Enhancing the Quality of Industrial Policies (EQuIP) – Tool 11	
Name of the tool:	Climate Change and manufacturing
Objective:	The objective of this tool is to present a set of indicators and related analyses which provide a general overview of a country's vulnerability to climate change and its greenhouse gas emissions focusing on the the manufacturing sector. The analysis relies on best available data from international organizations such as the IEA, World Bank and UNIDO. This component relies upon UNIDO's expertise in environmental diagnostics and the use of ready-to-use secondary data for benchmarking across countries. It seeks to provide policy makers with a tool for understanding their country's need for climate change adaptation and mitigation.
Key Questions:	• How exposed is a country to the impacts of a change in climate? • How big is the need for climate change adaptation? • How do a country's overall CO_2 emissions compare to those of other countries? • How much does the manufacturing sector and its different sub-sectors contribute to a country's CO_2 emissions? • Has the manufacturing industry achieved economic decoupling? • How can the growth of industrial CO_2 emissions be decomposed?
Indicators used:	1) Global climate risk 2) Share of industry and services in GDP 3) Losses in manufacturing labour productivity 4) Labour productivity in manufacturing 5) Value losses due to electrical outages 6) GDP per capita 7) Freshwater withdrawal for industry 8) Level of water stress 9) Total of CO_2 emissions as a share of world CO_2 emissions 10) CO_2 emissions per capita 11) Country CO_2 emissions intensity 12) Manufacturing of CO_2 emissions as a share of total CO_2 emissions 13) CO_2 emissions of manufacturing sub - sectors 14) Share of emission from coal in manufacturing (sub-)sectors emissions

15) Share of non-renewable energy sources in electricity generation
16) Emissions intensity of manufacturing
17) Emission intensity of manufacturing (sub-)sectors
18) Emission per unit of energy of manufacturing (sub-)sectors
19) CAGR of manufacturing CO_2 emissions and value added
20) Share of climate-friendly goods in exports

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Units and Abbreviations

Units of emissions	
$MtCO_2eq$	Million tons of CO_2 equivalent (1 $MtCO_2eq = 10^6\ tCO_2eq = 10^9\ kgCO_2eq$)
$MtCO_2$	Million tons of CO_2 (1 $MtCO_2 = 10^6\ tCO_2 = 10^9\ kgCO_2$)
tCO_2	Tons of CO_2 (1 $tCO_2 = 10^3\ kgCO_2$)
$kgCO_2$	kg of CO_2
Units of energy	
Ktoe	Kilo tons of oil equivalent (1 Ktoe = 10^3 toe)
toe	Tons of oil equivalent

1 Introduction

Current trends in the global economy are not sustainable. Industrial development so far has often come at the expense of the environment, and greenhouse gases have accumulated at levels that make a global warming of 1.5 degrees above pre-industrial levels likely to happen in the period between 2030 to 2052[1]. Growing awareness of the causes and effects of climate change has also given rise to sustainable development approaches focused on climate change mitigation and adaptation. 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 a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels. Reducing the emissions of the manufacturing sector is a crucial issue if countries want to deliver on their NDC pledges.

While global warming is only one of the threats to the earth's ecosystem, it is considered to be one of the most severe threats to human development. Adapting to a change in climate is particularly vital for developing countries as a way of enabling future economic and human development. Developing countries face the double challenge of addressing climate change without compromising their trajectory towards economic and social development. For countries of lower income, continuing to raise living standards and address poverty alleviation is of the utmost importance for improving the welfare of the population. Achieving this requires simultaneous structural change towards higher productivity along with progress in decoupling human well-being and economic progress from resource consumption and emissions[2]. Through commitment to conditional targets in their NDCs, developing countries can utilize specific development assistance and thereby actively benefit from climate change mitigation.

Climate change is not expected to affect all countries equally. Multiple studies have found climate change is likely to more negatively impact developing economies, and particularly economies in the African region, which is expected to be one of worse affected regions by the impacts of global warming[3]. Costs and opportunities will differ among countries due to their geographic location, with some regions being more negatively affected than others. Therefore, achieving climate change adaptation and mitigation should be a special concern for developing countries as a way to also limit its impact on the economy.

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[1]IPCC (2018) 'Summary for Policymakers', in Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty (Geneva: World Meteorological Organization).

[2]Altenburg T. and Rodrik D. (2017) 'Green Industrial Policy: Accelerating Industrial Change Towards Wealthy Green Economies', in Green Industrial Policy. Concept, Policies, Country Experiences, ed. T Altenburg and C Assmann (Geneva, Bonn: UN Environment; German Development Institute / Deutsches Institut für Entwicklungspolitk (DIE).

[3]Naudé, W. (2011). Climate Change and Industrial Policy. Sustainability, 3(7), 1003–1021. https://doi.org/10.3390/su3071003.

Tackling mitigation and adaptation requires coordinated efforts from multiple stakeholders both at the national and international level. For national policy formulation, climate change is a broad and encompassing topic which requires wide and coordinated actions of policy makers working in multiple spheres to address. It requires coordinated measures and policies of many ministries and is related to issues beyond the Ministry of Environment's mandate. Industry, for example, is a significant contributor to climate change. Reducing industrial emissions and adapting industry to climate change is a part of industrial strategy given the wide-reaching impacts that climate change is expected to have.

While climate change has been one of the most debated topics in the policy arena, there is little material with a specific focus on industry and a lack of a learning tool addressed to policy makers on this specific topic. This module focuses on both climate change adaptation and mitigation. The current module gives the learners the opportunity to understand indicators and data useful for the planning and monitoring of climate change. The central focus of this tool lies in understanding the possibilities and past progress for the manufacturing sector in terms of reducing its contribution to climate change. This tool also enables the investigation and understanding of the climate change adaptation needs of the manufacturing sectors. By providing information on exposure, vulnerability and resilience towards climate change related environmental hazards, learners can make decisions on adaptation needs. Only by assessing climate change risks on manufacturing a plan for adaptation can be created and implemented which enables industrial development despite the effects of global warming.

In order to achieve climate change mitigation and industrial development, an important starting point is to understand how much industry emits and how those emissions grow together as manufacturing activities expand. Benchmarking the performance of the manufacturing sector and its different sub-sectors against suitable comparators can help to develop analysis for identifying those sub-sectors that are making a lot of progress, lagging behind, or for which opportunities appear to exist in terms of emissions mitigation. Understanding the historic path and composition of the manufacturing sector's CO_2 emissions will help policy makers to analyse the development of industrial emissions and subsequently evaluate the progress in terms of reaching their established NDC targets.

The aim of this module is to provide policy makers with tools to understand both the adaptation needs and mitigation potential of their industry sector and to benchmark their country against other countries. In addition, by identifying which pathway for industry enables successful cases of economic decoupling within the manufacturing sector, analysts are also able to identify successful comparators and failures. The tool does this by answering different sets of questions: How big is the need for a country to adapt to the change in climate? What is a country's level of emissions and how have emissions developed over time? Which sectors are performing well or badly in terms of emission intensity? What is the structure of the economy and emissions in suitable comparator countries?

2 Setting the Stage

Human activity has led to an increasing accumulation of greenhouse gas emissions (GHGs) in the atmosphere. Although a certain level of GHGs naturally exist in the atmosphere, economic activity has drastically changed the atmospheric concentration of these gases. This has exacerbated global warming and has led to a gradual change in climate. As a result, the likelihood of the occurrence of extreme weather events and natural hazards, such as heat waves, droughts, forest fires, rising sea levels, floods or hurricanes, has increased. Countries are expected to be affected by different magnitudes. The effects on the countries in the Global South are predicted to be more severe than in other regions. In many cases, the countries with the highest exposure to the effects of climate change are also those with a lower ability to cope with damages caused by these events. These natural hazards can result in economic losses through infrastructure damage, reduced crop yields, and through other channels. They can also affect an economy's competitiveness due to heat effects on labour and agricultural productivity.

The social consequences of climate change will include altered access to drinking water and decreases in food security, as well as implications for human health through the spread of vector-borne and water-borne infectious diseases. Social structures are predicted to be destabilized, intensifying not only poverty, but also leading to forced migration.[4] Internal migration due to climate change is expected to affect 143 million people by 2050 across the regions of Sub-Saharan Africa, South Asia, and Latin America.[5] Furthermore, populations of Small Island States and coastal areas will be affected by sea level rise, contributing to further population displacement.

2.1 Adaptation and mitigation

The impacts of climate change are observable today. As of 2019, 20 of the warmest years on record had occurred in the preceding 22 years. Therefore, responses to climate change are already necessary. Responding to climate change will require both adapting to the consequences of the change in climate and acting to prevent further advancements of the effects by reducing climate change contributors through emission mitigation. Figure 1 gives a visual representation of these two responses to climate change and how they will be addressed in this tool. The figure outlines the two paths of analyses by highlighting the dimensions that are considered. Those dimensions that are not the focus of this tool are presented in dotted lines.

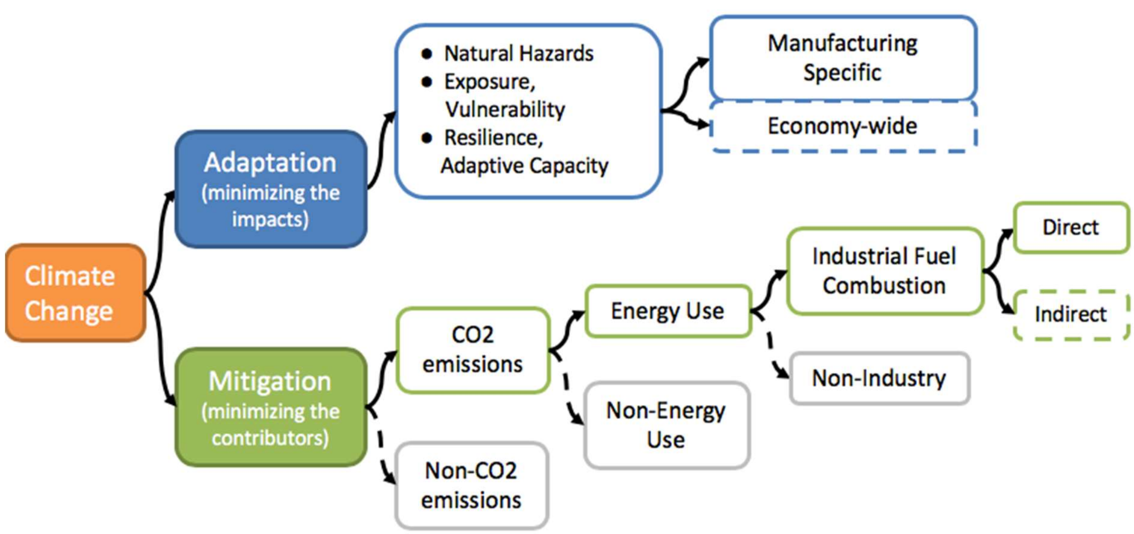
[4] Islam, S. N., Winkel, J. (2017). Climate Change and Social Inequality. DESA Working Paper No. 152, ST/ESA/2017/DWP/152.

[5] Rigaud, K., de Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., Adamo, S., McCusker, B., Heuser, S., Midgley, A. (2018). Groundswell: Preparing for Internal Climate Migration. World Bank, Washington, DC. World Bank. https://openknowledge.worldbank.org/handle/10986/29461.

Adaptation represents the response to the impacts of climate change (illustrated by the upper part of Figure 1). It aims to reduce and overcome potential damages by increasing a country's resilience to its exposure to natural hazards associated with climate change. Given that the impacts of climate change are expected to differ among regions, adaptation and required actions need to be assessed individually on the country and sector level. In addition, adaptation of the manufacturing sector is argued to have a positive impact on the future competitiveness of developing countries.[6]

The concept of adaptation can further be divided into the dimensions of natural hazards, vulnerability, exposure and resilience; all of which can be combined in order to assess a country's adaptive capacity towards climate change impacts. Guided by each of these elements, the tool equips policy makers with the required knowledge to assess a country´s need for adaptation. The analysis is concerned with manufacturing-specific effects and the role of manufacturing in enhancing resilience capacity. However, as many of the impacts of climate change concern the country as a whole, this tool also includes economy-wide adaptation indicators.

Figure 1. Guidance through the components of this tool



Beyond adapting to the changing circumstance, avoiding the future worsening of climate change is necessary. This would limit future changes in the climate, and in doing so reduce the future need for adaptation. The key intervention of climate change mitigation is to reduce the man-made emissions in order to avoid further increases in the atmospheric concentration of GHGs. This is represented in the bottom half of Figure 1. The concept of mitigation therefore aims to tackle climate change at its source through the reduction of anthropogenic greenhouse gas emissions. New technologies and the shift to renewable energy sources are viable options to achieve climate change mitigation. Internationally coordinated mitigation is needed to curb greenhouse gas emissions at the degree

[6]Altenburg T. and Rodrik D. (2017) 'Green Industrial Policy: Accelerating Industrial Change Towards Wealthy Green Economies', in Green Industrial Policy. Concept, Policies, Country Experiences, ed. T Altenburg and C Assmann (Geneva, Bonn: UN Environment; German Development Institute / Deutsches Institut für Entwicklungspolitk (DIE).

necessary to limit global temperature rise within this century to well below 2 degrees Celsius compared to pre-industrial levels, as agreed to during the COP21 in Paris. Greenhouse gases is an umbrella term that is used to refer to a number of different gases which trap heat and keep the Earth's atmosphere warm. These include gases such as water vapour, carbon dioxide, nitrous oxide, and other gases. Among anthropogenic GHG emissions – which are those emissions that result from human activity – carbon dioxide (CO_2) is the largest, having accounted for around 65% of man-made emissions (USA Environmental Protection Agency from IPCC 2014[7]). CO_2 emissions mainly result from burning fossil fuels, industrial processes, deforestation and other land use changes. Due to the importance of CO_2 emissions and the availability of more detailed data about them, this tool only focuses on GHG emissions of this type.

Man-made CO_2 emissions are produced as a result of different economic activities. These can be further distinguished between those emitted from fuel combustion for energy generation and non-energy related processes, such as land-use change. Part of the fossil fuel is consumed by the manufacturing sector during the production processes. The manufacturing sector is also a large consumer of electricity, the production of which still relies to a large degree on the combustion of fossil fuels. Therefore, it is possible to distinguish between the manufacturing sector's directly emitted CO_2 emissions through its direct use of fossil fuels, from those which are indirectly associated with the sector's activity by its consumption of electricity generated from fossil fuels.

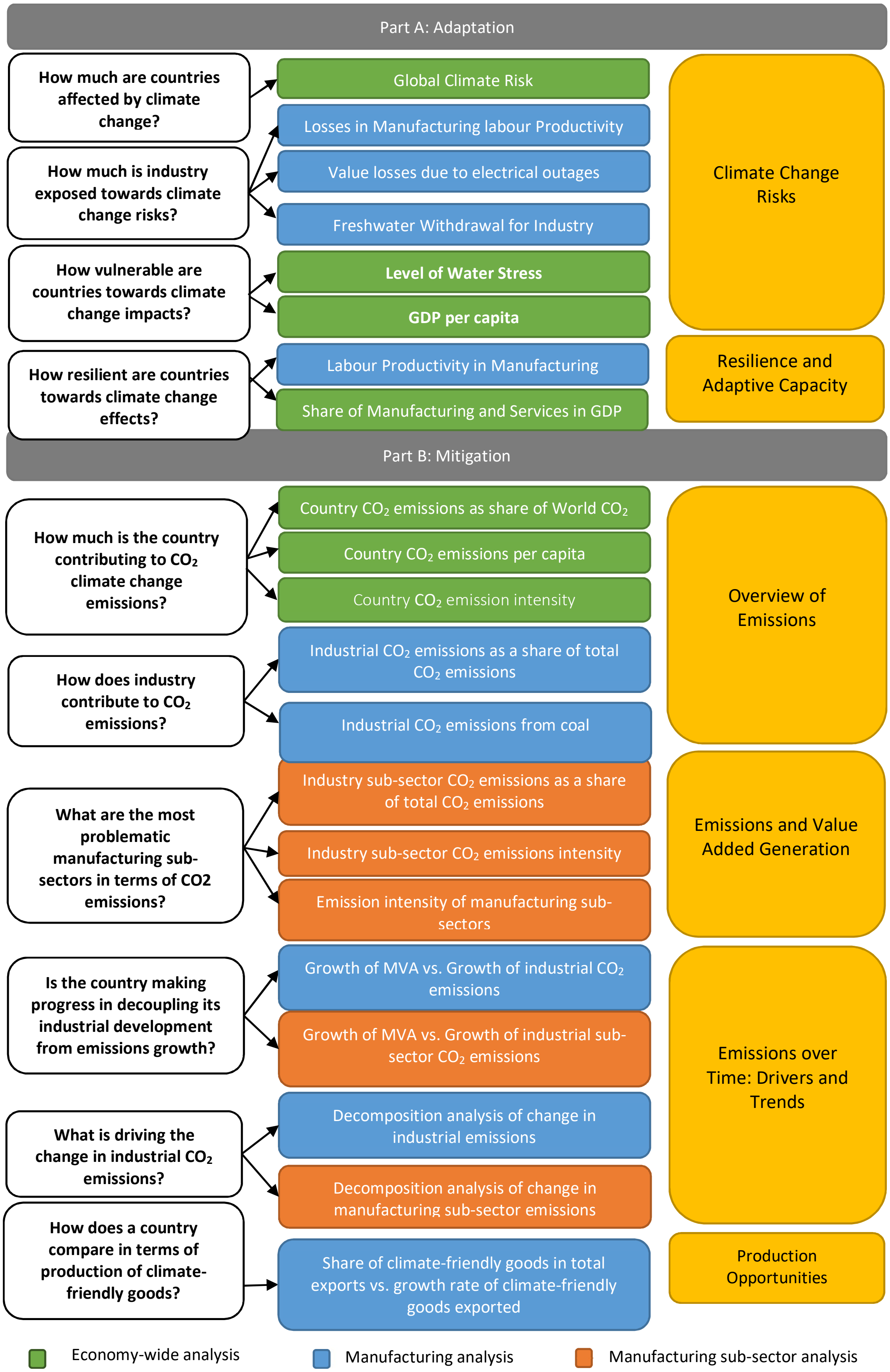
In order to provide more detailed analyses and comparisons across countries, this tool analyses not only the manufacturing sector as a whole, but also goes one step further, elaborating this issue on the sub-sector level. Despite the additional insights that can be drawn from the sub-sector analysis, this comes at the expense of limited data coverage. For example, currently the International Energy Agency's (IEA) dataset on CO_2 emission from fuel combustion (which is the main source for CO_2 emissions data used in this tool) does not include data on indirect emissions through the use of electricity for manufacturing sub-sector. This data at present only exists for the manufacturing sector as a whole without further sectorial disaggregation.

For the compilation of this tool, various indicators have been identified. These indicators are defined and discussed in the methodology section (3). This section also outlines the questions that can be addressed by specific indicators and refers to their respective data source. The methodology section is followed by the analysis. The analysis section (4) demonstrates in an exemplary fashion how these indicators can be used to assess the interdependency of a country´s manufacturing sector and climate change effects. This has been conducted first by addressing the concept of climate change adaptation (0) and then climate change mitigation (0). The analysis on adaptation provides first an overview of potential indicators addressing adaptation towards climate change by scoping exposure, vulnerability, and resilience on the cross-sectoral as well as manufacturing level. Climate change mitigation is analysed by first giving an overview of a country´s total CO_2 emissions. The analysis then shifts the

[7] Source available at the Environmental Protection Agency website https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

focus to CO_2 emissions related to the manufacturing sector and its different sub-sectors. The questions answered by the different indicators are presented in the Figure 2 below.

Figure 2. Conceptual structure of the analysis



3 Methodology

This section provides guidance on indicators that can be used to perform the various analyses illustrated and explained in the analysis section. A number of indicators are discussed, which allow to:

- Assess the exposure, vulnerability and resilience of countries towards climate change
- Illustrate trends in countries' total and manufacturing CO_2 emissions
- Evaluate progress so far toward decoupling economic growth from emissions growth
- Understand and reflect on past drivers of emissions growth/reduction, differentiating between the contributions of manufacturing development, structural change, energy efficiency, and emission intensity of fuels.
- Evaluate performance in the export of climate-friendly goods, a market expected to rapidly grow as mitigation efforts of countries take place

The International Energy Agency (IEA) dataset is used as the main source for data on CO_2 emissions, energy production and consumption in this tool. The IEA provides detailed data on CO_2 emissions from energy combustion of countries and economic sectors worldwide for both OECD and non-OECD countries. The wide time and country coverages provides a dataset suitable for producing comparable indicators across countries for benchmarking performance and progress. In addition, data collected at the manufacturing sub-sector level allows evaluating emissions at this level of analysis as well as analysing manufacturing in aggregate. The IEA's World Energy Balances dataset is the main data sources used in the Tool 6.1 (Greening Industry – Module 1: Energy Efficiency). Both datasets have been widely applied in economic and environmental assessments by national and international organisations.

3.1 Global Climate Risk

Definition of the indicator

The Germanwatch Global Climate Risk Index (CRI) measures fatalities and economic losses related to climate change and is of particular interest for countries facing extreme weather events. It focuses on weather-related loss events (e.g. storms, floods, heat waves etc.) only, while geological incidents such as earthquakes or indirect impacts of extreme weather events are not considered in this context. Based on four indicators, the CRI examines both absolute and relative impacts to create an average ranking of countries, with a stronger emphasis placed on the relative indicators. Each country's score is derived from a country's average ranking in all four indicating categories (according to the following weighting: death toll 1/6; deaths per 100,000 inhabitants 1/3; absolute losses in PPP 1/6; losses per GDP unit 1/3). The information for this indicator is based on the current and past climate variability over the last 20 years.

Main Questions

- To what extent are countries affected by extreme weather events?

Data Sources

This indicator is based on a composite index conducted by Germanwatch. The data is provided by Munich ReNatCatSERVICE, which is a reliable and complete database on this matter. The examination of this indicator covers four variables. The Global Climate Risk Index 2019 is based on loss-figures from 2017 and 1998-2017.

Indicator	Variables	Source
Global Climate Risk	Death toll	Germanwatch Global Climate Risk Index 2019, Munich Re NatCatSERVICE
	Number of deaths per 100 000 inhabitants	
	Absolute losses (in million US$ PPP)	
	Losses per unit GDP in %	

3.2 Share of Industry and Services in GDP

Definition of the indicator

The share of manufacturing and services in GDP (%) represents the resilience of a country as agricultural activities are highly sensitive towards changes in climate and natural hazards. The higher a country´s share of non-agricultural activities in GDP, the more it is expected to react resiliently towards environmental hazards[8].

Main Questions

- To what extent are countries resilient towards climate change risks?

Data Sources

This data is taken from the World Bank Database. The World Development Indicators provide data for 218 countries between 1960 and 2018. Both variables are in constant US Dollars.

Indicator	Variables	Source
	Gross Domestic Product (USD, constant prices)	

[8] Industry also includes the agri – food sector which is subject to vulnerability from climate uncertainty.

Share of non-agricultural activities in GDP (%)	Agriculture, Hunting, Forestry, Fishing VA (USD, constant prices)	World Bank (World Development Indicators)

3.3 Losses in Manufacturing Labour Productivity

Definition of the indicator

Working ability is dependent on working conditions including temperature and humidity. It is therefore assumed that increasing heat stress lowers labour productivity due to frequent pauses, lower speed and more. The indicator Manufacturing labour productivity losses is an estimate based on a climate change integrated assessment model. By conducting a meta-analysis, Roson and Sartori (2016)[9] estimated parameters for damage functions referring to heat effects on labour productivity. The functions have been estimated particularly for the manufacturing sector. The indicator is estimated on the basis of assumptions concerning the interaction of two temperature scenarios of +1°C and +3°C. Based on the typical hours that a person can work, the maximum percentage of working hours in relation to increasing temperature has been assessed. Thus, the indicator illustrates the future negative impact of heat stress on manufacturing labour productivity by modelling climate warming scenarios of +1°C and +3°C. Unlike other indicators in this module, the indicator represents the future impact of climate change on manufacturing.

Main Questions

- To what extent is manufacturing labour productivity expected to decrease because of global warming?

Data Sources

This indicator, based on an assessment model, has been calculated and published in the Journal of Global Economic Analysis in 2016. The estimation covers 140 regions of the GTAP9 Database.

Indicator	Variables	Source
Manufacturing labour productivity losses	Labour productivity	Roson and Sartori (2016)
	Temperature level +1°C and +3°C	

[9] Roson R., and Sartori M., (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Database. Journal of Global Economic Analysis 1, no. 2: 78–115, https://doi.org/10.21642/JGEA.010202AF.

3.4 Labour Productivity in Manufacturing

Definition of the indicator

The indicator ’Labour productivity in manufacturing’ is based on the value added generation of manufacturing (in current prices) and the absolute employment numbers of the manufacturing sector. It represents the resilience of the manufacturing sector. The higher the labour productivity of the manufacturing sector, the higher its resilience towards climate change and the associated negative effects on working ability.

Main Questions

- How vulnerable are manufacturing sectors in terms of labour productivity?

Data Sources

The data required for this indicator is derived from the UNIDO Statistics Database. The most current version, INDSTAT 2 has been launched in 2018 and is one of the largest industrial statistics databases. It provides data by single classification standards covering 172 countries from 1963 to 2016.

Indicator	Variables	Source
Labour Productivity in Manufacturing	Manufacturing Value Added (USD, current prices)	UNIDO Statistics Database (INDSTAT 2, Revision 3)
	Employment in absolute numbers	

3.5 Value losses due to electrical outages

Definition of the indicator

Disruptions of infrastructure services affect firms around the world and in many cases, even though not always, they are exacerbated by climate change. Environmental hazards can thereby be a crucial factor resulting in more power outages. The indicator ’Value losses due to electrical outages’ shows firms´ average losses due to electrical outages as a percentage of their total annual sales. It thus can be used as a proxy indicator to highlight a country`s vulnerability towards increased extreme weather events. The aggregated data on the national level is provided by the World Bank, based on the World Bank Enterprise Survey. It represents the extent firms are exposed to climate change related impacts.

Main Questions

- To what extent are manufacturing sectors exposed to climate change related energy infrastructure disruptions?
- What are the monetary losses of manufacturing sectors related to environmental hazards?

