Diversification and Upgrading*. Such goods diversify a country’s export portfolio, with potential implications for *trade* (Tool 2). Green industrial policies also have an impact on *Income and Employment* (Tool 5). Cost-effective material-intensity improvements generally increase a company or manufacturing sub-sector’s overall productivity, which may in turn increase wage levels and create additional jobs while possibly reducing employment in material extraction sectors. Considerable (re-)training efforts will likely be necessary to prepare parts of the workforce for the new technologies and modes of production that will emerge as a result of the drive towards a green economy.

In addition to these thematic links, analysing the indicators of Tools 1 and 3 may also uncover the causes of differences in trends in environmental performance indicators included in this tool, such as an increase in sub-sectoral CO_2 emission intensity. The indicators of the *Environmental Goods* chapter are based on export trade data and can therefore be considered an extension of Tool 2. The diffusion of these goods is relevant for diversification and upgrading as well. Finally, there are links between Tool 4 on global value chains (GVCs) and the material footprint indicators (RMC), as both trace their metric of interest along the supply chain – more information on this is available in the material chapter.

Policy implications

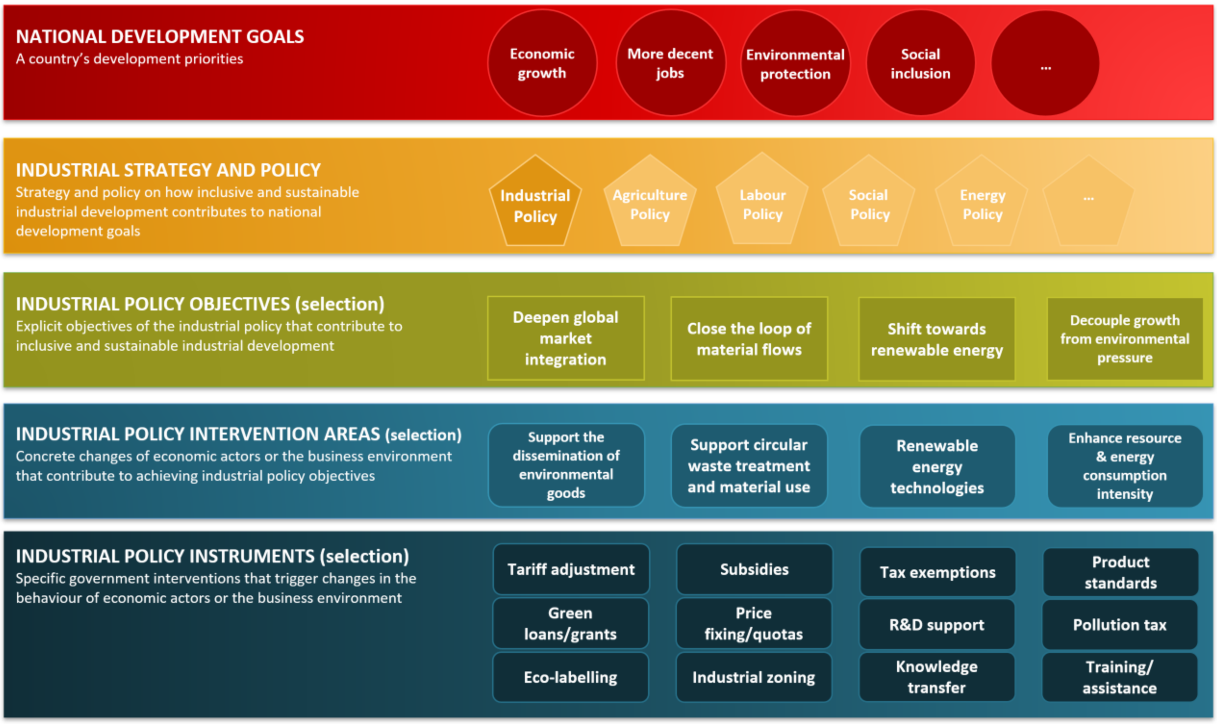
The policy implication matrix in **Table 1** illustrates how some of the industrial policy objectives, intervention areas and instruments discussed in this tool relate both to national development goals and, following from those, to economic policies. Similar matrices can be found in the policy options section of each chapter as well as in all other EQuIP tools. In line with the standard economic approach, so-called "market failures" are a natural focus for policy action and targeted interventions. They describe a situation in which individual incentives for rational behaviour do not lead to optimal outcomes for the group, i.e. a sustainably used environment, and occur when individuals who act in a rational self-interest way achieve a less than optimal or economically inefficient outcome. Much of the policy options provided in the following chapters are mechanisms designed to address such failures, either through market-based, decentralized measures or public inputs and regulations.

There are, however, other types of failures that can lead to undesirable environmental outcomes: government or systemic failures. Government intervention in the economy may fail to achieve an environmentally efficient allocation of resources, for example through fossil fuel subsidies. A lack of inter-departmental cooperation and coordination as well as communication within government can lead to further inefficiencies. Thus, institutional aspects of policymaking are important for overcoming departmental silos. According to Ohno (2012), *"Success in industrial policy formulation depends not only on the proper choice of policy measures […] but, more fundamentally, on policy procedure and organization from which good policies are produced and executed".*

Most sustainable industrial policymaking in developing countries address multi-sectoral issues managed by more than one ministry or agency. Intra-governmental coordination is crucial if the policy is to be effectively designed, budgeted, and implemented. A designated lead ministry or agency with a clear mandate to formulate the policy—usually the Ministry of Industry—has the main responsibility. Other ministries in charge of finance, science and technology, energy, environment, official development assistance (ODA) and foreign direct investment (FDI), etc. must be involved as well. While the working relationship should be as horizontal as possible, the entire process should be managed by the authorized lead ministry or agency and provides a forum in which multi-sectoral issues are deliberated and resolved (Ohno, 2012). Each department retains a clear responsibility for its contribution, and synergies often arise, turning the components of cooperation into a whole that is larger than the sum of its parts. This approach aims to break through the "complexity paradox" of modern public policy: the more complex given policy issues are, the more compartmentalized policymaking tends to become, fragmented into different and sometimes competing government departments and initiatives.

Furthermore, sustainable industrial policy should entail active participation of non-government stakeholders, such as domestic and foreign firms, environmental non-governmental organizations (NGOs), local residents, downstream users and other stakeholders (Ohno, 2012). A mechanism must be in place which coordinates the various voices and interests of these stakeholders. When all major actors within and outside the government participate in policy formulation, a growing sense of shared ownership and responsibility as well as a willingness to cooperate in the implementation of policies can be achieved. Support by the relevant organizations is more important than the elaboration of (theoretically) advanced policy documents: in the early stages, the documents can be relatively simple with a few specified policy actions, and still be adequate in terms of the country's ambition and capabilities.

Table 1. Environmental industrial policy implication matrix



NATIONAL DEVELOPMENT GOALS A country's development priorities	Economic growth	More decent jobs	Environmental protection	Social inclusion	...
INDUSTRIAL STRATEGY AND POLICY Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals	Industrial Policy	Agriculture Policy	Labour Policy	Social Policy	Energy Policy ...
INDUSTRIAL POLICY OBJECTIVES (selection) Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development	Deepen global market integration	Close the loop of material flows	Shift towards renewable energy	Decouple growth from environmental pressure	
INDUSTRIAL POLICY INTERVENTION AREAS (selection) Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives	Support the dissemination of environmental goods	Support circular waste treatment and material use	Renewable energy technologies	Enhance resource & energy consumption intensity	
INDUSTRIAL POLICY INSTRUMENTS (selection) Specific government interventions that trigger changes in the behaviour of economic actors or the business environment	Tariff adjustment Green loans/grants Eco-labelling	Subsidies Price fixing/quotas Industrial zoning	Tax exemptions R&D support Knowledge transfer	Product standards Pollution tax Training/ assistance	

References

Albaladejo, M., Franco Henao, L., & Mirazo, P. (2021). *The Circular Economy: A driver of inclusive and sustainable industrial development.* https://iap.unido.org/articles/circular-economy-driver-inclusive-and-sustainable-industrial-development

Commission on Growth and Development (2008). *The Growth Report Strategies for Sustained Growth and Inclusive Development.* Washington: The World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/6507/449860PUB0Box3101OFFICIAL0USE0ONLY1.pdf?sequence=1

De Souza et al. (2015). Vulnerability to climate change in three hot spots in Africa and Asia: Key issues for policy-relevant adaptation and resilience-building research. *Regional Environmental Change,* 15, 747–753.

International Energy Agency (2023). *Energy Technology Perspectives 2023*.

IPCC (2014). Summary for Policymakers. In *Climate Change 2014: Mitigation of Climate Change.* Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Jesus, F., Mehta, A., & Rhee, C. (2014). *Manufacturing Matters... But it's the Jobs that Count.* Asian Development Bank Working Paper No. 420.

Kaldor, N. (1967). *Strategic Factors in Economic Development.* New York State School of Industrial and Labor Relations, Cornell University.

Ohno, K. (2012). *Learning to Industrialize. Policy Procedure and Organization.* Routledge: London

Roe, D., Seddon, N., & Elliott, J. (2018). *Biodiversity loss is a development issue: A rapid review of evidence.*

Sanderson, B., & O'Neill, B. (2020). Assessing the costs of historical inaction on climate change. *Sci Rep,* 10, 9173.

United States Government Accountability Office (GAO) (2014). *Climate Change: Better Management of Exposure to Potential Future Losses Is Needed for Federal Flood and Crop Insurance.* Report to Congressional Requesters. https://www.reed.senate.gov/imo/media/doc/10%2029%2014-GAO%20Climate%20Change_Final%20Report%20(2)%20(1).pdf

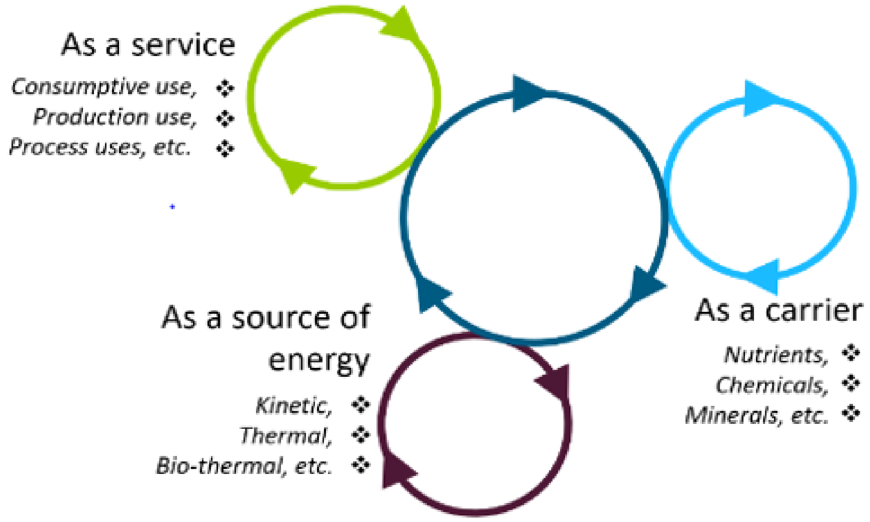
1 Water use

Introduction

The first section of this tool focuses on water as a resource and its use in industrial processes. Water is a fundamental basic need of all living being. This service to life, including human consumption, cannot be satisfied by substituting water with another measure or material. Natural water cycles underpin the way we grow food, generate hydropower electricity and supply water to our cities and industries. At the same time, water sustains important biophysical processes, such as climate regulation, and provides a safe haven for biodiversity to flourish (i.e. ecosystem services). In fact, industrial sectors rely either directly or indirectly on ecosystem services related to ground water and freshwater provision (e.g. food and beverages, wood and wood products, oil and gas). Accordingly, water is used and provides value in several different ways.

This section sheds light on a country's performance in terms of managing its water endowments: it investigates how much freshwater industry uses, i.e. the degree to which industry contributes to water stress. Developments in freshwater extraction relative to renewable freshwater resources can be assessed using time series data, giving indications whether policy measures need to be implemented to prevent a water crisis and reduce water stress. To better understand which measures are required for industry, we explore how much value industry creates for each cubic meter of freshwater it extracts, comparing the amount with historical trends and benchmarking the industry against other countries that have a similar industrial structure to determine whether the level of water intensity is justified. Benchmarking against other countries provides insights into water wastefulness and measures that must be taken to mitigate the situation.

Figure 5. Dimensions of water use



Source: Ellen MacArthur Foundation (2018)

Human water use can be clustered into three dimensions, namely *service*, *energy,* and *carrier* (see **Figure 5**, ARUP, 2018). Whether these can be harnessed and optimized to generate value while keeping the delicate balance between nature and human activities, varies depending on local basin features, level of economic development and type of use: agricultural, municipal, industrial, or environmental.

In line with the “Take-Make-Dispose” approach, which is synonymous with material consumption (as outlined later in the Material section), water is commonly used in a linear fashion characterized by the “Take-Use-Discharge” model. Freshwater is sourced or ‘withdrawn’ from streams, rivers, lakes, reservoirs, and groundwater aquifers or harvested directly as rainwater. Water for non-consumptive use is returned to the basin while consumed water is lost (IWA, 2016). This linear approach of human-managed water use, which is prevalent in the majority of basins today, is short-sighted and inherently unsustainable. According to the International Water Association, if we continue with ‘business as usual’, global demand for freshwater will exceed viable resources by 40 per cent by 2030. Industry is the second largest user of water worldwide, only surpassed by agriculture; the demand for water in manufacturing is expected to increase by 400 per cent by 2050 (IWA, 2016). Climate change and the ongoing increase in pollutants will further deplete the quality and amount of available freshwater resources. In a recent survey, CDP concluded that water risk to major corporations is substantial. As highlighted in **Table 2**, the potential financial impact of water risks (i.e. revenues at risk) are far greater than the costs of addressing them. The business case for mitigating water-related risk is evident in all continents, but particularly pervasive in Africa and Asia.

Table 2. Water risk financial implications for major corporations (billions USD)

Region	Financial impacts	Increased Costs
North America	40.9	31.4
Europe	17.6	3.73
Asia	132.1	5.06
Latin America	26.2	14.1
Africa	83.3	0.34
Oceania	0.92	0.12

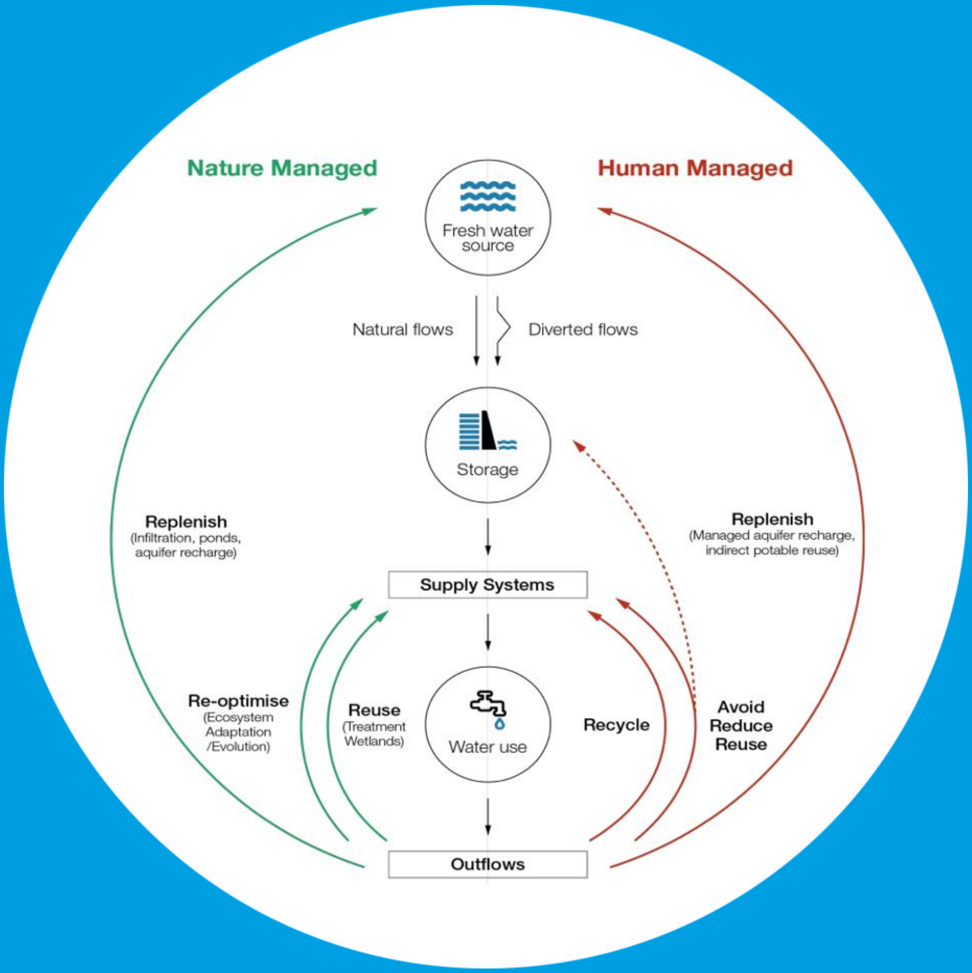
Source: CDP (2021)

The importance of water use is exemplified by the prominent role it plays in SDG6, which aims to “Ensure availability and sustainable management of water and sanitation for all”. While there is sufficient water to meet the world’s growing needs, a transformational change will be necessary in the way water is used, managed, and shared to ensure it remains available. At industry level, this means maximizing the extraction of value from water cycles to decrease the intensity of water resource use. This approach is enshrined in SDG target 6.4 from which we derive a number of indicators for this tool, as further outlined in the methodology section.

Adopting a circular economy approach that avoids or reduces water use and reuses outflows presents a tremendous opportunity for businesses, governments, and cities to minimize structural waste and thus realize greater value from industry while preventing further environmental degradation (see **Box 2**). Circular water management, which changes the use of water from a linear process with increasing contamination (becoming wastewater) into a circular one within which water recirculates and loops back for continual use, can also help businesses prepare for potential water scarcity risks exacerbated by climate change (UNESCO & UN-Water, 2020). The current "Take-Use-Discharge" approach defies all three circular economy principles: designing out waste externalities, keeping resources in use and regenerating natural capital (EMF, 2018).

Box 2. The water system & circular economy

Figure 6. System diagram of water in the circular economy



Source: Ellen MacArthur Foundation (2018)

The system diagram of water simplifies the complex water system to represent a single basin. There is continuous movement of water on, above and below the surface of the Earth. Precipitation is naturally collected within a basin's boundaries, flowing from higher to lower elevations. Water is captured and held by soil, vegetation, and surface water bodies until it ultimately percolates into the ground and aquifers. Water also leaves a basin through evaporation and transpiration, engineered water flows, discharges to oceans, embedded in products, or otherwise shipped out of the basin (EMF, 2018).

Nature Managed System

The left side of the diagram presents the natural water cycle, in which no human-induced uses occur. It helps to (EMF, 2018):

- Re-optimize – a specific supply of water is necessary to maintain the ecosystem and biodiversity. This naturally varies and is influenced by the ecosystem's complexity, climate and the general ability of plants and animals to adapt to a changing environment.
- Reuse – as water moves from higher to lower elevations and interacts with flora and fauna, it is naturally treated in its cycle.
- Replenish – the natural cycle concludes with a return of water to the environment through evapotranspiration, infiltration, or surface water flows.

Human Managed System

On the right side of the diagram, water's circularity is impacted by human activities, which alters the natural water cycle, including (EMF, 2018):

- Abstracting freshwater beyond its natural rate of replenishment;
- Accelerating water loss through inefficient irrigation and distribution methods;
- Polluting water and limiting its utility for other users.

Such outcomes have adverse impacts on the natural water cycle and can result in economic and environmental losses or additional costs to meet human needs.

Opportunities

The circular economy can help better align the human water cycle with the natural water cycle through the following measures (EMF, 2018):

- Avoid use – by rethinking products and services and eliminating intensive exploitation;
- Reduce use – driving continuous improvements in water use intensity, resource allocation and management;
- Reuse – pursuing all potential opportunities to reuse water within an operation (closed loop) and for external applications within the surrounding vicinity or community;
- Recycle – within internal operations and / or for external applications.
- Replenish – efficiently and effectively returning water to the basin

Decoupling pressure on water resources from economic growth is key to achieving sustainable development due to the uneven geographical distribution of global water resources and the cost of transporting water. In areas with insecure water supply, it is even more important to monitor both the intensity of water intake and the total amount of water taken in. Most water, after re-circulation, is released back into the environment either directly to the surface water (often at a reduced quality) or through evaporation. Increasing the rate of re-circulation and avoiding evaporation will reduce the amount of water that needs to be withdrawn from municipal, groundwater or surface waters. All facilities should measure how much water is being recycled or re-circulated (OECD, 2012).

Methodology

This section introduces the different indicators used to analyse water use, its availability as well as its vulnerability. The first indicator is the level of water stress, which is covered by Sustainable Development Goal 6.4.2 and compares a country's available freshwater resources with its total freshwater withdrawal. This potential bottleneck provides a useful overview of a country's water resource availability, use and vulnerability. The second indicator denotes the share of total freshwater withdrawal in a country for industrial use. The third indicator focuses on industrial water use intensity, which reflects SDG 6.4.1 "Industrial water use efficiency".

Table 3. List of water use indicators

Indicator	Level of analysis	Definition	Data source
Level of water stress (SDG 6.4)	Country	Degree to which a country's renewable freshwater resources are exhausted to meet society's needs	FAO: AQUASTAT
Share of freshwater withdrawal for industry	Industry	Share of freshwater withdrawal for direct industrial use in total freshwater withdrawal by all sectors in a country	
Industrial water use intensity	Industry	The mass amount of water required to generate USD 1 of industrial value added	

Data sources

The data on water use indicators are retrieved from the Food and Agriculture Organization's (FAO) database AQUASTAT, which collects, analyses, and disseminates data and information on water resources and agricultural water use by country. This dataset is part of the *Global SDG Indicator Database* compiled by the UN for the Secretary-General's annual report on progress made towards the SDGs. AQUASTAT plays a key role in monitoring SDG 6, in particular the indicators of Target 6.4 on water stress and water use efficiency.

Indicators 1.1 and 1.2 are available for download from AQUASTAT. As "intensity" is consistently used throughout the tool instead of "efficiency" (see "Key concept" section in the tool's introduction), we calculate Indicator 1.3 on industrial water use intensity manually and forego the pre-calculated measure of industrial water use efficiency. Data on water withdrawal for direct industrial use are also retrieved from the AQUASTAT database while we use value added data from the World Bank's "World Development Indicators" (WDIs). Data between 1960 and 2018 are available for 218 countries. The reason why WDIs are used instead of MVA data available from UNIDO's INDSTAT database, is that they include data on construction, mining, and electricity in addition to manufacturing, which corresponds to direct industrial water use as reported by AQUASTAT.

Water stress and other water-related risks can be traced at the sub-national level using the "Aqueduct Water Risk Atlas" (see here), which is updated monthly. In combination with a county's own regional industrial data, this allows for a more localized policy approach to water stress and water-related risks. Another valuable source on water use is the United Nations Environment Programme's (UNEP) SCP-HAT (*hotspot analysis tool for sustainable consumption and production*) database. It provides model calculations for freshwater consumption and the water stress contribution of industrial sub-sectors, allowing for a more in-depth analysis.

Indicators

1.1 Level of water stress (SDG 6.4.2)

Definition

The ‘level of water stress’ indicates the ratio between freshwater withdrawn by all major sectors of the economy and total renewable freshwater resources, after taking environmental water requirements into account. The sectors considered (as defined by ISIC standards) are agriculture, forestry and fishing, manufacturing, electricity industry and services. This indicator reveals the degree to which water resources are exploited to meet the country’s water demand and to sustain both the population and economy. It also reveals the extent to which renewable water resources are exhausted and indicates a country’s vulnerability in terms of climate change-related water scarcity. Moreover, it highlights potential hotspots in regions with scarce water resources where the rate of withdrawal is higher than that of replenishment in the hydrological cycle. The acute risk of depleting water resources due to unsustainable use leads to high water stress, which is what makes this a hotspot indicator. A critical threshold of water stress is when a 100 per cent or more of renewable freshwater resources are withdrawn annually, signified by values of “1” or above, resulting from the formula calculation.

This indicator thus functions as an alarm bell for policymakers. If the threshold of 1 is approached or even surpassed, urgent policy action to offset this development becomes crucial. If it persists, water stress can have detrimental effects on agriculture, manufacturing, energy generation and the population’s quality of life. The supply of raw materials will also be affected, disrupting supply chains, and causing damage to facilities, equipment, as well as infrastructure. This, in turn, could interrupt transport and affect energy supply (e.g. transmission lines and pipelines). The result could be a deterioration in working conditions, workers’ health, a higher level of absenteeism and lower productivity (UNESCO, 2020). This indicator thus helps countries avoid such situations by regularly monitoring their level of freshwater extraction in relation to their total renewable freshwater resources.

Strategic questions

Direct inferences:

- To what extent does the country withdraw water beyond its natural regeneration capacity?
- How has the country’s water stress level developed over time?

Follow-up questions:

- Why did the water stress level develop the way it did, and how can it be reduced?
- What role do industrial water withdrawal and climate change play in the development of a country’s water stress level?

Equation

$$\boldsymbol{Level\ of\ water\ stress} = \frac{\boldsymbol{Total\ freshwater\ withdrawal\ by\ all\ sectors\ (m^3)}}{\boldsymbol{Total\ renewable\ freshwater\ resources\ (m^3)}}$$

1.2 Share of freshwater withdrawal for industry

Definition

This indicator reflects industries' contribution to the country's water stress level by showcasing the total annual water withdrawal for direct industrial use as a share of total freshwater withdrawal. As water is a climate-sensitive resource, the indicator also illustrates the extent to which industries are exposed to climate change risks. Total freshwater withdrawal encompasses use for drinking water, municipal use, or supply, as well as use for public services, by commercial establishments and homes. Direct industrial use covers self-supplied industries that are not connected to the public distribution network. This includes the "MIMEC" sectors, namely mining and quarrying; manufacturing; electricity, gas, steam, and air conditioning supply; construction (ISIC B, C, D and F; see correspondence table in the appendix). While withdrawals for cooling thermoelectric plants and nuclear power plants are included, those for hydropower are not.

Although water covers over two-thirds of the earth's surface and is renewable on a global scale, local shortages and quality problems are widespread. Water withdrawn for industrial processes, if not returned to the same body of water in its original quantity and quality, could contribute to the depletion of rivers and lakes and the reduction of groundwater tables. One way to address this issue at industry level is by designing an appropriate water symbiosis network to minimize freshwater consumption (and subsequent withdrawal) or pollutant discharge (Chin et al., 2021).

Strategic questions

Direct inferences:

- What is the industry's share of total freshwater withdrawal?
- How dependent is industry on the climate-sensitive resource water?

Follow-up questions:

- What factors may have contributed to a changing share in industrial water withdrawal?
- How can the industry's water dependency and thus its vulnerability be addressed?

Equation

$$\boldsymbol{Share\ of\ freshwater\ withdrawal\ for\ industry}\ (\%) = \frac{\boldsymbol{Total\ freshwater\ withdrawal\ for\ industry}\ (\boldsymbol{m^3})}{\boldsymbol{Total\ freshwater\ withdrawal\ by\ all\ sectors}\ (\boldsymbol{m^3})}$$

1.3 Industrial water use intensity (SDG 6.4.1)

Definition

Decoupling industrial water use from value added in production is an opportunity to both capture more monetary value and reduce water stress. This indicator illustrates the amount of water required to generate 1 dollar of industrial value added in the country. The change in the ratio of the volume of water use to value added can be traced over time. As is the case for the previous indicator, industry comprises the "MIMEC" sectors, i.e. mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; constructions (ISIC B, C, D, and F; see correspondence table in the appendix). While reducing industrial water intensity is important to limit adverse environmental impacts, increases in absolute industrial water use as well as the efficiency rebound effect could still lead to rising water stress. It is therefore important to always consider all indicators of a chapter together to gain a holistic overview of the industry's environmental performance and associated risks.

Strategic questions

Direct inferences:

- How has the country's industrial water intensity developed over time?
- How does the country's industrial water intensity compare to that of other countries?

Follow-up questions:

- Why has the country's industrial water intensity developed in the direction it did, and how can it be improved?

Equation

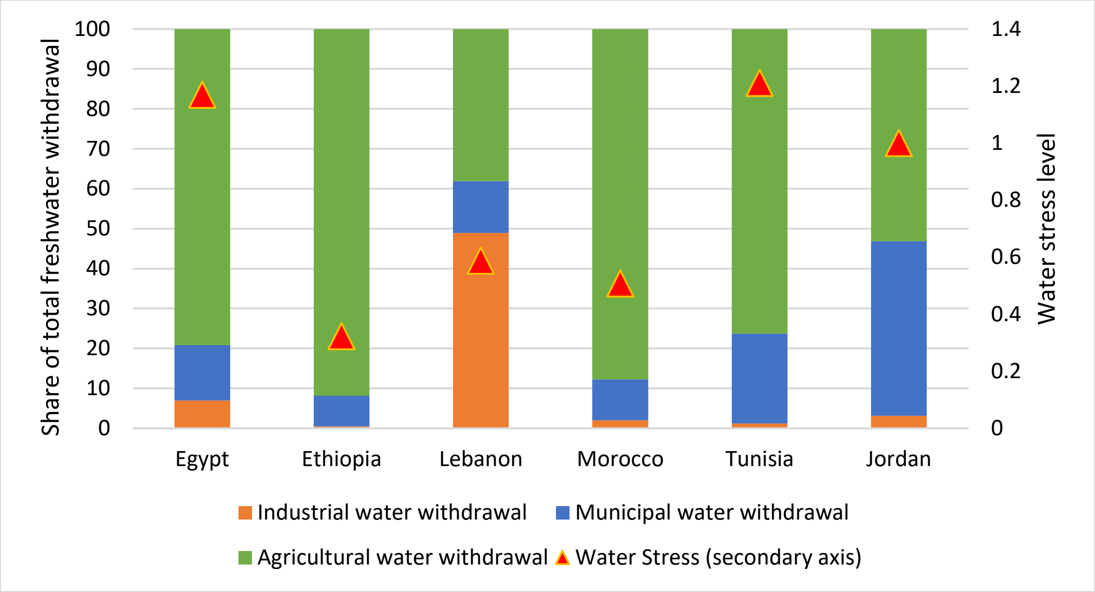
$$\boldsymbol{Industrial\ water\ use\ intensity}\ (\boldsymbol{m^3}\ \boldsymbol{per}\ \$) = \frac{\boldsymbol{Total\ freshwater\ withdrawal\ for\ industry}\ (\boldsymbol{m^3})}{\boldsymbol{Industry\ value\ added}\ (\$)}$$

Analysis

The analysis of water use applies the indicators introduced above and combines them to gain more in-depth insights into a country's water situation vis-à-vis its comparators. We use Egypt, Ethiopia, Lebanon, Morocco, Tunisia, and Jordan as examples.

The stacked bar chart in **Figure 7** plots sectors' shares of total freshwater withdrawal by country using the most recent available data from 2017. Aside from illustrating the extent of industrial water use in total water use in each economy (as well as the share of municipal and agricultural water use for context), it also shows the water stress level, represented by red triangles on the secondary axis. Ethiopia, Morocco, and Tunisia exhibit a similar composition of water withdrawal, with relatively low shares of industrial water use. Yet their water stress levels differ considerably, which can be attributed to the varying availability of renewable freshwater resources. While Morocco and particularly Ethiopia have relatively low water stress levels, Tunisia has reached a critical level of water stress beyond 1. The stress value of 1.2 implies that 120 per cent of renewable freshwater resources were withdrawn in 2017, indicating a significant vulnerability to water shortages and a necessity to introduce measures that address the extent of water withdrawal in the country. Egypt and Jordan, which both have a slightly higher share of industrial freshwater withdrawal than the two other countries, also exhibit critical levels of water stress. Lebanon is the country with the highest amount of industrial water withdrawal in the example group. While water stress is not a pressing concern there, the share of industry's water use might become problematic in future and should be closely monitored.

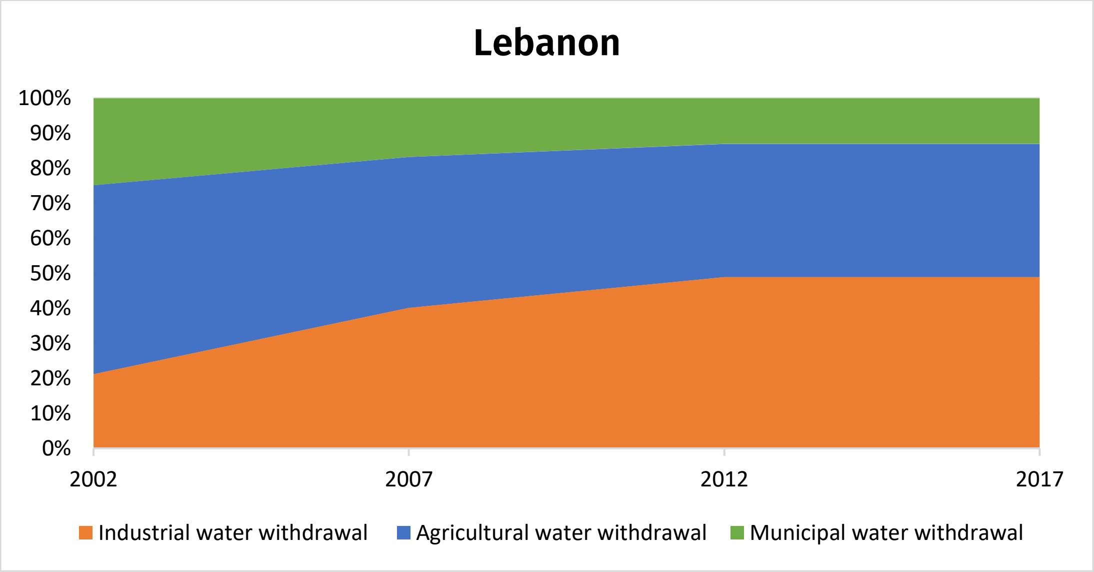
Figure 7. Levels of freshwater withdrawal and water stress in example countries (2017)



Source: Own graph based on FAO AQUASTAT data

Sectors' shares of total freshwater withdrawal can be tracked over time in individual countries using AQUASTAT data, which is available in 5-year intervals. In **Figure 8**, we exemplify this using the case of Lebanon, the country with the highest share of industrial water withdrawal. It becomes clear that the country's relative industrial water use has risen quite drastically in recent years before reaching about 50 per cent as reported in 2022. In 2007, industrial water use was around 20 per cent, which is still high compared to other countries but still less than half the share in 2022. This observation reinforces the conclusion that Lebanon needs to be cautious in terms of the amount of water resources used by industry and should consider options to reduce it.

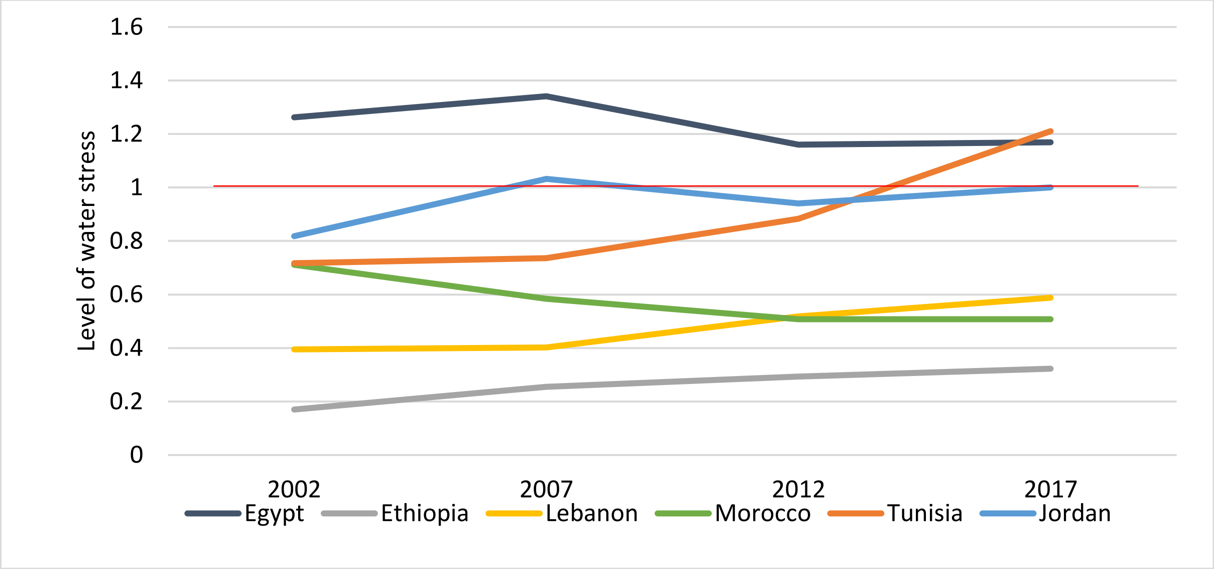
Figure 8. Lebanon: Development of sectors' shares in total freshwater withdrawal



Source: Own graph based on FAO AQUASTAT data

Tracing the level of water stress over time provides insights into the development of water resource exploitation and the associated supply risks (**Figure 9**). The plot shows that most of the example countries' water stress levels increased throughout the observed period. Morocco is one exception as it managed to decrease its water stress level from 0.7 to 0.5. Egypt is the other exception, though its water stress is still at a critical level above 1 (i.e. more freshwater withdrawal than renewable freshwater sources, see red line), even though the level has slightly decreased since 2002. Jordan and Tunisia witnessed worrying trends, their water stress levels rising significantly since 2002. Jordan reached a critical level around 2007 and Tunisia between 2012 and 2017. This means that Jordan and particularly Tunisia are at acute risk of experiencing lasting water scarcity due to water source depletion. Policymakers in Tunisia as well as in Egypt should adopt measures to reduce freshwater withdrawal and to thereby lower their water stress to non-critical levels.

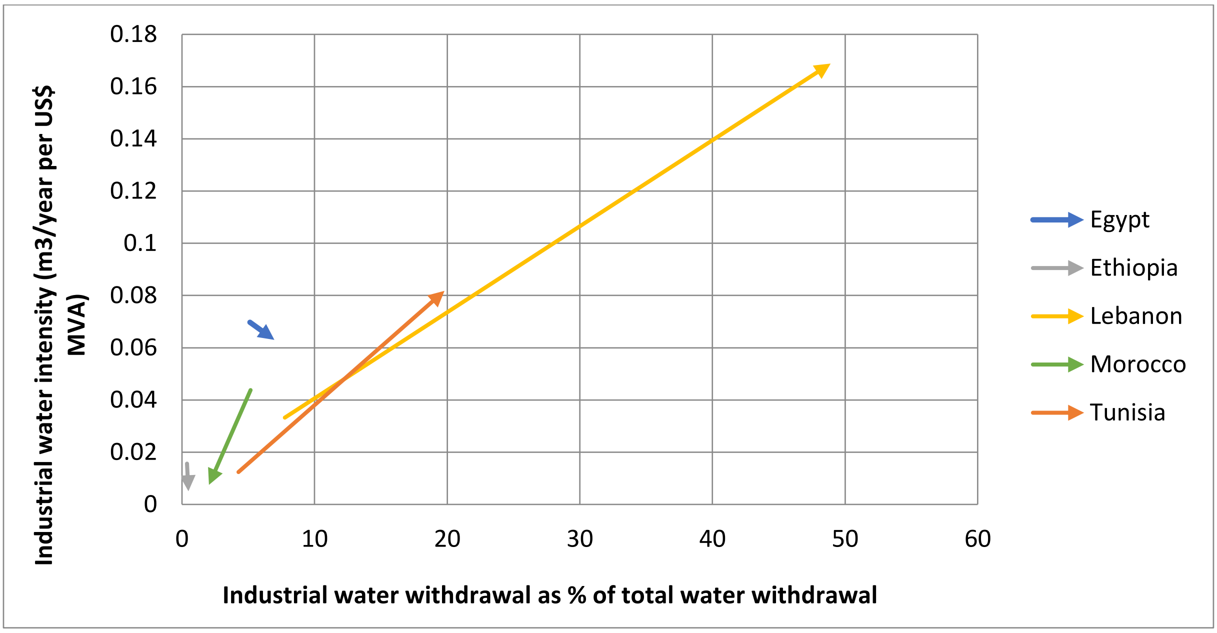
Figure 9. Level of water stress over time in example countries



Source: Own graph based on FAO AQUASTAT data

The following arrow plot (**Figure 10**) provides a better understanding of the role industry plays in the countries' share of water withdrawal and how to reduce its impact. The x-axis denotes the share of industrial water withdrawal in total freshwater withdrawal while the y-axis depicts industrial water intensity in cubic metres per dollar of manufacturing value added. The arrows illustrate the development of the relation between the two variables in each country between 2002 and 2017. The arrows' incline indicates which variable exerted a stronger pull effect over the observed period. Morocco reduced both its share of industrial water use and intensity during the observation period. Egypt and Ethiopia exhibited only little change. Tunisia and Lebanon, on the other hand, saw a massive increase in both their share of industrial water use and intensity. The share of water use of Lebanon's industry skyrocketed from below 10 per cent to nearly 50 per cent while its industrial water intensity rose from around 0.03 m^3 per $ of value added to nearly 0.17. This rapid change should raise alarm among Lebanese policymakers, who should consider the introduction of measures to reduce their industrial sector's water supply vulnerability.

Figure 10. Industrial water intensity and share of freshwater withdrawal for industry (change from 2002 to 2017)



Source: Own graph based on FAO AQUASTAT & World Bank WDI data

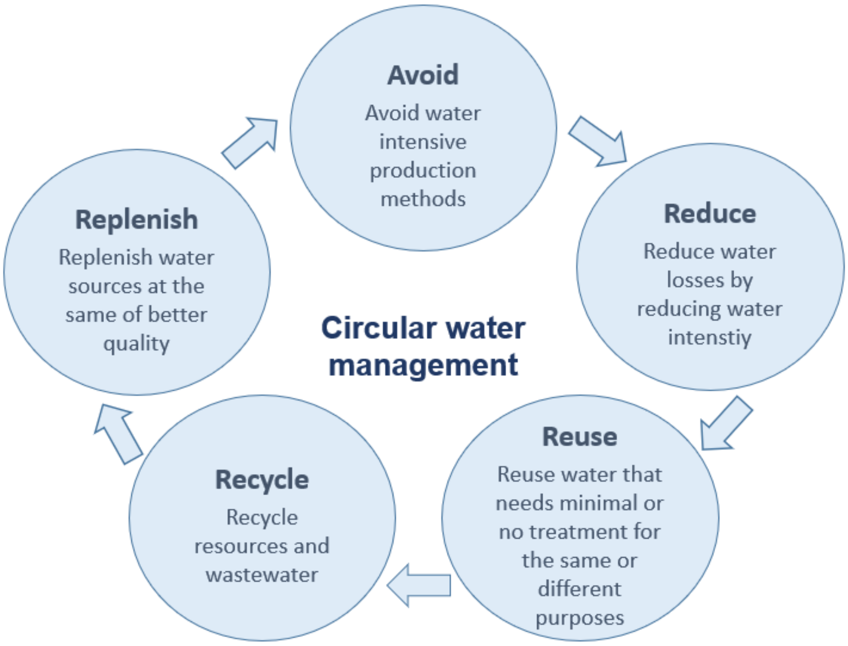
Policy options

The policy options discussed in this section are examples policymakers can use for orientation and inspiration purposes. They are not meant as a blueprint for policy responses but provide an overview of the wide range of potential options.

Water supply hinges on the natural boundaries associated with the developments of the hydrological cycle (such as river basins). Policy solutions to reduce water withdrawal should consider whether water is being efficiently distributed across sectors, i.e. whether industry enjoys adequate coverage with minimal losses and high productivity. In this context, the water cycle includes the movement of water from its source (surface water, groundwater, rainwater, etc.) to distribution and utilization in economic sectors (agriculture, industry, domestic, etc.), its treatment, recycling, and reuse in these economic sectors, and return flows to the natural environment and vice versa. The application of systems thinking is critical for identifying the circular economy opportunities that exist within the system as well as in other associated systems. According to this approach, systems consist of elements that interact with each other to create a structure with a characteristic set of behaviours. It allows for the assessment of feedback effects, which is not possible with the prevalent approaches, which are rooted in mechanics. A systems approach also enables an impact assessment and maximizes the value created as a result of the application of circular economy principles (EMF, 2018).

Circular water management avoids and reduces use, reuses, recycles and replenishes water. This approach can reduce operational costs, as significant water savings in industrial facilities are possible through technical measures. Options include optimizing and reducing water used for heating or cooling purposes, cleaning, and transport. External reuse is more complex but also offers significant potential for reducing water used for industrial purposes (EMF, 2018). The benefits of treated wastewater are notable – in 2010, 16 per cent of global freshwater withdrawal became industrial wastewater of which only a low percentage is treated in many countries (WBCSD, 2017). The business case for investing in wastewater treatment technologies has recently been reinforced by considering opportunities related to the recovery of materials and power generation that are made possible by the adoption of the most advanced technologies (Process-Net, 2017). Whilst existing plants in developed countries need to be upgraded, the latest available technologies and solutions could be applied in developing countries to maximize material recovery and energy generation possibilities. Ultimately, the adoption of circular economy approaches by businesses in different industrial sectors can untap a huge potential in terms of cost savings related to the recovery of materials from industrial sludge (World Bank, 2019b). Reduction in water use is often a co-benefit resulting from other efficiency measures that target energy use, for example, or closed material flows in overall industrial processes. The metals and mining, pulp and paper, textiles and chemicals industries entail substantial potential for water recycling and reuse (Gavrilescu et al., 2008). The water savings potential in these industries commonly range from 20 per cent to 80 per cent (UNEP, 2010).

Figure 11. Circular water management



Source: Adapted from WBCSD (2017)

Figure 11 presents a simplified abstraction of an industrial water system. Several potential circular economy initiatives have been identified that have the potential to enhance the operational optimization of the municipal water system, in addition to potential circular economy initiatives that rely on other systems, agriculture and industry, in this instance. Industry is at a critical nexus of water and energy use. Most industrial processes use water, which can be a component of the final product, of the production process, or even an indirect component through energy use. A wide range of measures in the industrial sector can have an impact on water withdrawal, including:

- Reducing energy intensity,
- utilizing renewable energy,

- reducing water intensity,
- circular water reuse,
- removing water from the production cycle.

In addition, industries can utilize by-products from municipal water systems that would normally be discharged into the environment (EMF, 2018).

Market mechanisms

Market instruments allocate resources to users that are most willing to pay for them; in other words, to those users that value these resources most. This form of allocation is considered efficient because it is assumed that users that are willing to pay for the use of resources will use them to produce other goods and services that are highly valued by society; they would otherwise not be willing to pay as much. However, water is more than simply a consumption good or input to production. It is also essential to human life and provides invaluable multiple ecosystem services. The political economy of defining the optimal price for water is therefore characterized by ethical considerations of the right to access to water as distinct from its economic value. Determining the optimal solution for water allocation from an economic perspective alone is therefore especially challenging (Spash et al., 2006; Urama et al., 2006b). To address these concerns, Dinar et al. (1997) propose criteria for optimization in water resource allocation: flexibility in the allocation of supply sources, security of tenure for established users, real opportunity cost of providing the resource, predictability of the outcome of the allocation process, equity of the allocation process, and political and public acceptability of the allocation process.

Appropriate water pricing

Pricing can be used as a tool to encourage less intensive water use, especially in areas affected by droughts. As many industry users have dedicated supplies that are not provided by a water utility company or other domestic supplier, a water resource management authority with the ability to implement a pricing policy for both freshwater and wastewater must be established. For some industries, water costs account for a comparatively small share of overall input costs, and volumetric prices may not be sufficient to encourage conservation (UNEP, 2015). More details on different pricing rationales can be found in "FAO (1993). *The State of Food and Agriculture*"[1].

Polluter pays principle (PPP)

The 'polluter pays' principle is a commonly accepted practice that calls on those who produce pollution to bear the costs of managing it to prevent damage to human health or the environment. This includes the cost of measures taken to prevent, control and remedy pollution and the costs it imposes on society**.** For instance, a factory that produces a potentially poisonous substance as a by-product of its activities is held responsible for the substance's safe disposal. This internalizes the cost of pollution to the producer (instead of externalizing it to society and the environment) and protects valuable water resources. The PPP is closely linked to the extended polluter responsibility which is detailed in the waste section of this tool. It is part of a set of broader principles to guide sustainable development at

---

[1] Available here: https://www.fao.org/3/T0800E/t0800e0b.htm

the global level (formally known as the 1992 Rio Declaration) and underpins most of the regulations on pollution that affect land, water, and air (LSE, 2018). The EU Industrial Emissions Directive, for example, is designed to transfer the costs of monitoring, extra treatment in urban wastewater treatment plants, remediation, and the management of contaminated sewage sludge to major industrial producers that are authorized to release industrial wastewater into the urban sewer network (ECA, 2021). A revision of the directive aims to include smaller facilities as well.

Water neutrality

The basic idea behind 'water neutrality' is that economic growth and related development should not lead to an overall increase in water demand in a basin (Hoekstra, 2008; Hoekstra et al., 2011). Water-neutral development is achieved when the water demand requirements of new developments are met through more efficient use of existing water resources by investing in water efficiency and water productivity instead of an increase in water withdrawal. This can be realized by requiring developers of new industrial areas to invest in water intensity and water productivity measures equivalent to their expected water consumption (Nel et al., 2008).

Trading schemes

There is a range of approaches to address both water use and intensity through trading spaces, which while often effective, require a substantial degree of preparation and (international) coordination. Some examples include:

1. *Water efficiency trading schemes and investment offsets*

Investment in efficiency gains in one sector can offset investment in others and vice versa. For example, technical measures and management approaches to improve water efficiency and water productivity in the industrial sector could be cheaper than strategies for water savings in domestic water supply systems.

2. *Virtual water trading*

International trade in goods and services may mask the link in a country between economic growth and water use if virtual water (water embedded in goods and services where water is required for production) is not accounted for. The most water-scarce regions or nations could import water-intensive products from water-abundant countries and at the same time develop products or services that require less water (water-extensive products), thereby relieving the pressure on domestic resources.

3. *Basin-scale water markets*

Basin-scale water markets facilitate the trading of water between sectors and can contribute to the allocation of water to uses that maximize economic efficiency.

Water management approaches

Integrated Water Resources Management (IWRM)

This approach incorporates all parts of the overall water cycle and treats the different water sectors as components of an integrated physical and institutional system (Mitchell, 2004). A hypothesis associated with the Integrated Water Resources Management (IWRM) approach is that better water efficiency and water productivity can be achieved through integrated basin-wide management (UNEP, 2015). If implemented properly, the IWRM approach can contribute to environmental protection, improve water efficiency, foster economic growth, and promote democratic participation in water governance (GWP, 2010). IWRM is now widely recognized and implemented in many countries in line with Article 26 of the World Summit on Sustainable Development in 2002 (ANEW, 2011). For more information on IWRM, see “Options for Decoupling Economic Growth from Water Use and Water Pollution” (2015) published by the UNEP-hosted International Resource Panel.

Corporate water reporting and accounting

Effective water accounting is an important component of corporate water management for cleaner production and allows companies to determine the impact of their direct and indirect water use and discharges on communities and ecosystems, to evaluate material water-related risks, track the effects of changes in their water management practices, and credibly report their trends and impacts to key stakeholders (Christ & Burritt, 2017). The corporate world has become more aware of the need to account for its water use, both in terms of volume and risks to business. Many approaches to quantify and assess water use and its impacts are applied: they include water footprinting; lifecycle analysis, inventories, impact assessments as well as other water management tools and corporate reporting indicators (WBCSD, etc.). An ISO standard (ISO46001) certification for water efficiency management systems is also available. UNEP’s (2012) report on measuring water use in a green economy introduces the analytical methods and policy frameworks needed to ensure that water use can be properly quantified over the lifecycle and integrated into other measures within the green economy.

Sustainable industrial water management requires substantial private investments by the manufacturing sector, especially in developing or emerging economies, to increase or update their wastewater treatment potential and reuse. Transparency and accountability are prerequisites for attracting private capital. Better sustainability reporting can thus help manufacturers attract private investment or access government funds with conditionality clauses (e.g. post-pandemic recovery packages). Sustainability information makes it possible, on the one hand, for asset managers to understand investment risk in terms of target companies’ performance, position, and development, and on the other, to flag the impact companies have on society and the environment (Cheng & Yi, 2020) In France, for example, multinational companies have been legally required to report on two aspects related to water strategy and accounting since 31 December 2012:

(i) measures to prevent, reduce or repair releases to air, water and soil that severely affect the environment, and

(ii) water consumption and water supply in relation to local constraints (Gibassier, 2018).

The “double materiality” concept (Adams et al., 2021; Bussot et al., 2021) implies that companies should also report how sustainability issues affect their performance, position, and development in addition to their impact on society and the environment. Making assessments of environmental impacts explicit is the first step towards internalizing positive external effects through regulatory (e.g. water fees) and market instruments (e.g. better access to credit and lower interest rates). What is needed then is a mechanism to reward manufacturers for the positive impacts (co-benefits) they have on local ecosystems when they manage water resources sustainably.

Industrial symbiosis

Designing water symbiosis networks at industrial sites is a solution for addressing water quality and security issues by minimizing freshwater consumption or pollutant discharge (Chin et al., 2021).

Corresponding to industrial symbiosis with solid waste, advanced technologies are employed for a circular reuse of wastewater as a resource, but also to extract and exploit energy and materials contained within industrial wastewater streams. Such water eco-industrial parks offer symbiotic arrangements linked to emerging business opportunities and nurture a variety of partnerships that arise around them at the local, regional, sectoral, and inter-sectoral level between business, water service providers, regulators, and policymakers. Implementing such a symbiosis requires large amounts of capital on the given sites and may require cost compensation by the authorities to facilitate its operation. To provide sufficient incentives for market actors to implement the solutions and join the scheme, the cost or profit from resource-saving must be distributed fairly among the stakeholders as well as the industrial park authority.

End-user public private partnership model

By demonstrating how circular practices maximize local co-benefits, manufacturers could improve their relationships with other stakeholders, such as local public water suppliers, industrial clients, NGOs, farmers, and other industries located in the same catchment to pursue sustainability objectives. Recovery from the pandemic represents a fundamental opportunity to "build back better" by experimenting with innovative cooperative ways between manufacturers and other stakeholders at the local scale. One example is the so-called end-user public private partnership model (illustrated in Figure 12), in which an industrial water user reaches an agreement with the local water utility/ authority to reuse treated wastewater. In the diagram below, the grey water comes from the effluents of the nearby municipality, but the model could be expanded to include the industry's own effluents to the treatment plant by building an additional conveyance main. The manufacturer could (co-)finance the conveyance facility and the waste treatment plant or supply bulk-treated wastewater to local farmers. These types of partnerships are an effective way to ensure wastewater treatment, especially for small and medium enterprises (SMEs). Local circumstances determine the preferred structure of the public private partnership model.

Figure 12. Diagram of end-user reuse model

Source: World Bank (2019a)

Nature-based solutions

Traditionally, “grey” infrastructural solutions—engineering projects that use concrete and steel—have dominated the efforts to reduce and manage impacts from natural disasters and to manage water resources. At the national level, however, the focus is shifting towards nature-based (“green”) solutions for water resource management. While built infrastructure and its benefits are well-documented, those of natural infrastructure are more difficult to quantify. A healthy natural infrastructure—which is shaped, grown, eroded, or deposited by nature over time—can amplify and optimize the performance as well as the financial returns of engineered water infrastructure such as dams, levees, and reservoirs. For example, when forests upstream are kept intact, water and soil run-off will be regulated by trees, which in turn protects reservoirs from sedimentation build-up, reducing costly clean-up efforts and ensuring continued electricity generation. Yet the ecosystem services that natural water infrastructure provide are not always accounted for, and it is consequently often side-lined in grey infrastructure projects. This can have negative environmental impacts and reduce the natural adaptability of river basins to cope with climate change, weakening its resilience.

Nature-based solutions (NbS) are defined by IUCN as “actions to protect, sustainably manage, and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (Cohen-Shacham, 2016). Each year, hundreds of billions of dollars are invested in equipment and facilities required for withdrawing, storing, treating, and distributing water. Nature-based solutions can add significant benefits and reduce spending by constituting a more sustainable investment in the form of ecosystem services. These solutions can also create synergies with grey infrastructure, forming a so-called “hybrid” solution. The World Bank (2019b) asserts that NbS can provide a cost-effective and flexible approach to water resource management and has already integrated NbS in around 100 projects in 60 countries since 2012. Businesses are waking up to the fact that nature loss has concrete and immediate costs and risks, including operational risks; supply chain continuity, predictability, and resilience risks; liability risks and regulatory, reputational, market and financial risks. From a macroeconomic perspective, investment in green infrastructure is key to driving the transition to a more resilient economy and to avoid locking-in polluting industries. The IUCN (2012) makes the following recommendations for investing in natural water infrastructure:

- Recognizing natural water infrastructure as an integral part of development, both at the basin and national levels. This requires valuation of the costs and benefits of ecosystem services in investment assessment, including for dams, storage, irrigation, and drainage.
- Valuing the returns on investment in natural infrastructure and ensuring these are clear and quantified to inform better decision making. Applying economic tools to create a business case in which the dividends from investment in natural infrastructure account for the benefits of ecosystems and water security.
- Implementing economic incentives for investing in natural water infrastructure. Using economic incentives to encourage changes in behaviour and approaches. Rewarding those who manage watersheds sustainably, using “soft” payments for ecosystem services where appropriate, ensuring participation and governance are in place.
- Financing for water resource management must be sustainable. Introducing a sound business case for mobilizing innovative financing of water resources management, including government, the private sector and water users.

Box 3. Case studies (https://waterscarcitysolutions.org/)

1. *Water reuse in the textile industry (India):*

Tiruppur is a hub of the textile industry, accounting for 80 per cent of India’s knitwear production and generating over US$ 1 billion of exports per year. However, its river and groundwater system is affected by severe water quality issues as a result of effluent discharges from industry. Financed by government grants and soft loans, combined reverse osmosis and thermal evaporation treatment systems were installed to meet a court mandate. Water demand has decreased by 75 per cent while water quality in the river has drastically improved, as 96 per cent of effluents are recovered for re-supply as freshwater to the industry.

2. *Reducing the cost of water reuse in the textile sector (India):*

The Arvind textile mill located near Kalol, Ahmedabad District, uses over 6.5 million m^3 of process water annually. Limitations to groundwater extraction coupled with the lack of a nearby location for effluent discharge led to the implementation of a four-stage wastewater treatment and reuse system consisting of filtration, reverse osmosis, falling film thermal evaporation and crystallization. Approximately 80 per cent of process water is now retained and reused, thus negating the need to withdraw 5 035 606 m^3 per year, while further achieving reductions in energy demand (up to 80 per cent) and operating costs (65 per cent).

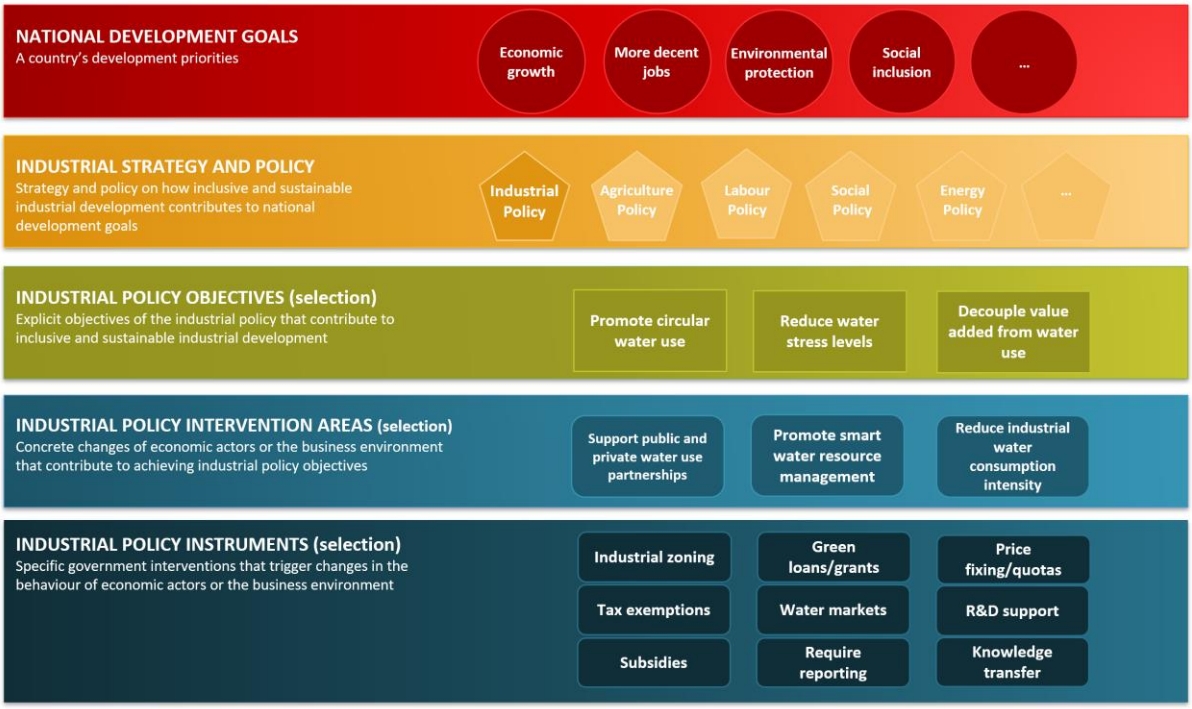
3. *An institutional capacity building approach (Jordan):*

Jordan is classified by the World Resources Institute as one of the 30 most water-stressed countries in the world with a water supply deficit projected to reach 365 m^3 by 2030, posing a major threat to its industrial sector’s economic stability, which accounts for 30 per cent of Jordan’s GDP. The USAID Water Reuse and Environmental Conservation Programme provided capacity building to the Ministry of Environment and to industrial wastewater testing facilities in addition to targeting 30 facilities in five industrial sectors to demonstrate opportunities for reductions in water and energy use. The intervention strategies have led to substantial self-financed reductions in water, diesel, and energy use in the facilities and to a new environmental protection law introduced by the Ministry.

4. Metering of non-revenue water (South Africa):

https://www.waterscarcitysolutions.org/wp-content/uploads/2015/07/Metering-of-non-revenue-water-Ekurhuleni-South-Africa.pdf

Table 4. Water policy implication matrix



NATIONAL DEVELOPMENT GOALS
A country's development priorities

Economic growth
More decent jobs
Environmental protection
Social inclusion
...

INDUSTRIAL STRATEGY AND POLICY
Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals

Industrial Policy
Agriculture Policy
Labour Policy
Social Policy
Energy Policy
...

INDUSTRIAL POLICY OBJECTIVES (selection)
Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development

Promote circular water use
Reduce water stress levels
Decouple value added from water use

INDUSTRIAL POLICY INTERVENTION AREAS (selection)
Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives

Support public and private water use partnerships
Promote smart water resource management
Reduce industrial water consumption intensity

INDUSTRIAL POLICY INSTRUMENTS (selection)
Specific government interventions that trigger changes in the behaviour of economic actors or the business environment

Industrial zoning
Green loans/grants
Price fixing/quotas
Tax exemptions
Water markets
R&D support
Subsidies
Require reporting
Knowledge transfer

Table 5. List of policy options: Water

		Sustainable water use policy instruments/ mechanisms	
		Market-based interventions/ Decentralized provision	**Public inputs/ Direct provision**
Policy domain/ market failure being addressed	**Product**	• Appropriate water pricing • Public campaigns aimed at producers for standards of water use in the production process through exhibitions/ trade fairs • Award scheme at sectoral, national and international level to educate and incentivize producers to use water efficiently • Public private partnerships as a strategy to ensure knowledge transfer • End-use public private partnerships model for reuse of treated wastewater	• Setting quotas for firms on water exploitation and use • Policy document to operationalize water efficiency improvement programmes • Promotion of environmental certifications and eco-labelling at industry level through information dissemination agencies such as industry associations and marketing boards, e.g. database of water efficient activities • Promoting water efficiency along the supply chain through regulations • Public disclosure programme for environmental compliance in the water realm, targeting medium-sized and large companies • Require corporate water reporting and accounting from large companies
	Capital	• “Green” incentives and support mechanisms granted for water efficiency investments - Direct subsidies - Internalize external benefits using double materiality perspective • Punitive taxes, fees, and user charges - Polluter-pays-principle - Water neutrality - Tax, levy, and royalty for use/ withdrawal of freshwater - Advanced recycling fee through the extended producer responsibility approach • Loan guarantees and lower interest rates for investments in water efficiency projects • Setting up of “dedicated funds” such as: - Green Investment Fund (GIF) - National adaptation funds	• Promote the portfolio approach, allowing for more favourable private financing conditions by aggregating projects (end users at the local/ regional scale to diversify risk and reduce transaction costs)
	Labour	• Grants for capacity development and training in water efficiency	• Establishment of dedicated institutions, such as technical, industrial and vocational education training institutions (TIVETs) with water efficiency expertise, in charge of spearheading water efficiency skills • Promotion of training, audits and capacity development activities for industrial water users • Healthcare coverage for workers due to harsher climatic conditions (e.g. floods, heatwaves)
	Land	• Public private partnership scheme for the development of eco-industrial parks • Tax incentives and subsidized rentals at industrial parks • Promotion of benefits of operating in eco-industrial parks for producers	• Regulation for land law for industrial zoning • Creation of eco-industrial parks/ clusters/ business corridors/ industrial technology parks • Use of strategic impact assessments (SEAs) and environmental impact assessments (EIAs) for new developments
	Technology	• R&D subsidies and grants to increase water efficiency-related patents and adapt foreign water efficiency technology to local needs	• Promotion of water efficiency technology alternatives • Creation of a research board to provide technical assistance, research support and disseminate best practice in industrial water use

References

Adam, C., et al. (2021). *The double-materiality concept. Application and issues.* GRI white paper. https://www.globalreporting.org/media/jrbntbyv/griwhitepaper-publications.pdf

ANEW (2011). *Analysis of Water and Sanitation Policies and Status of IWRM in Africa and Advocacy capacity assessment of African civil society on water supply and sanitation.* http://www.anewafrica.net/Files/capacity_assesment_report_summary.pdf GWP, 2010

ARUP, Ellen Mac Arthur Foundation, & Antea Group (2018). *Water and Circular Economy: A White Paper.* https://nextgenwater.eu/wp-content/uploads/2018/10/Water_and_circular_economy-Co.Project_White_paper.pdf

Bossut, M., Jürgens, I., Pioch, T., Schiemann, F., Spandel, T., & Tietmeyer, R. (2021). What information is relevant for sustainability reporting? The concept of materiality and the EU Corporate Sustainability Reporting Directive. *Sustainable Finance Research Platform., Policy Brief – 7/2021.*

CDP (2021a). *A wave of change. The role of companies in securing a water secure world.* https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/005/577/original/CDP_Water_analysis_report_2020.pdf?1614347489

CDP (2021b). *Transparency to Transformation. A chain report.* CDP Global Supply Chain Report 2020. https://6fefcbb86e61af1b2fc4-c70d8ead6ced550b4d987d7c03fcdd1d.ssl.cf3.rackcdn.com/cms/reports/documents/000/005/554/original/CDP_SC_Report_2020.pdf?1614160765

Cheng, T., & Yi, C. (2020). *Investing in Water for a Sustainable Future.* S&P Dow Jones Indices. https://www.spglobal.com/spdji/en/documents/education/education-investing-in-water-for-a-sustainable-future.pdf

Christ, K. L., & Burritt, R. L. (2017). Water management accounting: A framework for corporate practice. *Journal of Cleaner Production,* 152, 379–386.

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (2016). *Nature-based Solutions to address global societal challenges.* IUCN.

Dinar, A., Rosegrant, M., & Meinzen-Dick, R. (1997). *Water allocation mechanisms: Principles and examples.* World Bank Policy Research Working Paper No. 1779.

Ellen Mac Arthur Foundation (2018). *Water and Circular Economy: A White Paper.* https://www.ellenmacarthurfoundation.org/assets/downloads/ce100/Water-and-Circular-Economy-White-paper-WIP-2018-04-13.pdf

European Court of Auditors (2021). *The Polluter Pays Principle: Inconsistent Application across EU environmental policies and actions.* Special Report. https://www.eca.europa.eu/Lists/ECADocuments/SR21_12/SR_polluter_pays_principle_EN.pdf

FAO (1993). *The State of Food and Agriculture.* http://www.fao.org/3/T0800E/t0800e0b.htm

Fontein, M., Webster, J., & Trawick, P. (2010). Multiple-use water supply systems: Do the claims stack up? Evidence from Bangladesh. *Waterlines, 29(1),* 52–72.

Frontier Economics (2008). *Urban Water Markets: A Final Report Prepared for the Joint Steering Committee For Water Sensitive Cities (JSCWSC).* Australian National Water Commission.

Gavrilescu, M., Teodosiu, C., Gavrilescu, D., & Lupu, L. (2008). Strategies and practices for sustainable use of water in industrial papermaking processes. *Engineering in Life Sciences, 2(8),* 99–124.

Gibassier, D. (2018). Corporate Water Accounting, Where Do We Stand? The International Water Accounting Field and French Organizations. *Sustainability Accounting (Advances in Environmental Accounting & Management), 7,* 31–65.

GIZ (2016). *Climate Change Adaptation Policy for Industrial Areas—Framework for the State of Telangana, India.* https://tsiic.telangana.gov.in/wp-content/uploads/2017/03/061220116-TSIIC-CCA-Policy.pdf

Hoekstra, A. Y. (2008). Water neutral: Reducing and offsetting the impacts of water footprints. *Value of Water Research Report Series, 28.*

Hoekstra, A. Y., Chapagain, A. K., Aldaya, M. M., & Mekonnen, M. M. (2011). *The water footprint assessment manual: Setting the global standard. Earthscan.*

Hurlimann, A., Browne, G., Warren-Myers, G., & Francis, V. (2018). Barriers to Climate Change Adaptation in the Australian Construction Industry – Impetus for Regulatory Reform. *Building and Environment, 137,* 235–245. https://doi.org/10.1016/j.buildenv.2018.04.015

Increased Land Subsidence and Sea-Level Rise are Submerging Egypt's Nile Delta Coastal Margin (2017). *GSA Today, 27(5).*

International Union for Conservation of Nature. (2012). *Investing in Ecosystems as Water Infrastructure.* https://www.iucn.org/downloads/investing_in_ecosystems_as_water_infrastructure.pdf

International Water Association (2016). *Global Trends & Challenges in Water Science.* Research & Management. https https://iwa-network.org/wp-content/uploads/2016/09/IWA_GlobalTrendReport2016.pdf

Kopp, R. E., DeConto, R. M., Bader, D. A., Hay, C. C., Horton, R. M., Kulp, S., Oppenheimer, M., Pollard, D., & Strauss, B. H. (2017). Evolving Understanding of Antarctic Ice-Sheet Physics and Ambiguity in Probabilistic Sea-Level Projections. *Earth's Future, 5,* 1217–1233. https://doi.org/10.1002/2017EF000663

London School of Economics (2018). *What is the polluter pays principle?* https://www.lse.ac.uk/granthaminstitute/explainers/what-is-the-polluter-pays-principle/

Mikhail, M., & Yoder, R. (2008). *Multiple-Use Water Service Implementation in Nepal and India: Experience and Lessons for Scale-up.* International Development Enterprises (IDE), the Challenge Program on Water and Food (CPWF), and the International Water Management Institute (IWMI).

Mitchell, V. G. (2004). *Integrated Urban Water Management. A review of current Australian practice.* Australian Water Association and CSIRO, CMIT-2004-075.

Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A., & Kijne, J. (n.d.). Improving agricultural water productivity: Between optimism and caution. *Agricultural Water Management, 97(4),* 528–535.

Molden, D., Oweis, T. Y., Steduto, P., Kijne, J. W., Hanjara, M. A., & Bindraban, P. S. (2007). Pathways for increasing agricultural water productivity. In *Water for Food, Water for Life. A comprehensive assessment of water management in agriculture,* 278–310. Earthscan & International Water Management Institute.

Nel, D. C., Marais, C., & Blignaut, J. N. (2008). Water neutrality: A first quantitative framework for investing in water in South Africa. *Conservation Letters, 2(1),* 12–19.

OECD (2011). *Sustainable Manufacturing Toolkit – Water Intensity.* https://www.oecd.org/innovation/green/toolkit/o1waterintensity.htm

Rosegrant, M., & Biswanger, H. P. (1994). Markets in tradable water rights: Potential for efficiency gains in developing country water resource allocation. *World Development, 22(11),* 1613–1625.

Sadoff, C. W., Borgomeo, E., & de Waal, D. (2017). *Turbulent Waters: Pursuing Water Security in Fragile Contexts.* World Bank.

Salman, M. A., & Uprety, K. (2003). *Conflict and Cooperation on South Asia's International Rivers.* Law International.

Spash, C., Urama, K., Burton, R., Kenyon, W., Shannon, P., & Hill, G. (2006). Motives behind willingness to pay for improving biodiversity in a water ecosystem: Economics, ethics and social psychology. *Ecological Economics, 68(4),* 955–964.

UNEP (2010). *Rainwater Harvesting and Utilisation. An Environmentally Sound Approach for Sustainable Urban Water Management: An Introductory Guide for Decision-Makers.* United Nations Environment Programme.
http://www.unep.or.jp/ietc/publications/urban/ urbanenv-2/9.asp

UNEP (2012). *Measuring water use in a green economy.*
A Report of the Working Group on Water Efficiency to the International Resource Panel.

UNEP (2015). *Options for decoupling economic growth from water use and water pollution.*
Report of the International Resource Panel Working Group on Sustainable Water Management. https://www.unep.org/resources/report/options-decoupling-economic-growth-water-use-and-water-pollution-report-water

UNESCO, & UN-Water (2020). *United Nations World Water Development Report 2020: Water and Climate Change.* UNESCO.

UNFCC LCD Expert Group (2021). *National Adaptation Plans 2020 Progress in the Formulation and Implementation of Naps.* United Nation Framework Convention on Climate Change. https://unfccc.int/sites/default/files/resource/NAP-progress-publication-2020.pdf.

Water Scarcity Solutions (2015). *Water reuse in textile sector.*
https://www.waterscarcitysolutions.org/wp-content/uploads/2015/08/Water-reuse-in-textile-sector-Tiruppur-India.pdf

WBCSD (2017). *Business Guide to Circular Water Management: Spotlight on Reduce, Reuse and Recycle.* WBCSD. www.wbcsd.org/ Programs/Food-Land-Water/Water/Resources/spotlight-on-reduce-reuse-and-recycle.

Wong, J., & Schuchard, R. (2011). *Adapting to Climate Change: A Guide for the ICT Industry.* Adapting to Climate Change.

World Bank (2019a). *From Waste to Resource: Shifting paradigms for smarter wastewater interventions in Latin America and the Caribbean.* Background Paper V: Financial incentives for the development of resource recovery projects in wastewater. https://documents1.worldbank.org/curated/en/420981582254775447/pdf/Background-Paper-V-Financial-Incentives-for-the-Development-of-Resource-Recovery-Projects-in-Wastewater.pdf

World Bank (2019b). *Nature-based Solutions: A Cost-effective Approach for Disaster Risk and Water Resource Management.* https://www.worldbank.org/en/topic/disasterriskmanagement/brief/nature-based-solutions-cost-effective-approach-for-disaster-risk-and-water-resource-management

World Bank, & GDFRR (2020). *Enabling Private Investment in Climate Adaptation & Resilience.* https://openknowledge.worldbank.org/bitstream/handle/10986/35203/Enabling-Private-Investment-in-Climate-Adaptation-and-Resilience-Current-Status-Barriers-to-Investment-and-Blueprint-for-Action.pdf?sequence=5&isAllowed=y.

2 Energy and CO_2

Introduction

This chapter illustrates and analyses the environmental impact of energy consumption and its associated carbon dioxide (CO_2) emissions. Among anthropogenic greenhouse gas (GHG) emissions—climate-change-accelerating gases emitted as a result of human activity—CO_2 is the most prominent, accounting for around 65 per cent of all historic human-made emissions (USA Environmental Protection Agency from IPCC, 2014). CO_2 emissions primarily results from burning fossil fuels, industrial processes, and land use changes, notably deforestation. Due to the impact of CO_2 emissions and the availability of detailed data on them, this tool focuses specifically on CO_2 emissions and does not cover other GHGs.

Growing awareness of the causes and effects of climate change has given rise to sustainable development approaches focused on mitigation and adaptation. Providing clean and affordable energy is encapsulated in Sustainable Development Goal 7 (SDG 7), with targets related to clean energy consumption (SDG 7.2) and energy efficiency (SDG 7.3). CO_2 emissions is directly related to climate change and are therefore heavily monitored worldwide with the aim of curtailing GHG emissions. In 2015, 196 Parties signed the so-called Paris Agreement which entered into force in 2016. It is a legally binding treaty to limit global warming well below 2°C (preferably 1.5°C) compared to pre-industrial levels. To achieve this goal, the Parties must submit their plans for climate action known as Nationally Determined Contributions (NDCs) every 5 years. Reducing emissions from the manufacturing sector is crucial if countries are to deliver on their NDC pledges.

However, despite all the efforts to promote more sustainable energy sources, fossil fuels have remained the largest source of power generation (IEA, 2019e). Heavily polluting fossil fuels (e.g. coal) are the main contributor to power generation, particularly in developing countries, and represents a considerable challenge for the energy transition (IEA, 2019e). The availability of such fuels is influenced by geo-political developments, adding a security dimension to the quest of attaining a renewable energy supply. Transitioning to more sustainable forms of energy production and consumption may represent a comparative advantage for developing countries and their manufacturing sectors, for example through enhanced efficiency. As outlined above, many countries have committed to phasing out fossil fuels. This entails the need to increase the share of renewables in their energy supply mix. If done strategically, the energy transition can open new opportunities for countries with abundant renewable power sources. Such sources can provide energy at a lower cost compared to their fossil-fuel counterparts, which in turn can lower the costs of energy access for enterprises, enhancing the manufacturing sector's overall competitiveness. Furthermore, pursuing lower energy intensity in production can maximize energy use without compromising economic performance.

More investments in energy efficiency and renewable sources will promote technological development in the entire manufacturing sector, with the possibility of exploiting new sources of income and in turn creating more job opportunities (UNIDO, 2016). In fact, it appears that the lower the country's income level, the higher the effectiveness of investment in technologies to reduce energy use in industry (UNIDO, 2012). Indeed, while energy imports might represent a short-term solution to cover demand, building inland generation capacity to exploit renewable sources generates more economic and non-economic benefits in the long term. The bulk of costs for renewable sources is related to the capital-intensive initial investment but eventually, costs decrease as the facility becomes fully operational. Improving the domestic generation of renewable energy sources can also help establish a secure energy supply for all sectors of the economy, lowering dependency on fossil fuels imported from other countries. It is likely that the push to reduce the environmental impact of manufactured goods will entail a geographical shift of manufacturing companies to countries endowed with renewable energy sources. Thus, sun-rich, and wind-rich countries stand much to gain if they can exploit this potential with the help of adequate policy measures.

Methodology

As the focus of EQuIP lies on the manufacturing sector, this chapter primarily analyses how energy is consumed in this sector and the amount of CO_2 emissions associated with it. A large share of anthropogenic carbon dioxide emissions result from the combustion of energy carriers, establishing a direct link to energy consumption indicators. The EQuIP tool presents several indicators to assess the manufacturing sector's role in total energy consumption and CO_2 emissions. These shares are contrasted against the value added generated by the manufacturing sector to illustrate the intensity of industrial energy consumption and CO_2 emissions. This analysis can be carried out at a more disaggregated sub-sector level (see **Table 7**) for a more in-depth understanding of manufacturing sub-sectors with a high energy consumption of CO_2 emissions, allowing for a more tailored approach to policy action.

It is crucial for production processes' energy supply to be derived from renewable sources if the climate neutrality of manufactured produces is to be enhanced. Current trends are contrasted against Nationally Determined Contributions (NDCs)[2] within the framework of the Paris Agreement to measure the negative impact of fossil fuel subsidies. The hotspot analysis enables a close monitoring of the contributions of heavily polluting manufacturing sub-sectors and fossil fuels (e.g. coal) in the energy mix relative to the country's CO_2 emissions.

Table 6. List of indicators – Energy

Indicator	Level of analysis	Definition	Sources
Manufacturing (sub-sector) share in TFC	manufacturing, sub-sector	Manufacturing (sub-sector) TFC as a share of a country's TFC	IEA's Extended World Energy Balances
Manufacturing (sub-sector) energy intensity	manufacturing, sub-sector	Ratio between manufacturing (sub-sector) TFC and manufacturing (sub-sector) value added	IEA's Extended World Energy Balances, World Bank WDI, UNIDO: INDSTAT 4

---

[2] Nationally determined contributions (NDCs) are at the heart of the Paris Agreement and the achievement of its long-term goals. NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement (Article 4, paragraph 2) requires each Party to prepare, communicate and maintain successive nationally determined contributions (NDCs) that it intends to achieve. Parties shall pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions.

Energy self-sufficiency	Country	Ratio between primary production and domestic supply	IEA's Extended World Energy Balances
Share of renewable sources in (manufacturing) TFC	Country, manufacturing	(Manufacturing) TFC from renewables as a share of (manufacturing) TFC	IEA's Extended World Energy Balances, World Bank WDI
Share of energy from industrial waste in TFC	manufacturing	Manufacturing TFC from industrial waste as a share of manufacturing TFC	IEA's Extended World Energy Balances
Fossil fuel subsidies (SDG 12.c)	Country	Sum of fossil fuel subsidies granted each year in US$	OECD – IISD Fossil Fuel Subsidy Tracker

Table 7. List of Indicators – CO_2 emissions

Indicator	Level of analysis	Definition	Sources
Manufacturing (sub-sector) CO_2 emissions share in total CO_2 emissions	Industry, sub-sector	Manufacturing CO_2 emissions as a share of country's total emissions	IEA: CO_2 Emissions from Fuel Combustion
CO_2 emission intensity	Country, industry, sub-sector	CO_2 emissions per unit of GDP or manufacturing (sub-sector) VA	IEA: CO_2 Emissions from Fuel Combustion, World Bank WDI, UNIDO: INDSTAT 4
Emissions per unit of energy in manufacturing (sub-sectors)	Industry, sub-sector	Manufacturing (sub-sector) CO_2 emissions per unit of manufacturing (sub-sector) TFC	IEA: CO_2 Emissions from Fuel Combustion
Share of emissions from coal in manufacturing (sub-sector) emissions	Industry, sub-sector	Manufacturing CO_2 emissions from coal as a share of total manufacturing CO_2 emissions	IEA: CO_2 Emissions from Fuel Combustion
Manufacturing CO_2 emissions decoupling	Industry	Compound Annual Growth Rate (CAGR) (2008–2018) of manufacturing CO_2 emissions relative to MVA	IEA: CO_2 Emissions from Fuel Combustion, World Bank WDI
Current Paris Agreement target (NDC) shortfall	Country	Difference between CO_2 emissions CAGR goal in a country's NDC & the CAGR of actually emitted CO_2	IEA: CO_2 Emissions from Fuel Combustion, Climate Watch

Data sources

Data on energy consumption and supply are taken from the IEA's Extended World Energy Balances database. Total final energy consumption (TFC) was chosen for the analysis instead of primary energy consumption as it reflects actual consumption better and neglects the distributional and transformative losses. **Box 4** provides a full definition of the two variables as used in the IEA's World Energy Balances. TFC is then contrasted against socio-economic variables to calculate relevant indicators (e.g. intensity).

Where national energy data do not comply with international accounting standards, the IEA applies estimations which, wherever possible, are made in consultation with national statistical offices, oil companies, electricity utilities and national energy experts. To perform the analyses in this section, the data used mostly reflects the *total* flow that sums up all of the different energy carriers (e.g. fuels, nuclear, renewables). The user can also extract individual energy carriers (i.e. flows) from the database. For instance, the flow of TFC stemming from renewable sources has been selected for indicator 5. “Industrial waste” is the flow of choice for indicator 6. It is also possible to download energy consumption data for different economic sectors, as well as for the economy as a whole of a country.

Box 4. Total final consumption vs. primary energy consumption

Total final energy consumption (TFC) is the total energy consumed by end users, (e.g. households, industry and agriculture). It excludes energy used by the energy sector to produce electricity, including for delivery and transformation. It also excludes fuel transformed in the electrical power stations of industrial auto producers and coke transformed into blast-furnace gas where this is not part of overall industrial consumption, but of the transformation sector.

Primary energy consumption measures a country's total energy demand. It covers consumption of the energy sector itself, losses during transformation (for example from oil or gas into electricity) and distribution of energy, and final consumption by end users. It excludes energy carriers used for non-energy purposes (such as petroleum not used for combustion but for the production of plastics).

The main source of data on emissions is the IEA's database CO_2 Emissions from Energy Combustion Statistics. It contains data on estimates of CO_2 emissions based on countries' and sectors' energy mix, calculated according to the IPCC methodology (Eggleston et al., 2006) for 190 countries. The IEA's database has the same level of disaggregation as its Extended World Energy Balance. Data on CO_2 emissions for the (macro)-sectors of the socio-economy (households, business, industry) can be retrieved, along with different sources (e.g. fossil fuels) of those emissions. It is important to note that the IEA's CO_2 emissions dataset only reflects emissions generated from fuel combustion for energy generation and does not include, for example, emissions from other non-energy sources such as land-use change.

The World Bank's World Development Indicators database was used to obtain data on shares of non-renewable energy sources in energy consumption and electricity generation as well as the socio-economic variables GDP, MVA and population. Value added for manufacturing sub-sectors was retrieved from UNIDO's INDSTAT 4 (ISIC Revision 4) database.

Data on annual amounts of fossil fuel subsidies in US$ are collected by the Fossil Fuel Subsidies Tracker Initiative. It is a collaboration between the Organisation for Economic Co-operation and Development (OECD) and the International Institute for Sustainable Development (IISD). The computation procedure compares end-use prices with reference prices for pre-tax subsidies. Post-tax subsidies are also considered by comparing applicable taxes to external benchmarking of the marginal social costs of fossil fuel consumption. For further details on the methodology, see https://fossilfuelsubsidytracker.org/methodology.

Climate Watch collects data sources for indicator 12 on deviations from Paris Agreement targets. It derives data from the United Nations Framework Convention on Climate Change (UNFCCC) registry, which countries periodically submit their reports to, but it is a more accessible source with all relevant information stored in one comprehensive database.

Energy indicators

2.1 Manufacturing (sub-sector) TFC share in total TFC

This indicator reflects the aggregated contribution of a country's manufacturing sector to its TFC. Apart from the manufacturing sector, national TFC includes other economic sectors as well, such as agriculture, transport, services, and energy use by households. The ratio of manufacturing energy use relative to other sectors' level of consumption is determined by several factors. While country-specific differences in terms of size and productivity of the previously mentioned sectors play a role, the ratio is also shaped by the intensity of energy use in manufacturing, which is discussed in the section on indicator 2.3. Moreover, we must bear in mind that not all energy consumption is equally damaging for the environment – for more information on assessing the different energy flows including renewables, please refer to indicator 2.5. To obtain a holistic overview of the relative scope of manufacturing energy consumption, the indicator "Industry not elsewhere specified" (Industry nes) should be included in the analysis and added to total manufacturing which is separately listed in the IEA world energy balances data. This applies in particular to countries with sparse sub-sector data, as total manufacturing is the sum of these reported specific sub-sectors.

At a further level of disaggregation, this indicator provides insights into the contribution of individual sub-sectors to overall final energy consumption of manufacturing. Identifying high energy use sub-sectors can help guide specific sectoral policies to curb consumption in those sub-sectors and foster more sustainable production processes. This in turn may reduce energy demand, which translates into cost savings for the industry.

Strategic questions

Direct inferences:

- How prominent is the manufacturing sector's role in the overall economy's energy consumption and how does it compare to that of other countries?
- How prominent is manufacturing sub-sectors' role in the overall manufacturing sector's energy consumption and how does it compare to that of other countries?

Follow-up questions:

- What factors may have contributed to the trend in the share of the country's manufacturing (sub-) sector energy consumption, and how can it be reduced?

Equation

$$\boldsymbol{Manufacturing\ (sub-sector)\ TFC\ \ share\ in\ TFC}\ (\%) = \frac{Total\ Final\ Consumption\ (TJ)\ of\ Manufacturing\ (sub-sector)}{Total\ Final\ Consumption\ (TJ)\ of\ Country\ (or\ manufacturing)}$$

2.2 Manufacturing (sub-sector) energy intensity

This indicator measures energy intensity by relating energy consumption to the economic performance of manufacturing (sub-)sectors, i.e. their value added. In this sense, the more energy-intense a manufacturing process is, the more energy it uses per unit of value added produced for the economy. This allows for a comparison among countries of their manufacturing (sub-)sectors' relative intensity in energy consumption. As for the previous indicator 2.2, it is recommended to include the "Industry nes" category in the analysis and add it to the manufacturing total, as this is not the default in IEA data.

While a country's core industrial processes tend to require the highest amount of energy in absolute terms, some industrial sectors inherently have a higher relative energy intensity than others (see Table 8). Investments to reduce the intensity of energy use in industrial processes could, along with turning to more renewable energy sources, lower the risk of energy shortages, thereby securing productivity. Low energy-intense industrial sectors are better equipped to cope with environmental regulations, thus entailing potentially lower compliance costs.

Strategic questions

Direct inferences:

- What is the intensity of energy consumption of a manufacturing (sub-)sector relative to its value added?
- How does the level of energy intensity in manufacturing (sub-sectors) compare with that of other countries and can a capacity gap be identified?
- How do sub-sectors with high-intensity energy consumption compare relative to their economic performance?

Follow-up questions:

- How can the energy intensity of specific manufacturing (sub-) sectors be reduced?

Equation

$$\boldsymbol{Manufacturing\ (sub-sector)\ energy\ intensity\ (TJ\ per\ US\$)} = \frac{\boldsymbol{Manufacturing\ (sub-sector)\ Total\ Final\ Energy\ Consumption\ (TJ)}}{\boldsymbol{Manufacturing\ (sub-sector)\ Value\ Added\ (US\$)}}$$

2.3 Energy self-sufficiency

The indicator of energy self-sufficiency relates domestic energy production to the country's total primary energy supply (TPES). It illustrates the extent of dependency on foreign energy imports. Values lower than 1 denote dependency of national consumption on imports while a value higher than 1 signifies a country that is considered a net exporter. The indicator thus depicts a country's capacity to provide the energy sources needed by its production and consumption systems. While it is a useful indicator on a nation's energy security, it does not provide information on the sustainability of a country's energy sources. When combined with indicators 2.4, 2.5 and 2.6, this particular indicator can help guide not only industrial policy but also energy policy towards higher self-dependency and higher sustainability in terms of fossil fuels used in the economy.

Strategic questions

Direct inferences:

- To what extent is the country capable of autonomously providing energy for its production and consumption systems?

Follow-up questions:

- What is the level of dependency of the country on energy imports?

Equation

$$Energy\ self-sufficiency = \frac{Total\ Primary\ Energy\ Production\ (TJ)}{Total\ Primary\ Energy\ Supply\ (TJ)}$$

2.4 Share of renewables in (manufacturing) TFC

This indicator measures the share of energy from renewable sources in the economy's overall TFC in general or in the manufacturing sector in particular. A higher share of TFC corresponds to a higher amount of energy from renewable sources while a lower share of TFC indicates that a higher amount of energy from other flows, such as fossil fuels, is being used. The data illustrate the shares of various energy carriers (e.g. fossil-fuels, nuclear, renewables) in both a country and a sector's TFC. It might be insightful to compare the share of clean energy in the energy mix in different countries.

Within the ideal framework of "closing the loop", national economies might be able to increasingly supply energy to their production and consumption processes by tapping into renewable sources. Particularly countries with a structural lack of energy resources (fossil energy reserves) within their territory but favourable climatic conditions (e.g. sun-rich, wind-rich) may thus increase their self-sufficiency by improving their domestic energy generation capacity from renewables. This entails the manifold benefits of lowering dependency on energy imports, reducing pressure on the environment, as well as creating new income and job opportunities.

Strategic questions

Direct inferences:

- What share of total energy consumed in the economy and manufacturing comes from renewable sources?

Follow-up questions:

- How sustainable is the energy mix of both the economy and the manufacturing sector?
- What are the reasons for changes in the trend of the share of renewable energy sources in TFC (e.g. new discoveries of fossil fuel reserves, fossil fuel subsidies, renewable subsidies, technology)?
- Can an increased share of renewables in the energy mix help achieve energy self-sufficiency and further close the loop?

Equation

$$\boldsymbol{Share\ of\ renewables\ \ in\ (manufacturing)\ TFC\ (\%)} = \frac{\boldsymbol{Renewably\ sourced\ (manufacturing)\ TFC\ (TJ)}}{\boldsymbol{(Manufacturing)\ TFC\ (TJ)}}$$

2.5 Share of energy from industrial waste in TFC

This indicator relates the amount of consumed energy sourced from processing industrial waste to total energy consumed within a country. In this case, industrial waste only comprises waste originating from non-renewable origins (e.g. tyres), which is combusted in specific plants to produce heat or power. The energy intensity of both industry and the overall economy can be reduced by improving the use of secondary raw materials and fostering exchanges of power and heat between different economic sectors. Within this framework, the burning of non-renewable materials with no further use for industry to produce energy entails partially recovering their economic value, thus benefitting lower energy intensity.

This indicator directly connects with the waste chapter of this tool, where waste management and energy recovery are discussed in more detail (indicators 3.1 and 3.7). It represents a relevant proxy of the degree to which industries implement synergies to maximize the exploitation of available resources (energy and material). Producing energy from waste represents the best alternative when material can no longer be recovered. Furthermore, the more waste is used to produce energy, the less will be destined for landfilling which in turn leads to less pressure on the local environment.

Strategic questions

Direct inferences:

- What is the level of energy produced from burning industrial non-renewable waste?

Follow-up questions:

- To what extent do industrial processes exploit synergies with the objective of maximizing resource use?

Equation

$$\boldsymbol{Share\ of\ industrial\ waste\ energy\ in\ TFC}\ (\%) = \frac{\boldsymbol{TFC\ sourced\ from\ industrial\ waste\ (TJ)}}{\boldsymbol{TFC\ (TJ)}}$$

2.6 Fossil fuel subsidies (SDG 12.c)

This indicator monitors the amount of public funds allocated to subsidize fossil fuel-related energy sources. As such, it is a policy variable rather than a performance indicator. The amount of public financing granted each year can provide insights into how dependent an economy is on fossil fuels. Existing dependencies caused by a country's energy supply structure can be exasperated by economic behaviours resulting from such subsidies.

Subsidies may also be granted to end-users with the aim of lowering the cost of imported energy to cover demand. To benchmark the level of fossil fuel subsidies in different countries, the amounts should be standardized by dividing them by the respective country's GDP – thus attaining the sum of subsidies allocated per dollar of GDP generated.

The extent of subsidies should decrease over time in line with national policies and international pledges to substitute fossil fuels with more sustainable sources. Phasing out such subsidies serves as a means for policymakers to signal to the market to orientate future investments towards more sustainable energy sources. Public financial resources saved from fossil fuel subsidies can be diverted to prepare the economy for the sustainable energy transition.

Strategic questions

Direct inferences:

- What is the amount of funds allocated to subsidize fossil fuel energy sources?
- How does the share of fossil fuel subsidies per GDP compare to that of other countries?

Follow-up questions:

- Do fossil fuel subsidies prevent the closing of the loop?
- How could the funds be allocated instead?
- How could fossil fuel subsidies be phased out in a socially sustainable way?

CO_2 emission indicators

2.7 Manufacturing (sub-sector) CO_2 emissions share

This indicator provides information on how much the manufacturing sector contributes to a country's overall CO_2 emissions. Analysing the manufacturing sector's relative share in total CO_2 emissions of a country helps classify countries in terms of this sector's contribution to emissions. Higher shares of this ratio are associated with industrialized countries whose manufacturing sector uses large amounts of fossil fuels. Low shares do not necessarily imply that the manufacturing sector releases low absolute amounts of CO_2 emissions. Other sectors of the economy, such as transport or energy sectors, might be contributing higher shares to CO_2 emissions than the manufacturing sector. Similar to indicators 2.2 and 2.3, the "Industry not elsewhere specified" category should be manually added to the manufacturing sector's total emissions to account for emissions not reported for one specific sub-sector.

A distinction is made between direct and indirect industrial CO_2 emissions: the former are emitted through the direct use of fossil fuels in industry to produce energy, while the latter are generated indirectly by industry through the consumption of electricity produced from fossil fuels in the energy sector. Data on indirect industrial CO_2 emissions are available from the IEA's database on CO_2 Emissions from Fuel Combustion, by deducting the sector's direct emissions from total emissions, with electricity and heat allocated to the consuming sector (available on a separate sheet in the CO_2 highlights file). The total amount of emissions arising from industrial electricity consumption supplied by the energy sector can be used to calculate their share in the country's total CO_2 emissions, showcasing the difference between direct and indirect industrial CO_2 emissions. Note that the data on emissions with electricity and heat allocated to the consuming sector represent both the manufacturing and construction sectors together, whereas data on direct emissions only include the manufacturing sector. This discrepancy is due to the way the IEA reports data at different levels of aggregation. If indirect emissions account for the majority of a country's total manufacturing emissions, it is recommended to shift the entire analysis to the sum of the manufacturing and construction sectors' total emissions. This will ensure that the analysis is conducted on the basis of this broader definition to also include indirect emissions. When making this decision, data on value added should be recalculated to include the sum of the manufacturing and construction sectors' total emissions as opposed to MVA only.

At a level of further disaggregation, this indicator also measures the share of CO_2 emissions resulting from the fuel combustion each sub-sector represents compared to total (direct) CO_2 manufacturing emissions. The IEA provides data on manufacturing emissions of up to ten manufacturing sub-sectors which are approximately compatible with the third and fourth revision of the *International Standard Industrial Classification of All Economic Activities* (ISIC Rev. 3 and ISIC Rev. 4) (see Table 8). In addition to the ten sub-sectors, the manufacturing emissions from the 'Industry nes' category groups all remaining emissions that are not attributed to any other sector. This indicator thus provides an in-depth picture of the contribution of individual manufacturing sub-sectors to total manufacturing CO_2 emissions. Usually, the higher a (sub-)sector's productivity, the higher its energy consumption and in turn its emissions. Sectors with a high energy intensity produce outputs at a high cost in terms of energy consumption.

Strategic questions

Direct inferences:

- How much does the country's manufacturing sector contribute to the country's total CO2 emissions?
- What is the contribution of the different manufacturing sub-sectors to total manufacturing CO2 emissions?

Follow-up questions:

- Why might the shares of manufacturing emissions vary between different countries?
- What might be the reasons for changes (increases, reductions) in these shares?
- What are the causes of differences in trends (e.g. why are sectoral CO_2 emissions increasing/ decreasing)?

Equation

$$\boldsymbol{Manufacturing\ (sub-sector)\ CO_2\ as\ a\ share\ of\ CO_2}(\%) = \frac{\boldsymbol{Manufacturing\ (sub-sector)\ CO_2\ emissions\ (tonnes)}}{\boldsymbol{Total\ (manufacturing) CO_2\ emissions\ (tonnes)}}$$

2.8 CO_2 emission intensity

Depending on the level of data disaggregation used, this indicator provides information on the country's CO_2 emission intensity at the industry and sub-sector level. At the country level, emission intensity is calculated as total CO_2 emissions divided by the country's GDP in a given year. The emissions of the manufacturing sector and its sub-sectors are related to the corresponding amount of value added. This indicator thus illustrates how much CO_2 emissions are emitted from fuel combustion per unit of economic performance of a nation or sector.

It is possible to identify which manufacturing sub-sectors cause the most damage to the environment in relation to the value of their output. This is a key consideration when determining where to focus policy interventions. A highly emission-intensive manufacturing sector will likely entail future costs in terms of compliance and mitigation. At the same time, some sub-sectors are inherently more CO_2-intense than others, largely corresponding to the degree of energy intensity described in indicator 2.2 and Table 8. Accordingly, it makes sense to not only compare the energy intensities within a country, but to benchmark individual sub-sectors against those of fully industrialized countries or a region's average to identify a capacity gap.

Trends in emission intensity should ideally decline over time, reflecting increasingly sustainable production patterns. This, however, is unlikely to be the case for countries that depend on fossil fuels as their primary energy source. Decreasing trends in emission intensity at the manufacturing (sub-sector) level are associated with lower carbon industrial processes, more investments in mitigation and in turn lower compliance and adaptation costs in the future.

Strategic questions

Direct inferences:

- How has CO_2 emission intensity developed over time?
- How does the country's CO2 emission intensity compare to that of other countries?
- What are the emission intensities of the country's manufacturing sub-sectors and how do they compare to the country's manufacturing sector as a whole?
- Is the emission intensity of certain sub-sectors below or above the benchmark of other countries' and can improvement potentials be identified?

Follow-up questions:

- How can the country's emission intensity trends be explained?
- How can the emission intensities in the country's specific context be reduced?
- How much CO2 emissions is required for the country to sustain its level of economic activities?

Equation

$$\boldsymbol{CO_2\ emission\ intensity}\ (\boldsymbol{tonne\ per\ US\$}) = \frac{\boldsymbol{CO_2\ emissions}\ (\boldsymbol{tonnes})}{\boldsymbol{GDP\ or}\ (\boldsymbol{sub}\ -)\boldsymbol{sector\ VA}\ (\boldsymbol{US\$})}$$

2.9 Manufacturing (sub-sector) CO_2 emissions per unit of energy

This indicator investigates the level of decoupling of energy consumption from emissions. It is calculated by dividing the manufacturing (sub-)sector's CO_2 emissions from fuel combustion by its total energy use. The total energy used includes both renewable and non-renewable sources, this indicator is therefore highly dependent on the composition of energy supply. For example, countries that rely heavily on energy generated from coal will have a higher emission intensity than a country that relies on natural gas instead. This indicator directly relates emissions to energy consumption in the manufacturing sector. In light of the aim of this chapter, it can be considered a key indicator that bridges the two dimensions of energy and CO_2 emissions. Note that as for previous indicators, the "Industry nes" category should be added to total manufacturing emissions to account for emissions that were not reported for specific sub-sectors in the IEA database.

While a higher share of non-renewable sources in the energy mix implies a higher ratio, different industrial processes entail different levels of energy use and thus emissions. Progressively high ratio levels indicate a high amount of CO_2 emission embedded in energy consumption, while lower levels can be achieved by either energy efficiency policies or a more sustainable energy mix from the supply side.

Strategic questions

Direct inferences:

- How much CO2 does the manufacturing (sub-)sector emit for each unit of energy it consumes?
- What is the level of decoupling of energy consumption from CO2 emissions in the manufacturing (sub-) sector?

Follow-up questions:

- To what extent can changes in trends be related to policy measures (e.g. energy efficiency, promoting renewable sources)?
- Is the level of emissions per unit of energy for specific manufacturing sub-sectors below or above the benchmark of similar countries? Can these benchmarks be used to identify the potential of reducing emission intensity from fuel switching?

Equation

$$Manufacturing\ (sub - sector)\ emissions\ per\ unit\ of\ energy\ (tonne\ per\ TJ) = \frac{Manufacturing\ (sub - sector)\ CO_2\ emissions\ (tonne)}{Manufacturing\ (sub - sector)\ TFC\ (TJ)}$$

2.10 Manufacturing (sub-sector) share of CO_2 emissions from coal

This indicator monitors the share of coal-sourced CO_2 emissions generated by industrial processes. It serves as an indirect proxy for the level of coal burnt as fuel in the manufacturing sector in relation to other fossil fuels. A high share of emissions from coal in manufacturing should lead to considerations of possible phasing out of this highly CO_2-intense energy carrier from sectors with a high energy demand.

Strategic questions

Direct inferences:

- How much of the manufacturing (sub-)sector's CO_2 emissions are due to the use of coal as a fuel?

Follow-up questions:

- What measures can be introduced to reduce the share of coal? Are there any dependencies such as industrial processes that necessarily need coal to function?

Equation

$$\boldsymbol{Share\ of\ emissions\ from\ coal\ (manufacturing)(\%) = \frac{CO_2\ emissions\ from\ coal\ (manufacturing)(tonne)}{CO_2\ emissions\ \ (manufacturing)(tonne)}}$$

2.11 Manufacturing CO_2 emissions decoupling

This indicator provides a synthetic measure of the growth rate of emissions and value added in the manufacturing sector. Plotted together, the two indices provide insights into the growth rate of industrial performance and related CO_2 emissions. Decoupling is taking place when the CAGR of manufacturing value added is higher than the CAGR of CO_2 emissions. For a more detailed explanation of this concept and its stages, please refer to the "key concepts" section in the introduction of this tool.

Figure 34 in the analysis section presents a practical application of this relationship for five countries.

This indicator provides key information for analysing which phase of the decoupling process a country's manufacturing sector is experiencing. Some countries might lower their manufacturing emissions as an effect of sectoral policies addressing emissions. Through the lens of sustainable development, decoupling entails the independence of economic growth from environmental pressure to achieve the so-called triple bottom-line (i.e. environmental, economic, and social well-being). Ideally, a successful decoupling occurs as a result of more sustainable production within the manufacturing sector. In that case, decoupling entails new sources of income along with more job opportunities with a lower impact on the environment. This decrease is not considered sustainable from an economic perspective in case of recessive decoupling as it implies income loss for the sector.

Strategic questions

Direct inferences:

- What is the growth rate of industrial value added with respect to manufacturing-generated CO_2 emissions?

Follow-up questions:

- Is the manufacturing sector's economic performance decoupling from its CO_2 emissions?

Equation

$$Compound\ Annual\ Growth\ Rate = \left(\frac{End\ Value}{Start\ Valure}\right)^{\left(\frac{1}{number\ of\ years}\right)}$$

2.12 Current Paris Agreement target shortfall

This indicator measures the extent to which national emission trends need to change to reach the Paris Agreement targets defined in the NDCs. It computes the CAGR of the target emissions level in 2030 according to a country's NDC and its baseline emissions level in 2015. This is then subtracted from the country's current emissions CAGR between the baseline (2015) and the latest available year in the IEA data (2019 as of the time of writing).

NDCs are calibrated by considering a country's capacity and its contribution to current CO_2 emissions. In principle, the higher a country's income, the higher its potential contribution to emissions generation. Hence, the country's commitment is expected to be equally higher to tackle CO_2 emissions by the target year. Countries with zero or positive deviation from their actual commitment to CO_2 reductions are those that are on track to meet their NDCs. If a country reports a negative deviation, it produces more CO_2 than initially pledged, and intensified efforts are needed to curtail this rise in CO_2. The difference indicates by how much more CAGR (2015–2018) should be decreasing to meet the ideal

CAGR in line with the country's NDC. As NDCs are set on a country-by-country basis, this indicator can be considered a self-assessment of the mitigation potential of a country's own capacity.

Strategic questions

Direct inferences:

- Is there currently a discrepancy between the country's NDC and the development of its actual CO_2 emissions?
- To what extent do CO_2 emission trends need to change to reach the country's NDC?

Follow-up questions:

- How can CO_2 emission trends be influenced to fall in line with the country's commitments and pledges?

Equation

$$\boldsymbol{Deviation\ from\ Paris\ Agreement = CAGR\ (2015-2030) - CAGR(2015-2019)}$$

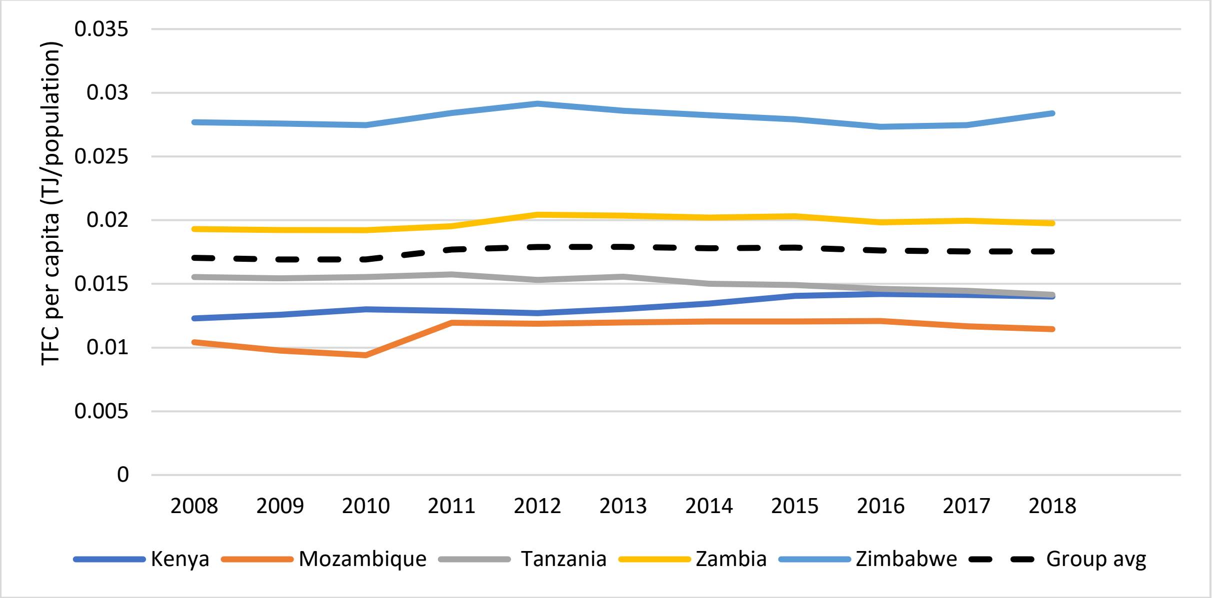
Analysis

These indicators provide an overview of how countries are performing in terms of energy consumption and CO_2 emissions in relation to relevant socio-economic variables. Where possible, data on energy and emissions are analysed jointly to assess the relevant links between these two dimensions. This link is very pronounced in the industrial sector. Manufacturing processes are generally highly energy consuming and thus tend to entail high levels of CO_2 emissions. To analyse the indicators presented in this section, five example countries have been selected: Kenya, Mozambique, Tanzania, Zambia, and Zimbabwe. Aside from data availability, the selection of these countries considered regional location (i.e. sub-Saharan Africa) to facilitate the comparison in light of their geographical proximity and their comparable socio-economic factors.

Country-level energy consumption

The first layer of analysis delivers reference points to position a country according to its overall energy consumption in relation to others. This is first done in terms of per capita consumption, as depicted in **Figure 13**.

Figure 13. Total final consumption per capita



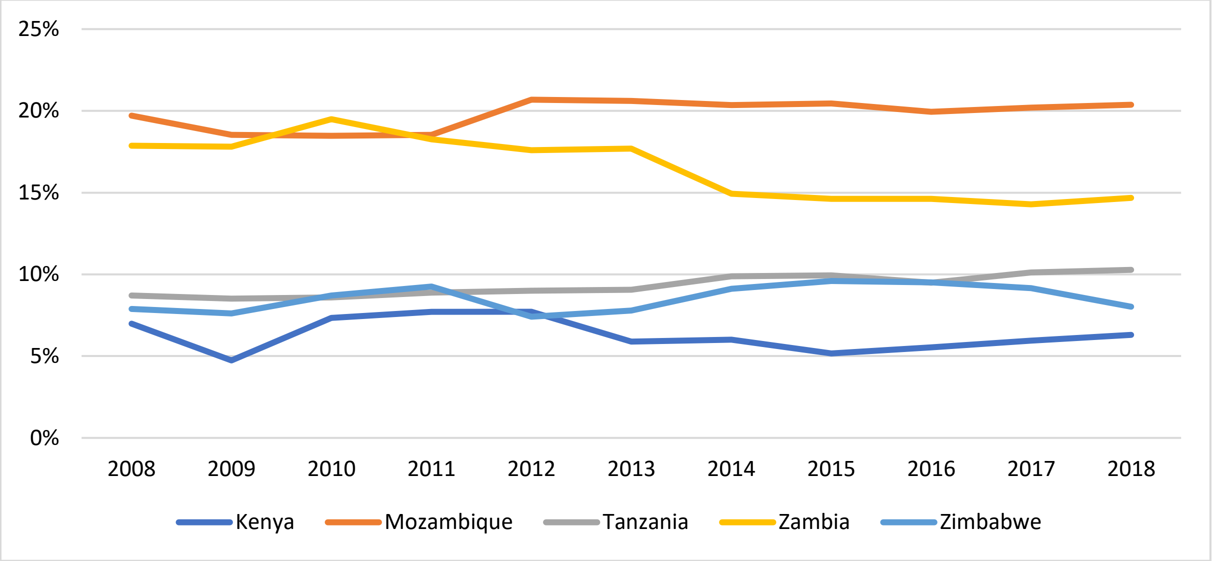
Source: Own elaboration based on data from IEA Extended World Energy Balances

For the majority of countries in our sample, traditional bioenergy (e.g. fuelwood) is the main form of energy supply, especially in households (IEA, 2019a). Zimbabwe and Zambia exhibit above-average levels of TFC per capita. Energy consumption in these countries mostly occurs in the residential sector, even though access to energy infrastructure (i.e. electricity) by households is quite low. Despite the low electrification (less than 5 per cent in rural areas and less than 80 per cent in urban areas), per capita energy consumption in Zambia is one of the highest in sub-Saharan Africa according to *GET.invest*. On the other hand, countries such as Kenya and Mozambique are relying on new sources of energy supply (e.g. natural gas) with progressive access for households to energy. The significant rise in electrification in Kenya over the last decade, connecting up to 75 per cent of the population to the energy grid in 2018 (IEA, 2019b), is in part attributable to this trend. The low level of TFC in Mozambique compared to most of the other countries in this group could be explained by its poor electrification rate, with 70 per cent of the population residing in sparsely populated areas with no access to the grid (IEA, 2019d), and the country's high reliance on traditional bioenergy as the main source of energy supply. Recent exploitations of new gas reserves in Mozambique may increase domestic energy consumption in the future.

Manufacturing energy use

After determining a country's total energy consumption, we assess the manufacturing sector's relative contribution. **Figure 14** presents the percentage of the manufacturing sector and sub-sectors' TFC in relation to overall TFC from 2008 to 2018. Where data are missing, the country has not reported its consumption at sub-manufacturing level.

Figure 14. Share of manufacturing in country's TFC

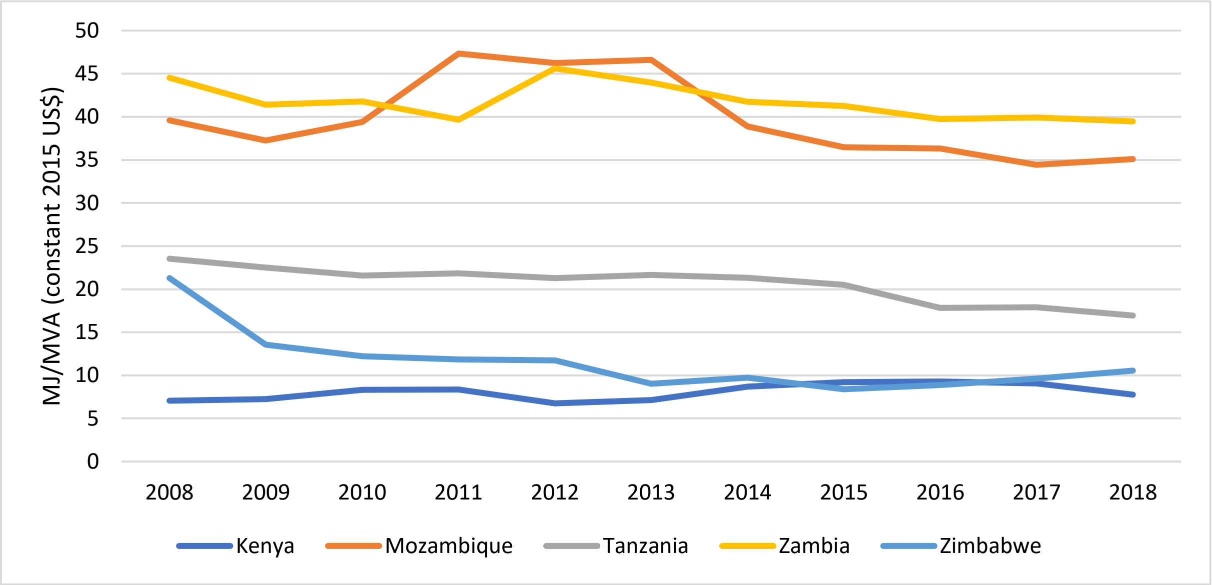


Source: Own elaboration based on data from IEA Extended World Energy Balances

In 2018, energy consumption by Mozambique's manufacturing sector accounted for 20 per cent of the country's TFC, indicating close to no increase since 2008. Mozambique still has the highest share in the sample, which might be associated with the increase in industrial production of energy-intensive sectors in Mozambique (e.g. aluminium, cement) (IEA, 2019d; 2019a). Zambia has the second highest manufacturing share overall, which could be explained by the country's poor electrification rate and its relatively low generation capacity, i.e. energy consumption in industry is increasing relative to residential energy consumption. However, Zambia is the only country where the role of manufacturing has declined significantly. Tanzania and Zimbabwe both reported relatively stable shares of between 8 per cent and 10 per cent throughout the period of analysis. Tanzania's position may be attributable to the fact that its energy consumption is primarily related to transportation and lighter industries (e.g. food and beverages) (IEA, 2019c; 2019a). The composition of Kenya's energy use is similar to Tanzania's, with higher consumption for transportation. But unlike in Tanzania, access by the population to electricity is rapidly increasing in Kenya. This may result in a relatively higher energy consumption by the residential relative to the productive sector, leading to a lower share of manufacturing TFC.

To determine how productive countries are in relation to the energy they consume, the intensity of energy consumption relative to manufacturing value added is analysed next. Energy intensity measures how much energy is necessary to produce one unit of value added. A high ratio implies that a relatively high amount of energy is used to reach certain level of industrial performance.

Figure 15. Manufacturing energy intensity



Source: Own elaboration based on data from IEA Extended World Energy Balances; World Development Indicators

Figure 15 presents the level of energy intensity of the manufacturing sectors in the selected countries, which has a similar distribution as the manufacturing share in TFC illustrated in **Figure 14**. One notable trend is that the intensity of energy use in manufacturing seems to be declining in all example countries. The manufacturing sector's energy intensity level remained stable only in Kenya, but this level is also the lowest overall, which is consistent with the country's low share of manufacturing in TFC. On the other hand, Mozambique's high energy intensity is consistent with the prevalence of its energy-intensive industrial sectors (e.g. aluminium, cement) and new discoveries (e.g. natural gas). Corresponding to the mid-level contribution of the manufacturing sector in TFC, Tanzania shows an average manufacturing energy intensity relative to the other countries. Even if other sectors of the economy contribute to the level of Tanzania's energy consumption, its manufacturing processes seem to be quite energy intensive.