Data Sources

This data is based on the World Bank Enterprise Survey, which provides a set of microdata for more than 143,000 firms in the non-agricultural private economy. The sample covers 139 countries and represents 78 percent of the world's population and 80 percent of the gross domestic product (GDP) of low- and middle-income countries. Typically, 1200-1800 interviews are conducted in larger economies, 360 interviews in medium-sized economies, and 150 interviews in smaller economies. Selected for the survey are those cities and regions that contain the majority of economic activities within a country. The aggregated data on the national level is provided by the World Bank Database.

Indicator	Variables	Source
Value losses due to electrical outages (% of total annual sales for affected firms)	Estimated loss resulted from power outages (% of total annual sales or total annual losses)	World Bank (World Bank Enterprise Survey)
	Total annual sales	

3.6 Vulnerability based on GDP per capita

Definition of the indicator

The indicator 'GDP per capita' consists of the GDP and the population size of a country. GDP is measured as the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. GDP per capita, however, is the gross domestic product divided by midyear population. By reflecting the socio-economic capacity to cope with climate change related environmental hazards, GDP per capita represents a country´s vulnerability.

Main Questions

- To what extent are countries vulnerable from a socio–economic point of view towards climate change impacts?

Data Sources

This data is taken from the World Bank Database, which provides data for 218 countries between 1960 and 2018. The indicator 'GDP per capita' is updated annually.

Indicator	Variables	Source
GDP per capita	GDP (USD, constant prices)	World Bank (World Development Indicators)
	Population	

3.7 Freshwater withdrawal for industry

Definition of the indicator

The indicator annual 'Freshwater withdrawal for industry' indicates the total withdrawal for direct industrial use as a share of total freshwater withdrawal. It includes withdrawals for cooling thermoelectric plants and excludes evaporation losses from storage basins. Withdrawals for domestic use include drinking water, municipal use or supply, and use for public services, commercial establishments, and homes. As water is a climate-sensitive resource, this indicator illustrates the extent to what industries´ are exposed to climate change risks.

Main Questions

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

Data Sources

This data is taken from the FAO database AQUASTAT. AQUASTAT collects, analyzes, and disseminates data and information by country on water recourses and agricultural water use. It plays a key role in the monitoring of the Sustainable Development Goal 6 and in particular indicators of target 6.4 on water stress and water use efficiency. This indicator can be downloaded directly from AQUASTAT (FAO), there is no need to calculate the shares.

Indicator	Variables	Source
Freshwater withdrawal for Industry	Water withdrawal for direct industrial use	Food and Agriculture Organisation AQUASTAT
	Total freshwater withdrawal	

3.8 Level of water stress

Definition of the indicator

The indicator 'Level of water stress' indicates the ratio between freshwater withdrawn by all major sectors and total renewable freshwater resources after taking into account environmental water requirements. The considered sectors are (as defined by ISIC standards) agriculture, forestry and fishing, manufacturing, electricity industry, and services. The purpose of this indicator is to show the degree to which water resources are being exploited to meet the country's water demand. It shows to what extent water resources are already used and signals the vulnerability of a country towards climate change related water scarcities.

Main Questions

- To what extent are countries withdrawing water beyond their natural regeneration capacity?

Data Sources

This dataset is the part of the Global SDG Indicator Database compiled through the UN System in preparation for the Secretary-General's annual report on Progress towards the Sustainable Development Goals. This indicator can be downloaded directly from AQUASTAT (FAO), there is no need to calculate the shares.

Indicator	Variables	Source
Level of water stress	Total freshwater withdrawal by all major sectors (m^3/year)	Food and Agriculture Organization AQUASTAT
	Total renewable freshwater resources (m^3/year)	

3.9 Total CO_2 emissions as a share of World CO_2 emissions

Definition of the indicator

This indicator illustrates the size of a country's total CO_2 emissions from fuel combustion in relation other countries' total emissions. The percentage share is calculated by dividing a country's total CO_2 emissions in a given year by world emissions of that year. It is important to note that this indicator only evaluates 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.

Main questions

- How much does a country contribute to world CO_2 emissions?
- How has this share changed over time?

Data sources

Data is provided by the International Energy Agency (IEA) as part of IEA CO_2 Emissions from Fuel Combustion Statistics (measured in $MtCO_2$), which reports the basic data for 149 countries for the time period of 1960 to 2016 (1990 to 2016 for some countries).

Indicator	Variables	Source
Country CO_2 emission as a share of World CO_2 emissions	CO_2 emission from fuel combustion ($MtCO_2$)	International Energy Agency (CO_2 Emissions from Fuel Combustion Statistics)
	World CO_2 emission from fuel combustion ($MtCO_2$)	

3.10 CO_2 emissions per capita

Definition of the indicator

CO_2 emissions per capita are the country's total CO_2 emissions divided by the country's population. This indicator allows for taking into account differences in population size when comparing countries' emissions. This provides an overview of a country's per capita emissions which is more suitable for comparisons between countries as it corrects for these differences in size.

Main questions

- How do countries compare in terms of their per capita CO_2 emissions?
- How have the per capita CO_2 emissions evolved over time?

Data sources

For data on CO_2 emissions from fuel combustion, see indicator 3.9. As CO_2 data is reported in $MtCO_2$ we multiply this number by 1,000,000,000 to get the $kgCO_2$ equivalent. Data on population is taken from the World Bank Database which provides population data for 218 countries between 1960 and 2018.

Indicator	Variables	Source
CO_2 emission per capita ($kgCO_2$/ population)	Country CO_2 emissions from fuel combustion ($MtCO_2$)	International Energy Agency (CO_2 Emissions from Fuel Combustion Statistics)
	Population	World Bank (World Development Indicators)

3.11 Country CO_2 emission intensity

Definition of the indicator

This indicator provides information on a country's CO_2 emission intensity and illustrates how much CO_2 is emitted per unit of GDP. The emissions intensity is thus calculated as the total CO_2 emissions divided by the GDP of the respective country in a given year.

Main questions

- To what extent are countries decreasing the carbon content of each unit of value added produced?
- How has the emission intensity developed over time?

Data sources

For data on CO_2 emissions from fuel combustion, see indicator 3.9. Data on GDP is taken from the World Bank Database, which provides data for 218 countries between 1960 and 2018. As CO_2 data is reported in $MtCO_2$ this number is multiplied by 1,000,000,000 to get the $kgCO_2$ equivalent.

Indicator	Variables	Source
CO_2 emission intensity ($kgCO_2$ / USD)	Country CO_2 emissions from fuel combustion ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	Gross Domestic Product (USD, constant prices)	World Bank (World Development Indicators)

3.12 Manufacturing CO_2 emission as a share of total CO_2 emissions

Definition of the indicator

The indicator on the direct industrial CO_2 emissions provides information on how much the manufacturing sector contributes to the overall emissions of a country. The distinction is between direct and indirect industrial emissions. That is, emissions generated by the (direct) use of fossil fuels by industry to produce energy and the emissions generated (indirectly) by industry through the production of electricity that the sector consumes. See Box 5 for more on the concept of direct and indirect emissions.

Main questions

- How much of a country's total CO_2 emissions are due to industrial emissions?
- How important are indirect emissions in comparison to direct emissions?

Data sources

For data on CO_2 emissions from fuel combustion, see indicator 3.9. Data on manufacturing emissions are provided by the International Energy Agency (IEA). As the IEA reports data only for industry and construction together, the aggregated data for industry is calculated either by taking the sum of all manufacturing sub-industries, or by subtracting construction from the 'manufacturing industries and construction' variable. Data is reported for 144 countries for the time period of 1990 to 2016.

Indicator	Variables	Source
Direct Industrial CO_2 emissions as a share of total CO_2 emissions	Direct Industrial CO_2 emissions from fuel combustion ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	CO_2 emissions from fuel combustion ($MtCO_2$)	
Indirect Industrial CO_2 emissions as a share of total CO_2 emissions	Indirect Industrial CO_2 emissions from fuel combustion ($MtCO_2$)	
	CO_2 emissions from fuel combustion ($MtCO_2$)	

3.13 CO_2 emissions of manufacturing sub-sectors as a share of total manufacturing CO_2 emissions

Definition of the indicator

A country's direct industrial CO_2 emissions can be further broken down to the manufacturing sub-sector level. This indicator measures how much of the CO_2 emissions resulting from fuel combustion each sub-sector represents compared to the total manufacturing (direct) CO_2 emissions. The IEA provides data on manufacturing emissions on up to 10 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). In additional to the 10 sub-sectors, 'Non-specified' manufacturing emission groups all remaining emissions which are not attributed to any other sector (see section 5 for more details).

Table 1 presents the sub-sector code included in the IEA data and their ISIC Rev. 3 and ISIC Rev. 4 correspondence. The correspondence with ISIC sector groups is important as it allows us to match the emissions data with data sources which group data using the same classification, such as INDSTAT value added data.

Table 1. IEA manufacturing industries

IEA Industry Name	IEA Industry Code	ISIC Rev. 3 correspondence	ISIC Rev. 4 correspondence
Food and tobacco	FOODPRO	Divisions 15 to 16	Division 10 to 12
Textile and leather	TEXTILES	Divisions 17 to 19	Division 13 to 15
Wood and wood products	WOODPRO	Division 20	Division 16
Paper, pulp and printing	PAPERPRO	Divisions 21 and 22	Division 17 to 18

Chemicals and petrochemicals	CHEMICAL	Division 23 and 24	Division 20 to 21
Non-metallic minerals	NONMET	Division 26	Division 23
Iron and steel	IRONSTL	Division 27	Division 24
Non-ferrous metals	NONFERR		
Machinery	MACHINE	Divisions 28 to 32	Division 25 to 28
Transport equipment	TRANSEQ	Divisions 34 and 35	Division 29 to 30
Non-specified	INONSPEC	Any manufacturing industries not included separately	Any manufacturing industries not included separately

Main questions

- Which are the manufacturing sub-sectors contributing the most to CO_2 emissions in a country?
- How has the sub-sector composition of manufacturing CO_2 emissions changed over time?

Data sources

Data is provided by the International Energy Agency's CO_2 Emissions from Fuel Combustion Statistics dataset. Annual data is reported for 151 countries for the time period of 1960 to 2017 (1971-2016 for non-OECD countries).

Indicator	Variables	Source
Manufacturing sub-sector CO_2 emissions as a share of manufacturing emissions	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	CO_2 emission from fuel combustion of manufacturing ($MtCO_2$)	

3.14 Emission from coal as a share of manufacturing sub-sector emissions

Definition of the indicator

In order to obtain energy required for industrial production processes, different fuels are burned to release energy. The IEA provides detailed data on how much of emissions were generated from the burning of each type of fuel, providing details on emission generated from sources such as coal, oil and natural gas. Box 1 discusses how these figures are calculated in more detail. This indicator measures the proportion of emissions generated from the burning of coal representing total manufacturing emissions.

Main questions

- How much of a sub-sector's emissions are due to the use of coal as a fuel?
- How reliant is a sub-sector on coal?

Data sources

Data is provided by the International Energy Agency's CO_2 Emissions from Fuel Combustion Statistics dataset. Annual data is reported for 151 countries for the time period of 1960 to 2017 (1971-2016 for non-OECD countries).

Indicator	Variables	Source
Share of coal emissions in manufacturing by sub-sector	Coal CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	

3.15 Share of non-renewable energy sources in electricity generation

Definition of the indicator

Electricity can be produced by many energy sources and fuels that can be either renewable (such as hydro, solar, and wind) or non-renewable (such as coal, oil, and natural gas). This indicator measures the share of non-renewable energy sources used to produce electricity in a given country. The indicator captures a measure of how environmentally friendly the production of electricity is in a country and also reflects how much emissions are generated in the production of electricity. Since the manufacturing sector is a large consumer of electricity, the energy sources used to produce electricity are related to the emissions generated indirectly by the sector.

Main questions

- What share of electricity is generated using non-renewable energy sources?

Data sources

Data is provided by the International Energy Agency's Renewables Information Statistics dataset. Annual data is reported for 144 countries for the time period of 1990 to 2017.

Indicator	Variables	Source
Share of non-renewable energy sources in electricity	Electricity output generated from renewable energy sources (Ktoe)	International Energy Agency (Renewables Information Statistics)
	Electricity output (Ktoe)	

3.16 Emission intensity of manufacturing

Definition of the indicator

The emissions of the manufacturing sector or a specific sub-sector can be related to data on value added in order to illustrate how much economic value is being generated per unit of CO_2 emission. This indicator is defined as the manufacturing (sub-sector) CO_2 emissions from fuel combustion divided by the manufacturing (sub-sector) value added. It is the same concept of emission intensity introduced in indicator 3.11, but calculated either for a single manufacturing sub-sector or for an aggregate of all manufacturing, which provides an overview of the country's situation.

Main questions

- What is the emission intensity of a country's manufacturing sub-sectors and how do they compare to the emission intensity of manufacturing as whole in that country?
- How has the emission intensity of manufacturing sub-sectors developed over time?
- Is the emission intensity of certain sub-sectors below or above the benchmark of similar countries (or the world as a whole) and can improvement potentials thus be identified?

Data sources

Data on emission is provided by the International Energy Agency's CO_2 Emissions from Fuel Combustion Statistics dataset. Annual data is reported for 151 countries for the time period of 1960 to 2017 (1971-2016 for non-OECD countries). Manufacturing value added data is taken from the World Development Indicators for MVA or UNIDO's INDSTAT 2 database for a specific sub-sector. For this indicator, data from the two datasets needs to be matched and grouped into the same sub-sectors. As both datasets contain missing observations, a combined dataset of the two sources covers fewer countries / years (see section 5 for more details).

Indicator	Variables	Source
Emission intensity of the manufacturing sector ($kgCO_2$/USD)	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	Manufacturing Value added, by country (USD, constant prices)	World Bank (World Development Indicators)
Emission intensity of manufacturing (sub-) sectors ($kgCO_2$/USD)	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	Manufacturing Value added, by sub-sector and country (USD, current prices)	UNIDO's Industrial Statistics Databases (INDSTAT2)

3.17 Emission per unit of energy

Definition of the indicator

This indicator is calculated as a manufacturing sub-sector's CO_2 emission from fuel combustion divided by the sub-sector's total energy use. The total energy used includes both energy used from fossil fuels, as well as renewable energy sources. The emission intensity of the sub-sector will depend on which fuels are being used to generate that energy. For example, a sub-sector which relies heavily on energy generated from the use of coal as a fuel will likely have a higher emission intensity than another sub-sector which relies more on natural gas.

Main questions

- How do manufacturing sub-sectors compare in terms of their emission intensity, i.e. emissions per unit of consumed energy?
- Is the carbon intensity of energy for certain sub-sectors below or above the benchmark of similar countries (or the world as a whole)? Can we use these benchmarks to identify potentials for emission intensity reduction from fuel switching?

Data sources

Data on emission is provided by the International Energy Agency's CO_2 Emissions from Fuel Combustion Statistics and the World Energy Balance datasets. Annual data is reported for 151 countries for the time period of 1960 to 2017 (1971-2016 for non-OECD countries).

Indicator	Variables	Source
Emission intensity of energy of manufacturing (sub-) sector (kg CO_2 / toe)	CO_2 emission of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
	Total Final Energy Consumption (TFC) of manufacturing sub-sector (in Ktoe)	International Energy Agency (World Energy Balance)

3.18 Exports of climate-friendly goods as a share of total exports

Definition of the indicator

The World Bank[10] report 'International Trade and Climate Change' presents a list of 43 goods and technologies which contribute to lowering of CO_2 emissions. A similar group of environmentally friendly goods is currently being negotiated by the WTO, but is not agreed upon yet. To the best of our knowledge the World Bank list is therefore the best available definition of climate-friendly goods

[10]World Bank (2008). International Trade and Climate Change. World Bank Group, Washington D.C.

that exists today. Although the World Bank list is somewhat older, it is still being used as a reference by many scholars (for examples, see Sugathan (2013)[11] or Dinda (2019)[12]). The sum of these goods exported as a share of total goods exported is used to create a proxy indicator for how much a country is contributing to CO_2 mitigation by producing and subsequently exporting these goods. As it is assumed that the demand for these goods is likely to rise in the future, this can also be seen as a market opportunity that countries should consider expanding into.

Main questions

- How important is the production of climate-friendly goods in a country's manufacturing sector?
- How does the share of climate-friendly goods exports in total exports compare to other countries?

Data sources

UN Comtrade reports export data based on 6-digit HS codes. Using the HS codes (HS 2002 version) of climate-friendly goods (CFGs) it is possible to calculate the sum of climate-friendly goods exported by a given country. This can be taken as a share of total exports of the respective country. UN Comtrade reports data for HS 2002 codes for 151 countries for the time period of 2002 to 2016.

Indicator	Variables	Source
CFGs exports as a share of total exports	Country's Climate-friendly Goods (CFGs) exports (USD)	UN COMTRADE
	Country's total exports (USD)	

4 Analysis

This section illustrates how the indicators presented in section 3 can be used to assess and compare CO_2 emission contribution of countries, their drivers, and the product markets which emerge from mitigation and adaptation action. The analysis section contains two parts: part A discusses adaptation, while part B focuses on mitigation. The different indicators used in the analysis are used to answer questions related to manufacturing emissions and evaluate different dimensions of the link between climate change and industry.

Part A assesses the risks of climate change and the capacity to reduce or cope with climate change related damages. Adaptation is observed on the cross-sectoral and on the manufacturing level. The

[11]Dinda, S. (2019). Climate Friendly Goods and Technologies in Asia, Springer.

[12]Sugathan, M. (2013). List of Environmental Goods: An Overview. Information Note. International Centre for Trade and Sustainable Development.

extent of environmental hazards a country is facing is assessed by the Global Climate Risk Index. Manufacturing´s exposure and vulnerability towards climate change effects is represented by the indicators ‘Losses in manufacturing labour productivity’, ‘Value losses due to electrical outages’, and ‘Freshwater withdrawal for industry’. The indicators ‘Level of water stress’ and ‘GDP per capita’ are used to indicate a country´s economy wide vulnerability. The above mentioned indicators are used to provide an overview of climate change risks. Finally, the resilience and adaption capacity is addressed on both the cross-sectoral and manufacturing level by the ‘Labour productivity in manufacturing’ and the ‘Share of non-agricultural activities in GDP’.

Part B starts with a general overview of the selected countries’ contribution to global CO_2 emissions, before zooming in to manufacturing-specific emissions. Analysis of indicators on countries’ total emissions give the analyst an initial understanding of a country’s relative size of CO_2 emissions. In the next step, the focus shifts to analyse to what degree the manufacturing sector of each country is responsible for the respective country-level CO_2 emissions – as well as analysing how much different manufacturing sub-sectors are responsible. This first set of indicators is intended to be used by the analysist to familiarize themselves with the CO_2 data, to give an overview of CO_2 emissions, and to understand which activities are generating them. The second block explores the link between economic activity and emissions, discussing the efficiency with which value added generation produces emissions and benchmarking this across countries. The third block of the analysis section focus on the link between economic activity and emissions over time, both in terms of decomposing past emissions as well as analysing growth rates. By focusing on the time component the analysis can identify progress in decoupling emissions and value added generation, and also what is driving emissions change over a given period. Finally, the analysis focuses on country’s export of climate-friendly goods to show that mitigation can be seen as a business opportunity for countries.

Box 1. Emissions and Energy: How are they related?

From turning on a light bulb at home to turning on a machine in a factory, countries need energy for their economy to operate. To produce that energy, the world still relies heavily on fossil fuel sources. Of total energy consumed worldwide in 2015, about 82% was produced using non-renewable (fossil fuel) energy sources that result in net GHG emissions and further contribute to climate change.

Which fuels are being used to produce energy makes a difference in terms of the emissions generated. To produce the same amount of energy, different fuel sources can produce significantly different amounts of emissions. This emission to energy relation is called the Carbon Emission Factor. In Table 2 the Carbon Emission Factor captures how many kg of CO_2 are produced by the combustion of different fuel types to generate one gigajoule worth of energy. The Carbon Emission Factor can be significantly different from one fuel to another. Producing one gigajoule worth of energy from lignite coal, for example, will generate almost double the CO_2 emissions that producing a gigajoule of energy from natural gas would (27.6 versus 15.3 kg of CO_2). Because of these differences, fuel-switching to relatively cleaner fossil fuel sources can also be a contributor and driver of emission mitigation (see section 4B.4 for more on this). In the long-run, switching to renewable (net) carbon-neutral energy sources such as hydro, wind, solar and other sources will allow for further reducing emission and decoupling energy from emissions.

Table 2: Carbon Emission Factor of Energy Sources

Fuel Source	Fuel Source Sub-Type	Carbon Emission Factor (kgCO_2/gigajoule)
Coal, Peat, and Oil Shale	Oil Shale	29.1
	Peat	28.9
	Lignite	27.6
	Coking Coal	25.8
Oil	Diesel	20.2
	Crude Oil	20.0
	Gasoline	18.9 – 19.1
	Liquefied Petroleum Gas	17.2
Natural Gas	Natural Gas	15.3
Other	Non-Renewable Industrial Waste	39.0
	Non-Renewable Municipal Waste	25.0
Renewable	Biomass	0.0
	Hydro	0.0

Source: adapted from IEA (2018)[13].

Carbon emission factors also allow for transforming energy data into emission data. By multiplying the amount of energy used by the carbon emission factor corresponding to the fuel used to produce the energy it is possible to calculate how much CO_2 emission was generated by the production, or consumption, of energy (Figure 3).

Figure 3. How are emissions related to energy?

$$\boxed{\text{CO}_2 \text{ Emissions}} = \boxed{\text{Energy Use}} \times \boxed{\text{Carbon Emission Factor}}$$

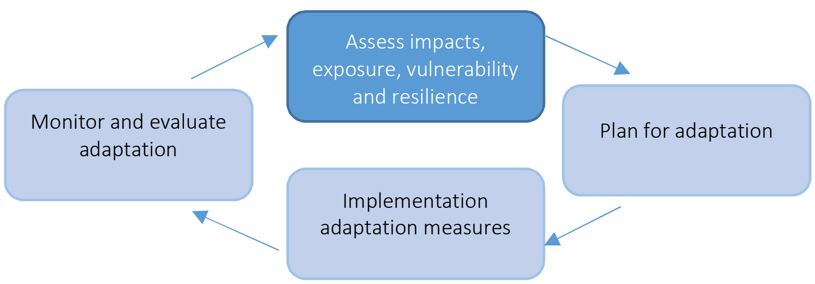
Carbon emission factors are what link energy use to the climate change impacts (emissions) of the use of that energy. EQuIP Tool 6.1 focuses on economies energy use. However, the focus on total energy consumed gives an incomplete picture in terms of how much that energy consumption is contributing to climate change. Since energy may be produced in different countries using a different mix of fuels, analysing both energy use and emissions generation produce complementary analysis.

4A Adaptation

4A.1 Conceptual framework: from natural hazards to resilience

As impacts of global warming already occur and are assumed to last for many years, the tool focuses on the adjustment to climate change impacts. The concept of adaptation deals with a country's ability to cope with changes in climate by focusing on resilience and capacity on the country level. It thereby represents a local response to a global problem and allows countries to react to negative climate change impacts. By providing a tool for countries to elaborate their adaptation strategies towards those risks, negative impacts on their economy and competitiveness can be minimized or diminished. The process of adaptation implies an ongoing cycle covering the steps of vulnerability and risk/opportunity assessment, adaptation plan, implementation measures, and monitoring and evaluation (Figure 4).

Figure 4. The Climate Change Adaptation Cycle



Source: Own graph based on UNFCCC.

As highlighted in Figure 4, the following analysis focuses on the assessment of exposure and vulnerability towards climate change risks and a country´s resilience and adaptive capacity. It also paves the way for planning and implementation measures if needed. The assessment is conducted according to a framework compiled by the European Commission, which enables the operationalization of the climate change adaptation concept. As seen in Table 3, the framework covers the main elements which measure the need for adaptation: natural hazards, exposure and vulnerability, and resilience and adaptive capacity.

[13]IEA (2018). CO_2 from Fuel Combustion: Database Documentation (2018 Edition). International Energy Agency. Available at: http://wds.iea.org/wds/pdf/WorldCO2_Documentation.pdf.

Table 3. Elements of the Climate Change Adaptation Framework

(1) Natural hazards	Natural hazards are flooding, storms, droughts, sea level rise and all the other hazards bringing risks with different impacts on economic, social and natural systems.
(2) Exposure and Vulnerability	Exposure refers to the inventory of elements in an area in which hazard events may occur (IPCC 2014).[14] Vulnerability refers to the propensity of exposed elements such as human beings, their livelihoods, and assets to suffer adverse effects when impacted by hazard events (IPCC 2014). It is possible to be exposed but not vulnerable (for example by living in a floodplain but having sufficient means to modify building structure and behaviour to mitigate potential loss). However, to be vulnerable to an extreme event, it is necessary to also be exposed.
(3) Resilience and Adaptive Capacity	Resilience is the ability of social, environmental and economic systems to cope, recover, and reconstruct with regard to climate change. Resilience can be increased by enhancing the strength of socio-economic systems, reducing the intensity of the impact of climate change, or both. Adaptive capacity considers various characteristics such as economic wealth, technology, information and skills referring to the stocks of human capital, Infrastructure, and Institutions. Strengthening capacity is expected to increase resilience and eventually lead to reduced risk. Capacity is also seen as the opposite of vulnerability, as an increase in capacity is supposed to reduce vulnerability.

Source: EC (2015)[15], IPCC (2012)[16]

The distinction of the different phases representing the adaptation framework is important from a policy perspective. Natural hazards and exposure represent exogenous components affecting

[14]Oppenheimer, M., M. Campos, R. Warren, J. Birkmann, G. Luber, B. O'Neill, and K. Takahashi (2014). Emergent risks and key vulnerabilities. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1039-1099.

[15] European Commission (2015). Climate resilience development index: theoretical framework, selection criteria and fit-for-purpose indicators.