Energy use in manufacturing sub-sectors

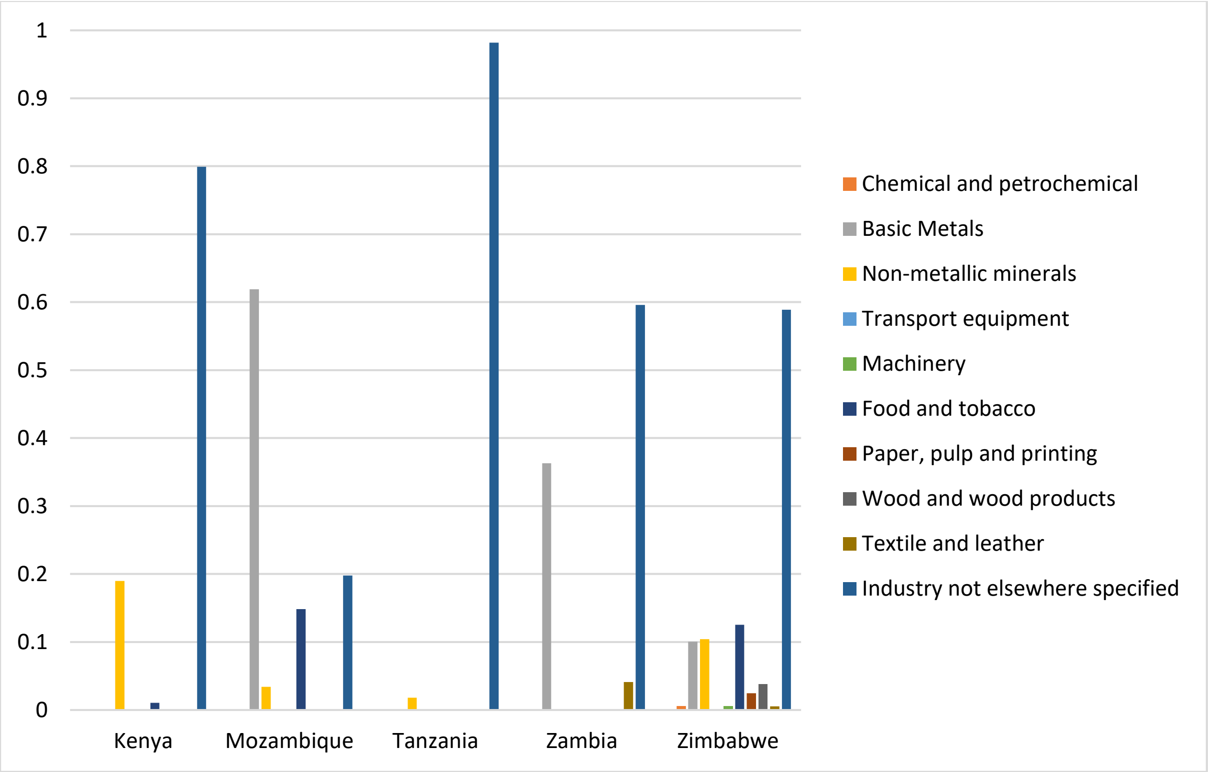
A more detailed level of analysis investigates energy intensity in sub-sectors of manufacturing. This further specification provides more information on (sub)sectors characterized by high energy consumption in their production processes. Globally, approximately 75 per cent of industrial energy is used to create material from ores and biomass for downstream manufacturing of products (Fischedick et al., 2014). The most energy-intensive sectors (see **Table 8**) are those whose global production has increased over the last decade (Fischedick et al., 2014). Together with pulp and paper, basic chemicals, refining, iron and steel, nonferrous metals (primarily aluminium) and non-metallic minerals (primarily cement) are considered energy-intensive industries, accounting for half of the energy consumed by the industrial sector in general (IEA, 2016). In fact, energy consumption for industrial processes can be reduced if scraps, material reuse, exchange of waste materials and heat are used for production.

Table 8. IEA manufacturing industries grouped according to energy intensity (ISIC Rev 3 & 4)

Industry	ISIC Rev 3	ISIC Rev 4	Energy Intensity Group
Petrochemicals	Division 23	Division 20	**High energy intensive**
Non-metallic minerals	Division 26	Division 23	**High energy intensive**
Metals	Division 27	Division 24	**High energy intensive**
Paper, pulp printings	Division 21 to 22	Division 17 to 18	**Moderate to high energy intensive**
Textile and leather	Division 17 to 19	Division 13 to 15	**Moderate to high energy intensive**
Wood and wood products	Division 20	Division 16	**Moderate energy intensive**
Chemicals and chemical products	Division 24	Division 21	**Moderate energy intensive**
Food and tobacco	Division 15 to 16	Division 10 to 12	**Low to moderate energy intensive**
Machinery	Division 28 to 32	Division 25 to 28	**Low to moderate energy intensive**
Non-specified	Division 25, 33 and 36	Any manufacturing industries not included separately	**Low to moderate energy intensive**
Transport equipment	Division 34 to 35	Division 29 to 30	**Low energy intensive**

Source: Adapted from UNIDO (2012)

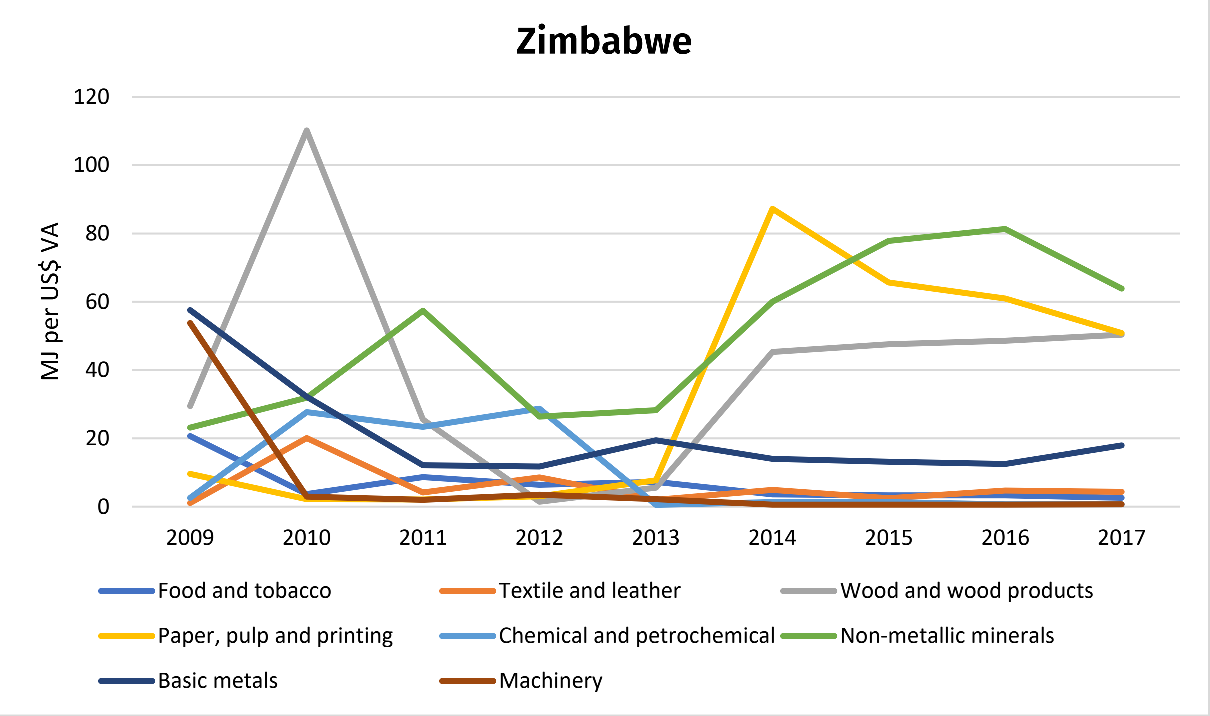
Figure 16. Manufacturing sub-sectors' share in manufacturing TFC



Source: Own elaboration based on data from IEA Extended World Energy Balances

Figure 16 shows data on the share of sub-sectors in manufacturing TFC, for which recent data were available. The sub-sector level data confirm the trends presented in the charts above (compare **Table 8**). In Mozambique and Zambia, a consistent share of energy is consumed by the basic metals sub-sector, comprising iron and steel along with non-ferrous metals. In Kenya, the level of energy consumption by the non-metallic minerals sub-sector reflects the fact that the mining industry and the processing of minerals have focused on non-metallic minerals until the recent discoveries of oil (Institute for Human Rights and Businesses, 2016). In all countries, with the exception of Mozambique, most of the energy consumed is accounted for by unclassified industrial sectors (Industry nes). This high share of energy consumption by the 'Industry nes' category is an indication of poor accounting and reporting of energy consumption at the sub- sector level by this group of countries.

Figure 17. Manufacturing energy intensity at the sub-sector level



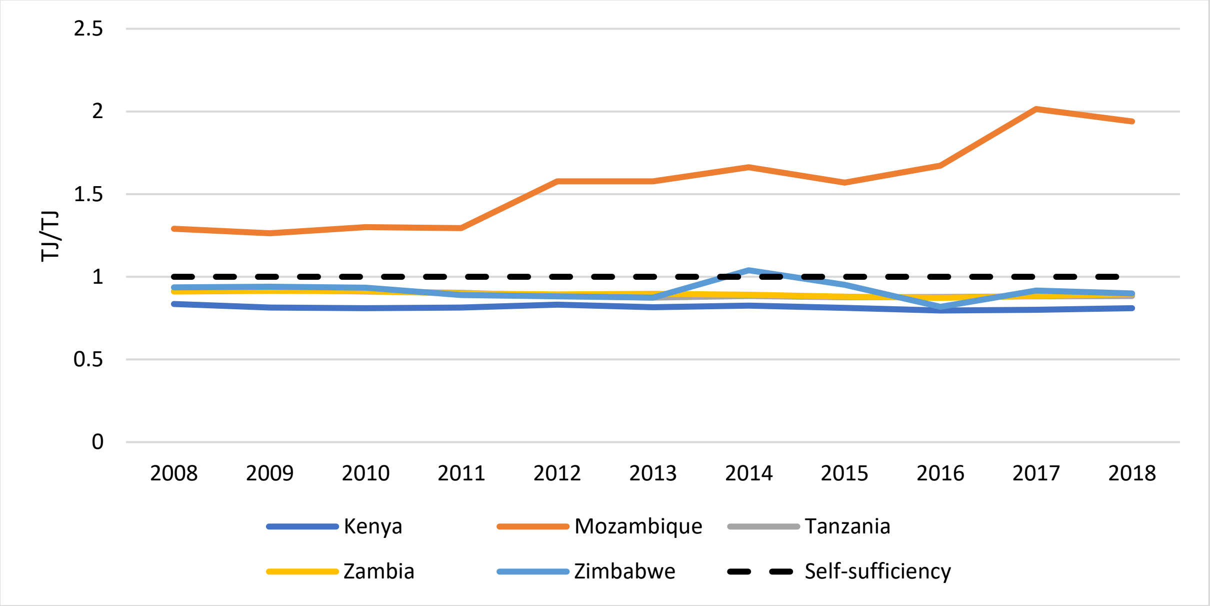
Source: Own elaboration based on data from IEA Extended World Energy Balances; UNIDO Indstat Rev 4

Figure 17 shows trends of energy intensity for manufacturing sub-sectors. Of all selected countries, a time series analysis was only possible for Zimbabwe, based on the combination of available data on CO_2 emissions and value added at the sub-sector level. The high energy intensity of non-metallic minerals is in line with the classification in **Table 8**. The decrease in overall manufacturing energy intensity (**Figure 15**) is mostly driven by sustained improvements in the basic metals and machinery sectors. Other sub-sectors characterized by high energy intensity are paper, pulp and printing as well as wood and wood products, which have both experienced a significant rise since 2013. In the face of the erratic variation in energy intensity that most sub-sectors exhibit, it must be assumed that reporting lacks some degree of accuracy.

Sustainable energy consumption

After a detailed analysis of the manufacturing sector's energy intensity has been carried out, the next step is to investigate sustainability in energy consumption. As inferred, high-energy intensity implies correspondingly high energy requirements to maintain a certain level of economic performance. The objective is to conceive pathways for industrial and economic growth that exert progressively lower levels of pressure on the environment. With respect to energy and emissions, possible solutions involve promoting the consumption of renewable energy sources along with reducing the intensity of energy use. This latter dimension is also related to a country's capacity to produce sufficient energy to cover internal demand.

Figure 18. Energy self-sufficiency



Source: Own elaboration based on data from IEA Extended World Energy Balances

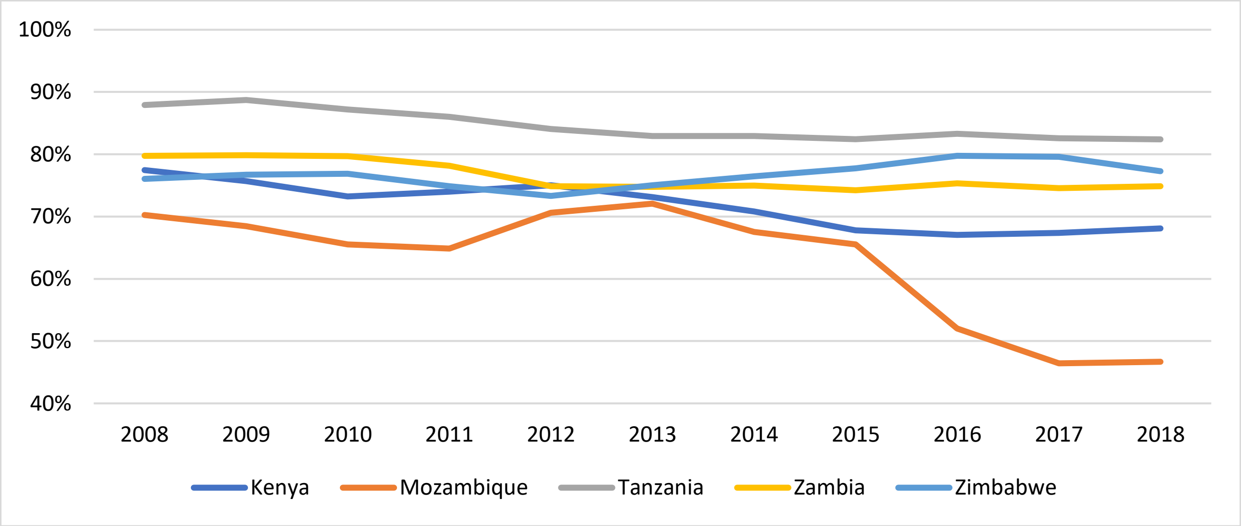
Figure 18 plots levels of energy self-sufficiency over time for our five sample countries. As self-sufficiency relates domestic primary production and energy supply, the ratio indicates the capacity of the country's power system to provide enough energy to cover demand. Countries with the capacity to independently cover demand tend to consume more energy, and thus have higher energy intensity. This in turn implies more extensive use of resources (i.e. fossil fuels), which will eventually be depleted more rapidly. A more sustainable approach to consumption seeks to maximize energy productivity (e.g. by producing goods with a higher technology content) along with the introduction of renewable sources in the energy mix.

From another perspective, energy self-sufficiency analyses the capacity of a system to operate within its own limits. A country is said to be self-sufficient when the ratio of (domestic) production and supply exceeds 1 (dashed line, **Figure 18**). This indicator tends to favour countries with internal fossil fuel reserves (e.g. Saudi Arabia, Nigeria, Venezuela) due to their capacity to meet domestic energy demand. Hence, this indicator provides rather limited insights into sustainability in terms of supply, not to be confused with environmental sustainability.

This is the case for Mozambique, where new domestic reserves have recently been discovered. **Figure 18** shows that the country performs above the threshold value of 1 throughout the observation period. It is projected that Mozambique will consume more energy in absolute terms as it exploits these new resources (IEA, 2019d). Since most of the country's consumption is related to energy-intensive industrial sectors (e.g. basic metals), lowering its intensity might be a serious challenge in the future. On the other hand, countries with a structural energy dependence will ideally improve their capacity by pursuing renewable sources or energy efficiency measures.

As Figure 19 illustrates, the energy mix in most of our sample countries relies heavily on renewable sources to meet consumption. The majority of the region's energy sources come from hydropower (27 per cent), while households still rely on more traditional sources for cooking and heating (e.g. fuelwood) (IEA, 2019a). However, it appears that all countries analysed have experienced a decrease in the share of renewables in TFC. Reasons for this overall decrease could be related to the new discoveries of domestic fossil fuel reserves (e.g. in Kenya, Mozambique, Tanzania) along with the progressive industrialization of most of these countries. This fuels a need for new infrastructure (e.g. roads, electricity grid) and, in turn, demand from high energy-intensive sectors (e.g. iron and steel, cement) (IEA, 2019a). Hence, countries in the region are gradually adapting their energy mix by introducing more fossil fuels to cope with increasing energy demand. In 2018, natural gas surpassed hydropower as the main source of energy supply in sub-Saharan Africa (27 per cent natural gas compared to 26 per cent hydropower) (IEA, 2019a). To cope with increased demand in the face of weak domestic generation capacity, most countries in our sample import fossil fuels (mostly oil) and energy products (IEA, 2019a). This is a short-term measure to cover demand and keep pace with the country's economic development as opposed to increasing sustainable domestic generation capacity.

Figure 19. Renewable energy consumption as a share of country TFC



Source: Own elaboration based on data from IEA Extended World Energy Balances

Figure 19 reveals that Zimbabwe is the only country whose share of renewable energy sources increased. In 2014, Zimbabwe was also able to briefly achieve energy self-sufficiency (see Figure 18). With no domestic reserves, Zimbabwe's energy mix heavily relies on renewable sources (mostly hydropower) (GET.invest; UNEP, 2015). Poor access to the grid and the prevalence of less energy-intensive sectors could be factors that are curbing demand. One key factor in reducing reliance on fossil fuels in TFC is to specifically increase the share of renewable energy use in the manufacturing sector. This can also be achieved by introducing new energy sources as a result of more circular industrial processes (e.g. waste-to-energy from industrial waste).

All other countries in our sample experienced a decrease in the share of renewable energy sources in consumption. The most significant drop was observed in Mozambique, from around 70 per cent in 2008 to less than 50 per cent in 2018. The reduction in the share of renewables in the energy mix generally result from the TFC growing stronger than renewable energy supply, often due to limited capacities.

Figure 20. Renewable energy consumption in absolute terms

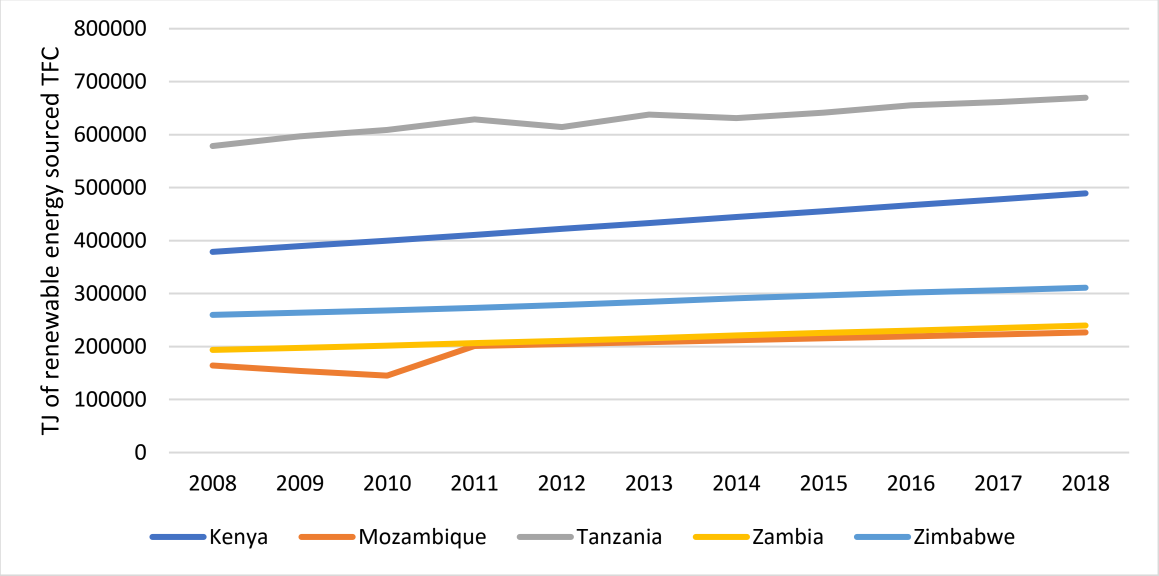
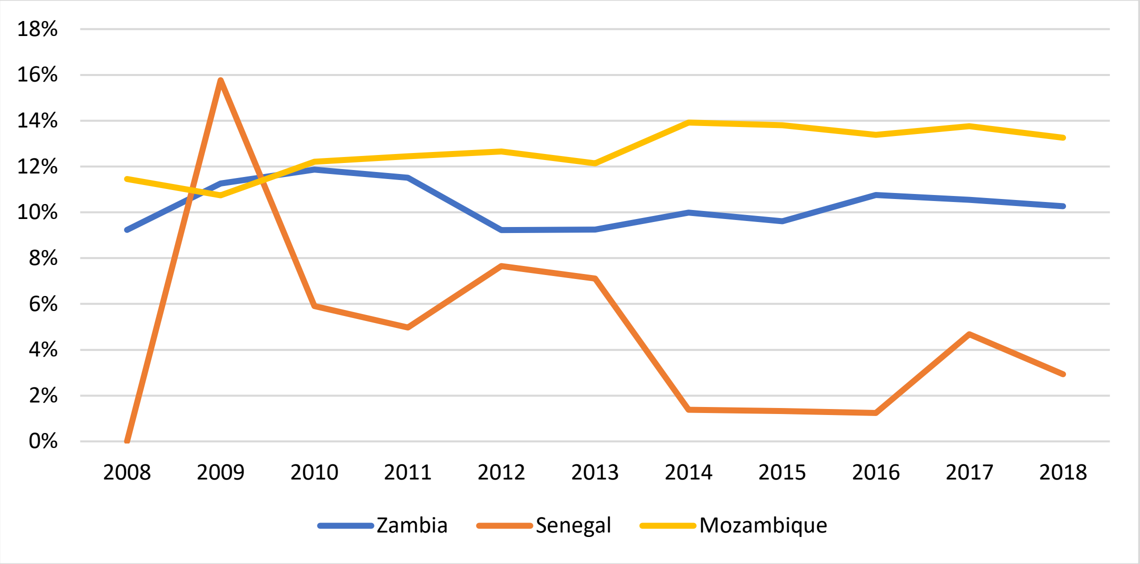


Figure 20 confirms that absolute renewable energy consumption rose in all selected countries. Thus, any drop in the share of renewables in the energy mix is the result of consumption outpacing the growth in the supply of renewable energy.

Figure 21. Renewable energy consumption in the manufacturing sector as a share of TFC



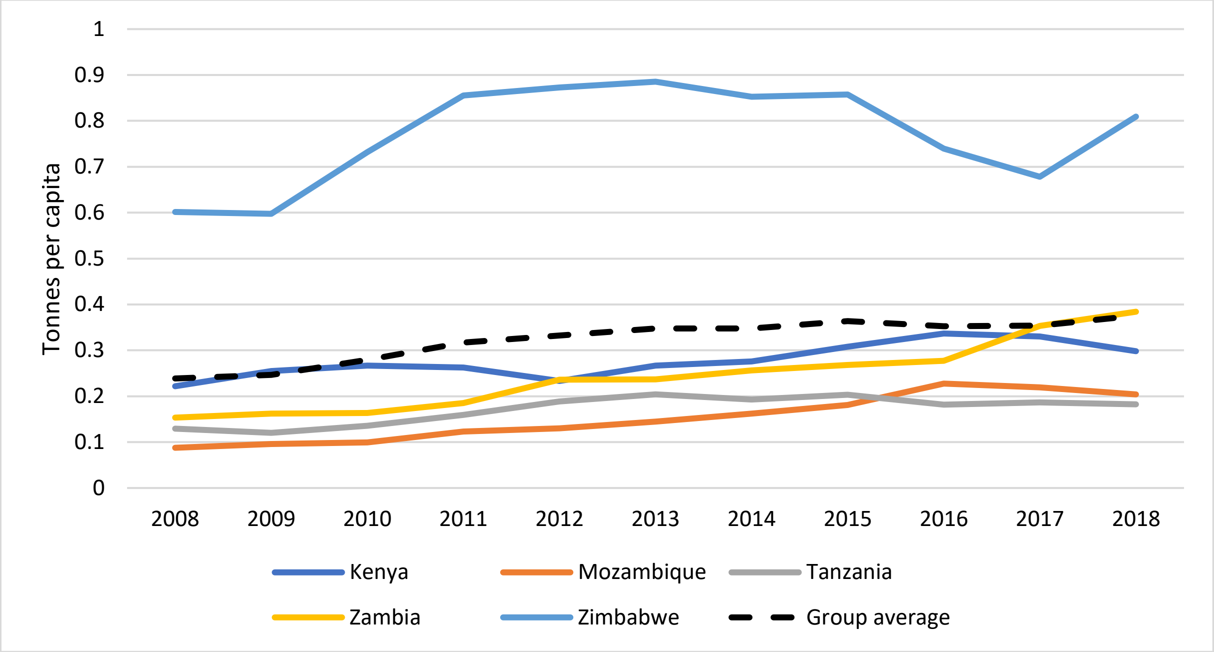
Source: Own elaboration based on data from IEA Extended World Energy Balances

The only countries in our sample that report data on renewable energy consumption in the manufacturing sector are Mozambique and Zambia. The share of renewable energy sources in their manufacturing sectors remained between 11 per cent and 14 per cent, and 9 per cent and 12 per cent, respectively. Benin and Senegal, for which some data were available, are included in the graph for context. The lack of data for the other countries in our sample may imply a lack of attention to alternative sources to supplement the current energy mix. The potential of achieving more sustainable production and consumption within the overall framework of *closing the loop* is disentangled in other chapters of this tool (see Waste, Material). Aside from strictly environmental benefits (decreased human footprint), this approach may also lead to long-term socio-economic returns related to new sources of income (e.g. the emergence of new industrial sectors) along with more job opportunities and increasing quality of life.

Country-level CO_2 emissions

Figure 22 presents the trends of CO_2 emissions per capita in our selected countries. In general, TFC per capita consumption trends in per capita CO_2 emissions are increasing in all sample countries. This generally means that CO_2 is increasingly being embedded in production and consumption patterns, even at per capita level. Zambia has witnessed an increase in emission per capita in recent years, reaching the group's average in 2017. Zimbabwe's emission levels were between 700 and 900 kg CO_2 per inhabitant for the entire period. In fact, Zimbabwe and Zambia reported above average levels of TFC per capita. It seems that Zambia is faring better than Zimbabwe in terms of CO_2 emissions relative to population size.

Figure 22. CO_2 emissions per capita

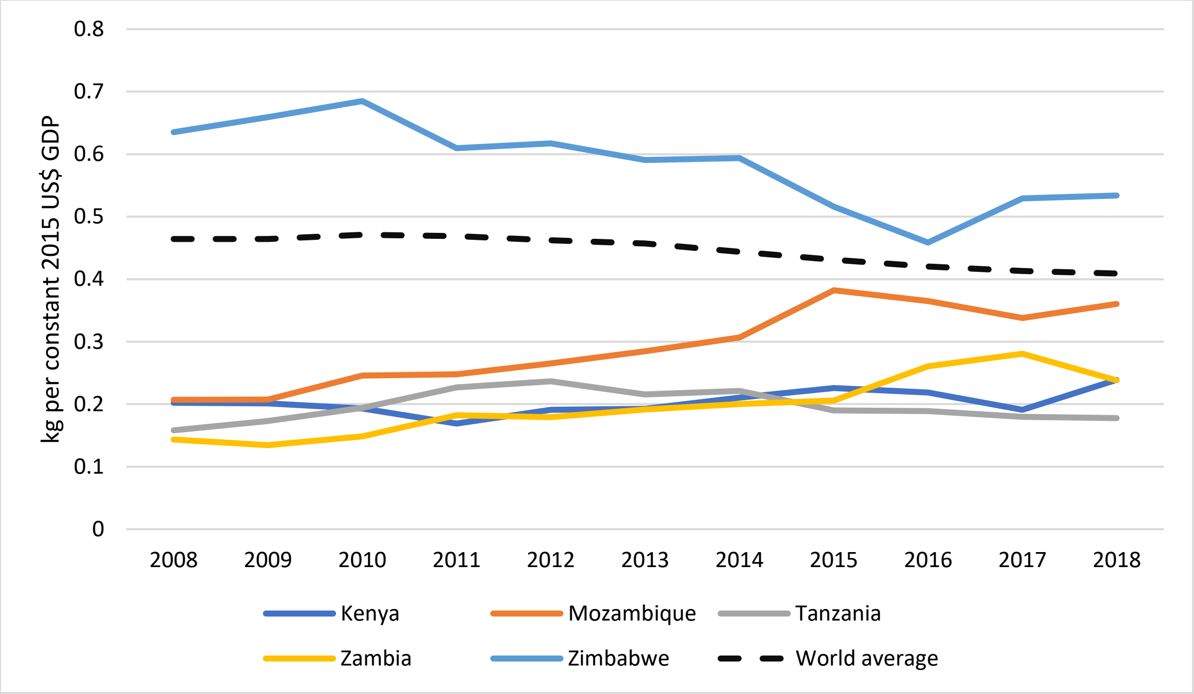


Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion

Emission intensity

Relating CO_2 emission levels to GDP provides a measure of emission intensity relative to the size of the country's economy. This indicator can be considered a rough proxy for decoupling trends between emission generation and economic output. A higher level of emissions per dollar of GDP implies that more CO_2 is being emitted to produce one unit of income. On the other hand, a declining trend means that GDP is growing at a relatively higher pace than the country's total CO_2 emissions. Tanzania's steady increase in CO_2 intensity may be related to the discovery of new gas reserves, which enabled a higher energy supply based on increased self-sufficiency. This in turn led to a rising share of gas in the energy mix, along with the associated CO_2 emissions (IEA, 2019c).

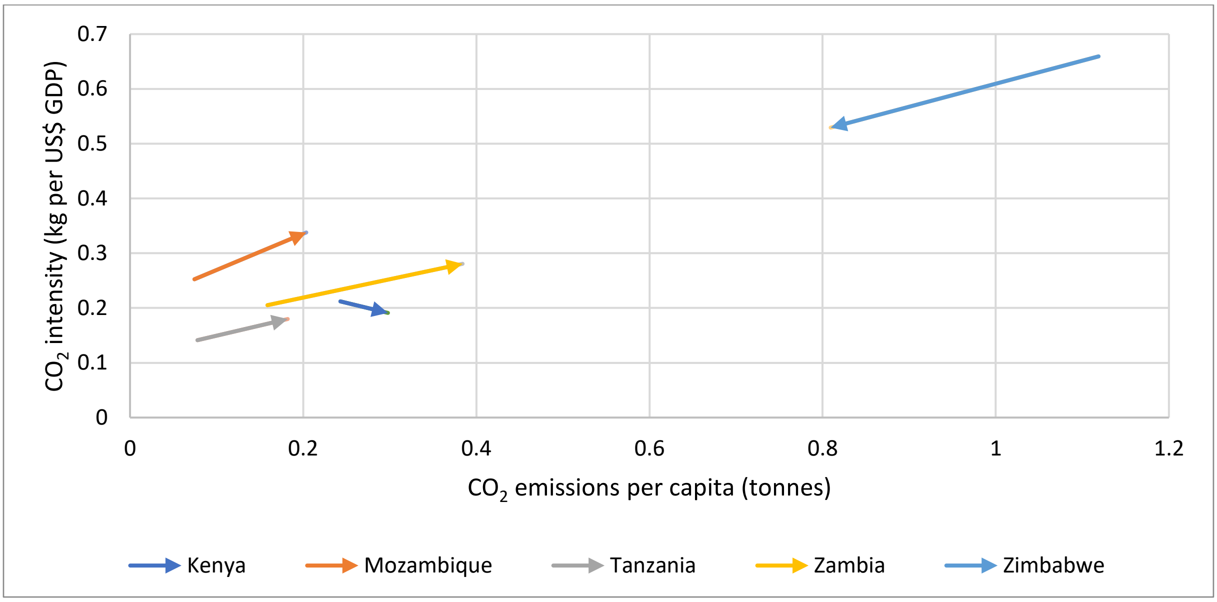
Figure 23. CO_2 emission intensity



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion

Figure 23 illustrates emission intensity for the five countries in our sample. Unlike other charts presented in this section, which reflect the group's average, in the present figure, our sample countries are benchmarked against the world's average CO_2 emission intensity (dashed line). As was already the case with the per capita values, Zimbabwe has the highest CO_2 emission intensity compared to the rest of the sample, even ranking above the world average in terms of CO_2 emissions per unit of economic value (GDP). However, Zimbabwe's CO_2 emission intensity is decreasing over time, unlike the increasing trend seen in the other countries. For instance, Mozambique's CO_2 emission intensity increased, almost reaching the world average level from 2018 onwards. A similar trend was observed in Zambia. Mozambique's progressive industrialization, led by energy-intensive sectors, is the reason for the country's intensifying energy consumption and CO_2 emissions. Considering the potential changes in the country's energy mix (e.g. natural gas discoveries) and energy consumption projections, CO_2 intensity in Mozambique is bound to increase steadily in coming years. Zambia's electrification targets may have contributed to its comparatively high emission intensity and per capita emissions according to "GET.invest".

Figure 24. CO_2 emission intensity vs CO_2 emissions per capita (2000–2018)



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion

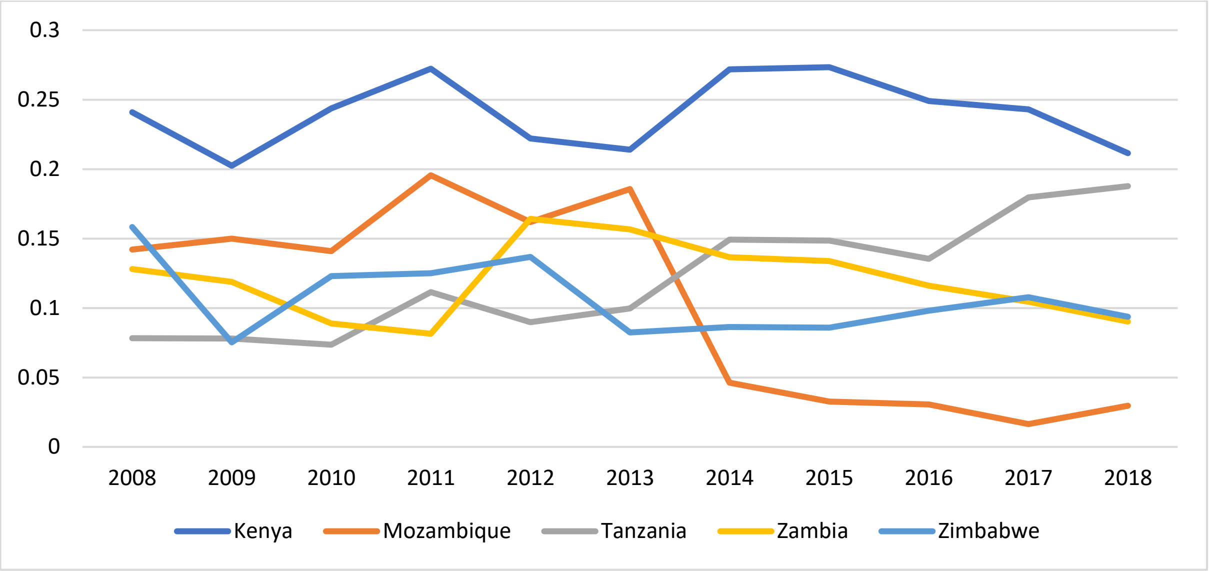
Emission intensities in terms of productive economic performance (per US$ of GDP) and demographics (per capita) provide insights into how much CO_2 is emitted in relation to these dimensions of the socio-economic system. Ideally, both should be declining in a move towards more sustainable production and consumption patterns. Plotting these two dimensions against each other can help reveal and dissect the extent to which they each contribute to CO_2 emissions at the country level.

Figure 24 depicts the change in the two indicators between 2000 and 2018 for the five selected countries. Zimbabwe is a clear outlier far above the group's average for both measures, indicating a deteriorating environmental performance. Even though its emission intensity decreased as opposed to that of the other countries, its emissions per capita further increased to about 760 kg. While all five countries exhibit a significant rise in per capita emissions, emission intensity only grew marginally in Kenya and Tanzania. The latter achieved the best overall score and had the lowest emissions impact both in terms of per capita and per unit of economic output (GDP) in 2018. Mozambique and Zambia's position was similar to Tanzania's in 2000, but then witnessed a considerable increase in their emission intensity in addition to their per capita development. As already discussed in other parts of this chapter, the population dimension (i.e. households) plays a more important role in Zambia both in terms of energy consumption and CO_2 emissions, while the large share of industry in Mozambique's energy composition might explain the country's relatively high CO_2 intensity per unit of economic output.

Manufacturing CO_2 emissions

After exploring the overall situation in terms of CO_2 emissions in each country, the next step is to deepen the analysis of the countries' industrial sector. **Figure 25** shows direct manufacturing CO_2 emissions from fuel combustion relative to the country's total CO_2 emissions.

Figure 25. Share of manufacturing CO_2 emissions of total country emissions



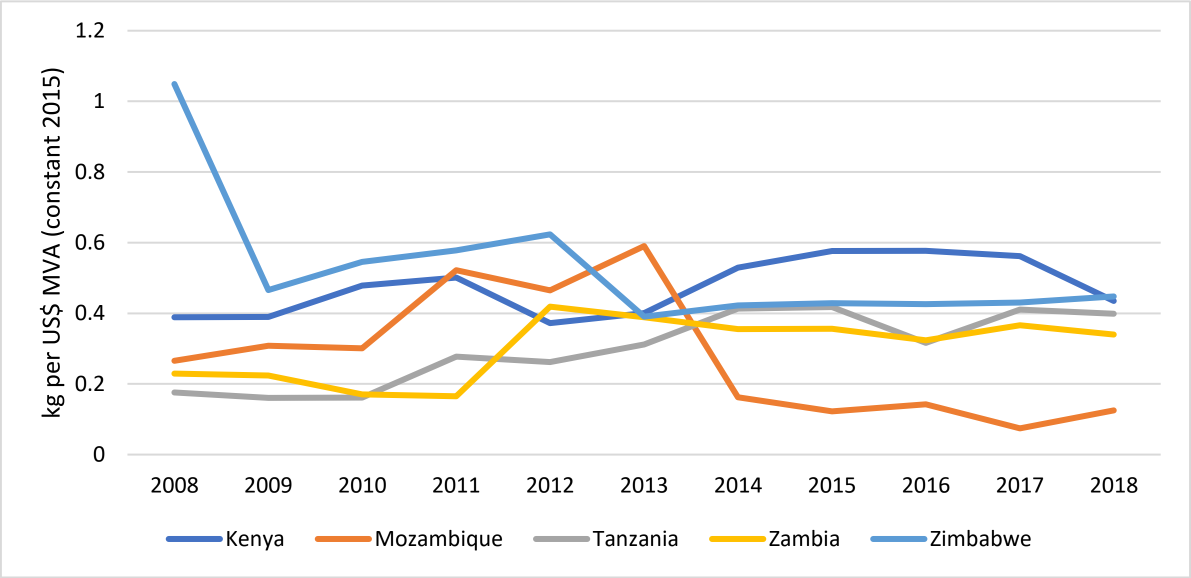
Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion

Among our sample countries, Kenya has the highest share of emissions from manufacturing, reaching peaks above 27 per cent between 2014and 2015. These levels started to decrease after thereafter, and now stand at about 21 per cent. Considering that this decline occurred while Kenya's absolute CO_2 emissions were on the rise, we can assume that other sectors started contributing more to the country's overall CO_2 emissions. Mozambique exhibited the second highest share of around 19 per cent in 2013, but this share decreased considerably to just above 3 per cent by 2018. A falling trend was also observed in Zambia and Zimbabwe, where the share of CO_2 emissions from manufacturing dropped in both countries from above 15 per cent to less than 10 per cent in 2018. The population dimension (i.e. households) plays an important role in both CO_2 emissions and energy consumption in Zambia and Zimbabwe. Tanzania is the only country exhibiting a marked increase of over 10 per cent in the share of CO_2 emission from manufacturing over the course of the observed period. This trend is not consistent with the manufacturing sector's contribution to TFC, which remained stable at a low level, raising questions as to what causes this discrepancy.

Manufacturing emission intensity

Emissions are linked to MVA to determine how much CO_2 is generally embedded in industrial processes. The higher the emission intensity, the higher the amount of CO_2 emission relative to the country's level of industrial performance.

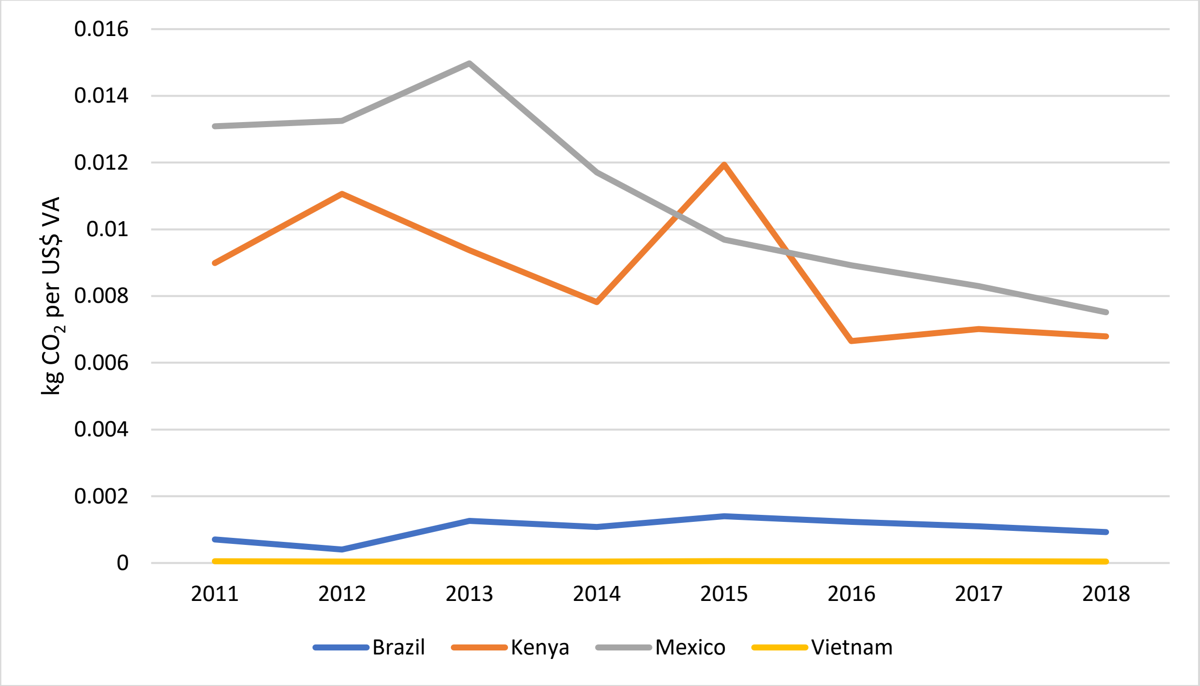
Figure 26. Manufacturing CO_2 emission intensity



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; World Development Indicators

Figure 26 shows the trend of manufacturing emission intensity of our five example countries. Kenya and Zimbabwe had the highest level of emission per unit of value added throughout most of the observation period. Interestingly, Kenya's manufacturing sector exhibited the lowest energy consumption. Despite the relatively low contribution to energy consumption, we can infer that Kenya's industrial processes have a relatively high level of CO_2 emissions. Possible reasons for this may include the composition of the manufacturing sector's energy mix, with its high dependency on fossil fuels. Zimbabwe, which has the second highest level of CO_2 intensity, is in a similar situation. Tanzania's increasing emission intensity is consistent with the rising trend of the manufacturing sector's energy consumption. In Zambia, manufacturing emission intensity increased slightly, while trends in manufacturing TFC remained stable and the share of manufacturing emissions decreased. Thus, it seems that Zambia managed to lower the intensity of CO_2 emissions in its manufacturing processes despite the sector's largely unchanged demand for energy. Mozambique has consistently exhibited high energy consumption and intensity compared to the other countries in our sample. The abrupt decrease of manufacturing CO_2 emission intensity after 2013 could be linked to a contingent slowdown in production, but not to effective mitigation strategies.

Figure 27. CO_2 intensity in the food & beverages sub-sector

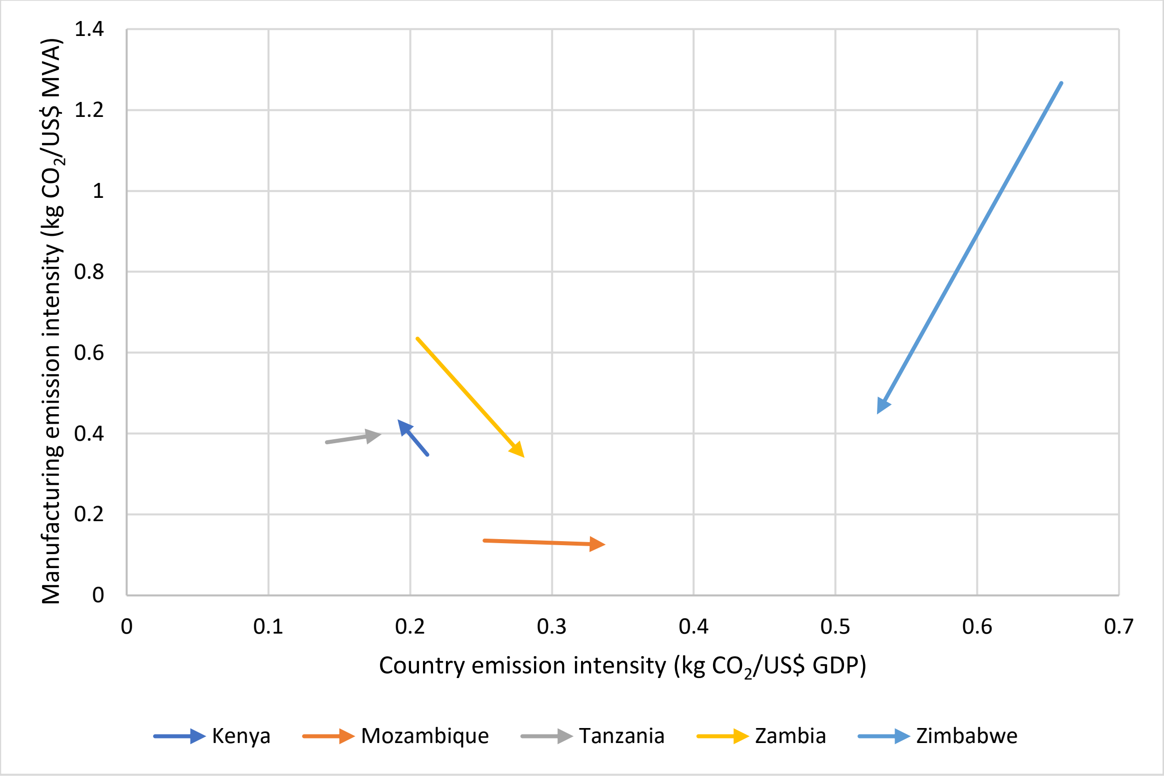


Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; UNIDO Indstat Rev 4

Figure 27 presents emission intensities for the food & beverages sub-sector of Kenya, as well as those of three other non-African comparator countries for which sufficiently disaggregated data are available. Compared to the previous **Figure 23** and **Figure 26**, the scale on the y-axis shows that the sub-sector is generally less CO_2-intensive than other sub-sectors. Kenya and Mexico both show a similar trend of slowly declining emission intensity, standing at around 0.007 kg of CO_2 per US$ of VA. Brazil and Viet Nam both exhibit stable intensities, but at a much lower level. This is particularly true for Viet Nam at around 0.0005 kg per US$. This reveals the capacity gap for Kenya in terms of CO_2 intensity in the food & beverages sub-sector, which it may want to address with targeted policy measures.

CO_2 intensity measures for the manufacturing sector can be plotted against the overall economy's CO_2 intensity (per unit of GDP) to provide a comparison (**Figure 28**) of economic performance relative to associated emissions. The analysis of CO_2 intensity, which is an output of the manufacturing process, complements that on energy intensity, which analysed an input, thus completing the picture.

Figure 28. CO_2 emissions per unit of GDP vs. CO_2 emissions per unit of MVA (2000–2018)



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; UNIDO Indstat Rev 4

Since fossil fuel use (fuel combustion) is the primary source of CO_2 emissions, the level of CO_2 intensity is driven by factors such as the energy mix or the level of energy intensity in the manufacturing sector as well as in the overall economy. The bulk of industrial processes still use non-renewables, mostly coal (IEA, 2020c). In fact, four countries in our sample show below average values of manufacturing emission intensity. As already shown in other charts above, CO_2 emission intensity is progressively declining in manufacturing processes over time. This is in line with data for manufacturing energy intensity, which has been shown to remain stable if it does not decrease (see **Figure 15**).

By contrast, the figures on per capita energy consumption and CO_2 emissions are increasing for the entire sample. It appears that a higher contribution to CO_2 emissions may be linked to demographic dynamics (e.g. Kaya Identity). Africa has experienced the highest population growth rate of any continent in recent decades (Ayompe et al., 2020).

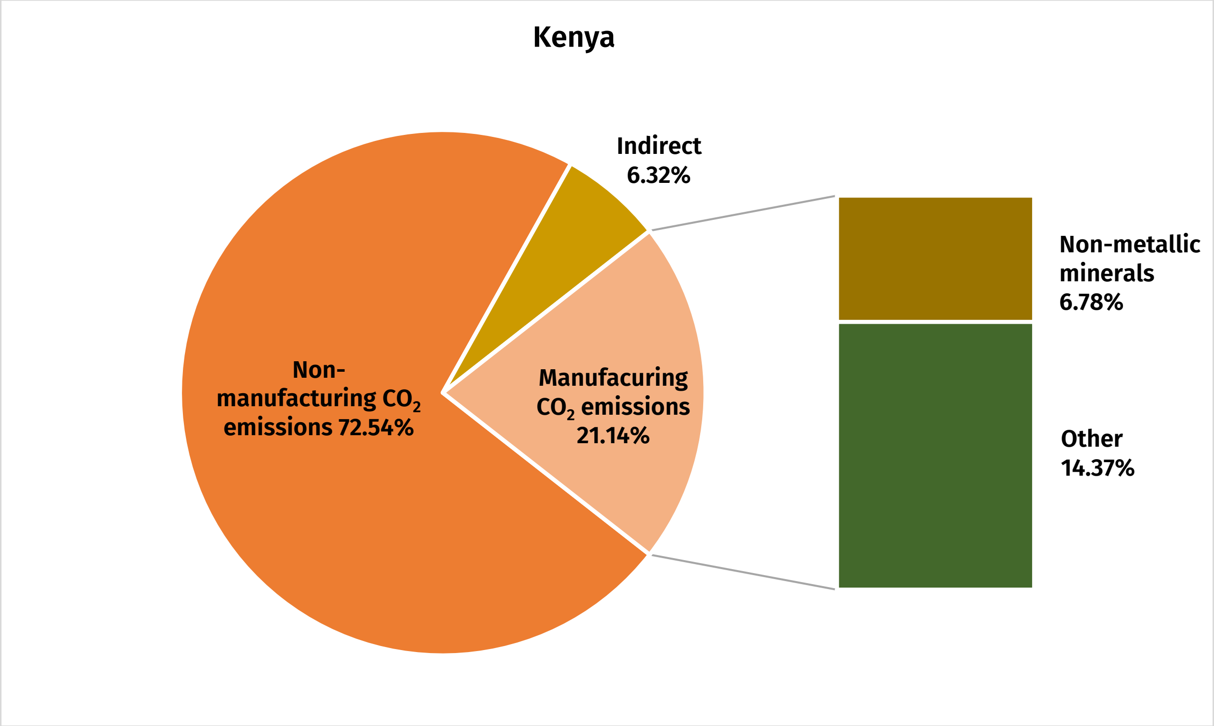
Thus, apart from domestic manufacturing production, other sources of CO2 emissions, such as transport and trade to meet the increasing demands of the growing population, seem to be gaining in relevance (Davis and Caldeira, 2010) (see **Box 5**). Imports of goods to Africa have contributed to a sharp increase in CO_2 emissions from trade, namely from around 400 000 tonnes in 1990 to 40 million tonnes in 2008, accounting for 5 per cent of Africa's overall CO_2 emissions (Guan and Reiner, 2009). This development may in part have influenced the observations depicted in **Figure 28**, with some countries exhibiting low emission intensities for the manufacturing sector, but high intensities for the economy as a whole. The analytical framework of this chapter only provides a partial picture of the relationship between CO_2 emissions and socio-economic systems. Most of these relationships are country-specific, thus focused insights and analyses are necessary to properly disentangle them for individual countries.

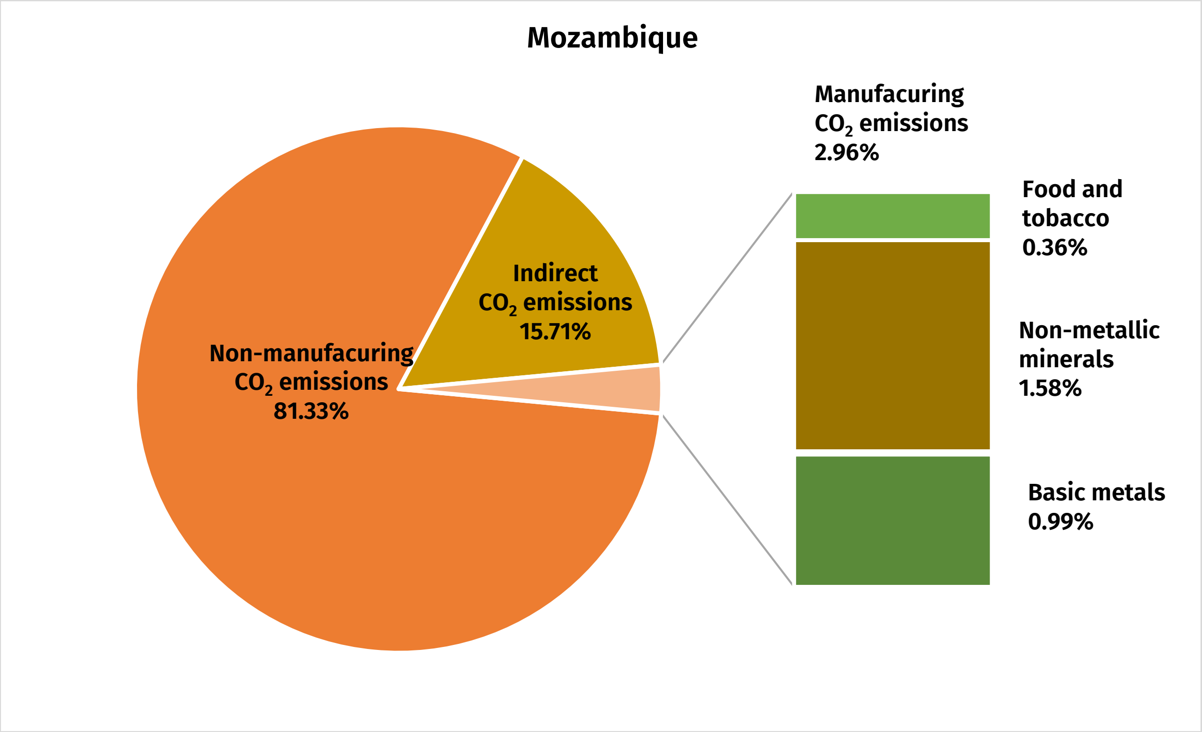
Figure 28 shows that Zimbabwe is a clear outlier in our sample, with the highest intensities at both the country and manufacturing level in 2018, even though the country has seen a significant decline since 2000. Mozambique's economy has generally exhibited a relatively high and increasing emission intensity, which is consistent with its increasing trend in energy consumption, particularly in energy-intensive sectors, along with a higher level of fossil fuels in the energy mix (see **Figure 19**). Kenya is the only country in which manufacturing emission intensity increased but emission intensity per unit of GDP declined. Despite a relatively low intensity of energy consumption in manufacturing output, manufacturing processes in Kenya have high levels of CO_2 emissions per unit of economic value. One possible explanation may be the prevalence of emission-intensive industrial sub-sectors (e.g. non-metallic minerals) in energy consumption, along with an extensive presence of oil reserves. This favours the production of CO_2 emission-intensive goods (e.g. plastic products).

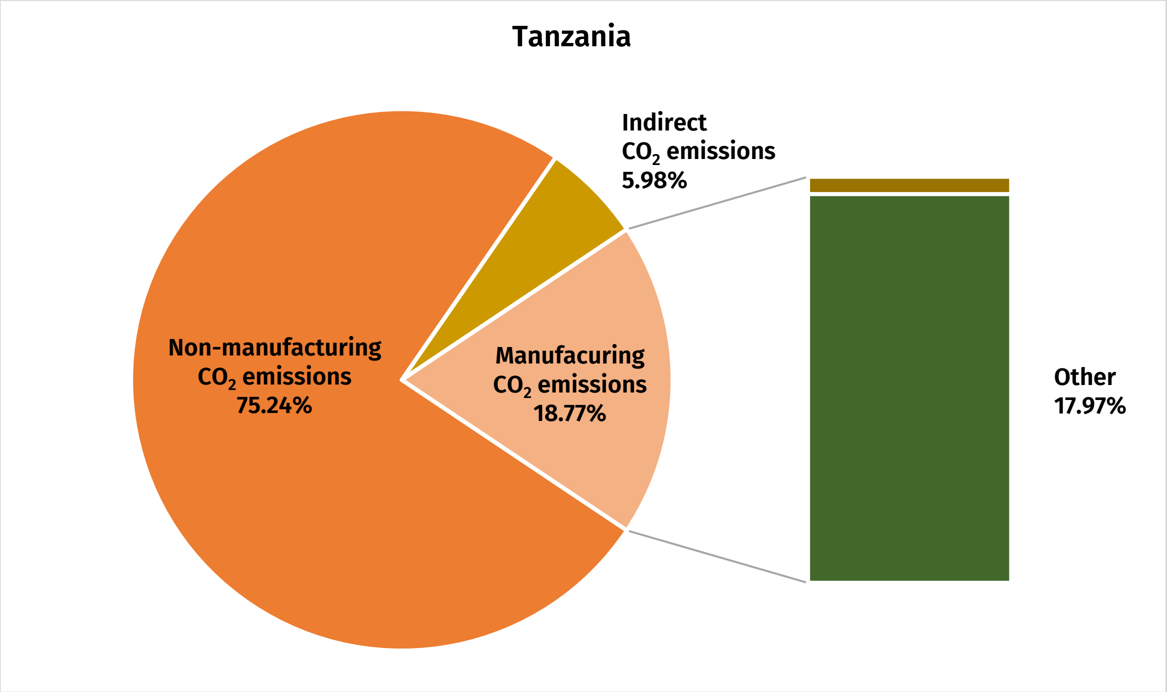
Manufacturing sub-sector emissions

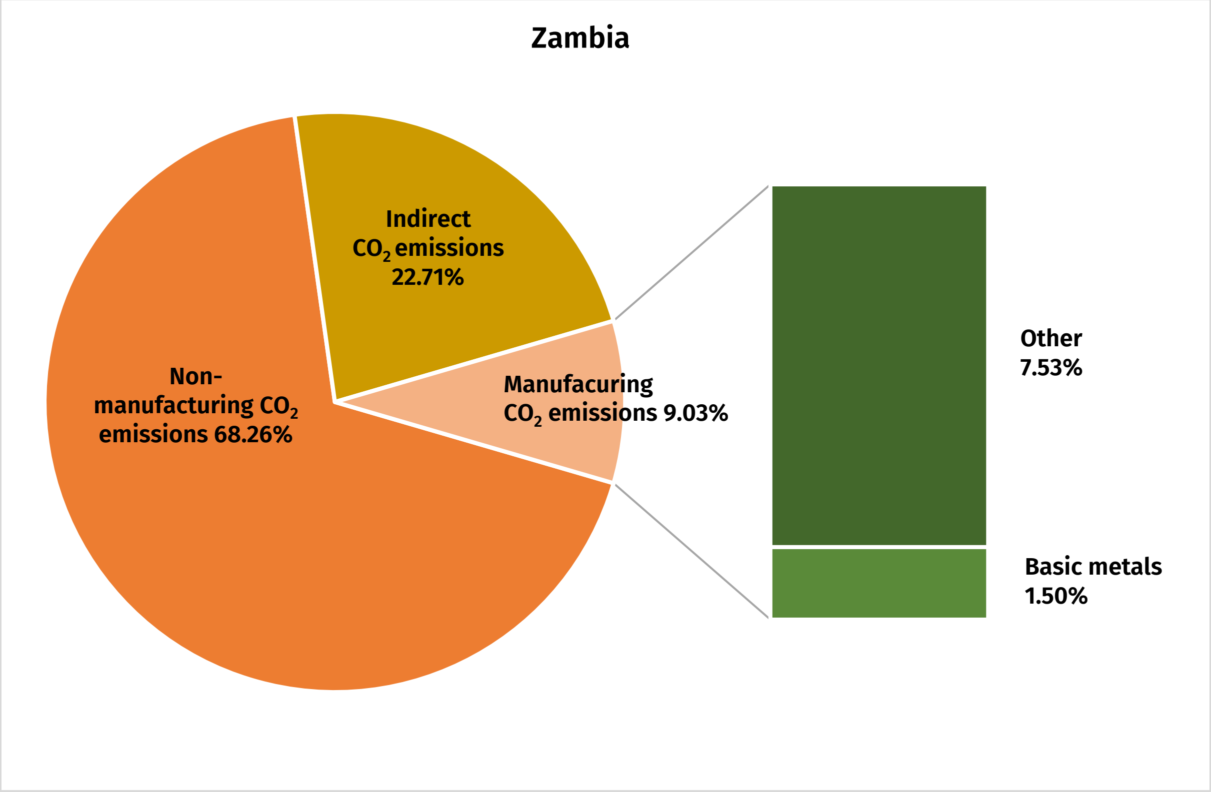
To further disaggregate the analysis, we investigate the composition of the manufacturing sector's overall CO_2 emissions. This provides insights into the contribution of individual industries to overall emissions and can contribute to identifying industrial processes that emit disproportionate amounts of CO_2. Generally, energy intense industrial processes are also high contributors to CO_2 emissions. Please note that the emissions presented in this section are only those directly attributed to industrial production processes. Total CO_2 emissions of a specific manufacturing sub-sector would also include indirect sources such as electricity consumption. The computation of data for indirect CO_2 emissions is explained in the description of indicator 2.9 on the share of manufacturing sub-sector emissions. As regards the chart below (**Figure 29**), depicting such contributions depends on data availability for CO_2 emissions at the sub-sector level. The more data are on absolute values of CO_2 emissions at sub-sector level are available, the more refined the percentages will be. Thus, the subsequent analysis is also significantly influenced by data availability.

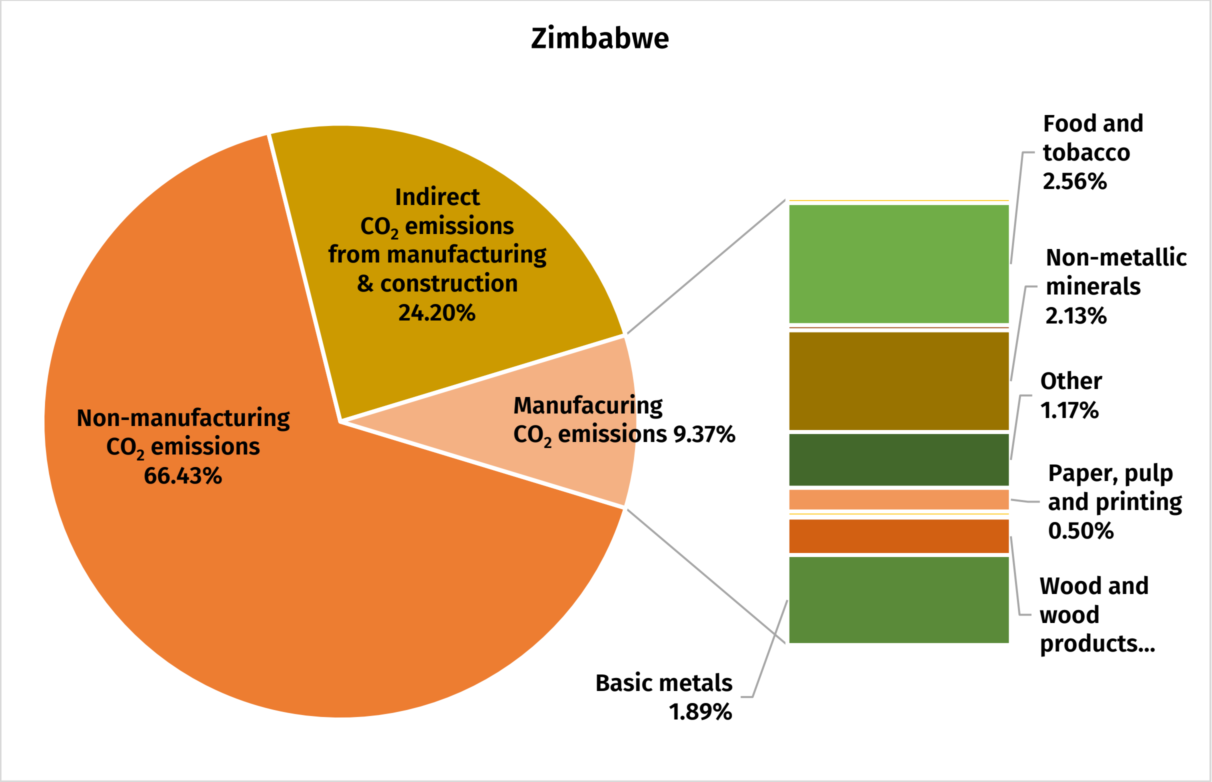
Figure 29. CO_2 emission decomposition analysis (2018)






Tanzania
Indirect
CO2 emissions
5.98%
Non-manufacturing
CO2 emissions
75.24%
Manufacuring
CO2 emissions
18.77%
Other
17.97%


Zambia
Indirect
CO2 emissions
22.71%
Non-
manufacturing CO2
emissions 68.26%
Manufacuring
CO2 emissions 9.03%
Other
7.53%
Basic metals
1.50%



Source: Own elaboration based on data from IEA CO₂ Emissions for Fuel Combustion

Figure 29 shows the analysis of direct and indirect emissions from manufacturing sub-sectors (ISIC Rev 4 classification) for the selected countries in 2018. Based on this, we can deduce that the non-metallic minerals sub-sector accounts for a significant share of emissions from industrial processes. This apparent trend is also observable in countries with a more diversified industrial structure but may be influenced by limited data reporting (i.e. emissions accounted for by the "Other" sub-sector).

Indirect CO_2 emissions from the manufacturing and construction sectors of our example countries range between a minimum of 5.98 per cent (Tanzania) and a maximum of 24.20 per cent (Zimbabwe). This renders overall industry-related CO_2 emissions a significant contributor to the total emissions in all countries, from 18.67 per cent in Mozambique to 33.57 per cent in Zimbabwe. It is remarkable that the share of indirect emissions is higher than that of direct emissions from manufacturing in three of the five countries, namely in Mozambique, Zambia, and Zimbabwe. While this may in part by related to data reporting and the fact that indirect emissions include the construction sector as well, it should nonetheless raise questions about the sustainability of industrial electricity consumption among the policymakers in these countries.

Box 5. Carbon leakage

Carbon leakage refers to relocation of production by businesses to other countries with more lenient environmental regulations or costs related to climate policies. This might lead to an increase in GHG emissions in some regions as a result of climate change mitigation efforts in others. Since the primary source of GHG emissions is the combustion of fossil fuels, the energy market and energy-intensive (industrial) sectors are the main channels of carbon leakage (Yu et al., 2021). The literature identifies three underlying mechanisms that trigger carbon leakage (Jakob, 2021):

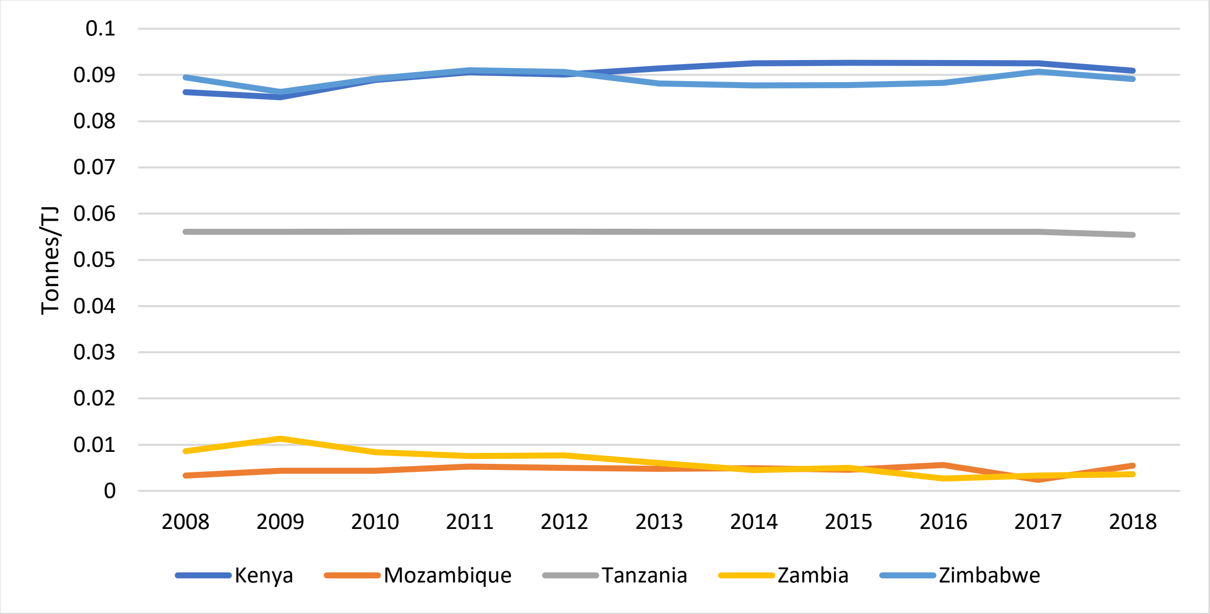
1. *Energy market effects*: climate policy in one region might reduce fossil fuel demand in another. This might result in increasing fossil fuel consumption in other regions.
2. *Trade specialization*: increases in energy prices due to more stringent climate policies might affect trade. Rising prices in one country might be related to higher imports of energy-intensive goods from other countries with laxer environmental regulations (i.e. *comparative advantage*).
3. *Free-riding*: game-theoretic analysis has shown that the theoretically most advantageous response for each country to emission reductions in one country is to increase its own. On the other hand, the more countries adopt or strengthen their climate policies, the less likely it becomes for carbon leakage to occur.

Potential solutions for specific adjustments in policy design have been identified for sectors that are particularly exposed. Recently, the implementation of *border-carbon adjustment* (BCAs) mechanisms for imports and exports of energy-intensive goods and services has been discussed (Campbell et al., 2021). Imports with taxes would be levied to charge imported goods and services at the same environmental cost as domestic production. So far, only the European Union (EU) is considering the implementation of the BCA mechanism. The EU is trying to design carbon-adjustment mechanisms that are in line with its current climate policy framework (i.e. the European Emission Trading Scheme) and international trade policy (e.g. WTO)

Emissions per unit of energy in manufacturing

The next step in the analysis investigates the ratio of CO_2 emissions from fuel combustion in the manufacturing sector's energy consumption. **Figure 30** shows emissions per unit of energy for the entire manufacturing sector.

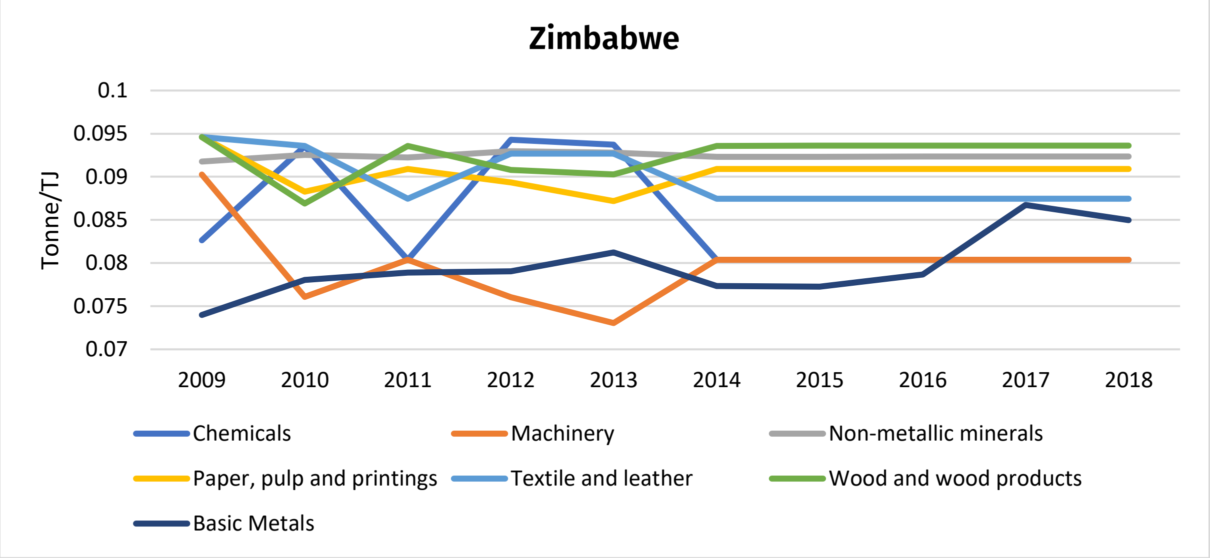
Figure 30. CO_2 emissions per unit of energy consumption in the manufacturing sector



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; IEA Extended World Energy Balances

Kenya, Zimbabwe, and to some degree Tanzania show relatively higher and stable levels of emissions per unit of energy consumed. This chart complements the overall analysis by relating CO_2 emissions in tonnes directly to energy used. As illustrated in previous charts, Kenya is characterized by increasingly CO_2-intensive manufacturing processes. Possible explanations are linked to the prevalence of certain CO_2 emission-intensive industrial sub-sectors (e.g. non-metallic minerals) and sufficient fossil fuel resources to sustain production (e.g. oil reserves). Together with Zimbabwe, Kenya has the highest level of CO_2 emissions per energy consumption. The higher CO_2 emission intensity per unit of energy in Zimbabwe is reported for sectors with traditionally low energy intensity (e.g. textile and leather, wood and wood products, pulp, paper and printing) with the exception of chemicals (see **Figure 31** below).

Figure 31. CO_2 emissions per unit of energy consumption in manufacturing sub-sectors



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; IEA Extended World Energy Balances

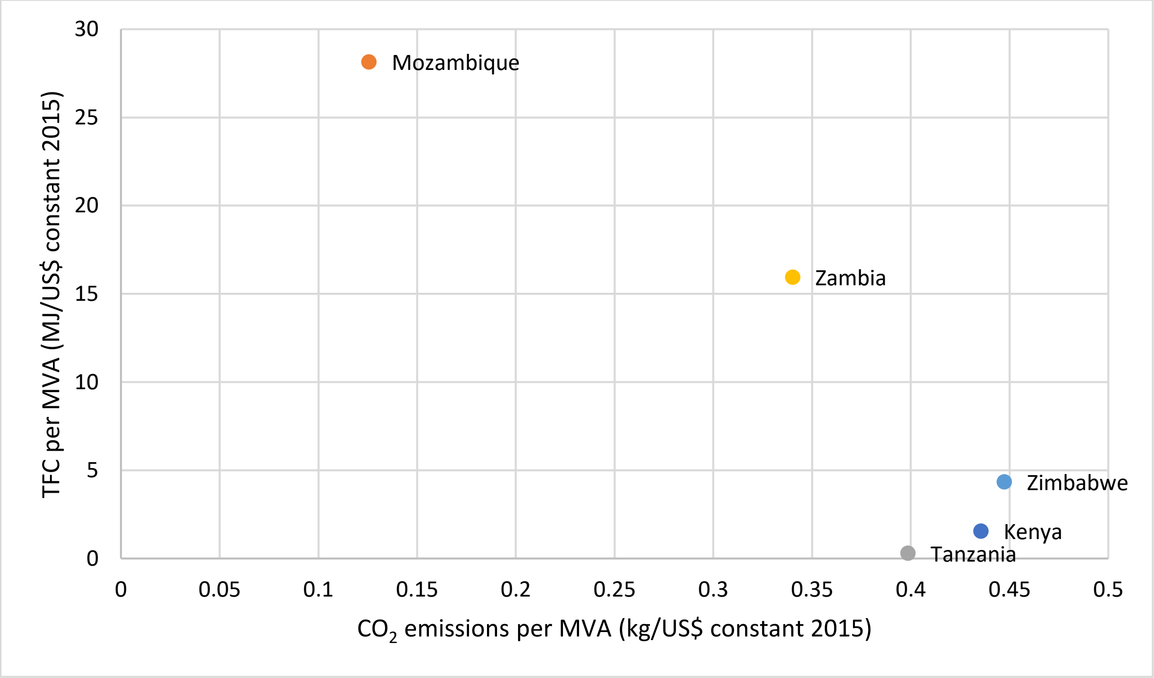
At the sub-sector level, sufficiently disaggregated data for a meaningful analysis were only available for Zimbabwe. The results of this chart are in line with the country's industrial structure. Its manufacturing sector is mostly driven by agriculture-related sub-sectors (Damiyano et al., 2012). However, those sectors are characterized by a relatively low energy intensity (see **Table 8**). Even though the country's main source of energy supply comes from hydropower, the chart indicates a high intensity of CO_2 per unit of energy consumption. Considering Zimbabwe's main sub-sectors, it appears feasible to increase the energy mix's sustainability by exploiting synergies with the manufacturing processes (e.g. industrial symbiosis, see Waste Chapter). Scraps in these processes could become a new source of energy (e.g. waste-to-energy, see Waste Chapter).

Basic metals and non-metallic minerals are among the most energy-intensive sub-sectors, implying that higher amounts of CO_2 emissions are being generated, also with respect to the overall value chain. Industrial mitigation policies targeting those specific manufacturing sub-sectors will be a challenge for Zimbabwe. Pathways to decrease the CO_2 emissions of the associated industrial processes entail exploiting all potential energy sources from by-products, for instance controlling and re-employing waste heat in basic metals production. Recovering heat to be used in the production process might consistently lower CO_2 emissions, as most heat is still generated by burning coal (IEA, 2021).

Emissions vs. energy in manufacturing

Figure 32 presents the degree to which energy consumption and CO_2 emissions are corelated in the countries' manufacturing sectors.

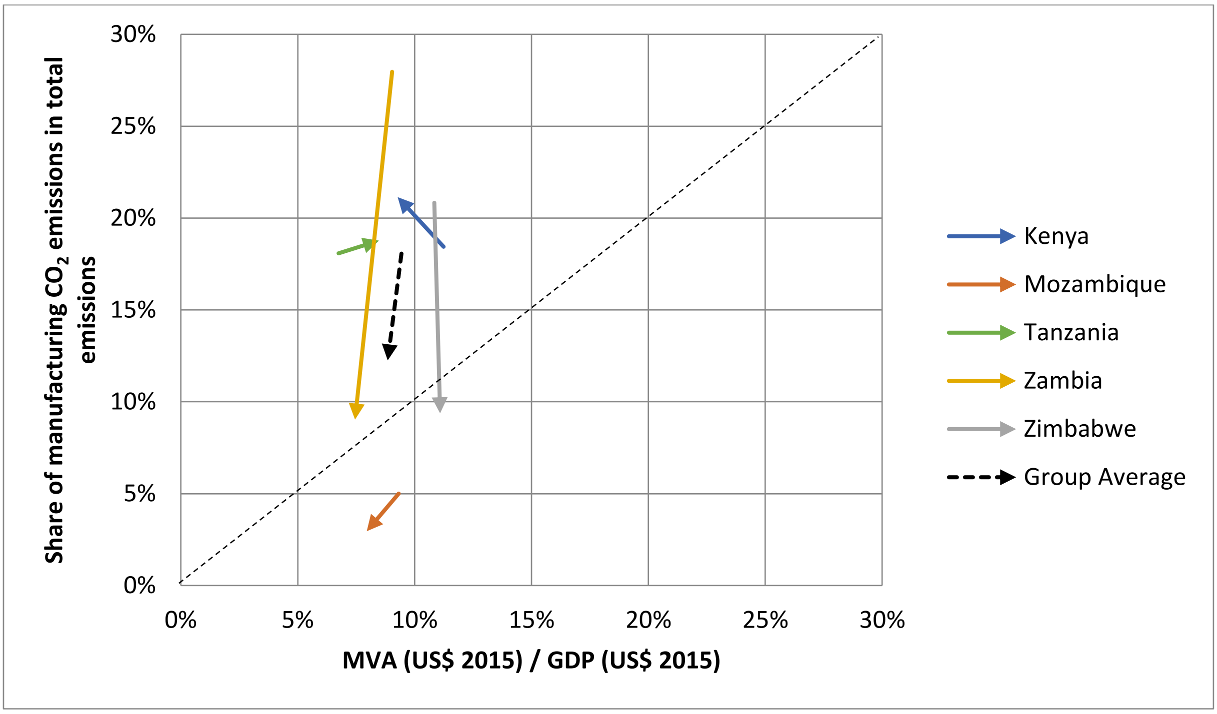
Figure 32. Energy vs emission intensity in manufacturing



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; IEA Extended World Energy Balances

Zimbabwe, Kenya, and Tanzania are clustered in the graph's bottom right corner, indicating a high level of emissions in relation to energy consumption. As already shown in other charts, Kenya's manufacturing processes embed high levels of CO_2 emissions in relation to energy consumed, despite their relatively low contribution to overall TFC. In fact, the country's progressive electrification has reduced the manufacturing sector's contribution to energy consumption. Still, a more sustainable energy mix oriented towards renewable sources could certainly lower CO_2 emissions in relation to the energy consumed by the sector. Zambia and Mozambique show high levels of energy consumption as opposed to low levels of CO_2 emissions. This also emerged from the analysis on CO_2 emissions per unit of energy, with the level being relatively low in these two countries. Mozambique's trend is related to the decrease in CO_2 emissions per energy consumed for the basic metals sub-sector. In Zimbabwe, this can be attributed to the composition of the industrial tissue, mostly formed by less energy-intensive sub-sectors.

Figure 33. Share of MVA in GDP vs share of manufacturing in total emissions (change from 2000 to 2018)

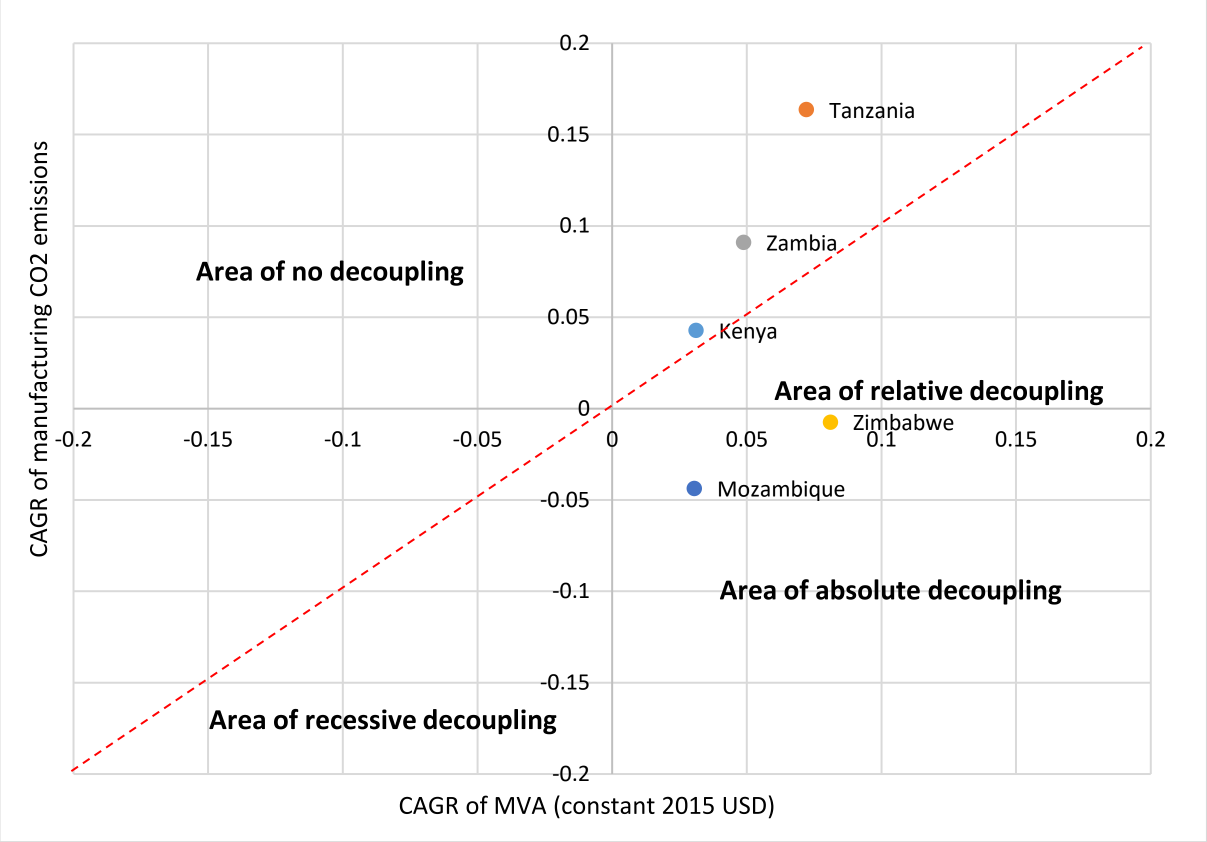


Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; World Development Indicators

Figure 33 plots the change in shares of manufacturing emissions (between 2000 and 2018) in a country's total emissions and MVA in GDP. The direction of the arrow points towards an increase or decrease of the shares in the two main axes over the observations period. As the objective is to decouple industrial performance from environmental pressure (i.e. CO_2 emissions), this graph provides an indication of the extent of decoupling that has been achieved in manufacturing. It completes the analysis of the relationship between energy consumption and CO_2 emissions in the manufacturing sector with information on potential decoupling of the two dimensions over time. For example, there might be cases in which although industrial performance is decreasing, emissions per unit of energy are increasing (lack of efficiency/ high intensity).

In the case of Zambia, a plunge in the share of manufacturing emissions coincided with a slight decrease in the share of MVA in GDP. Decoupling in energy consumption might still occur but is related to a general slowdown in industrial production. In Zimbabwe, a similar fall in share of manufacturing emissions coincided with a stable share of MVA in GDP, indicating a strong decoupling trend. Of the five countries of our sample, Tanzania is the only one where MVA/GDP increased. As the level of manufacturing CO_2 emissions in the country's total emissions rose as well, no decoupling occurred. For Mozambique, the arrow points towards the bottom left side of the chart, signalling a decrease in the share of manufacturing CO_2 emissions, which may be related to the general slowdown in industrial productivity (i.e. recessive decoupling).

Figure 34. CO_2 decoupling in the manufacturing sector (2008–2018)



Source: Own elaboration based on data from IEA CO_2 Emissions for Fuel Combustion; World Development Indicators

To complement the analysis of decoupling,

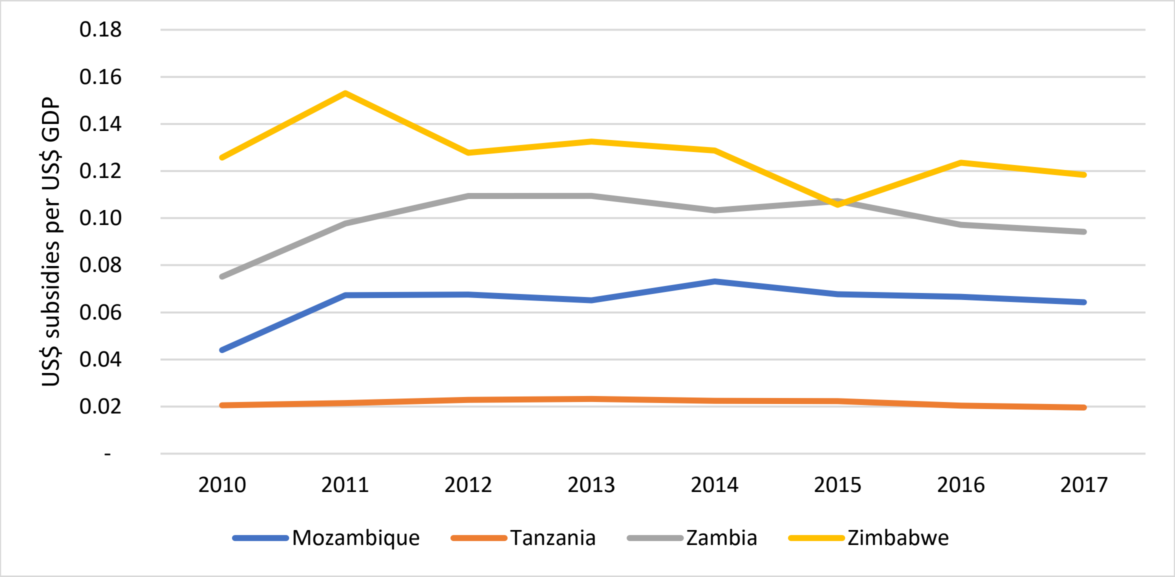
Figure 34 positions the countries according to their effective level of emissions decoupling in manufacturing. Due to the lack of data, this analysis could not be carried out at the sub-sector level. This chart plots the CAGR of CO_2 emissions and MVA between 2008 and 2018. Note that this time period differs from that used in the previous graph, which analysed the change between 2000 and 2018. Zimbabwe and Mozambique are located in the area of absolute decoupling whereas none of the sample countries achieved relative decoupling. Possible factors explaining these results are related to differences in the composition of the manufacturing sector. By reducing its emission intensity, Mozambique's manufacturing sector attained absolute decoupling despite being characterized by high energy intensity. However, policymakers should take other sectors into consideration as well, since previous analyses highlighted that the manufacturing sector is not the main contributor to the country's CO_2 emissions. The position of Zimbabwe could be explained by a general slowdown in production (see Figure 34) rather than effective mitigation in the manufacturing sector. In fact, the country is positioned right on the border of the quadrant of relative decoupling. Kenya, Zambia, and Tanzania did not decouple their manufacturing sector's value added from its CO_2 emissions between 2008 and 2018.

Fossil fuel subsidies

This sub-section sheds light on the extent of countries' support of fossil fuels through subsidies. Despite significant efforts at the international level, the fossil fuel industry is still being heavily subsidized by national governments. Overall, it is estimated that fossil fuel subsidies (fossilfuelsubsidytracker.org/) amounted to around US$ 487 billion worldwide in 2017. In comparison, supply-side subsidies for renewable energy sources were estimated at around US$ 167 billion, with subsidies for power generation reaching US$ 128 billion in 2015 (IRENA, 2020).

Figure 35 shows the per capita amount of direct and indirect fossil fuel subsidies provided over the years. Of our sample countries, Zimbabwe had the highest level of subsidies, ranging from US$ 0.11 to US$ 0.16 per dollar of GDP per year, or US$ 1.7 billion to US$ 2.5 billion in absolute terms. This consistently accounts for more than 10 per cent of Zimbabwe's annual national income. The trend has been slightly decreasing since 2011. Zambia, Mozambique, and Tanzania's fossil fuel subsidies per dollar of GDP increased, especially between 2010 and 2011. Tanzania, on the other hand, spent a stable 2 cents per dollar of GDP on fossil fuel subsidies. Since its GDP grew during this period, this translates into an absolute increase from US$ 700 million to US$ 1 billion in subsidies between 2010 and 2017.

Figure 35. Fossil fuel subsidies per GDP



Source: Own elaboration based on data from Fossil-fuel Subsidies Tracker

This could be related to the recent uptake of renewable energy sources and consequent increases in the sum of subsidies to this end. As already mentioned, renewable energy sources can cover energy demand in countries with no domestic fossil fuel reserves (see the case of Zimbabwe in self-sufficiency, **Figure 18**). Despite the presence of domestic reserves, especially oil, most of the countries in the region do not have refineries (see the case of Kenya, for instance: Institute for Human Rights and Businesses, 2016). In most cases, these countries export the raw material and import the refined product (e.g. electricity, oil-derived products) at a higher cost. Data disaggregated by fossil fuel/ energy product (see data description for details) shows that the majority of subsidies in all countries of the sample has been provided for electricity end-use. The subsidies are thus designed to keep the prices for end-users low.

Without any recent fossil fuel discoveries in their territories, Zimbabwe and Zambia need to import most of their energy supply to cover demand. Lower levels of subsidies for Mozambique and Tanzania are likely attributable to new natural gas discoveries.

Policy options

This chapter highlighted the nexus between sustainable energy production and consumption, CO_2 emissions and climate change. As these dimensions are strongly interrelated, policy efforts in one area influence the others. Investing in a cleaner energy system may entail benefits for energy access, secure energy supply and favour job creation in developing countries. Shaping policy interventions with the aim of promoting more sustainable production and consumption patterns (SDG 12) implies a considerable reduction or discontinuation of public subsidies for unsustainable energy sources, particularly fossil fuels (SDG 12.c.1).

Due to the significant role of manufacturing in energy consumption and CO_2 emissions, policy interventions should focus on this sector along with energy production. The two dimensions of the energy transition call for the promotion of a higher share of renewables in the energy mix, on the one hand, while improving the efficiency of energy consumption, on the other. The IEA policy database (https://www.iea.org/policies) is a valuable resource for gaining an overview of all conceivable energy policies that have been implemented worldwide in recent years, searchable by policy type, topic, technology, etc.

Renewable energy capacity

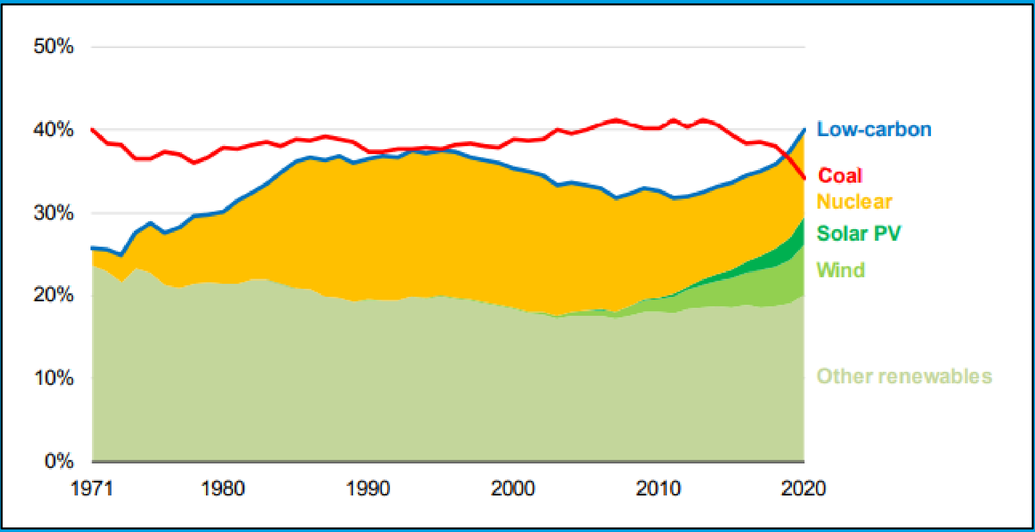
Energy production accounts for a major share of emissions. Accordingly, promoting sustainable production is directly related to lowering the human impact on the environment. Policy instruments that phase out fossil fuels (e.g. coal), which are responsible for the high level of CO_2 emissions, while improving renewable energy generation capacity are an important component in the energy transition. As already emphasized throughout this chapter, a diversification of energy supply may be beneficial when facing limited energy access and a lack of electricity infrastructure.

Many countries, including Botswana, Rwanda and Burundi (UNICEF Burundi, 2016; IEA, 2016), have introduced incentives for the adoption of small-scale, off-grid solutions in rural areas with low access to the centralized grid. Small-scale initiatives can adopt clean technologies for cooperative societies and federations (e.g. Mauritius, IEA, 2018a). Some countries also provide tax incentives for investments in renewable energy, both for businesses and households (e.g. Madagascar, Kenya). Another option is exemplified by Colombia, which is investing in new renewable sources through its first geothermal project in 2021 (Ministerio de Minas y Energia, 2021), having already provided incentives for capital investments in renewable energy integration in 2014 (IEA, 2018). According to the latest national budget, India has planned to improve its renewable energy generation capacity through the Solar Energy Corporation and the India Renewable Energy Agency, expanding their loan facility up to 102 billion rupees (Government of India, 2021).

Box 6. Coal power

Various airborne toxins and pollutants are released when coal is burned. These include CO_2, which has a long-term global impact on climate change as a GHG. Additionally, surface or underground coal mining has been known to cause physical disturbances of the landscape, subsidence of settlements, erosion, surface run-off and sediment control, degradation of surface and ground water quality, fugitive methane, threats to public safety, human health (e.g. coal miners) and local biodiversity (Suárez-Ruiz, Diez and Rubiera, 2019). The burning of coal generates local pollutants at a higher intensity than many other fossil fuels that have serious impacts on human health. Burning coal is also a leading cause of smog, acid rain and toxic local air pollution. These pollutants include mercury, lead, sulphur dioxide, nitrogen oxides, fine particulate matter, and other heavy metals. Furthermore, coal is among the fossil fuels that emit the highest rate of CO_2 when combusted, producing between 40 per cent and 50 per cent more emissions than gasoline. Recently, coal and coal-fired power has experienced a progressive decline in demand and in turn in consumption (IEA, 2020). Figure 36 shows that power generated from low-carbon sources has been outperforming coal power globally since 2019, as many countries are pushing for a phasing-out of coal with concrete policy actions.

Figure 36. Sources of global power supply



Source: IEA, 2020

After recognizing the significant impact of coal-sourced emissions on human and environmental health, the Senate of Chile approved a law prohibiting future installations and the operation of coal-fired power plants on its territory. Chile has also pledged to eliminate coal from its energy mix by 2040, phasing out 11 coal units by 2024 (Ministerio de Energias, 2020). Slovakia has ordered the decommissioning of two solid-fired power plants from 2021 onwards. Hungary is planning to phase out coal-fired electricity generation by 2030, with a parallel ten-fold increase in solar power generation of its current capacity.

The shift towards renewable energy sources is also driven by linkages to the circular economy paradigm and the recovery of energy through waste-to-energy procedures. Jamaica has been focusing on waste-to-energy a as relevant source since 2015 within the National Renewable Energy Policy 2010–2030 and the National Biofuel Policy 2010–2030 (Jamaican Ministry of Energy and Mining, 2010). To promote a more circular energy production and consumption system, Ireland is drafting a new circular economy legislation (Circular Economy Bill), prohibiting new explorations for the extraction of oil and gas by 2021 (Department of the Environment, Climate and Communications, 2021).

Energy consumption and intensity

Another significant component of the overall efforts to reduce energy consumption is energy intensity and sustainable energy management. Indonesia, for instance, has introduced standards of maximum electricity consumption per tonne of production in industrial (sub-)sectors. Viet Nam has also set specific targets for energy efficiency, efficient combustion of fossil fuels, lighting technologies, and heating and cooling for industries (Viet Nam Law Insight, 2014). In 2022, Brazil piloted the "Demand Response Programme", aiming at reducing the consumption of electricity, particularly through financial compensation for energy savings (Nacional, 2020). South Africa, Chile and Brazil have promoted new energy management standards (ISO 50001/SANS 50010) in the industrial sector with the purpose of improving energy security, promoting job creation and reducing emissions (UNIDO, 2019).

Energy consumption as a major contributor to CO_2 emissions has been subject to strict regulation, especially for large enterprises. In Moldova, for instance, the government has established a system of energy audits for large companies (IEA, 2021b). The Russian Federation has implemented a system of "energy passports" which enterprises must present during mandated (or voluntary) energy audits (Federal Law No. 261-FZ On Saving Energy and Increasing Energy Efficiency, and on Amendments to Certain Legislative Acts of the Russian Federation; IEA, 2020). Following in the footsteps of the European Union, California, Quebec, China and Kazakhstan, Mexico has implemented an emission trading system for heavily polluting industrial sectors (Secretaría de Medio Ambiente y Recursos Naturales, 2021). On the other hand, South Africa has introduced a carbon tax on different types of GHGs, along with a system of emission allowances for specific sectors (Republic of South Africa, 2017).

Box 7. Nuclear power

As of 2018, nuclear power provides 10 per cent of global energy supply, with 452 active reactors operating in 31 countries. It covers over half of the energy demand in France, Hungary and Slovakia, and one-third in the Republic of Korea and the USA. As coal-fired energy generation is progressively declining, many countries are relying on nuclear power to meet demand (IEA, 2019a). Nuclear power can help curb CO_2 emissions as a transitional energy source, but due to the problem of nuclear waste, debates are ongoing whether it can be considered a sustainable source of energy. For instance, nuclear power has been included within the EU-wide taxonomy for sustainable finance, despite calls against this by some Member States (European Commission, 2022)

High global demand for heating and cooling make it a suitable area for policy intervention (IEA, 2021a). Industrial process heating emitted 7.5 metric gigatonnes of CO_2 worldwide in 2016 (Bloomberg NEF, 2021). Meanwhile, the investment gap for renewable industrial heating stands at a staggering US$ 3.7 trillion (Bloomberg NEF, 2021). The Republic of Korea, for example, is increasing its efforts in monitoring and has introduced a nation-wide heat map to increase the use of wasted heat for all its sources. India, on the other hand, was the first country to issue a comprehensive policy package on sustainable cooling in 2019 (Indian Cooling Action Plan), with specific targets to reduce its demand and energy requirements and to improve research on sustainable cooling. India's research and development (R&D) in new cooling systems envisions investments in new manufacturing technologies (e.g. equipment and machinery) to align domestic production and demand (Ministry of Environment, Forest Climate Change, 2019).

Meeting more industrial energy needs for heating could also be achieved by exploiting synergies, as some industrial processes (e.g. cement, food processing) involve heat as an input. In fact, some industry sub-sectors (i.e. food and beverages, chemicals) produce residues that can be used as feedstock for biogas production used for heating purposes (IEA, 2021a). The implementation of more integrated solutions at the local level (urban, industrial) are designed to enhance cooling and heating efficiency, as well as to recover waste heat from industrial processes and other available excess heat. So-called "district heating and cooling" (DHC) systems consist of one or more sources of heat and a network of pipes that deliver a hot or chilled fluid to consumption centres. The centre may be a residential block, a neighbourhood, a district or even an entire city and its residential and industrial consumers. For instance, 12 per cent of Finland District Heating's heat supply consists of residuals of industrial wood (IEA, 2021a), fitting into the general framework of industrial symbiosis where waste (e.g. wood scraps) produced by one sector is used to produce energy for another.

Box 8. Blended finance

Blended finance is the strategic use of development finance for the mobilization of additional funds towards sustainable development in developing countries. It encompasses all efforts of public and philanthropic entities to promote private investments in areas related to the SDGs (OECD, 2019; Convergence, 2020). Blended finance initiatives provide capital at a below-market cost (concessional debt or equity), ensure guarantees for credit enhancement for certain initiatives, facilitate investment in the utilization of funds (i.e. technical assistance fund) or the design of the transaction (Convergence, 2020). Examples include Blue Bonds for debt conversion in Small Island Developing States, ACELI Africa and the Sustainable Seafood Fund.

Box 9. Green hydrogen

Due to hydrogen's high mass energy density, light weight, and easy electrochemical conversion it can carry energy through pipelines or in the form of liquid fuels. So-called "green" hydrogen is produced through water electrolysis powered by renewably sourced energy, splitting water molecules into hydrogen and oxygen. It can thus play a key role in decarbonizing the economy. Currently, green hydrogen entails higher production costs compared to other energy carriers, batteries or hydrogen produced with fossil fuels (Oliveira et al., 2021). While only 5 per cent of produced hydrogen was "green" in 2018, it is estimated to become cost-competitive by the mid-2030s and account for 14 per cent of the world's total final energy consumption by 2050 (IRENA, 2019). There are four main channels through which green hydrogen can spur industrial development (IAP, 2022):

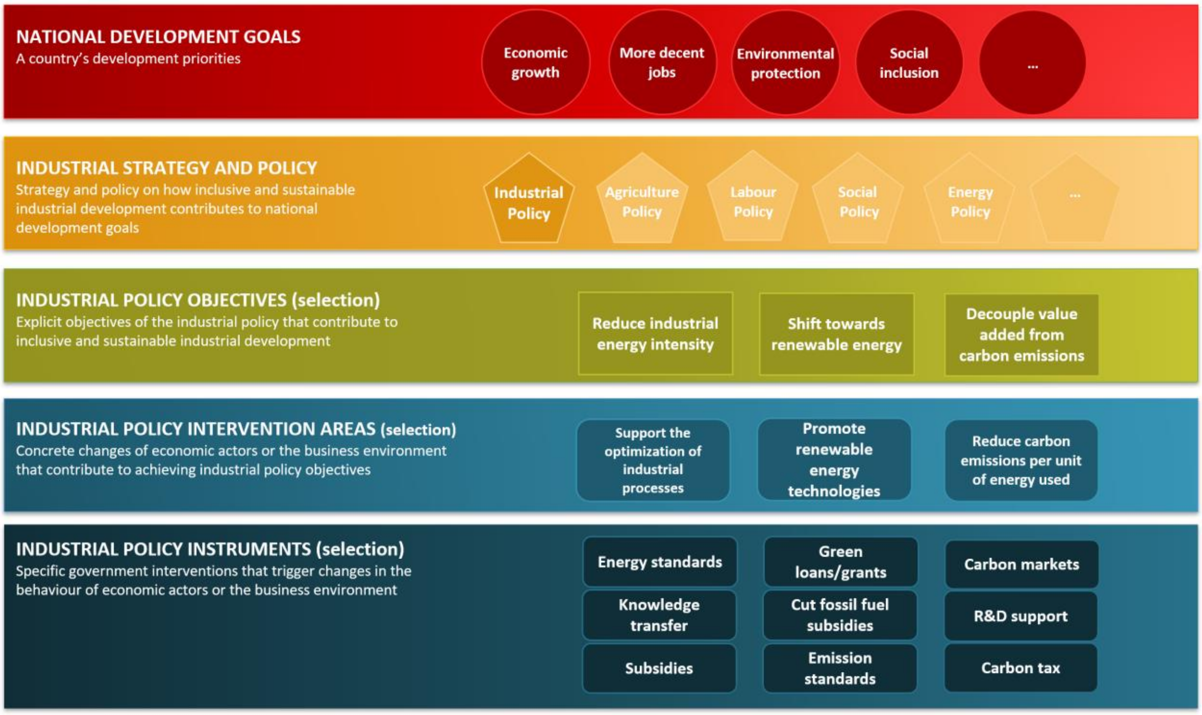
1. Investments in renewable power
2. Investments in electrolysers
3. Increase its attractiveness for energy-intensive industries
4. Hydrogen-based technology exports.

Green hydrogen is a promising export option for many low- and middle-income countries, many of which are endowed with abundant renewable energy resources. The IEA (2019) estimates that the most attractive sites for producing green hydrogen on the basis of solar and wind energy are located in Africa, the Middle East, Southern Asia and the Western parts of South America. These countries usually have relatively small domestic industries and thus lower local demand for green hydrogen. They are presented with the strategic choice of turning green hydrogen into a new export commodity (channels 1 and 2) or use it as a steppingstone towards a diversified and knowledge-based economy (channels 3 and 4) (IAP, 2022).

In the first scenario, countries that are well-endowed with solar, wind or other renewable power sources need to encourage investments in energy parks, electrolysers, and related feedstock as well as the required export infrastructure, including pipelines and ports. Such investments can boost export revenues, yet tend to be capital-intensive, with very limited effects in terms of employment creation and technological learning. In the second scenario, governments take low-cost renewable power and green hydrogen as the basis for creating industrial clusters and value chains with higher value added. Countries such as South Africa and Brazil have already settled on a hybrid option by engaging in both pathways (IAP, 2022).

For a country to successfully exploit green hydrogen to attract energy-intensive industries, such as the steel and chemical industries, a variety of factors must be considered: inter-industry linkages, the availability of a qualified workforce and investment climate issues affect the choice of location for such industries. Furthermore, regulatory safeguards are needed to ensure that green hydrogen industry development does not exacerbate existing water scarcity or land use conflicts (IAP, 2022).

Table 9. Energy & CO_2 policy implication matrix



NATIONAL DEVELOPMENT GOALS
A country’s development priorities

Economic growth
More decent jobs
Environmental protection
Social inclusion
...

INDUSTRIAL STRATEGY AND POLICY
Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals

Industrial Policy
Agriculture Policy
Labour Policy
Social Policy
Energy Policy
...

INDUSTRIAL POLICY OBJECTIVES (selection)
Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development

Reduce industrial energy intensity
Shift towards renewable energy
Decouple value added from carbon emissions

INDUSTRIAL POLICY INTERVENTION AREAS (selection)
Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives

Support the optimization of industrial processes
Promote renewable energy technologies
Reduce carbon emissions per unit of energy used

INDUSTRIAL POLICY INSTRUMENTS (selection)
Specific government interventions that trigger changes in the behaviour of economic actors or the business environment

Energy standards
Knowledge transfer
Subsidies
Green loans/grants
Cut fossil fuel subsidies
Emission standards
Carbon markets
R&D support
Carbon tax

Table 10. List of policy options: Energy & CO_2

		Energy consumption and CO_2 emissions policy instruments/ mechanisms	
		Market-based interventions/ decentralized provision	**Public inputs/ direct provision**
Policy domain/ market failure being addressed	**Product**	• Lifecycle analysis with a focus on CO_2 emissions	• Energy management standards for production (e.g. ISO) • Promoting energy efficiency along the supply chain through regulations • Net-zero and net-positive industrial standards • Cap on emissions or fossil fuel use
	Capital	• "Green" incentives and support mechanisms granted for energy efficiency investments: - Capital incentives for off-grid solar/wind facilities - Subsidizing improvements of domestic energy generation capacity from renewables - Loan guarantees and lower interest rates for investments in energy efficiency projects • Phasing out of fossil fuel subsidies • Punitive taxes, fees, and user charges: - Taxes on fossil fuel extraction - Non-renewable energy tax - Carbon (emission) tax - Shadow carbon pricing • Carbon markets	• Ban on new exploration of fossil fuel discoveries (reserves)
	Labour	• Grants for capacity-building in energy efficiency and renewable energy (e.g. construction and maintenance)	
	Technology	• R&D subsidies and grants to - finance technological development of renewables and energy efficiency - improve discovery, use and market scalability of alternative sources (e.g. hydrogen, waste) - improve adaptation at industrial level	• State-supported wind and solar farms • Promotion of energy efficiency technology alternatives

References

Austen, M., Andersen P., Armstrong C., Döring R., Hynes S., Levrel H., Oinonen S., Ressurreição A., & Coopman J. (2019). *Valuing Marine Ecosystems – Taking into Account the Value of Ecosystem Benefits in the Blue Economy.* Preprint. MarXiv. https://doi.org/10.31230/osf.io/vy3kp.

Ayompe, L. M., Davis, S. J., & Egoh, B. N. (2020). Trends and Drivers of African Fossil Fuel CO_2 Emissions 1990–2017. *Environmental Research Letters 15 (12):* 124039. https://doi.org/10.1088/1748-9326/abc64f.

Bloomberg NEF (2021). *Hot Spots for Renewable Heat.* https://assets.bbhub.io/professional/sites/24/BloombergNEF-Hot-Spots-for-Renewable-Heat-Sep-2021.pdf.

Borthakur, A. (2020). Policy Approaches on E-Waste in the Emerging Economies: A Review of the Existing Governance with Special Reference to India and South Africa. *Journal of Cleaner Production 252 (April):* 119885. https://doi.org/10.1016/j.jclepro.2019.119885.

Campbell, E., McDarris, A., and Pizer, B. (2021). *Border Carbon Adjustments 101. 6.*

Canada, Natural Resources (2020). *Government Invests in Canada's Tidal Power Industry.* News releases. 9 September 2020. https://www.canada.ca/en/natural-resources-canada/news/2020/09/government-invests-in-canadas-tidal-power-industry.html.

Carlos-Alberola, M., Izquierdo, A. G., Colomer-Mendoza, F. J., and Barreda-Albert, E. (2021). Design of a Municipal Solid Waste Collection System in Situations with a Lack of Resources: Nikki (Benin), a Case in Africa. *Sustainability 13 (4):* 1785. https://doi.org/10.3390/su13041785.

Chin, H. H., Varbanov, P. S., Klemeš, J. J., and Bandyopadhyay, S. (2021). Subsidised Water Symbiosis of Eco-Industrial Parks: A Multi-Stage Game Theory Approach. *Computers & Chemical Engineering 155 (December):* 107539. https://doi.org/10.1016/j.compchemeng.2021.107539.

Chopra, K. R., & Millennium Ecosystem Assessment (Program), eds. (2005). Ecosystems and Human Well-Being: Policy Responses: Findings of the Responses Working Group of the Millennium Ecosystem Assessment / Edited by Kanchan Chopra ... [et Al.]. *The Millennium Ecosystem Assessment Series, v. 3.* Washington, DC: Island Press.

Damiyano, D., Muchabaiwa, L., Mushanyuri, B. E., & Chikomba, C. P. (2012). *An Investigation of Zimbabwe's Manufacturing Sector Competitiveness,* 18.

Davis, S. J., & Caldeira, K. (2010). Consumption-Based Accounting of CO2 Emissions. *Proceedings of the National Academy of Sciences 107 (12):* 5687–92. https://doi.org/10.1073/pnas.0906974107.

Department of the Environment, Climate and Communications (2021). *Circular Economy Bill.* Government of Ireland. https://assets.gov.ie/137605/10140ef7-a8ef-41c2-b7e9-de375b9f4a18.pdf.

Eggleston, H. S., Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme, & Kikan, C. K. S. K. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2.* http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

Egüez, A. (2021). Compliance with the EU Waste Hierarchy: A Matter of Stringency, Enforcement, and Time. *Journal of Environmental Management 280 (February):* 111672. https://doi.org/10.1016/j.jenvman.2020.111672.

EIA (2016). *Industrial Sector Energy Consumption.*

European Commission (2022). *Complementary Climate Delegated Act.* Commission Delegated Regulation amending Delegated Regulation (EU) 2021/2139 (March 9th). https://eur-lex.europa.eu/resource.html?uri=cellar:8cee7f13-a162-11ec-83e1-01aa75ed71a1.0023.02/DOC_1&format=PDF

Fischedick, M.J., Roy, J., Abdel-Aziz, A., Acquaye, A., Allwood, J. M., Ceron, J-P., Geng, Y., et al. (2014). Industry. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* 739–810. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter10.pdf.

GET.invest. (n.d.) *Zambia- Energy Sector.* Accessed 2 December 2021. https://www.get-invest.eu/market-information/zambia/energy-sector/

GIZ (2021). *Modernized, Climate-Friendly Solid Waste and Recycling Management in Albania.* https://www.giz.de/en/downloads/Solid%20Waste_Factsheet_EN.pdf.

Government of India (2021). *Budget 2021–2022.* Speech of Nirmala Sitharaman Minister of Finance.

Guan, D., & Reiner, D. M. (2009). Emissions Affected by Trade among Developing Countries. *Nature, Opinion, 462:* 1.

IAP (2022). *Green Hydrogen: Fuelling industrial development for a clean and sustainable future.* IAP. 2022. https://iap.unido.org/articles/green-hydrogen-fuelling-industrial-development-clean-and-sustainable-future

IEA (2016). *Renewable Energy Fund for Off-Grid Solutions – Policies.* IEA. 2016. https://www.iea.org/policies/5899-renewable-energy-fund-for-off-grid-solutions.

IEA (2017a). *Business Models for Collecting Waste in Low-Income Areas.* https://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/1%20Waste%20Collection_Apr6/index.pdf.

IEA (2017b). *Business Models for Integrated Waste Management.* http://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/4%20Integrated%20Waste%20Manangement_Apr6/index.pdf.

IEA (2018a). *Green Energy Scheme for Cooperatives – Policies.* IEA. 2018. https://www.iea.org/policies/6432-green-energy-scheme-for-cooperatives.

IEA (2018b). *The Future of Petrochemicals,* 132.

IEA (2019a). *Africa Energy Outlook 2019,* Regional Report, 288.

IEA (2019b). *Africa Energy Outlook 2019 – Kenya,* 20.

IEA (2019c). *Africa Energy Outlook 2019 – Tanzania,* 19.

IEA (2019d). *Africa Energy Outlook 2019 – Mozambique,* 20.

IEA (2019e). *World Energy Outlook 2019.* World Energy Outlook, 11.

IEA (2019f). *The Future of Hydrogen – Seizing today's opportunities*

IEA (2020). *Federal Law No. 261-FZ 'On Energy Conservation and Increase of Energy Efficiency'*

IEA (2021a). *Renewable Energy Policies in a Time of Transition: Heating and Cooling,* 150. Innovation Policy Platform.

IEA (2021b). *Energy Efficiency Law - Republic of Moldova,* Policies.

Institute for Human Rights and Businesses (2016). Setting the Scene :Overview of Kenya's Extractive Sector. In *Human Rights in Kenya's Exctractive Sector, 10.*

IRENA (2020). *Energy Subsidies: Evolution in the Global Energy Transformation to 2050.* https://www.irena.org/publications/2020/Apr/Energy-Subsidies-2020.

Jakob, M. (2021). Climate policy and international trade – A critical appraisal of the literature. *Energy Policy, 156,* 112399. https://doi.org/10.1016/j.enpol.2021.112399

Jamaican Ministry of Energy and Mining (2010). *Draft- National Energy-from-Waste Policy.* https://www.mset.gov.jm/wp-content/uploads/2019/07/Draft-Waste-to-Energy-Policy_0.pdf.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. *Resources, Conservation and Recycling 127 (December):* 221–32. https://doi.org/10.1016/j.resconrec.2017.09.005.

KPMG Global (2021). *Carbon Border Adjustment Mechanism (CBAM). 4.*

Ministerio de Minas y Energia (2021). *Histórico de Noticias GM.* 2021. https://www.minenergia.gov.co/en/web/10180/historico-de-noticias?idNoticia=24279957.

Ministry of Environment, Forest Climate Change (2019). *India Cooling Action Plan.* http://www.indiaenvironmentportal.org.in/files/file/INDIA%20COOLING%20ACTION%20PLAN.pdf.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., de Meester, S., & Dewulf, J. (2019). Circular Economy Indicators: What Do They Measure? *Resources, Conservation and Recycling 146 (July):* 452–61. https://doi.org/10.1016/j.resconrec.2019.03.045.

Nacional, Imprensa (2020). *Portaria Nº 460, de 21 de Dezembro de 2020 – DOU – Imprensa Nacional.* 29 December 2020. https://www.in.gov.br/web/dou.

Nicastro, R., & Carillo, P. (2021). Food Loss and Waste Prevention Strategies from Farm to Fork. *Sustainability 13 (10):* 5443. https://doi.org/10.3390/su13105443.

OECD (2018). Improving Plastics Management: Trends, Policy Responses, and the Role of International Co-Operation and Trade. *OECD Environment Policy Papers 12. Vol. 12.* OECD Environment Policy Papers. https://doi.org/10.1787/c5f7c448-en.