[16] Cardona, O.D., M.K. van Aalst, J. Birkmann, M. Fordham, G. McGregor, R. Perez, R.S. Pulwarty, E.L.F. Schipper, and B.T. Sinh (2012). Determinants of risk: exposure and vulnerability. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 65-108.

economies of countries. Those natural hazards are typically natural phenomena that are caused by climate change to some extent (see World Bank Report 2019[17]). They are phenomena that policy makers need to monitor if there are circumstances they can predict but cannot be part of the policy plan. It is true that climate change does not always cause natural hazards. Exposure represents assets and economic activities which are affected when natural hazards occur. Impacts from climate change, as the literature finds, will be mostly concentrated in middle and low income countries. For instance, climate change related flood risks are predicted to be particularly high in China, India and Bangladesh.[18] Exposure captures the geographical/territorial dimension of risk. The reduction of exposure is not normally the core of the policy space. The elimination of the exposure to infrastructure damage caused by a typhoon would require the removal of the infrastructure from a specific area, which is quite difficult from a practical point of view. The reduction of vulnerability and the increase in resilience are typically the core of the policy agenda. The decrease of vulnerability has to do with a decrease in inequality determinants, poverty and many other variables affecting socio-economic status but also with a decrease in dependency of climate-sensitive resources. From this point of view, policy makers can work to reduce the intensity of impacts. As pointed out by IPCC (2014) 'Vulnerability reduction thus constitutes an important common ground between the two areas of policy and practice'. Overall, natural hazards, exposure and vulnerability are related to the risk of countries that are to be affected by climate change.

Resilience and adaptive capacity refer to the capacity of countries to cope, recover, or reconstruct after climate change damages. From a resilience perspective, policy makers can work to increase the capacity of countries to react to damages. Overall, decreasing vulnerability and strengthening resilience have to do with the capacity of a country to reduce the impacts of climate change or to cope with them.

This discussion lets the reader understand that the issue of adaptation is cross sectorial by nature. It encompasses different areas of development and different economic sectors. However, as shown by the literature, the ability of countries to grow in many cases depend on their capacity to industrialize.[19] If industry is so pivotal for the development agenda, the question is how to preserve industry from climate change damages through adaptation and how industry can serve the purpose of increasing the resilience of countries and companies (see Figure 5).

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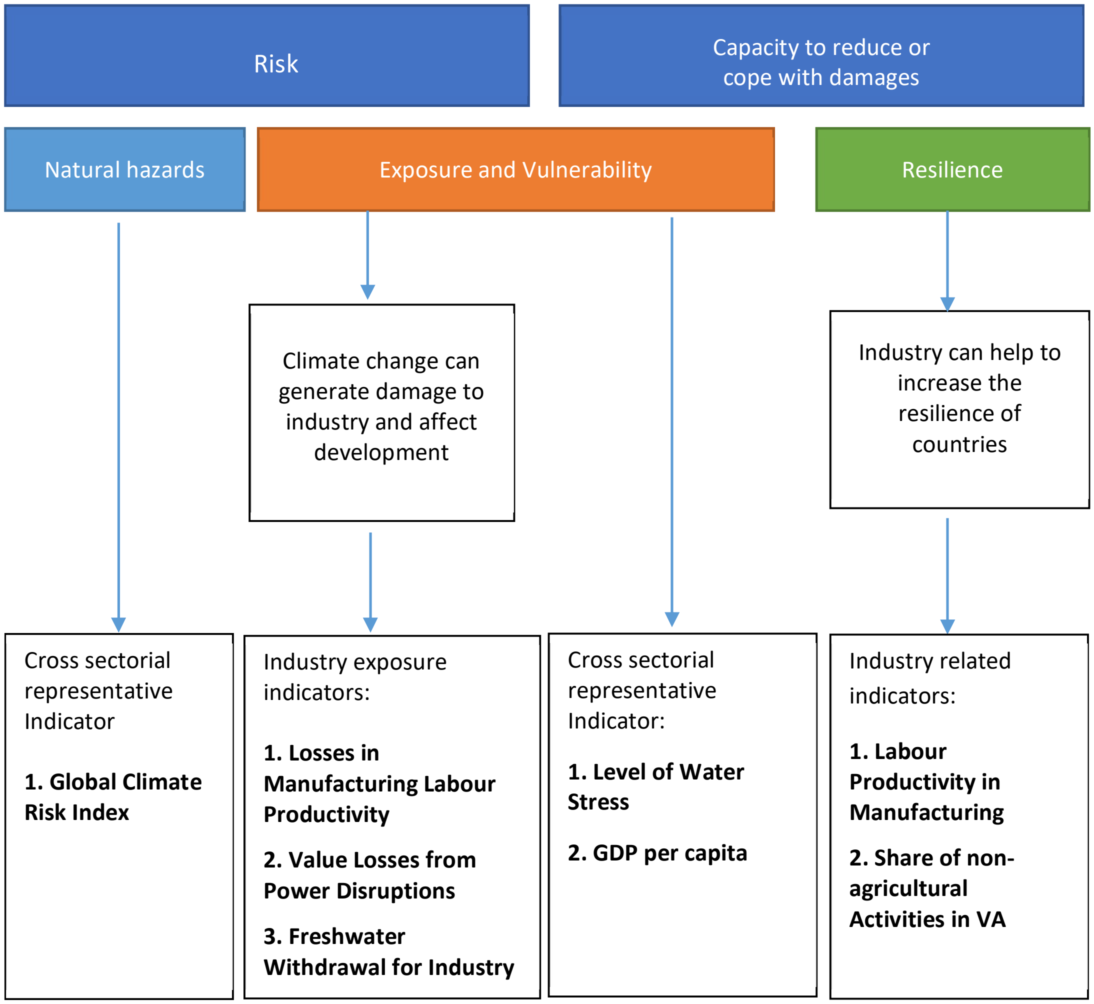
[17]Hallegatte, S., Rentschler, J., Rozenberg, J. (2019). Lifelines. The Resilient Infrastructure Opportunity. Sustainable Infrastructure Series. World Bank Group.

[18]OECD (2015). The Economic Consequences of Climate Change, OECD Publishing, Paris. http://dx.doi.org/10.1787/9789264235410-en.

[19]Kniivilä, M. (2007). Industrial development and economic growth: Implications for poverty reduction and income inequality. In book: Industrial Development for the 21st Century: Sustainable Development Perspectives. Chapter: 3.1 Publisher: United Nations, Department of Social and Economic Affairs. New York, USA.

Figure 5. Industry and the Adaptation Framework



The reader can find an exhaustive list of indicators concerning the adaptation framework in the European Commission Report[20]. The original contribution of the present module is to provide a short zoom in on manufacturing related aspects. The current module proposes manufacturing related indicators which refer to vulnerability and resilience where the role of the manufacturing sector is more distinguishable and clearer. Three indicators specifically measure inputs availability in the manufacturing production process. Labour Productivity losses of the manufacturing sector based on climate change, value losses due to power disruptions in manufacturing and services firms on the basis of data from the World Bank Enterprise Survey and industry water withdrawals represent threats of climate change to labour, energy and water inputs. There is not available data capturing losses from power disruptions specifically for manufacturing, but information is indicative to understand to what extent manufacturing could be exposed to climate change related natural hazards. Next to 'Labour

[20]European Commission (2015). Climate resilience development index: theoretical framework, selection criteria and fit-for-purpose indicators.

productivity in manufacturing', the 'Share of manufacturing and services in GDP' is selected as a resilience indicator as the development of countries and the dependence on non-agricultural vulnerable sectors rely on the size of the service sector. Three cross-sectoral indicators are selected as representative of the natural hazards and vulnerability tiers of the adaptation framework. These are based on the Global Climate Risk Index, the 'Level of water stress', and the 'GDP per capita'. Even though they are not strictly manufacturing related, from a policy analysis perspective, they can be very useful when compared with manufacturing related indicators concerning exposure, vulnerability or resilience. High cross sectoral vulnerability or low cross sectorial resilience can contribute to amplify climate change risks for the manufacturing sector.

Each of the diagrams proposed in the following sections should be considered as illustrative of the possible diagrams which are not discussed in the tool but which can be produced by using different combinations of the proposed indicators. A selection of diagrams is presented in the following section as orientation for the analyst.

Box 2 Potential variations in the analysis

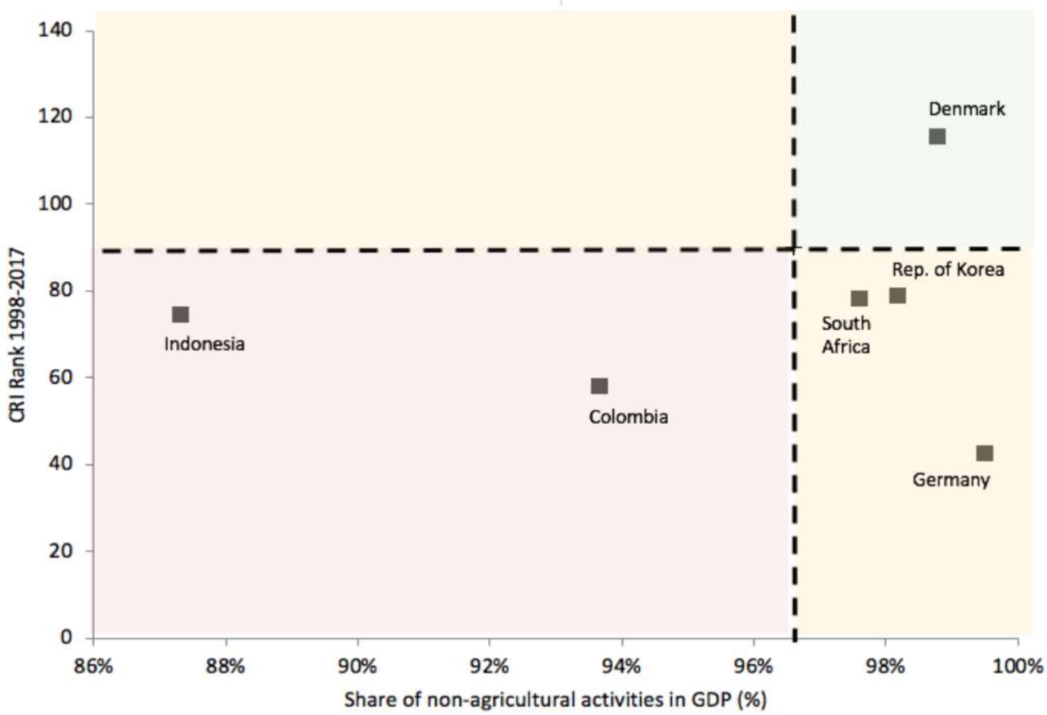
In this module, examples are provided on how to address and analyse climate change mitigation and adaptation needs. It should be considered that a number of variations of this analysis are possible; the figures can have different typologies and styles but also the compilation of the indicators can vary.

The Climate Risk Index (CRI), for example is analyzed together with the share of manufacturing activities in GDP. Another option would be to combine the CRI with the indicator 'Value loss due to electrical outages'. By this option, the relation between a country´s exposure to climate change and the vulnerability of the industry sector would be observed. Similarly, the combination of CRI with 'Freshwater withdrawal for industry' or 'Losses in Manufacturing Labour Productivity' can provide further interesting information covering the dimensions exposure and vulnerability of countries in terms of their availability of production process inputs .

4A.2 Exposure to climate change and manufacturing related resilience

Although EQuIP is concerned about manufacturing specific analyses at the sub-sector level, it is conducted an assessment on climate change exposure by comparing a country´s risk of extreme weather against the share of non-agricultural activities in GDP (Figure 6). The Global Climate Risk Index (CRI) quantifies the effects of extreme weather events for a 20-year period 1998-2017, both in terms of fatalities and economic losses. The countries ranking highest (i.e. lower CRI score) are the ones most impacted, or, in other words, those which are exposed to a greater degree to the consequences of climate change related extreme weather events. As the agricultural sector is considered the most affected sector by climate change, the share of non-agricultural activity in GDP is used to represent a country ́s resilience to extreme weather events.

Figure 6. Exposure to climate change and manufacturing related resilience



Source: Eckstein et al. (2019)[21] and World Bank WDI (2017).
Note: Dotted lines represent the world average for the indicators on each axis.

Figure 6 represents climate change exposure and climate change resilience to assess a countrý s overall adaptation need. The horizontal axis shows the share of non-agricultural activities in GDP for the year 2017, while the vertical axis presents the CRI rank for the period 1998-2017. The world averages of both indicators (dotted lines) divide the graph into the four areas: low risk area (green), medium risk area (yellow) and high risk area (red). The high risk area indicates a high share of agricultural activities and a low ranking on the Global Risk Index. Countries located in this area, in contrast to the low risk area, tend to be less resilient towards extreme weather events and were relatively highly affected by natural hazards within the period of 1998 to 2017. Countries in the medium risk area, however, are either highly dependent on agricultural activities but face low risks of extreme weather events, or face risks of extreme weather events but have a more resilient economic structure. Looking at the sample countries we can see that countries such as Indonesia and Colombia have a relatively high share of agricultural activities in GDP, indicating a lower resilience of these countries towards extreme weather events. Both countries are also located below the world average on the CRI ranking, showing a high risk towards extreme weather events. Facing high risks of extreme weather events while being dependent on agricultural activities is the reason why these countries are located in the (red) high risk area for demonstrating high vulnerability, and therefore, have a particular need for climate change adaptation. Countries that rely relatively little on agricultural activities in GDP

[21] Eckstein D., Hutfils M., and Winges M. (2019). Global Climate Risk Index 2019. Briefing Paper. Germanwatch, Bonn.

are located on the right side of this graph, showing a medium or low exposure to climate change risks. While Denmark has relatively little exposure to climate change, Republic of Korea, South Africa and Germany are in the medium risk area. These countries have a high risk of fatalities and economic losses due to extreme weather events, but are expected to act resiliently based on their high share of non-agricultural activities in GDP.

In this graph adaptation measures are urgent to a different degree among countries as their economies are differently exposed and resilient towards extreme weather events. Particularly exposed towards environmental hazards are those countries that rely on agricultural activities and face extreme weather events at the same time.

4A.3 Manufacturing related risk of exposure and manufacturing related resilience

Climate change is predicted to induce risks for manufacturing sectors worldwide; it destabilizes not only a country´s manufacturing process and its competitiveness, but also builds up a risk for global supply chains. Adaptation activities of manufacturing sectors towards climate change can therefore play a crucial role. The analysis in the following is based on two different roles of the manufacturing sector vis a vis adaptation. First, the development of the manufacturing sector can be seen as a driver of resilience to cope with extreme weather events affecting a country´s economy. Second, the manufacturing sector will particularly be affected in those countries that currently demonstrate low productivity levels. Thus, the choice of indicators covering these two roles also needs to reflect socio-economic disparities, as adaptation is of particular importance for developing countries that are predicted to face the highest impact of global warming.

The following assessment observes the effect of rising temperatures on the manufacturing sectors in order to capture their exposure regarding global warming. In particular it is observed the risk of the manufacturing sector towards climate change in terms of labour productivity. Heat affects national output through its impact on the ability to work, which results in labour productivity loss through this impact´s output. [22][23] The framework that is used here has been developed by Roson and Sartori (2016)[24] to measure the exposure of different manufacturing sectors. It compares the expected impact of different increasing temperature scenarios on the manufacturing labour productivity (for the latest year available, it is used here to present competitiveness and resilience). Based on a climate change integrated assessment model, predictions about labour productivity losses are provided for global

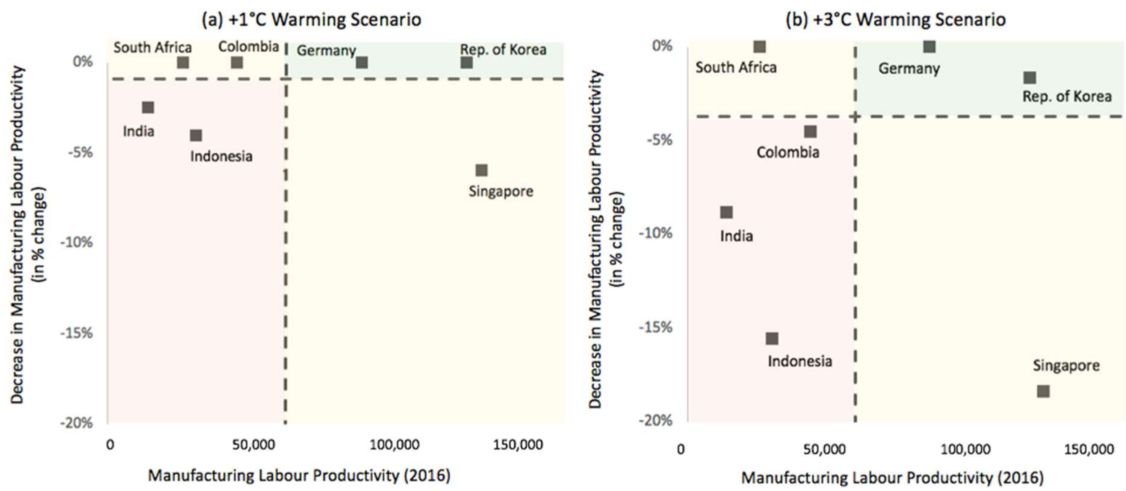
[22]Day E., Fankhauser S., Kingsmill N., Costa H., and Mavrogianni A. (2019). Upholding labour productivity under climate change: an assessment of adaptation options, Climate Policy, 19:3, 367-385, DOI: 10.1080/14693062.2018.1517640.

[23]ILO (2019). Working on a warmer planet. The impact of heat stress on labour productivity and decent work. International Labour Office – Geneva.

[24]Roson R., and Sartori M. (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Database. Journal of Global Economic Analysis 1, no. 2: 78–115, https://doi.org/10.21642/JGEA.010202AF.

warming scenarios of +1°C and +3°C. As building scenarios are based on various assumptions projecting about future evolution of social, economic and environmental variables, the following analysis differs from the rest of the indicators presented in the analysis section.

Figure 7. Climate change effects on manufacturing labour productivity



Source: Own graph based on Roson and Sartori[25] and UNIDO Statistics Database (manufacturing labour productivity in US$).
Note: Dotted lines represent the world average for the indicators on each axis.

Figure 7 illustrates the effect of climate change on a country's manufacturing labour productivity within two global warming scenarios. The horizontal axis shows the labour productivity in absolute numbers, which represents the competitiveness of the manufacturing sector as a proxy of resilience. The vertical axis shows the impact on manufacturing labour productivity in percentage change under different modelling scenarios. A decrease in manufacturing labour productivity (vertical axis ranging between 0% and -20%) indicates an increasing climate change effect on a country's manufacturing labour productivity.

Two global warming scenarios are illustrated, a +1°C warming scenario on the left (a) and a +3°C warming scenario on the right (b). Here again, the global averages of both indicators are used to facilitate the benchmarking of countries and to divide each of the two graphs into four areas indicating a high, medium and low risk of manufacturing towards climate change impacts. Within the +1°C scenario, the manufacturing labour productivities of India and Indonesia are below the global average. At the same time, heat stress is predicted to have a relative high impact on their work ability. Thus, with a global warming of +1°C, both countries´ manufacturing labour productivity is assumed to decrease due to climate change related heat stress. Although global warming also impacts the manufacturing labour productivity of Singapore relatively strongly, the performance conditions of its manufacturing sector are assumed to be more resilient. Being located in the low risk area, Germany

[25] Roson R., and Sartori M. (2016). Estimation of Climate Change Damage Functions for 140 Regions in the GTAP 9 Database. Journal of Global Economic Analysis 1, no. 2: 78–115, https://doi.org/10.21642/JGEA.010202AF.

and the Republic of Korea show manufacturing labour productivities above the global average and a resilient work ability towards heat stress as well.

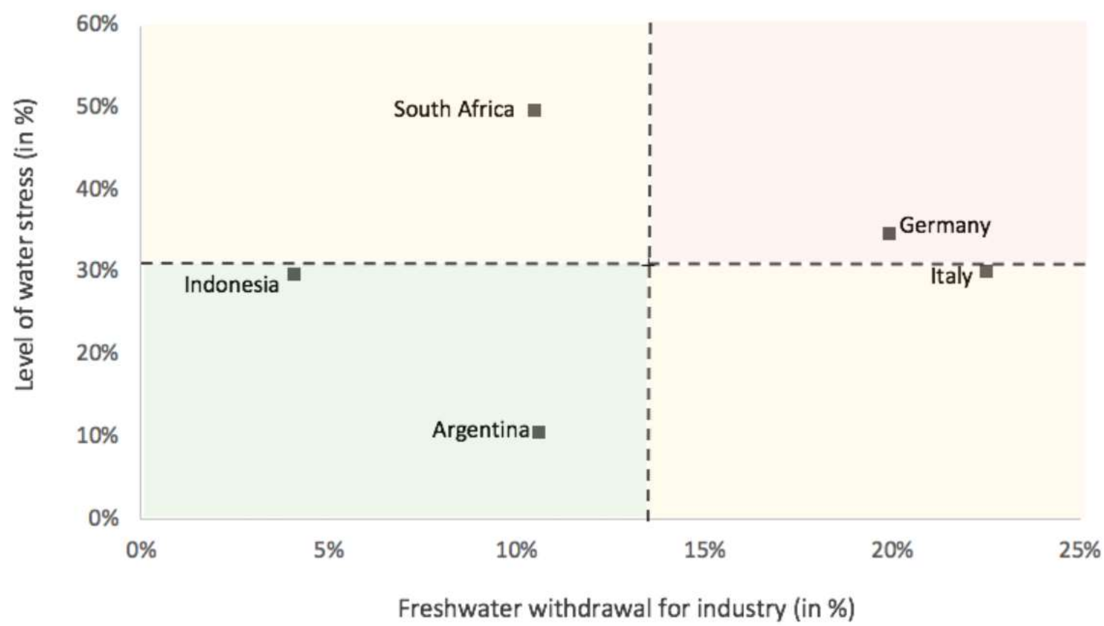
Within the +3°C global warming scenario, almost all example countries are predicted to remain on the same quadrants as in the +1°C scenario. Colombia, however, drops from the medium risk to the high risk area as heat stress within the +3°C scenario causes a higher risk to its working ability then within the +1°C scenario. Furthermore, it can be noted that the manufacturing sectors of those countries that were already under high risk are assumed to be affected stronger in the +3°C scenario. The heat stress caused by +1°C warming decreases the working ability in Indonesia by 5% and already by more than 15% if global warming reaches +3°C. The manufacturing labour productivities of Germany and the Republic of Korea, already little affected by a warming of +1°C, remain under low risk when the average global temperature increases by 3°C.

Although scenarios come with uncertainties, manufacturing sectors with technological progress and high labour productivity levels (representing competitiveness) are more resilient to negative impacts of future global warming. This accounts especially for countries with a highly resilient manufacturing sector such as in Germany or the Republic of Korea. At the same time, less resilient manufacturing sectors, including those of Indonesia or Colombia, are predicted to be increasingly affected by ongoing warming temperatures, indicating a higher need for adaptation.

4A.4 Manufacturing related exposure and countries´ water stress level

Industrial activities rely on natural resources. Some of these resources are limited or difficult to access, which is expected to become more crucial with regard to increasing temperatures due to global warming. One example is water scarcity caused by droughts or extreme weather events. The following figure shows the countries´ water stress level as a share of total renewable freshwater resources and the share of freshwater withdrawal for industry in particular.

Figure 8. Countries´ water stress level and industries´ exposure towards climate change



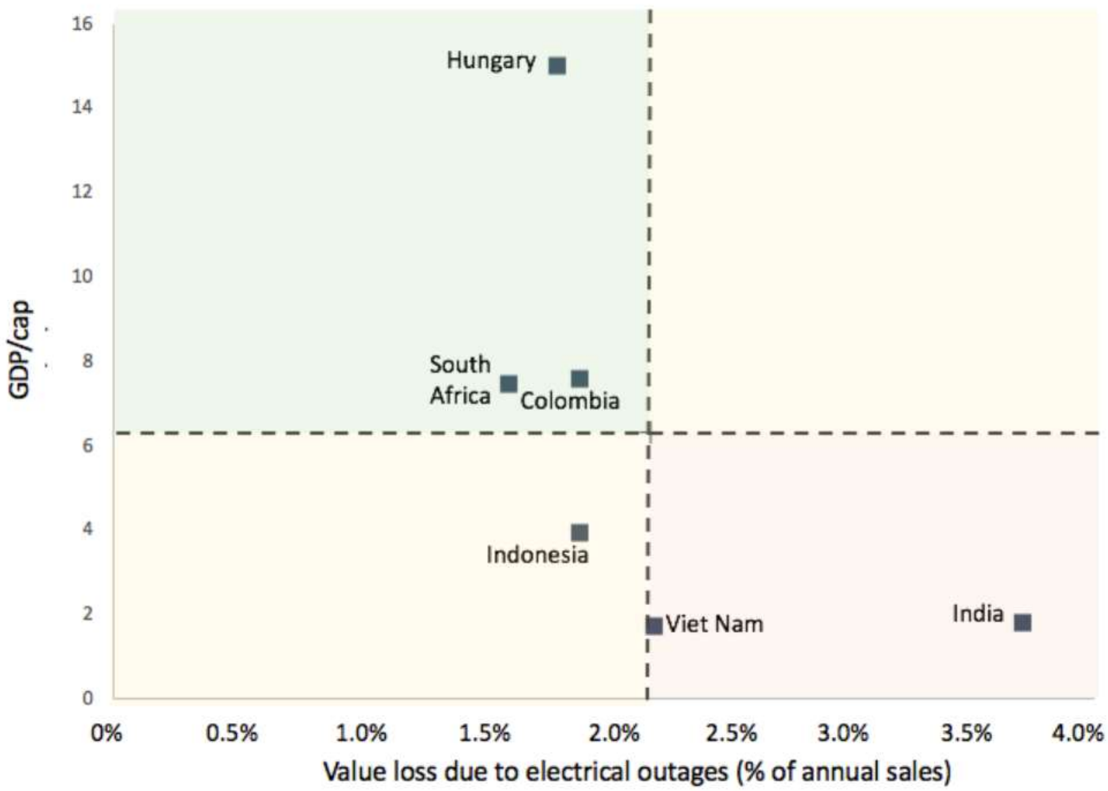
Source: World Bank WDI and FAO.
Note: Dotted lines indicate the average of both indicators based on selected countries. Data refers to the most recent available data over the period 2012 – 2017.

Figure 8 shows on the horizontal axis the annual freshwater withdrawal for industries and the level of water stress on the vertical axis. All countries withdraw less than 25% of the country´s total freshwater withdrawal for industrial activities. Italy is the country with the highest freshwater withdrawal for its industry while exhausting about 30% of its renewable water resources. This dependency explains why Germany is located in the high risk area. The level of water stress varies highly among countries. Argentina withdraws about 10% of the renewable freshwater sources, while South Africa and Germany withdraw around 50% and 35%. Due to their intensive use of freshwater sources but relatively lower water requirements of their industry, countries such as the South Africa and Indonesia are located in middle risk area showing high vulnerability but low exposure of its industry towards climate change related water risks. Argentina, using little shares of their water sources, is under low risk when it comes to water related issues. Italy is the country showing the highest percentage of water use for industrial uses, but the risk of water shortage is moderated by a relatively below the average water stress.