Republic of South Africa (2017). *Draft Carbon Tax Bill.* http://www.treasury.gov.za/public%20comments/CarbonTaxBll2017/Draft%20Carbon%20Tax%20Bill%20December%202017.pdf.

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A Taxonomy of Circular Economy Indicators. *Journal of Cleaner Production 207 (January):* 542–59. https://doi.org/10.1016/j.jclepro.2018.10.014.

Salhofer, S., Jandric, A., Soudachanh, S., Xuan, T. L., & Tran, T. D. (2021). Plastic Recycling Practices in Vietnam and Related Hazards for Health and the Environment. *International Journal of Environmental Research and Public Health 18 (8):* 4203. https://doi.org/10.3390/ijerph18084203.

Secretaría de Medio Ambiente y Recursos Naturales (2021). *Documentos técnicos sistema de comercio de emisiones.* Gobierno de México. https://www.gob.mx/semarnat/documentos/documentos-tecnicos-sistema-de-comercio-de-emisiones

Sotamenou, J., De Jaeger, S., & Rousseau, S. (2019). Drivers of Legal and Illegal Solid Waste Disposal in the Global South – The Case of Households in Yaoundé (Cameroon). *Journal of Environmental Management 240 (June):* 321–30. https://doi.org/10.1016/j.jenvman.2019.03.098.

Tearfund (2016). *Virtuous Cycle- How the Circular Economy Can Create Jobs and Save Lives in Low and Middle-Income Countries.* Tearfund. https://www.researchgate.net/publication/306562812_Virtuous_Circle_how_the_circular_economy_can_create_jobs_and_save_lives_in_low_and_middle-income_countries.

TEEB (2010). *The Economics of Ecosystems and Biodiversity.* The Economics of Ecosystems and Biodiversity. http://teebweb.org/publications/teeb-for/business-and-enterprise/.

UNEP (2015). *Energy Profile- Zimbabwe.* United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/20589/Energy_profile_Zimbabwe.pdf?sequence=1&isAllowed=y.

UN-HABITAT (2010). *Collection of Municipal Solid Waste, Key Issues for Decision-Makers in Developing Countries.* United Nations. https://unhabitat.org/sites/default/files/download-manager-files/Collection%20of%20Municipal%20Solid%20Waste%20%2C%20Key%20issues%20for%20Decision-makers%20in%20Developing%20Countries.pdf.

UNICEF Burundi (2016). *Decentralized Rural Electrification Strategy (2015–2017).* UNICEF. http://causetech.net/files/DRE-Strategy-One-pager.pdf.

UNIDO (2012). Industrial Development Report 2011: Industrial Energy Efficiency for Sustainable Wealth Creation – Capturing Environmental, Economic and Social Dividends. *Industrial Development Report.* UN. https://doi.org/10.18356/2361d4c0-en.

UNIDO (2019). *Industrial Energy Efficiency Improvement Project.* https://www.unido.org/sites/default/files/2011-12/IEE%20BROCHURE-22%2022%2022%20signoff%20for%20print_0.pdf.

UNIDO (2016). Industrial Development Report 2016. *Industrial Development Report, 42.*

Viet Nam Law Insight (2014). *Circular 24/2014/TT-BCT.* Vietnam Law Insight. 2014. https://vietnamlawinsight.wordpress.com/tag/circular-242014tt-bct/.

World Bank, GDFRR (2011). *Climate Risk and Adaptation Country Profile – Sri Lanka.* https://climateknowledgeportal.worldbank.org/sites/default/files/2018-10/wb_gfdrr_climate_change_country_profile_for_LKA.pdf.

World Business Council for Sustainable Development (2018). *Circular Metrics- Landscape Analysis.* https://docs.wbcsd.org/2018/06/Circular_Metrics-Landscape_analysis.pdf.

World Economic Forum (2016). *The New Plastics Economy Rethinking the Future of Plastics.*

Wright, N. H. (2012). Dealing with Biodiversity in Corporate Venture Risk Exploration and Production. In *International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production.* Perth, Australia: Society of Petroleum Engineers. https://doi.org/10.2118/156806-MS.

Yu, B., Zhao, Q., & Wei, Y.-M. (2021). Review of carbon leakage under regionally differentiated climate policies. *Science of The Total Environment, 782,* 146765. https://doi.org/10.1016/j.scitotenv.2021.146765

3 Waste

Introduction

The third section of this tool focuses on waste production, prevention, and management. Waste management influences environmental and social well-being in many ways. Waste prevention and minimization is included in the framework of the SDGs, namely in Goal 11 (target 11.6). Signatory states have committed to reducing environmental pressures per capita by making "cities and human settlements inclusive, safe, resilient and sustainable". The objective, effectively, is to reduce waste from cities and municipalities, among other targets. Waste management also features in Goal 12: "Ensure sustainable consumption and production patters". The objective is not only to reduce the amount of waste produced (SDG 11), but also to improve the design and production methods of goods, thereby reducing the amount of waste their production and use generates (SDG 12).

More recent conceptual frameworks have considered waste to be a relevant part of the production and consumption process, with the possibility of (partial) recovery of its economic value for society. Within the ideal conceptualization of "*closing the loop*" of the production process, waste is central to the circular economy paradigm. Besides fostering a drastic reduction of waste generation, with the overarching aim of decoupling economic growth from environmental pressure, the circular economy framework is devoted to promoting the concept of waste as a *resource*. As opposed to a linear framework where waste would be merely collected and landfilled at the end of the lifecycle, the circular economy aims to reduce the amount of waste that has no value for society to the absolute minimum possible. This goal can be achieved through coherent waste treatment policies.

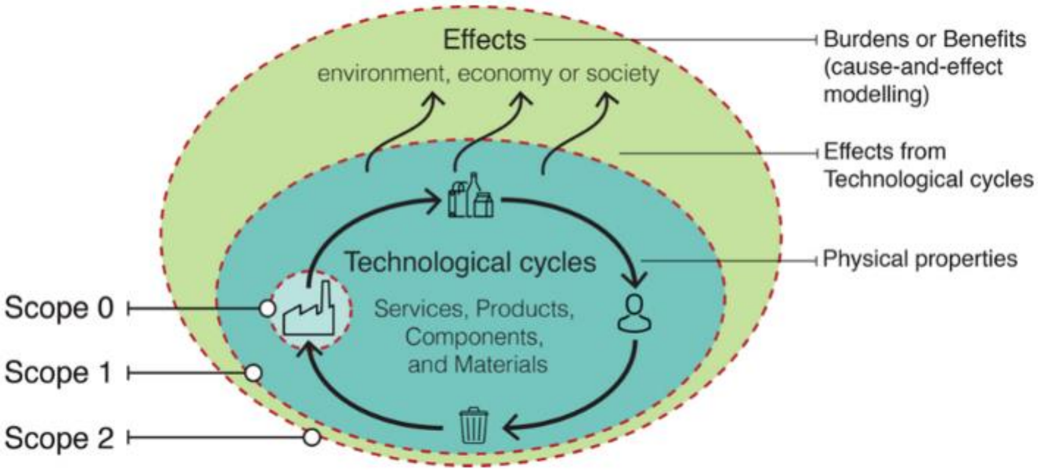
The underlying philosophy of waste management is summarized in the concept of the *waste hierarchy*. SGD target 12.5 requires states to "substantially reduce waste generation through prevention, reduction, recycling and reuse by 2030". The rationale behind the hierarchization of waste treatment options is to prefer processes that (partially) recover the value of waste and, even more so, waste reduction. The so-called *waste pyramid,* illustrated in **Figure 37**, provides an intuitive visual representation of this framework.

Figure 37. Waste pyramid

Source: https://ec.europa.eu/environment/topics/waste-and-recycling/waste-framework-directive_en

These processes are, up to a certain extent, applicable to certain kind of waste. Where it is not possible to recover waste for reuse or recycling, the hierarchy next recommends disposal methods that recover energy via either chemical or physical transformations (e.g. aerobic/anaerobic digestion, composting, incineration). At the very end of the pyramid, the share of material that cannot be recovered is disposed of in landfills. Waste management is a major component of the circular economy paradigm and is very much related to the end of the value chain as well as to both the production and consumption processes. Conceptually, the upper side of this virtuous production cycle comprises product design and engineering (e.g. eco-design), with a strong emphasis on industry and production processes. In the ideal framework of a circular production process, all waste that is recovered through appropriate management options will contribute to the raw material stock for the production of goods. Accordingly, waste management could ideally become a consistent supplier of inputs for industrial production processes in the form of either (secondary) raw materials or energy. On the production side, the more a system relies on such sources as inputs, the more self-sufficient its production (and consumption) regime becomes, i.e. the closer it comes to closing the loop of the circular economy.

Figure 38. Scope of analysis of circular production and consumption systems



Source: (Moraga et al., 2019)

In practical terms, it is not possible to achieve fully closed production systems. Nonetheless, a comprehensive strategy promoting a circular-aligned waste management policy, energy and material efficiency is considered a pivotal step in achieving a societal transition towards sustainability. In this sense, as depicted in **Figure 38**, the analysis of those aspects may comprise an assessment only of the technological cycle (e.g. recycling rate) in *Scope 0*. In the next step, *Scope 1* also includes the potentials of that specific technological cycle (e.g. recycle, reuse, recovery). Finally, in *Scope 2*, the focus lies on the effects of the technological cycle with respect to the economy and the environment. Due to its intrinsic materiality, manufacturing plays a major role in how resources are transformed and managed, and hence plays a major role in the transition towards circularity. The degree to which waste products can become a secondary material supply stream of significant proportions largely depends on the products' initial design, which determines whether repair or recycling is possible (World Bank, 2018). Thus, product standards are crucial in directing a critical mass of waste flows into circularity.

Box 10. Industrial symbiosis

Within the framework of a circular self-sufficient production process, the concept of *industrial symbiosis* represents virtuous collaborations among industries in terms of exchange of resources. The term “symbiosis” has been borrowed from the discipline of ecology, where different ecosystems are linked through the exchange of nutrients, chemicals, and organic matter. In the industrial sector, this mutually beneficial exchange has mostly focused on the exploitation of unutilized resources from one industry that can be beneficial for another (e.g. *co-processing*) (Lawal et al., 2021). In more practical terms, the waste of one manufacturer may serve as a resource for a different one. The final objective of industrial symbiosis is to create chains of value among different industries to maximize resource utilization within the overall system. Co-processing instances are well-established in some industries (cement, iron and steel), where the waste of one industrial process is used as raw material for another (Cravioto et al., 2021). Exchanges may also involve energy where waste in one industry can provide energy to another via waste-to-energy practices (e.g. the use of lignin as fuel in pulp and paper or wood scraps or bagasse from sugar production) (Mancini et al., 2021; Fraccascia et al., 2021). Industrial symbiosis involves both the industrial sector and relevant stakeholders (e.g. municipalities, government, civil society), with the aim of creating an urban-industrial ecosystem of sustainable production and consumption.

This chapter singles out an appropriate set of measures and indicators to provide users of this tool with a comprehensive dashboard that includes several aspects of waste management and the analysis of waste flows.

The underlying objective is to present a set of tools to assess the state of waste management in the country and to facilitate benchmarking with comparable economies. The focus lies on the circularity aspects of waste management, namely procedures in line with a circular economy approach. The level of analysis entails the country’s overall socio-economic system with specific insights on the industrial sector. The more granular the data availability, the better for effective evidence-based policymaking. As the drive to collect waste data is relatively new, coverage and granularity are unfortunately still limited. This analysis is therefore limited to the national level, as a deeper and more detailed industry-level analysis was not possible. While this chapter primarily uses publicly available data from international databases, it may be possible in some countries to find more granular data at local or national level. It is recommended for policy analysts to investigate the availability of such data from the respective national waste authority/ office for national statistics, etc. to better understand the industrial sector’s waste flows. The same indicators can then be used for a more disaggregated level of analysis. In fact, the availability of data on specific flows (e.g. industrial, hazardous, etc.) or at different levels of analysis (e.g. regional, municipal, plant) should be considered a proxy of how much waste management implementation and monitoring is taken into consideration within the country’s policymaking framework.

Methodology

Box 11. Municipal waste generated vs collected

Two main flows of waste are used throughout this section as the basis for the computation of indicators. Data on waste collected, derived from the UNSD Environmental Indicators, represent the flow of waste collected by either the municipal authorities or by their bodies. Data on waste generated, which are taken from the World Bank, comprise the flow of waste collected plus an estimation of the flow that is not collected.

Data sources

Table 11 presents a summary of indicators and data sources analysed throughout this section. The main source of global data on waste at the country is the UN Environmental Statistics database (https://unstats.un.org/unsd/envstats/qindicators). It provides time series for flows of municipal (including industrial), hazardous and electronic waste (e-waste) along with the share of collected and recycled waste, waste composition and treatment options. It is currently considered the most comprehensive and best maintained dataset and is likely to improve further over time as countries report SDG data. Other advantages are that the UN collects data for each year, facilitating analyses of the trends of the most relevant variables in the set, and that several variables have been standardized to reflect countries' different socio-economic characteristics, thereby allowing for comparisons among a relatively diverse set of countries. The data are collected and reported by the office of national statistics of each country in compliance with the Basel Convention on "controlling the transboundary movements of hazardous waste and their disposal" (each member of the convention is required to report the status of waste management, available here: https://unstats.un.org/unsd/envstats/country_files).

A complementary source for the analysis is the "What a Waste 2.0 – A Global Snapshot of Waste Management to 2050" report issued by the World Bank Group in 2018. It provides an extensive snapshot on the state of waste management, focusing on municipal solid waste (MSW) flows. Data from this database cover municipal-, industrial- and hazardous waste generated (for the difference between waste generated and collected, see **Box 11**). This supplements the UN database as data on industrial and hazardous waste are reported in a separate account from the flow of municipal waste generated, which only comprises residential, commercial, and institutional sources. Moreover, the database also collects statistics on waste generated by the major cities of each country, thus enabling the same analysis at city level.

As for the choice of socio-economic variables for standardization, the analysis mainly uses value added for the industrial sector and GDP for the economy, as waste generation tends to increase with economic growth (Word Bank, 2018). Data on socio-economic variables have been retrieved from the World Bank database. Due to its particularly harmful impact on humans and the environment, hazardous waste has been classified as a hotspot indicator (see table below).

Table 11. List of indicators

Indicator	Level of analysis	Definition	Data source
Industrial waste share	Industry	Shares of industrial and hazardous waste flows in total amount of waste generated	World Bank: What a Waste 2.0
Hazardous waste share (SDG 12.4)	Country		
Intensity of municipal solid waste generated	Country	Ratio of municipal waste amount generated per unit of GDP	World Bank: What a Waste 2.0
Industrial waste intensity	Industry	Ratio of industrial waste amount generated per unit of industrial VA	World Bank: What a Waste 2.0 / WDI
Intensity of municipal solid waste collected	Country	Ratio of municipal waste amount collected per unit of GDP	UN Statistics: Environmental Indicators / World Bank: WDI
Waste composition	Country	Share of main categories (e.g. paper, metal, plastic, organic, non-organic) in total waste collected	UN Statistics: Environmental Indicators
Waste treatment (SDG 12.5)	Country	Share of waste treated per treatment option (compost, incineration, recycling, landfill, etc.)	UN Statistics: Environmental Indicators
Q index	Country	Sum of weighted share of treatment options (e.g. recycling, composting, incineration, landfill)	UN Statistics: Environmental Indicators

In a first step, the flows of the relevant waste categories (industrial, hazardous) are analysed in terms of integral values to aggregate the total amount of waste (in addition to municipal waste), as well as their respective shares in this total amount. Next, municipal waste is related to income levels (GDP), providing a specific measure of a country's tendency to produce waste in relation to different levels of wealth. In this sense, relating waste to socio-economic outputs also provides a measure of waste generation vis-à-vis the production of economic value. In another perspective, industrial waste generation is related to value added in the industrial sector as a measure of waste intensity. On the one hand, the rate of waste generated per unit of income is a proxy of the pressure that waste exerts on humans and the environment. On the other hand, the rate of waste collected reflects the potential capacity of a system to recover material or energy, as only waste that is collected can undergo further treatment. Waste collected per unit of income proxies the potential of a country to provide a reliable flow of waste for successive treatment.

Subsequently, an analysis on the composition of waste collected as a share of the key categories is provided. As regards materials, waste collection is plotted in relation to relevant measures of the stock of materials within a country. A further level of policy analysis aims to disentangle the share of treatment options and provides more in-depth insights into how diversified a country's waste treatment policy is. The analysis then focuses on different aspects of waste policy and its level of adoption or implementation in different countries.

A synthetic measure of a country's level of circularity policies regarding waste treatment is delivered using the Q Index (see indicator description below for more details). A combination of waste collected, and the Q Index classifies countries with respect to their achievement in terms of waste policy implementation as well as their level of circularity. A brief summary of the indicators follows, highlighting computation methods and data sources.

Indicators

3.1 Shares of industrial and hazardous waste

Definition

This indicator provides information on the shares of industrial and hazardous waste in total waste generated in a country. Total waste generated includes the flow of municipal solid waste, which is the most general level of information required to analyse a country's waste sector. Subsequent indicators provide examples of how the measure of waste generated can be employed, e.g. by relating waste generation to socio-economic variables. This enables a comparison among countries with different socio-economic characteristics.

While absolute waste generation trends can provide useful insights for policymakers about how to deal with future investments in the collection, coverage and capacity of treatment facilities, the relative share of waste flows illustrates the contribution of industry in total waste. Increasing attention is being paid to certain types of waste (e.g. plastics and e-waste) with harmful potential for both humans and the environment. Furthermore, controlling the level of hazardous waste generated in a country features prominently among the SDG targets (SDG 12.4) and within the framework of the Basel Convention. We therefore label it as a hotspot indicator.

Strategic questions

Direct inferences:

- How have the country's share of waste flows developed, i.e. how prevalent is industrial and hazardous waste?
- How does the share of waste flows compare with that in other countries?

Follow-up questions:

- How can the country's total amount of waste in general, and its amount of industrial and hazardous waste in particular, be reduced?

3.2 Municipal solid waste intensity

Definition

This indicator measures a country's municipal solid waste (MSW) generation in relation to its level of income. Relating waste generation to a socio-economic output can be considered a rough proxy of the country’s potential to decouple its economic growth from its waste generation. The relationship between MSW and GDP provides a standardized measure of the level of waste produced per unit of economic output at the country level. The indicator can thus be considered a measure of intensity of waste generation in the national economy. In strictly environmental terms, the higher the intensity of waste per unit of economic value, the higher the level of resources required to produce that unit of value. From this perspective, the amount of waste generated per unit of GPD allows for a certain inference on production and consumption behaviours associated with the country’s relative wealth.

The bulk of circular economy policy initiatives has been introduced by high-income countries that are now facing a structural lack of natural resources along with high production and consumption patterns. On the other hand, demographic trends accompanied by progressive economic development might influence consumption and production patterns as well as waste generation in low- to middle-income countries in the long run.

Strategic questions

Direct inferences:

- What is the amount of waste generated per unit of national income?
- How has the country’s waste intensity developed over time?
- How does this development compare to that of other countries?

Follow-up questions:

- Why are some countries with similar increases in wealth generating less waste?
- How can the country’s waste intensity be reduced?

Equation

$$\boldsymbol{Municipal\ solid\ waste\ intensity\ (tonnes\ per\ \$)} = \frac{\boldsymbol{Municipal\ solid\ waste\ generated\ (tonnes)}}{\boldsymbol{Gross\ Domestic\ Product\ (US\$)}}$$

3.3 Industrial waste generated per unit of MVA

Definition

This indicator relates the industrial sector’s waste flow to its value added. Data on industrial waste does not include the construction sector, which is why MVA can be used here (see this tool’s correspondence table). This measure assesses the industrial sector’s relative intensity in producing disposable outputs in relation to its capacity to generate value for a country’s economy. The lower the amount of waste per dollar of value added, the better the industrial sector’s capacity to produce value by fully harnessing the use of material and energy resources. This indicator addresses waste intensity in the manufacturing sector specifically, providing insights into the capacity of a country’s manufacturing sector to provide value without overexploiting resources.

Strategic questions

Direct inferences:

- What is the rate of waste generation in the country's industrial sector considering its capacity to generate value?
- How does this intensity compare to that of similar countries?

Follow-up questions:

- How can industrial waste intensity be reduced in the country's specific context?

Equation

$$Industrial\ waste\ generated\ per\ value\ added\ (tonnes\ per\ US\$) = \frac{Industrial\ waste\ generated\ (tonnes)}{Manufacturing\ value\ added\ (US\$)}$$

3.4 (Municipal) waste collected per unit of GDP

Definition

"Waste collected" represents the starting point of waste management. Ideally, all waste generated from various sources is collected by municipal authorities, administrative bodies or the private sector (e.g. consortia, private enterprises) and subjected to different treatment procedures. Flows of waste collected represent a first step in the analysis with respect to the country's potential to recover material and energy. In fact, the more diversified collected waste is, the higher is the capacity of a system to enable circular production and consumption patterns.

Waste collected includes mixed waste and fractions collected separately for recovery operations (through door-to-door collection and/ or through voluntary deposits). It also includes bulky waste (e.g. white goods, old furniture, mattresses) and waste from selected municipal services, e.g. waste from park and garden maintenance, from street cleaning services (street sweepings, the content of litter containers, market cleansing waste), if reported as waste. It may be that countries only report certain sources of collection (e.g. households) and the definition generally excludes waste from municipal sewage networks and treatment, municipal construction and demolition waste.

This indicator relates the flow of waste collected to the country's income level measured in GDP. As mentioned above, the choice of standardizing waste flows with the respective income level is related to the correlation between level of income level and waste generation. It can be considered an indirect proxy of waste coverage with respect to the country's relative wealth, which represents the extent of implementation and scope of monitoring as well as the enforcement of a waste policy framework. Data on municipal waste is mostly collected for the residential and non-residential sectors (e.g. small businesses, commercial). While waste generated is a more direct measure of the intensity of waste in the economic system, waste collected provides insights into the system's potential to recover material and energy with respect to different income levels.

Strategic questions

Direct inferences:

- How does the amount of waste collected relate to the country's income level?
- How does this relationship compare with that of other similar countries?

Follow-up questions:

- How can the share of waste collected be increased while less waste is generated?

Equation

$$\boldsymbol{(Municipal\ Solid)\ Waste\ collected\ per\ income\ levels\ (tonnes\ per\ US\$)} = \frac{(Municipal\ Solid)\ Waste\ collected\ (tonnes)}{Gross\ Domestic\ Product\ (US\$)}$$

3.5 Waste composition

Definition

This indicator provides an overview of the composition of collected waste according to the main categories (paper, plastic, metals, organic, textiles and other inorganic materials). If collected separately, these flows could possibly be recycled. To provide insights into the effective rate of recycling of these main categories, the indicator should be coupled with the share of municipal waste that is recycled as a waste treatment option. A more diversified composition implies that the country's collection method is more segregated, therefore, a more complex set of treatment options to treat different types of waste exists as well. The more segregated a waste collection system is, the more opportunities it offers in terms of material recovery and circularity options.

Treatment options for unsegregated waste collection are limited to waste-to-energy, where some of the waste's energy content can be recovered or as a very last resort, be landfilled, which is the lowest value-recovery treatment option. In countries with a high share of organic waste, composting techniques are a more cost-efficient method to recover the most value from organic waste. Coupled with information on the rate of recycling, this indicator provides additional insights as to what extent a specific waste category is collected and treated. This might point towards an improvement of the industrial sector's capacity to treat specific streams of waste.

Strategic questions

Direct inferences:

- What is the composition of waste collected?
- What is the composition of waste that is recycled?

Follow-up questions:

- To what extent are the main waste material categories recycled in the country?

Equation

$$\boldsymbol{Waste\ composition}\ (\%) = \frac{\boldsymbol{Category\ of\ waste\ collected\ (tonnes)}}{\boldsymbol{(Municipal\ Solid)\ Waste\ collected\ (tonnes)}}$$

3.6 Waste treated (as a share of treatment options)

Definition

This indicator presents the shares of MSW that undergo different treatment options (i.e. landfill, recycling, composting, incineration, other – all remaining treatment options and those unaccounted for). This analysis aggregates all available treatment options into five main groups, considering their capacity to partially recover the economic value of waste – be it through material recovery or transformation into energy. The treatment option 'unaccounted for' represents the share of municipal waste generated for which no treatment information is available, and which therefore is estimated based on the shares reported by countries. The data allow for a comparison of different waste treatment methods employed at country level.

A highly diversified set of treatment options indicates a higher level of complexity in the country's waste policy, along with a higher commitment to aligning its waste management policy to circular economy principles. This indicator can therefore be considered a proxy of the presence of a diversified waste policy framework, whereas the presence of certain treatment options (e.g. recycling) can provide insights into its circularity. On the one hand, the higher the share of recycling and composting, the closer the country's alignment with circular economy principles that promote the possibility for waste to supply recovered material and energy to production processes. On the other hand, a high presence of flows that are landfilled or openly dumped implies more linear production and consumption patterns.

Strategic questions

Direct inferences:

- How diversified are a country's waste treatment options?

Follow-up questions:

- How sophisticated is the country's waste policy framework?

Equation

$$\boldsymbol{Waste\ treatment}\ (\%) = \frac{\boldsymbol{Flows\ of\ waste\ treated\ (tonnes)}}{\boldsymbol{(Municipal\ Solid)Waste\ collected\ (tonnes)}}$$

3.7 Q Index

Definition

The Q index is designed to proxy a country's policy preference on waste treatment for a given administrative unit (e.g. municipality, province, region, country). The score is the result of the weighted sum of shares of waste flows that undergo different treatments. The methodology has already been tested in the context of EU NUTS 2 regions (Egüez, 2021), providing a standardized means of comparison for the implementation of waste policy in an EU-wide framework and in assessing the cost effectiveness of waste treatment options in Italian provinces (Mazzarano et al., forthcoming).[3]

To make this methodology applicable to a wide range of countries, this analysis focuses on the four main treatment options of the waste pyramid (recycling, composting, incineration, landfilling). These categories comprise several processes that might at least partially imply the recovery of material or energy. This analysis assigns a score of 1 to 4 to each treatment option. According to the waste pyramid (**Figure 37),** recycling is considered the most preferable option, aside from waste reduction and reuse,

---

[3] Nomenclature of Territorial Units for Statistics (NUTS) is the geocoded standard for referencing the subdivision of countries for statistical reasons adopted by the European Union in 2003.

as it entails the recovery of material. Processes that involve the recovery of energy (e.g. waste that undergoes chemical or physical transformation to extract energy) is the next best option. The least preferred options are those that imply a mere disposal of waste, losing all recovery potential in terms of materials or other forms (e.g. incineration, landfill). Hence, in

Table 12, higher weights of 4 and 3 were assigned to the preferred categories of recycling and composting, respectively. The lower weight assigned to composting reflects its role in waste-to-energy treatments rather than in material recovery. Composting also comprises aerobic and anaerobic digestion as well as other processes to retrieve energy from waste. Lower weights of 2 and 1 were assigned to incineration and landfilling, respectively. Incineration also encompasses incineration processes that imply the (at least partial) recovery of energy through combustion (e.g. pyrolysis). On the other hand, landfilling also includes sanitary landfilling that implements a mechanism for treatment of gases. Even lower weights of 0.5 and 0.25 are associated with open dumping (Other) and waste which is unaccounted for. Collected waste without treatment information falls into the "Unaccounted for" option. The reason for this score is to penalize the lack of monitoring and enforcement mechanisms within a country's waste policy framework.

Strategic questions

Direct inferences:

- To what extent is the country's waste policy framework circular?

Follow-up questions:

- How is the country pursuing the ideal objective of "closing the loop"?

Equation

The Index Q represents the sum of each weighted group, divided by total flow. Accordingly, the computation of the Index is as follows:

$$\boldsymbol{Q_{i,t}} = \frac{\boldsymbol{w_1 G_1 + w_2 G_2 + w_3 G_3 + w_4 G_4 + w_5 G_5}}{\boldsymbol{MSW_{it}}}$$

$w_1 G_1$ = *weight and share of total waste recycled*
$w_2 G_2$ = *weight and share of total waste incinerated*
$w_3 G_3$ = *weight and share of total waste composted*
$w_4 G_4$ = *weight and share of total waste landfilled*
$w_5 G_5$ = *weight and share of total waste unaccounted for*
MSW= *Municipal Solid Waste*
i = *administrative unit*
t =*time*

Table 12. Weights per treatment option

Weight	Option
4	Recycling

3	Composting
2	Incineration
1	Landfill
0.5	Other
0.25	Unaccounted for

Analysis

Waste flow analysis has always been considered key for achieving a circular economy. Due to the nature of the circularity concept, it is quite challenging to provide a workable definition for policymakers and researchers (Kirchherr et al., 2017). This in turn has effects on the construction of a reliable set of indicators that encompasses all multiple dimensions of circularity. Indicators can either be classified in relation to the direct or indirect capacity of measuring an economy's circularity, or in relation to the level of analysis (e.g. product, country) (Saidani et al., 2019; Moraga et al., 2019). Direct indicators can be related to specific strategies of the circular economy paradigm (e.g. the rate of recycling is related to material recovery), whereas indirect indicators merely approach it via proxies (e.g. eco-innovation scores).

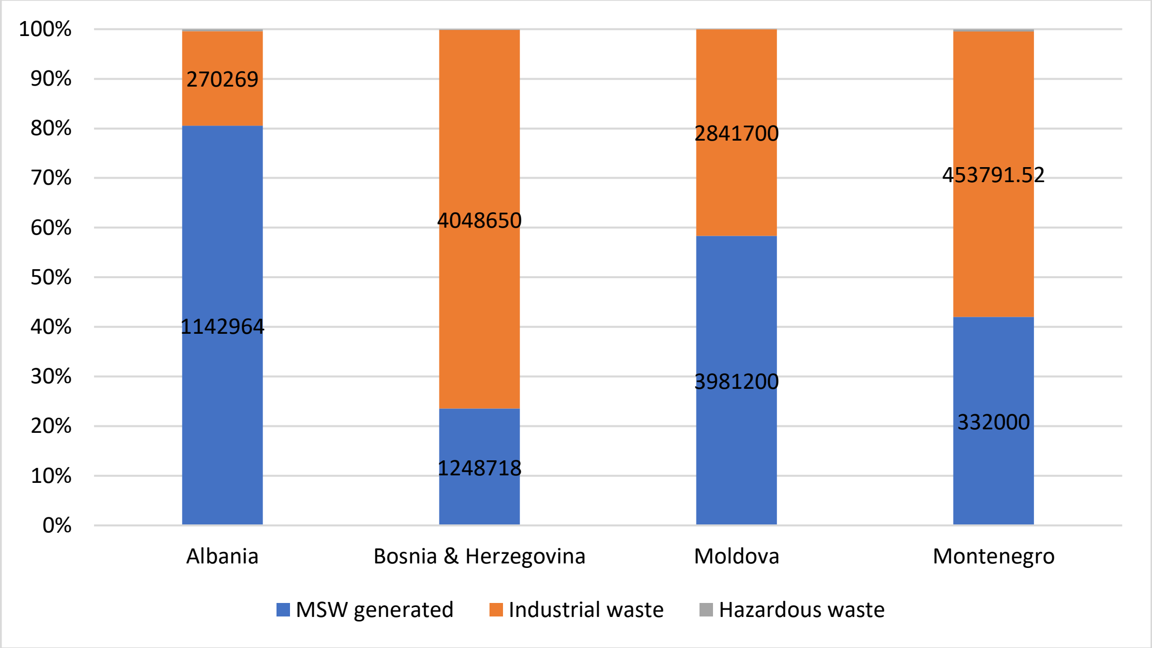
The following section provides an in-depth analysis of the main dimensions of the waste realm with a focus on indicators that are strongly linked to the circularity dimension. Indicators measure and possibly monitor physical flows (*Scope 0* of **Figure 38**), partially capturing the "looping" dimension of circularity *(Scope 1* of **Figure 38**) at the macro level (Moraga et al., 2019) (*Scope 2* of **Figure 38**). In other terms, the analytical approach in this section first provides insights into the flows of waste and the main dimensions of waste management (e.g. recycling). In a second step, by analysing the collection, composition, and treatment of waste at country level, this section offers insights into a system's potential to recover material or energy from waste flows. In a final step, coupled with the Material Section of this tool, the analysis illustrates the potential effects of a circularity-aligned waste management system for society and the environment.

We emphasize the policy aspect of waste management to assess the different stages of implementation of a circular-aligned waste policy framework. Five countries have been selected (Albania, Armenia, Bosnia and Herzegovina, Moldova, and Montenegro) to illustrate the previously presented indicators. Countries from the same region were chosen to allow for a better comparison in terms of waste generation and management, since this keeps socio-economic, cultural, and historical differences as limited as possible. Another more practical reason is the availability of complete waste data to feed all of the indicators presented.

Waste generation

Even though EQuIP targets the industrial sector as the primary object of analysis, all main categories of waste flows for which data are currently available (i.e. municipal, industrial, hazardous) are covered here to better understand how waste management can contribute to the achievement of a circular economy. **Figure 39** depicts the shares of waste flows in the total sum of waste generated that has been reported by each of the five example countries. The share of industrial waste in Bosnia and Herzegovina is remarkably high. The hazardous waste category only accounts for a negligible share in the data for all sample countries. Naturally, the overall picture this graph delivers is skewed by uneven and incomplete reporting on the part of the country. Nonetheless, it provides an initial overview of the role industrial and hazardous (chiefly from industrial sources) waste flows play in a country's waste generation.

Figure 39. Shares of waste generated



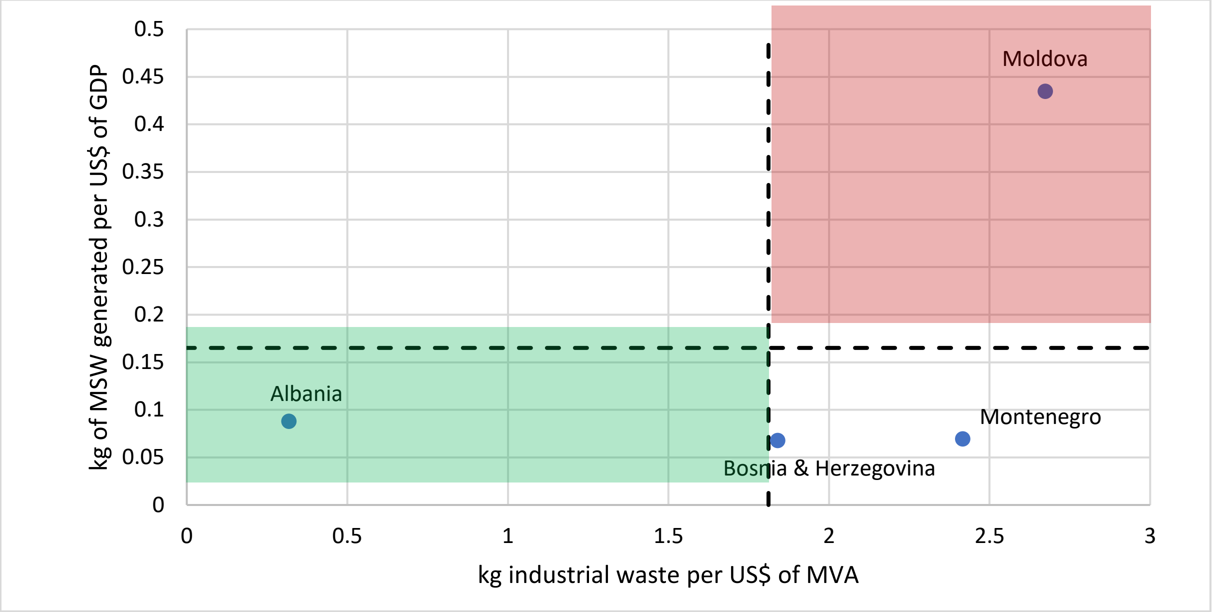
Source: Own graph based on World Bank "What a Waste 2.0" data 2018

When MSW is divided by GDP, we gain a standardized measure for waste generated per unit of income at the country level. This enables some inference on production and consumption behaviours associated with the country's relative wealth. When dividing industrial waste generated by value added, we obtain a measure of intensity for the amount of waste generated in relation to the sector's capacity to produce added value from the resources used. The higher a sector's industrial waste intensity, the more waste the sector generates relative to the added value it produces. The lower its industrial waste intensity, the more competitive the sector is at producing value added from the resources it uses. This indicator thus provides policymakers with a measure on the industrial sector's material efficiency. Aside from the environmental costs, highly waste-intensive production, and consumption systems, both at the industrial and municipal level, imply high administrative costs for waste collection, treatment and eventually disposal.

Ideally, a lower waste intensity implies that less waste is generated from one unit of economic output. Production processes with high waste intensity generate high administrative costs for waste collection and disposal. Plotting these two measures against each other provides insights into which sector contributes extensively to waste generation in relation to its capacity to produce (economic) value. This information could contribute to targeted policy measures to address waste intensity either at sectoral level or at the level of the overall economy.

Figure 40 proposes the positioning of countries considering their waste intensity measures (municipal vs. industrial).

Figure 40. Municipal vs. industrial waste intensity (GDP/MVA)



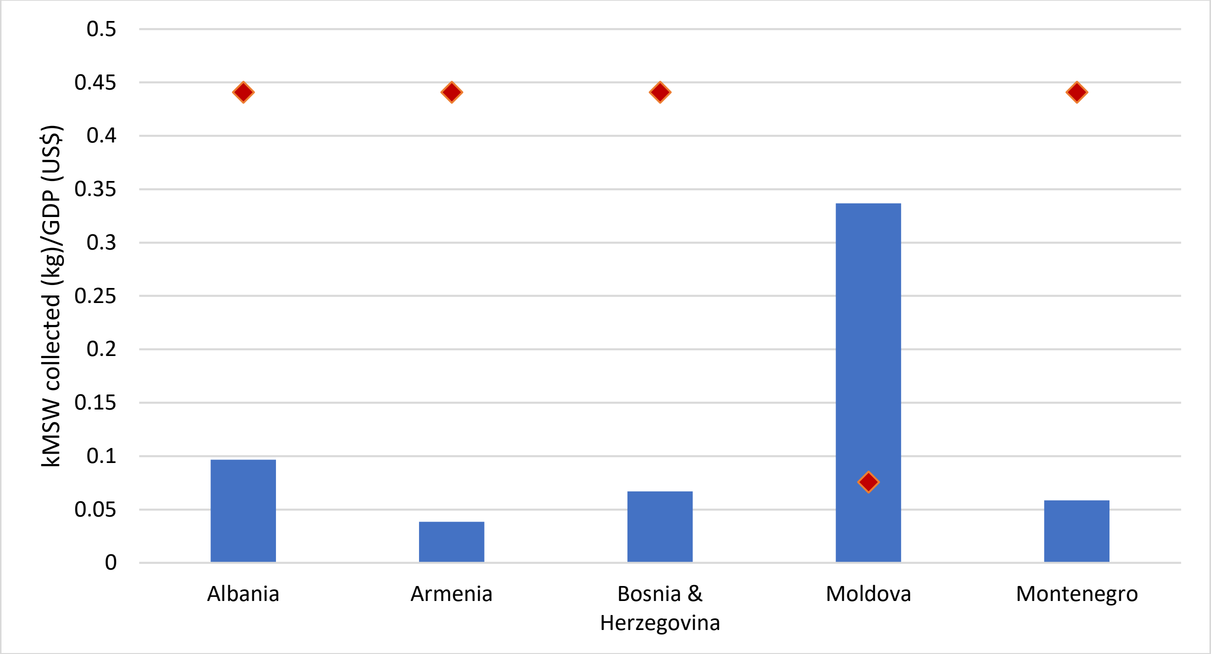
Source: Own graph based on World Bank "What a Waste 2.0" data 2018

A position in the upper right side of the chart indicates a waste generation intensity level that is above the group average for both municipal and industrial waste, which does not apply for any of the sample countries. Ideally, countries should aim to lower waste intensity for both their entire economy and their manufacturing sector. Countries with below group-average waste intensities are positioned in the bottom left area (i.e. green colour). Albania is located there, with below average levels of municipal and industrial waste intensity. Bosnia and Herzegovina reported the lowest intensity of municipal waste in our sample, coupled with slightly above average levels of waste intensity with respect to industrial output. In the bottom right quadrant, Montenegro's industrial sector has a high level of waste intensity, while scoring below average municipal waste intensity. In the upper right quadrant, Moldova has both the highest ratios of industrial waste relative to manufacturing value added as well as of municipal waste relative to GDP among all example countries.

Waste collected

An indicator that measures the intensity of waste (i.e. amount of waste collected per unit of income) can proxy the implementation, scope of monitoring and enforcement of a waste policy framework in relation to the size of the country's economy. Countries can then be compared according to the rate of waste collected relative to their wealth. **Figure 41** presents data for collected waste as a ratio of income level (GDP). The red dots indicate the income level group's average (World Bank classification) of each respective country, i.e. lower middle-income (Moldova) and upper middle-income (Albania, Armenia, Bosnia and Herzegovina, Montenegro). The amount of waste collected per dollar of GDP is far below the average of countries with a comparable income for all our sample countries with the exception of Moldova, which has a much higher intensity of waste collected than the average country in the lower middle-income classification. In fact, it has a higher waste collection intensity than all other countries in our sample, which are upper middle-income countries, but still scores below the average of that classification.

Figure 41. Municipal solid waste collected per unit of GDP

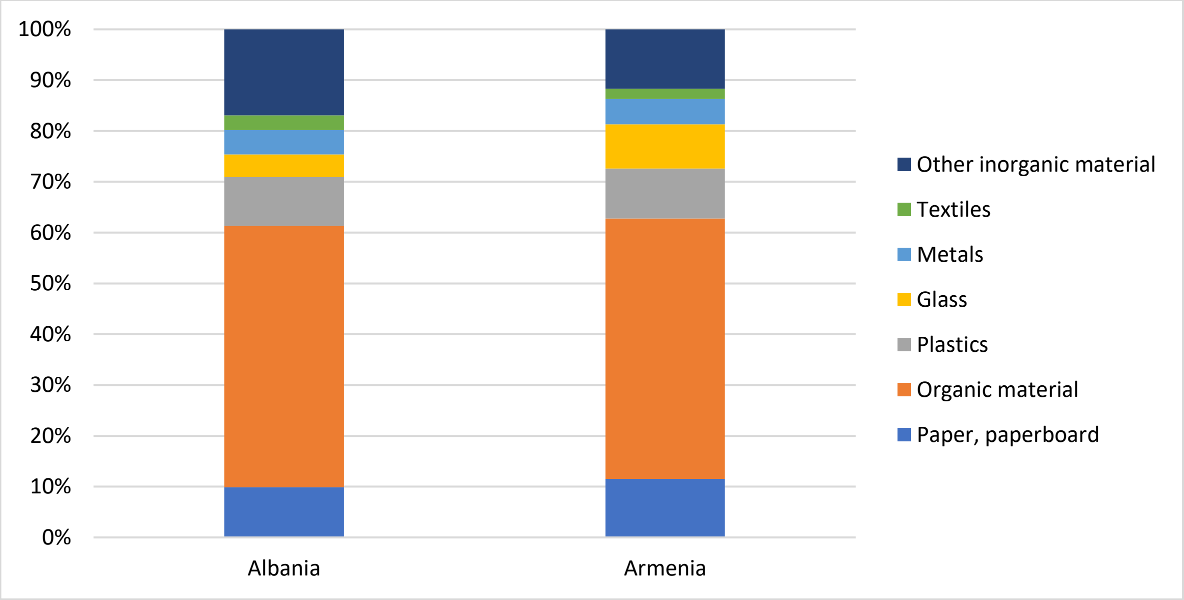


Source: Own graph based on UN Statistics Division data from 2017. The red diamonds represent the averages

Waste composition

Waste composition analysis provides insights into the main categories of waste flows that are eventually directed to treatment. Information on the content of municipal waste is useful to ensure sufficient treatment capacity exists for each type of waste that is collected. As already mentioned in the introduction to this section, the collection of data on waste flows is at an early stage. In the case of waste composition, the main data source (UN Environmental Statistics) provides incomplete data on flows of waste by main category, including for our sample countries.

Figure 42. Waste composition as a share of the main categories of waste flows



Source: Own graph based on UN Statistics Division data from 2017

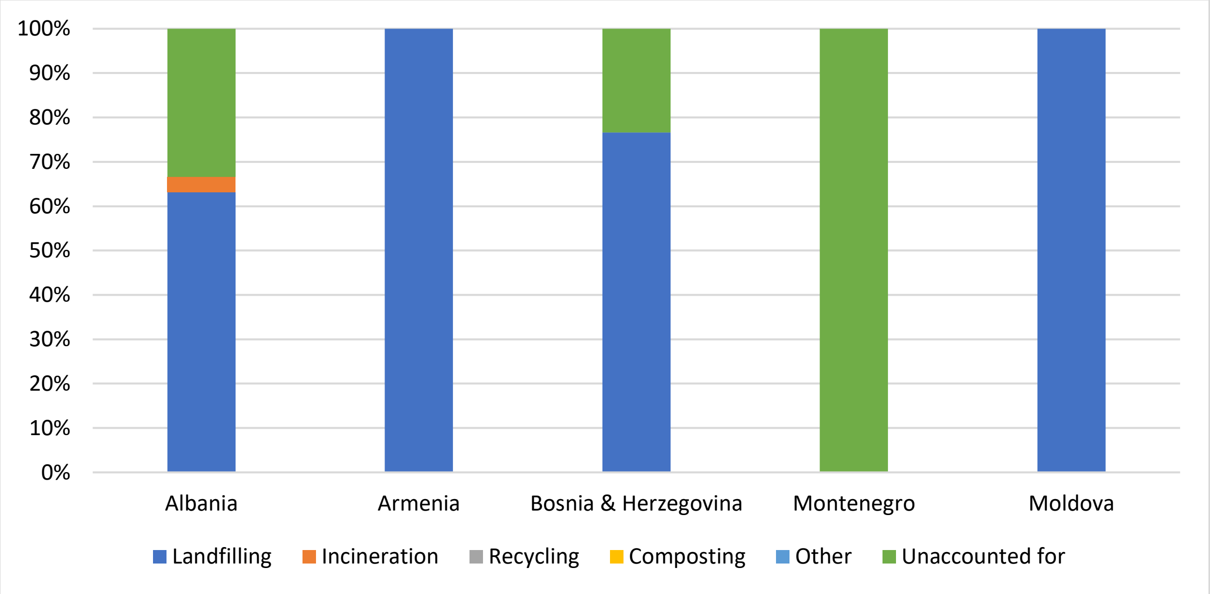
Among the five case countries, only Albania and Armenia reported data on waste composition. The composition of waste collected in the two countries is quite diversified, with organic material accounting for the highest share. The lack of reporting in the other countries could signal deficiencies regarding the quality and category of waste collected (see *Policy* section). In the following, more information on waste treatment (**Figure 43**) is provided to paint a more detailed picture on how the example countries differ in terms of implementing the circular economy paradigm.

Waste treatment

As **Figure 43** indicates, all countries in the sample are either characterized by poor reporting or a meagre set of treatment options, indicating that their economy runs on the linear model of 'take-make-use-dispose'. Coupling this information with **Figure 42** on waste composition, we can infer that the treatment of the separated waste likely does not prioritize recovery of the materials' value. Poor reporting applies in particular to Montenegro, where no data were available. Armenia and Moldova reported that their entire waste flow is directed to landfills, a treatment option that has a high prevalence in both Albania and Bosnia and Herzegovina as well. Since waste reporting is generally still in its infancy, it is possible that landfills are the only reference point for data collection on waste and are therefore the only data being reported.

In Albania, where the most granular data on treatment options were available, incineration is a relevant alternative to landfilling. In fact, the country could better exploit its potential to recycle organic material, accounting for most of its MSW generated (62 per cent of total flow). Most of the country's MSW flow is landfilled with various degrees of environmental standards (GIZ, 2021). Uncontrolled landfill of organic material leads to methane emissions, along with potential contamination of soil and (ground)water. As an EU candidate country since 2014, Albania is undertaking efforts to align its waste management objectives with the standards of the Union, adopting the concept of waste hierarchy to increase material recovery (GIZ, 2021).

Figure 43. Waste collected as a share of treatment options

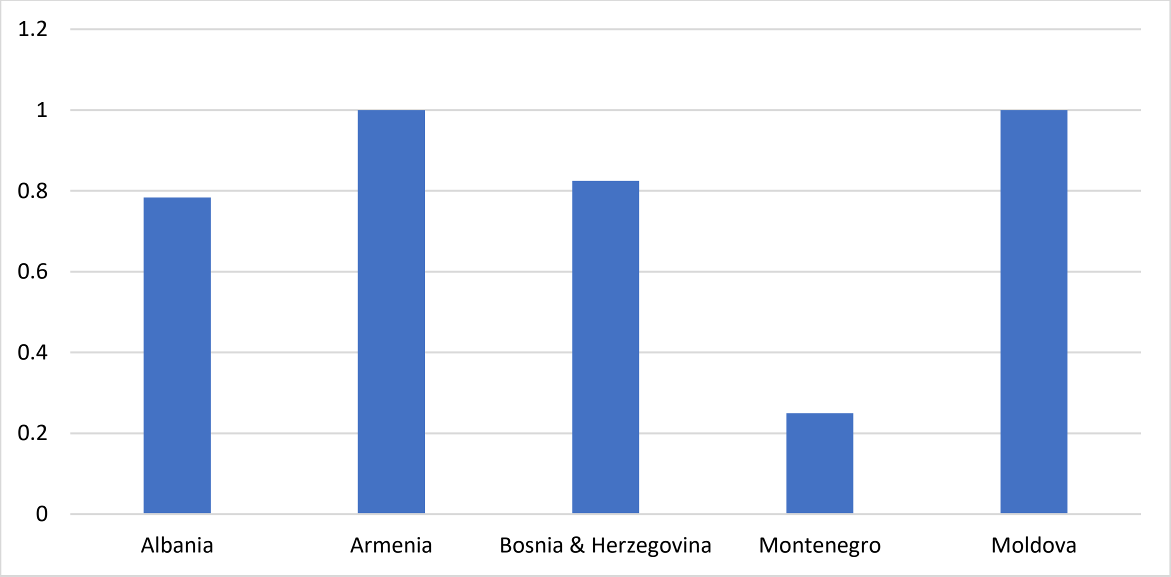


Source: Own graph based on UN Statistics Division data from 2017

Waste policy analysis

The Q Index, a synthetic measure of circularity on the set of options for waste treatment at policy level, represents a further level of analysis. It has an embedded preference for treatment methods that offer higher recovery of materials and/ or energy. The Index is applied to our example countries in **Figure 44**. When we compare this chart with the previous one in **Figure 43**, it quickly becomes clear that the Index scores are higher for those countries that possess a more diverse range of treatment options oriented towards the recovery of materials or energy. The scoring also tends to favour those countries for which information on waste treatment is available. For the sample considered, none of the countries score above 1, signalling poor diversification of waste treatment options along with a structural lack of more detailed information on waste treatment reported. Countries such as Albania, which has a more diversified set of options but a higher level of waste that is unaccounted for, tend to score lower compared to countries such as Armenia or Moldova that have more complete information on waste treatment.

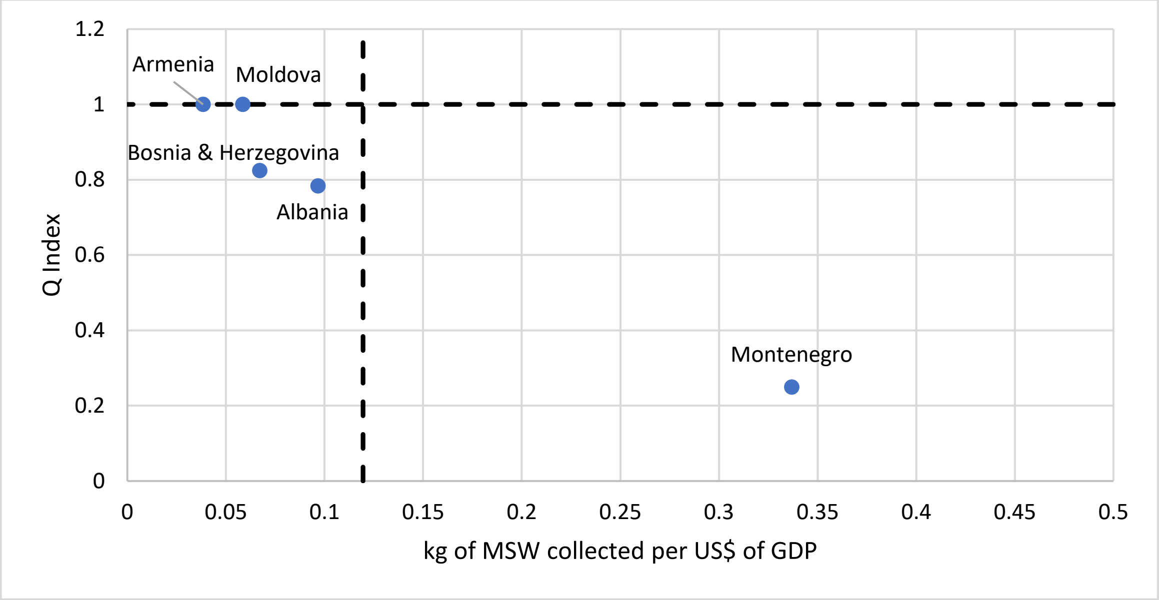
Figure 44. Q Index



Source: Own graph based on UN Statistics Division data from 2017

Plotting the Q Index against the rate of waste collected, as was the case in **Figure 45**, provides further more contextualized insights. The relationship between municipal waste collected and income level provides insights into the intensity of waste collection in a country. Higher levels of waste collection with respect to income imply that a wider flow of waste is available for treatment. Additionally, to be considered a country with a circular-aligned waste treatment policy mix, the Q Index score should be at least more than 1.

Figure 45. Collection intensity vs Q Index



Source: Own graph based on UN Statistics Division data from 2017

The upper right quadrant suggests above-group average levels of waste collection along with a waste treatment mix that is well-aligned with circularity, which does not apply to any of the example countries. On the opposite lower left side, countries have below-average levels of waste collection in relation to income along with a subpar Q Index score, which applies to Albania and Bosnia and Herzegovina. The scores of the countries in our sample imply that their waste treatment options mostly consist of landfilling. Scores below 1 signal missing information on specific treatment that is either self-reported by the country (Albania and Bosnia and Herzegovina) or estimated (i.e. Montenegro) considering the available information. Moldova and Armenia perform best, as they are positioned in the upper left side, which signifies a circularity-aligned set of treatment options, with room for improvement in waste collection. In the bottom-right side of the chart, Montenegro's waste treatment is deficient even though it collects a high share of the waste it produces.

Policy options

Areas of policy intervention in the realm of waste are explored by considering the respective country's current level of implementation, monitoring, and enforcement. The ultimate objective of a circularity-aligned waste policy is to reduce the amount of waste generated and to promote more sustainable forms of disposal. Considering the broader perspective, waste policy should be integrated in the overall policy framework, promoting more sustainable production and consumption patterns aiming at the greatest possible extent of circular resource use. Circular economy and sustainable production and consumption are also linked with other objectives at the policy level (e.g. poverty, food and nutrition) (Nicastro and Carillo, 2021).

Collection mechanisms

The first step to promote a more circularity-aligned waste management framework is to improve the collection mechanism's quality. Policymakers should look at more flexible ways of collection to cope with the increasing trends of waste generation, especially in low middle-income countries. To meet the increasing demand for waste collection, enterprises are facing high administrative costs by introducing community-based collection mechanisms (Innovation Policy Platform, 2017a). Brazil, for instance, has introduced informal pickers within an integrated management scheme for electronic waste (Borthakur, 2020). Such solutions increase collection coverage without incurring high costs. Waste collection design should always take the specificities of the territory where it will be implemented into account, along with closer collaboration between the public (e.g. municipality) and private sphere, incorporating formal and informal methods (UN-HABITAT, 2010; Carlos-Alberola et al., 2021).

While centralized options appear to be more efficient in high-income countries, low- and middle-income countries tend to rely on informal networks of pickers instead (Tearfund, 2016). As regards the different categories of waste, the policy implementation mechanism should, where possible, harmonize the collection options in accordance with the specific types of waste generated within the territory. Moreover, the monitoring mechanism should not exclusively consider the collection rate and coverage, but also include data on productivity, administrative costs and composition for better decision-making at policy level (UN-HABITAT, 2010). Improving the waste collection rate and coverage prevents environmental disruption through illegal disposal while providing inputs for recycling and recovering processes (UN-HABITAT, 2010; Wright, 2012; Innovation Policy Platform, 2017b; Sotamenou et al., 2019).

Box 12. Municipal waste generated vs collected

Extended producers' responsibility (EPR) refers to the possibility of governments to require producers to take responsibility for the collection, sorting and above all, final treatment of waste. In practical terms, EPR secures a monitoring and enforcing mechanism of waste management along with a reliable stream of waste material for recycling and recovering processes.

End-of-waste (EoW) denotes the virtual frontier of when "waste" should not be considered as such, but rather as a by-product. In other words, EoW policies provide all the conditions to include waste in (secondary) raw material flows. A mandate to set an EoW requirement would represent a policy application to promote a higher level of environmental protection.

Waste management

Policy interventions should additionally focus on the management of specific waste streams that put significant pressure on the environment (e.g. plastics, e-waste, see **Box 13** below). Besides promoting and increasing the rate of recycling, waste management at the policy level should aim to reduce the total amount of waste generated, addressing the upper side of the value chain (i.e. the production of goods) (OECD, 2018). Governments should also focus on enabling repair and remanufacturing industries with the twofold aim of reducing waste and creating jobs (Tearfund, 2016).

As recycling in low-income countries is mostly driven by informal structures, governments should provide a more structured framework to better exploit the raw materials contained in waste as a resource, tackling issues related to the quality of recycled material as well as the health and safety of workers (Salhofer et al., 2021). *Information and Communication Technologies* (ICT) are helpful supporting schemes of informal waste management value chains from collection to sorting and recycling in countries such as Kenya (https://www.startupranking.com/gorecycler) or India (https://www.indiamart.com/green-nerds/) (Innovation Policy Platform 2017b). Furthermore, within the ideal concept of "closing the loop" of the production process, actions should also be directed at creating demand for secondary raw materials and addressing the illegal transfer of waste between countries. Developing countries in particular are now coping with specific legislation on electronic waste, incorporating recycling, enhancing environmental the performance of electronic products and avoiding (e-)waste imports (Borthakur, 2020).

To tackle the issues related to the quality of recyclable materials, countries could invest in better sorting methods (OECD, 2018). In some cases, policy implementation at the country level includes circularity measures and waste management within the broader framework of sustainable production and consumption. For instance, countries such as India, Brazil and Jordan have not implemented specific policies on circular economy but have introduced circularity dimensions within relevant policy areas related to agriculture and food production, transport, building and construction, cities and mobility (World Business Council for Sustainable Development, 2018). China, Japan and the European Union have adopted more integrated policy action focusing on both the upper side of the "loop" (e.g. eco-design, industrial parks, product engineering) and the lower side, mostly represented by waste management (e.g. extended producer responsibility, end-of-waste) (World Business Council for Sustainable Development, 2018). One significant element common to the entire policy framework is to extend the responsibility for waste collection, sorting, and treatment to producers (*extended producer responsibility*). Some countries (e.g. the Republic of Korea) apply this principle to manage some relevant categories of waste (e.g. electronic, plastics) (Borthakur, 2020).

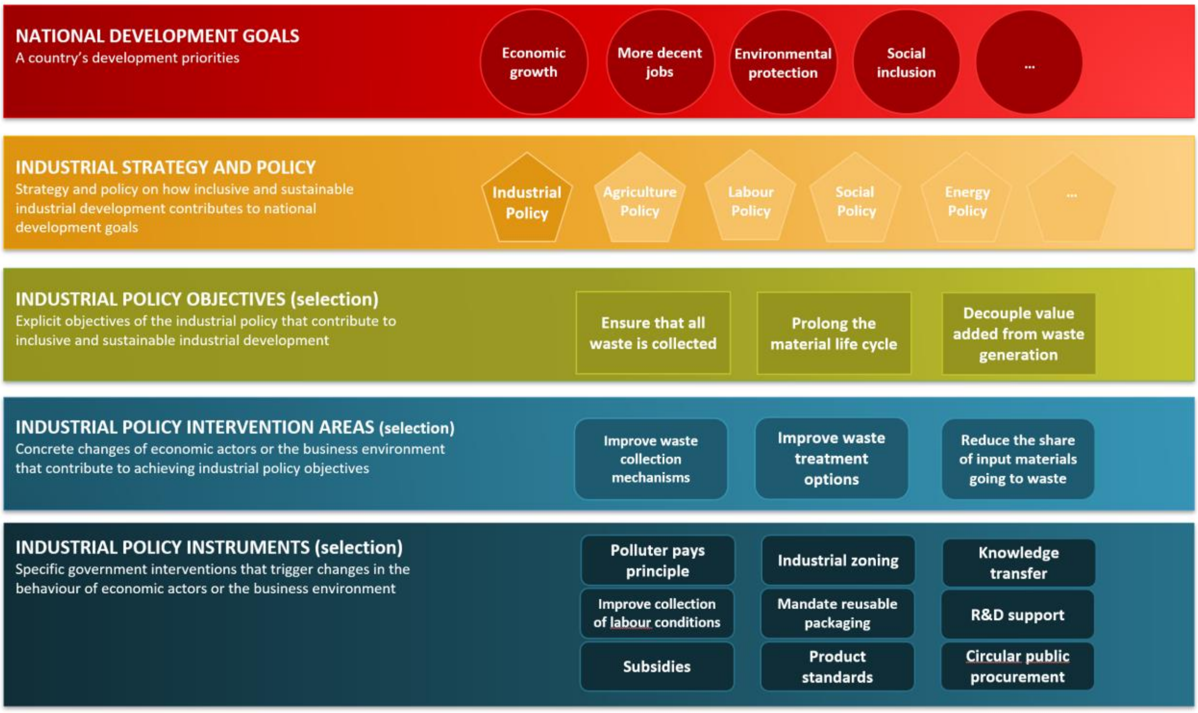
It is estimated that 95 per cent of plastic packaging material value (US$ 80-120 billion) is lost after a short first use (World Economic Forum, 2016). Furthermore, whereas 14 per cent of packaging is effectively recycled, 8 per cent is transformed into lower-value plastics products. The example of plastic packaging showcases how improving closing-loop recycling enables the recovery of the economic value of waste (at least partially), with the possibility of triggering an entire industrial impulse towards treatment processes for waste. In fact, in industries such as iron and steel, the use of scrap as a main raw material entails benefits in terms of materials and energy efficiency. One tonne of recycled steel saves 630 kg of coking coal, 55 kg of limestone and requires between 16 per cent to 17 per cent less energy and 40 per cent less water (https://pib.gov.in/newsite/PrintRelease.aspx?relid=194359). Providing materials from domestic recycling could secure supply of raw materials in countries where there is a structural lack of resources.

Box 13. Case study: E-waste management in Nigeria

Despite the lack of comprehensive data, e-waste generation and imports in Nigeria have become a structural issue over the past decade (Woggsborg and Schröder, 2019). In fact, Nigeria and Ghana are among the main destinations for e-waste in the world. The first attempt to tackle this issue at the national level dates back to 2016, with the introduction of the first EPR programme. As of 2020, Nigeria has been implementing its EPR system for e-waste through the “E-waste Producer Responsibility Organization” (EPRON). EPRON is at the centre of e-waste management, bridging the public and private sector. In terms of monitoring and enforcement, Nigeria has implemented a black box system where producers can calculate the amount of fees to be paid for the collection and recycling of their electronic products. This ensures transparent information for producers regarding costs incurred as an effect of EPR policies. Currently, Hinckley Recycling and E-Terra Technologies are the two licensed recyclers in the country.

However, despite all the efforts of centralization, e-waste management is predominantly informal and lacks infrastructure. Therefore, a US$ 15 million project jointly funded by the Global Environmental Facility (GEF) and UNEP has been launched with the aim of improving livelihoods and work conditions for e-waste collectors and recyclers. For instance, together with Verde Impacto, Hinckley is now trying to incorporate informal pickers into their business, providing training, equipment, insurance coverage and health services.

Table 13. Waste policy implication matrix



NATIONAL DEVELOPMENT GOALS
A country’s development priorities
- Economic growth
- More decent jobs
- Environmental protection
- Social inclusion
- ...

INDUSTRIAL STRATEGY AND POLICY
Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals
- Industrial Policy
- Agriculture Policy
- Labour Policy
- Social Policy
- Energy Policy
- ...

INDUSTRIAL POLICY OBJECTIVES (selection)
Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development
- Ensure that all waste is collected
- Prolong the material life cycle
- Decouple value added from waste generation

INDUSTRIAL POLICY INTERVENTION AREAS (selection)
Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives
- Improve waste collection mechanisms
- Improve waste treatment options
- Reduce the share of input materials going to waste

INDUSTRIAL POLICY INSTRUMENTS (selection)
Specific government interventions that trigger changes in the behaviour of economic actors or the business environment
- Polluter pays principle
- Improve collection of labour conditions
- Subsidies
- Industrial zoning
- Mandate reusable packaging
- Product standards
- Knowledge transfer
- R&D support
- Circular public procurement

Table 14. List of policy options: Waste

		Circular waste management policy instruments/mechanisms	
		Market-based interventions/ decentralized provision	**Public inputs/ direct provision**
Policy domain/ market failure being addressed	**Product**	• Targeted programmes to increase awareness of the potential of the recycling industry • Award scheme at sectoral, national, and international level to educate and incentivize producers	• Improve quality of waste collection mechanism • Eco-labelling programmes • Circular public procurement • Product standards and technical requirements for repairability, recyclability and durability • Extend warranty periods • Punish planned obsolescence • Mandate reusable packaging systems • Linkage and knowledge transfer programmes through participation in knowledge platforms, global CE programmes
	Capital	• Eliminate/ reduce VAT (or even subsidize) on repairs, remanufactured products and recycled materials • Levy tax on waste production • “Green” incentives and support mechanisms for CE investments • Loan guarantees for investments in CE projects	• End of waste regulation • Favour demand of secondary raw materials • Cap-and-share rationing scheme for waste • Implement green accounting system to accurately measure waste flows
	Labour	• Enhance the structural framework for informal collection • Grants for capacity development and training	• Support capacity development in product engineering • Improve working conditions, health and safety of workers in informal collection • Promotion of trainings, audits and capacity development activities for producers
	Technology	• Improve use of ITC in the collection of waste • R&D subsidies and grants to improve recycling technologies and reduce hazardous categories of waste (e.g. plastic, e-waste)	• Government expenditure to increase capacity and options of waste treatment • Government R&D expenditure to improve quality and treatment of collected waste • State-supported eco-industrial parks

References

Austen, M., Andersen, P., Armstrong, C., Döring, R., Hynes, S., Levrel, H., Oinonen, S., Ressurreição, A., & Coopman, J. (2019). *Valuing Marine Ecosystems – Taking into Account the Value of Ecosystem Benefits in the Blue Economy.* Preprint. MarXiv. https://doi.org/10.31230/osf.io/vy3kp.

Ayompe, L. M., Davis, S. J., & Egoh, B. N. (2020). Trends and Drivers of African Fossil Fuel CO_2 Emissions 1990–2017. *Environmental Research Letters 15 (12):* 124039. https://doi.org/10.1088/1748-9326/abc64f.

Bloomberg NEF (2021). *Hot Spots for Renewable Heat.* https://assets.bbhub.io/professional/sites/24/BloombergNEF-Hot-Spots-for-Renewable-Heat-Sep-2021.pdf.

Borthakur, A. (2020). Policy Approaches on E-Waste in the Emerging Economies: A Review of the Existing Governance with Special Reference to India and South Africa. *Journal of Cleaner Production 252 (April):* 119885. https://doi.org/10.1016/j.jclepro.2019.119885.

Canada, Natural Resources (2020). *Government Invests in Canada's Tidal Power Industry.* News releases. 9 September 2020. https://www.canada.ca/en/natural-resources-canada/news/2020/09/government-invests-in-canadas-tidal-power-industry.html.

Carlos-Alberola, M., Izquierdo, A. G., Colomer-Mendoza, F. J., & Barreda-Albert, E. (2021). Design of a Municipal Solid Waste Collection System in Situations with a Lack of Resources: Nikki (Benin), a Case in Africa. *Sustainability 13 (4):* 1785. https://doi.org/10.3390/su13041785.

Chin, H. H., Varbanov, P. S., Klemeš, J. J., & Bandyopadhyay, S. (2021). Subsidised Water Symbiosis of Eco-Industrial Parks: A Multi-Stage Game Theory Approach. *Computers & Chemical Engineering 155 (December):* 107539. https://doi.org/10.1016/j.compchemeng.2021.107539.

Chopra, K. R., & Millennium Ecosystem Assessment (Program), eds. (2005). Ecosystems and Human Well-Being: Policy Responses: Findings of the Responses Working Group of the Millennium Ecosystem Assessment / Edited by Kanchan Chopra ... [et al.]. *The Millennium Ecosystem Assessment Series, v. 3.* Washington, DC: Island Press.

Damiyano, D., Muchabaiwa, L., Mushanyuri, B. E., & Chikomba, C. P. (2012). *An Investigation of Zimbabwe's Manufacturing Sector Competitiveness,* 18.

Davis, S. J., & Caldeira, K. (2010). Consumption-Based Accounting of CO_2 Emissions. *Proceedings of the National Academy of Sciences 107 (12):* 5687–92. https://doi.org/10.1073/pnas.0906974107.

Department of the Environment, Climate and Communications (2021). *Circular Economy Bill.* Government of Ireland. https://assets.gov.ie/137605/10140ef7-a8ef-41c2-b7e9-de375b9f4a18.pdf.

Eggleston, H. S, Intergovernmental Panel on Climate Change, National Greenhouse Gas Inventories Programme, & Kikan, C. K. S. K. (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories. Vol. 2.* http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm.

Egüez, A. (2021). Compliance with the EU Waste Hierarchy: A Matter of Stringency, Enforcement, and Time. *Journal of Environmental Management 280 (February):* 111672. https://doi.org/10.1016/j.jenvman.2020.111672.

EIA (2016). *Industrial Sector Energy Consumption.*

Fischedick, M. J., Roy, J., Abdel-Aziz, A., Acquaye, A ., Allwood, J. M., Ceron, J-P., Geng, Y., et al. (2014). Industry. In *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* 739–810. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter10.pdf.

Get.invest. (n.d.). *Zambia- Energy Sector.* Accessed 2 December 2021. https://www.get-invest.eu/market-information/zambia/energy-sector/.

GIZ (2016). *Climate Change Adaptation Policy for Industrial Areas – Framework for the State of Telangana, India.* https://tsiic.telangana.gov.in/wp-content/uploads/2017/03/061220116-TSIIC-CCA-Policy.pdf.

GIZ (2021). *Modernized, Climate-Friendly Solid Waste and Recycling Management in Albania.* https://www.giz.de/en/downloads/Solid%20Waste_Factsheet_EN.pdf.

Government of India (2021). *Budget 2021–2022*. Speech of Nirmala Sitharaman Minister of Finance.

Guan, D., & Reiner, D. M. (2009). Emissions Affected by Trade among Developing Countries. *Nature, Opinion, 462:* 1.

Hurlimann, A. C., Browne, G. R., Warren-Myers, G., & Francis, V. (2018). Barriers to Climate Change Adaptation in the Australian Construction Industry – Impetus for Regulatory Reform. *Building and Environment 137 (June):* 235–45. https://doi.org/10.1016/j.buildenv.2018.04.015.

IEA (2016). *Renewable Energy Fund for Off-Grid Solutions – Policies.* IEA. 2016. https://www.iea.org/policies/5899-renewable-energy-fund-for-off-grid-solutions.

IEA (2018a). *Green Energy Scheme for Cooperatives – Policies.* IEA. 2018. https://www.iea.org/policies/6432-green-energy-scheme-for-cooperatives.

IEA (2018b). *The Future of Petrochemicals,* 132.

IEA (2019a). *Africa Energy Outlook 2019,* Regional Report, 288.

IEA (2019b). *Africa Energy Outlook 2019 – Kenya,* 20.

IEA (2019c). *Africa Energy Outlook 2019 – Tanzania,* 19.

IEA (2019d). *Africa Energy Outlook 2019 – Mozambique,* 20.

IEA (2019e). *World Energy Outlook 2019.* World Energy Outlook, 11.

IEA (2021). *Renewable Energy Policies in a Time of Transition: Heating and Cooling,* 150.

Innovation Policy Platform (2017a). *Business Models for Collecting Waste in Low-Income Areas.* https://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/1%20Waste%20Collection_Apr6/index.pdf.

Innovation Policy Platform (2017b). *Business Models for Integrated Waste Management.* http://www.innovationpolicyplatform.org/www.innovationpolicyplatform.org/system/files/4%20Integrated%20Waste%20Manangement_Apr6/index.pdf.

Institute for Human Rights and Businesses (2016). Setting the Scene :Overview of Kenya's Extractive Sector. In *Human Rights in Kenya's Exctractive Sector,* 10.

IRENA (2020). *Energy Subsidies: Evolution in the Global Energy Transformation to 2050.* https://www.irena.org/publications/2020/Apr/Energy-Subsidies-2020.

Jamaican Ministry of Energy and Mining (2010). *Draft- National Energy-from-Waste Policy.* https://www.mset.gov.jm/wp-content/uploads/2019/07/Draft-Waste-to-Energy-Policy_0.pdf.

Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the Circular Economy: An Analysis of 114 Definitions. *Resources, Conservation and Recycling 127 (December):* 221–32. https://doi.org/10.1016/j.resconrec.2017.09.005.

Mazzarano M., Quatrosi M., Pronti A. (2021). "Waste Management and Italian Provinces: why pay more for less?". Under revision: *Waste Management.* Submitted: 26/06/2021

Ministerio de Minas y Energia (2021). *Histórico de Noticias GM.* 2021. https://www.minenergia.gov.co/en/web/10180/historico-de-noticias?idNoticia=24279957.

Ministry of Environment, Forest Climate Change (2019). *India Cooling Action Plan.* http://www.indiaenvironmentportal.org.in/files/file/INDIA%20COOLING%20ACTION%20PLAN.pdf.

Moraga, G., Huysveld, S., Mathieux, F., Blengini, G. A., Alaerts, L., Van Acker, K., de Meester, S., & Dewulf, J. (2019). Circular Economy Indicators: What Do They Measure? *Resources, Conservation and Recycling 146 (July):* 452–61. https://doi.org/10.1016/j.resconrec.2019.03.045.

Nacional, Imprensa (2020). *Portaria Nº 460, de 21 de Dezembro de 2020 – DOU – Imprensa Nacional.* 29 December 2020. https://www.in.gov.br/web/dou.

Nicastro, R., & Carillo, P. (2021). Food Loss and Waste Prevention Strategies from Farm to Fork. *Sustainability 13 (10):* 5443. https://doi.org/10.3390/su13105443.

OECD (2018). Improving Plastics Management: Trends, Policy Responses, and the Role of International Co-Operation and Trade. *OECD Environment Policy Papers 12. Vol. 12.* OECD Environment Policy Papers. https://doi.org/10.1787/c5f7c448-en.

Republic of South Africa (2017). *Draft Carbon Tax Bill.* http://www.treasury.gov.za/public%20comments/CarbonTaxBll2017/Draft%20Carbon%20Tax%20Bill%20December%202017.pdf.

Saidani, M., Yannou, B., Leroy, Y., Cluzel, F., & Kendall, A. (2019). A Taxonomy of Circular Economy Indicators. *Journal of Cleaner Production 207 (January):* 542–59. https://doi.org/10.1016/j.jclepro.2018.10.014.

Salhofer, S., Jandric, A., Soudachanh, S., Xuan, T. L., & Tran, T. D. (2021). Plastic Recycling Practices in Vietnam and Related Hazards for Health and the Environment. *International Journal of Environmental Research and Public Health 18 (8):* 4203. https://doi.org/10.3390/ijerph18084203.

Sotamenou, J., De Jaeger, S., & Rousseau, S. (2019). Drivers of Legal and Illegal Solid Waste Disposal in the Global South – The Case of Households in Yaoundé (Cameroon). *Journal of Environmental Management 240 (June):* 321–30. https://doi.org/10.1016/j.jenvman.2019.03.098.

Tearfund (2016). *Virtuous Cycle- How the Circular Economy Can Create Jobs and Save Lives in Low and Middle-Income Countries.* Tearfund. https://www.researchgate.net/publication/306562812_Virtuous_Circle_how_the_circular_economy_can_create_jobs_and_save_lives_in_low_and_middle-income_countries.

TEEB (2010). *The Economics of Ecosystems and Biodiversity.* The Economics of Ecosystems and Biodiversity. http://teebweb.org/publications/teeb-for/business-and-enterprise/.

UNEP (2015). *Energy Profile- Zimbabwe.* United Nations Environment Programme. https://wedocs.unep.org/bitstream/handle/20.500.11822/20589/Energy_profile_Zimbabwe.pdf?sequence=1&isAllowed=y.

UNFCC LCD Expert Group (2021). *National Adaptation Plans 2020 Progress in the Formulation and Implementation of Naps.* United Nation Framework Convention on Climate Change. https://unfccc.int/sites/default/files/resource/NAP-progress-publication-2020.pdf.

UN-HABITAT (2010). *Collection of Municipal Solid Waste, Key Issues for Decision-Makers in Developing Countries.* United Nations. https://unhabitat.org/sites/default/files/download-manager-files/Collection%20of%20Municipal%20Solid%20Waste%20%2C%20Key%20issues%20for%20Decision-makers%20in%20Developing%20Countries.pdf.

UNICEF Burundi (2016). *Decentralized Rural Electrification Strategy (2015–2017).* UNICEF. http://causetech.net/files/DRE-Strategy-One-pager.pdf.

UNIDO (2012). Industrial Development Report 2011: Industrial Energy Efficiency for Sustainable Wealth Creation – Capturing Environmental, Economic and Social Dividends. *Industrial Development Report.* UN. https://doi.org/10.18356/2361d4c0-en.

UNIDO (2019). *Industrial Energy Efficiency Improvement Project.* https://www.unido.org/sites/default/files/2011-12/IEE%20BROCHURE-22%2022%2022%20signoff%20for%20print_0.pdf.

UNIDO (2020). *Industrial Development Report 2016.* Industrial Development Report, 42.

Viet Nam Law Insight (2014). *Circular 24/2014/TT-BCT.* Vietnam Law Insight. 2014. https://vietnamlawinsight.wordpress.com/tag/circular-242014tt-bct/.

Wong, J., & Schuchard, R. (2011). Adapting to Climate Change: A Guide for the ICT Industry. *Adapting to Climate Change,* March 8.

World Business Council for Sustainable Development (2018). *Circular Metrics – Landscape Analysis.* https://docs.wbcsd.org/2018/06/Circular_Metrics-Landscape_analysis.pdf.

World Economic Forum (2016). *The New Plastics Economy Rethinking the Future of Plastics.*

Wright, N. H. (2012). Dealing with Biodiversity in Corporate Venture Risk Exploration and Production. In *International Conference on Health, Safety and Environment in Oil and Gas Exploration and Production.* Perth, Australia: Society of Petroleum Engineers. https://doi.org/10.2118/156806-MS.

4 Material

Introduction

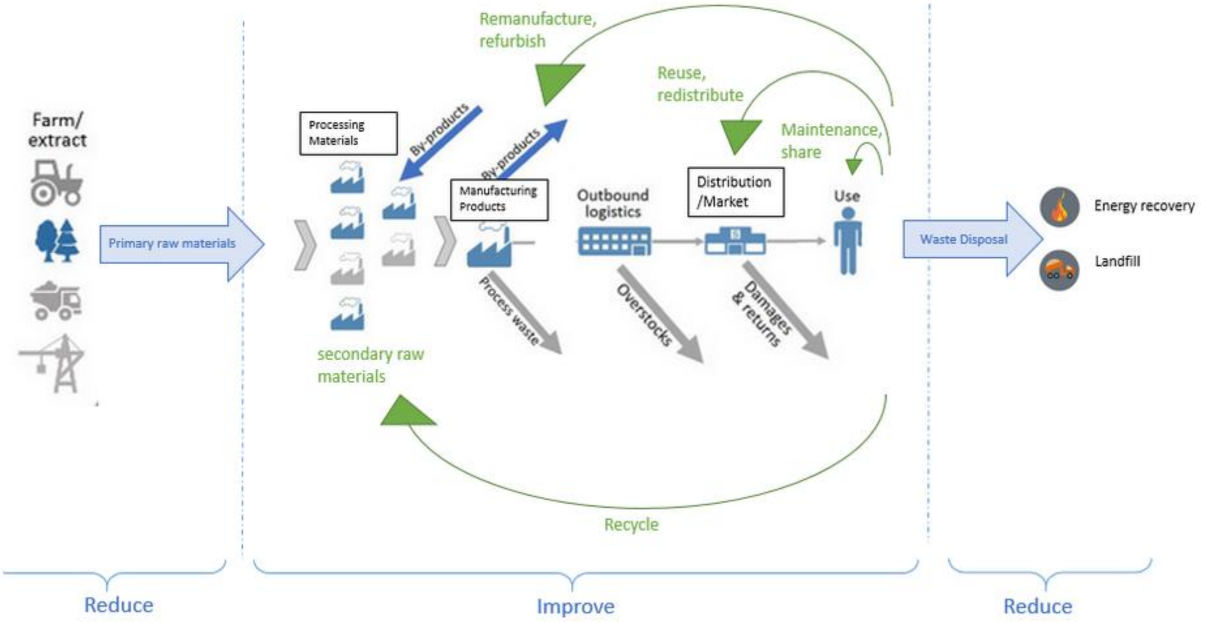
The use of raw materials is essential to meet key human needs such as housing, nutrition, and mobility. These natural resources are furthermore the basis for industrial manufacturing: as countries develop, and their economies grow, so does consumption of industrial commodities and materials such as steel, cement, aluminium, plastics, and oil to maintain infrastructure, transport systems, buildings, and factories, and to produce and packaged consumer goods. In our current system of linear material use in production, these needs are satisfied by extracting and processing resources and trading them for further manufacturing. These manufactured goods then serve end-use. However, materials and products lose their functionality after being used, ending up as waste that is often burned or landfilled. This current economic system, together with an increasing geographic separation of production and consumption, has resulted in a highly complex, material- and energy-intensive, and environmentally damaging web of supply chains.

Domestic extraction (DE) is the starting point of all material flows. It is therefore also the first indicator in this section, standardized by GDP. DE serves Domestic material consumption (DMC), on the one hand, and exports, on the other. The intensity of DMC is included in SDG 12.2: Sustainable management and use of natural resources and represents the second indicator in this section.

Domestic material extraction and consumption are, to some degree, inevitable for ensuring human well-being and economic activity. The expansion of these material flows along with increasing industrialization often becomes unsustainable as it has significant environmental repercussions, including resource depletion, land use change, ecosystem degradation and pollution. Biodiversity loss is a particularly serious ecological consequence of these dynamics at the domestic level; it is a critical planetary boundary that has been eroded at alarming levels around the globe. While ecosystems and biological diversity are degraded by the material use throughout the economy and society as a whole, they also constitute integral parts of the natural sphere which provides the very basis for any economic activity and for society itself. According to Rockström et al. (2009), "*transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental-scale to planetary-scale systems.*" Biodiversity loss from industrial land use change, i.e. forestry, is thus included as a hotspot indicator in this section. Natural resource depletion is another issue caused by extensive material extraction and consumption. It is linked to the aforementioned environmental issues and additionally threatens future industrial manufacturing due to critical raw material shortages. Furthermore, expanding material flows entails increasing energy requirements that cause further environmental problems, particularly CO_2 emissions, as outlined in the section on energy.

There are two principal ways of tackling these far-reaching issues, which should ideally be pursued simultaneously. Firstly, the recirculation of materials as envisioned by the concept of circular economy (see Introduction), which entails recycling (see Waste chapter) and remanufacturing (see Box 14) should be prioritized. The circular economy pursues sustainable development of the economic system without harming the natural ecosystem. In short, the material circular economy aims to replace the linear economic concept of "take, make, dispose" by looping resources that have lost their former desirability back into the material lifecycle. Materials and products are not meant to run through these loops only once, but to run through them as often as possible (see **Figure 46**). By improving the productivity of materials and products, both the extraction of virgin resources and the generation of waste can be reduced, limiting the harmful impacts of the current economic structure, including the depletion of natural resources and environmental pollution.

Figure 46. Building blocks of material circular economy



Source: materialflows.net/circular-economy/

The second approach to limiting the repercussions of industrial material use is to reduce material intensity, which the analytical part of this chapter focuses on (for more information on the difference between material intensity and efficiency, see the concepts section in the introduction). At the country level, material intensity is measured by connecting DMC to GDP, i.e. how much material mass is employed to generate 1 dollar of national income. This relationship is part of SDG 12.2 and of the indicator in this section. Reducing material intensity and decoupling material use from income helps lower the pressure on both the environment and resource stocks. Furthermore, it can benefit the manufacturing sector's competitiveness and material security. Other possible outcomes are reduction in economic risk from fluctuating commodity prices and positive employment impacts are other possible outcomes. The International Resource Panel estimates that worldwide resource intensity improvements could reduce natural resource use by 28 per cent and GHG emissions by 72 per cent, yet improve economic growth (IRP, 2020). More details on the effects of lowering material intensity can be found in the policy options section.

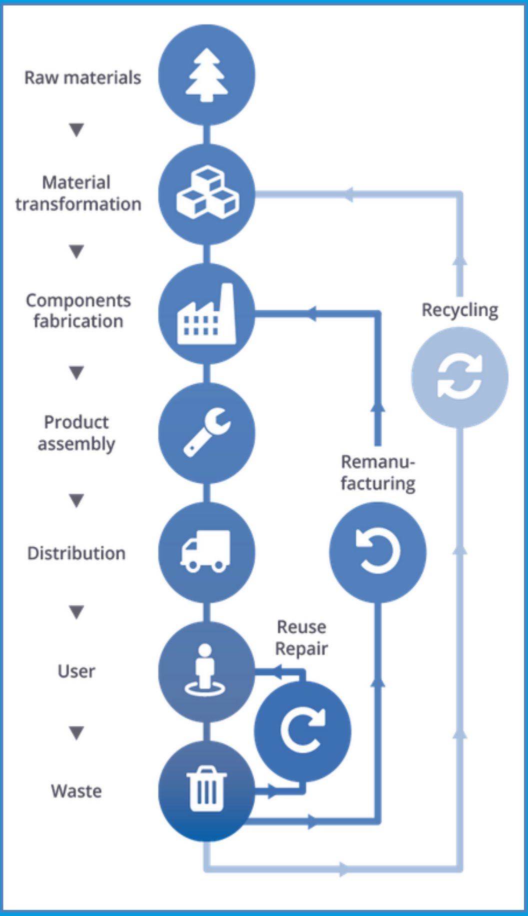
Box 14. Remanufacturing

Remanufacturing entails returning a used product to at least its original state with a warranty that is equivalent to or better than that of the newly manufactured product. This involves dismantling the product, restoring, and repairing or replacing components, and testing the individual parts as well as the entire product to ensure that it is within its original design specifications. The difference to recycling is that the waste is not broken down into raw materials. Instead, remanufacturing establishes a shorter circle by focusing on discarded manufactured parts that can be restored to full functionality, resulting in fewer required resources and a faster return to consumption (**Error! Reference source not found.**). From a customer perspective, the remanufactured product can be considered equal to a new product.

Remanufacturing is an important component of a resource efficient manufacturing industry. By keeping components and the materials they consist of in use for longer, it can significantly reduce raw material consumption. Using fewer raw materials than needed to produce new products is particularly beneficial where the product contains critical raw materials with a supply risk. By limiting the amount of raw materials extracted and the manufacturing of new components, remanufacturing furthermore reduces energy consumption and associated CO_2 emissions. As not all end-of-life products and their components are suitable for recycling, many end up in landfills instead. Remanufacturing reduces this flow of material by keeping materials in use for longer.

Besides the environmental advantages, remanufacturing also benefits the remanufacturer: the remanufactured products typically have higher profit margins than the original item; it provides the opportunity to create local skilled jobs and paves the way for new techniques and better customer relationships.

Figure 47. Product lifecycle process



Source: The European Remanufacturing Network

Subsequently, this section addresses material use in the manufacturing sector and sub-sector level, using the Raw Material Consumption measurement (RMC, also called material footprint) which is part of SDG 12.2. One indicator illustrates the share each sub-sector has in total manufacturing RMC as well as the share of manufacturing in the entire economy's RMC. Another indicator sheds light on the material intensity of various manufacturing sub-sectors in terms of RMC.

Table 15. List of indicators

Indicator	Level of analysis	Definition	Data source
Extraction intensity	Country	Amount of domestic material extraction per dollar of income over time	UNEP: IRP
Material use intensity	Country	Amount of domestic material consumption per dollar of income over time	UNEP: IRP
Manufacturing (sub-sector) raw material consumption	Industry / sub-sector	Demand for raw materials by manufacturing (sub-sectors) as share of total (manufacturing) raw material demand (RMC)	UNEP: SCP-HAT
Manufacturing (sub-sector) raw material intensity (RMC/MVA)	Industry / sub-sector	Amount of material embodied in manufacturing (sub-) sector production per dollar of value added	UNEP: SCP-HAT/ UNIDO: INDSTAT 2 Revision 3
Biodiversity loss	sub-sector	Potential species loss from forestry land use	UNEP: SCP-HAT

Methodology

Data sources

Data on DE and DMC are taken from UNEP's International Resource Panel (IRP) "Global Material Flows Database". It is a global reference database for national material flow assessments, covering 200 countries and regions between 1970 and 2019. Pre-calculated data on per capita flows of DE and DMC, as well as intensity (per GDP) values for DE at the country level are also available in the database. Separately downloaded GDP data need to be used to calculate DMC intensity values.

GDP data can be found in the World Bank's World Development Indicators database, which provides data for 218 countries between 1960 and 2018. GDP in constant US dollars is used. Since material intensity values tend to be below 1, it is recommended to convert the mass unit into kilogrammes, resulting in intensity unit kg per dollar GDP (in constant US$). Data on value added is provided by UNIDO INDSTAT 2 (Revision 3), which covers 175 countries and regions between 1963 and 2018, depending on the specific country.

Compared to the IEA data on energy and CO_2 emissions, there is no similarly comprehensive data source for material use and material intensity. While UNEP's International Resource Panel Data adequately covers the economy-wide level, it does not disaggregate by sector or sub-sector (e.g.

manufacturing, ISIC 15-37 in Revision 3). For this level of analysis, we refer to the “Hotspot Analysis Tool for Sustainable Consumption and Production” (SCP-HAT). Module 2 on hotspot identification (http://scp-hat.lifecycleinitiative.org/module-2-scp-hotspots/) offers disaggregated data on manufacturing sub-sectors for a variety of material-related indicators. The database covers 171 UN Member States between 1990 and 2018. In this tool, we specifically incorporate raw material use from a consumption perspective and potential species loss from industrial land use from a production perspective. While environmental harm in the latter perspective is attributed to the industry causing disruptions during production, the former is based on the premise that the ultimate polluter is the end product’s consumer (European Commission et al., 2017). These approaches are complementary and are explained in more detail in the respective indicator descriptions.

Indicators

4.1 Extraction intensity

Definition

DE comprises all biotic and abiotic raw materials that are extracted from the domestic environment and further used in production processes. In other words, it refers to the materials extracted within a country’s territory which then enter the economic sphere. This indicator can be disaggregated into the four major material categories biomass, metal ores, minerals, and fossil fuels (see **Box 15**). To illustrate the development of material extraction in a given country, the trend can also be traced over time. Doing this for the different material groups can help policymakers identify which related extraction sectors are putting additional pressure on the environment. While absolute values serve in-country analyses and disaggregation well, the amount of extraction should be standardized by GDP (in constant dollars) for benchmarking against other countries, corresponding to material consumption intensity, which is discussed in more detail as a separate indicator. Another option for this is per capita data. Both are readily available in the IRP database.

A certain level of domestic extraction is inevitable to locally source the national economy’s material demand. In the past, countries extracted raw materials to achieve material self-sufficiency. Excessive material extraction can lead to an overexploitation of domestic resource stocks and threaten the natural ecosystems they are embedded in.

Extraction that considerably exceeds domestic demand for the purpose of unmanufactured raw material exports can be disadvantageous. It often leads to domestic resource assets being sold off at unfavourable rates while the natural assets’ integrity, including ecosystem services, are undermined. This is quite literally the case for the mining sector, and also applies to forestry timber extraction for the export market (Luckeneder, 2021). Since export revenues of natural resources do not account for how the extraction process affects the ecosystem from which they are drawn, relying on them results in a transfer of wealth from countries that export primary products to importing countries (Dasgupta, 2021).

Recycling waste for reintroduction into the economy as raw materials can alleviate the pressure material extraction exerts on the environment and paves the way towards a more circular economy. In 2015, around 84.4 Gt of raw materials such as minerals, biomass or fossil fuels were extracted worldwide. In comparison, only 8.4 Gt (about 10 per cent) of recycled materials re-entered the economic system. This relationship underlines the tremendous untapped potential of circularity to shift from extraction to reuse and the recycling of raw materials. Policymakers interested in investigating this subject further can find data on mineral and fossil fuel resource depletion on SCP-HAT's website (see data sources section). The data are based on a lifecycle impact assessment by Huijbregts et al. (2016), which models resource scarcity in relation to rising extraction costs.

Strategic questions

Direct inferences:

- What quantities of raw materials are extracted from the country's domestic territory to sustain economic activities and income generation?
- Which raw material groups contribute most to domestic extraction and how has this changed over time?
- How does the country's raw material extraction intensity level compare to that of other countries?

Follow-up questions:

- Why have the country's extraction trends developed the way they did?
- What can be done to reduce the country's extraction intensity and dependency?

Equation

$$\boldsymbol{Extraction\ intensity}\ (\boldsymbol{kg\ per}\ \$\ \boldsymbol{GDP}) = \frac{\boldsymbol{Domestic\ Extraction}\ (\boldsymbol{kg})}{\boldsymbol{Gross\ Domestic\ Product}\ (\boldsymbol{constant}\ \$)}$$

Box 15. The four major material categories

To assess material use, different renewable and non-renewable raw materials are aggregated into four main material groups (Eurostat, 2013):

1. Biomass: biotic materials from agricultural harvest, forestry or fishery activities. This is by definition the only renewable material category but includes both sustainably and non-sustainably (e.g. virgin forest clearing, overfishing) extracted resources.
2. Metal ores: iron ores and all other non-ferrous metals (including bulk metals such as copper or aluminium as well as precious metals such as gold or platinum).
3. Minerals: this category comprises industrial minerals (such as salt, gypsum or asbestos) as well as construction materials (such as stones and sands).
4. Fossil fuels: various forms of coal as well as crude oil and natural gas.

While this tool focuses on countries' and sectors' total material use, policymakers can explore further by running their own analyses disaggregated by these material groups.

4.2 Material intensity (SDG 12.2.2)

Definition

The most commonly used material use indicator at the national level is Domestic Material Consumption (DMC). It measures the total quantity of materials directly used within an economic system. Accordingly, it is a good proxy indicator for the overall environmental pressures an economy exerts on the domestic territory, as all materials that enter the economy are eventually emitted back into the environment, either as solid waste or as air and water emissions. DMC equals the sum of domestic extraction and imports minus exports (the physical trade balance) of directly traded materials. It is thus calculated as the extraction of raw materials of all four major raw material categories within a country's territorial borders (measured in mass units, i.e. tonnes) plus imports measured in mass units (e.g. electronic products in tonnes) minus exports measured in mass units.

Just like the domestic extraction data for indicator 4.1, DMC can be disaggregated by the four major material categories, allowing for a more nuanced impression of the composition of national material demand. Furthermore, and again corresponding to DE, it can be depicted within a specified time frame to identify trends and be displayed per capita to facilitate cross-country comparisons (available pre-calculated on the IRP database). Disaggregated trends of material consumption indicate which resource types are increasing or prevalent in a country's material throughput, which has environmental ramifications due to the associated extraction and disposal. Advanced economies are often linked to high DMCs, which, however, is not a means to an end. The relationship between DMC and other factors such as extraction, income, waste, and recycling are crucial in achieving sustainable prosperity.

Material intensity describes the quantity of materials used per unit of economic value (US$) generated. We set DM in relation to GDP to illustrate this at the level of the national economy. The lower the resulting ratio of material tonnes consumed per unit of national income produced, the better the country's material intensity, as fewer raw materials are needed to generate economic value. Reducing the required input is an opportunity to both capture more monetary value and reduce stress on the environment through material decoupling. It is useful to calculate the DMC/GDP indicator over a specific time period and compare it across countries with a similar economic development or comparable economic structure. Comparing the per capita trends of both DMC and material intensity provides insight into whether population or economic growth is the stronger pull factor in domestic material use.

Strategic questions

Direct inferences:

- Which material categories are the hotspots for resource management measures related to domestic material consumption?
- How has the country's material intensity developed over time?
- How does the country's material intensity compare to that of other countries?
- How does the country's material intensity trend compare to its DMC per capita trend and extraction intensity?

Follow-up questions:

- How can the country's domestic material consumption trends be explained and what role does manufacturing play in them?
- How can current material intensity be reduced at the level of the economy?

Equation

$$\boldsymbol{Material\ intensity\ (kg\ per\ \$\ GDP)} = \frac{\boldsymbol{Domestic\ Material\ Consumption\ (kg)}}{\boldsymbol{Gross\ Domestic\ Product\ (constant\ \$)}}$$

Box 16. Raw material equivalents and material footprints – who is the polluter?

Both material extraction and DMC represent flows of natural resources (minerals, metal ores, biomass, fossil fuels) from the environment into the economy. Both include domestic extraction of materials measured in tonnes of gross material (e.g. gross ore or gross harvest). Additionally, in DMC, imports and exports are measured as the actual mass of products as they cross country borders. Raw material equivalents offer a complementary view by replacing material trade flows in mass weight by estimates of the raw material equivalents of the products traded, i.e. how much foreign extraction was needed to produce the traded products. By extension, the indicator RMC denotes the amount of extraction required to produce the goods demanded by final users in the geographical reference area, irrespective of where in the world the material extraction from the environment took place. Such calculations attributing environmental pressures to domestic final demand are called "footprint" indicators.

When only considering DMC, a country can appear to be decoupling even when it is not. If it replaces its domestic extraction and production of a given resource with extraction and production elsewhere in the world, acquired through trade, its economy is not changing its reliance on the given resource. This is called *burden shifting*, and often appears as countries transition from an extraction- and production-based economy towards an economy with a higher share of services. This *burden shifting* can conceal the depletion of existing sources of resources abroad (UNEP, 2014). Countries and industries positioned at a later stage in the supply chain of manufacturing tend to have a higher RMC than primary resource processing, as all materials required along a product's international production path are accumulated in this figure. Thereby, RMC more accurately captures the resource requirements of countries that outsource their production, a practice that is not accounted for or adequately reflected in DMC (Giljum et al., 2014). At the same time, developing countries with large amounts of raw material exports have equally less RMC, which is shifted to end-users via trade. RMC is therefore an indicator for a country's overall material demand and dependency, including embodied raw materials from outsourced production, while DMC can be more directly linked to domestic environmental pressures from physical material flows.

4.3 Material consumption by manufacturing & manufacturing sub-sectors

Definition

This indicator first reflects the manufacturing sector's share of material use in percentage (the sum of all manufacturing sub-sectors, ISIC 15-37 in Revision 3) compared to all aggregated sectors of the economy, including agriculture, mining, transport, or services. It thus provides information on the manufacturing sector's significance in overall economic demand for raw materials.

Secondly, this indicator denotes manufacturing sub-sectors' share of material use in total manufacturing material use. This is calculated by adding up each manufacturing sub-sector's absolute amount of material use and then dividing each individual absolute amount by the total. The results deliver an estimation of the various manufacturing sub-sectors' material requirements in a given country. i.e. they deliver a material use profile across manufacturing sub-sectors, which allows us to identify the sub-sectors with the highest absolute material use. By determining which manufacturing sub-sectors consume the highest share of embodied raw material along their supply chains, this indicator helps prioritize these sub-sectors for policy action to address raw material demand.

The material use variable used in this indicator is not DMC as in the previous indicators, but RMC. This consumption-based indicator can be considered an extension of DMC, as it comprises the sum of DMC and the raw material trade balance (see **Box 17** below for more details). RMC thereby depicts an economy or sector's material footprint (MF). While both measures link material accounts to economic factors (input/output), they have different system boundaries. The DMC's territorial approach effectively draws a "black box" of the economy, only accounting for materials that enter or leave its borders. It is therefore only applicable at the country level. Instead, RMC captures the amount of both the domestic **and** foreign extraction of materials needed along all supply chains to produce the final products consumed in a country. RMC equals the sum of DE plus imports of raw material equivalents minus exports in raw material equivalents. Thus, RMC is a material footprint measurement similarly to the more widely known CO_2 footprint and presents the domestic final use of products in terms of raw material equivalents (see **Box 16** above). This approach is based on the premise that the ultimate polluter is the end product's consumer (European Commission et al., 2017). For more information on the methodology, see Annex I of the SCP-HAT technical documentation.

RMC is an established measure for material use at the (sub-)sector level, and the only one for which data based on complex input-output analyses are readily available at a global coverage. It is included in SDG 12.2: Sustainable management and use of natural resources. While it is not an ideal measurement for the illustration of material use of domestic industrial production, it is currently the best available proxy. RMC is limited in that it only includes production and parts delivered for domestic final demand, while production for export or for other sectors, which is part of total output, is **not**. The final consumer groups of any country are private consumers, government consumption, and capital investment. Accordingly, RMC accounts for all materials embodied in the goods produced for a given sector's local final demand. One advantage is that RMC is free from double counting, i.e. adding the RMC of all sub-sectors aggregates total manufacturing material demand serving domestic consumption. Thus, the indicator helps illustrates final domestic demand trends in manufacturing and the prevalence of various sub-sectors therein. Ideally, as much as possible of material demand should be covered by recycled materials or local extraction, and material intensity should be low to keep environmental repercussions at a minimum. The next indicator looks more closely at material intensity at the manufacturing (sub-)sector level. In the SCP-HAT database, RMC is termed as raw material use under the "consumption footprint" perspective.

Strategic questions

Direct inferences:

- What is the manufacturing sector's share in the economy's raw material consumption footprint?
- What is each manufacturing sub-sector's share in the manufacturing sector's total embodied material use in the country?
- Which manufacturing sub-sectors have the highest raw material consumption in the country?

Follow-up questions:

- Why have the shares of manufacturing (sub-sector) material use developed the way they did?
- What can be done to reduce the manufacturing sector's raw material consumption?

Equation

$$\boldsymbol{Share\ of\ sub-sector\ raw\ material\ demand}\ (\%) = \frac{\boldsymbol{Sub-sector\ raw\ material\ demand}\ (\boldsymbol{t})}{\boldsymbol{Manufacturing\ sector\ raw\ material\ demand}\ (\boldsymbol{t})}$$

Box 17. Difference between DMC and RMC – a practical example

Assuming that Country B imports 5 tonnes of raw materials such as iron ore from Country A, where it is extracted, to manufacture a car that weighs about 1.5 tonnes. The car is then exported to Country C. In terms of DMC, Country C would only have 1.5 tonnes of the final product enter its economy, while 3.5 tonnes of DMC are attributed to Country B where the car is manufactured, resulting from the trade balance of plus 5 tonnes of iron ore and minus 1.5 tonnes for the finished car. Country A, where the iron ore to produce steel was extracted, is not assigned any DMC weight in this transaction, as the entire extracted mass leaves the country via export. In terms of RMC, however, the total amount of 5 tonnes of raw material equivalents embodied in the car is entirely assigned to Country C, where final consumption takes place. This example refers to the material flow at the level of the national economy.

When looking at the (sub-)sector level instead of the economy as a whole, DMC is no longer an appropriate measurement due to its system boundaries allowing for no further disaggregation. RMC is the established means of material accounting for industrial sectors in the literature but has some limitations, namely that it only includes the embodied materials of all products delivered for domestic final demand. All goods destined for final consumption in a country are accounted for by RMC in terms of raw material equivalents (see Box 16), assigned to the producing sub-sector. Finished goods imported for direct final demand are attributed to the corresponding sub-sector, even if no further steps of production take place within the country. Any goods destined for export or inter-sector deliveries are not considered.

The car will NOT be attributed to any manufacturing sub-sector of Country C, as it did not partake in the production and supply chain of the final good consumed. Neither will it show up in Country C's overall RMC, as it is the exact sum of all products directed towards domestic demand and that completed their final production stage domestically. If the car's last production stage took place in Country C, the entire embodied material of the car would be attributed to the relevant sector and thereby to the country as a whole.

4.4 Material intensity of manufacturing (& manufacturing sub-sectors)

Definition

Corresponding with the material intensity at country level, we can calculate the manufacturing sector and sub-sector levels' material intensity by setting the relevant material consumption in relation to the generated income. We use the RMC of each (sub-)sector and their respective MVA (RMC/MVA) (please see the previous indicator 2.5 "Material consumption of manufacturing" for a detailed explanation of RMC). This indicator thus illustrates how much embodied material is consumed per dollar of MVA in a given sector. Decoupling material demand (accumulated along the supply chain) from the value added in industry is an opportunity to capture more monetary value and reduce stress on the environment.

The benefits of reducing material intensity in the manufacturing sector are essentially the same as those for the entire economy, which are discussed in indicator “2.3 Material intensity”. As the manufacturing sector is more reliant on steady material input to produce manufactured goods than other sectors, the potential gains are even more significant. As such, the manufacturing sector and its sub-sectors play a major role in decoupling industrial production from environmental pressures by lowering material intensity. The manufacturing sector and sub-sectors will consequently benefit from increased cost competitiveness of raw materials, which is considered one of the most important drivers of overall competitiveness, even above competitive wage rates (Deloitte, 2013). This can be explained by a number of factors, including the increasing importance of material purchasing costs for manufacturing industries and the positive link between resource productivity and innovation performance (Steger and Bleischwitz, 2009).

Furthermore, decreasing material intensity supports the industrial sector’s diversification and the upgrading of exports structures while increasing material security for industrial production. The transition towards manufacturing and the export of higher value-added goods with higher technological content is thereby facilitated, also for those countries that do not have a significant production of raw materials within their borders. High commodity prices in combination with increasing volatility pose a problem to cost planning in manufacturing industries. Decreasing material intensity can help reduce the material costs of production as well as the negative effects of high volatility in commodity prices.

Lastly, improving material intensity can have positive impacts on employment. Traditionally, companies reduced labour costs to lower the overall costs of production. This cost-cutting strategy puts pressure on labour markets. Decreasing material intensity can be considered an alternative strategy to the reduction of production costs. Cost-effective material intensity improvements generally increase the overall productivity of a company or of a manufacturing sub-sector, which could raise wage levels. A further expansion of the manufacturing sector based on new, material-efficient products could also lead to the creation of additional jobs. However, at the same time, reduced demand for raw materials could lead to reduced employment in material extraction sectors, such as mining (see Tool 5 for more employment-oriented analyses). In developing countries, micro-, small- and medium-sized manufacturing firms often account for the largest share of industrial employment and thus play a key role in job creation. As the material saving potentials are generally higher in such firms than in larger companies, decreased material intensity offers huge potential for increasing productivity and, as a result, employment.

Please note that relating RMC to value added (VA) is technically not fully consistent, as VA includes export and inter-sector deliveries while RMC only covers production for domestic final demand. Nonetheless, this is the best approximation available for material intensities at the sub-sector level, which does not involve extensive advanced calculations. While it is important to keep in mind that the resulting material intensities relate to the final goods consumed instead of gross production, they nonetheless provide a meaningful estimation of which sub-sector has the highest and most intense material use. The estimations may be distorted in the rare cases where a stark divergence exists between demand for final goods and a sector’s VA. Such a mismatch is possible in particular for sectors that exclusively produce for export.

Strategic questions

Direct inferences:

- How does the manufacturing sector's material intensity compare to that of other countries?
- Which manufacturing sub-sectors in the country have the highest material intensity?
- How do the material intensities of manufacturing sub-sectors compare to those in other countries?

Follow-up questions:

- Why has the material intensity of manufacturing (sub-sectors) developed the way it did?
- How can the material intensity of manufacturing (sub-sectors) be reduced?

Equation

$$\boldsymbol{Material\ intensity\ (kilogrammes\ per\ \$\ VA)} = \frac{\boldsymbol{Raw\ Material\ Consumption\ (kg)}}{\boldsymbol{Value\ Added\ (\$)}}$$

4.5 Biodiversity loss from land use (hotspot)

Box 18. What is biodiversity loss and why does it matter?

Biodiversity is an important foundation for the functioning of many natural systems and ecosystem services (see introduction) that human societies depend on – from the food we eat, to the air we breathe, to the decomposition of our waste. We are currently witnessing a rapid decline in biological diversity worldwide, coined the sixth mass extinction: between 1970 and 2016, the population of species dropped by 68 per cent, on average, globally, and extinction rates are more than 100 times higher than the normal process of species loss over the past several million years (Dasgupta, 2021). The 2019 *Global Assessment Report on Biodiversity and Ecosystem Services*, published by the United Nations' Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, posits that roughly one million species of plants and animals face extinction within decades as the result of human actions (CBD, 2019).

The human activities causing this mass extinction include habitat destruction through deforestation and land use change, pollution, hunting, accelerated climate change and the transmission of infectious diseases. Many of these causes are linked to a rise in material demand and extraction exceeding the levels of sustainable supply. This persistent demand overshoot is endangering the prosperity of current and future generations, fueling significant risk for our economies and well-being (Dasgupta, 2021). Biodiversity loss results in increasing genetic vulnerability and the spread of diseases among flora and fauna, consequently leading to the collapse of ecosystems and a volatile food supply for human societies (CBD, 2019). In other words, it harms the fragile natural equilibrium underpinning our mode of production.

Definition

Land use is a main driver of global biodiversity loss (see **Box 16** for more information) and represents a significant share of the total environmental burden of forestry-based products in the wood and paper industry. Therefore, we use the indicator "Potential species loss from land use" provided by the SCP-HAT platform, specifically the domestic production perspective of the forestry sub-sector. Since land use change and biodiversity are very local features contained within the country's geographical boundaries, this perspective was chosen as it attributes the environmental harm to the industry causing it during production as opposed to the consumption (footprint) perspective taken in other indicators (European Commission et al., 2017).

The unit of this indicator is *PDF*year*, which refers to the Potentially Disappeared Fraction of species for the duration of one year. The corresponding data on the SCP-HAT website was calculated according to the model approach proposed by Chaudhary et al. (2015), which uses species-area relationships to determine biodiversity loss for both land occupation and transformation. The two forestry land use classes, which represent the extractive industrial impact, are defined as follows:

i) Intensive forests feature either even-aged stands and clear-cut patches or less than three naturally occurring species at planting/ seeding;

ii) Extensive forests feature selective logging, where timber extraction is followed by re-growth, including at least three naturally occurring tree species.

Land use impact modelling assumes that once an activity (forestry) stops, the system will slowly return to the natural state. The indicator therefore does not reflect the full extinction of species but a potentially temporary decline in biodiversity which nonetheless deteriorates ecosystem quality.

There are a number of other freely available data resources on biodiversity which have a less explicit link to industrial production but can provide more in-depth insights for the interested policymaker: the Integrated Biodiversity Assessment Tool (IBAT), the IUCN Red List Index and Global Forest Watch. IBAT (https://www.ibat-alliance.org/country_profiles) is an online tool which illustrates the distribution and overlap of protected areas and key biodiversity areas via country profiles and a data map. The IUCN Red List Index helps assess biodiversity loss at various levels of disaggregation as part of *Sustainable Development Goal 15*. Global Forest Watch (https://www.globalforestwatch.org/dashboards/global/) is an online platform, established by the World Resources Institute, that provides deforestation data gathered from satellite images.

Strategic questions

Direct inferences:

- How has the Potentially Disappeared Fraction of species from forestry land use developed over time in the given country?
- To what extent does the forestry industry contribute to the country's overall species loss from land use, and how does this compare to other countries?
- How does the Potentially Disappeared Fraction of species from forestry land use trend over time relate to that of forestry biomass resource extraction?

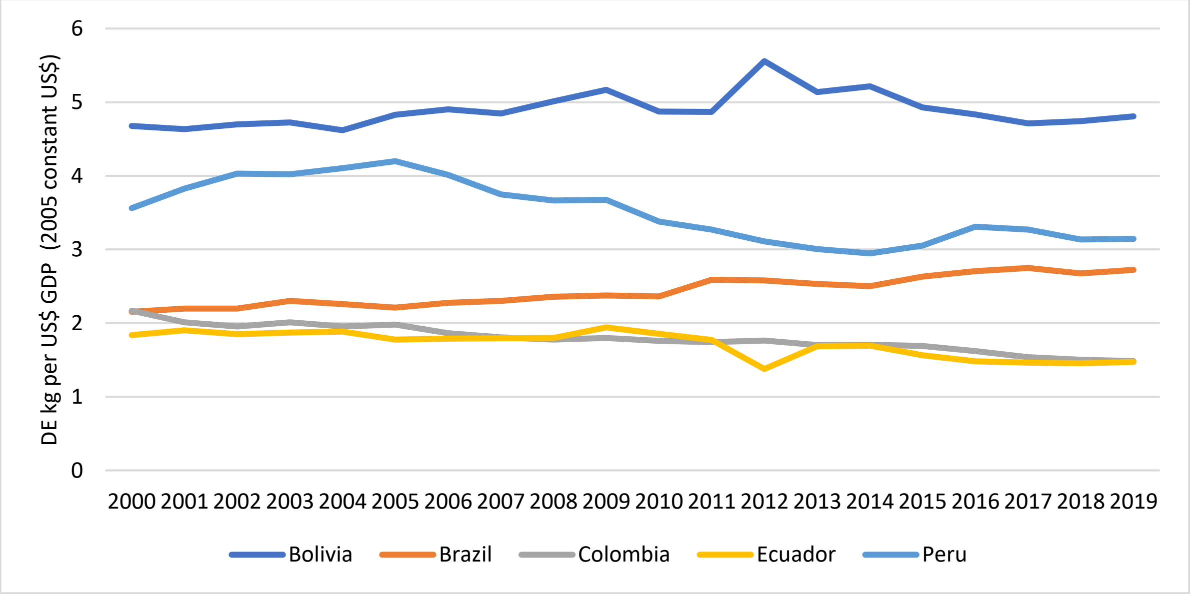
Follow-up questions:

- Why has the forestry-induced biodiversity loss developed the way it did?
- How can the Potentially Disappeared Fraction of species from forestry land use be reduced?

Analysis

In this section, we apply the material use and extraction indicators to analyse a group of example countries in Latin America, namely Bolivia, Brazil, Colombia, Ecuador and Peru. The following graph (**Figure 48**) compares these countries' domestic extraction intensity between 2000 and 2019. Bolivia exhibited the highest values throughout this period, with a relatively stable trend around 5 kg per US$ GDP and a slight spike in the year 2012. Peru had an extraction intensity of about 4 kg per US$ GDP up until the year 2006 and has reported a considerable decrease to around 3 kg per US$ GDP since. Brazil, Colombia, and Ecuador had about equally low extraction intensity values at the turn of the millennium of about 2 kg DE per US$ GDP. Since then, extraction intensity increased in the former while slightly improving in the two latter countries. Accordingly, DE volumes in Brazil have surpassed GDP since 2000, soliciting further analysis into the causes and remedial policy measures this warrants.

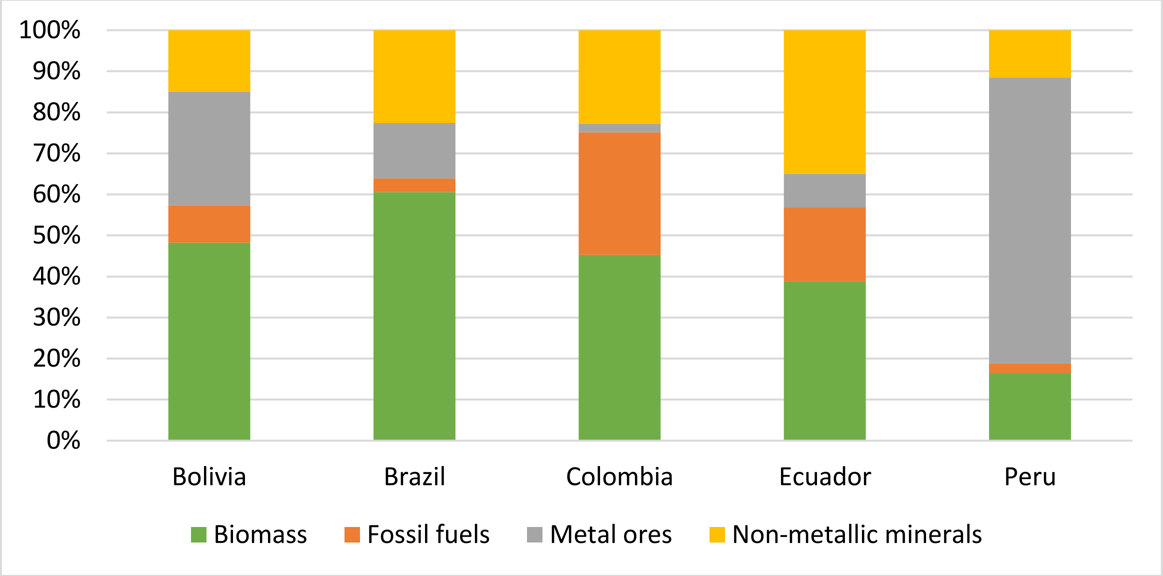
Figure 48. Domestic extraction intensity in Latin American example countries



Source: Own graph based on World Resource Panel data

Figure 49 depicts the shares of the four major resource categories in the domestic extraction of our example countries, providing a better understanding of the aggregate trend from the previous figure. This composition can also be traced over time, depicting the development of each single country. We find large shares of metal ores in Bolivia and particularly in Peru's total domestic extraction, which exhibited the highest extraction intensity in the previous figure. Presumably, much of this metal is destined for export either in a raw state or as content of manufactured products. Brazil, on the other hand, shows an above-average share of biomass extraction, hinting at a prevalence of agriculture (crops) and forestry (wood) (see Box 15 for details on the categories). Colombia and Ecuador have a less pronounced focus on a single resource category. The former nonetheless has a significant share of fossil fuels in total extraction, while the latter's share of non-metallic minerals is relatively high.