4A.5 Manufacturing related exposure and countries´ vulnerability towards climate change

Environmental hazards caused by climate change can lead to value losses in many ways. Next to decreasing labour productivity, the resilience of the infrastructure in which the manufacturing sector is located can play a crucial role and accelerate negative impacts. Electricity outages caused by extreme weather events, for instance, can leave production capacities unused and cause utilization losses. Extreme events are often related to climate change. In the following, it is presented manufacturing sectors´ exposure towards climate change risks by looking at monetary losses due to electrical outages (Figure 9. This information is based on the World Bank Enterprise Survey, in which firms reported their average losses due to electrical outages as a share of their total annual sales. This data, aggregated on the national level, is provided by the World Bank. A country´s overall vulnerability to climate change is presented by the GDP per capita. It measures the capacity to cope to external environmental risks, which is expected to be lower in countries with a relatively low GDP level.

Figure 9. Climate Change vulnerability and monetary losses in manufacturing due to energy disruptions



Source: World Bank WDI. Data refers to 2016 for GDP per capita (thousands USD 2010 constant price) and to the most recent available data for value loss due to electrical outages since 2013.
Note: Dotted lines indicate the average of both indicators based on selected countries.

Figure 9 illustrates the effect of climate change on monetary losses in manufacturing. The horizontal axis shows the value loss of firms due to electrical outages as percentage of their annual average sales, indicating the exposure of manufacturing towards climate change risks in terms of electricity availability which is a key element of the production process. The vertical axis shows the GDP per capita representing the vulnerability of countries towards climate change impacts. The higher the percentage of annual value losses but the lower the GDP per capita, the higher are economies and manufacturing sectors exposed and vulnerable towards climate change impacts. Countries in this situation are located in the high risk area shown in red. Among the country samples, the firms in India and Viet Nam report value losses of more than 2% due to electrical outages and are relatively high exposed towards extreme weather events. Due to their relatively low GDP per capita, they are located in the high risk area. Countries located in the bottom left area show a relatively low GDP per capita but also relatively low value losses due to electrical outages. This is the case of Indonesia in the selected sample. Despite their relatively high vulnerability, firms in these countries are little exposed to value losses due to electrical outages. Hungary in particular and South Africa and Colombia show the lowest risk to climate change effects among these country examples as countries are characterized by value losses from power disruptions below the average and a relatively lower vulnerability as their higher GDP per capita.

Adaptation to climate change and the identification of its needs forms a challenging task. It is urgent particularly for manufacturing sectors that are exposed, but also for those with low resilience towards climate change impacts. Manufacturing sectors of developing countries are more likely to be exposed to global warming threats, they are more vulnerable, and they are less resilient towards climate change risks. The discourse on adaptation needs to take place especially in those countries. Next to direct impacts of extreme weather events, manufacturing sectors deal with indirect stressors in the form of decreasing labour productivity or with infrastructure disruptions. In order to tackle threats and enable adaptation, more indicators would be helpful for reflecting and measuring manufacturing related climate change impacts while considering socio-economic indicators. This is required in order to ensure industrial development in highly affected countries. Potential indicators could, for example, be ‘Reduced work productivity due to heat stress’, financial losses of businesses due to extreme weather events’. Although data for such indicators are missing, their accessibility could enable a comprehensive risk assessment of countries´ manufacturing sectors, allowing adaptation planning and implementing as a next step. Also, climate change related indices such as the Notre Dame Global Adaptation Index (see Box 3) could be applied to gain further information.

Box 3 Potential indicator for the Climate Change Adaptation analysis

The Notre Dame Global Adaptation Index

The Notre Dame Global Adaptation Index is an additional indicator that can be considered for this analysis. It measures the two dimensions of adaptation; vulnerability and readiness. The vulnerability dimension in this index is conducted by the indicators exposure, sensitivity, and capacity, while each indicator covers the life-supporting sectors of food, water, health, ecosystem service, human habit, and infrastructure. Within this index the focus is on the sensitivity indicator. As it is concerned about socio-economic elements of weakness, it is equivalent to our understanding of vulnerability and ensures the separate observation of exposure and vulnerability. The sensitivity indicator is measured through a dependency assessment of the six climate-sensitive sectors and each sector´s sensitivity is represented by two variables. In the case of infrastructure, for example, the sensitivity indicator assesses the dependency of imported energy and the percentage of population that lives 5 meters under sea level. The sensitivity of the ecosystem service, meanwhile, is measured by the dependency on natural capital and the ecological footprint. The final sensitivity score results through the mean value of all sectors.

Data source

The Notre Dame Global Adaptation Index (ND-GAIN) is a free open-source index that measures a country's current vulnerability to climate related disruptions and its readiness to leverage investments for adaptive actions. It covers 192 countries from 1995 to present.

4B Mitigation

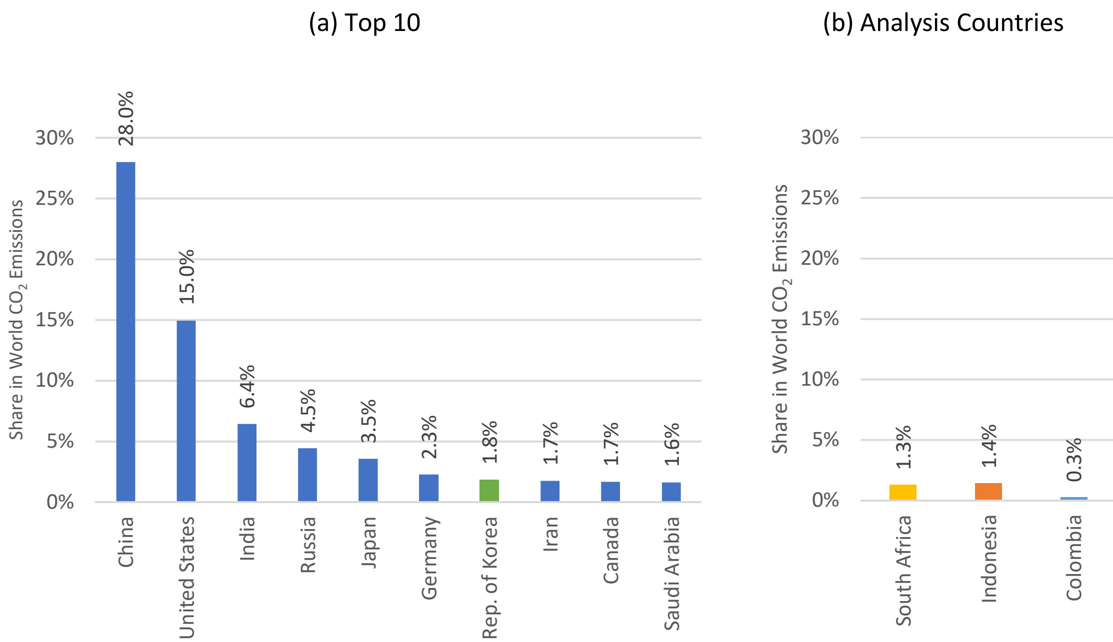
4B.1 Country overview: contribution to world CO_2 emissions

The world's countries emit vastly different amounts of carbon dioxide into the atmosphere. Before discussing manufacturing emissions and emission mitigation, it is important to first understand how any given country contributes to total world CO_2 emissions. The section starts with an overview of how a country's emissions compare to that of other countries in terms of absolute emissions.

To illustrate how the indicators can be used for analysis and benchmarking, this section uses four example countries for which data is presented: Indonesia, the Republic of Korea, Colombia, and South Africa. These countries are at different income levels, from different global regions, that vary of population size, and their stage of industrial development. Benchmarking their performance and progress against each other highlights the differences in the trajectories of these countries.

Figure 10 presents countries' individual CO_2 emission represented of global CO_2 emissions in 2016. Panel (a) shows the top 10 countries contributing to emissions worldwide. What is immediately clear is that a small number of countries contribute a large share of world CO_2 emissions: the top 10 emitters alone accounted for 67% of world CO_2 emissions. Among our selected example countries for the analysis, in 2016 the Republic of Korea was the world's 7th largest emitter. Another two were among the top 20 world emitters; Indonesia was 11th and South Africa was 14th. Colombia, which accounts for 0.3% of world emissions, was the world's 45th largest emitter for that year.

Figure 10. Selected countries' shares in world CO_2 emissions, in 2016

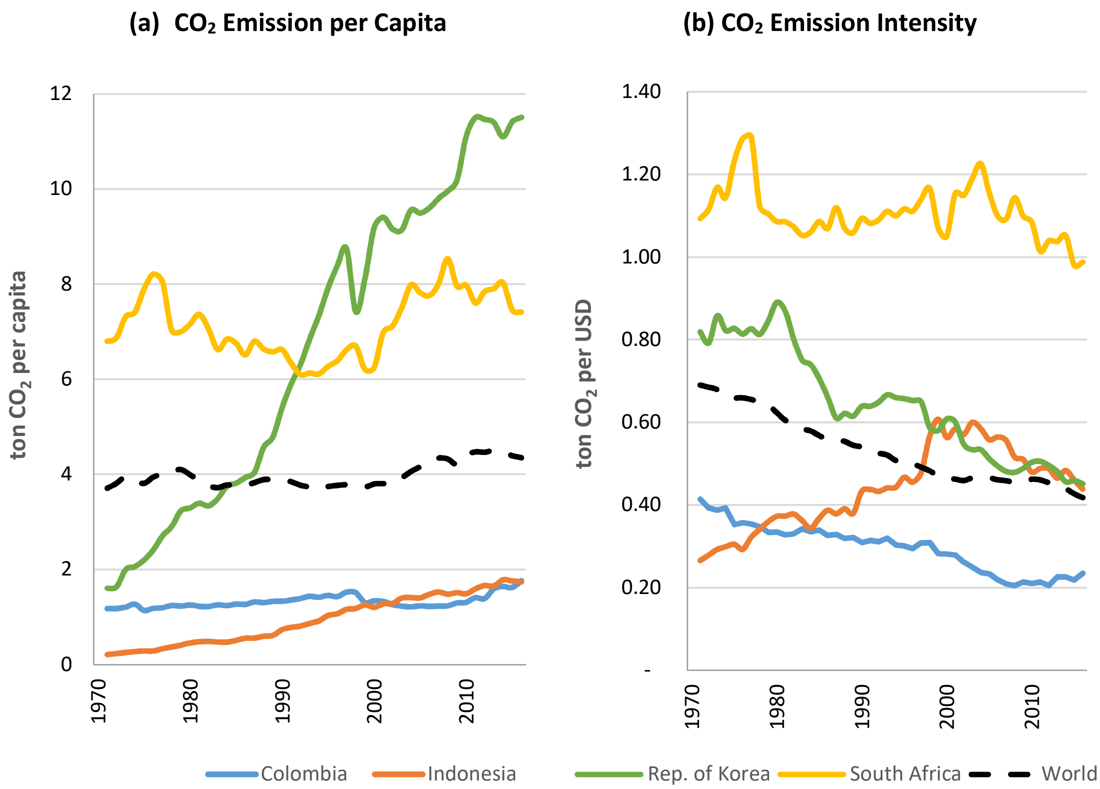


Source: IEA CO_2 Emissions from Fuel Combustion Statistics.

Figure 10 gives a first look of how large a country's emissions are compared to those of other countries and also shows how concentrated emissions are in a smaller group of countries. At the same time, this indicator cannot capture any of the other differences that exist among countries. India, for example, can be expected to have larger emissions than South Africa simply due to the fact that India's population is about 23 times larger than that of South Africa. A larger population and a larger economy are linked to a country's emissions. It is possible to account for these differences by including them in the indicators and by analysing and comparing emissions per capita and emission intensity.

Figure 11 presents each of these two indicators (emission per capita and emission intensity) of our analysis countries between 1970 and 2016. Emissions measured in per capita terms allow for comparing countries with very different population sizes such as Colombia (48 million inhabitants) and Indonesia (261 million inhabitants), which had very similar emissions per capita in 2016 despite Indonesia's share in world emissions being almost five-times larger than that of Colombia (Figure 11a). The world average per capita emissions can also be used as a benchmark for identifying the *high* and the *low emitters.* Looking over the 1970-2016 period, it is also possible to clearly identify a difference in trends between the Republic of Korea – which increase its emissions per capita six-fold over the period – and Indonesia (eight-time increase) compared to South Africa and Colombia which remained relatively similar.

Figure 11. Selected countries' CO_2 emissions per capita and CO_2 emission intensity from 1970-2016



Source: IEA CO_2 Emissions from Fuel Combustion Statistics and World Bank WDI.
Note: CO_2 emission intensity is calculated using GDP at USD constant prices.

In the same way, emissions can also be scaled taking the economy's size into consideration to measure the emissions intensity of a country. Two economies of similar size, measured by income per capita (GDP per capita), and emissions per capita such as Colombia and South Africa may be significantly different in terms of their emission intensity (Figure 11b). These differences emerge from how the economy operates in terms of energy sources used, production technology, rate at which economic activity is expanding and other factors. It is important for the emission intensity of economies to reduce for progress to be made toward more climate-friendly growth, but in terms of emissions mitigation, only analysing emission intensity also does not capture the entire picture, since total emissions can continue to rise while the emission intensity reduces. Comparing individual country's emission per capita or intensity to the world average (or the average for that country's income group) also allows for benchmarking a country to other countries with similar characteristics.

Box 4. CO_2 Emissions Embodied in Trade

The CO_2 emissions analysed in this module are all production-based measures of CO_2 emissions. That is, the indicators presented measure the CO_2 emissions generated by the production (output) of each country, sector or sub-sector. It captures how much emission were generated to produce goods. Consumption-based CO_2 emissions on the other hand, measure how much emissions are contained in any consumed goods. Because of international trade, a good may be produced in one country (which generates emissions to produce it) but consumed in another. From a global perspective, *who is responsible for these emissions?* The consumer or the producer? Many studies have pointed out that developing countries are larger emitters when their emissions are measured using production-based measures, as in many cases a large share of their CO_2 emissions result from the production of goods that are then exported for the consumption in advanced economies. By off-shoring their production and manufacturing activities to other countries, advanced countries have been able to reduce their (production-based) emission and import goods from abroad – essentially outsourcing the emission generation itself.

Nonetheless, the analysis section of this tool focused only on production-based CO_2 emissions for a number of reasons. Firstly, the EQuIP toolbox is concerned about industrial output and the performance of the manufacturing sector. While discussing where consumption of that production takes place is relevant, it is not directly related to mitigation efforts which need to occur to reduce emissions generated in the production process. Secondly, consumption-based CO_2 measures are constructed by combining CO_2 emissions data with the inter-country input-output (ICIO) models which are used to trace back emissions generated by the consumption of goods. Due to insufficient data, a number of assumptions are made in the ICIO model to create the consumption-based measures which are not made when dealing with production based data. Interested analysts can refer to the OECD's *Trade in embodied* CO_2 and the database documentation for an overview of how consumption and production measures are calculated.

4B.2 Manufacturing Emissions

The first section of the analysis introduced the overall CO_2 emissions as well as the emission intensity of a country. In order to gain a better understanding of how the manufacturing industry, and specifically the different sectors within the manufacturing industry, are responsible the analysis provide disaggregated information on the ISIC 2-digit level[26].

4B2.1The importance of manufacturing emissions

Manufacturing contributes substantially to total emissions. However, the manufacturing sector's emissions are likely to be even higher if it is taken into consideration the emissions from electricity consumption. In 2016, about 40% of electricity generated worldwide was consumed by manufacturing industries[27]. Figure 12 gives an indication of this difference, as it includes indirect emissions from

[26]As the IEA does not use ISIC classification, some of the groups are pooled together.

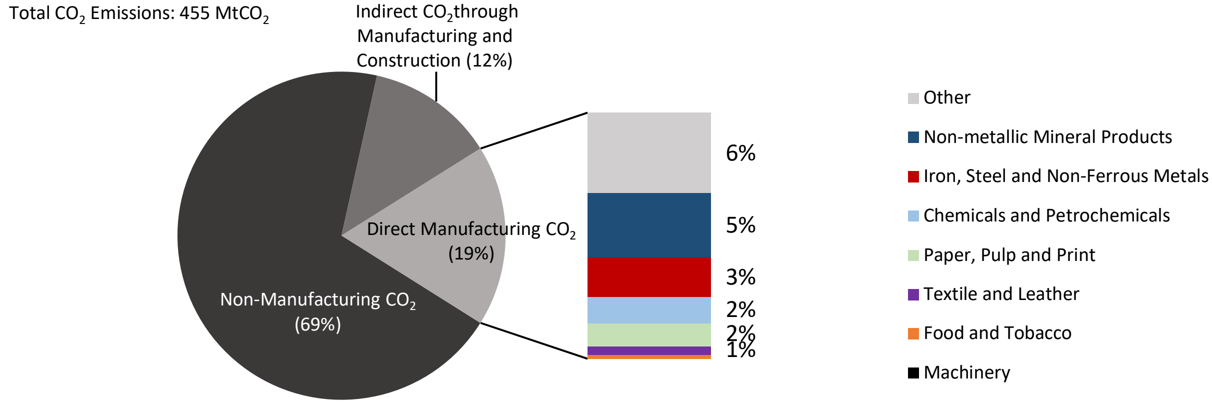
[27] This is a UNIDO elaboration based on IEA data (IEA World Energy and Statistics Balances)

manufacturing and construction. Indirect emissions can unfortunately not be broken apart into the different subsections (see Box 5 for further information on this).

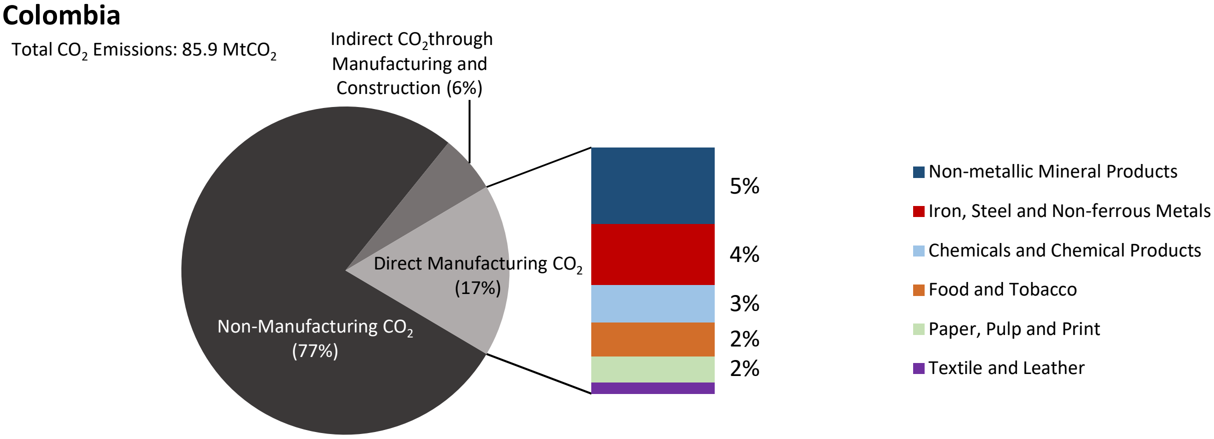
Figure 12 displays the CO_2 emissions composition for selected economies in the year 2016. The contribution of the manufacturing sector to total CO_2 emissions is relatively similar between the four example countries. In each of the four countries the manufacturing direct emissions account for 11 to 20 percent of overall emissions, and thus lies below the world average. However, the weighting of the different sub-sectors differs considerably between the four countries. The bar chart next to the pie chart shows the emission contributions from each sub-sector. Note that the percentage point next to each sector represents the percentage of the respective sub-sector in the overall, economy-wide, emissions, not just within manufacturing emissions. As expected, the iron, steel and non-ferrous metals sector as well as non-metallic mineral products are the sectors that contribute most to CO_2 emissions in most of the four countries, followed by chemical and chemical products. Note that manufacturing CO_2 emissions that are not allocated to a specific manufacturing sub-sector in the IEA data have been allocated to ‘other’ (see section 5, Suggestions for data Analysis for more information on this).

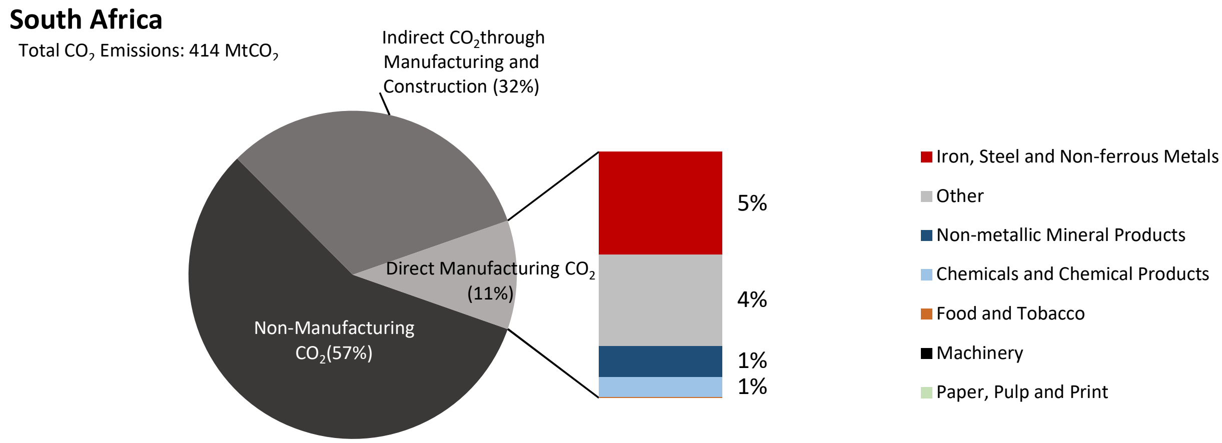
Figure 12. Manufacturing CO_2 Emissions

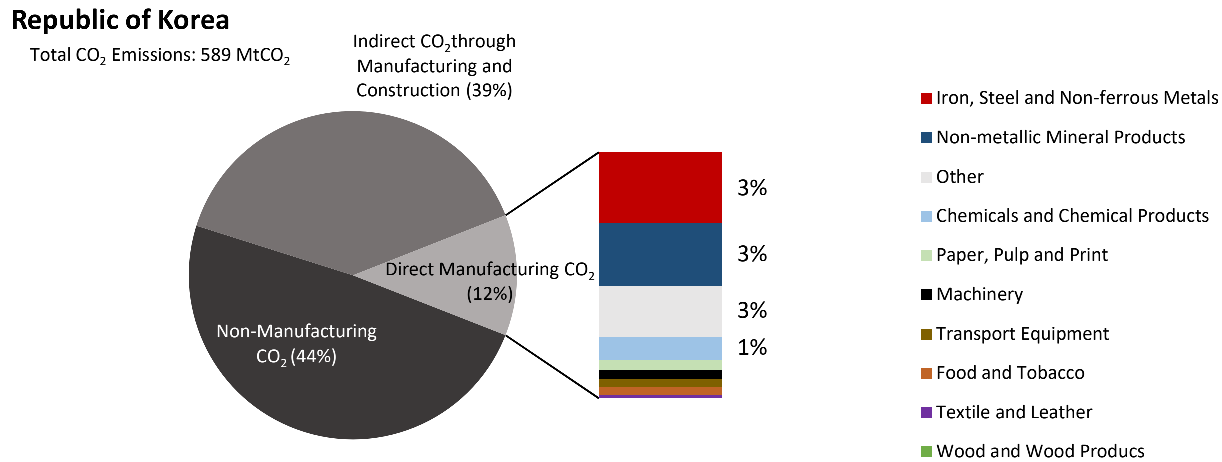
Indonesia



Colombia





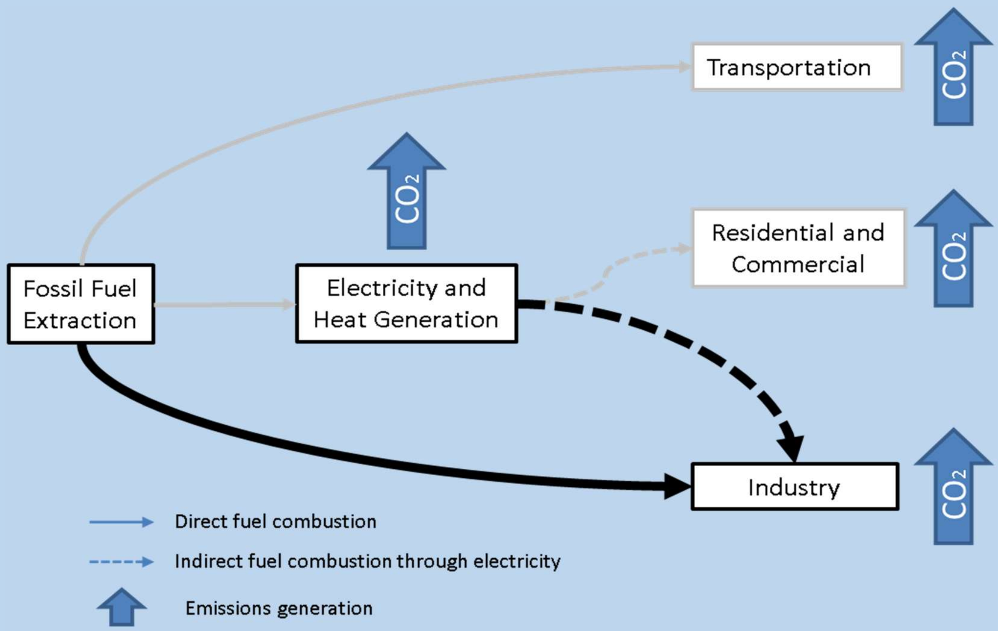


Source: IEA CO_2 Emissions from Fuel Combustion Statistics.
Note: Sectors with a marginal contribution to the overall energy use of the manufacturing sector are not listed by name in order to ensure readability of the figure.