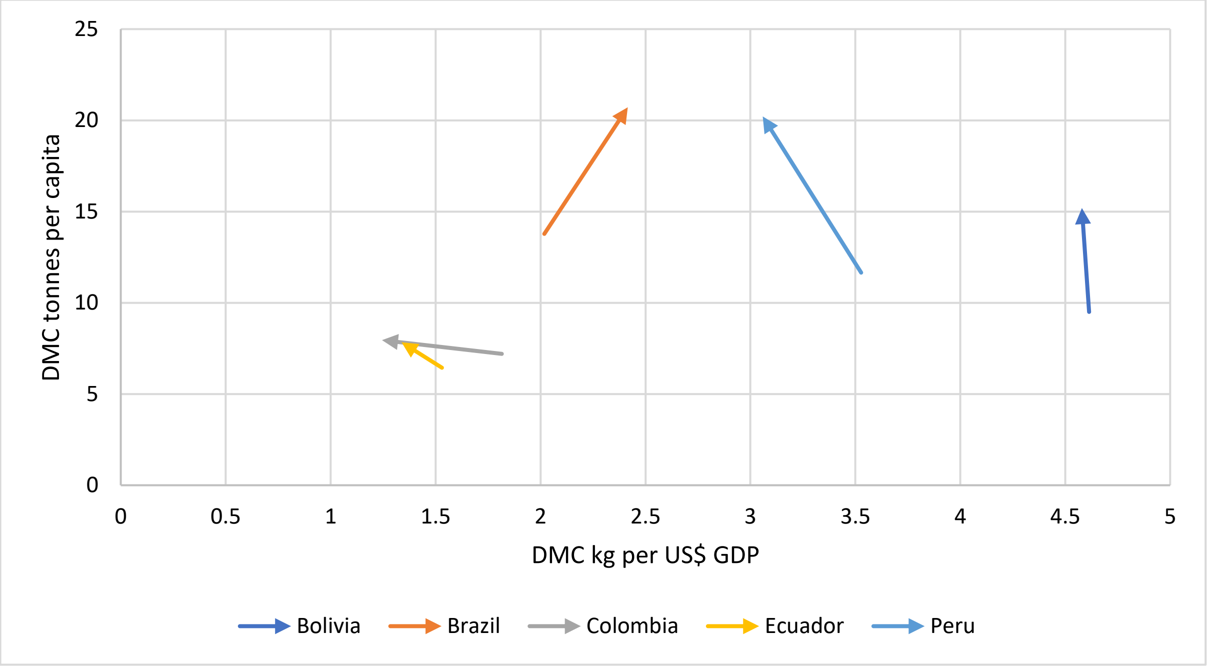
Figure 49. Share of main resource categories in domestic extraction



Source: Own graph based on World Resource Panel data

Figure 50 plots DMC per capita against DMC per GDP (material intensity) and the change of this relationship between 2000 and 2019. This helps differentiate the effects both GDP and population dynamics have had on material use. First, this graph highlights the fact that all countries of the group experienced an increase in their per capita material consumption, since the arrows are pointing upwards along the y-axis. This development was weakest in Colombia, which had the second-lowest per capita and per GDP material use of the group in 2000 and has in fact managed to decrease its material intensity since then. Peru was also able to reduce its material intensity, but it is still higher at about 3 kg per US$, and at the same, witnessed a significant increase in its per capita consumption. Brazil's overall material intensity increased significantly: its material intensity rose by around 1 kg DMC per US$ of GDP, while its per capita DMC grew by more than 5 tonnes. Bolivia had the highest material intensity among the group at over 4.5 kg per US$ of GDP. While this value remained stable, Bolivia's per capita material consumption also rose by more than five tonnes. One explanation is that the country's sustained economic growth coincided with expanding material consumption and declining population growth.

Figure 50. Material intensity vs DMC per capita in example countries (change 2000–2019)



Source: Own graph based on World Resource Panel data

Table 16 presents global domestic material extraction and consumption averages, standardized by population (per capita) as well as income (intensity = per GDP constant 2015 US$) by country income group. The material data were taken from the IRP database where material extraction and consumption values are available for most countries between 1970 and 2019. We used pre-standardized data, which are also available in the IRP database, but needs to be classified by country income group. These classifications are provided and regularly updated by the World Bank (https://datahelpdesk.worldbank.org/knowledgebase/articles/906519). This table aims to facilitate the benchmarking of any country's material extraction and consumption level with comparable economies based on a standardized measure.

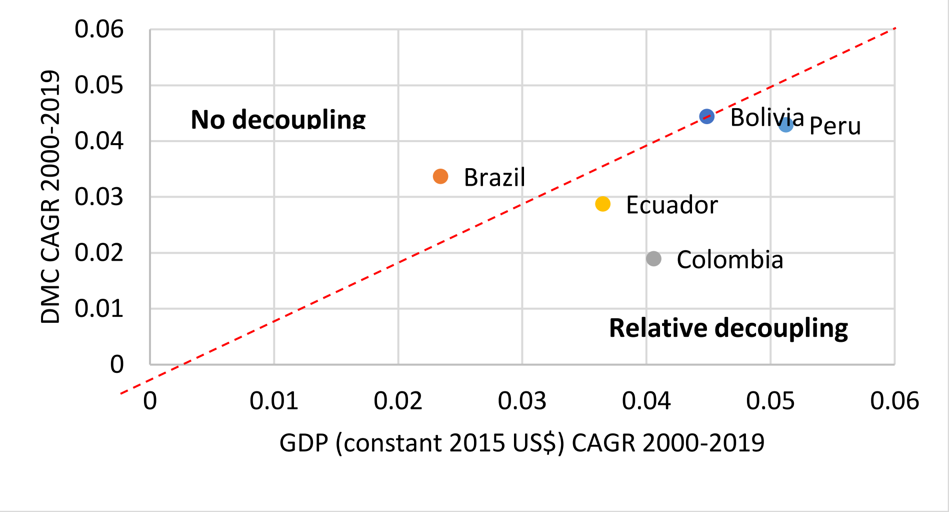
Table 16. Domestic material extraction and consumption global averages across income groups

2019 country averages	Low-income	Lower middle- income	Upper middle- income	High-income
DE tonnes per capita	3.97	8.72	14.15	18.89
DMC tonnes per capita	4.00	8.45	13.83	18.49
DE kg per US$ GDP (2015 constant US$)	6.94	3.71	2.12	0.65
DMC kg per US$ GDP (2015 constant US$)	5.19	2.50	2.08	0.44

Source: Own calculations based on World Resource Panel and World Bank data

Figure 51 below depicts the trend of material decoupling in the example countries by relating the CAGR of GDP on the x-axis and DMC on the y-axis. The resulting point diagram is split diagonally into two halves: in the bottom right corner, relative decoupling took place as GDP grew faster than DMC. At the top left, no decoupling took place as DMC outpaced GDP. Accordingly, Colombia, Peru and Ecuador are positioned in the relative decoupling half, meaning their economic growth was stronger than their increase in material demand. Even though Peru reached a higher CAGR of GDP than the other two countries, its CAGR of DMC was also higher. Consequently, Peru and Ecuador are positioned at about an equal distance to the line, indicating a similar decoupling effect. Colombia's material decoupling development was thus stronger. Bolivia is positioned close to line, indicating that its DMC grew at almost exactly the same pace as its GDP since 2000. Brazil, on the other hand, lagged behind in terms of decoupling its material consumption from national income. None of the sample countries achieved the ideal case of absolute decoupling, (GDP increases while DMC decreases).

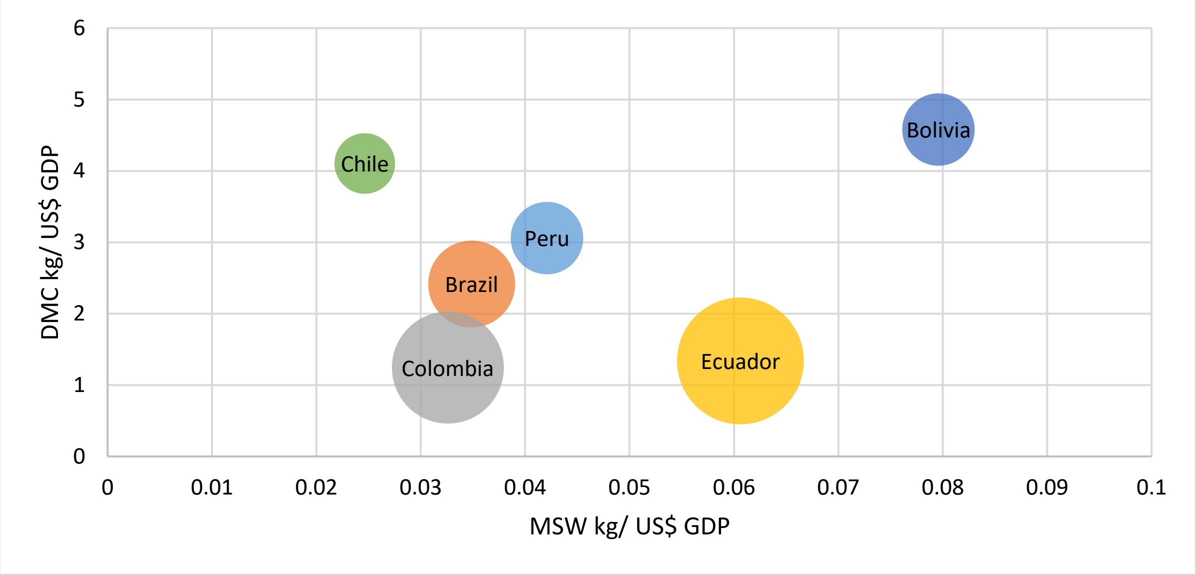
Figure 51. Material decoupling: developments in DMC and GDP (CAGR 2000-2019)



Source: Own graph based on World Resource Panel data

In this graph (**Figure 52**), indicators from the thematic sections on material and waste are combined to illustrate the relationship between the material in- and outputs of different economies. Both flows are depicted in intensities, which are the standardized throughput in mass units per dollar of GDP. This measure is more comparable than absolute total amounts when looking at different countries of various sizes. In addition to these two axes, the bubble size of each country represents the percentage share of municipal solid waste (MSW) generated in DMC. Bolivia stands out in this figure, as it has the group's highest material and waste intensity. This is most likely because Bolivia has the lowest GDP in comparison to the others. While Ecuador's material intensity is similar to Peru, Brazil and Colombia's, its waste intensity within the group is above average. The amount of MSW represents the highest share in DMC in both Ecuador and Colombia, exemplified by bubble size. This type of analysis can also be conducted at the manufacturing sub-sector level if the necessary data are available, which is currently not the case in many countries for waste data. Chile was included in this graph to exemplify how is it possible to achieve low waste intensity while having relatively high material throughputs.

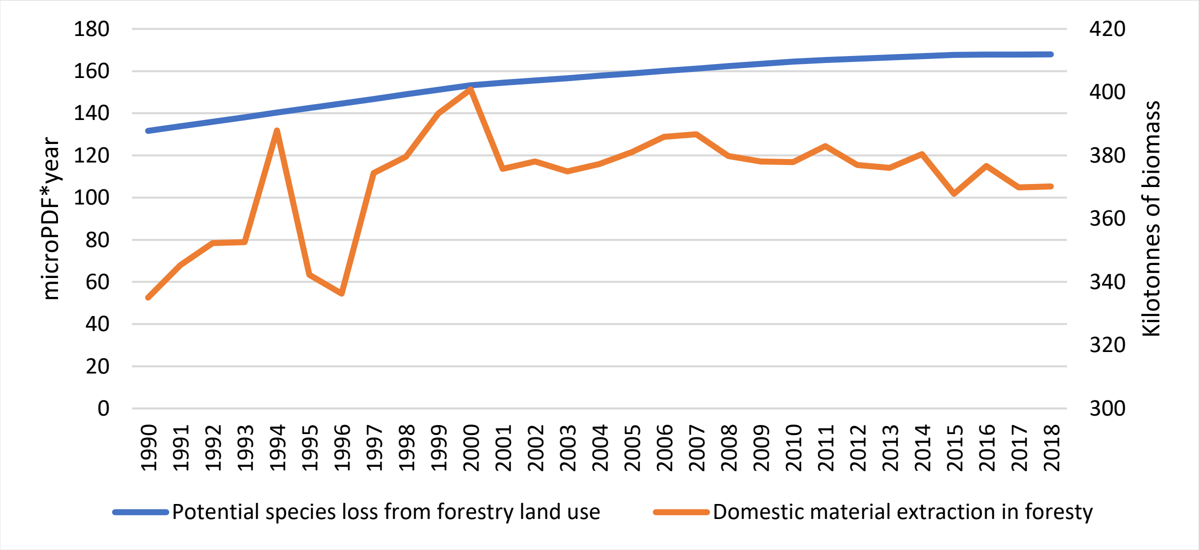
Figure 52. Material and waste intensity (bubble size: % of MSW in DMC)



Source: Own graph based on World Resource Panel and "What a Waste 2.0" data

Figure 53 below depicts the Potentially Disappeared Fraction (PDF) of species per year from forestry land use in Peru on the primary y-axis, and the biomass domestic material extraction from forestry on the secondary y-axis. Aside from a dip in biomass extraction around 1996, both metrics exhibited a growth trend up to the year 2000. Forestry extraction volumes then stalled and have remained around 380 kilotonnes per year since, while biodiversity loss from forestry land use continued to slightly increase every year, highlighting that not only the volume but also the manner of extraction plays a role in the degree of associated environmental degradation.

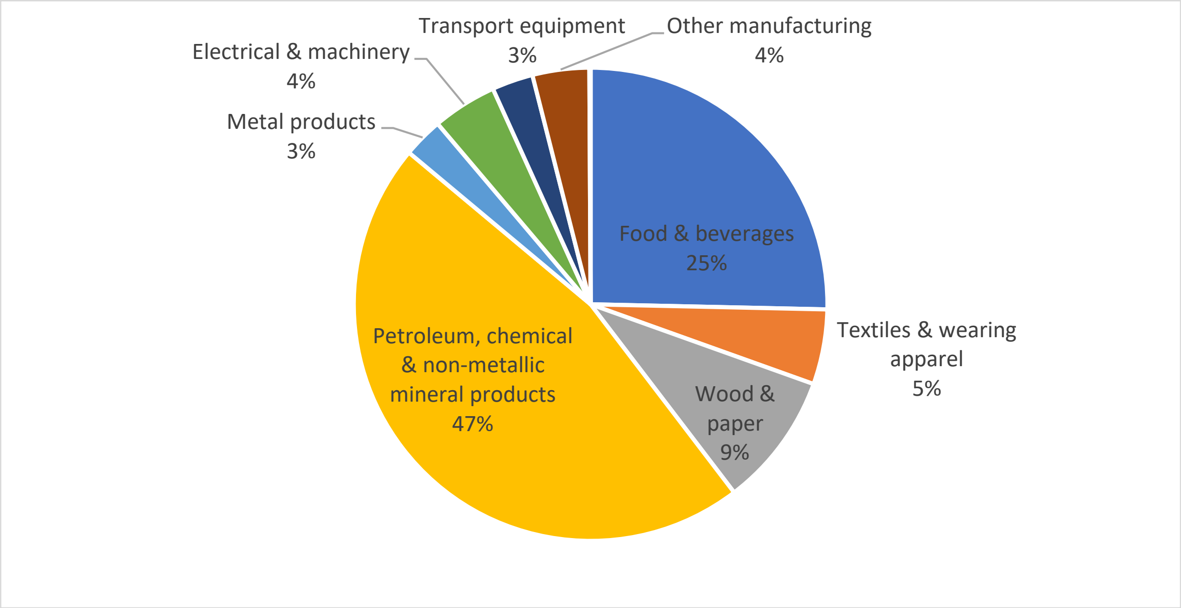
Figure 53. Potential species loss from forestry land use in Peru



Source: Own graph based on SCP-HAT data

The pie chart in **Figure 54** illustrates each manufacturing sub-sectors' share in total manufacturing material use in Viet Nam in terms of RMC. Since RMC only adds those products to each sub-sector's material footprint account which are produced for domestic consumption, those sub-sectors geared towards manufactured exports will appear to have a lower share of material use than they actually have in gross output. In the case of Colombia, for example, the petroleum and chemicals sub-sector is the largest consumer of materials used to meet domestic demand, followed by food and beverages. It is likely that these sub-sectors also have considerable export-driven material demand, which cannot, however, be clearly inferred from this data. Other traditional industrial manufacturing sub-sectors, such as electrical and machinery, are not as relevant in terms of material use for domestic consumption but may still use significant amounts of natural resources to produce goods destined for export.

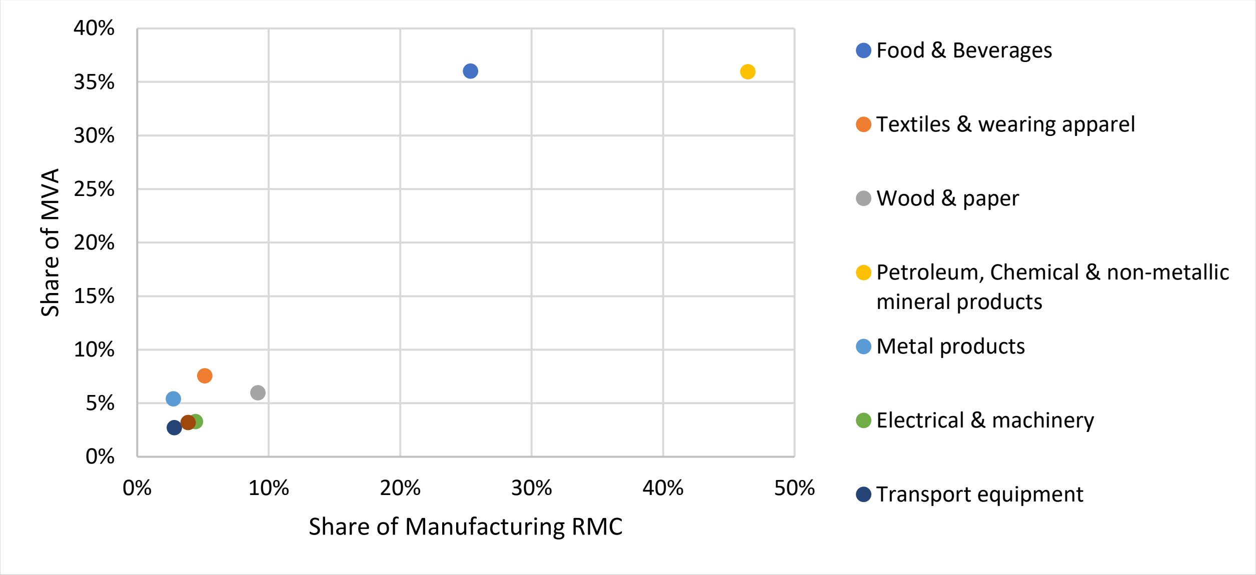
Figure 54. Sub-sectors' share of manufacturing material consumption (RMC) in Colombia



Source: Own graph based on SCP-HAT data

Figure 55 shows the share of Viet Nam's manufacturing sub-sectors in total manufacturing RMC on the x-axis and MVA on the y-axis, thereby depicting the variables of manufacturing material intensity. Please bear in mind that RMC only includes the final products of domestic consumption while VA also covers products for export and inter-sector exchange. The analysis based on this indicator is therefore more of an approximation than an accurate metric for evidence-based policymaking, due to the lack of appropriate and accessible data. Colombia's two dominant sub-sectors in the previous graph also stand out in this analysis: petroleum & chemicals and food & beverages. While both have the same share of VA among the manufacturing sub-sectors presented (at around 35 per cent), their demand for raw material demand differs significantly, with the former at 47 per cent and the latter at 25 per cent. It can be deduced that food & beverages has lower material intensity, e.g. material required per VA, while petroleum & chemicals has a higher intensity. Again, this result may be biased by the discrepancy in scope of the variables. Nonetheless, the degree to which petroleum & chemicals stands out among the manufacturing sub-sectors in the metrics of total manufacturing RMC and in material intensity warrants concern. Local policymakers should consider measures that lower the raw materials required by this sector, both in absolute terms as well as relative to the value generated.

Figure 55. The share of sub-sector in manufacturing material use (RMC) and manufacturing value added (MVA) in Colombia



Source: Own graph based on SCP-HAT data

Policy options

Material intensity

Lowering material intensity is a means to increase competitiveness by reducing production costs. This is particularly true for the rising cost of purchasing raw material inputs and the associated competition for these natural resources on markets (World Bank, 2015). While this generates higher profits in the short term for resource-exporting countries, high commodity prices may also conceal medium- to long-term requirements of reducing dependency on a few exports with low value added through more diversified industrialization. A key strategy for such countries is to upgrade their industrial structure and diversify their export portfolio to move from processing towards producing and exporting goods with higher technological content and higher value added (1st transformation). Lowering material intensity can support a transition from resource-intensive primary production activities towards producing high value-added goods.

Improving material intensity reduces the vulnerability of manufacturing industries in countries dependent on imports of strategic raw materials, especially when these come from politically unstable countries. By expanding industrial production and affluence, developing and emerging economies will continue to rapidly increase their absolute material consumption. In the medium term, decreasing material intensity can thus provide an important contribution to ensuring that the necessary resource base for industrial development will not be depleted for current or future generations. This will also lower the risk of conflicts about access to raw materials.

Decoupling economic activities from the generation of environmental pressures associated with the use of various material resources is a key objective of the greening industry agenda. Decreasing material intensity is a key strategy to realizing such a decoupling. Overall demand for raw materials is thereby reduced compared to a development path without improving material intensity. Lowering material intensity thus translates into a relative improvement in the environmental situation (i.e. relative decoupling), e.g. in terms of negative pollution and waste impacts of resource extraction and processing. However, such intensity reductions may also lead to so-called rebound effects as they may lower production costs, thus stimulating growth and demand. Whether an absolute reduction of environmental pressures (i.e. absolute decoupling) can therefore be realized also depends on other factors besides intensity improvements, such as the implementation of policy instruments (e.g. environmental taxes) which limit these rebound effects.

Material intensity in the manufacturing sector can be improved through several strategies: applying less resource-intense designs and technologies that help save material inputs for production; developing integrated material management systems, which minimize the generation of waste; or specializing in those manufacturing sub-sectors that require less material per generated unit of VA. Increased competition over natural resources on world markets and higher raw material prices have resulted in incentives in many countries for several resource-intensive industries, including cement, iron and steel, chemicals, and paper, to implement resource intensity measures. Industry representatives generally perceive these measures as a key strategy to decreasing production costs and to thus improve international competitiveness (Ecorys, 2011).

There are a range of policy measures that can contribute to a less resource-intense and more materially circular economy (UNEP, 2014), for example:

1. Reducing investment uncertainty and political lock-in
2. Increasing innovation capacity
3. Adjusting government pricing instruments to align market resource prices with decoupling
4. Environmental fiscal reform
5. Restricting harmful activities or products, and strengthening markets for innovation
6. Stimulate demand for resource productivity.

1. Reducing uncertainty and providing direction

For industry to adapt today to prepare for the challenges of tomorrow, clear indications about what the future will look like are crucial. When policymakers can provide a credible direction for change, they can reduce uncertainty around investments in resource productivity. Strategies are frequently used to create visions and goals for the future and provide clear direction to achieve those goals through credible mechanisms and measures. This may require adaptation of new institutional structures to streamline the necessary capabilities. A strategy’s effectiveness in delivering predictability depends on its degree of credibility and clarity, and the level of political support behind it. This often means that the process by which the strategy is developed or agreed can have an impact on its success. Sufficient cooperation between government, industry and other stakeholders must be part of the policy framework, if it is to be seen as credible and relevant. Coordination between various policies is important to ensure coherence, reduce costs and increase benefits from complementarity (UNEP, 2014).

2. Innovation-enabling policies

The second area of measures to generate greater resource productivity are instruments that increase or facilitate an economy's capacity to innovate. Neither the country's innovation capacity nor the measures must necessarily be specifically aimed at increasing resource productivity. The creation of generic innovation capacity is the starting point in many developing countries (UNEP, 2014). There are two kinds of innovation capacity that are often related: firstly, policies that boost the capacity to innovate. These measures can directly support research, stimulate demand, remove obstacles to supply, or take many other forms. They include promoting skills, creating networks, exchanging international experience, infrastructure planning to support innovation, and capacity development and education curriculum reform (Desha and Hargroves, 2012). Secondly, policies that facilitate change and the spread of innovation by reducing its shortcomings, namely reducing the social costs of change, thereby enabling political acceptance. These include policies that support redundant workers in finding new jobs and reskilling.

Box 19. Industrial Symbiosis Programme in South Africa (Ellen MacArthur Foundation, 2020)

Africa's first Industrial Symbiosis Programme supports the transition to a circular economy by enabling manufacturing firms to exchange under-used resources that usually become waste. The Western Cape Industrial Symbiosis Programme (WISP) in Cape Town is a multiple award-winning programme and Africa's first industrial symbiosis project. It is a free facilitation service that helps companies identify mutually beneficial opportunities to exchange resources. By matching companies' supply and demand for secondary raw materials (materials recycled from waste), it helps businesses identify new opportunities.

Industrial symbiosis promotes circular flows within the industrial sector, creates new business opportunities, and provides mutual benefits for businesses through the exchange of underused resources. The programme provides mutual benefits for businesses by generating new revenue streams and reducing operational costs. Moreover, it:

- adds value to materials
- extends material use through multiple applications
- reduces the harmful effects of dumped waste.

Funded by the City of Cape Town and delivered by GreenCape (https://www.greencape.co.za/about-us/the-wc-green-economy/), an NGO, WISP connects companies so they can identify business opportunities to use unused or residual resources. The Western Cape government wanted to reduce the unemployment rate, which had reached 24 per cent in 2011, stimulate economic growth and create jobs while reducing environmental degradation. It put forward its Green Economy Strategy Framework in 2013, which highlighted the benefits of a green economy, and sought innovative projects to support. Jenny Cargill, special advisor of Western Cape's Premier, travelled to the United Kingdom (UK) on an industrial symbiosis study tour. Drawing inspiration from the UK's National Industrial Symbiosis Programme (NISP) and adapting it to the South African context, the WISP pilot was launched in 2013.

To date, the programme has diverted over 104,900 tonnes of material from becoming waste in a landfill, while creating 218 economy-wide jobs, mainly in SMEs. By providing many new business opportunities, WISP has generated over ZAR 120 million (US$ 8.50 million) in additional revenue, cost savings and private investments. For every rand invested by the government, WISP has returned 7 rands in economic benefits to its network. WISP's success has encouraged the development of other industrial symbiosis programmes in other South African provinces and African countries.

3. Policies directly affecting resource prices

One of the key conditions for encouraging resource-productive investments in market economies is the relative price of resources. For a market economy to make a transition in the direction society wants it to, the price signals need to align with the society's strategic goals. This has the potential to redefine the agenda of firms and individuals in such a way that the investment and purchase decisions they make in their own interest are in line with society's. A policy change that corrects price distortions at one point in the production chain passes that benefit on to other aspects of production and consumption of a good, addressing not only manufacturers and service providers, but consumers as well. Unless the state has the power to set prices itself, the policies that directly affect resource prices can be price-based (charges, fees, taxes, or removal of subsidies) or rights-based (tradable permits, auctioned user rights), the latter usually requiring the setting up of new market institutions (UNEP, 2014).

4. Environmental fiscal reform (EFR)

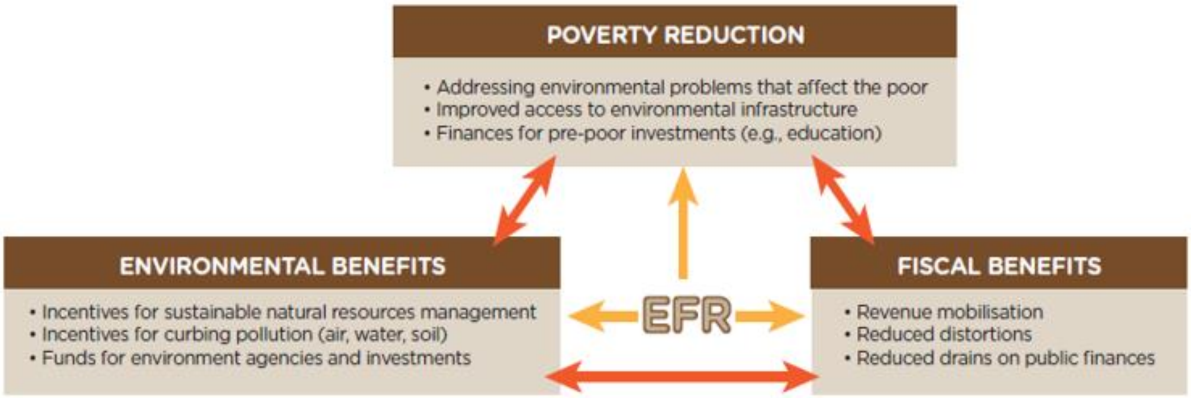
Tax and subsidy reforms can be used to correct the inadequacies of current pricing systems and to contribute to the internalization of external costs associated with the extraction, processing, and use of natural resources. For rapidly industrializing economies, environmental fiscal reform (EFR) can play a key role in leapfrogging to promote resource efficiency and control industrial pollution.

Subsidies supporting the continued inefficient use of resources are often called "perverse subsidies" (Kent and Myers, 2011) because their dynamic effects run counter to productivity goals. Perverse subsidies represent a large and often growing direct drain on public finances, depriving other sectors of the economy of budgetary resources. Reform of explicit subsidies (IEEP et al., 2007) yields fiscal benefits during times of budgetary constraint. More information on subsidies, including a harmful subsidies reform tool, can be found in the 2009 publication "Environmentally Harmful Subsidies: Identification and Assessment" by the Institute for European Environmental Policy.

Taxes and fees on raw materials can target all sectors and physical flows where resource use arises (Langsdorf, 2016). What is particularly relevant for developing countries is creating fiscal revenue from the extraction of their natural resources by foreign-owned interests. Extraction taxes can also serve as an incentive to overcome the often careless and wasteful methods of extraction. Where these taxes are linked to pollution, such taxes can also be an appropriate means of ending deleterious trends of deteriorating air and water quality (UNEP, 2004; UNEP and ECLAC, 2003). The administrative costs of eco-taxes tend to be considerably lower than those of value added taxes (UNEP, 2014). They are usually equally motivated by other fiscal goals, for example tax revenues can be used to finance technology development or resource productivity programmes where these are not used to lower other "distorting taxes", such as labour taxes (Ekins and Speck, 2011; OECD, 2010; Jaeger, 2011).

Nearly all of the literature on optimal levels of taxation assumes that taxes for resources should be set at an "optimal" rate, corresponding to the "external" cost of societal or environmental impacts caused by the use of the respective commodities (UNEP, 2014). They are thereby designed to correct the typical market failures in resource prices and to integrate negative "externalities" into the cost of products and services. Despite the evidence in academic literature, the vast majority of existing taxes on raw materials are designed primarily to raise revenue (Commonwealth Secretariat and ICMM, 2009). When the decision-maker's goal is to create the conditions that facilitate greater resource-productive investments, the estimation of the appropriate level of taxation will usually need to consider a wider range of factors rather than the "optimality" of taxation. This may include investigating the role prices play in overcoming barriers to transition, thereby taking the extent of those barriers into account – for example the impact of subsidies on the effective price of the resource, as well as other factors creating a bias in the economy (UNEP, 2014).

Figure 56. Assumed benefits of an environmental fiscal reform



Source: World Bank (2005)

5. Bans, prohibitions, and mandated requirements

Some of the most important policy measures used for resource productivity and the reduction of environmental harm were implemented by a regulation to restrict environmentally damaging behaviour, with the threat of legal sanctions if the regulation is disregarded. This type of policy measure can limit products or processes, or alternatively require an adaptation of the different processes, technologies, or products to be used. This includes product standards, efficiency standards and emission limits. They can take many forms and have different layers of complexity – with some combining different standards that must be met with various forms of activity to meet them (UNEP, 2014).

Direct regulatory requirements can be very effective at driving change. They often have a clear purpose and outcome and can furthermore send clear signals on what changes are being sought (Harrington and Morgenstern, 2004). The threat of legal sanctions can be a strong motivation for change, the effectiveness of which depends on the public authorities enforcing the regulation and the penalty's impact. Although often primarily regarded as a way to directly reach a public goal, this type of instrument plays a crucial role in creating the conditions for investment in resource-productive technologies: when regulations prohibit some of the existing (poorly performing) technologies, they create new demand for alternative, more resource-productive technologies and reward innovators. It is very unusual for regulations to bring an end to the economic activity that is being regulated and instead stimulate change to alternative products that serve the same function, or alternative methods to produce the same product. They remove less resource-productive (or more environmentally harmful) products or technologies from the market, reducing competition and opening markets for more resource-productive products. This can be essential to overcome biases that have created conditions where less-productive technology is cheaper than the more resource-productive alternatives (UNEP, 2014).

The effects of direct regulation depend on many factors, including how trade patterns, skills and capabilities and demand changes. One disadvantage can be that the standards are naturally “static”: they usually provide incentives to reach a specific goal, but no incentives for innovating beyond that. This can be mitigated by mechanisms that periodically review and reset the standards (UNEP, 2014).

6. Stimulate demand for resource productivity

Schemes describing products or technologies' resource use help commercial buyers select more efficient products. These include forest certification schemes (such as the Forest Stewardship labelling programme: https://fsc.org/en) and help boost markets, thereby rewarding resource-productive investments. Standards reduce uncertainty about innovative products or processes by providing a benchmark for performance. They also communicate new norms or standard practices, which help people move away from past norms. Industrial norms and standards that have been used for a long time to safeguard quality, compatibility, and safety, are increasingly being used for environmental and resource efficiency purposes. The International Organization for Standardization (ISO) has used the ISO 14000 series (https://www.iso.org/iso-14001-environmental-management.html) for environmental performance (ISO 14040:2006; ISO 14044:2006), mostly focusing on pollution control. Some standards apply beyond products, services, or technologies. They can be extended to a systematic, strategic, and practical management approach: compliance with the standard provides a guarantee that good practice is being followed. The use of standards in this context can promote the adoption of norms that include maximization of resource productivity within business models (UNEP, 2014).

Public organization's purchasing power is considerable and can be harnessed to drive markets to produce ever-more resource-efficient products and services. Green procurement provides a sufficiently large niche market to reward innovators that bring their resource-efficient products or services to commercial scale. The presence of the market encourages investments in commercialization of technology, which can then also break into private sector markets where there is a natural advantage for existing products, or where innovators are unsure of market demand (UNEP, 2014).

Environmental hotspots

Naturally, environmental hotspots, biodiversity loss and deforestation benefit from any improvement in material productivity through the aforementioned instruments, such as environmental regulations or fiscal reform. However, there are also some policy options that specifically address these issues, as explained in the following.

Payment for ecosystem services (PES)

Payment for ecosystem services (PES) are voluntary transactions where a well-defined ecosystem service (or land-use likely to realize that service) is paid for by at least one ecosystem service buyer from at least one ecosystem service provider that secures ecosystem service provision. This can also include ecosystem payments required by regulation and direct transfers from governments or compensations for direct financial losses as a result of ecosystem damage (WBCSD, 2010). For an explanation of what constitutes ecosystem services, consult Box 1 in the introduction. Forests are a practicable and cost-effective option for the provision of ecosystem services, preservation of biodiversity and climate change mitigation. They also tend to have low opportunity costs and can make an immediate and direct contribution to sustainable development and rural livelihoods. In recent years, particularly the concept of payments for Reducing Emissions from Deforestation and Forest Degradation (REDD) has been high on many policymakers' agendas. Over time, the concept of REDD has broadened to 'REDD+' an includes sustainable forest management and the enhancement of carbon stocks alongside the reduction of emissions from ongoing deforestation and degradation (WBCSD, 2010).

Increasing forest rent over time is a way to protect them: high demand and a limited supply of forest products stimulate stabilization of forest cover and regrowth (Rudel et al., 2005). While this path has historically been driven by forest extractive rent (i.e. rent from forest products), the fundamental underlying idea of REDD+ is to stimulate forest cover stabilization through an increase in protective rent (rent from environmental services). An increase in forest rent, however, will not affect deforestation, unless land users can capture a share (and include it in deciding how to use the land). There are two main ways to 'internalize the externalities' for optimal forest use: by moving decisions to a greater scale at which the effects are felt and can therefore be incorporated, and by creating a market for the public good, i.e. environmental services that are provided by standing forests (Angelsen, 2009).

Mitigation hierarchy, biodiversity offsets and "no net loss"

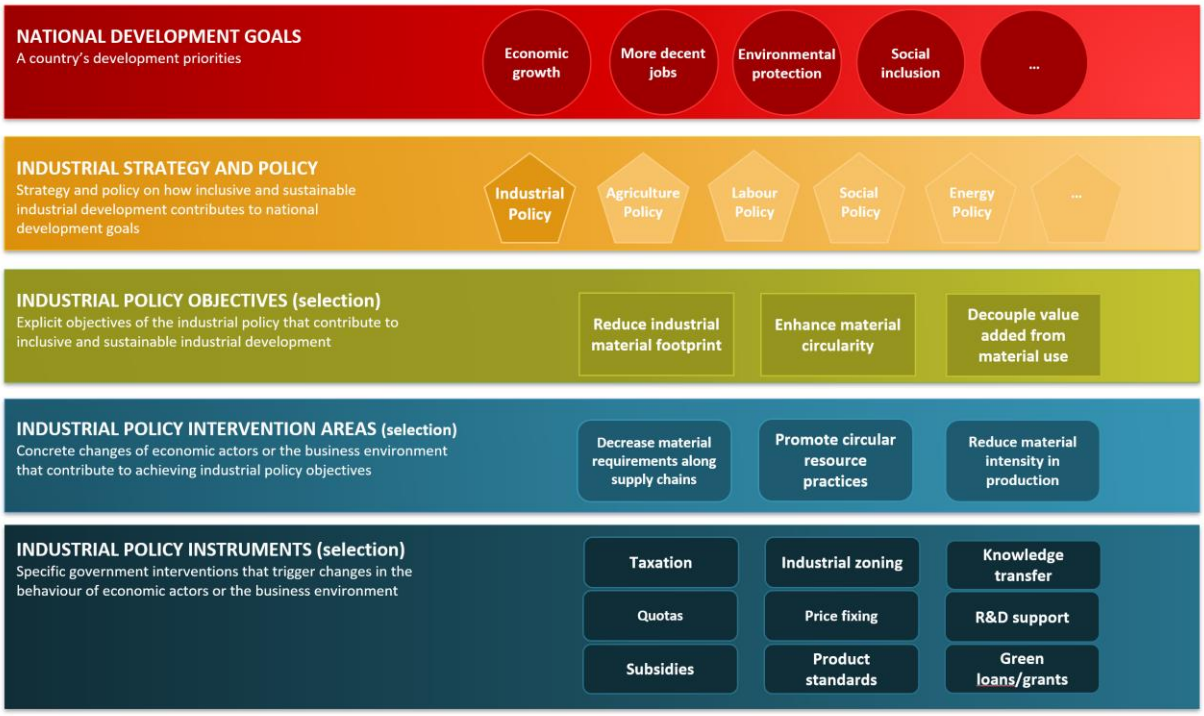
The mitigation hierarchy is a recognized approach for managing biodiversity risk at both the project- and the strategic environmental planning level. According to the hierarchy, efforts should be made to prevent or avoid impacts on biodiversity, to then minimize and reduce, and ultimately repair or restore adverse effects. Some groups have suggested that any significant residual effects be addressed via a 'biodiversity offset' after these steps to achieve a 'no net loss' of biodiversity. No net loss is an aspirational objective of measures to mitigate biodiversity impacts underpinned by the concept that loss of conservation value in one geographically or otherwise defined area can be balanced by commensurate gains elsewhere. This raises several issues, including accurate scientific biodiversity measurement and the slow pace of ecosystem recovery (WBCSD, 2010).

National green accounting

Green accounting incorporates environmental assets and their source and sink functions into national and corporate accounts. It is a popular term for environmental and natural resource accounting. Conventional national accounts largely disregard new or newly observed scarcities of natural resources, which threaten to undermine the sustainability of economic performance and growth, and environmental degradation as an 'external' cost of economic activity.

Further critique refers to a possible distortion from counting environmental protection expenditure as an increase in national income, despite the fact that such 'defensive expenditure' tends to maintain rather than increase the welfare of society. The most comprehensive and widely accepted guide for green accounting is the System for integrated Environmental and Economic Accounting (SEEA: https://seea.un.org/), which was issued by the United Nations. SEEA introduces nature's environmental and economic assets and the 'environmental cost' of their degradation and depletion into the System of National Accounts.

Table 17. Material policy implication matrix



NATIONAL DEVELOPMENT GOALS
A country's development priorities

Economic growth
More decent jobs
Environmental protection
Social inclusion
...

INDUSTRIAL STRATEGY AND POLICY
Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals

Industrial Policy
Agriculture Policy
Labour Policy
Social Policy
Energy Policy
...

INDUSTRIAL POLICY OBJECTIVES (selection)
Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development

Reduce industrial material footprint
Enhance material circularity
Decouple value added from material use

INDUSTRIAL POLICY INTERVENTION AREAS (selection)
Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives

Decrease material requirements along supply chains
Promote circular resource practices
Reduce material intensity in production

INDUSTRIAL POLICY INSTRUMENTS (selection)
Specific government interventions that trigger changes in the behaviour of economic actors or the business environment

Taxation
Industrial zoning
Knowledge transfer
Quotas
Price fixing
R&D support
Subsidies
Product standards
Green loans/grants

Table 18. List of policy options: Material

		Sustainable material use policy instruments/mechanisms	
		Market-based interventions/ decentralized provision	**Public inputs/ direct provision**
Policy domain/ Market failure being addressed	**Product**	• Price fixing of resources • Public campaigns aimed at producers for products, product packaging and production process standards through exhibitions/ trade fairs • Award scheme at sectoral, national and international level to educate and incentivize producers • PPPs as a strategy to ensure knowledge transfer • Punitive taxes, fees and user charges to produce hardly recyclable materials	• Setting quotas for firms on the exploitation and use of resources • Policy document to operationalize Resource Efficiency (RE) improvement programmes • Establishing one-stop-shops for promoting, facilitating, catalysing RE and cleaner production through service providers: information dissemination, investment opportunities, guidelines and technical standards • Linkage and knowledge transfer programmes through participation in knowledge platforms, global RE programmes • Promotion of environmental certifications and eco-labelling at industry level through information dissemination agencies such as industry associations and marketing boards, e.g. database of RE activities • Promoting RE and CE along the supply chain through regulations • Green public procurement to incorporate RE and CE values, e.g. purchase of remanufactured cars • Public disclosure programme for environmental compliance, targeting medium-sized and large companies

			• Introduce minimum legal warranty for remanufactured products • Reclassify “cores” necessary for remanufacturing to not become waste, as international import and export restrictions apply to waste • Provide data for open-source production of spare parts • Standards for repairability, reusability and durability of products
	Capital	• Eliminate or reduce value-added tax (VAT) on repairs, remanufactured products, and recycled materials (or even subsidize) • “Green” incentives and support mechanisms for RE and CE investments • Tax, levy, and royalty for the use/ extraction of natural resources • Advanced recycling fee through the extended producer responsibility approach • Promotion of targeted loans/ green loans/ soft loans/ commercial credits/ performance bonds to finance investment activities in environmental projects • Loan guarantees for investments in RE and CE projects • Voluntary agreements among banks to provide lending for green projects and introduce environmental screening in credit risk analyses of investment projects • Setting up of “dedicated funds” such as - Green Investment Fund (GIF) - National Adaptation Funds • Biodiversity offsets	• Clear strategy direction to reduce uncertainty around investments in resource productivity • Implement a green accounting system to measure material throughput
	Labour	• Grants for capacity development and training • Tax incentive for hiring personnel trained in resource efficiency	• Establishment of dedicated institutions, such as TIVETs with RE and CE expertise, in charge of spearheading RE skills • Promotion of trainings, audits and capacity development activities for producers • Support redundant workers to find new jobs and reskilling
	Land	• PPP scheme for the development of eco-industrial parks • Tax incentives and subsidized rentals at industrial parks • Promotion of benefits of operating in eco-industrial parks for producers	• Regulation of land law for industrial zoning • Creation of eco-industrial parks/ clusters/ business corridors/ industrial technology parks, Special Economic Zones (SEZ), Free Trade Zone (FTZ) • Use of SEAs and EIAs for new developments
	Technology	• R&D subsidies and grants to increase RE- and CE-related patents and adapt foreign RE technology to local needs	• Promotion of RE and CE technology alternatives • Technical assistance and technology transfer support • Technical environmental norms and certification for goods and services • Incubation centres for infant RE and CE industries • Creation of a research board to provide technical assistance, research support and disseminate best practice.

References

Angelsen, A. (2009). *Policy Options to Reduce Deforestation.* https://www.cifor.org/publications/pdf_files/Books/BAngelsen090210.pdf

Chaudhary, A. (2016). Characterization factors for assessing potential species loss from land use within LCA. In *LC-Impact Methodology.* https://www.researchgate.net/publication/305725092_Characterization_factors_for_assessing_potential_species_loss_from_land_use_within_LCA

Chaudhary, A., Verones, F., de Baan, L., & Hellweg, S. (2015). Quantifying Land Use Impacts on Biodiversity: Combining Species-Area Models and Vulnerability Indicators. *Environmental Science & Technology, 49.*

Dasgupta, P. (2021, September). Economics Nature's way: Good economics demands that we manage Nature better. *Finance & Development.*

Deloitte (2013). *Global Manufacturing Competitiveness Index 2013.* Deloitte Global Services Limited.

Desha, C., & Hargroves, K. (2012). *Engineering Education and Sustainable Development: A Guide to Rapid Curriculum Renewal.* Earthscan.

Ecorys (2011). *Study on the Competitiveness of the European Companies and Resource Efficiency.* Ecorys.

Ekins, P., & Speck, S. (2011). *Environmental Tax Reform (ETR): A Policy for Green Growth.* Oxford University Press.

Ellen MacArthur Foundation (2020). *Case Study: Africa's First Industrial Symbiosis Programme. Circular Economy in Cities.* https://www.ellenmacarthurfoundation.org/assets/downloads/Africa%E2%80%99s-first-industrial-symbiosis-programme_Case_Study.pdf

European Commission, Food and Agriculture Organization of the United Nations, Organisation for Economic Co-operation and Development, United Nations, & World Bank (2017). *System of Environmental-Economic Accounting 2012.* Applications and Extensions.

Eurostat (2013). *Economy-wide Material Flow Accounts (EW-MFA).* Office of the European Communities. https://ec.europa.eu/eurostat/documents/1798247/6191533/2013-EW-MFA-Guide-10Sep2013.pdf/54087dfb-1fb0-40f2-b1e4-64ed22ae3f4c

Giljum, S., Bruckner, M., & Martinez, A. (2014). Material Footprint Assessment in a Global Input-Output Framework. *Journal of Industrial Ecology.* https://doi.org/10.1111/jiec.12214

Hansen, M. C., & et al. (2013). High-Resolution Global Maps of 21st Century Forest Cover Change. *Science, 342,* 850. https://doi.org/10.1126/science.1244693

Harrington, W., & Morgenstern, R. D. (2004). *Economic Incentives versus Command and Control: What's the Best Approach for Solving Environmental Problems?* Resources for the Future.

Hertwich, E., Lifset, R., Pauliuk, S., & Heeren, N. (2020). *Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbon Future.* United Nations Environment Programme.

Huijbregts, M., & et al. (2016). *A harmonized life cycle impact assessment method at midpoint and endpoint level Report I: Characterization.* RIVM Report 2016–0104.

IEEP, Ecologic, FEEM, & IVM (2007). *Reforming Environmentally Harmful Subsidies. Final report to the EU Commission – DG Environment.* IEEP.

IEEP, & et al. (2009). *Environmentally Harmful Subsidies: Identification and Assessment. Executive Summary.* IEEP.

International Union for Conservation of Nature (2009). *IUCN Red List Index—Guidance for national and regional use.* https://www.iucn.org/sites/dev/files/import/downloads/rli_guidelines_final_4march09_1.pdf

Jaeger, W. K. (2011). *Environmental Taxation and the Double Dividend.* Internet Encyclopedia of Ecological Economics.

Langsdorf, S. (2016). A Policy Mix for Dematerialisation. *Dynamix Project Policy Report, 3.* https://www.ecologic.eu/sites/default/files/publication/2016/2714-dynamix-policyfield-roadmap-metals_16-02-12-final.pdf

Luckeneder, S., Giljum, S., Schaffartzik, A., Maus, V., & Tost, M. (2021). Surge in global metal mining threatens vulnerable ecosystems. *Global Environmental Change, 69,* 102303. https://doi.org/10.1016/j.gloenvcha.2021.102303

OECD (2010). *Taxation, Innovation and the Environment.* OECD.

Rockström, J., & et al. (2009). Planetary Boundaries: Exploring the Safe Operating Space for Humanity. *Ecology and Society, 14(2),* 32. https://doi.org/10.5751/ES-03180-140232

Rudel, T. K., Coomes, O. T., Moran, E., Achard, F., Angelsen, A., Xu, J., & Lambin, E. (2005). Forest transitions: Towards a global understanding of land use change. *Global Environmental Change, 15,* 23−31. https://doi.org/10.1016/j.gloenvcha. 2004.11.001

Steger, S., & Bleischwitz, R. (2009). Decoupling GDP from resource use, resource productivity and competitiveness. In *Sustainable growth and resource productivity: Economic and global policy issues* (pp. 172–193). Greenleaf Publishing Limited.

UNEP (2004). *The Use of Economic Instruments in environmental Policy: Opportunities and Challenges.* UNEP.

UNEP and Economic Commission for Latin America and The Caribbean (ECLAC) (2003, November 20). Economic Instruments and Fiscal Policy. *Information Package for the 14th Meeting of the Forum of Ministers of the Environment of Latin America and the Caribbean.*

WBCSD (2010). *Effective biodiversity and ecosystem policy and regulation.* COP 2010. https://www.cbd.int/business/doc/WBCSD_Biodiversity_Ecosystem_Policy_Paper_COP%2010%20.pdf

Weizsäcker, E. U., de Larderel, J., Hargroves, K., Hudson, C., Smith, M., & Rodrigues, M. (2014). *Decoupling 2: Technologies, opportunities and policy options* (UNEP, Ed.). A Report of the Working Group on Decoupling to the International Resource Panel.

https://www.resourcepanel.org/sites/default/files/documents/document/media/-decoupling_2_technologies_opportunities_and_policy_options-2014irp_decoupling_2_report-1.pdf

World Bank (2005). *Environmental Fiscal Reform: What should be done and how to achieve it.* World Bank.

World Bank (2015). *World Bank Commodity Price Data.* World Bank.

5 Environmental goods (EGs)

Introduction

This last section explores how countries can view environmental safeguarding as an opportunity for an emerging new market for goods created to prevent or minimize environmental damages. With a growing focus on environmental themes such as climate change mitigation, renewable energy, and resource use, it is reasonable to assume that goods that contribute to their improvement will be met with growing demand in the future.

Governments are increasingly taking action to mitigate the impacts economic activity has on the environment, both locally and globally. Many of the adopted measures to address issues such as local air and water pollution or GHG emissions take the form of regulations that aim to change the behaviour of firms or households. To comply with these regulations, private actors often acquire new techniques and equipment specifically meant to prevent and abate pollution. The same is true for the renewable energy sector, where huge investments have been (and are still being) made in capital hardware to generate energy from renewable sources – photovoltaic cells, wind, and water turbines, etc. This, in turn, generates growth in the market for environmental goods (EGs) which are increasingly international in scope as more countries tighten their environmental regulations (Sauvage, 2014). It is thus beneficial for countries to position themselves in that market and to grow into it. To keep up with growing demand and address its increasingly specialized and high-tech nature, international trade in EGs has been growing faster than the production of EGs in recent years (Delabroye et al, 2016). Manufacturing of environmental goods is a way to increase the export basket’s technology content, increases innovation, upgrade skills used in manufacturing, attract FDI and has several spillovers into other areas of manufacturing (IPCC, 2014).

On the one hand, the EGs category comprises goods and technologies that help measure, control, restore, prevent, treat, minimize, research, and sensitize environmental damage to air, water, and soil as well as problems related to energy, waste, noise, biodiversity, and landscapes. This includes “cleaner” technologies and goods that prevent or minimize pollution or emissions, such as renewable energy production. On the other hand, it promotes careful use of natural resources, resulting in resource-efficient goods and technologies. It is important to flag that this often includes goods deemed as contributing to the reduction of CO_2 emissions through their technical application but are themselves not necessarily produced in a climate-friendly way. Analysing the production and export of goods that have a neutral CO_2 emissions footprint represents another interesting analysis for policymakers, which is not covered here due to the lack of data availability at the country level.

A group of WTO members launched plurilateral negotiations in July 2014 to establish the Environmental Goods Agreement (EGA), which seeks to promote trade in several key environmental products by eliminating tariffs. The benefits of this new agreement will be extended to full WTO membership, meaning all WTO members will enjoy improved conditions in the markets of EGA participants. The aim of the negotiations is to increase the transfer of cleaner and more cost competitive technologies, including technologies geared towards air pollution control, waste treatment, renewable energy, environmental monitoring, and energy efficiency. The WTO hopes to provide higher-quality environmental goods at lower costs and to help developing countries expedite the process of obtaining and adopting cleaner technologies. This agreement also aims to lower the costs of environmental protection and to promote "green" jobs around the world (WTO, 2014).

Methodology

Since negotiations for the EGA are still in progress as of 2022, a choice had to be made about which of the different existing EG lists to use in this tool. We reviewed four of them: the World Bank's list of climate-friendly goods (2008), the "Friends" list (WTO, 2009), the EG list of the Asia-Pacific Economic Cooperation (APEC, 2012) and the indicative list of climate-relevant goods for a "Plurilateral EG & Services Agreement" ("PEGS") (OECD, 2010). The latter three lists also feature in the compound "Combined List of Environmental Goods" (CLEG) used by the OECD (Sauvage, 2014). While no list is ideal and many are arguably, at least to some degree, self-serving, we finally settled on a combination of two lists, namely that provided by the World Bank and APEC's. The reasons for this decision are outlined below.

Climate-friendly goods—goods and technologies that can be used to measure, prevent, or minimize GHG emissions—form a subset of EGs. Note that this definition does not imply that the list includes goods that are necessarily produced in a climate-friendly way. Although slightly older, the World Bank report *International Trade and Climate Change* (2008) contains the most extensive list of climate-friendly goods and is still being used as a reference by many scholars (for example see Sugathan (2013) or Dinda (2019)). The report lists 43 tariff groups based on HS-6-digit codes, which includes goods and technologies that contribute to lower CO_2 emissions. The APEC EG list was created in 2012 and has been widely referenced since (e.g. Delabroye et al., 2016 or Gaigné et al., 2018). While there is some overlap with the World Bank's list, it expands the scope and covers mostly goods that reduce environmental damage (pollution treatment and monitoring equipment). With this list of 54 goods, APEC liberalizes trade and investment in EGs by reducing applied tariff rates to 5 per cent or less within its market zone (APEC, 2012), making it the only international EG trade agreement in effect to date.

The "Friends" list, prepared by proponents of EG trade liberalization seeking tariff reductions in the WTO, was never officially adopted (Sauvage, 2014). Moreover, the most environmentally relevant of the 153 proposed goods are already covered by the World Bank list, which is why the "Friends" list did not materialize. The OECD's PEGS list, prepared for the G20's 2010 Toronto Summit, was ultimately not included in this tool because a number of the goods on the list have "dual use" issues, meaning that the products explicitly have non-environmental uses. Such goods, especially the parts and components, are 'environmental' in certain uses, but can often also be deployed for non-environmental purposes (Delabroye et al., 2016). Such dual-use issues must be addressed in the future to achieve a meaningful implementation of preferential WTO tariff treatment for goods with truly environmental end-uses.

It should be noted that it is difficult to distinguish an EG that is purely based on its Harmonized System (HS) codes, and furthermore that expert knowledge of the product or technology is required. Another issue with reliance on the HS system is that despite the highly disaggregated level offered at the HS-6 level, components of other technologies that do not necessarily contribute to lowering the environmental or climate change impact are included. This means that the HS code does not distinguish between a product that has been manufactured in an environmentally-friendly way to one that has not – they are both assigned the same code. Until such a distinction is made, negotiating cheaper tariffs for truly environmental goods will not be possible. For these reasons, the values calculated in this section represent estimates of the total value of EGs (as identified by the HS code groupings). To understand how large the EG market is and what type of goods are in high demand, the tool analyses the following:

1. Size of the EG market: share of global EG exports in total global manufacturing exports

2. Country share in world's EG market
3. EG market dynamism between 2007 and 2020 and country shares.

Table 19. List of indicators

Indicator	Level of analysis	Definition	Data source
Share of EG exports in country's total manufacturing exports	Industry	Share of environmental goods in a country's total manufacturing exports (in per cent)	UN Comtrade
Country's market share in EGs	Country	Share of a country's environmental goods exports in total global export of environmental goods	
Country's market share in most dynamic EGs	Country	Share of a country's exports in the 25 most dynamic EGs in total global export of these goods for the time periods 2007–2013 & 2014–2020	

Data sources

UN Comtrade reports export data based on 6-digit HS codes. In this tool, we use HS 2007 codes as this is the classification used by the relevant EG lists enabling us to trace the development of worldwide EG exports since 2007. Using EGs' HS codes from the list provided (see Annex), we can calculate the sum of environmental goods exported by a given country. This can be expressed as a share of the respective country's total exports. It is also possible to calculate the total sum of environmental goods exported worldwide, i.e. a country's market share in these exports can be calculated. UN Comtrade reports data for HS 2007 codes for 151 countries between 2007 and 2020.

Indicators

5.1 Share of EG exports in country's total manufacturing exports

Definition

The sum of EGs exported as a share of total manufacturing exports gives an indication of what role the manufacturing of EGs currently play in a country's exports. It can also serve as a proxy indicator for how much a country contributes to minimizing environmental damages by producing and subsequently exporting these goods. Demand for environmental goods is here to stay and will intensify in the future. Because of all these benefits for industrial development, EGs should be considered a market opportunity for countries to expand into. This indicator reveals to what degree a country's manufacturing sector has embraced the opportunity to produce EGs for export, which promises benefits such as profits, environmental safeguarding, and improved competitiveness of the industrial sector as a result of spill-over effects. Clearly, not all EGs a country produces are exported – they also serve to meet domestic demand. This is equally desirable from an environmental standpoint and may help establish the country’s EG producers on the market. It is not possible, however, to measure EG production for domestic consumption with the available trade data.

Strategic questions

Direct inferences:

- How important is the production of environmental goods for the country’s export basket?
- How does the share of environmental goods exports in total exports compare to other countries?

Follow-up questions:

- How can the importance of environmental goods for export be enhanced?
- Which goods are the most prominent in this share?

Equation

$$\boldsymbol{Share\ of\ EG\ exports\ in\ country's\ total\ manufacturing\ exports}\ (\%) = \frac{\boldsymbol{Total\ environmental\ goods\ exports}\ (\$)}{\boldsymbol{Total\ manufacturing\ exports}(\$)}$$

5.2 Country’s market share in environmental goods

Definition

While the previous indicator established the importance of EGs in a country’s manufacturing exports, this one highlights the role the country plays in the international EG market. The trade in EGs has been growing and is likely to continue to expand. A sizable market share in the worldwide EG market is therefore a profitable prospect, both in terms of revenue and as a market leader. Focusing on EG production and exports can contribute to economic growth as a new manufacturing sector, support increased competitiveness of the entire industry and lead to beneficial spill-over effects to other manufacturing sectors. A country’s share in the global EG market thus indicates the extent to which the country has taken advantage of emerging EG trade by locally producing and internationally selling EGs for profit. Policymakers interested in the “revealed comparative advantage” of a certain EG can refer to Tool 2 on Manufacturing Trade.

Strategic questions

Direct inferences:

- What role does the country play in international environmental goods trade?
- How does the country’s market share in environmental goods trade compare to that of other countries?

Follow-up questions:

- How could the country’s market share be improved?
- Are there certain environmental goods the country has a comparative advantage?