The section above outlined the manufacturing sector's contribution to total CO_2 emissions of a specific country. In the following section it is analysed how the manufacturing sector's emissions relate to the contribution to economic performance. To do so it is plotted the share of manufacturing emissions (Indicator 3.12) against the size of the manufacturing sector. To measure the relative size of the manufacturing sector a proxy measure of manufacturing value added (MVA) in GDP is adopted. Figure 13 plots the change in the share of manufacturing CO_2 and the change in MVA in GDP between 2000 and 2016 for selected countries. If a country is below the 45-degree line, the manufacturing sector's relative contribution to CO_2 emissions (that is the size of manufacturing emissions in relation to other non-industrial emissions) is smaller than its relative contribution to GDP.

Box 5. Direct versus Indirect Manufacturing Emissions

The IEA only reports *direct* manufacturing CO_2 emissions from fuel combustion on the sub-sectoral level, which means the numbers do not include *indirect* emissions generated through electricity used in the production process. Electricity produced from coal, for instance, produces more CO_2 emissions than electricity from natural gas, which in turn produces more CO_2 than renewable sources. For an analysis of a country's energy composition, please refer to EQuIP Tool 6.1.



The graph above explains the stages at which the use of fossil fuels can lead to CO_2 emissions. To obtain the full picture of CO_2 emissions for which the industrial sectors are responsible, it would be needed to analyse emissions from fuel combustion (direct emissions) together with emissions from any electricity (indirect emissions) used during the industrial processes. However, as data on indirect emissions cannot be allocated to the respective manufacturing sub-sectors, these emissions have to be excluded from the analysis.

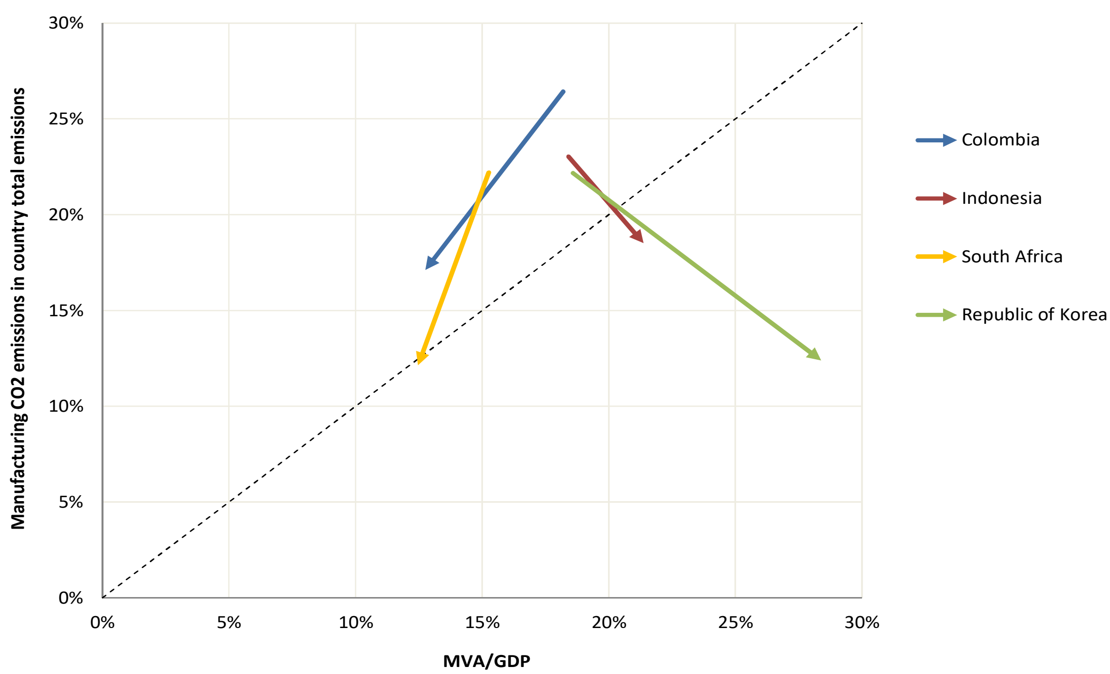
Figure 12 indicates how large the discrepancy between direct and indirect emissions can be for certain countries. Whereas for Colombia this difference is only marginal, the indirect emissions for South Africa are around twice the size of direct emissions from fuel combustion in industrial production. Policy makers can refer to the IEA database on CO_2 Emissions from Fuel Combustion to get a better understanding of a country's difference between direct and indirect emissions. Note that the share of indirect emissions is for manufacturing and construction industries together, whereas direct emissions are for manufacturing only. This discrepancy is due to the way the IEA reports data at different levels of aggregation.

In the case that indirect emissions account for the majority of a country's manufacturing total emissions, it is recommended that the analysts focus on combined direct and indirect emissions at the manufacturing level only. While the IEA does not report data on indirect emissions for the manufacturing sector, it does so for the sum of indirect emissions in the manufacturing and construction sector. Therefore, if this the case – as can be seen in the data for the Republic of Korea in Figure 12 – it is recommended to shift the entire analysis for this country from the manufacturing sector only, to the sum of manufacturing and construction. This will ensure that it can be included data from indirect emissions in all the analysis now conducted with this broader definition. Please note that when making this decision, data on value added should also be recalculated to include the sum of manufacturing and construction and not just to consider MVA only. A recommended source for accessing value added data for these two sectors combined is the United Nations Statistics Division (UNSD) database.

Figure 13 can help policy-makers to understand whether or not the increase or decrease of a country's relative emissions by the manufacturing sector is potentially due to increases or decreases in the relative size of the manufacturing sector. Note that a change in the relative size of CO_2 emissions or MVA can also be caused by increases or decreases of other sectors in relation to the manufacturing sector. The data for Colombia and South Africa, indicated by the blue and yellow arrow, indicate that the decrease in the manufacturing sector's contribution to overall CO_2 emissions in these countries might have been due to a relative decrease in the size of the manufacturing sector.

For countries aiming to increase their relative size of the manufacturing sector but at the same time want to lower the share of industrial emissions in total emissions, the policy target should be to move to the bottom right part of the graph. In Figure 13, we see that the Republic of Korea and Indonesia have successfully managed to reduce their share of manufacturing emissions in CO_2 (vertical axis) without any reduction in manufacturing's contribution to GDP (horizontal axis). The countries thus managed to decrease the size of manufacturing CO_2 emissions in relation to the rest of the economy without decreasing the relative size of the manufacturing sector constituting a best trajectory in terms of this indicator.

Figure 13. Share of MVA in GDP versus the share of manufacturing emissions in country emissions (Change from 1990 to 2016)



Source: IEA CO_2 Emissions from Fuel Combustion Statistics and World Bank WDI (USD 2010 constant prices).
Note: Data about manufacturing CO_2 emissions and value added can also be taken from the UNIDO database (https://stat.unido.org/SDG) for the period 2000 – 2016. A wider time horizon for manufacturing value added is available at the UN Statistics Account https://unstats.un.org/unsd/nationalaccount/data.asp.

This module focuses on CO_2 emissions generated from fuel use and therefore the emissions produced depend themselves on which fuels are being used to produce the required energy for production.

Analysing how energy consumed by the manufacturing sector is produced can help to identify the potential for fuel switching to cleaner fuels and other emission mitigation.

The emission intensity of different types of fuel vary greatly. While renewable energy sources are typically considered carbon-neutral (e.g. hydro, solar and wind), different fossil fuels emit different amounts of CO_2 in relation to the energy they produce when burned. The burning of coal, for example can produce on average twice as much CO_2 when compared to when natural gas is burned to generate the same amount of energy. Manufacturing activities in particular are heavily dependent on the use of coal as a fuel source due to coal's requirement in several production processes such as steel production and other metallurgical production processes. In addition to its intensive CO_2 emissions, the burning of coal also produces serious impacts on air pollution (see Box 6).

Box 6. Use of coal as a fuel source

When coal is burned it releases a number of airborne toxins and pollutants. These include CO_2, which has a long-term global impact on climate change as a GHG. In addition to this, burning of coal generates a number of local pollutants, at a higher intensity than many other fossil fuels, which have serious impacts for 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 various other heavy metals. Coal is also among the fossil fuels which emit the highest rate of CO_2 when combusted (see Box 1 for details), producing about 40 to 50% more emission compared to gasoline.

Comparing the energy source mix of countries among a comparison group allows for benchmarking when energy production-mix consumed by manufacturing is relatively clean or dirty in terms of its emissions. Figure 14 can be used for this purpose by exploring multiple dimensions of energy use and emission origin simultaneously. Figure 14 compares:

- Share of manufacturing emissions generated from coal use (vertical axis) in total manufacturing direct emissions: coal is a more emission intensive fuel which also generates greater air pollution impacts. Comparing how much emissions come from coal in manufacturing industries of different countries identifies the potential to shift away from coal emission within manufacturing activities, as other countries have done this, in particular when the graph is constructed for manufacturing sub-sectors. Please note that the contribution of coal to direct emissions is considered, excluding the manufacturing consumption of electricity. The intent is to measure to what extent direct manufacturing emissions are exposed to carbon intensive sources of energy.
- Share of non-renewables in electricity generation (horizontal axis): the manufacturing sector is a large consumer of electricity. If the electricity generated is emission intensive, the manufacturing sector's contribution to CO_2 emissions in broader terms is also larger. Using electricity produced with a higher share of renewable energy sources (lower share of non-renewables) also signals that manufacturing's contribution to emissions (defined broadly) will also be lower. The intent is to measure to what extent direct electricity emissions are exposed to carbon intensive sources of energy.

- Energy Intensity (bubble size): energy intensity captures how much energy is required to produce 1 USD-worth of manufacturing value added. This indicator was introduced in EQuIP Module 6.1[28]. Because the production of energy is linked to the generation of emissions, the amount of energy is required in production is also central to understanding how polluting a sector is[29]. A country may be using relatively clean energy sources, but be producing energy intensive goods which result in more energy and emission generation in comparison to a less energy intensive industry.

World averages, represented by the dotted lines, are used to benchmark the performance of countries in terms of their reliance on coal and electricity energy-mix. The horizontal dotted line presents share of coal emission in manufacturing emission for the world in 2016 which represented 62% of manufacturing CO_2 emission. The vertical dotted line is the world average share of non-renewable energy sources in electricity generation (76% in 2016).

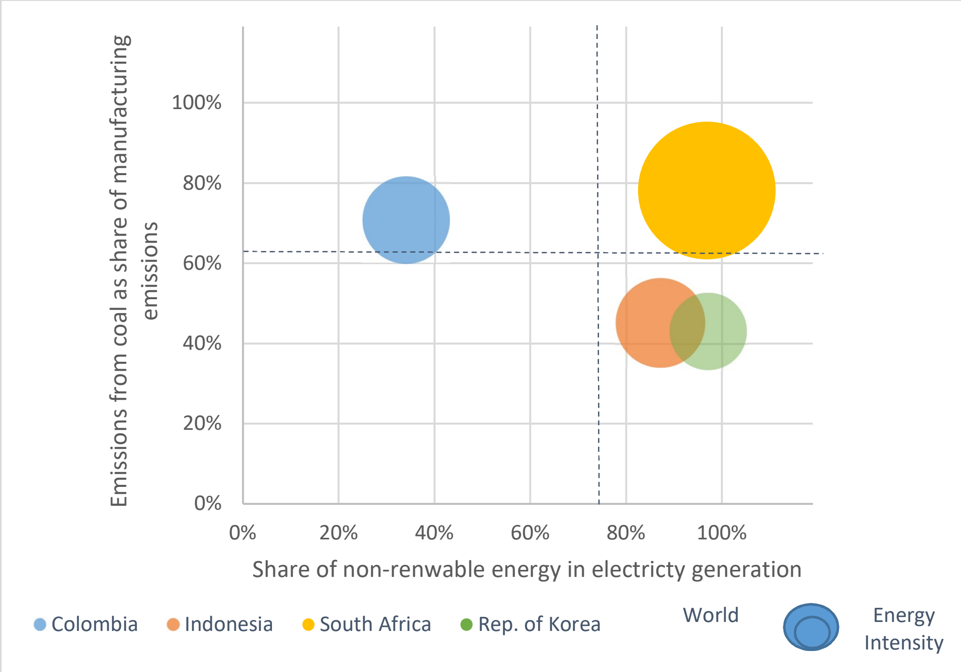
The top-right quadrant includes the most pollutant countries both in manufacturing emissions and in electricity production. South Africa is positioned in the top-right quadrant in Figure 14. Among selected countries for analysis, South Africa simultaneously had: (1) the highest share of emissions from coal (vertical axis) which indicates a higher dependency on this dirtier fuel source; (2) the highest share of electricity being produced using non-renewable energy sources (horizontal axis) and, therefore, the most pollutant electricity production; (3) and also the highest energy intensity in manufacturing (bubble size) which indicates that a higher volume of energy is demanded (and polluting is generated) when manufacturing activities grow. All of this indicates that South Africa is performing relatively poorly regarding all three dimensions.

The bottom-left quadrant presents countries with relatively clean manufacturing energy and electricity generation. The top-left and bottom-right quadrants include countries which either have relatively clean electricity generation (Colombia) or have a lower than average reliance on coal for industrial use (the Republic of Korea and Indonesia), representing a half-way situation between the two other quadrants.

[28] Indicator 3.4 in EQuIP Tool 6.1 is presented as the 'Energy Efficiency' indicator. The 'Energy Intensity' indicator required for this analysis is mathematically the same indicator as that one. The change in indicator name is due to the fact that there is an 'Energy Efficiency' Effect which is calculated in the decomposition. To avoid confusion between the effect and the indicator, we use 'Energy Intensity of manufacturing sub-sectors' here.

[29] Unless energy can be produced 100% through zero emission fuels, the production and consumption of energy generates emissions. As a result of this, intensity of energy use (captured in the energy efficiency indicator) is directly related to emission generation.

Figure 14. Coal emissions, non-renewable energy in electricity and energy intensity of manufacturing, in 2016



Source: IEA and World Development indicators for manufacturing value added (USD 2010 constant prices).

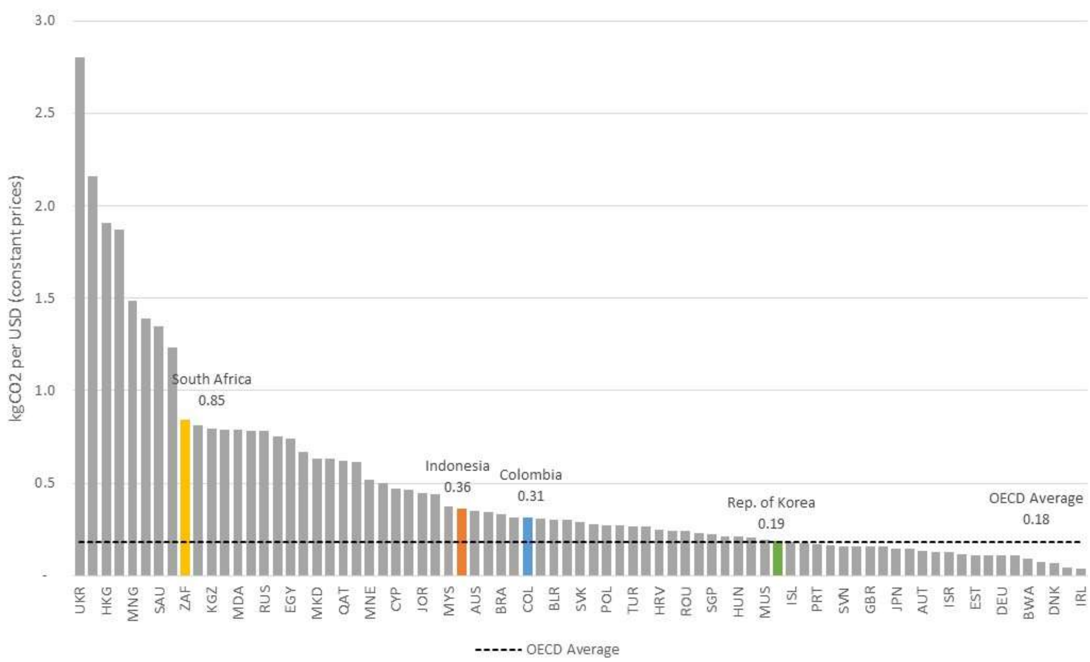
4B2.2 Emission intensity of manufacturing

The section 4B2.1 shows that the energy intensity of manufacturing sectors of different countries can vary greatly. Since the use of energy is directly linked to the production of emissions (at different degrees), the emission intensity of countries will also differ. Analysing the emission intensity of manufacturing activities essentially captures the trade-off that exists been the generation of value added (and economic benefit) and the generation of impacts which contribute to climate change (CO_2 emissions). A lower emission intensity can be interpreted as a more efficient way of generating economic value when taking into account the climate change impact of that activity.

Figure 15 presents the emission intensity of the manufacturing sector in selected countries. It is immediately clear that the emission intensity can vary significantly from country to country. As previously highlighted, the emission intensity of manufacturing activities depends on two central elements: the sector's energy intensity and the types of fuel being used (see Box 1 for more on this). The emission intensity is influenced by these two elements. Developed economies (and in particular industrialized economies) represent a group of countries which on average has made more progress toward production in a more environmentally friendly way. Part of this progress is explained by the use of newer production technologies in these countries which frequently come hand in hand with higher energy efficiency and lower relative use of dirtier fuels.

Because of this difference between this group of developed countries and the world average, it can be used the emission intensity of this group of countries to benchmark the performance, in terms of emission intensity, of the countries under analysis. That is, by comparing the emission intensity of manufacturing activities against a group of 'high-performance' countries, it is possible to identify the space for emission intensity reduction in other countries.

Figure 15. Emission intensity of the manufacturing sector selected countries, in 2016



Source: IEA and World Bank WDI

Note: Data about manufacturing CO_2 emissions and manufacturing value added can also be taken from the UNIDO database (https://stat.unido.org/SDG) for the period 2000 – 2016. A wider time horizon for manufacturing value added is available at the UN Statistics Account https://unstats.un.org/unsd/nationalaccount/data.asp.

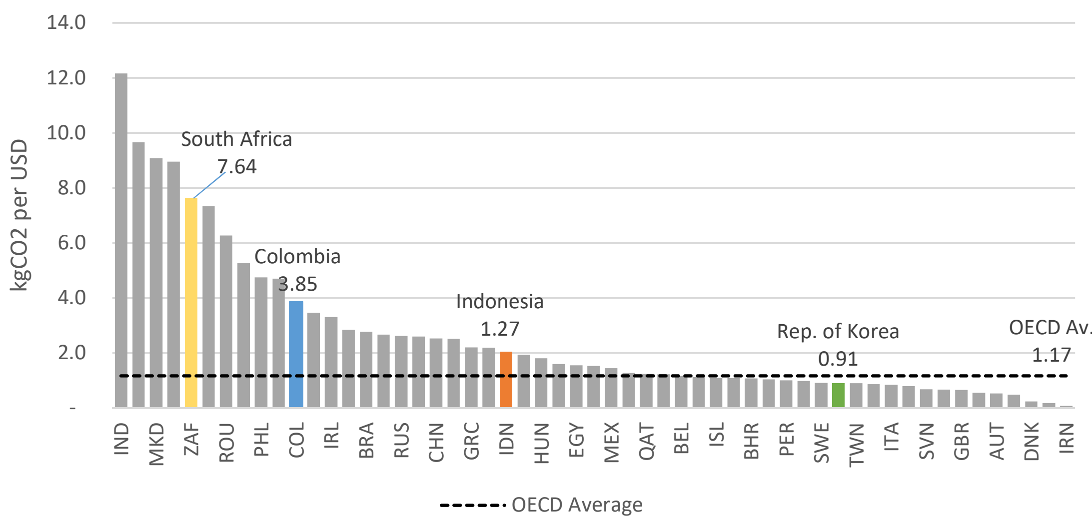
For example, in Figure 15 South Africa's manufacturing sector is much more carbon intensive in comparison to both the other two comparator countries (Indonesia and Colombia) and also compared to the OECD average. That South Africa is also amongst the world's most emission intensive manufacturing sectors (ranked 9th in 2016) highlights that possibly many opportunities exist for the country to lower its emission intensity. The Republic of Korea, however, is around the OECD average, indicating that further reduction to their emission intensity might be harder to obtain. At the same time, the country with the lowest emission intensity reported in 2016 was Ireland (0.03 kg CO_2/USD), indicating that there might be potential for all countries to continue to lower their intensity in the future.

Which industries make up a country's manufacturing sector matters for understanding how manufacturing generates CO_2 emissions. Some sub-sectors are much more energy efficient than others on average. This is the particularly the case of the Iron, Steel and Non-Ferrous Metals and Non-

Metallic Mineral sectors. Estimate based on the IEA and UNIDO INDSTAT database, show that these two sectors had a world average emission of, respectively 2.6 and 2.4 $kgCO_2$/USD of value added. This is significantly different to light industry sectors such as Textiles and Leather (and Food, Beverage and Tobacco sectors (both 0.2 $kgCO_2$/USD of value added)[30].

For this reason, it is possible to further use the emission intensity indicator to benchmark sub-sector performance. Figure 16 presents the emission intensity of the Iron, Steel and Non-Ferrous Metals sector, on average one of the most emission intensive sectors within manufacturing. When the analysis is conducted at the sub-sector level some differences emerge. South Africa once again is among the most emission intensive producers, now ranked 5th when focussing on only the Iron, Steel and Non-Ferrous Metals sector. Colombia, while lower compared to South Africa, is now above the OECD average. This indicates that there might be more options for emission mitigation within the Iron, Steel and Non-Ferrous Metals sector for Colombia.

Figure 16. Emission intensity of the Iron, Steel and Non-Ferrous Metals sector in selected countries, in 2016



Source: IEA and UNIDO.

This indicator is of interest for policy makers as it provides an overview and option for benchmarking counies in terms of their generation of climate change impacts in generating value added. The case of South Africa, for example, highlights an example of a country where multiple options might be available for reducing emissions generated in manufacturing production. Once opportunities for reducing emissions have been identified through the use of benchmarking, specific technical studies should follow in order to pin-point what solutions exist for improving the emission intensity of that specific sector. Different sectors have very different contexts and technical studies are necessary to identify these opportunities.

[30] Note that the emission intensity indicator presented here only measure the direct manufacturing emissions.

4B.3 Decoupling economic and emissions growth

In 0 it is contained an analysis of the manufacturing sector's contribution to GDP and overall CO_2 emissions in relation to other sectors in the economy. As example countries have shown, there are cases of economies that have managed to decrease their manufacturing emissions without decreasing the relative size of their manufacturing sector. This analytical section will elaborate further on the idea of developing a country's manufacturing sector without adding further stress on the environment. Whereas previous sections describe the relative size of the manufacturing sector, that is its size in relation to other sectors, this section analyses trends in absolute numbers.

Central to this section is the concept of economic decoupling. Using the Compound Annual Growth Rate (CAGR) of the past ten years of manufacturing CO_2 emissions and manufacturing production output, it is possible to analyse past trends in these two variables. A country is considered to have decoupled if the growth rate of their MVA is higher than the growth rate of CO_2 manufacturing emissions. A further distinction can be made between relative and absolute decoupling. Relative decoupling describes a situation in which the growth rate of MVA is higher than that of CO_2, but CO_2 emissions are rising, nonetheless. Absolute decoupling is achieved when there is a positive growth rate in MVA while CO_2 emissions are actually decreasing. No decoupling describes cases where the growth rate of CO_2 emissions has exceeded the growth rate of production output.

It is important to note that this analysis only concerns decoupling of the manufacturing sector[31]. For an assessment whether or not the country has achieved overall decoupling of the economy, policy makers would need to look at the development of total CO_2 (or even GHG) emissions compared to the compound growth rate of GDP.

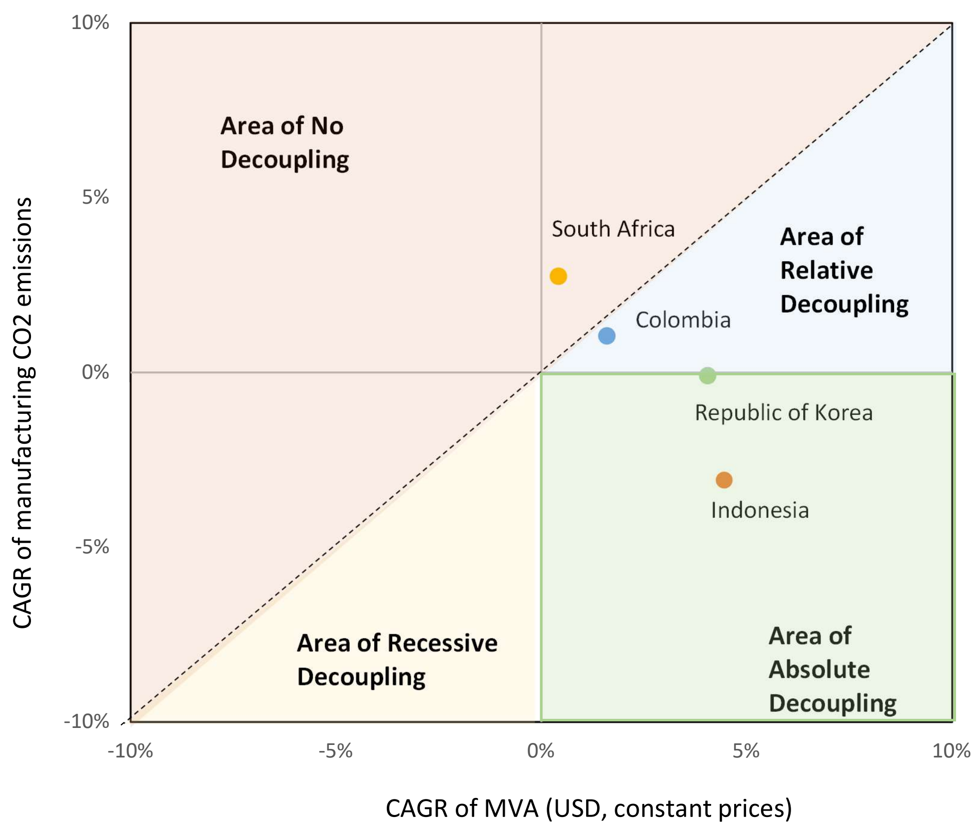
Figure 17 shows the development of MVA and manufacturing CO_2 emissions for our four example countries. The dashed line at a 45-degree angle divides the graph into three areas: Values on the left side of the line indicate cases where CO_2 emissions have grown faster than MVA, which describes a case of no decoupling. The area in yellow, classified as recessive decoupling, describes cases where both CO_2 emissions and manufacturing output have decreased, but CO_2 emissions have decreased faster than manufacturing output. As CO_2 emissions are decreasing this can be considered positive from an environmental perspective, but given that the country is also deindustrializing this is an undesirable position for countries to find themselves in. On the upper right-hand side of the dotted line and above the x-axis, MVA is growing faster than CO_2 emissions, meaning that the manufacturing sector has achieved relative decoupling, i.e. that the manufacturing sector has become more efficient in terms of CO_2 emissions. Finally, the lower right side of the dotted line and below the x-axis is the area where absolute decoupling occurs. In such a situation, not only is industrial development decoupled from CO_2 emissions, but also the overall industrial CO_2 emissions are decreasing. For countries aiming to achieve an improvement in CO_2 efficiency, the policy target should be set to

[31]As explained in the previous section, the decoupling captured here is only related to direct manufacturing emissions.

achieve a relative decoupling (and an absolute decoupling in the long run), i.e. a situation, in which MVA grows faster compared to CO_2 emissions.

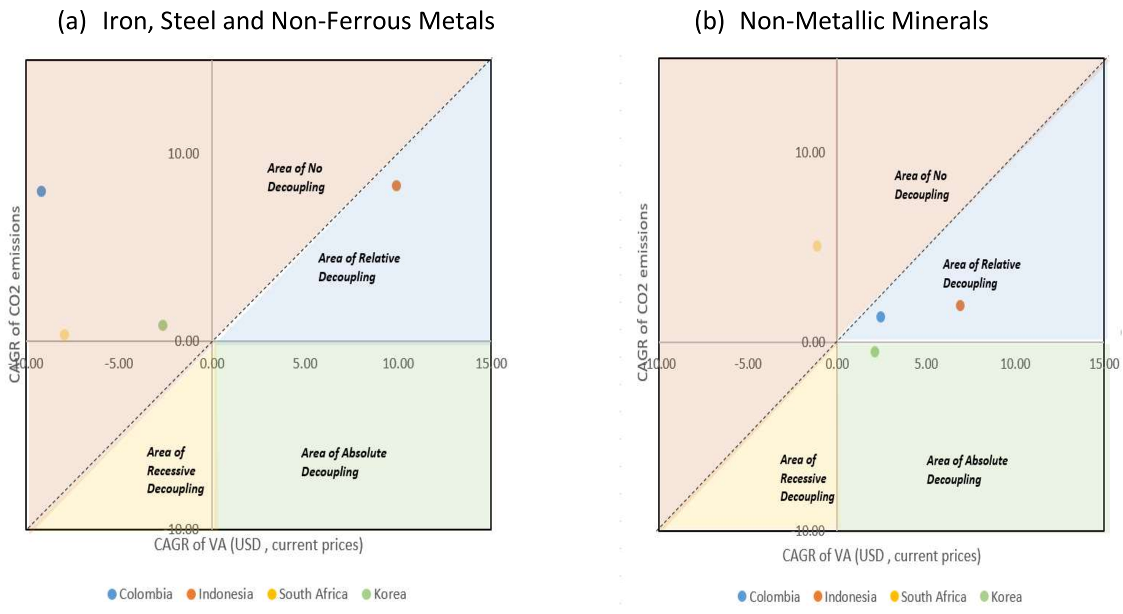
Figure 17 indicates the change of these two variables from 2007 to 2016. Indonesia displays a country that has managed to significantly increase its manufacturing production output with a CAGR in MVA of 4% annually, while at the same time it has lowered its manufacturing CO_2 emissions. Hence, it is considered a case of absolute decoupling. Colombia's manufacturing emissions have increased between 2007 and 2016, but at a lower rate than the growth rate of their manufacturing section which makes Colombia a case of relative decoupling. The Republic of Korea is border line between the area of relative and absolute decoupling, as it has a slightly positive MVA growth rate and a growth of emissions close to 0. Lastly, South Africa's manufacturing CO_2 emissions have increased by 2% each year even though their manufacturing sector has increased by less than 0.5% annually during the same period, making it a case of no decoupling.

Figure 17. Measuring decoupling at manufacturing level (2007-2016)



Source: IEA and World Bank WDI.
Indicators: CAGR of manufacturing CO_2 emissions and value added.
Note: Data about manufacturing CO_2 emissions and value added can also be taken from the UNIDO database (https://stat.unido.org/SDG) for the period 2000 – 2016. A wider time horizon for manufacturing value added is available at the UN Statistics Account https://unstats.un.org/unsd/nationalaccount/data.asp.

Figure 18. Decoupling within the Iron, Steel and Non-Ferrous Metals Sector and Non Metallic Minerals (2007-2016)



Source: IEA and UNIDO.
Indicators: CAGR of manufacturing sub-sector CO_2 emissions and value added.

The same exercise from Figure 17 can be repeated for individual manufacturing sub-sectors. Figure 18 analyses cases of potential decoupling in the Iron, Steel and Non-Ferrous Metals sector as well as the Non-Metallic Minerals sector. These two sectors have been selected as examples as they contribute the most to the manufacturing CO_2 emissions in our example countries, as can be seen from Figure 12. None of the example countries have achieved absolute decoupling in the Iron, Steel and Non-Ferrous Metals sector (as can be seen from the graph on the left side of Figure 18). Only Indonesia managed to achieve relative decoupling. Colombia's, South Africa's and the Republic of Korea's CO_2 emissions in the Iron, Steel and Non-Ferrous Metals sector all increased despite this sector has experienced declining output during this time.

The situation within the Non-Metallic Minerals sector (displayed by the graph on the right in Figure 18) is encouraging for the Republic of Korea, Indonesia and Colombia. The Republic of Korea has achieved absolute decoupling while the latter two have achieved relative decoupling. Conducting the decoupling analysis at sub-sector level allows policy makers to identify those sectors in which improvements in emission intensity are needed the most if overall economic decoupling is to be achieved. The next section will take this analysis one step further and analyse how the change in CO_2 emissions can be decomposed into different drivers.

4B.4 Identifying the drivers of emissions growth

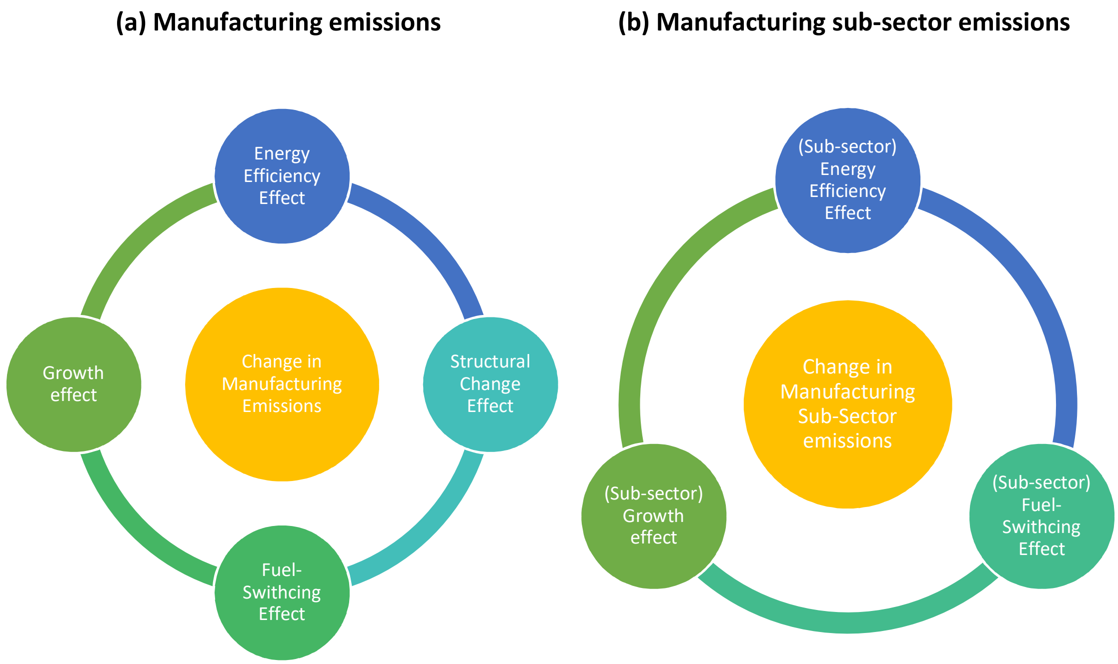
Countries' manufacturing emissions change over time, in some cases the total emissions are increasing and in others, they are decreasing. However, which specific factors are contributing to this change in manufacturing emissions over time is not immediately known. Linking these factors to their effects on emissions change over time can be very useful for drawing conclusions in terms of what is pushing emissions to rise or contributing to their reduction. For example, it is possible to measure how much energy efficiency improvements contributed to emission reduction over a given period. Or, how much the growth of manufacturing activities contributed to an emission rise.

One way through which this can be done is by using an emission decomposition method. Many decomposition methodologies exist that take into account different technical and economic factors which contribute to emissions growth. The method allows us to allocate the changes in emission to each of these factors in quantitative terms. Here, it is explored only one of the possible decomposition options tailored for analysing the change in manufacturing energy-related emissions.

In this section, the analysis focuses on the change in emissions of selected countries over the 2010-2016 period, comparing the change in the emission in the initial year with that of the final year. It is then analyzed how four different factors also changed for the country under analysis over this same period, which include: the size of the manufacturing sector, the composition of the manufacturing sector in terms of the size of sub-sectors, the energy intensity of manufacturing sub-sectors, and the carbon intensity of energy of manufacturing sub-sectors.

By comparing the change of these factors (comparing the initial and final year values) and applying the Logarithmic Mean Divisia Index (LMDI) method, it is possible to calculate how the four different *effects* contributed to the emission change (see technical appendix for more details on how these effects are calculated). The decomposition can be conducted for total manufacturing emission or also at the manufacturing sub-sector level. The methodology for calculating each of these differs slightly in terms of which effects are captured. Figure 19 summarizes the four effects captured when the decomposition is conducted for total manufacturing (a) and at the manufacturing sub-sector level (b).

Figure 19. Decomposition of manufacturing energy-related emissions



Source: Own graph.

Each of the components capture the effect that a change in the factor has on emission change, which can result in a positive or negative contribution to total emissions variation. These four effects are further explained below:

- Growth Effect: an expansion of manufacturing activity produces an impact on emissions. This link is further explored in the section on decoupling (section 4B.3). The growth effect captures how the overall expansion of manufacturing activities contributed to the change in emissions. In countries where absolute decoupling occurs, this effect will be negative, while it will be positive in other cases. Understanding the importance of this effect to total emission change over a period is of particular importance for countries which are undergoing a process of industrial development (industrializing countries), as the growth effect is likely to be the main driver of emission growth.
- Structural Change Effect: manufacturing sub-sectors generate different impacts in terms of the emissions they produce (as analysed in section 4B2.2 on the emission intensity of manufacturing sub-sectors). For example, if a country undergoes a change over time in which heavy industry (e.g. Iron, Steel and Non-Ferrous Metals industry) grows at a faster pace than other industries (such as a light industry sector like the Textile and Leather sector), this structural change within the manufacturing sector will contribute to a rise in emissions. This is because the relative size of the emission intensive sectors (here, Iron, Steel and Non-Ferrous Metals) within manufacturing activities is rising. In the same way, the growth of a low emission

intensive sector may also contribute to a positive structural change in which emissions decline.

- Energy Efficiency Effect: improvements in the energy efficiency (reduction of energy intensity) of manufacturing sub-sectors will also contribute to emission reduction since less energy (and emissions) is required to produce the same value of manufacturing value added. Energy efficiency improvement is one of the main channels which countries can use to reduce industrial emissions (see Box 7).
- Fuel-Switching Effect[32]: not all fuels generate the same impact in terms of emissions. As presented in Box 6, certain types of fuel (such as coal) generate more CO_2 emission per unit of energy when compared to other fuels (such as natural gas). Because of this, switching to less carbon intensive energy sources (which reflect a change in the fuel types being used) can contribute to reducing industrial emissions. For example, if a country substitutes the use of coal in industry for natural gas, this will be reflected in a reduction of the carbon intensity of energy used in industry and will contribute to reducing emissions.

Figure 20 presents the results of the emission decomposition calculated for Indonesia and the Republic of Korea in the 2010 to 2016 period. During this period, Indonesia's manufacturing CO_2 emissions rose by 26 $MtCO_2$ (from 55 to 81 $MtCO_2$ or a 46% increase). The Republic of Korea's manufacturing CO_2 emissions fell by 24 $MtCO_2$ (from 94 to 70 $MtCO_2$ or a 25% reduction). The two example countries represent countries at different levels of their industrialization process and with different trends in terms of emissions change.

The change in emissions for these countries over the 2010-2016 period is represented in Figure 20 as the difference in the size of the emission values in orange (the first and last bar). The four effects included in this decomposition when summed equal the change in the emission over this period. Each of these effects may have a positive or negative contribution to the change in emissions depending on the factors detailed previously. Analysing each of these effects enables policy makers to further understand the causes of changes in emissions.

Below it is clear that the expansion of manufacturing activities (the growth effect, in blue) was what contributed the most for both countries in terms of emission increases. In the case of the Republic of Korea, even though the final change in emissions was negative, it is possible to see that the expansion of activities contributed positively to emission growth (in an amount equivalent to 42 $MtCO_2$). For countries which are rapidly expanding their industries, the growth effect can be even more substantial. In Indonesia the growth effect has generated an increase of 109 $MtCO_2$.

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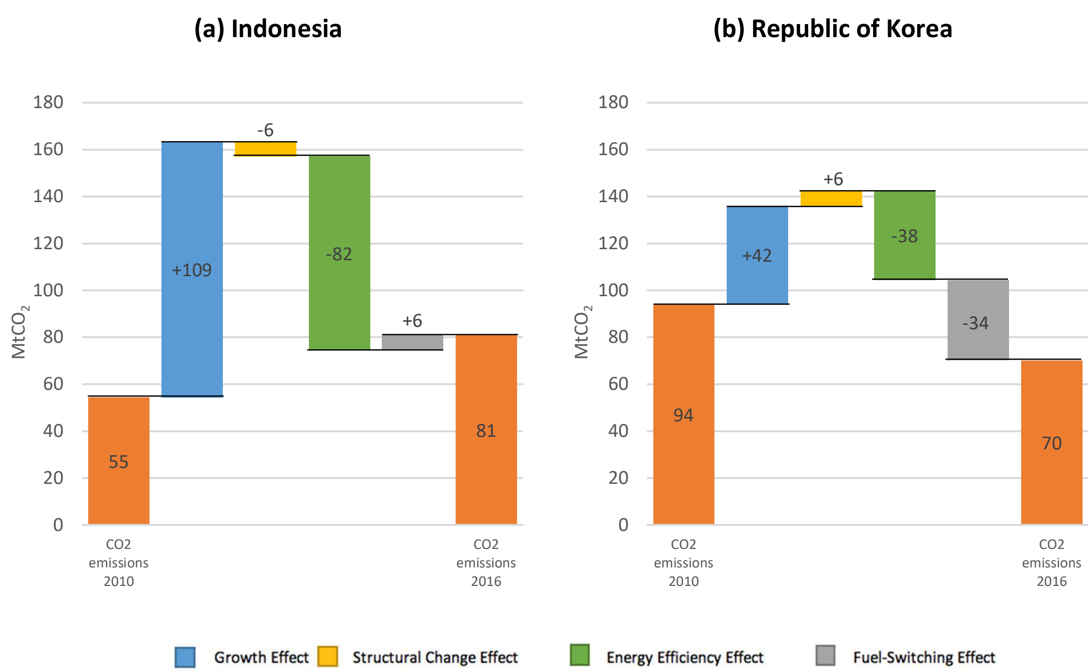
[32]The terms energy efficiency and fuel-switching effect are used to highlight the main factor to which they are associated with and are used for illustrative purpose. Note that the four effects should not be considered as generally independent from each other. For example, substituting coal with natural gas as a source of energy generation will affect the CO_2 emission per unit of energy. However, if this fuel switching came together with a change in the technology (e.g. machinery) which is used to switch the fuel being used, the energy efficiency (energy intensity) of that sector may also be affected.

Figure 20 also indicates that the structural change effect contributed to a small emission reduction in Indonesia (equivalent to a 6 $MtCO_2$ reduction, in yellow) over the 2010–2016 period. Over this period, the relative size of the food, beverage and tobacco industry increased greatly, growing from 18% to 31% of MVA. This shift towards a lower emission intensive sector contributed to emission reduction. The reverse was true for the Republic of Korea's industry where structural change contributed to a positive contribution to emissions change. Structural change in any economy occurs gradually over time. If the decomposition is conducted over a short period (e.g. less than 10 years), this effect will typically be relatively small compared to the other effects included.

Figure 20. Decomposition of manufacturing CO_2 emission for Indonesia and the Republic of Korea in the 2010-2016 period



Source: Own calculations based on IEA and UNIDO.

The role that energy efficiency improvements and fuel-switching can play in energy-related emission mitigation for industry also becomes visible when analysing the role these two effects play (respectively, in green and grey) in compensating the emission growth from industry expansion. The energy efficiency effect (energy intensity reduction) played a large role in compensating the emission rise from the growth effect for both Indonesia and the Republic of Korea. As explained below, for Indonesia, a large part of that reduction can further be attributed to energy efficiency improvements in the Iron, Steel and Non-ferrous Metals sector by conducting the decomposition at the sub-sector level. Understanding how energy efficiency improvements have contributed to emission change in the past guides policy makers on how these improvements may continue to contribute to emission mitigation over the future years.

For the fuel-switching effect (change in the emission intensity of energy), Figure 20 shows how this has a strong negative effect in the Republic of Korea, but a positive effect in Indonesia. For the Republic of Korea, fuel-switching to less emission intensive energy sources can contribute to a significant emission reduction which (for the 2010-2016 period) had almost the same effect as the energy efficiency improvements. Figure 20 gives many insights into what is driving emission change in the countries being analysed and also allows for comparing and benchmarking the drivers of emission across countries. The decomposition of manufacturing emission gives insights into what cause the emission change, but this may be the result of different trends at the sub-sector level. This same type of decomposition can also be conducted for a single manufacturing sub-sector.

Box 7. Energy efficiency and emission mitigation

Energy efficiency is a topic further discussed in tool 6.1 of EQuIP. However, at the same time, energy efficiency is closely related to the discussion of emission mitigation as it is one of the main channels in industry for reducing the sector's carbon footprint. Exploring the extent to which energy efficiency can contribute to emission mitigation is central to bridging these two topics.

Energy efficiency enhancement is often a very important form of induced technological change for climate change mitigation because it is cost-effective for investors already in the short-run following implementation measures. Investments in energy efficiency typically produce a positive net economic benefit for the investors, even prior to consideration of any economy-wide rebound effects they may have[33]. As a result, it is potentially the most important and cost-effective means for mitigating industrial greenhouse gas emissions[34].

Historically, industrial energy-efficiency improvement rates have been around 1% per year, but various countries have demonstrated that it is possible to double these rates for extended periods of time through the use of policy mechanisms[35]. However, there is a wide scope for emission mitigation through industrial energy efficiency by using the best available (existing) technologies available for industrial production.

Particularly among developing economies, the best available technologies (BAT) are not being used in many manufacturing industries. Upgrading production technologies to more energy efficiency ones generates the opportunity for these countries to quickly reduce industrial emissions significantly in the short- to medium-run[36]. For example, Prins et al.[37] report that the adoption of BAT in the steel industry globally could reduce CO_2 emissions annually by around 340 million tons.

Figure 21 presents the decomposition calculated for change in emissions from the Iron, Steel and Non-Ferrous Metals sector of Indonesia and the Republic of Korea in the 2010–2016 period. At the sub-

[33]Rosen R., and Guenther E., (2015). The Economics of Mitigating Climate Change: What Can We Know? Technological Forecasting and Social Change 91: 93–106. https://doi.org/10.1016/j.techfore.2014.01.013.

[34]Worrell E., Bernstein L., Toy J., Price L., Harnisch J. (2009). Industrial Energy Efficiency and Climate Change Mitigation.

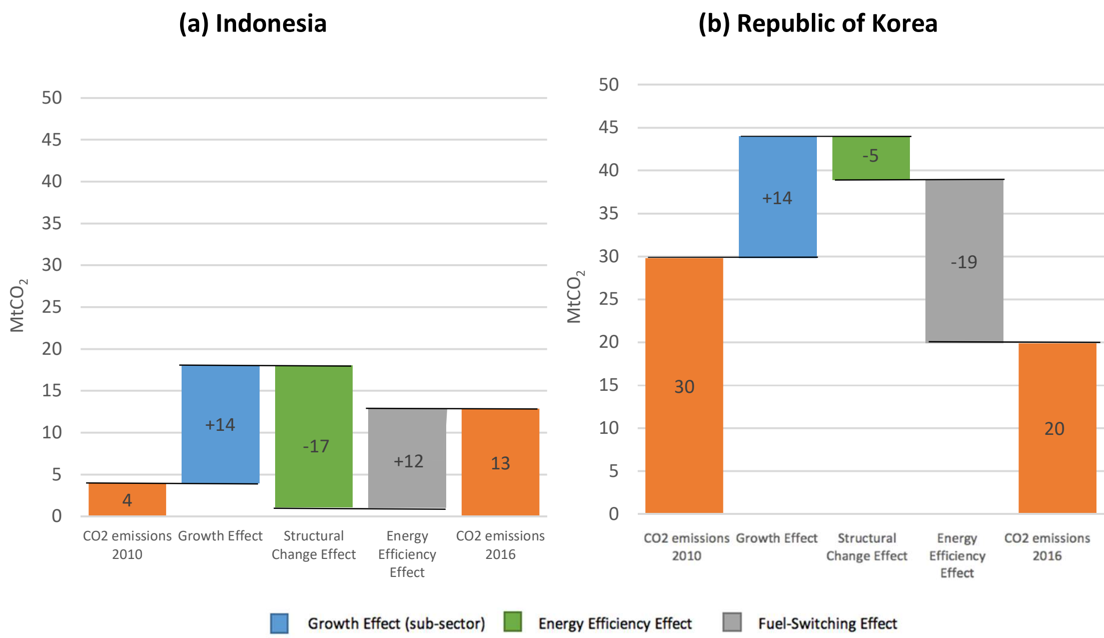
[35]Worrell E., Bernstein L., Toy J., Price L., Harnisch J. (2009). Industrial Energy Efficiency and Climate Change Mitigation.

[36]Naudé W. (2011). Climate Change and Industrial Policy. Sustainability 3, no. 7: 1003–21. https://doi.org/10.3390/su3071003.

[37]Prins G., Galiana I., Green C., Grundmann R., Korhola A., Laird F., Nodhaus T., Pielke R., Rayner S., Sarewitz D., Shellenberger M., Stehr N., Tezuko H. (2010). The Hartwell Paper: A New Direction for Climate Policy after the Crash of 2009. London: University of Oxford and London School of Economics.

sector level, the three effects contribute in different ways to the emission variation of the period. Note that the growth effect calculated for the Iron, Steel and Non-Ferrous Metals sector only considers the specific size of this sub-sector and not the size of the manufacturing sector as whole. For example, in the Republic of Korea's Iron, Steel and Non-Ferrous Metals sector the fuel-switching effect played a larger role in limiting emission increases than the gains from improvements in energy efficiency (the grey effect is larger than the green effect in Figure 21b). However, the opposite when looking at manufacturing as whole.

Figure 21. Decomposition of Iron, Steel and Non-Ferrous Metals CO_2 emission for Indonesia and the Republic of Korea in the 2010-2016 period



Source: calculations based on IEA and UNIDO.

For policy makers, understanding the main drivers of emission growth in the past can help understand what is causing emissions to grow. Better understanding these drivers will also contribute to understanding how they will continue to drive emission growth in the future, and may help in identifying possible emission mitigation channels within industry. For example, if the fuel-switching has not contributed to emission reduction in the period being analysed, policy makers may choose to conduct further research to better understand why this is happening through the use of more sector specific studies. Manufacturing sub-sectors moving towards dirtier fuel sources can be pin-pointed using the decomposition at the sub-sector level.

The decomposition analysis presented above links a change in emission to the factor associated with that emission growth/reduction over a given period. The reason why each factor had a positive or negative impact on emission change can then be further understood by complementing this approach with specific technical studies by the policy maker for the country or sector in question.

4B.5 Performance of Climate-friendly Goods (CFGs) exports

So far, the analysis has focused on the relationship between CO_2 emissions and output, how this relationship has changed over time and how it can be explained by different factors. The next section will look at an example of how countries can see climate change mitigation as an opportunity for an emerging new market for goods created to improve mitigation. With a growing focus on climate change mitigation as well as countries' need to deliver on their NDC pledges, it is reasonable to assume that goods which contribute to a reduction in CO_2 emissions will be met with growing demand in the future. As outlined in the methodology section, the World Bank's list of Climate-friendly Goods (CFGs) poses as good reference for such goods that help to achieve climate change mitigation (see indicator 3.18. or Appendix 7C for further details on this reference). It is important to flag that this list includes goods that are considered to contribute to lower CO_2 emissions but are not necessarily produced in a climate-friendly way themselves. Analysing the production and export of goods that have a neutral CO_2 emissions footprint could be another interesting analysis for policy makers.

Box 8: List of Climate-friendly Goods

Climate-friendly goods are goods and technologies that can be used to measure, prevent or minimize GHG emissions. Note that this definition does not mean that the list includes goods that are necessarily produced in a climate-friendly way. Climate-friendly goods form a subset of the 'environmental goods' a set of goods that is discussed for preferential tariff treatment under WTO law and which have been subject to negotiations since the Doha declaration. While environmental goods have been discussed widely and defined by the OECD and APEC in different studies, climate-friendly goods have not had the same attention yet. Although slightly older, the most extensive list of such climate-friendly goods can be found in the World Bank report *International Trade and Climate Change*[38], which presents a list of goods using climate-friendly technologies. The report lists 43 tariff groups, based on HS-6-digit codes, which include such climate-friendly goods. The full list of climate-friendly goods can be found in Appendix 7C: List of Climate-friendly Goods. An issue with reliance on the HS system to identify these goods is that when products are classified at the HS-6 level, components of other technologies that do not necessarily contribute to climate change mitigation are included. For these reasons, the values calculated in this section represent over-estimates of the total value of climate-friendly goods (as identified by the HS code groupings). Additionally, it should be highlighted that it is only used the combined aggregate of all climate-friendly goods. An interested policy maker might want to look at the different climate-friendly goods individually in order to get a better understanding of the country's performance.

Figure 22 analyses the share of climate-friendly goods in total exports of a country as well as the annual growth rate of CFGs. Similarly, as in the exercises above, the scatterplot has been divided into four areas by the world average on the two variables. Ideally, countries want to find themselves in the top right corner of the graph which represents countries that are exporting a relatively large share of CFGs and have managed to sustain high growth rates within this sub-sector. This is the case for Korea, where CFGs already account for more than 2% of total exports and have grown at a high pace in the past 10 years. The implications for achieving such outcome are twofold: (1) establishing itself as an important producer in the emerging market of climate-friendly goods poses a market opportunity that

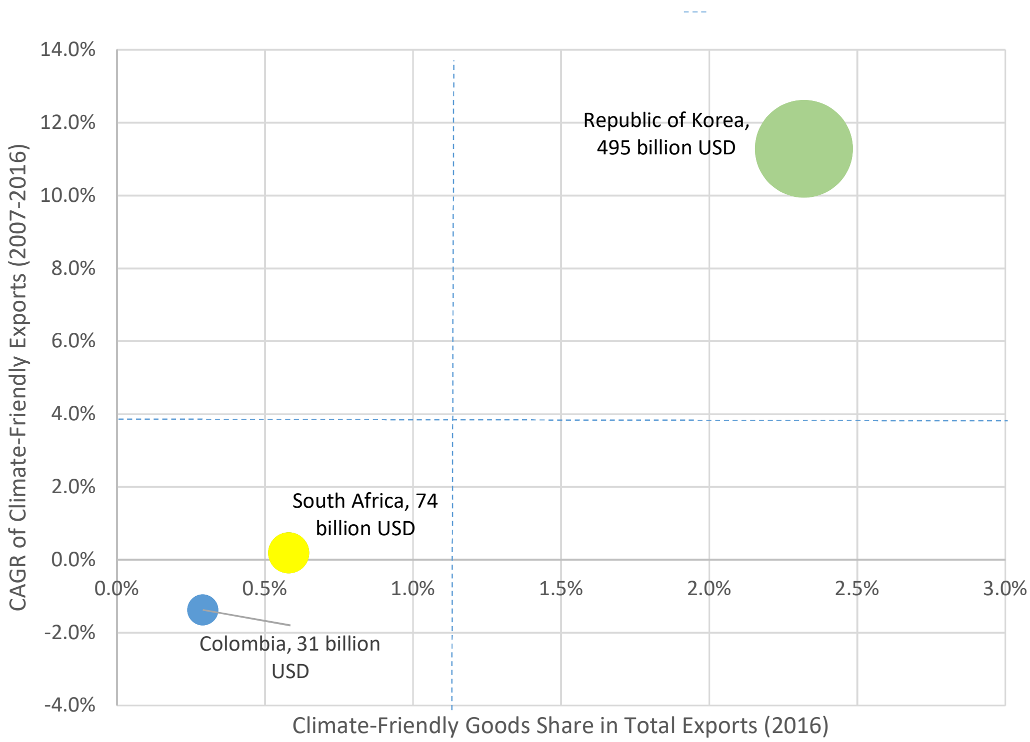
[38]World Bank (2008). International Trade and Climate Change. World Bank Group, Washington D.C.

countries should try to seize; and (2) exporting climate-friendly goods will promote the use of such goods and thereby actively contribute to climate change mitigation on a global scale.

Some countries, such Colombia and South Africa, for instance, might find themselves in the bottom left quadrant of the graph which represents a relatively low share of CFGs in total exports and a relatively lower growth rate of these during the past decade. This could be cause for immediate concern, because the size and the slow growth of CFGs exports flag untapped business opportunities. Countries could explore the adoption of measures to develop capabilities in the domestic production and international competitiveness of climate friendly goods exports.

Analysing a country's exports of climate-friendly goods is based on the assumption that climate change mitigation can be seen as a business opportunity that is worth exploring for developing countries. However, from an environmental perspective, a low share of climate-friendly goods exported is not necessarily bad. Importing these goods, and thereby contributing to climate change mitigation, is a positive outcome already. If this is the case, it might be worth exploring the potential for supporting the local production of these goods as the domestic market already poses an opportunity.

Figure 22. Share of CFGs in Exports and CAGR of CFGs



Note: Bubble size presents the size of a country's total exports in 2016. Dotted lines represent world share of climate friendly goods in 2016 and CAGR world climate friendly goods over the period 2007 – 2016. Indonesia is not included in the graph as in the other analyses concerning mitigation as the lack of data until 2010.
Source: COMTRADE (WITS) and World Bank List of 43 Climate-friendly Environmental Goods.

Interested policy makers can use the list of climate-friendly goods from Appendix 7C and apply this to the analysis from EQuIP tool 3 on industrial and export upgrading[39]. A further idea that could be interesting for policy makers to look into is to identify the main importers of climate-friendly goods. While this is not an analysis suitable for the benchmarking type of exercises that EQuIP is concerned with, it would help policy makers to identify those countries that could pose an interesting case to explore for new markets. Especially those importers in close proximity to the country of interest should be considered when encouraging market expansions.

5 Suggestions for data Analysis

CO_2 Emissions: national statistics and data from the IEA

In its publications, the IEA states that national energy statistics often do not comply with international accounting standards[40]. Therefore, the IEA needs to apply estimations in order to provide the required data detail. As the IEA states, these estimations are, whenever possible, made in consultation with national statistical offices, oil companies, electricity utilities and national energy experts. However, discrepancies between the IEA and national statistical data might exist. The difference between IEA data and national statistics is especially relevant when using this data in union with targets set based on national statistics data. For example, this is the case for tracking emissions reduction progress towards targets set in Nationally Determined Contributions (NDCs) which are based on national emissions data. Appendix 7A further discusses NDCs and their importance.

Combining datasets: data coverage and sub-sector reporting

Data availability is a challenge which limits the number of countries which can be analysed using this methodology. Most of the analyses in this tool rely on data from both the IEA and UNIDO datasets. Because of varying data coverage between the two datasets, data coverage is lower than it would be if only a single data source were used. When data is not available for a given country in both datasets, many of the analyses presented in section 4 of this tool are not possible. However, data may only be

[39] Data refers to gross exports including re – exports rather than exports as other EQUIP tools to fully capture the business opportunity aspect of environmental goods.

[40] "Based on the IEA globally collected energy data, the IEA estimates of CO_2 emissions from fuel combustion are a global database obtained following harmonised definitions and comparable methodologies across countries. They do not represent an official source for national submissions, as national administrations should use the best available country-specific information to complete their emissions reporting. The IEA CO_2 estimates can be compared with those reported by countries to the UNFCCC Secretariat to highlight possible problems in methods, input data or emission factors. Still, care should be used in interpreting the results of any comparison since the IEA estimates may differ from a country's official submission for many reasons" in: IEA. 'CO_2 Emissions from Fuel Combustion: Database Documentation.' Paris: International Energy Agency, 2018. Available at: http://wds.iea.org/wds/pdf/WorldCO_2_Documentation.pdf.

incomplete for a few years of indicators and the analyst should consider checking the time series for the data even if data for the latest year is not available.

A second challenge when analysing IEA, UNIDO or the combined datasets is changes in terms of sector-level aggregation. Care must be taken as different datasets report data at varying aggregation level. IEA Emission and Energy Data report data at a maximum of 11 sub-sectors, while INDSTAT data may be reported in up to 23 sub-sectors. Sub-sector data must be aggregated into compatible groups before being compared across databases. It should be noted also that data reported at the manufacturing sub-sector level may change over time. Data disaggregation and data quality is constantly improving which in many cases means that countries are collecting and reporting more and more disaggregated data at the sub-sector level. This may require that some data at the sub-sector level be aggregated for the grouping to match one another if comparing data over a period (e.g. CAGR or decomposition indicators).

Non-specified emissions from Manufacturing Industries

IEA CO_2 emission dataset presents data on total manufacturing emission as well as at a sub-sector level. However, data at the sub-sector level is not always available for all sub-sectors. Emission of sub-sectors which cannot be individually distinguished are grouped under 'non-specified' (referred to as 'other manufacturing' in this module) emissions. 'Non-specified' includes all emission data for which there is insufficient data to allocate to a specific sub-sector. Sub-sector data may vary from country to country and therefore which sub-sectors are included in 'non-specified' will depend on which sub-sectors separate data is reported. In many cases, data on CO_2 emission in manufacturing industries is entirely aggregated into 'non-specified'. That is, no sub-sector data is available. Due to this difference in definition of the sub-sector, any comparisons of the 'non-specified' sub-sector between different countries should be avoided. Similarly, a sudden change in the size of the 'other' sector in a given country might be due to changes in the reporting of the respective national statistical office.

Emissions from manufacture of coke, refined petroleum products and nuclear fuel

In the IEA data, emissions generated in the production of other fossil fuels are allocated separately from the rest of manufacturing emissions. While the refinement and processing of fossil fuels is part of manufacturing activities (sub-sector 23 in ISIC Rev. 3), emissions from fuel combusted in oil refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries are reported in a separate category within the IEA data – under 'Other energy industry own use'. However, data disaggregation of 'Other energy industry own use' is insufficient to distinguish between the emissions generated, for example, in the extraction of petroleum (an activity which is part of Mining and Quarrying) and the refining of petroleum (which is part of Manufacturing activities).

6 Possible extensions and further readings

Climate change is a broad and complex topic. The environmental and climate change impacts of industrialization have frequently been analysed separately from the policies promoting it. However, there is a growing need for industrial policy formulation to take into account industry's impacts and contribution to climate change. To ensure sustainable industrialization, the analyses of other EQuIP tools can be further enhanced by integrating and combining the climate change adaptation and mitigation elements from this tool. Furthermore, considering and limiting the impacts of climate change through mitigation action also has the potential to generate a number of beneficial impacts on the economy and enhance the results of other industrial policy pillars discussed in other modules of the EQuIP toolkit.

It is not the intention of this tool to present a list of all available indicators and data sources to analyse and address the topic of manufacturing and climate change. Being so, this analysis can be expanded in many directions. This section provides a list of further reading material for the analyst should they decide to expand their analysis to include additional elements which go beyond what is covered in this present module and tailor it to their needs. In addition to this, a list of selected additional available data sources is provided.

Additional Datasets

Climate Action Tracker. Available at: https://climateactiontracker.org/

DIE. Klimalog Platform. Available at: https://klimalog.die-gdi.de/

GAINS Model. International Institute for Applied Systems Analysis. Available at: http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html

OECD. Carbon dioxide emissions embodied in international trade. Available at: https://stats.oecd.org/Index.aspx?DataSetCode=IO_GHG_2019

UNFCCC. 'GHG data from UNFCCC'. United Nations Framework Convention on Climate Change (UNFCCC). Available at: https://unfccc.int/process-and-meetings/transparency-and-reporting/greenhouse-gas-data/ghg-data-unfccc/ghg-data-from-unfccc.

World Bank. The NDC Platform. Available at: http://spappssecext.worldbank.org/sites/indc/Pages/INDCHome.aspx

Additional Reading

Cristea, A., Hummels, D., Puzzello, L., & Avetisyan, M. (2013). Trade and the greenhouse gas emissions from international freight transport. *Journal of Environmental Economics and Management*, *65*(1), 153–173. https://doi.org/10.1016/j.jeem.2012.06.002.

Feng, K., Chapagain, A., Suh, S., Pfister, S., & Hubacek, K. (2011). Comparison of Bottom-up and Top-down Approaches to Calculating the Water Footprints of Nations. *Economic Systems Research*, *23*(4), 371–385. https://doi.org/10.1080/09535314.2011.638276.

IPCC (2015). Chapter 10: Industry. In: *Fifth Assessment Report Climate Change 2014: Mitigation of Climate Change*. International Panel on Climate Change. Available at: https://www.ipcc.ch/assessment-report/ar5/.

Ma, L., Chong, C., Zhang, X., Liu, P., Li, W., Li, Z., & Ni, W. (2018). LMDI Decomposition of Energy-Related CO2 Emissions Based on Energy and CO2 Allocation Sankey Diagrams: The Method and an Application to China. *Sustainability*, *10*(2), 344. https://doi.org/10.3390/su10020344.

Ma, X.-W., Ye, Y., Shi, X.-Q., & Zou, L.-L. (2016). Decoupling economic growth from CO 2 emissions: A decomposition analysis of China's household energy consumption. *Advances in Climate Change Research*, *7*(3), 192–200. https://doi.org/10.1016/j.accre.2016.09.004.

Wiebe, K. S. and N. Yamano (2016). Estimating CO2 Emissions Embodied in Final Demand and Trade Using the OECD ICIO 2015: Methodology and Results. OECD Science, Technology and Industry Working Papers, No. 2016/5, OECD Publishing, Paris. Available at: https://doi.org/10.1787/18151965.

Vaidyula, M., & Hood, C. (2018). *Tracking progress towards NDCs and relevant linkages between Articles 4, 6 and 13 of the Paris Agreement* (OECD/IEA Climate Change Expert Group Papers No. 2018/04). https://doi.org/10.1787/358aae24-en.

7 Appendices

Appendix 7A. **Nationally Determined Contributions**

Nationally determined contributions (NDCs) pledged at the Paris Agreement embody countries efforts in mitigating and adapting to climate change. NDCs present each country's ambitions for cutting or avoiding the GHG emissions, outlining their climate change mitigation action plan that Parties have pledged to undertake in addressing the issue. Emission mitigation targets for 2030 are part of the internationally coordinated effort to keep a global temperature rise this century well below 2 degrees Celsius compared to pre-industrial levels.

Mitigation measures of each country have been determined in a different way when compared to previous emission mitigation agreements, such as 1997 Kyoto Protocol. Under the Kyoto Protocol, a standard approach to a mitigation target was set and agreed to. The Annex I Parties pledged to reduce their emissions level in 2012 by 8 to 10 percent compared to their 1990 emissions. However, under the Paris agreement, pledges and targets related to mitigating emissions were set by each country ('nationally determined') depending on how much they could 'contribute' to the effort, given a country's specific conditions. NDCs, as opposed to Kyoto pledges, come in many shapes and forms and differ also in terms of how targets are set, which GHG are included as part of the mitigation target, as well as in other ways (see Box 9 for more details).

Among developing countries, NDC targets have frequently been established in relation to a Business As Usual (BAU) scenario. A Business As Usual (BAU) scenario estimates how much emissions *would have occurred* if no action to curb them had been taken and target mitigation is frequently set against this 'no-action' scenario. The BAU scenarios themselves are determined by a number of modelling assumptions and are subject to revisions. This, in turn, results in the emissions target itself being revised when the BAU scenario is revised and can create a 'moving target" for policy makers in terms of their emission mitigation.

NDCs are the tool in the hands of policy makers to plan mitigation actions, calculate the mitigation potential, and – through subsequent communications with the UNFCCC – monitor the progress of the country in achieving these targets. The differences which exist among the NDC targets make it difficult to track and compare the progress in achieving them across countries. Under the NDCs, each country is charged with producing its own detailed analysis, studies, and targets. These are based on national data sources and national emission inventory data, which is what is reported to the UNFCCC.

Furthermore, mitigation commitments and targets in NDCs are set for countries' total emissions reduction. Action plans and subsequent communications with the UNFCCC in many cases specify which emissions sources will be reduced (e.g. through reduction of emissions from transportation, the switch to renewable energy sources, from agricultures, land-use etc.), but action plans may be revised as country´s conditions and mitigation opportunities emerge.

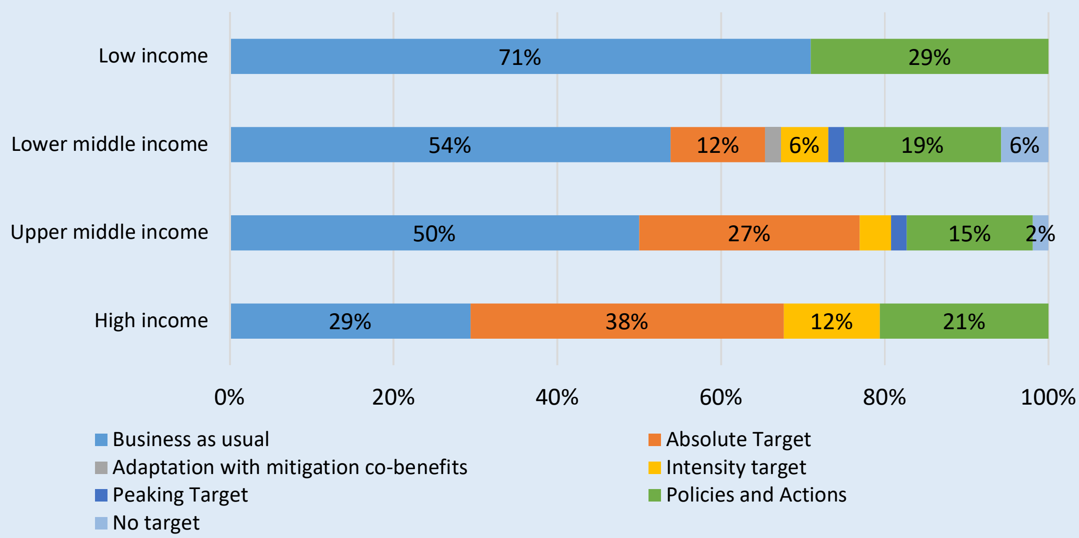
Box 9. Differences in how mitigation targets are defined in Nationally Determined Contributions

Mitigation targets are discussed in a variety of ways in the NDCs of each country. How mitigation targets are established vary mainly in three ways. The first is related to which GHGs are included in the emission target. For example, the targets may include only CO_2 emissions, or also other GHGs (such as CH_4, N_2O, SF_6 and others). In addition, the targets of some countries also consider emissions generated from Land Use, Land-Use Change and Forestry (LULUCF).

The second way in which NDCs of countries vary is in term of how the emission target is set. Some countries have established fixed level (or absolute) reduction targets. For these a specific level of emission (absolute target or an intensity target) is set and countries seek to reach that target. About 50% of countries have defined emission mitigation NDCs based on an emission reduction compared to a Business as Usual scenario. That is, their mitigation pledge is associated to the reduction of emission (as a percentage reduction) compared to a situation in which no effort to mitigate emission would have been made. A few countries have established trajectory targets that express the trajectory of future GHG emissions, which can include a target for emissions peaking. A group of countries have also outlined their intended polices, actions plans, or emission mitigation without specifying the total mitigation intended. Other targets, which related to specific non-GHG emission or renewable energy, are also included in NDCs of some countries. In some countries, multiple targets are set.

Countries at different stages of development have relied on different types of pledges. As it can be seen in Figure 23, Low- and Middle-income countries have made more pledges that are either Business as Usual target or established policies and actions plans .

Figure 23. What type of Nationally Determined Contribution have countries made?



Source: NDC Explorer (Klimalog Platform, German Development Institute).

Third, many countries have determined both unconditional (mitigation implemented with national resources) and conditional targets, which are conditional upon international provision of means of its implementation (e.g. capacity building, technology development and transfer, financing etc.). Finally, it is important to note that the methodologies used in the construction of the national emission statistics vary between countries. Mitigation targets are set using national statistics which may vary compared to the data available in international databases. As a result, this creates difficulties in comparing the targets and progress towards these targets in the NDCs of different countries.

The commitment related to achieving the total reduction and the action plan is also subject to change. Both these facts make it difficult to create a single approach for evaluating the progress in a relatively simple and straight-forward approach.

As discussed in section 5, emission data as reported by the IEA may vary due to differences in the methodology and sources used in each of these datasets. Due to these differences, IEA data in many cases cannot be considered the official source for monitoring.

Box 10. Exemplifying the possible discrepancies between national and international sources

EQuIP emphasizes the use of internationally comparable sources for comparing and benchmarking across countries. For this, an international data source (such as the IEA data which has been used in other sections of this report) is required. However, NDCs BAU and targets are set based on national data sources. Comparing these targets with internationally available data can present some challenges if discrepancies exist between these two data sources, especially as these discrepancies may be significant. While these differences may be smaller when comparing countries total emission, they become more evident when analysing only the manufacturing emissions or going even deeper to the manufacturing sub-sector level. On the basis of the IEA dataset for manufacturing and construction, Indonesia's emissions in 2014 were of 94MtCO_2. However, Indonesia's Nature Conservancy (TNC) reported emissions of 170 MtCO_2 (plus 46 MtCO_2eq of IPPU (Industrial Processes and Product Use) emissions). This difference between the two sources makes matching the IEA data with the NDC target a challenge. As a result, given statistical and technical differences, internationally comparable statistics (e.g. IEA) cannot be used to monitor the implementation of policies with data conducted with national statistics. Nevertheless, EQuIP remains a purely empirically based tool which can still be extremely useful for the NDCs as it allows benchmarking countries with very detailed NDCs such as Indonesia. Indonesia´s NDC is very detailed, but the use of statistical data does not allow comparing what is happening in the country with other comparators. NDCs also require the breakdown of fuel combustion emissions into IPPU emissions and energy related emissions. IEA data normally include IPPU and energy related emissions together. However, a new IEA dataset is now available including this breakdown to facilitate national submissions analyse.

Unfortunately, the differences that exist between the NDCs lead to the fact that there is no one common guideline for policy makers to follow in order to monitor in a practical and *quick* way the progress towards the accomplishment of a target. Measuring progress toward a target is a challenge because the emission target, in most cases, rests on a series of assumptions itself. Integrated assessment models can the tools to analyse progress on emissions targets on the basis of scenarios assuming different hypotheses[41]. Determining how much industrial emission will contribute to emission mitigation is also a challenge as target specified NDCs typically do not refer to targets specifically for industry.

EQuIP can help policy makers view, discuss, and begin to answer key questions regarding NDCs and the ways through which these targets can be achieved, such as:

[41] Among others the GAINS model is an authoritative tool developed by IIASA to monitor cost –effective emissions control strategies. http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.html

- Is it possible to have a (rough) idea about how much progress a country has made towards reaching its emission target?
- How can a policy maker get a sense of the role that industry will play in reaching the overall mitigation target?

No available cross-country data can replace the accurateness of the study conducted specifically for a country in the submissions of an NDC. Practitioners and policy makers of international organizations are often exposed to work which obliges them to orient their work to create such cross-country comparisons. However, policy makers working at the national level can also gain insights by conducting comparisons and analysing other countries work and action plans for GHG emission mitigation to understand other countries strategies and plans. As previously seen, these comparisons cannot, as of yet, be conducted in a quick and easy way across multiple countries and, therefore, need to be analysed on a tailored case-by-case basis.

Appendix 7B. **Technical description of the decomposition of manufacturing emissions**

The decomposition of manufacturing energy-related emissions is a methodology which allows for decomposing the total change in manufacturing CO_2 emissions of given period into the factors which drive this change. This technical appendix provides a step-by-step explanation of how the emission decomposition can be calculated for a given country using Excel. It presents how to go from the indicators presented in the EQuIP tools to an analysis of the graphs presented in section 4B.4 of the tool, which identify the factors are contributing to emissions growth over time. The method allows for breaking down a change in emissions into 'effects', or the 'drivers', which help explain the cause of the change in emissions. For a discussion, refer to section 4B.4 of this report.

In this example, we use CO_2 emission data and Primary Energy Consumption data from the International Energy Agency (IEA) and manufacturing value added data from UNIDO's INDSTAT database. If no data is available for the country that will be analyzed, national data sources can be used instead. This method can also be used to compare drivers of emissions across different countries. However, doing so requires the use of the same data sources for all countries being analyzed.

7B.1 Required Data for Analysis

As discussed in section 4B.4 of this tool, the decomposition of manufacturing emissions analyses how CO_2 emissions are driven by different factors associated to them. The decomposition needs to be produced at the manufacturing sub-sector level. To begin the analysis, we require data on manufacturing CO_2 emissions:

a) CO_2 emissions of manufacturing sub-sectors (indicator 3.13 – in $MtCO_2$)

The analysis presents how emissions are related to industrial development, production technology and the fuel types used to produce energy. This relation is captured in four indicators in the analysis:

b) Total Manufacturing Value Added (see EQuIP Tool 1, indicator 2.1 – in million USD)
c) Share of manufacturing sub-sector in MVA: divide the MVA of each sub-sector by MVA total (see EQuIP Tool 2, indicator 2.5.1 – in share)
d) Energy intensity of manufacturing sub-sectors (see EQuIP Tool 6.1, indicator 3.4 – in Ktoe per million USD)
e) Emission per unit of energy (indicator 3.17 – in $MtCO_2$ per Ktoe)

Since the decomposition is calculated at the manufacturing sub-sector level, it is important to ensure that the manufacturing sub-sector data for the three series are comparable as well. For example, the IEA reports data on emissions from foods and beverages (ISIC Rev. 3 sector 15 and 16) together, while UNIDO's INDSTAT may report data for food (ISIC Rev. 3 sector 15) and beverages (ISIC Rev. 3 sector 16) separately. Check the correspondence of the data with the ISIC sector groups to ensure you are comparing the same sub-sectors across all the data we will use. For the IEA data, sub-sector data is presented in the sub-sector in Table 1. We add the INDSTAT data to have the same sub-sector groups.

7B.2 Preparing for the Decomposition Analysis

The decomposition analyses demonstrate the change in emissions over a given **period of time**. Therefore, to begin the analysis, it is necessary to select an initial (start) and final (end) year. In our example in this technical appendix, the analysis focuses on the change in CO_2 emissions of the Republic of Korea between the years of 2000 and 2016. Data should be organized at the most disaggregated sub-sector level possible. Because of how the IEA aggregates its data, in our example, we have also added a sector group called 'other manufacturing sectors' which groups all other manufacturing emissions which are not assigned to other sectors. In our example, we include all 'non-specified' data under the 'other manufacturing sectors" row. At the bottom of the sub-sectors being listed, we calculate the 'Total" which refers to the sum of that indicators for all sectors. Below is an example of how the data can be organized:

	A	B	C	D	E	F	G	H	I	J	K
41		2000					2016				
42		(MtCO2)	(Mio USD)	(%)	(ktoe / mio USD)	(MtCO2 / ktoe)	(MtCO2)	(Mio USD)	(%)	(ktoe / mio USD)	(MtCO2 / ktoe)
43		CO2	MVA Total	Sub-sector Share in MVA	Energy Intensity	Emission per unit of energy	CO2	MVA Total	Sub-sector Share in MVA	Energy Intensity	Emission per unit of energy
44	Food and Bev. (15t16)	3.2	189,020	8%	0.10	0.0020	2.1	316,418	9%	0.07	0.0011
45	Textile and Leather (17t19)	6.4	189,020	8%	0.27	0.0015	1.5	316,418	5%	0.13	0.0008
46	Wood (20)	0.3	189,020	1%	0.19	0.0014	0.1	316,418	1%	0.20	0.0003
47	Pulp and Paper (20t22)	4.5	189,020	5%	0.26	0.0019	3.0	316,418	3%	0.25	0.0014
48	Chemicals (24)	7.7	189,020	10%	0.34	0.0012	6.6	316,418	14%	0.18	0.0008
49	Non-metallic mineral products (26)	18.5	189,020	4%	0.74	0.0033	17.7	316,418	4%	0.42	0.0032
50	Iron, Steel and Non-ferrous Metals (27)	29.8	189,020	7%	0.58	0.0042	19.9	316,418	7%	0.47	0.0019
51	Machinery, Electric and Electronic (28t32)	1.8	189,020	37%	0.04	0.0006	2.5	316,418	26%	0.09	0.0003
52	Transport Equipment (34t35)	4.4	189,020	13%	0.09	0.0019	2.2	316,418	22%	0.04	0.0007
53	Other manufacturing sectors	17.7	189,020	7%	0.37	0.0035	14.6	316,418	9%	0.16	0.0031
54	Total	94.3	189,020	100%	0.20	0.0025	70.2	316,418	100%	0.14	0.0015

Box 11. Dealing with incomplete data

For the decomposition, it is essential to have complete data for the same sub-sector groupings for the initial and final year of the analysis. For example, if only information on MVA of a given sub-sector in the initial year is missing, it is not possible to include that sub-sector in the analysis separately. When incomplete data occurs due to insufficient sub-sector coverage, the sub-sector with incomplete data needs to be included as part of the 'Other manufacturing sector' group which includes all the remaining emissions, energy use and value added data which cannot be further disaggregated.

For some countries where data coverage is limited, only data for the total manufacturing sector will be available. For these countries, the decomposition analysis can still be conducted following the step by step method presented here. The difference will be that we will not be able to calculate the *Structural Change Effect* (this effect will be zero) since there is insufficient information on the composition of the manufacturing sector. If this is the case, include only one sector in your analysis ('Total') and follow the same steps for analysing the data at the sub-sector level.

Note that if we multiply the four indicators at the manufacturing sub-sector, we arrive at value of CO_2 emissions. That is, for each sub-sector:

$$CO_2 \text{ emissions} = \text{MVA Total} \times \text{Sub– sector share in MVA} \times \text{Energy Intensity} \times \text{Emission per unit of Energy}$$

The indicators 2 through 5 are an identity (equivalent) of the CO_2 emissions of that manufacturing sub-sector. Calculating CO_2 emission of a manufacturing sub-sector through these four other indicators.

which also arrive at its value allows us to analyze which of these dimensions is related to the change in emissions. With this identity we can analyze which are the drivers of emission change.

7B.3 Calculating the (LMDI) Decomposition Analysis

Decomposing the change in emissions means comparing the change in indicators in over the period being analysed. In the decomposition presented here four effects are presented: the growth effects, the structural change effects, the energy efficiency effect and the fuel-switching effect. The decomposition captures, for a given period of time, CO_2 emissions from manufacturing activities as the product of changes in the level of manufacturing activities, the relative size of each sub-sector in manufacturing, the change in the energy intensity of manufacturing activities and the emission intensity of the energy (or the fossil fuel mix).

For this decomposition, we will explain how to calculate a decomposition using the additive *Logarithmic Mean Divisia Index* (LMDI) method[42]. While mathematically complex, the LMDI decomposition has been widely applied to analysing the influencing factors of CO_2 emissions growth in many countries[43].

The **first step** is to calculate the change in CO_2 emission between the initial and final year. That is, we calculate the emissions at the end year (2016 in our example) minus de emission in the initial year (2010). The four effects we will calculate will be equal to this **change in** CO_2 **emission** in the period.

	A	B
58		Change in CO2
59	Food and Bev. (15t16)	=G29-B29
60	Textile and Leather (17t19)	-4.9
61	Wood (20)	-0.2
62	Pulp and Paper (20t22)	-1.5
63	Chemicals (24)	-1.1
64	Non-metallic mineral products (26)	-0.8
65	Basic metals (27)	-9.9
66	Machinery, Electric and Electronic (28t32)	0.7
67	Transport Equipment (34t35)	-2.2
68	Other manufacturing sectors	-3.1
69	Total	-24.1

[42] Due to non-linear interactions between terms, if a simple decomposition is used, the sum of the percentage changes of the four factors may not perfectly match the percentage change of total CO_2 emissions. To avoid this, a more complex decomposition method is needed. Based on Ang (2004), we opt for the logarithmic mean Divisia index (LMDI) method. Please refer to the paper for a complete explanation on how to use the LMDI method. It should be noted that the four effects should be considered neither as fundamental driving forces in themselves, nor as generally independent from each other. For instance, substituting coal with gas as a source of energy generation would likely affect both the CO_2 emission per unit of energy used as well as the energy intensity of the sector. See: B.W Ang, 'Decomposition Analysis for Policymaking in Energy" *Energy Policy* 32, no. 9 (June 2004): 1131–39, https://doi.org/10.1016/S0301-4215(03)00076-4.

[43] See Ma et al. (2018) for a literature review. Ma, L., Chong, C., Zhang, X., Liu, P., Li, W., Li, Z., & Ni, W. (2018). LMDI Decomposition of Energy-Related CO_2 Emissions Based on Energy and CO_2 Allocation Sankey Diagrams: The Method and an Application to China. Sustainability, 10(2), 344. https://doi.org/10.3390/su10020344.

The **second step** is to calculate the logarithmic mean of the change in CO_2 emission for each manufacturing sub-sector. This logarithmic mean of CO_2 will later be used to calculate different effects. The formula for calculating the logarithmic mean of change in CO_2 is:

$$log\ mean\ of\ CO2 = \frac{CO2_{final\ year} - CO2_{initial\ year}}{\ln\left(CO2_{final\ year}\right) - \ln\left(CO2_{initial\ year}\right)}$$

Using Excel, the logarithmic mean of change in CO_2 emissions is calculated using the formula below:

	A	B	C
58		Change in CO2	logarithmic mean (CO2)
59	Food and Bev. (15t16)		=(G29-B29)/(LN(G29)-LN(B29))
60	Textile and Leather (17t19)	-4.9	3.4
61	Wood (20)	-0.2	0.2
62	Pulp and Paper (20t22)	-1.5	3.7
63	Chemicals (24)	-1.1	7.1
64	Non-metallic mineral products (26)	-0.8	18.1
65	Basic metals (27)	-9.9	24.5
66	Machinery, Electric and Electronic (28t32)	0.7	2.1
67	Transport Equipment (34t35)	-2.2	3.2
68	Other manufacturing sectors	-3.1	16.1
69	Total	-24.1	81.7

The **third step** is calculating the four effects of the decomposition. Each effect captures the change in one of the four indicators we have data for. We will first calculate the growth effect. The effect is calculated by multiplying, for each sub-sector, the logarithmic mean of CO_2 by the logarithm of the division of the indicator (in this case, total MVA) in the final year by the initial year. That is, growth effect can be calculated as:

$$Growth\ effect = log\ mean\ of\ \ CO2\ \times\ ln\left(\frac{MVA_{final\ year}}{MVA_{initial\ year}}\right)$$

In excel, the growth effect is calculated as we can see below:

	A	B	C	D
58		LMDI (CO2)	Change in CO2	Growth Effect
59	15t16	2.6	-1.1	=B59*LN(H29/C29)
60	17t19	3.4	-4.9	1.74
61	20	0.2	-0.2	0.09
62	21t22	3.7	-1.5	1.91
63	24	7.1	-1.1	3.68
64	26	18.1	-0.8	9.32
65	27	24.5	-9.9	12.63
66	28t32	2.1	0.7	1.10
67	34t35	3.2	-2.2	1.64
68	Non-specified	16.1	-3.1	8.30
69	Total	81.7	-24.1	42.07

In the same way, the other effects (structural change, energy efficiency and fuel switching) are also calculated (for each sub-sector) by multiplying the logarithmic mean of CO_2 by the logarithm of the division between the final and initial year. Similar to the growth effect, the other effects can be calculated as:

$$Strcutural\ Change\ effect = log\ mean\ of\ \ CO2\ \times\ ln\left(\frac{Share\ in\ MVA_{\ final\ year}}{Share\ in\ MVA_{initial\ year}}\right)$$

$$Energy\ Efficiency\ effect = \log mean\ of\ \ CO2\ \times\ ln\left(\frac{Energy\ Efficiency_{final\ year}}{Energy\ Efficiency_{initial\ year}}\right)$$

$$Fuel\ Switching\ effect = log\ mean\ of\ \ CO2\ \times\ ln\left(\frac{Emission\ Intensity\ of\ Energy_{final\ year}}{Emission\ Intensity\ of\ Energy_{initial\ year}}\right)$$

The formulas for each of the effects can be calculated as we see in the example below:

	A	B	C	D	E	F	G
45		Change in CO2	logarithmic mean (CO2)	Growth Effect	Structural Change Effect	Energy Efficiency Effect	Emission Intensity Effect
46	Food and Bev. (15t16)	=G29-B29	=(G29-B29)/(LN(G29)-LN(B29))	=C46*LN(H29/C29)	=C46*LN(I29/D29)	=C46*LN(J29/E29)	=C46*LN(K29/F29)
47	Textile and Leather (17t19)	=G30-B30	=(G30-B30)/(LN(G30)-LN(B30))	=C47*LN(H30/C30)	=C47*LN(I30/D30)	=C47*LN(J30/E30)	=C47*LN(K30/F30)
48	Wood (20)	=G31-B31	=(G31-B31)/(LN(G31)-LN(B31))	=C48*LN(H31/C31)	=C48*LN(I31/D31)	=C48*LN(J31/E31)	=C48*LN(K31/F31)
49	Pulp and Paper (20t22)	=G32-B32	=(G32-B32)/(LN(G32)-LN(B32))	=C49*LN(H32/C32)	=C49*LN(I32/D32)	=C49*LN(J32/E32)	=C49*LN(K32/F32)
50	Chemicals (24)	=G33-B33	=(G33-B33)/(LN(G33)-LN(B33))	=C50*LN(H33/C33)	=C50*LN(I33/D33)	=C50*LN(J33/E33)	=C50*LN(K33/F33)
51	Non-metallic mineral products (26)	=G34-B34	=(G34-B34)/(LN(G34)-LN(B34))	=C51*LN(H34/C34)	=C51*LN(I34/D34)	=C51*LN(J34/E34)	=C51*LN(K34/F34)
52	Basic metals (27)	=G35-B35	=(G35-B35)/(LN(G35)-LN(B35))	=C52*LN(H35/C35)	=C52*LN(I35/D35)	=C52*LN(J35/E35)	=C52*LN(K35/F35)
53	Machinery, Electric and Electronic (28t32)	=G36-B36	=(G36-B36)/(LN(G36)-LN(B36))	=C53*LN(H36/C36)	=C53*LN(I36/D36)	=C53*LN(J36/E36)	=C53*LN(K36/F36)
54	Transport Equipment (34t35)	=G37-B37	=(G37-B37)/(LN(G37)-LN(B37))	=C54*LN(H37/C37)	=C54*LN(I37/D37)	=C54*LN(J37/E37)	=C54*LN(K37/F37)
55	Other manufacturing sectors	=G38-B38	=(G38-B38)/(LN(G38)-LN(B38))	=C55*LN(H38/C38)	=C55*LN(I38/D38)	=C55*LN(J38/E38)	=C55*LN(K38/F38)
56	Total						

Note that we did not calculate the effects for the 'Total' row (manufacturing total). To arrive at the Total, we sum the effects of each of the sub-sectors. For example, the 'Total' Growth effects are the sum of the growth effects of the each of the sectors or the sum of cells D46 through D55 in our example:

D56 =SUM(D46:D55)

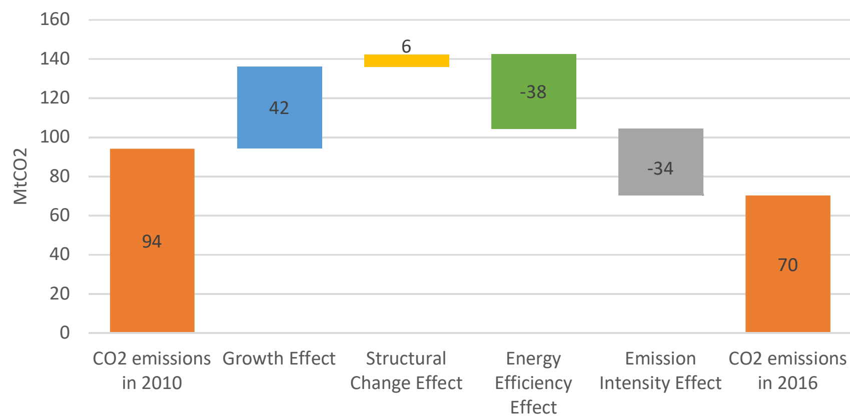
	A	B	C	D	E	F	G
45		Change in CO2	logarithmic mean (CO2)	Growth Effect	Structural Change	Energy Efficiency	Emission Intensity
46	Food and Bev. (15t16)	-1.10	2.6	1.35	0.22	-1.11	-1.55
47	Textile and Leather (17t19)	-4.90	3.4	1.74	-1.82	-2.56	-2.26
48	Wood (20)	-0.20	0.2	0.09	-0.01	0.01	-0.30
49	Pulp and Paper (20t22)	-1.50	3.7	1.91	-2.25	-0.12	-1.04
50	Chemicals (24)	-1.10	7.1	3.68	2.68	-4.73	-2.73
51	Non-metallic mineral products (26)	-0.80	18.1	9.32	1.24	-10.49	-0.88
52	Basic metals (27)	-9.90	24.5	12.63	1.58	-5.03	-19.07
53	Machinery, Electric and Electronic (28t32)	0.70	2.1	1.10	-0.73	1.81	-1.48
54	Transport Equipment (34t35)	-2.20	3.2	1.64	1.57	-2.46	-2.95
55	Other manufacturing sectors	-3.10	16.1	8.30	3.90	-13.41	-1.89
56	Total	-24.10		41.75	6.39	-38.10	-34.14

We can check if the effects have been correctly calculated by checking if (for each sub-sector) the sum of four effects is equal to the change in CO_2. For example, in our example, check if the change in CO_2 emissions from the Food and Beverage sub-sector (-1.1, cell B46) is equal to the sum of the four effects we calculated (1.35 + 0.22 - 1.11 -1.55, cells D46 + E46 + F46 + G46). In the example, we can see that the result is correct. The same should be true for the 'Total'.

Organizing the decomposition results: manufacturing total

Now that we have the complete results of the decomposition, we need to organize the results to interpret them. Using graphs is a good way to quickly visualize data and interpret it. We will first look at the decomposition results for the total manufacturing sector. If you are using Office 365, we recommend using a *Waterfall Chart* to analyse the results of the decomposition. This is the same type of graph displayed in the analysis section of this paper. If using the *Waterfall Chart*, the results of the decomposition can be displayed as:

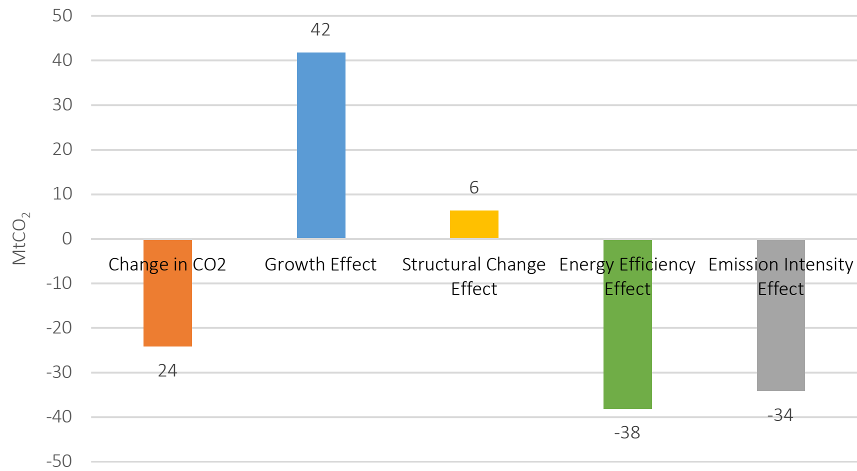
24. Decomposition results using a Waterfall Chart



This figure is the same as the one presented in the analysis section 4B.4. Here we compare the manufacturing CO_2 emission in the initial year (2010) and the final year (2016) and breakdown this change into the four effects we have just calculated. By presenting the results we have calculated as a table in this *Waterfall Chart,* it becomes easier to visualize the how much each of the effects *helped drive* the change in emissions during the period being analysed.

If you are using an earlier version of Excel, the *Waterfall Chart* will not be available. However, we can also interpret the results of the decomposition using a bar chart. The graph below also presents the same decomposition results that have been calculated but are presented using a bar chart. A second difference is that we now include the change in CO_2 emission of the period. In terms of interpretation, this graph also can be used to identify the main contributors to the growth of emissions (Growth Effect) and to the reduction of emissions (Energy Efficiency Effect).

Figure 25. Decomposition Example using Bar chart



Organizing the decomposition results: manufacturing sub-sectors

The results of the decomposition can also be presented for each of the sub-sectors. In order to calculate the decomposition of emissions of the total manufacturing sector, we have already had to calculate the decomposition of each of the sub-sectors. When analysing the results at the sub-sector level, there is one main difference: at the sub-sector level, the growth effect is the sum of the growth effect we have calculated plus the Structural Change Effect. The reason for this is that, at the sub-sector level, there is no need to separate how the change in the manufacturing productive structure changes since we are focusing on a more detailed level of analysis. Therefore, we do not need to separate the *relative growth of each sub-sector* (the structural change) from the *absolute growth* (growth effect). This again requires some reorganizing of the data in order to produce the graphs.

	A	B	C	D	E
73		Change in CO2	Growth Effect (*)	Energy Efficiency Effect	Emission Intensity Effect
74	Food and Bev. (15t16)	-1.1	1.6	-1.1	-1.6
75	Textile and Leather (17t19)	-4.9	-0.1	-2.6	-2.3
76	Wood (20)	-0.2	0.1	0.0	-0.3
77	Pulp and Paper (20t22)	-1.5	-0.3	-0.1	-1.0
78	Chemicals (24)	-1.1	6.4	-4.7	-2.7
79	Non-metallic mineral products (26)	-0.8	10.6	-10.5	-0.9
80	Basic metals (27)	-9.9	14.2	-5.0	-19.1
81	Machinery, Electric and Electronic (28t32)	0.7	0.4	1.8	-1.5
82	Transport Equipment (34t35)	-2.2	3.2	-2.5	-3.0

In the example above, Growth Effect (*) refers to the sum of the previous Growth Effect and Structural Change Effect that were calculated. Using this adapted Growth Effect (*), we can represent the decomposed emission change in the Iron, Steel and Non-Ferrous Metals sector using either the *Waterfall Chart* (see section 4B.4) or a bar chart.

7B.4

The table below details the data sources, variables, and indicators required for calculating each of the decomposition components described above.

Table 4. Data sources of the decomposition components

Decomposition Component	Indicator	Variables	Source
Change in CO_2 emissions of manufacturing (sub-)sector	CO_2 emissions of manufacturing sub-sector as a share of manufacturing	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
Growth effect	Manufacturing Value Added (USD)	Manufacturing Value added (USD, current prices)	UNIDO's Industrial Statistics Database (INDSTAT2)
Structural Change Effect	Manufacturing sub-sector share in MVA (share)	Manufacturing Value added, by sub-sector (USD, current prices)	
		Manufacturing Value Added (USD, current prices)	
Energy Intensity Effect	Emission intensity of energy of manufacturing (sub-) sector (kg CO_2 / toe)	CO_2 emission from fuel combustion of manufacturing sub-sectors ($MtCO_2$)	International Energy Agency (IEA CO_2 Emissions from Fuel Combustion Statistics)
		Total Final Energy Consumption (TFC) of manufacturing sub-sector (in Ktoe)	International Energy Agency (World Energy Balances)
Fuel-Switching Effect	Emission per unit of Energy Used, (sub-) sectors (toe per USD)	Total Final Energy Consumption (TFC) of manufacturing sub-sector (Ktoe)	
		Manufacturing Value added, by sub-sector and country (million USD, current prices)	UNIDO's Industrial Statistics Database (INDSTAT2)

Appendix 7C. **List of Climate-friendly Goods**

The table below presented the list of climate-friendly goods produce by the World Bank[44]. Goods listed are 6-digit HS 2002 codes.

Table 5. List of Climate-friendly Goods

HS 2002	Product Description
392010	Plates, sheets, film, foil and strip, of non-cellular plastics, not reinforced, laminated, supported or similarly combined with other materials, without backing, unworked or merely surface-worked or merely cut into squares or rectangles (excl. self-adhesive products, and floor, wall and ceiling coverings of heading 3918)
560314	Nonwovens, whether or not impregnated, coated, covered or laminated, n.e.s., of man-made filaments, weighing > 150 g
701931	Mats of irregularly laminated glass fibres
730820	Towers and lattice masts, of iron or steel
730900	Reservoirs, tanks, vats and similar containers, of iron or steel, for any material 'other than compressed or liquefied gas', of a capacity of > 300 l, not fitted with mechanical or thermal equipment, whether or not lined or heat-insulated (excl. containers specifically constructed or equipped for one or more types of transport)
732111	Appliances for baking, frying, grilling and cooking and plate warmers, for domestic use, of iron or steel, for gas fuel or for both gas and other fuels (excl. large cooking appliances)
732190	Parts of domestic appliances non-electrically heated of heading 7321, n.e.s.
732490	Sanitary ware, incl. parts thereof (excl. cans, boxes and similar containers of heading 7310, small wall cabinets for medical supplies or toiletries and other furniture of chapter 94, and fittings, complete sinks and wash basins, of stainless steel, complete baths and fittings)
761100	Reservoirs, tanks, vats and similar containers, of aluminium, for any material (other than compressed or liquefied gas), of a capacity of > 300 l, not fitted with mechanical or thermal equipment, whether or not lined or heat-insulated (excl. containers specifically constructed or equipped for one or more types of transport)
761290	Casks, drums, cans, boxes and similar containers, incl. rigid or collapsible tubular containers, of aluminium, for any material (other than compressed or liquefied gas), of a capacity of <= 300 l, n.e.s.
840219	Vapour generating boilers, incl. hybrid boilers (excl. central heating hot water boilers capable also of producing low pressure steam)
840290	Parts of vapour generating boilers and super-heated water boilers, n.e.s.
840410	Auxiliary plant for use with boilers of heading 8402 or 8403, e.g. economizers, super-heaters, soot removers and gas recoverers;
840490	Parts of auxiliary plant of heading 8402 or 8403 and condensers for steam or other vapour power units, n.e.s.
840510	Producer gas or water gas generators, with or without their purifiers; acetylene gas generators and similar water process gas generators, with or without their purifiers (excl. coke ovens, electrolytic process gas generators and carbide lamps)
840681	Steam and other vapour turbines, of an output > 40 MW (excl. those for marine propulsion)
841011	Hydraulic turbines and water wheels, of a power <= 1.000 kW (excl. hydraulic power engines and motors of heading 8412)
841090	Parts of hydraulic turbines and water wheels, n.e.s.; hydraulic turbine regulators
841181	Gas turbines of a power <= 5.000 kW (excl. turbo-jets and turbo-propellers)
841182	Gas turbines of a power > 5.000 kW (excl. turbo-jets and turbo-propellers)

[44]World Bank (2008), *International Trade and Climate Change.* Washington D.C.: World Bank Group

841581	Air conditioning machines incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle ‘reversible heat pumps’ (excl. of a kind used for persons in motor vehicles and self-contained or ‘split-system’ window or wall air conditioning machines)
841861	Compression type units whose condensers are heat exchangers
841869	Refrigerating or freezing equipment and absorption heat pumps (excl. refrigerating and freezing furniture)
841919	Instantaneous or storage water heaters, non-electric (excl. instantaneous gas water heaters and boilers or water heaters for central heating)
841940	Distilling or rectifying plant
841950	Heat exchange units (excl. instantaneous heaters, storage water heaters, boilers and equipment without a separating wall)
841989	Machinery, plant or laboratory equipment, whether or not electrically heated, for the treatment of materials by a process involving a change of temperature such as heating, cooking, roasting, sterilizing, pasteurizing, steaming, evaporating, vaporizing, condensing or cooling, n.e.s. (excl. machinery used for domestic purposes and furnaces, ovens and other equipment of heading 8514)
841990	Parts of machinery, plant and laboratory equipment, whether or not electrically heated, for the treatment of materials by a process involving a change of temperature, and of non-electric instantaneous and storage water heaters, n.e.s.
848340	Gears and gearing for machinery (excl. toothed wheels, chain sprockets and other transmission elements presented separately); ball or roller screws; gear boxes and other speed changers, incl. torque converters
848360	Clutches and shaft couplings, incl. universal joints, for machinery
850161	AC generators ‘alternators’, of an output <= 75 kVA
850162	AC generators ‘alternators’, of an output > 75 kVA but <= 375 kVA
850163	AC generators ‘alternators’, of an output > 375 kVA but <= 750 kVA
850164	AC generators ‘alternators’, of an output > 750 kVA
850231	Generating sets, wind-powered
850680	Primary cells and primary batteries, electric (excl. spent, and those of silver oxide, mercuric oxide, manganese dioxide, lithium and air-zinc)
850720	Lead acid accumulators (excl. spent and starter batteries)
853710	Boards, cabinets and similar combinations of apparatus for electric control or the distribution of electricity, for a voltage <= 1.000 V
854140	Photosensitive semiconductor devices, incl. photovoltaic cells whether or not assembled in modules or made-up into panels; light emitting diodes (excl. photovoltaic generators)
900190	Lenses, prisms, mirrors and other optical elements, of any material, unmounted (excl. such elements of glass not optically worked, contact lenses and spectacle lenses)
900290	Lenses, prisms, mirrors and other optical elements, mounted, of any material, being parts of or fittings for instruments or apparatus (excl. objective lenses for cameras, projectors or photographic enlargers or reducers, such elements of glass not optically worked, and filters)
903210	Thermostats
903220	Manostats (excl. taps, cocks and valves of heading 8481)