Equation

$$\boldsymbol{Country's\ market\ share\ in\ environmental\ goods}\ (\%) = \frac{\boldsymbol{Country\ environmental\ goods\ exports}(\$)}{\boldsymbol{Global\ environmental\ goods\ exports}\ (\$)}$$

5.3 Country’s market share in most dynamic environmental goods

Definition

This indicator provides insights into the development of the most dynamic EGs in international trade and reveals to what extent a country was able to profit from this trend. EG trade as a whole can be seen as a significant market opportunity, but some goods perform better than others within this market. Countries want to strategically position themselves as market leaders for these products, but these change over time. The dynamics of the most sought-after goods can be monitored by ranking their CAGR in the market for certain time periods. The pre-calculated lists of the most dynamic EGs for the period between 2007 and 2013 and between 2014 and 2020 can be found in the analysis. This in itself delivers an interesting perspective in terms of which EG the world demands the most. We can then calculate any given country’s share of the market for highly demanded EGs.

The most dynamic EGs of any given period are determined by the CAGR of their global export value within this period. After having calculated the CAGR for all EGs in a separate column in an Excel sheet, they can be sorted by their CAGR value in descending order, with the most dynamic EGs at the top of the list. After extracting the total export values of each individual dynamic EG for the desired time period(s), a country’s share in total worldwide exports of a single dynamic good (or of all most dynamic goods) can be calculated.

Strategic questions

Direct inferences:

- To what degree does the country participate in the trade of the most dynamic environmental goods?
- How does the country’s market share in the most dynamic environmental goods trade compare to that of other countries?

Follow-up questions:

- How can the country increase its share in the trade of the most dynamic environmental goods?
- Are there any dynamic EGs the country could easily start producing?

Equation

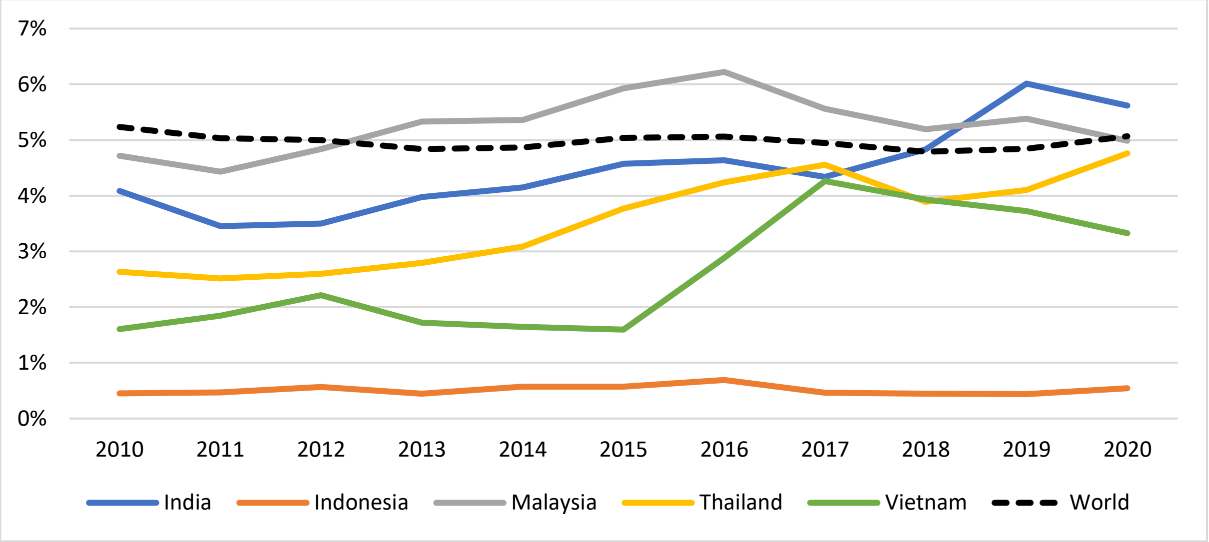
$$\boldsymbol{Country's\ share\ in\ most\ dynamic\ environmental\ goods'market}\ (\%) = \frac{\boldsymbol{Country\ total\ exports\ in\ most\ dynamic\ EGs}(\$)}{\boldsymbol{World\ total\ exports\ in\ most\ dynamic\ EGs}\ (\$)}$$

Analysis

The analysis first focuses on the global EGs market before the focus shifts to India, Indonesia, Malaysia, Thailand, and Viet Nam as example countries for a regional benchmark analysis. The global EGs market has proven to be stable in recent years and promises to be profitable in the future. The trade data show that both the share of global EG exports in total global exports as well as the share of global EG exports in global manufacturing exports have increased by about 1 percentage point since 2007. This equals a market volume increase of US$ 227.9 billion. Most of this growth occurred during an investment boom in the wake of the global financial crisis in 2007. Demand for EGs is on the rise and holds immense potential, particularly in the light of recent WTO efforts to formalize EG tariff waivers in addition to a general move towards more environmental safeguarding and climate change mitigation (De Melo, 2020). A post-pandemic investment boost could also lead to similar growth rates as those seen after the financial crisis.

Figure 57 plots the share of EGs in the manufacturing exports of a group of sample countries between 2010 and 2020. All countries in the sample, except Indonesia, saw their share increase over time. Thailand and Viet Nam reported the highest growth rates, with EG shares of 2.5 percentage points. In the case of Thailand, this development was facilitated by a significant increase in exports of optical parts such as lenses, prisms, and mirrors (HS 900290). In Viet Nam, a boost in sales of liquid crystal devices (HS 901380) and AC generators (HS 850164) accounted for the country’s high share of EGs in manufacturing exports. Considerable developments have also taken place in India, where the share of EG manufactured exports increased by nearly 2 per cent, leading the group by 2020 at close to 6 per cent. India is thus the only country in the group to perform above global average in 2020. In Malaysia and Indonesia, the growth of EG exports has been minimal, with Malaysia’s strong position at the beginning of the decade stalling around the global average and Indonesia remaining at the bottom of the group.

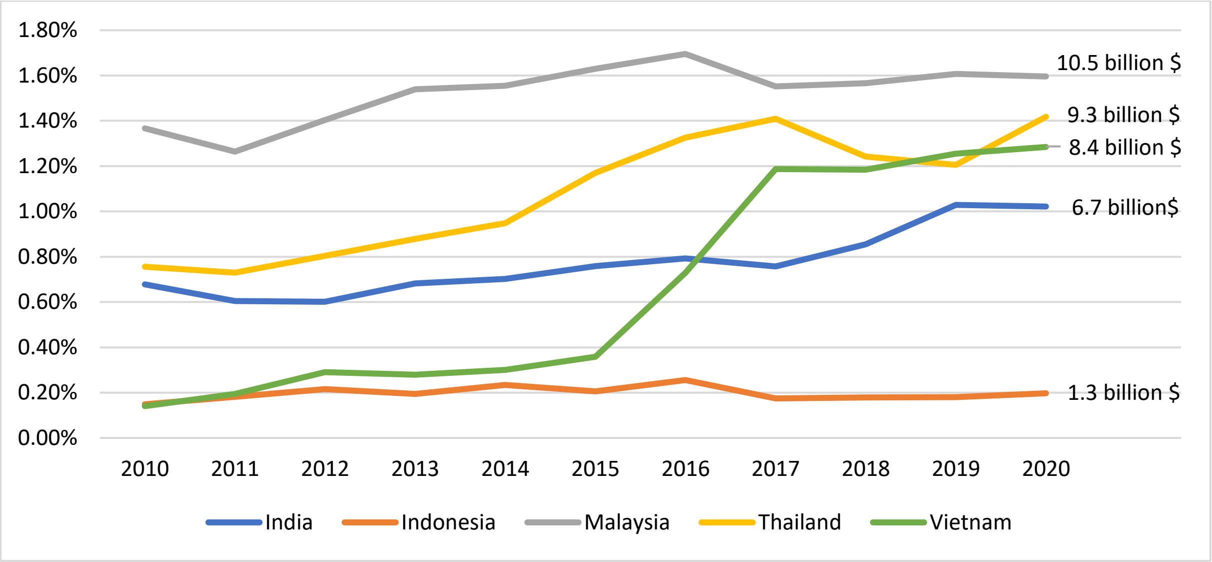
Figure 57. Share of EG exports in total manufacturing exports



Source: Own graph based on WITS UN Comtrade

When looking at the market shares in total global EG exports over time, as is the case in **Figure 58** below, we find that the shape of the curves of each respective sample country is largely the same as in the previous graph. What differs, however, is the share these curves amount to, because this depends on the absolute size of each country's EG exports compared to that of other countries instead of simply their own manufacturing sector. In 2020, Malaysia took the lead with a global EG market share of 1.6 %, followed by Thailand (about 1.4 per cent). This equals the 2020 market volumes of US$ 10.5 billion and US$ 9.3 billion, respectively. Viet Nam (US$ 8.4 billion) and India (US$ 6.7 billion) also account for more than 1 percentage point of all EG exports, whereas Indonesia (US$ 1.3 billion) only accounts for 0.2 percentage points. While Malaysia and Indonesia remained almost stagnant over the course of the decade, India's share grew by about 0.3 percentage points. Both Thailand and Viet Nam were able to increase their global EG market share by around 0.8 percentage points, and 1 percentage point, respectively.

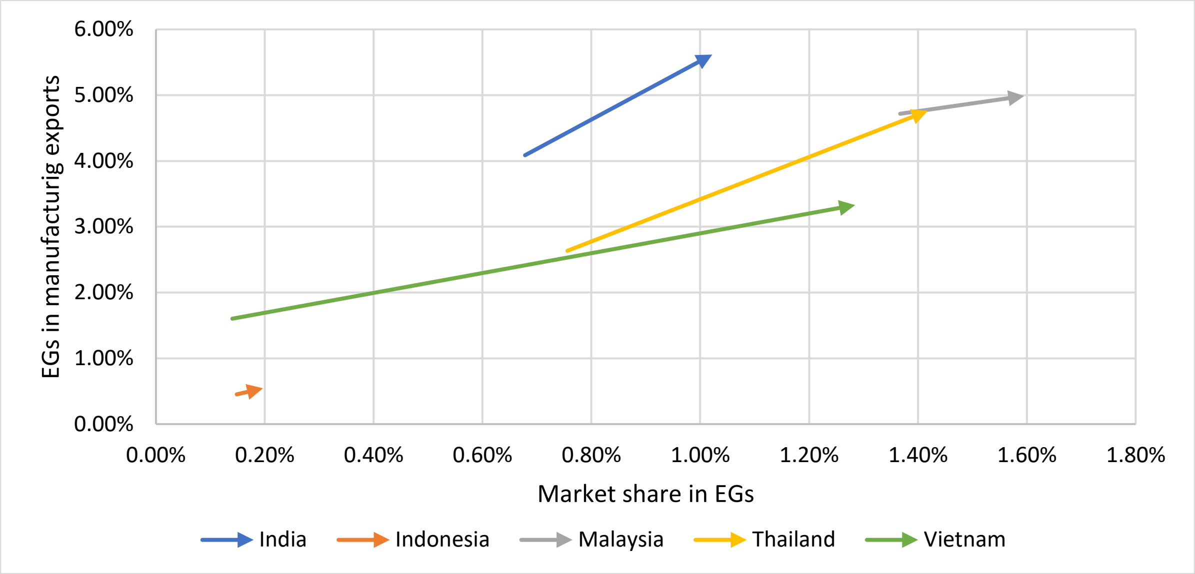
Figure 58. Country's market share in global EG exports



Source: Own graph based on WITS UN Comtrade

Plotting the previously analysed shares of EGs in countries' manufacturing exports and their shares in the global EG exports market against each other with a time scale provides insights into a country's overall trend in the EG sector. **Figure 59** below does this for the sample countries between 2010 and 2020, as many of them only really entered this market in 2010. Viet Nam recorded the greatest overall improvement, particularly in terms of market share. India and Thailand also witnessed significant developments in the EG sector during this decade, having started it with an average share within the sample group context. Malaysia further improved its already advantageous position, mainly by increasing its EG market share. In Indonesia, on the other hand, close to no improvement in the EG sector has taken place.

Figure 59. Country EG market share versus EG share in the country's manufacturing exports (change from 2010 to 2020)



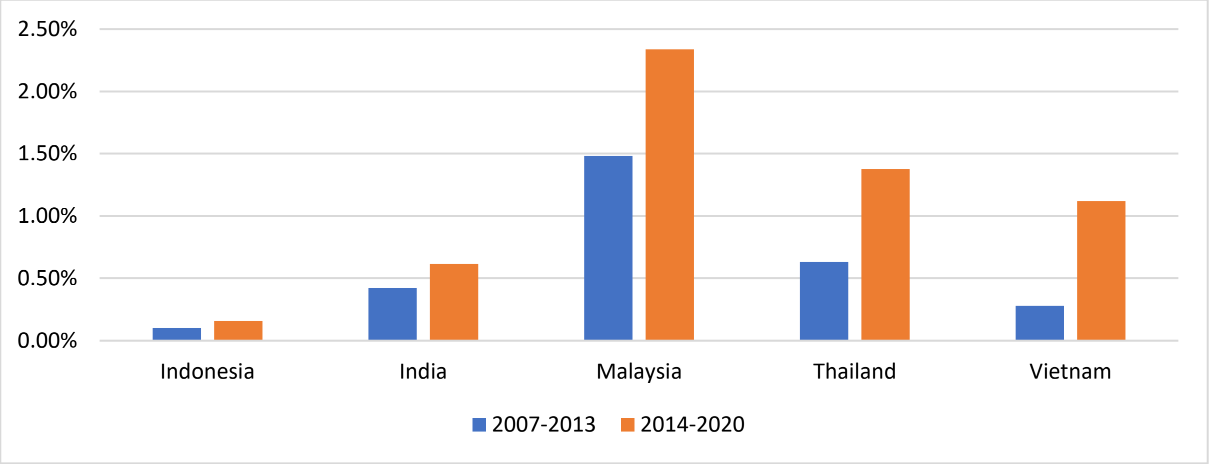
Source: Own graph based on WITS UN Comtrade

Table 20 and

Table 21 present the 25 most dynamic EGs according to the APEC and World Bank lists for the periods 2007 to 2013 and 2014 to 2020, respectively. Please refer to the description of indicator 5.3 for the method of calculation. One eye-catching fact is that the CAGRs of the earlier time period were much higher, on average, than in the more recent one. This does not mean that overall EG trade is becoming less profitable or relevant, however; on the contrary, as mentioned at the beginning of the analysis, the share and volume of EG exports is on the rise. At closer inspection, it becomes clear that a large share of the most dynamic EGs between 2007 and 2013 was technology that was required for renewable energy production. Naturally, these capital goods experienced a boom phase of high demand when many countries started transitioning towards renewable energy during this time period. More recently, specialized technological products continue to remain in demand, but are less clustered around renewable energy alone. Examples include machinery for distilling, filtering, and purifying. As shown in the following **Figure 60**, this diversification in the EG market's dynamism allowed many countries to increase their market share in these particularly valued goods.

Figure 60 below contrasts the shares countries had in the trade of the most dynamic EGs between 2007 and 2013 and 2014 to 2020. The shares of Malaysia, Thailand and Viet Nam grew at about 0.8 percentage points during these time periods, corresponding to an absolute increase of US$ 25.3 billion, US$ 18.7 billion, and US$ 18.9 billion, respectively. During the latter period, Malaysia accounted for the highest share in the most dynamic EG exports at about 2.3 percentage points, with Thailand ranking second at around 1.4 percentage points. India's share increased by about 0.2 percentage points to 0.6 percentage points (US$ 6.2 billion in absolute terms), losing its third place in the sample group to Viet Nam, which had a market share of the most dynamic EGs of around 1.1 percentage points between 2014 and 2020. Only incremental developments took place in Indonesia, meaning it remained at the bottom of the group with the lowest total share.

Figure 60. Country share in the most dynamic global EG exports



Source: Own graph based on WITS UN Comtrade

Table 20. List of 25 most dynamic EGs between 2007 and 2013 (APEC & WB lists)

Product Code (HS 2007)	Product Description	CAGR 2007-2013
840410	Auxiliary plant for use with boilers of 84.02/84.03 (e.g., economisers, super-heaters, soot removers, gas recoverers)	0.147330491
850231	Wind-powered electric generating sets	0.127048535
841011	Hydraulic turbines & water wheels, of a power not >1000 kW	0.126037979
730820	Towers & lattice masts of iron/steel	0.125752343
840219	Vapour generating boilers, incl. hybrid boilers (excl. of 8402.11 & 8402.12; excl. central heating hot water boilers capable also of producing low pressure steam)	0.122445116
903149	Other optical instruments & appliances, other than 9031.41	0.118290464
901390	Parts & accessories of the articles of 90.13	0.115198593
840681	Steam turbines & other vapour turbines (excl. for marine propulsion), of an output >40MW	0.113953222
841290	Parts of the engines & motors of 8412.10-8412.80	0.112769074
854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether/not assembled in modules/made up into panels; light emitting diodes	0.112761177
853710	Boards, panels, consoles, desks, cabinets & other bases, equipped with 2/more apparatus of 85.35/85.36, for electric control/distribution of electricity, incl. those incorporating instruments/apparatus of Ch. 90 & numerical control apparatus (excl. switching apparatus for line telephony)	0.1059189
840420	Condensers for steam/other vapour power units	0.102787718
901380	Liquid crystal devices not constituting articles provided for more specifically in other headings; other optical appliances & instr., n.e.s. in Ch.90	0.098041735

902710	Gas/smoke analysis apparatus	0.080237537
902620	Instruments & apparatus for measuring/checking pressure	0.078399632
842129	Filtering/purifying machinery & apparatus for liquids (excl. of 8421.21-8421.23)	0.075058189
850720	Electric accumulators, incl. separators therefor, whether/not rectangular (incl. square), lead-acid (excl. of 8507.10)	0.068598629
840690	Parts of the steam turbines & other vapour turbines of 8406.10-8406.82	0.068264644
902680	Instruments & apparatus for measuring/checking the flow/level/ pressure/other variables of liquids/gases (e.g., flow meters, level gauges, manometers, heat meter), excl. instruments/apparatus of heading 90.14 & 90.15, 90.28	0.067813421
850490	Parts of the machines of 85.04	0.066897209
850239	Electric generating sets n.e.s. in 85.02	0.06440301
842121	Filtering/purifying machinery & apparatus for filtering/purifying water	0.06378465
732490	Sanitary ware & parts thereof, of iron/steel (excl. of 7324.10-7324.29)	0.06335203
841181	Gas turbines other than turbo-jets/turbo-propellers, of a power not >5000kW	0.06268234
732111	Cooking appliances & plate warmers, for gas fuel/for both gas & other fuels.	0.062608406

Table 21. List of 25 most dynamic EGs between 2014 and 2020 (APEC & WB lists)

Product Code (HS 2007)	**Product Description**	**CAGR 2014-2020**
841940	Distilling/rectifying plant, whether/not electrically heated	0.07292059
850162	AC generators (alternators), of an output >75kVA but not >375kVA	0.07213449
903149	Other optical instruments & appliances, other than 9031.41	0.06179495
902750	Instruments & apparatus for physical/chemical analysis, using optical radiations (UV, visible, IR), n.e.s. in 90.27	0.05813999
902710	Gas/smoke analysis apparatus	0.0553656
902720	Chromatographs & electrophoresis instr.	0.05017663
842139	Filtering/purifying machinery & apparatus for gases, other than intake air filters for internal combustion engines	0.04752475
732490	Sanitary ware & parts thereof, of iron/steel (excl. of 7324.10-7324.29)	0.03664161
850490	Parts of the machines of 85.04	0.03575933
842121	Filtering/purifying machinery & apparatus for filtering/purifying water	0.03559803
903190	Parts & accessories of the instr., apparatus & machines of 90.31	0.03326934
853710	Boards, panels, consoles, desks, cabinets & other bases, equipped with 2/more apparatus of 85.35/85.36, for electric control/distribution of	0.03284809

	electricity, incl. those incorporating instruments/apparatus of Ch. 90 & numerical control apparatus (excl. switching apparatus for line telephony)	
902780	Instruments & apparatus for physical/chemical analysis, n.e.s. in 90.27	0.03228355
854390	Parts of electrical machines & apparatus, having individual functions, not specified/incl. elsewhere in this Ch..	0.03154306
902790	Microtomes; parts & accessories of instr. & apparatus of 90.27	0.0303013
841861	Compression-type refrigerating/freezing equip. whose condensers are heat exchangers	0.02989189
900290	Lenses, prisms, mirrors & other optical elements, of any material, mounted, being parts of/fittings for instr./apparatus (excl. such elements of glass not optically worked), n.e.s. in 90.02	0.02733143
851410	Resistance heated furnaces & ovens	0.02591309
900190	Lenses (excl. of 9001.30-9001.50), prisms, mirrors & other optical elements, of any material, unmounted, other than such elements of glass not optically worked	0.02477796
841869	Refrigerating/freezing equip. n.e.s. in 84.18; heat pumps	0.02351231
847989	Other machines & mechanical appliances, other than Machines & mechanical appliances for treating metal, incl. electric wire coil-winders/Mixing/kneading/crushing/grinding/screening/sifting/ homogenising/emulsifying/stirring machines	0.0234263
854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether/not assembled in modules/made up into panels; light emitting diodes	0.02255281
842199	Parts of the filtering/purifying machinery & apparatus of 84.21 (excl. of centrifuges, incl. centrifugal dryers)	0.02137326
847982	Mixing/kneading/crushing/grinding/screening/sifting/homogenising/ emulsifying/stirring machines, n.e.s. in Ch.84	0.01944737
732190	Parts of the non-electric domestic appliances of 7321.11-7321.83, of iron/steel	0.01854868

Policy options

Environmentally minded industrial policy can contribute to the establishment of a wide range of environmental industries. Their output holds substantial export potential for developing countries, which in some cases has already materialized. Aside from diversification and state-led initiatives, development in such sectors can also arise from interactions and joint ventures with multinational corporations. Serving as local suppliers to larger foreign EG firms leads to product-upgrading in the domestic partnering enterprises. The investment and expertise delivered by foreign firms can furthermore enable job creation (e.g. in post-sales services) and skills and technology transfers (ITC, 2014).

Although the private sector plays the biggest role in the development and diffusion of new technologies, closer collaboration between the government and industry would considerably stimulate the development of a broad range of low-carbon technologies at more affordable prices. A focus on EG innovation could place a country in an advantageous position in the EG market. Note that innovation does not necessarily entail the invention of entirely new goods and technologies but includes the implementation of a technology that is considered new to the party adopting it. There are several factors that can hamper the development of new climate-friendly goods and technologies, and may inhibit innovation in the EG sector (WTO, 2009):

1. The problem of “environmental externality”: since carbon emissions do not come with a price tag, firms and consumers have no direct incentive to find ways to reduce them.
2. The “knowledge effect”: individual companies may not always be able to fully profit from their investment in innovation because “knowledge” about such technologies (and therefore, the opportunity to make a profit from them) may spread to other companies and countries, reducing companies’ incentive to invent and develop new technologies.
3. Companies may not always be able to convince private investors about the relevance and benefit of a research project in climate change, because they may not be in a position to demonstrate their product’s environmental effectiveness until it has been put to use on a wide scale.
4. Bringing new technologies to the market is also associated with a “learning cost”, i.e. the additional cost involved in adapting to the new technology. The learning cost is high if the learning rate is low and/ or the time before the technology becomes competitive extends over decades, and private sector firms may be unwilling to risk deploying the new technology. In fact, new technologies may not become cost-effective until significant investment has been made and experience has been accrued, which may reduce the incentive to deploy high-tech EGs.

In response to all these factors that affect the cost of climate-friendly technologies and EGs in general, targeted government funding may help reduce the gap between their cost and that of conventional technologies and sources of energy (ibid). Measuring the innovation in EGs provides insights into its main national drivers and its environmental and economic impact, both in the short and long term. By benchmarking the different levels of innovative activities through the production of environmental goods, policymakers can identify whether its drivers are influenced by national regulations or by economic incentives, adapting their policies and taxes accordingly (Mongo et al., 2021).

Policymakers have sought to liberalize EGs trade by means of tariff cuts and the removal of other obstacles to trade to reap the economic and environmental benefits associated with widespread international diffusion of EGs. These efforts are exemplified by the current WTO negotiations on the Environmental Goods Agreement. Preferential tariff treatment would help promote the diffusion of EGs on the world market. Studies show that OECD countries that lowered their EG import tariffs have also experienced a rise in EG exports (Sauvage, 2014). These countries often possess a comparative advantage in the EG sector. Developing countries may be inclined to use protective trade measures for their infant EG industries. However, strategically liberalizing key EG inputs can enhance the efficiency and competitiveness of other industries, particularly if this lowers the cost of adapting to environmentally sustainable processes (ITC, 2014).

Beyond tariffs, several scholars suggest that demand for environmental products essentially remains influenced, and even determined, by the stringency of environmental regulations which, if effective, prompt firms to modify their modes of production and to adopt new environmentally friendly equipment (Sauvage, 2014; Delabroye et al., 2016; Puertas & Marti, 2021). According to these authors, regulation spurs the development of an EGs market, while the increased market size, in turn, has important implications for international EGs trade. Delabroye et al. (2016) claim that harmonizing regulations and capacity development is more effective at spreading the use of green technologies than trade agreements, while low consumer awareness and weak environmental policies are bigger obstacles to trade in EGs than high tariffs. EGs trade thereby promises to make trade and environmental policy objectives compatible, which may help ease the apparent tension between environmental protection and economic competitiveness.

Further consideration of the trade opportunities that may arise from the adoption of environmental regulations domestically could help counter-balance traditional concerns about the impacts these regulations have on pollution-intensive sectors. Several analyses identify a positive relationship between a country's regulatory stringency, e.g. environmental taxation, and its relative share of world exports in environmental products (Gaigné et al, 2018; Sauvage, 2014). In other words, ambitious environmental regulations play a crucial role in generating and sustaining demand, which in turn increases trade and export opportunities.

Financial mechanisms

a) Incentives to promote innovation in EGs

Due to the deterrents to investment outlined above, basic research must often be stimulated through grants and awards to encourage eco-innovators. Government grants can facilitate the development of GHG emission-reducing technologies or other EGs by financing the cost of research. For example, in New South Wales (Australia), the Climate Change Fund provides, *inter alia*, grants to support the early commercialization of new renewable energy technologies (NSW, 2020). There is also growing interest in other means to encourage innovation, such as awards for the development of new technologies. Such awards may be provided *ex post* by recompensing existing innovations, i.e., by making a return on investments that have already been made in R&D. Grants may also be awarded *ex ante* to encourage new R&D projects, in which case the technological improvement to be achieved is generally specified prior to the research process (WTO, 2009). Government support measures for innovation can be implemented upon fulfilment of certain conditions, such as reaching performance targets, which usually implies achievement of a particular emission target.

b) Incentives to encourage the deployment of EGs

Deployment incentives often take the form of financial assistance or support for the cost of production or use of EGs. Government support measures may be implemented upon the fulfilment of certain conditions and criteria. As such, they may be linked to output (usually through a feed-in tariff or through direct payments and tax credits provided in proportion to the volume of production), target intermediate inputs in the production process such as the energy sources that are used for heat and electricity, or focus on value adding factors such as capital and labour (WTO, 2009).

i) Fiscal measures

Two types of fiscal measure are typically used to encourage participation in environmental efforts: tax reductions (i.e. tax exemptions, tax deductions and tax rebates) and tax credits (i.e. income-, personal-, corporate-, production- and investment tax credits). Such fiscal measures may either be targeted at consumption (i.e. they may reward the purchase and installation of certain technologies) or at facilitating investment in the production of EGs. Another fiscal measure is "accelerated depreciation", which allows investors in renewable energy technologies to depreciate the value of their plant and equipment at a faster rate than is typically allowed, thereby reducing their stated income for the purposes of income taxation.

ii) Investment support

Investment support policies are used to reduce the capital cost of deploying environmental technologies: a specified percentage of the costs of installation is returned to the investor in the form of a capital grant, resulting in significant reductions in the overall cost of such technologies. Investment support policies may also take the form of favourable lending conditions or low-cost financing with subsidized interest rates for investors in EGs (WTO, 2009). One example is the Indian Solar Loan Programme, which provides low-cost financing for solar energy systems (CSTEP & WISE, 2015).

iii) Price support measures

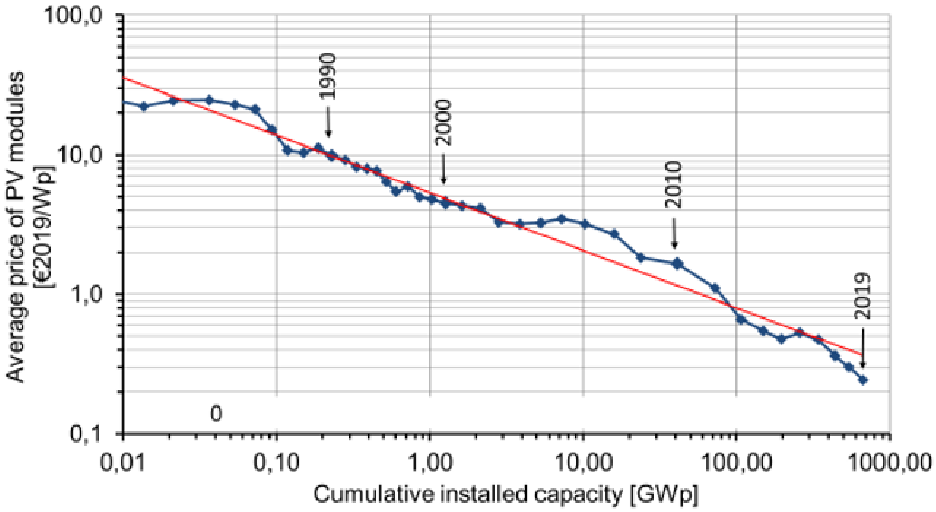
Programmes based on financial incentives (rather than direct payments) usually occur at the national level. One example are renewable energy feed-in tariffs which provide a regulated minimum guaranteed price per kilowatt-hour that an electricity company must pay for renewable energy fed into the national electricity grid by a private, independent producer (WTO, 2009). Feed-in tariffs have been successful due to their long timeframe, providing a high level of security for investors and their flexible design, which can be adjusted to account for advances in technology and changing market conditions, making them more effective and efficient (ibid).

This is important for photovoltaic (PV) power plants, for example, as the investor may otherwise delay their investment based on trends that show that costs continue to decline. The price development of PV modules follows a so-called “price learning curve”, in which doubling total capacity installed causes prices to fall by a constant percentage (see **Figure 61**). Provided that significant progress continues to be made in product development and manufacturing processes, prices are expected to keep dropping in accordance with this rule. Since all installed PV power plants largely produce electricity simultaneously, the more expensive electricity from the older power plants would no longer be competitive in the future (Wirth, 2021).

Feed-in tariffs indisputably also encourage the development of local production of renewable energy, thereby increasing price competition, and furthermore contribute to increasing companies’ profit margins, thus encouraging innovation. Strategies that feature feed-in tariffs as part of a broad package of support measures, including tax deductions, “soft” loans (i.e. at subsidized rates) as well as investment incentives (such as subsidies or partial debt relief) for selected technologies are particularly successful (WTO, 2009).

Another financial incentive for energy companies to invest in renewable energy are capacity charges, which are fixed payments for each period for each kilowatt of available (not dispatched) capacity *(*Bjørndal, 2009)*.* This availability-based regime provides investors with a higher security on their returns, as fixed charges are passed on to the procurer. These include repayment of the debt used to construct the facility, return on equity as well as the costs for operation and maintenance that are independent of the amount of energy generated (e.g. staffing costs, administrative expenses, operator fee, insurance premiums). Furthermore, invested equity is typically recovered through depreciation of power plant assets based on the prescribed rates in applicable tax laws.

Figure 61. Historical development of inflation-adjusted world market prices for PV modules



Source: Wirth (2021)

Technical requirements

i) Design-based requirements

The technical requirements for energy efficiency or emission reduction that are based on design characteristics specify the particular features a product must have or the specific actions that must be undertaken during production. They thereby determine what goods to use or which technologies to install. Such design standards based on descriptive characteristics are best used when there are few options for the polluter to control emissions, as the regulator is able to specify the technological steps a firm should take. When emissions cannot be measured or concerns exist about the feasibility of other policy options, design standards related to existing technologies may provide a practical means to reduce pollution by helping eliminate the least efficient technologies from the market and promoting the use of more efficient ones (WTO, 2009).

ii) Performance-based requirements

Performance standards for emission reduction or energy efficiency dictate environmental outcomes to be delivered by products or production methods, without specifying how the outcomes should be achieved (e.g. they may limit emissions to a certain number of grams of CO_2 per kilowatt-hour of electricity generated) (WTO, 2009). Performance requirements are often established to encourage the removal of cost-ineffective, energy-inefficient products from the marketplace, and to stimulate the development of more efficient alternatives and processes. They generally provide more flexibility than design-based requirements, and costs may be lower because firms can choose how they will meet the stipulated environmental target. By not mandating a single technology, performance standards thus increase the options for achieving compliance, including finding solutions through changes in the production process, reductions in output, switching to different fuels or other inputs and alternative technologies (IPCC, 2014).

Box 20. Case study: Malaysia's EGs industry

Malaysia has consistently been a net exporter of EGs since 2000, particularly in renewable energy (RE) technology (Paramasuaa et al, 2019). A sharp increase in exports after 2009 has been largely attributed to three key policies:

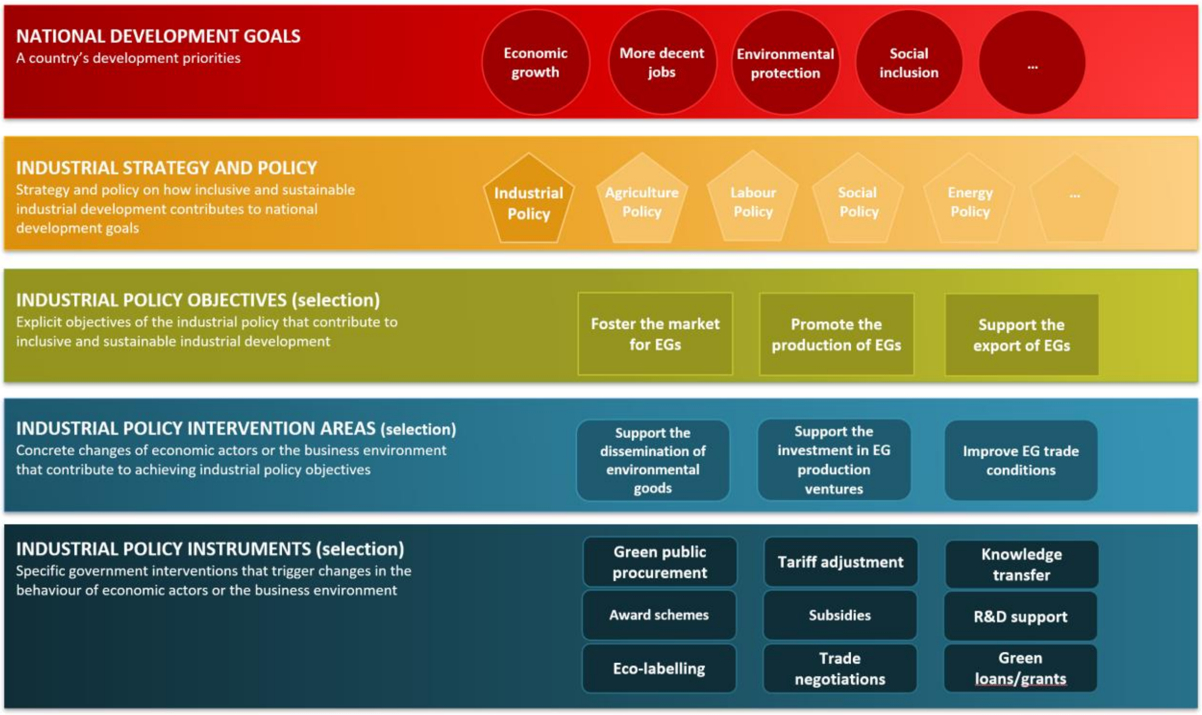
(i) the National Climate Change Policy,
(ii) the National Renewable Energy Policy and
(iii) the National Green Technology Policy.

Subsequently, the Renewable Energy Act (2011) introduced a lauded feed-in-tariff scheme. The 2014 budget also introduced several tax incentives to be accorded to companies involved in the EG sector (ibid). This included an investment tax allowance for the purchase of green technology equipment and an income tax exemption on the use of green technology services and system. The government also introduced the Green Procurement Initiative which prioritizes the purchase of green products in all government-related projects or activities, which constitute about 15 per cent of GDP (EPU, 2013).

Apart from the initiatives listed above, the government also regulates the EGs sector by enacting non-tariff measures. In total, there are five technical barriers to trade (TBTs), such as differing standards, as well as one export measure for this sector which is protective in nature (Paramasuaa et al., 2019). For example, Malaysia has introduced a higher standard biodiesel for the country, namely B5 (5 per cent methyl ester blend with 95 per cent diesel). This has reduced total imports from foreign countries by half. As Malaysia also produces high-quality biodiesel at an optimized cost, the shortage of supply was supported by local suppliers. This eventually protected Malaysia’s domestic producers (Alavi, 2007). Tax and subsidies are also known to be protective of nature. Malaysia subsidized prices for blended diesel using palm oil. This measure helped plantation owners secure supply to produce sustainable biofuel (Masjuki et al., 2013).

By segments of the EGs sector, 63.3 per cent of total exports and 19.3 per cent of total imports of EGs consisted of RE in 2016 (Paramasuaa et al., 2019). Malaysia has thus emerged as a leading exporter of RE, particularly solar energy, and is ranked as the world’s third largest producer of PV cells and modules, after China and Taiwan, Province of China (ibid). This follows from Malaysia’s focus on the adoption of cleaner technologies and the usage of EGs that reduce carbon emissions due to the commitment to curb its carbon emission intensity by up to 40 per cent (ibid). According to Malaysia’s Sustainable Energy Development Authority (SEDA), the country also has the necessary ecosystem for solar power with 250 companies that include some of the top manufacturers, such as First Solar, Jinko Solar, JA Solar, Flextronics, Q-Cells (now Hanwha Q-Cells) and SunPower. The markets with the greatest potential for Malaysia’s PV exports are China, the United States and Japan (ITC, 2017). Malaysia has managed to build a comparative advantage in solar, as foreign companies outsourced the production functions of their manufacturing processes, particularly for the PV segment, thereby linking Malaysia to the global environmental supply chain. As of 2015, 48 solar projects have been implemented with total investments of US$ 5.787.600.000 to produce solar wafers, cells, modules, and a balance of system components (Paramasuaa et al., 2019). Of this, 95.3 per cent came from foreign investments (MIDA, 2017).

Table 22. Environmental goods policy implication matrix



NATIONAL DEVELOPMENT GOALS
A country's development priorities

Economic growth
More decent jobs
Environmental protection
Social inclusion
…

INDUSTRIAL STRATEGY AND POLICY
Strategy and policy on how inclusive and sustainable industrial development contributes to national development goals

Industrial Policy
Agriculture Policy
Labour Policy
Social Policy
Energy Policy
…

INDUSTRIAL POLICY OBJECTIVES (selection)
Explicit objectives of the industrial policy that contribute to inclusive and sustainable industrial development

Foster the market for EGs
Promote the production of EGs
Support the export of EGs

INDUSTRIAL POLICY INTERVENTION AREAS (selection)
Concrete changes of economic actors or the business environment that contribute to achieving industrial policy objectives

Support the dissemination of environmental goods
Support the investment in EG production ventures
Improve EG trade conditions

INDUSTRIAL POLICY INSTRUMENTS (selection)
Specific government interventions that trigger changes in the behaviour of economic actors or the business environment

Green public procurement
Award schemes
Eco-labelling
Tariff adjustment
Subsidies
Trade negotiations
Knowledge transfer
R&D support
Green loans/grants

Table 23. List of policy options: Environmental goods

		Environmental goods trade/ export policy instruments/ mechanisms	
		Market-based interventions/ decentralized provision	**Public inputs/ direct provision**
Policy domain/ Market failure being addressed	**Product**	• Public campaigns aimed at potential producers through EGs exhibitions/ trade fairs • Award scheme at sectoral, national and international level to educate and incentivize producers	• Establishing capacity centres to promote, facilitate and catalyse EGs and cleaner production through service providers: information dissemination, investment opportunities, guidelines and technical standards • Eco-labelling programmes • Product standards and technical requirements
	Capital	• Reduce or eliminate tariffs on raw materials for EG production • Tax incentives such as free VAT or accelerated depreciation • Direct subsidies for EG producers/ adopters • Taxes on CO_2, pollutants and fossil fuels to promote EGs adoption • Promotion of targeted loans/ green loans/ soft loans/ commercial credits/ performance bonds to finance investment activities in EGs	• Emission limit values for GHG (CO_2, methane) and pollutants (NO_x, SO_x, PM_x)
	Labour	• Grants for capacity development and training in less intensive production methods • Tax incentives for hiring green tech engineers	• Promotion of trainings, audits and capacity development activities for EGs producers • State-supported apprenticeship programmes for engineers in green tech
	Technology	• R&D subsidies & grants to increase EG-related patents and adapt foreign EG technology to local needs • Feed-in tariffs (FITs) for renewable energy technologies	• Government R&D expenditure on environmentally friendly technology such as renewable energy • Manufacturing production technology requirements • Technical assistance and technology transfer support • Incubation centres for EG industries

References

Alavi, R. (2007). *An overview of key markets, tariffs and non-tariff measures on Asian exports of select environmental goods.* International Centre for Trade and Sustainable Development (ICTSD).

APEC (2012). *2012 Leaders' Declaration: Annex C – APEC List of Environmental Goods.* https://www.apec.org/Meeting-Papers/Leaders-Declarations/2012/2012_aelm/2012_aelm_annexC.aspx

Bjørndal, E., Bjørndal, M., Pardalos, P., & Rönnqvist, M. (2009). *Energy, Natural Resource and Environmental Economics.* Springer.

De Melo, J., & Solleder, J. (2020). Barriers to trade in environmental goods: How important they are and what should developing countries expect from their removal. *World Development, 130,* 104910. https://doi.org/10.1016/j.worlddev.2020.104910

Delabroye, S., Nimubona, A., & Sinclair-Desgagné, B. (2016). CHAPTER 12: International Trade and the Environmental Goods and Services Industry. In *The WSPC Reference on Natural Resources and Environmental Policy in the Era of Global Change* (pp. 295–328).

Dinda, S. (2019). *Climate Friendly Goods and Technologies in Asia.* Springer.

EPU (2013). *Government Green Procurement (GGP) Short-term Action Plan 2013 – 2014.*

Gaigné, C., & Tamini, L. D. (2018). *Environmental regulation and eco-industry trade: Theory and evidence from the European Union.* Working Paper SMART – LERECO N°18-09.

IPCC (2014). *Climate Change 2014: Mitigation of Climate Change.* Cambridge University Press.

ITC (2014). *Trade in environmental goods and services: Opportunities and challenges.* International Trade Centre (ITC).

Masjuki, H. H., Kalam, M. A., Mofijur, M., & Shahabuddin, M. (2013). Biofuel: Policy, standardization and recommendation for sustainable future energy supply. *Energy Procedia, 42(1),* 577–586.

MIDA (2017, March 15). Malaysia, well positioned to attract more solar investments. *The Star Online,* 11.

Mongo, M., Belaïd, F., & Ramdani, B. (2021). The effects of environmental innovations on CO_2 emissions: Empirical evidence from Europe. *Environmental Science & Policy, 118,* 1–9. https://doi.org/10.1016/j.envsci.2020.12.004

OECD (2005). *OECD Environmental Performance Reviews – Chile.* OECD Publishing.

Puertas, R., & Marti, L. (2021). Eco-innovation and determinants of GHG emissions in OECD countries. *Journal of Cleaner Production, 319,* 128739. https://doi.org/10.1016/j.jclepro.2021.128739

Sauvage, J. (2014). The stringency of Environmental Regulations and the Trade in Environmental Goods. *OECD Trade and Environment Working Papers 2014/03.* https://dx.doi.org/10.1787/5jxrjn7xsnmq-en

State of NSW and Department of Planning, Industry and Environment (2020). *NSW Climate Change Fund. Annual Report 2019—2020.* https://www.environment.nsw.gov.au/-/media/OEH/Corporate-Site/Documents/Climate-change/nsw-climate-change-fund-annual-report-2019-2020-200499.pdf

Sugathan, M. (2013). *List of Environmental Goods: An Overview. Information Note.* International Centre for Trade and Sustainable Development.

USAID (2011, October). Chile Environmental Industry 2011 – Case Study. *Report by Environmental Business International, Inc. and Nathan Associates Inc. for the United States Agency for International Development on Behalf of the Asia-Pacific Economic Cooperation (APEC) Forum.*

Weizsäcker, E. U., de Larderel, J., Hargroves, K., Hudson, C., Smith, M., & Rodrigues, M. (2014). *Decoupling 2: Technologies, opportunities and policy options* (UNEP, Ed.). A Report of the Working Group on Decoupling to the International Resource Panel. https://www.resourcepanel.org/sites/default/files/documents/document/media/-decoupling_2_technologies_opportunities_and_policy_options-2014irp_decoupling_2_report-1.pdf

Wirth, H. (2021). *Recent Facts about Photovoltaics in Germany.* Fraunhofer ISE. https://www.ise.fraunhofer.de/en/publications/studies/recent-facts-about-pv-in-germany.html

World Bank (2008). *International Trade and Climate Change.* World Bank Group.

World Trade Organization (2009). *Trade and Climate Change.* WTO-UNEP Report. https://www.wto.org/english/res_e/booksp_e/trade_climate_change_e.pdf

World Trade Organization (2014). *Trade Topics: Environmental Goods Agreement.* https://www.wto.org/english/tratop_e/envir_e/ega_e.htm

Appendix

ISIC Revision 3 & Revision 4 sector correspondence tables

ISIC Rev 3		**Manufacturing sector classification of databases used**					
Code	**Description**	**UNIDO database (INDSTAT 2)**	**IEA databases**	**FAO AQUASTAT**	**(Municipal Solid) Waste**	**WB**	
A (01, 02)	Agriculture, hunting, and forestry						
B (05)	Fishing						
E (40 to 41)	Electricity, gas, steam, and air conditioning supply			Industry		Industry = 10-45	
C (10 to 14)	Mining and quarrying		Industry		Mining & quarrying		
D (15 to 37)	Total manufacturing	Manufacturing			Industrial waste		Manufacturing MVA
F (45)	Construction				Construction		

ISIC Rev 3		**Manufacturing sub-sector classification of databases used**		
Code	**Description**	**UNIDO database (INDSTAT 2)**	**IEA databases (world energy balances, emissions in fuel combustion)**	**SCP-HAT database**
15	Food products & beverages	Food products & beverages	Food and tobacco	Food & beverages
16	Tobacco products	Tobacco products		
17	Manufacture of textiles	Manufacture of textiles	Textile and leather	Textiles and wearing apparel
18	Wearing apparel; dressing and dyeing	Wearing apparel; dressing and dyeing		
19	Manufacture of leather products	Manufacture of leather products		
20	Wood and wood products	Wood and wood products	Wood and wood products	Wood and paper
21	Paper and paper products	Paper and paper products	Paper, pulp, and print	
22	Printing and publishing	Printing and publishing		
23	Coke and refined petroleum products	Coke and refined petroleum products	Petrochemical industry	Petroleum, chemical and non-metallic Mineral products
24	Chemicals and chemical products	Chemicals and chemical products	Chemicals and chemical products	

25	Rubber and plastic products	Rubber and plastic products	*No corresponding manufacturing group*	
26	Non-metallic mineral products	Non-metallic mineral products	Non-metallic minerals	
27	Manufacture of basic metals	Manufacture of basic metals	Iron and steel	Metal products
			Non-ferrous metals (2720 and 2732)	
28	Fabricated metal products	Fabricated metal products	Machinery	
29	Machinery and equipment	Machinery and equipment		Electrical and machinery
30	Office and computing machinery	Office and computing machinery		
31	Electrical machinery and apparatus	Electrical machinery and apparatus		
32	Radio, TV, and communication equipment	Radio, TV, and communication equipment		
33	Medical, precision, and optical instruments	Medical, precision, and optical instruments	*No corresponding manufacturing group*	
34	Motor vehicles, trailers, and semi-trailers	Motor vehicles, trailers, and semi-trailers	Transport equipment	Transport equipment
35	Other transport equipment	Other transport equipment		
36	Furniture and other manufacturing	Furniture and other manufacturing	*No corresponding manufacturing group*	Other manufacturing
37	Recycling	Recycling	*No corresponding manufacturing group*	Recycling
			Non-specified, includes: Rubber and plastic products; medical, precision and optical instruments; furniture and other manufacturing; recycling	

ISIC Rev 4		**Manufacturing sector classification of databases used**					
Code	**Description**	**UNIDO database (INDSTAT 2)**	**IEA databases**	**FAO AQUASTAT**	**(Municipal Solid) Waste**	**WB**	
			ISIV rev 2	**ISIC Rev 4**		**ISIC Rev 3**	
A (01, 03)	Agriculture, forestry, and fishing						
B (05,09)	Mining and quarrying		Industry	Industry	Mining & quarrying	Industry = 10-45	
C (10 to 33)	Total manufacturing	Manufacturing			Industrial waste		Manufacturing MVA
F (41 to 43)	Construction				Construction		
D (35)	Electricity, gas, steam, and air conditioning supply						
E (36 to 39)	Water supply; sewerage, waste management and remediation activities						

ISIC Rev 4		**Manufacturing sub-sector classification of databases used**		
10	Food products	Food products	Food and tobacco (FOODPRO)	Food & beverages
11	Beverage products	Beverage products		
12	Tobacco products	Tobacco products		
13	Textiles	Textiles	Textile and leather products	Textiles and wearing apparel
14	Wearing apparel	Wearing apparel		
15	Leather and leather products	Leather and leather products		
16	Wood and wood products	Wood and wood products	Wood and wood products	Wood and paper
17	Paper and paper products	Paper and paper products	Paper, pulp, and printings	
18	Printings	Printings		
19	Coke and refined petroleum products	Coke and refined petroleum products	*No corresponding manufacturing group*	Petroleum, chemical and non-metallic mineral products
20	Chemicals and chemical products	Chemicals and chemical products	Chemical and petrochemical products	
21	Basic pharmaceutical products and pharm. preparations	Basic pharmaceutical products and pharm. preparations		

22	Rubber and plastic products	Rubber and plastic products	*No corresponding manufacturing group*	
23	Non-metallic mineral products	Non-metallic mineral products	Non-metallic minerals	Metal products
24	Basic metals	Basic metals	Non-ferrous metals (242, 2432)	
			Iron and steel (241, 2431)	
25	Fabricated metal products	Fabricated metal products	Machinery	
26	Computer electronics and optical products	Computer electronics and optical products		Electrical and machinery
27	Electrical equipment	Electrical equipment		
28	Machinery and equipment nec	Machinery and equipment nec		
29	Motor vehicles, trailers, and semi-trailers	Motor vehicles, trailers, and semi-trailers	Transport	Transport equipment
30	Other transport equipment	Other transport equipment		
31	Furniture and other manufacturing	Furniture and other manufacturing	*No corresponding manufacturing group*	Other manufacturing
32	Other manufacturing	Other manufacturing	*No corresponding manufacturing group*	Recycling
33	Repair and installation of machinery and equipment	Repair and installation of machinery and equipment	*No corresponding manufacturing group*	No corresponding manufacturing group
			Non-specified, includes: rubber and plastic products; furniture and other manufacturing; recycling	

Complete list of environmental goods used in this tool (including HS codes)

HS Code	Product description
392010	Plates, sheets, film, foil & strip, of polymers of ethylene, non-cellular reinforced, laminated, supported/similarly combined with other materials (excl. self-adhesive)
441872	Assembled flooring panels, multilayer
560314	Nonwovens, whether/not impregnated/coated/covered/laminated, of man-made filaments, weighing >150 g/m^2
701931	Mats of glass fibres
730820	Towers & lattice masts of iron/steel
730900	Reservoirs, tanks, vats & similar containers for any material other than compressed/liquefied gas, of iron/steel, of a capacity >300 l, whether/not lined/heat-insulated but not fitted with mechanical/thermal equip.
732111	Cooking appliances & plate warmers, for gas fuel/for both gas & other fuels.
732190	Parts of the non-electric domestic appliances of 7321.11-7321.83, of iron/steel
732490	Sanitary ware & parts thereof, of iron/steel (excl. of 7324.10-7324.29)
761100	Aluminium reservoirs, tanks, vats & similar containers, for any material (other than compressed/liquefied gas), of a capacity >300 l, whether/not lined/heat-insulated but not fitted with mechanical/thermal equip.
761290	Aluminium casks, drums, cans, boxes & similar containers, incl. rigid tubular containers but excl. collapsible tubular containers, for any material (other than compressed/liquefied gas), of a capacity not >300 l, whether/not line/heat-insulated, but not fitted
840219	Vapour generating boilers, incl. hybrid boilers (excl. of 8402.11 & 8402.12; excl. central heating hot water boilers capable also of producing low pressure steam)
840290	Parts of the boilers of 8402.11-8402.20
840410	Auxiliary plant for use with boilers of 84.02/84.03 (e.g., economisers, super-heaters, soot removers, gas recoverers)
840420	Condensers for steam/other vapour power units
840490	Parts of the auxiliary plant of 8404.10 & 8404.20
840510	Producer gas/water gas generators, with/without their purifiers; acetylene gas generators & similar water process gas generators, with/without their purifiers
840681	Steam turbines & other vapour turbines (excl. for marine propulsion), of an output >40MW
840690	Parts of the steam turbines & other vapour turbines of 8406.10-8406.82
841011	Hydraulic turbines & water wheels, of a power not >1000kW
841090	Parts (incl. regulators) of the hydraulic turbines & water wheels of 8410.11-8410.13
841181	Gas turbines other than turbojets/turbo-propellers, of a power not >5000kW
841182	Gas turbines other than turbojets/turbo-propellers, of a power >5000kW

841199	Parts of the other gas turbines of 8411.81 & 8411.82
841290	Parts of the engines & motors of 8412.10-8412.80
841581	Air-conditioning machines incorporating a refrigerating unit & a valve for reversal of the cooling/heat cycle (reversible heat pumps)
841780	Industrial/laboratory furnaces & ovens (excl. of 8147.10 & 8417.20), incl. incinerators, non-electric
841790	Parts of the industrial/laboratory furnaces & ovens of 8417.10-8417.80
841861	Compression-type refrigerating/freezing equip. whose condensers are heat exchangers
841869	Refrigerating/freezing equip. n.e.s. in 84.18; heat pumps
841919	Instantaneous/storage water heaters, non-electric (excl. of 8419.11)
841939	Dryers for use as machinery/plant/laboratory equip., whether/not electrically heated (excl. of 8419.31, 8419.32, 84.36-84.38 & 84.51)
841940	Distilling/rectifying plant, whether/not electrically heated
841950	Heat exchange units, whether/not electrically heated
841960	Machinery for liquefying air/other gases, whether/not electrically heated
841989	Machinery, plant & equip., n.e.s. in Ch.84, other than for making hot drinks/for cooking/heating food, whether/not electrically heated
841990	Parts of machinery, plant/laboratory equipment, whether/not electrically heated (excl. furnaces, ovens & other equipment of heading 85.14), for the treatment of materials by a process involving a change of temperature such as heating, cooking, roasting
842121	Filtering/purifying machinery & apparatus for filtering/purifying water
842129	Filtering/purifying machinery & apparatus for liquids (excl. of 8421.21-8421.23)
842139	Filtering/purifying machinery & apparatus for gases, other than intake air filters for internal combustion engines
842199	Parts of the filtering/purifying machinery & apparatus of 84.21 (excl. of centrifuges, incl. centrifugal dryers)
847420	Crushing/grinding machines for earth/stone/ores/other mineral substance, in solid (incl. powder/paste) form
847982	Mixing/kneading/crushing/grinding/screening/sifting/homogenising/emulsifying/stirring machines, n.e.s. in Ch.84
847989	Other machines & mechanical appliances, other than Machines & mechanical appliances for treating metal, incl. electric wire coil-winders/Mixing/kneading/crushing/grinding/screening/sifting/homogenising/emulsifying/stirring machines
847990	Parts of Machines & mechanical appliances having individual functions, not specified/incl. elsewhere in this Ch..
848340	Gears & gearing (excl. toothed wheels, chain sprockets & other transmission elements presented sep.); ball/roller screws; gear boxes & other speed changers, incl. torque converters
848360	Clutches & shaft couplings (incl. universal joints)
850161	AC generators (alternators), of an output not >75kVA

850162	AC generators (alternators), of an output >75kVA but not >375kVA
850163	AC generators (alternators), of an output >375kVA but not >750kVA
850164	AC generators (alternators), of an output >750kVA
850231	Wind-powered electric generating sets
850239	Electric generating sets n.e.s. in 85.02
850300	Parts suit. for use solely/principally with the machines of 85.01/85.02
850490	Parts of the machines of 85.04
850680	Primary cells & primary batteries n.e.s. in 85.06
850720	Electric accumulators, incl. separators therefor, whether/not rectangular (incl. square), lead-acid (excl. of 8507.10)
851410	Resistance heated furnaces & ovens
851420	Furnaces & ovens functioning by induction/dielectric loss
851430	Other furnaces & ovens other than Resistance heated furnaces & ovens/ Furnaces & ovens functioning by induction/dielectric loss
851490	Parts of Industrial/laboratory electric furnaces & ovens (incl. those functioning by induction/dielectric loss); other industrial/laboratory equipment for the heat treatment of materials by induction/dielectric loss.
853710	Boards, panels, consoles, desks, cabinets & other bases, equipped with 2/more apparatus of 85.35/85.36, for electric control/distribution of electricity, incl. those incorporating instruments/apparatus of Ch. 90 & numerical control apparatus, other than
854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether/not assembled in modules/made up into panels; light emitting diodes
854390	Parts of electrical machines & apparatus, having individual functions, not specified/incl. elsewhere in this Ch..
900190	Lenses (excl. of 9001.30-9001.50), prisms, mirrors & other optical elements, of any material, unmounted, other than such elements of glass not optically worked
900290	Lenses, prisms, mirrors & other optical elements, of any material, mounted, being parts of/fittings for instr./apparatus (excl. such elements of glass not optically worked), n.e.s. in 90.02
901380	Liquid crystal devices not constituting articles provided for more specifically in other headings; other optical appliances & instr., n.e.s. in Ch.90
901390	Parts & accessories of the articles of 90.13
901580	Surveying/hydrographic/oceanographic/hydrological/meteorological/geophysical instr. & appliances (excl. compasses), n.e.s. in 90.15
902610	Instruments & apparatus for measuring/checking the flow/level of liquids
902620	Instruments & apparatus for measuring/checking pressure
902680	Instruments & apparatus for measuring/checking the flow/level/pressure/other variables of liquids/gases (e.g., flow meters, level gauges, manometers, heat meter), excl. instruments/apparatus of heading 90.14 & 90.15, 90.28

902690	Parts & accessories of the instr. & appliances of 90.26
902710	Gas/smoke analysis apparatus
902720	Chromatographs & electrophoresis instr.
902730	Spectrometers, spectrophotometers & spectrographs using optical radiations (UV, visible, IR)
902750	Instruments & apparatus for physical/chemical analysis, using optical radiations (UV, visible, IR), n.e.s. in 90.27
902780	Instruments & apparatus for physical/chemical analysis, n.e.s. in 90.27
902790	Microtomes; parts & accessories of instr. & apparatus of 90.27
903149	Other optical instruments & appliances, other than 9031.41
903180	Measuring/checking instr., apparatus& machines, n.e.s. in Ch. 90
903190	Parts & accessories of the instr., apparatus & machines of 90.31
903210	Thermostats
903220	Manostats
903289	Automatic regulating/controlling instr. & apparatus, n.e.s. in 90.32
903290	Parts & accessories of the instr. & apparatus of 90.32
903300	Parts & accessories n.e.s. in Ch.90. for machines/appliances/instr./apparatus of Ch.90

Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 26026-0

www.unido.org

unido@unido.org

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION