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EQuIP

Enhancing the Quality of Industrial Policies

TOOL 6

Greening Industry – Module 1: Energy Efficiency

EQuIP Tool 6: Greening Industry

Module 1: Energy Efficiency

Summary Sheet

Enhancing the Quality of Industrial Policies (EQuIP) – Tool 6	
Name of the tool:	Greening Industry/ Module 1: Energy Efficiency
Objective:	The objective of this tool is to provide a set of indicators and related analyses, which allow (a) to assess the performance of a country regarding energy efficiency and energy vulnerability of its manufacturing sector, and (b) to identify priority sub-sectors with low energy efficiency performance and/or a high vulnerability regarding its energy supply due to limited domestic energy supply.
Key questions addressed:	How self-sufficient is an economy with regard to energy supply, i.e. how dependent is the overall economic system on energy imports from abroad? Which manufacturing sub-sectors are most dependent on energy imports and thus most vulnerable with regard to their energy supply? How do manufacturing sub-sectors compare in terms of their energy efficiency, i.e. the value added created per unit of energy consumption? Is the energy efficiency of certain sub-sectors below or above the benchmark of OECD countries? Which sectors should receive priority attention in energy efficiency initiatives?
Indicators used:	Final energy consumption by manufacturing sub-sectors Share of the manufacturing sector in national energy consumption Energy efficiency (value added of manufacturing sub-sectors per energy consumption of manufacturing sub-sectors) Energy self-sufficiency (domestic energy production per domestic energy demand)

Contents

1. Introduction

1.1. Objectives of the Greening Industry Tool

Improving resource efficiency is a key strategy to create greener industries. This tool helps the user understand and evaluate how efficiently a country and, in particular, its manufacturing industries use natural resources in their production activities. This is of specific relevance as increasing resource efficiency – as well as increasing recycling rates – is understood to be essential when aiming to improve the environmental sustainability of an industrial system. Improving industrial performance in this regard is closely related to creating and supporting "green industries". Green industries provide environmental technologies, goods and services that contribute to reducing negative environmental impacts, and as such are an important driver in creating sustainable industrial processes. When new "green jobs" are created with these principles in mind, the result can be a triple-win (economic-environmental-social) scenario.

The greening industry tool focuses on inputs of natural resources, such as energy, raw materials and water to manufacturing industries and assessments of resource efficiency. Issues related to pollution and waste production, which go back to the environment as an output of production activities, are only considered in this tool to a limited extent, although these categories are of high importance for the environmental performance of industries. A focus on resource inputs is taken as the positive economic and employment impacts typically associated with the greening of industries are generated through using natural resources more efficiently as inputs in manufacturing processes.

In the final version of the greening industry tool, all main categories of natural resources of relevance for manufacturing industries, i.e. energy, raw materials and water, will be covered (see Figure 1). However, this first module of the greening industry tool focuses only on energy use and energy efficiency, as energy data is the most readily available on both the national and manufacturing sub-sectors levels.

Box: "Energy efficiency" versus "energy intensity"

The two indicators of energy efficiency and energy intensity describe two sides of the same issue. In the context of economic-environmental assessments, energy efficiency illustrates how much economic value (for example, a certain amount of value added measured in dollars) is being generated per unit of energy input. Broadly speaking, energy intensity is the inverse of energy efficiency. The intensity indicator describes, how much energy inputs were required to produce one unit of economic value. High energy efficiency thus goes along with low energy intensity and vice versa.

In the greening industry tool as described below, the energy efficiency indicator will be used. However, the energy intensity indicator can also be found in various databases and publications (see Figure 2 below).

1.2. The Environmental Pillar in Relation to Other Pillars of the Toolkit

The greening industry tool, or "environmental pillar", of this toolkit is closely interrelated with the economic and social pillars of the toolkit, with activities in this pillar affecting the performance in the others; hence, specific economic, social and environmental trends go hand in hand.

For the specific case of energy, enhanced energy efficiency and energy self-sufficiency could have the following positive impacts on other thematic areas in the toolkit:

Industrial growth/competitiveness:

- Energy efficiency can be regarded as a driver of economic growth, as it reduces production costs and increases the international competitiveness of manufacturing companies.
- This is particularly important for small- and medium-sized enterprises (SMEs), which often have a larger productivity gap to international productivity benchmarks compared to larger companies.

Enhanced technological sophistication:

- Positive effects, such as the adoption (or even domestic development) of new production technologies with higher energy efficiency, will provide a positive push for technological sophistication.
- Investments into renewable energy technologies can trigger technological development (see renewable energy policies in some European countries).

Poverty alleviation:

- Local and low-cost renewable energy systems, e.g. solar cooking systems, can lower the energy costs of households.
- Higher energy efficiency in households through use of more energy efficient appliances can also lower household spending on energy.

Employment and wage generation:

- There are potential job-generating effects of higher energy efficiency (see, for example, UNIDO's Industrial Development Report 2011).
- Investments in renewable energy systems can also have a positive employment effect (see European countries with "green jobs" discussion).

Health and wellbeing:

- Depending on the rate of efficiency increases, a more efficient use of natural resources could lead to a decrease in overall resource use and, as a consequence, to less pressure on the environment. This would result in better air quality and cleaner ecosystems, having both a direct and indirect impact of human health and hence health-care costs.

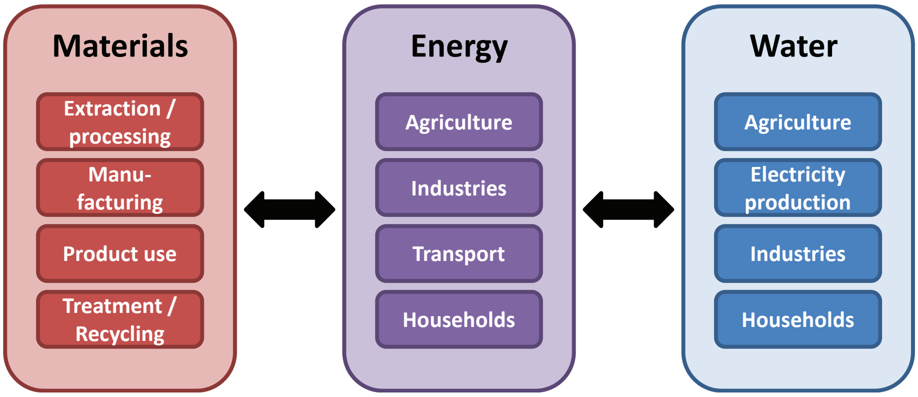
Externalities of resource use:

- Extraction and processing of natural resources often takes place in politically instable areas where institutions are weak and often unable to provide the necessary framework for these processes. As a consequence, in many cases resource extraction has been known to go along with (sometimes violent) conflicts and/or environmental destruction or degradation. Increased resource efficiency can lower the pressure on the local resources and provide a means to diversify industrial structures.

1.3. The Energy Efficiency Module in Relation to Other Categories of Natural Resource Use

The use of energy is also related to the use of other natural resources, such as raw materials and water, which will be further explored in a later version of this tool. Figure 1 shows a schematic representation on the inter-linkages between the three categories of energy, materials and water.

Figure 1: The inter-linkages between different categories of resource use



Source: adapted from BIO IS et al. (2012)

Energy use is closely related to the use of raw materials, such as minerals or metal ores, as energy is required in all stages of a product's life-cycle: from extraction and processing of raw materials through product manufacturing and transport, to energy required in the use-phase of a product. Finally, energy is also required for end-treatment of products and recycling. Similar inter-linkages can be observed with water use, which is used, for example, in electricity production, as well as in many industrial production processes.

Increasing energy efficiency in manufacturing industries and a shift towards renewable energies will therefore have impacts on other resource categories. On the one hand, the demand for primary energy carriers, such as fossil fuels, will be lower compared to a development path without energy efficiency improvements, which will in relative terms reduce material consumption and related environmental impacts. Water use in electricity production could also be positively affected, when industrial energy efficiency is significantly increased and demand for electricity is lowered. At the same time, a shift towards renewable energies could increase the demand for biomass (e.g. wood or energy plants) with rising demand for irrigation water.

Therefore, a comprehensive assessment of a strategy for greening industries needs to take into account several resource categories in addition to energy use and efficiency (see Section 5). While this tool will present indicators to analyse the energy efficiency and dependency performance of a country's industry, Table 1 also provides a short overview of the indicators used for raw material and water use. The table also includes indicators for emissions, which could be used as counterparts for the energy related indicators. In addition, the most recent data sources are provided.

Table 1. Overview of indicators used for raw material and water use and GHG emissions

Name of indicator	Source	Latest year	Number of countries covered
Resource input indicators			
Domestic Material Extraction	SERI/WU Global Material Flows Database	2011	220
Domestic Material Consumption (DMC)	SERI/WU/ifeu Global Material Flows Database	2010	179
Water Withdrawal	FAO AQUASTAT	2005-2013	200
Water Footprint	Water Footprint Network	1996-2005	172
Emission indicators			
Energy-related CO_2 emissions	International Energy Agency (IEA)	2011	132
Intensity of energy-related CO_2 emissions	International Energy Agency (IEA)	2011	132
GHG emissions	World Resources Institute (WRI)	2010	183
GHG emissions intensity (CO_2e/GDP)	World Resources Institute (WRI)	2010	183

Further development of other modules of the environmental pillar will use this table as a starting point which indicators would be best suited for their analysis, considering coverage of the relevant aspects of resource use, and availability and quality of data.

2. Module 1 on Energy Efficiency – An Overview

The objective of this tool is to:

- Inform about the energy use of manufacturing sector as a whole, as well as specific sub-sectors, and illustrate whether the energy efficiency per unit of value added in the manufacturing sector has decreased or increased;
- Assess the vulnerability of individual manufacturing sub-sectors on energy imports by disaggregating energy use by different energy carriers and analysing this information in the context of national energy self-sufficiency for oil, coal and gas; and,
- Benchmark sub-sectoral energy use and energy efficiency with the performance of corresponding industries in other countries.

When discussing resource use and resource efficiency, one very important aspect is to benchmark resource use against the available resource stock, in order to get an insight into the extend the use of a specific resource (in this case energy) that's being used is sustainable or not. While very important, the application of using specific indicators is very restricted due to data limitations. As a consequence, in the present version of the energy efficiency module, the analysis of stocks is included only indirectly via the indicator self-sufficiency.

2.1. Importance of Energy Efficiency for the Greening Industry Agenda

Increasing energy efficiency in the manufacturing industries can bring about several key advantages:

2.1.1. Energy Efficiency Supports Competitiveness

In its Industrial Development Report of 2011, UNIDO analysed the relation between the energy intensity of the manufacturing industries of various countries and their international competitiveness, measured with UNIDO's Competitive Industrial Performance Index (see the *Industrial Growth and Capacity* Tool, as well as the *Export and Industrial Deepening* Tool for an analysis of countries industrial competitiveness). In Figure 2 below, the energy intensity is shown on the x-axis, while the competitiveness indicator is found on the y-axis.

Figure 2: The relation between energy intensity and competitiveness

Source: UNIDO (2011)

The figure illustrates a clear positive relation between low energy intensity (which equals high energy efficiency) and strong industrial competitiveness. Industrialised countries (blue dots in Figure 2) are characterised by very low levels of energy intensity: their manufacturing industries generally require less than 0.5 tonnes of oil equivalents to generate US$ 1,000 of manufacturing value added (MVA). At the same time, these countries rank highest with regard to international competitiveness (see, for example, the cases of Japan, Germany or the USA). Thus, increasing energy efficiency, for instance through technological development, may have positive economic effects through energy savings. This can be translated into cost savings, which result in increased competitiveness. Developing and emerging economies (red dots in Figure 1) generally have much higher energy inputs per manufacturing value added and are thus located to the right of Figure 1. Their competitiveness index is generally lower, i.e. below 0.25.

There is a significant potential to decrease energy intensity (or increase energy efficiency) in manufacturing industries, which could also strengthen a countries' performance on world markets. The potential for energy efficiency improvements in developing countries are especially large in small- and medium-size industrial enterprises, which tend to be less energy efficient than larger firms. Depending on the industrial sector, energy efficiency improvements could save between 10% and 85% of the total energy costs, and thus significantly contribute to cost reductions in production (see UNIDO, 2011).

2.1.2. Energy Efficiency Increases Energy Security

With increasing efficiency in domestic energy use the overall energy demand is decreased compared to a development path without energy efficiency improvements. Hence, energy supply can be covered to a larger extent from domestic sources, while the share of energy imports from abroad can be reduced. Improving the energy efficiency performance thus can contribute to reducing the vulnerability of manufacturing industries on energy imports, which is of specific relevance when energy imports stem from politically unstable countries.

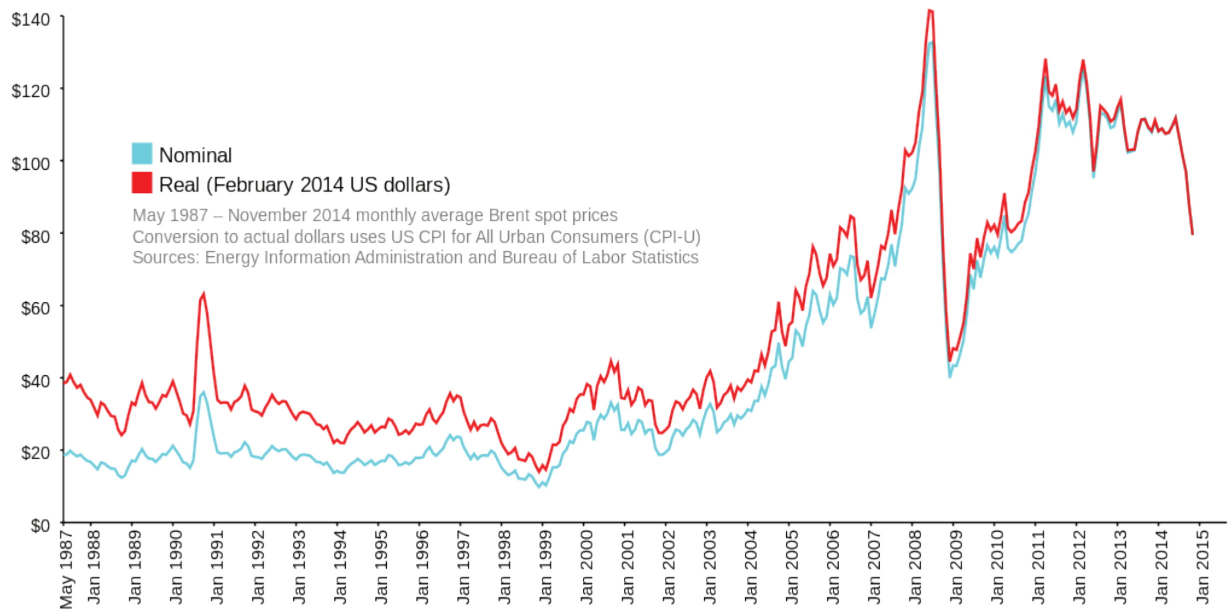
While reserves of traditional energy sources such as oil, coal or gas are often concentrated in certain countries and geographical areas, significant opportunities to increase energy efficiency exist across all developing countries. In combination with a shift towards renewable energies from local sources, increasing energy efficiency can thus contribute to improving the energy security of the manufacturing sector.

However, it must be taken into account that building up a strong renewable energy sector does not come at zero cost, rather it requires companies and governments to invest significantly in renewable energy technologies and energy infrastructure.

2.1.3. Reducing Exposure to Fluctuating and Rising Energy Prices

Energy prices were highly volatile in recent years, with a clear upward trend since the turning of the millennium (see Figure 3 for the price development of crude oil below). While the average oil price was between US$ 30 and 40 per barrel between end of the 1980s and beginning of the 2000s, it has significantly increased in the recent years, peaking around US$ 140 in 2008, and fluctuating on a level between US$ 100 and 120 per barrel since then.

Figure 3: Global crude oil prices (Brent), 1987-2013, in nominal and real values



Source: US Energy Information Administration (2014)

Fluctuating energy prices along with generally upward price trends make financial planning in companies more difficult, as the costs related to energy consumption are difficult to estimate and generally growing. With increasing energy efficiency – especially regarding the use of fossil energy – this planning risk can be reduced. Limiting the exposure to and dependency from world energy markets can also be reached by expanding the share of domestically produced renewable energy in the overall energy mix. However, supply risks can also occur in the case of an increased share of energy from renewable energy resources, for example due to the dependency of bio-energy on weather and climate conditions with potential impacts on prices of renewable energies.

As this toolkit is aimed at low-income countries, which are commonly constrained in terms of their electrification, there are also large social spill-over effects in terms of enhanced energy security.

2.1.4. Energy Efficiency Can Create Positive Impacts on Employment

Traditionally, companies reduced labour costs in order to bring down overall costs of production. This cost-cutting strategy puts pressures on the labour markets. Energy efficiency – and resource efficiency more general – can be seen as an additional, and possibly alternative strategy to reduce production costs. Cost-effective, energy-efficiency improvements generally increase the overall productivity of a company or a manufacturing sub-sector, which accelerates growth and thus potential expansions in employment (see the inclusiveness tool for more employment-oriented analyses).

In developing countries, micro-, small- and medium-size manufacturing firms often make up the largest part of industrial employment and therefore have a key role in creating jobs. As the energy saving potentials are generally larger in SMEs compared to bigger companies (see above), increased energy efficiency offers a particularly huge potential for increasing productivity, and thus employment, too (UNIDO, 2011).

2.1.5. Energy Efficiency Helps Safeguarding Future Generations and Protecting the Climate

Developing and emerging economies have rapidly increased their absolute energy consumption in the past decades and will, according to global energy outlooks (see IEA, 2013), continue to increase their energy demand, as affluence rises and industrial production expands. In this context, increasing energy efficiency can provide an important contribution to ensuring that the resource base necessary for industrial development will not be deprived for current or future generations. This will also lower the risk of conflicts about the access to energy resources.

Compared to an industrial development path without energy efficiency improvements, increasing energy efficiency will also bring about a reduction of negative environmental impacts related to resource extraction and processing, as well as lowering the production of emissions and pollutants from manufacturing. Combustion of fossil fuels is by far the number one contributor to global greenhouse gas emissions. Shifting to energy carriers with less climate impacts, such as renewable energy sources, along with increasing energy efficiency, would contribute significantly to mitigating climate change and to reduce exposure to its negative consequences. This is of special relevance, as low-income countries will be affected the most by climate change. In this way, a decrease in (the growth of) emissions will also decelerate the pressure of climate change.

The Key Message: Increase Energy Efficiency and Shift towards Renewable Energy Sources

As illustrated in this chapter, increasing energy efficiency has various positive effects and can bring about economic, social and environmental benefits. Through reducing costs of production, higher energy efficiency contributes to improved competitiveness of manufacturing companies and positive employment effects. In a situation of often rapidly rising demand for energy, an energy efficiency strategy also reduces the dependency on energy imports from abroad, and enables better management and planning of energy costs. The various positive effects can particularly be exploited when higher energy efficiency is combined with a strategy to increase the supply of energy from national renewable energy sources.

3. Methodology

This section provides guidance on indicators that can be used to perform the various analyses illustrated and explained in this section. We present and discuss four indicators, which allow us to:

- Illustrate the contribution of energy use of the manufacturing sectors to total national energy consumption[1];
- Reflect to what extent a country is self-sufficient regarding various energy carriers (e.g. fossil fuels, nuclear, renewable energy), which has important implications for the energy security of the manufacturing sector;
- Show the absolute energy use of various manufacturing sub-sectors and its composition by energy carriers;
- Illustrate the energy efficiency in manufacturing sub-sectors by linking sectoral energy consumption to data on manufacturing value added.

We suggest using the International Energy Agency (IEA) as the main source for data on energy production and consumption on the global level. With its annual energy statistics and energy balances for OECD and non-OECD countries, the IEA provides the most detailed data on energy production and energy use of countries and economic sectors worldwide. IEA data are widely applied in economic and environmental assessments by national and international organisations. However, some important issues regarding data quality and completeness also need to be considered (see box below).

A short note on the quality and completeness of IEA energy data

In its publications, the IEA states that national energy statistics often do not comply with international accounting standards. 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.

Data at the level of individual manufacturing sub-sectors is also limited in the IEA energy balances for non-OECD countries. In many cases, data on final energy consumption in manufacturing industries is aggregated to a single category called "non-specified", which makes analyses of energy efficiency on the level of single sub-sectors difficult (see Section 3.3).

If such a situation of missing disaggregation of energy consumption data occurs for a specific country, the user should try to obtain more detailed data from national statistical institutions and from other non-official sources (e.g. business reports, academic studies, etc.).

1 Note that indicators used here focus on the production perspective (e.g. in case of the indicator of Domestic Energy Production as part of the self-sufficiency indicator), or a partial consumption perspective (such as Total Primary Energy Supply, which considers imports of energy carriers from other countries). A full consumption (or energy footprint) perspective would mean considering energy inputs along the supply chain of products finally consumed in a country. This dimension cannot be considered with the suggested indicators in this chapter.

3.1. Share of the Manufacturing Sector in National Energy Consumption

Definition of the indicator

This indicator illustrates the aggregated contribution of the manufacturing sector of a country in its total final energy consumption (TFC). Apart from the manufacturing sector, national TFC includes other economic sectors, such as agriculture, transport or services, and energy use by households. TFC reflects the total actual energy use of sectors and households, i.e. it does not contain distribution losses, energy consumption of the energy sector itself, and non-energy consumption of energy carriers. This indicator can potentially be disaggregated by various energy carriers (e.g. fossil fuels, nuclear, renewable energy).

Main questions

Main questions that can be addressed with this indicator:

- How important is the manufacturing-related energy consumption in the respective economy, and how has its share in total TFC changed over time?
- How large is the fraction of energy consumed by the manufacturing sector with regard to different energy carriers?

Data sources

Data are provided by the International Energy Agency (IEA) as part of the World Energy Balances, which reports basic energy data for 163 countries from 1960 to 2011 (current; 2012 for some countries).

Table 2. Indicator description Share of the Manufacturing Sector in National Energy Consumption

Indicator	Variables	Source
Share of energy consumption of manuf. sector in national energy consumption	Total Final Energy Consumption (TFC) by sector (in percentage shares)	International Energy Agency / World Energy Balances

3.2. Energy Self-sufficiency

Definition of the indicator

The indicator of energy self-sufficiency relates the domestic energy production to the total primary energy supply (TPES)[2] of a country. Therefore, it illustrates the extent of dependence on foreign energy imports. If the domestic energy production exactly equals energy supply, the self-sufficiency rate is one (1). Numbers above one (1) illustrate that domestic production is higher than total supply, while numbers below one (1) indicate a dependency on imports. The IEA publishes data for overall energy self-sufficiency as well as disaggregated data of self-sufficiency rates regarding coal, oil and gas.

The national energy self-sufficiency can then be connected with the sectoral energy consumption to assess foreign energy dependency on the level of manufacturing industries (see Section 4).

2 TPES equals production plus imports minus exports minus international bunkers plus or minus stock changes.

Main questions

Questions that can be addressed with this indicator:

- How self-sufficient is an economy with regard to energy, i.e. how dependent is the overall economic system on energy inputs from abroad?
- Which energy carriers show particularly low self-sufficiency rates?
- When linked to data on sub-sectoral energy use by energy carriers: How dependent are various manufacturing sub-sectors on energy imports?

Data sources

Data are provided by the International Energy Agency (IEA) in the section on World Indicators, which reports basic energy data for 163 countries from 1960 to 2011 (currently; 2012 for some countries).

Table 3. Indicator description Energy Self-sufficiency

Indicator	Variables	Source
Energy self-sufficiency	Domestic Energy Production (in ktoe)	International Energy Agency / Energy balances
	Total Primary Energy Supply (in ktoe)	

3.3. Energy Consumption of Manufacturing Sub-sectors

Definition of the indicator

The final energy consumption (TFC) of a specific manufacturing sub-sector is defined as the energy that is supplied to a sub-sector for all final energy uses such as heating, cooling and lighting.

The IEA data disaggregate a number of manufacturing industries. The IEA industry classification was aggregated to comply with the third revision of the International Standard Industrial Classification of All Economic Activities (ISIC Rev. 3), which is generally applied by UNIDO in its industrial databases. We also provide a rough classification in energy intensity groups based on the assessment in UNIDO's Industrial Development Report (2011).

Table 4: IEA manufacturing industries grouped according to ISIC Rev 3

Industry	ISIC Rev 3 correspondence	Energy intensity groups (adapted from UNIDO, 2011)
Petrochemicals	Division 23	High energy intensive
Non-metallic minerals	Division 26	High energy intensive
Metals	Division 27	High energy intensive
Paper, pulp and printing	Divisions 21 and 22	Moderate to high energy intensive
Textile and leather	Divisions 17 to 19	Moderate to high energy intensive
Wood and wood products	Division 20	Moderate energy intensive
Chemicals and chemical products	Division 24	Moderate energy intensive
Food and tobacco	Divisions 15 to 16	Low to moderate energy intensive
Machinery	Divisions 28 to 32	Low to moderate energy intensive
Non-specified	Divisions 25, 33 and 36	Low to moderate energy intensive
Transport equipment	Divisions 34 and 35	Low energy intensive

Data on sub-sector TFC can be disaggregated by various energy carriers. This will be important when assessing the vulnerability of industries regarding energy imports.

Main questions

Questions that can be addressed with this indicator:

- What are the most energy consuming manufacturing sub-sectors in a country (in absolute terms)?
- How has the sub-sector composition in overall manufacturing energy use changed over time (illustrating structural changes)?
- How does the absolute energy consumption of a given manufacturing sub-sector perform in international comparison, i.e. compared to benchmarks?
- Broken down by energy carriers and linked to self-sufficiency data for a country: How vulnerable are specific manufacturing sub-sectors with regard to energy imports?

Data sources

Data are provided by the International Energy Agency (IEA) in the section on World Energy Balances, which reports basic energy data for 163 countries from 1960 to 2011 (currently; 2012 for some countries).

Table 5. Indicator description Energy Consumption of Manufacturing Sub-sectors

Indicator	Variable	Source
Energy consumption of manufacturing sub-sectors	Total Final Energy Consumption (TFC) of manufacturing sub-sectors (in ktoe)	International Energy Agency / World Energy Balances

3.4. Energy Efficiency of Manufacturing Sub-sectors

Definition of the indicator

The energy consumption of a manufacturing sub-sector (manufacturing TFC or, in short, MTFC) can be related to data on value added in order to illustrate how much economic value is being generated per unit of energy input. The energy efficiency of a manufacturing sub-sector is thus calculated as the total value added of a sub-sector divided by its energy consumption. The energy efficiency indicator can be calculated either for a single manufacturing sub-sector or for all manufacturing sub-sectors of a country as an aggregate. This provides an overview of the country situation (see Figure 4). This indicator is calculated as the aggregated manufacturing value added (MVA) divided by the energy consumption of all manufacturing sub-sectors of a country.

Main questions

Main questions that can be addressed with this indicator:

- How do manufacturing sub-sectors compare in terms of their energy efficiency, i.e. the value added created per unit of energy consumption?
- How has the energy efficiency of manufacturing sub-sectors developed over time?
- Is the energy efficiency 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

For data on TFC of manufacturing sub-sectors, see indicator above. Data on value added of manufacturing sub-sectors is provided by UNIDO's INDSTAT database, which provides detailed sectoral data from 1990 to 2011.

Table 6. Indicator description Energy Efficiency of Manufacturing Sub-sectors

Indicator	Variables	Source
Energy efficiency of manufacturing (sub-) sector	Total Final Energy Consumption (TFC) of manufacturing sub-sector (in ktoe)	International Energy Agency / World Energy Balances
	Value added of manufacturing sub-sector (in national currencies or current US$)	UNIDO INDSTAT 4

4. Analysis

In this section, it is illustrated how the indicators presented in the Section 3 can be applied for the assessment of energy efficiency and energy self-sufficiency (or, alternatively, energy vulnerability) of the manufacturing sub-sectors in various developing countries. Hence, the purpose of this analysis is to get a better idea of where a country stands in terms of its energy efficiency and self-sufficiency, so as to determine priorities for enhancing resilience and competitiveness.

The section starts with an analysis providing an overview of the large spectrum of specific situations, which countries around the world face with regard to the two key dimensions of energy efficiency and energy self-sufficiency in the manufacturing sector. This overview guides the reader towards selecting four country examples characterised by different performance levels regarding energy efficiency in the manufacturing sector, as well as different situations regarding energy self-sufficiency.

For these four countries, the aim is to understand how much pressure the manufacturing sector is putting on overall energy consumption, and the main types of energy carriers it requires. First, an overview is provided of the national structure of energy consumption and the role of the manufacturing sub-sectors as a contributor to the country total. Then the national energy self-sufficiency situation is assessed, with regard to the three main fossil energy carriers, i.e. coal, oil and gas. This analysis provides the background information on the national situation, which is required for the assessment on the level of manufacturing sub-sectors.

In a next step, the national information is applied to the context of energy consumption of the manufacturing sub-sectors, which is also broken down by different energy carriers. This allows us to evaluate the energy vulnerability on the level of single manufacturing sub-sectors. Furthermore, this allows those sub-sectors with the highest energy vulnerability and thus with the most pressing need to design targeted interventions to reduce energy dependency to be identified.

Finally the focus is set on the issue of energy efficiency and the assessment of the manufacturing sub-sectors in the example countries perform with regard to energy efficiency. The differences in energy efficiency levels between various manufacturing sub-sectors are illustrated and the efficiency performance of manufacturing sub-sectors in the example countries with the OECD average compared. This allows us to pinpoint the manufacturing sub-sectors that have the largest potential for energy efficiency improvements in the future. Also the data requirements and data limitations for this type of analysis are discussed.

4.1 Country Overview: Energy Efficiency and Energy Self-sufficiency

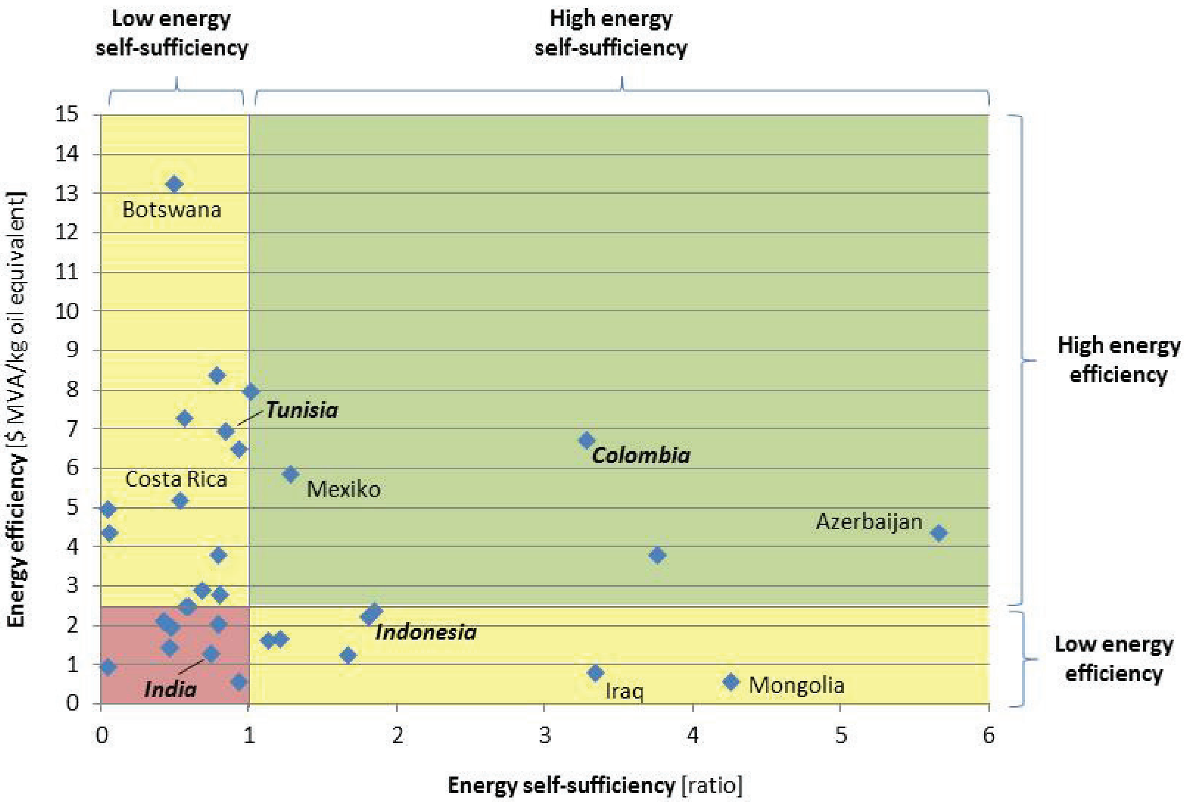
In the introduction, we argued that achieving high levels of energy efficiency could result in multiple win-win situations, creating positive economic impulses, stimulating the labour market and having a potentially positive impact on the environment. This is particularly the case when a strategy to increase energy efficiency is combined with a transformation of the energy mix away from fossil fuels towards renewable resources, which, when keeping environmental considerations in mind during their production, have lower impacts on the climate and the ecosystems.

The section therefore starts with an investigation on how various developing countries perform with regard to the two main indicators of energy efficiency and energy self-sufficiency. This analysis allows us to identify where a country stands in terms of its energy efficiency and self-sufficiency and thus where action should be focused.

Figure 4 plots a number of countries, illustrating the energy self-sufficiency ratio on the x-axis and the energy efficiency performance on the y-axis. In order to group the large number of countries, we define four quadrants, with both axes being divided into two sections. For separating countries with low versus high energy self-sufficiency, the limit is set at a ratio of one (1), i.e. a situation, in which all energy required for the national economy can in principle be supplied by domestic resources. All countries that have ratios below one (1) have low energy self-sufficiency, i.e. their domestic demand in one year exceeds the domestic production of energy in that year, whereas ratios above one (1) indicate that the domestic production exceeds the domestic demand for energy.

On the y-axis, the energy efficiency of the manufacturing sector is illustrated, calculated as the aggregated MVA, divided by the energy consumption of the manufacturing sector of a country. The line dividing countries with low energy efficiency from those with high energy efficiency is being drawn at US$ 2.5 of MVA per kilogram of oil equivalent to energy input. This value represents an approximation of the global average energy efficiency across all manufacturing sub-sectors, which has been calculated on the basis of the IEA and UNIDO INDSTAT data for a group of around 80 countries from all continents.

Figure 4: Energy efficiency and energy self-sufficiency, selected countries, 2010



Source: IEA (2014): World Energy Balances

Figure 4 illustrates that countries across the world have very different profiles regarding the two key indicators of energy efficiency and energy self-sufficiency. The upper-right quadrant (shaded in green colour) contains countries that perform well in both dimensions, having levels of domestic energy production (partly far) beyond their national demand and thus high ratios of self-sufficiency. They also perform above the world average with regard to energy efficiency. The two blocks shaded in yellow indicate that one of the two dimensions can be addressed as being critical. Either these countries have low ratios of energy self-sufficiency or a low energy efficiency performance of their manufacturing sub-sectors. The countries that need to worry most about their current situation regarding energy use and efficiency are located in the bottom-left corner of the Figure 4 (red colour). These countries perform critically with regard to both energy efficiency and energy self-sufficiency.

For the following exemplary analyses and detailed assessments we select four example countries that represent the four different situations as explained above. Apart from the criterion of the representation of different profiles, we aimed to select representative countries from various continents. We also cross-checked the availability of energy consumption data from the IEA and only selected those countries for which a satisfying level of disaggregated energy consumption data was available for various manufacturing sub-sectors. For that reason, countries such as Botswana, Azerbaijan, Mongolia or Iraq could not be selected as example countries.

The final selection revealed the following four country examples:

- **Colombia** as a Latin American country with high domestic energy production and thus a very favourable energy self-sufficiency index along with a high average energy efficiency performance in its manufacturing sub-sectors.
- **Indonesia** as an example for a country well endowed with domestic energy resources, but with energy efficiency values below the global average and far below the performance of Colombia.
- **Tunisia** as an African representative characterised by a high energy efficiency in its manufacturing sub-sectors; i.e. almost three times the economic value is being generated per unit of energy input compared to the global average; but at the same time lacking sufficient domestic energy supply.
- Finally, **India** is selected as an example country, which has a low energy efficiency performance in its manufacturing sub-sectors, i.e. only half the global average value is being generated per unit of energy input, and at the same time a critical situation regarding the ratio of energy demand per domestic energy production can be observed.

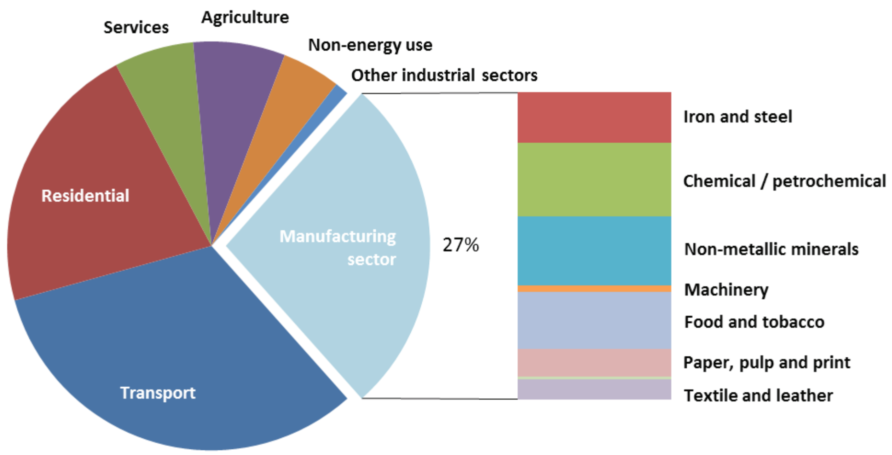
Summarising, we started with an analysis providing an overview of the large spectrum of specific situations, which countries around the world face with regard to the two key dimensions of energy efficiency and energy self-sufficiency in the manufacturing sector. Building on this, the four example countries, Colombia, India, Indonesia, and Tunisia were selected because they are characterised by different performance levels regarding energy efficiency in the manufacturing sector, as well as different situations regarding energy self-sufficiency. In the following section, the focus will be set on the assessment on these four example countries.

4.2 The Importance of Manufacturing Sub-sectors for Total Energy Consumption

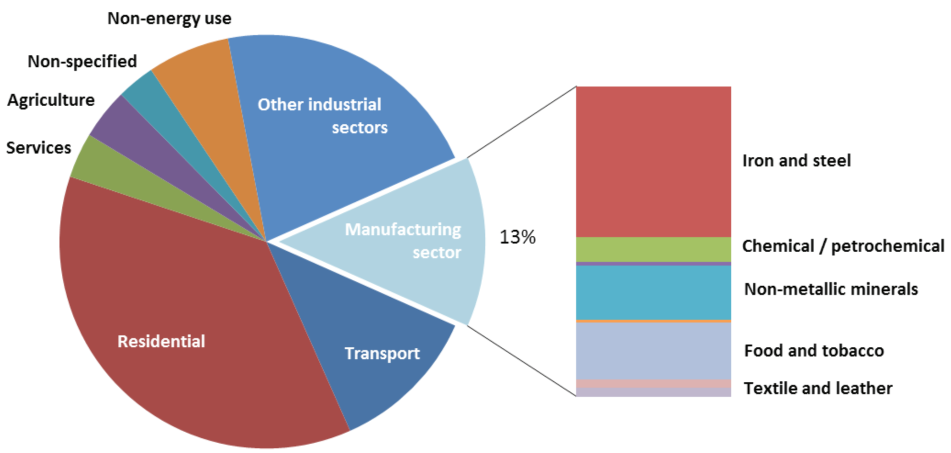
As background information for the following analyses the aim is to understand how much pressure the manufacturing sector is putting on overall national energy consumption. Therefore, we provide an overview of total energy consumption of the domestic economy and the contribution of the manufacturing sub-sectors (see Figure 5). Note that in Figure 5, the industrial energy consumption, which is not allocated to a specific manufacturing sub-sector and thus reported as "non-specified" industrial energy consumption by the IEA, has been allocated to "other industrial sectors". In addition, as manufacturing sub-sectors are likely to contribute to this "non-specified" energy consumption, but no disaggregated data are available, the percentage contribution of the manufacturing sector in total energy consumption is underestimated.

Figure 5: Structure of sub-sectoral energy consumption in example countries, year 2010

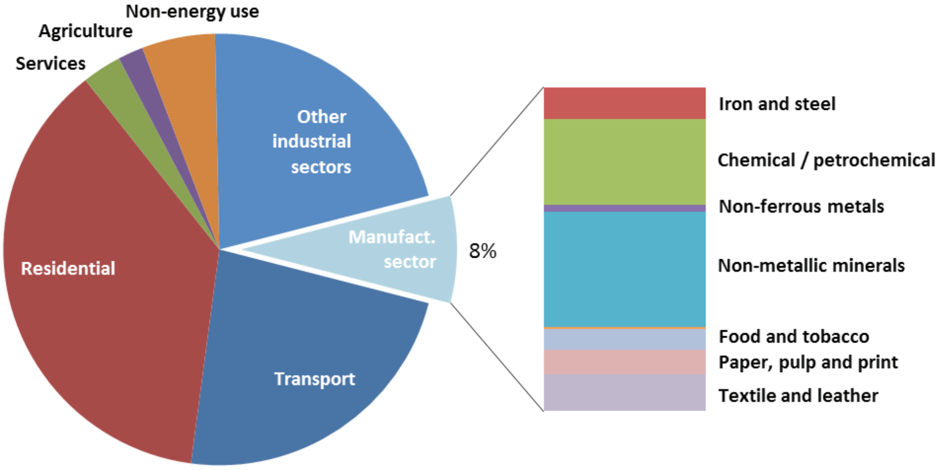
Colombia



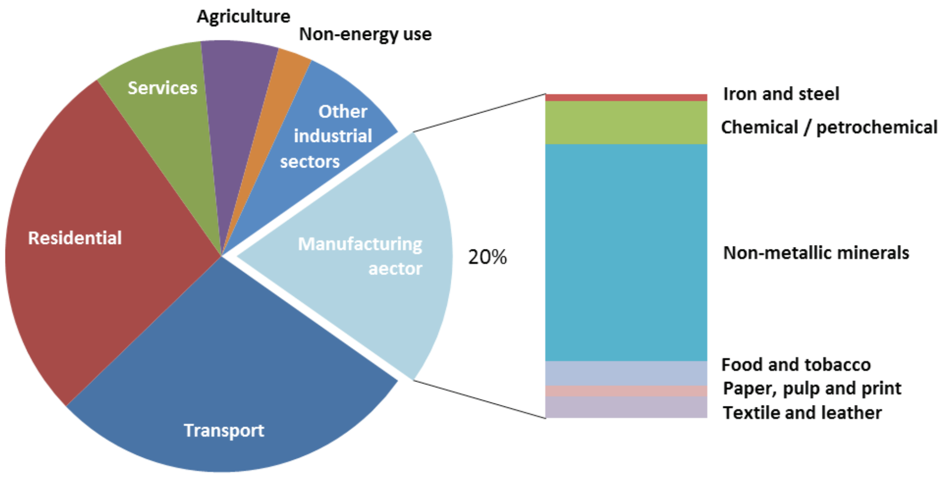
India



Indonesia



Tunisia



Source: IEA (2014): World Energy Balances

Note: Sectors with a marginal contribution to the overall energy use of the manufacturing sector are not listed by names, in order to ensure readability of the figure.

The contribution of the manufacturing sector to total national energy consumption differs considerably between the four example countries. It accounts for 27% of total energy consumption in Colombia, 20% in Tunisia, 13% in India, and only 8% in Indonesia. However, as explained above, the real shares of the manufacturing sector are likely higher, as large amounts of energy consumption are reported as "non-specified", and thus categorised in the fraction of "other industrial sectors".

Figure 5 also illustrates that the sub-sectoral composition of manufacturing energy consumption is very different in the four selected countries, reflecting different patterns of economic specialisation. For example, the iron and steel industry in India consumes almost 50% of all energy consumed by the manufacturing sector, while the share of that particular industry is 16% in Colombia, 10% in Indonesia, and only 2% in Tunisia. However, in the latter country, 67% of manufacturing energy consumption is contributed by the non-metallic mineral sector.

Apart from the manufacturing sub-sectors, total national energy consumption is particularly determined by households (residential), the various transport industries (road, rail, etc.) and by other industries.

This part of the analysis thus reveals the extent to which the manufacturing sector as a whole contributes to total national energy consumption, as well as which manufacturing sub-sectors make up the largest shares of energy consumption.

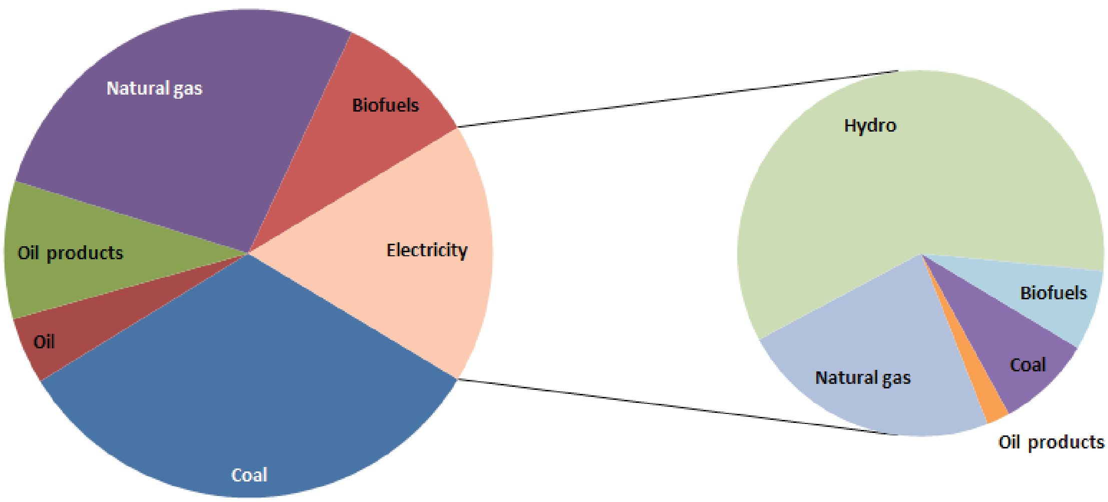
4.3 The Energy Mix of the Industry Sector

Before analysing in detail the patterns of energy consumption on the level of sub-sectors, it is interesting to investigate the aggregated industrial sectors of a country. For many countries, data for the aggregated industry level is of higher completeness and quality compared to the reporting of energy consumption on the level of single sub-sectors. An assessment on the level of industry as a whole is therefore generally more robust compared to analyses of single sub-sectors.

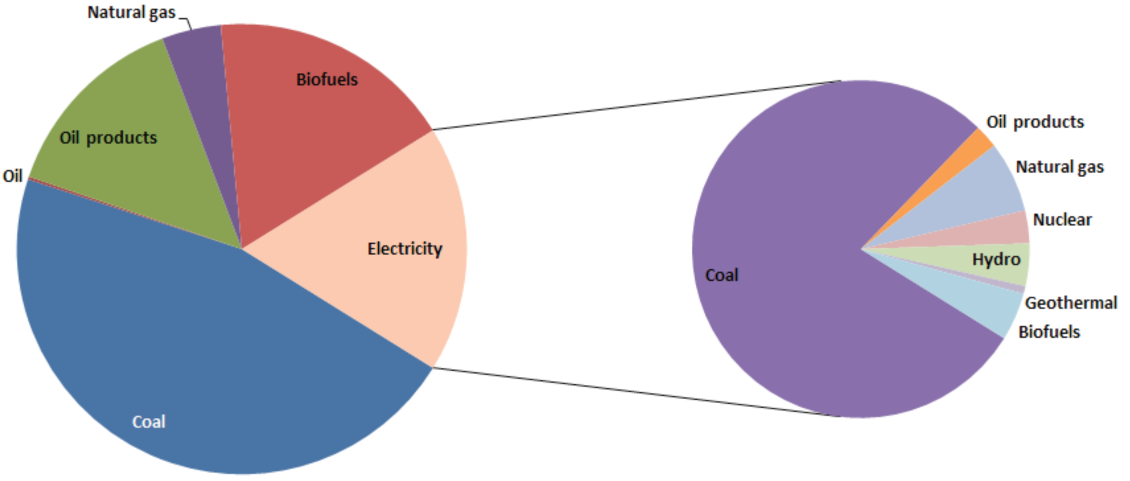
Figure 6 provides an overview of the energy mix used in the aggregated industry sector (large pies on the left). The smaller pies on the right side of each figure illustrate the composition of energy carriers used for producing electricity in each of the example countries.

Figure 6: Structure of industry energy consumption (left) and the national composition of electricity production (right), 2011

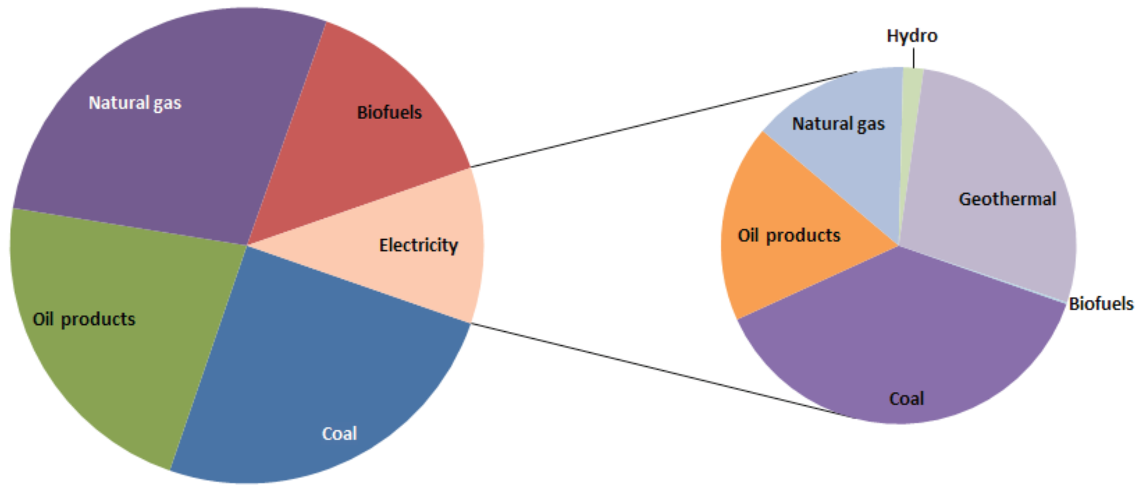
Colombia



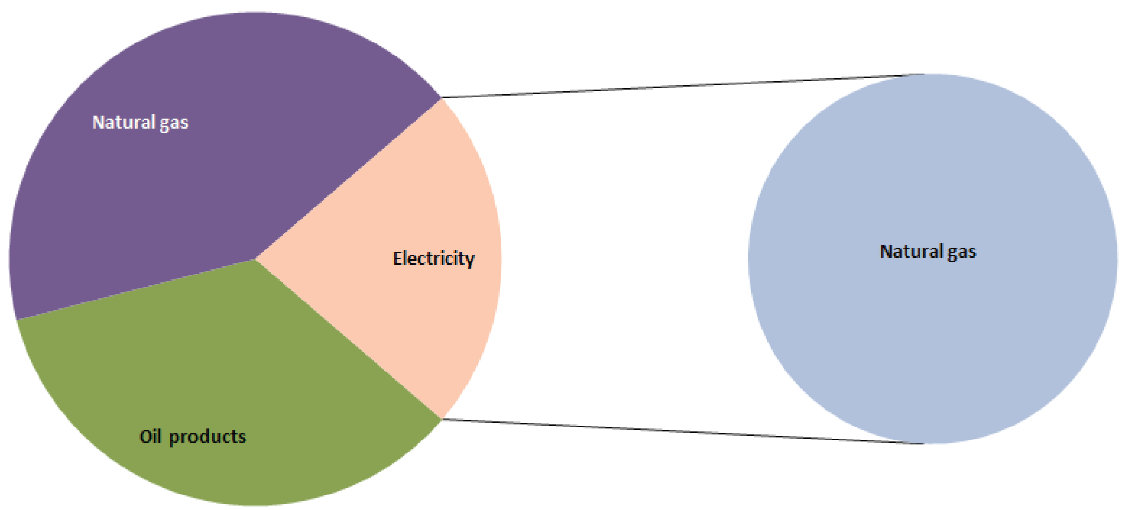
India



Indonesia



Tunisia



Source: IEA (2014): World Energy Balances

The figure illustrates that the four example countries have very different patterns of energy mixes. Regarding overall energy consumption, Colombia's industrial sectors on average rely heavily on coal and natural gas, which together account for 60% of all energy used, while electricity production in Colombia is clearly dominated by hydro power (making up 60% of all electricity produced in Colombia). With a share of 46%, industrial sectors in India are fuelled by energy from coal to an even larger extent. Biofuels rank second with 18%, followed by oil products (14%). The large dominance of coal is also reflected in the electricity production sector, where 78% of electricity production is based on burning coal. In contrast, Indonesia has quite a diversified structure of energy supply, with coal, oil products, natural gas and biofuels each contributing a substantial share to total energy consumption of industrial sectors. With only 11%, electricity has a smaller share in total energy use compared to the other three example countries and electricity production itself is based on a variety of energy carriers. Remarkable is the relatively high share of geothermal and other renewable energy sources in electricity production, which makes up almost 30%. Tunisia's structure of industrial energy use is much less diversified: oil products and natural gas together account for 77% of total energy use and the remaining 23% of electricity itself is completely produced by natural gas power plants. Together, natural gas contributes to 65% to Tunisia's industrial energy consumption.

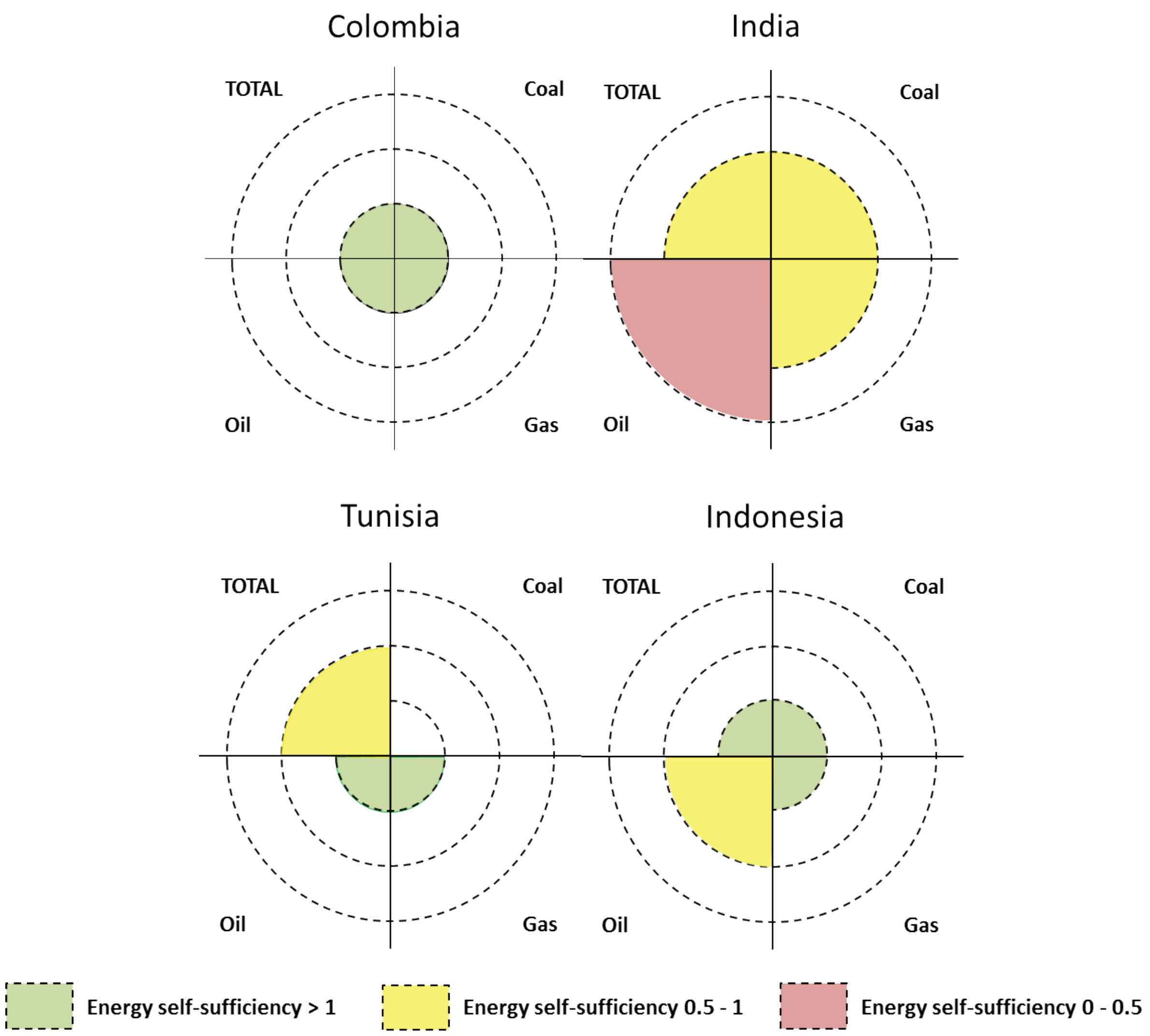
4.4 Energy Self-sufficiency and Energy Vulnerability of Manufacturing Sub-sectors

In the section above, we identified the role of the manufacturing industry in the four example countries with respect to its share in overall energy consumption in a country. This section aims to contrast energy consumption in terms of different energy carriers in different manufacturing sub-sectors with the availability of the different energy carriers.

We start by analysing the counties' overall self-sufficiency – or, conversely, energy vulnerability – regarding different types of fossil fuels. In a second step, we compare the vulnerability results with data on energy consumption by energy carrier per industry. By that means it can be identified which industries of a specific country rely heavily on an energy source that is (not) abundantly available within a country's borders.

Figure 7 illustrates the vulnerability profiles for the four example countries in radar format. The four quadrants represent (clock-wise): 1) the vulnerability level for the country as a whole; 2) for coal; 3) for gas; and, 4) for oil. An energy self-sufficiency ratio above one (1) is translated into "no or low vulnerability" (green colour). A ratio between 0.5 and one (1) is interpreted as "moderate vulnerability" (yellow colour). Values below 0.5 are considered a situation of "high vulnerability" (red colour).

Figure 7: Energy vulnerability profiles of example countries, 2010



Source: Calculations based on IEA (2014): Energy Balances

The difference in results shown in Figure 7 is significant for the four example countries. Colombia has a high self-sufficiency with regard to all three fossil energy carriers – coal, oil, and gas. Consequently, also the overall energy self-sufficiency is provided to a large extent. Therefore, energy vulnerability in terms of import dependence is low in Colombia.

In India, the situation is considerably different. According to the IEA data on energy self-sufficiency, India's overall energy self-sufficiency was below one (1), implying that on average India is relying on energy imports to satisfy its domestic energy demand. In the case of coal and gas the values are between 0.5 and one (1), indicating a moderate dependency on foreign energy sources. However, in the case of oil, India is heavily relying on foreign sources, with a self-sufficiency value of 0.3, which indicates that domestic oil production equals only 30% of the total national oil demand.

Indonesia is confronted with circumstances similar to the ones found in Colombia. Provision with domestic energy carriers is in general good (coal and oil have self-sufficiency ratios above one (1)); only in the case of oil a moderate dependence on foreign energy sources can be identified. Energy vulnerability is therefore generally low in Indonesia.

Tunisia represents a special case for this analysis, as data availability is restricted. The IEA reports a general self-sufficiency level of below one (1), meaning a dependence on foreign energy supplies and consequently moderate energy vulnerability. However, when looking at the specific energy carriers, for the cases of oil and gas sufficiency levels above one (1) can be identified. Hence the overall moderate vulnerability has to be explained by the third energy carrier, i.e. coal. However, for coal, no data on self-sufficiency levels are provided, making a more detailed analysis impossible.

Overall, the four example countries represent a diverse selection of energy self-sufficiency and vulnerability levels, reflecting the different resource endowments in the specific countries. As we will see in the following analysis, also the use of specific energy sources in different industries differs significantly between countries. Hence, energy policies designed to reduce energy vulnerabilities will need to be defined on a country-by-country basis, taking the local circumstances into account.

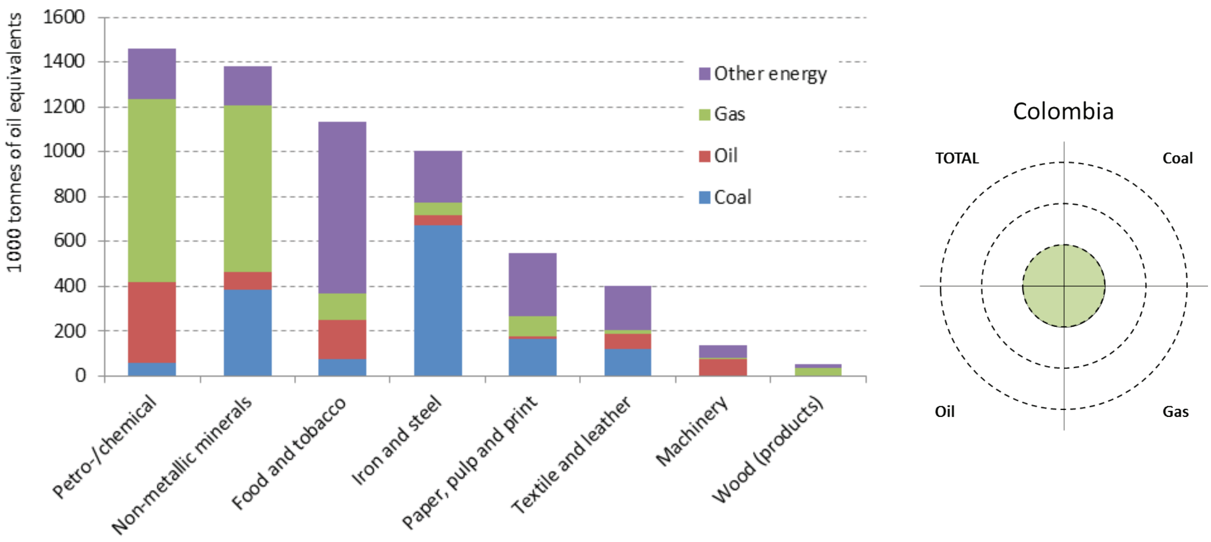
Figures 8-11 show an analysis of the use of different energy carriers in the various manufacturing sub-sectors. In order to take the dimension of energy vulnerability into account, we also show the national vulnerability profile in addition to sub-sector energy consumption. This allows us to identify manufacturing sub-sectors in a country that are most vulnerable.

We distinguish a maximum of eight different manufacturing sub-sectors (and industry groups) and four different types of energy sources (coal, oil, gas and other energy sources). When comparing the four graphs, it becomes apparent that data coverage differs between the four countries. For all countries except Tunisia, data for eight industries are available (for Tunisia only six). However, only for Colombia four different types of energy carriers can be discerned – for the other countries data on one or two energy sources are missing. While this reduces the level of expressiveness, it reflects the difficulties faced when carrying out this type of analysis on the level of single manufacturing sub-sectors in developing countries. As explained in Section 2, in such cases users of the tool need to refer to data provided by national statistical institutions or non-official sources, if available, to fill the data gaps.

Figure 8 shows the analysis for Colombia. It can be seen that the industry most dependent on coal is the iron and steel industry, followed by non-metallic minerals and paper, pulp and print. With regard to oil, not surprisingly, the petro-/chemical industries are the biggest consumers, followed by food and tobacco, and the machinery industries. Gas is consumed in considerably large quantities in the petro-/chemical and the non-metallic minerals industries. Finally, other types of energy (renewables, heat, etc.) are consumed in all industries, with the largest quantities in the food and tobacco industries.

As discussed before, Colombia has a very low level of vulnerability with regard to the domestic supply of fossil energy carriers. It can therefore be assumed that industries which rely heavily on coal oil and gas (petro-/chemical, non-metallic minerals, and iron and steel industries) are not likely to face supply shortages soon, as supply chains are to a large extent domestic.

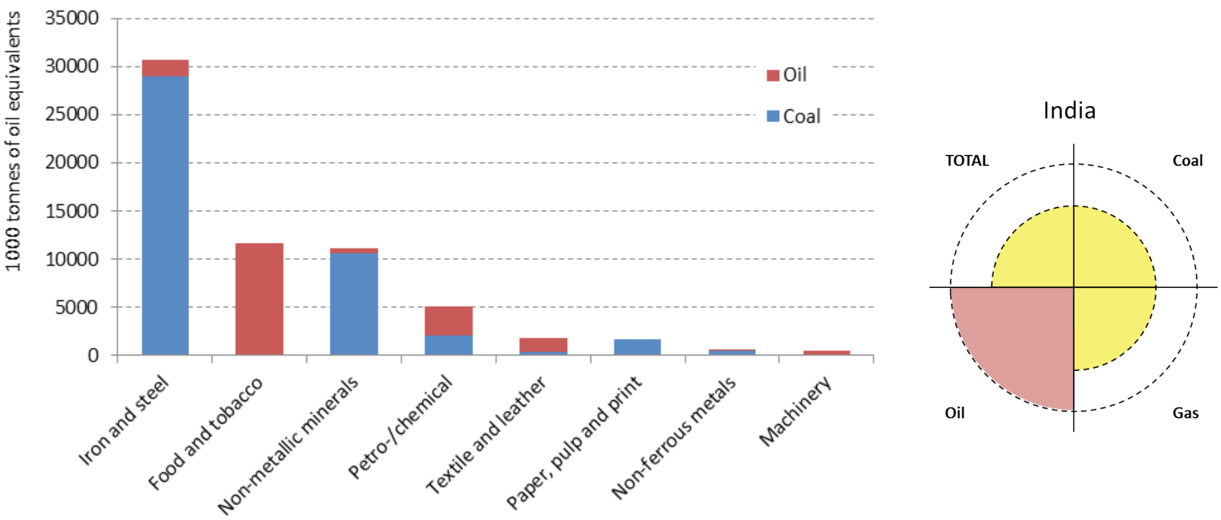
Figure 8: Energy consumption of manufacturing sub-sectors by energy carriers and energy vulnerability in Colombia



Source: IEA (2014): World Energy Balances

Energy consumption by different manufacturing sub-sectors in India is illustrated in Figure 9. It can be seen that data availability is rather limited, with data provided by the IEA only for the two energy carriers of coal and oil. However, the available data convey a clear message: India is a country relying on the provision with fossil fuels from abroad, especially in the case of oil.

Figure 9: Energy consumption of manufacturing sub-sectors by energy carriers and energy vulnerability in India



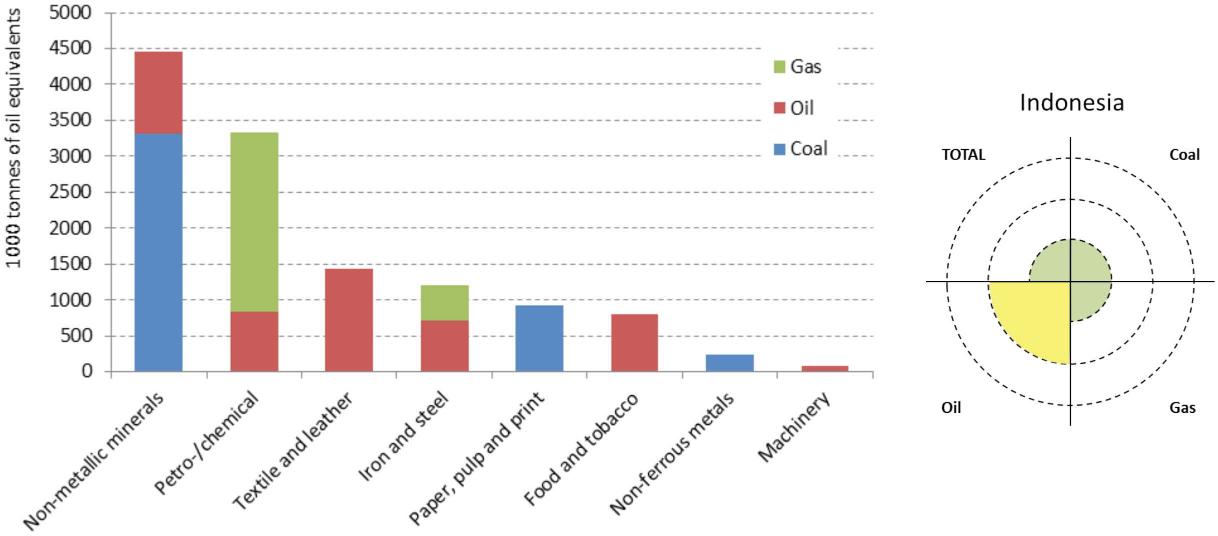
Source: IEA (2014): World Energy Balances

When looking at Figure 9, it becomes apparent that that: 1) Indian manufacturing sectors use more than ten times more energy compared to manufacturing sectors in Colombia; 2) the iron and steel industry group is by far the biggest consumer, depending almost 100% on coal; and, 3) the food and tobacco industry group consumes large quantities of oil. Additionally, also the non-metallic minerals industries depend mostly on coal for their mineral processing activities.

Reflecting these numbers before the background of India's high energy vulnerability, it can be stated that the industries in the areas of iron and steel, food and tobacco, and non-metallic minerals depend heavily on fossil energy carriers, all of which are provided to a significant extend by foreign sources. Hence, industrial and resource policies have to bear in mind that in case of supply constraints these industries will be the "hot spots" which suffer first.

Figure 10 illustrates the consumption of coal, oil and gas by the different industry groups in Indonesia. The non-metallic minerals industries are the main consumers of energy, its consumption being split by about 2/3 coal and 1/3 oil. The second biggest consumers are the petro-/chemical industries, which refer mainly to gas as an energy source, followed by oil. The textile and leather, as well as the food and tobacco industries, and machinery industries, use only oil as a fossil energy source (in addition to other energy sources, for which no data are available).

Figure 10: Energy consumption of manufacturing sub-sectors by energy carriers and energy vulnerability in Indonesia

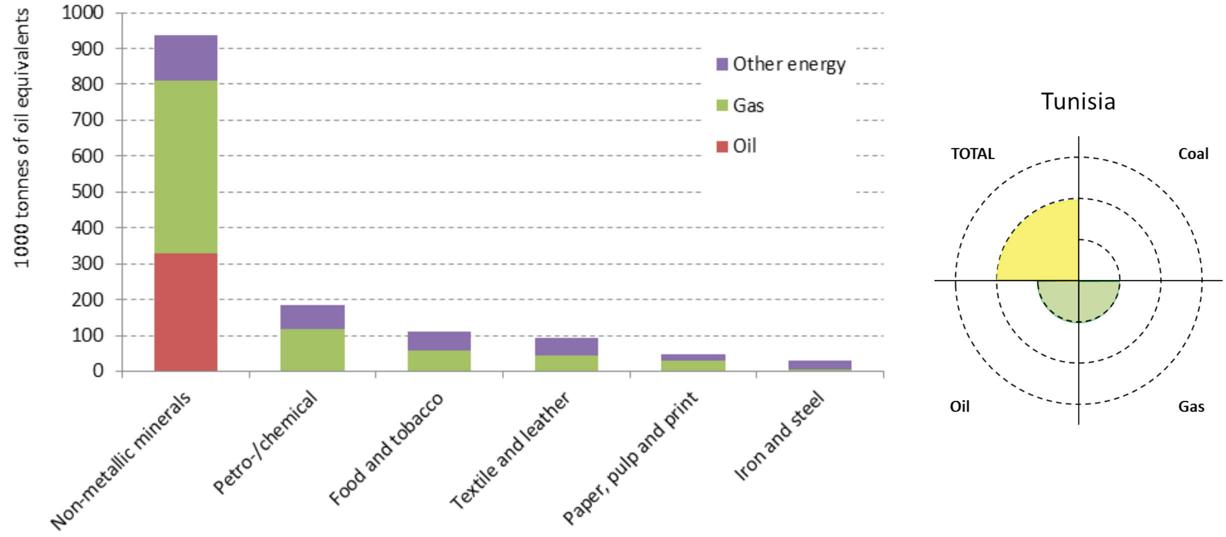


Source: IEA (2014): World Energy Balances

In general, Indonesia has a low level of energy vulnerability, in particular with regard to coal and gas. However, its dependence on foreign oil sources has to be considered when designing industrial and resource policies, especially bearing in mind that three industry groups are completely – and three others to a large extend – contingent on oil as the main energy source for their production processes.

Finally, Figure 11 shows the situation in Tunisia. As stated above, data availability is an issue in Tunisia, and as in the case of the vulnerability analysis, no data regarding the consumption of coal in manufacturing sub-sectors is available.

Figure 11: Energy consumption of manufacturing sub-sectors by energy carriers and energy vulnerability in Tunisia



Source: IEA (2014): World Energy Balances

According to the data provided by the IEA, the industry group with by far the largest energy consumption is the non-metallic minerals group. This group consumes to the largest extent gas, followed by oil and other energy sources. The other industry groups do not rely on oil according to the IEA data, but this reality is questionable in particular for industries such as the chemical and petrochemical industry, and potentially points to data gaps also for the case of oil consumption.

Given that vulnerability levels in Tunisia are low for oil and gas, supply risks seem to be rather low. However, more focus must be set on the case of the data on coal consumption, as no information can be provided here.

Concluding, this section aimed at comparing the availability of the different energy carriers in the countries with energy consumption in different manufacturing sub-sectors. By that means, the most vulnerable manufacturing sub-sectors could be identified, i.e. those sectors which rely most heavily on a type of fossil energy, which is not sufficiently available within domestic border. Such an analysis is crucial to identify so-called “hot spots”, which should be at the heart of political energy efficiency interventions.

4.5 Energy Efficiency of Manufacturing Sub-sectors

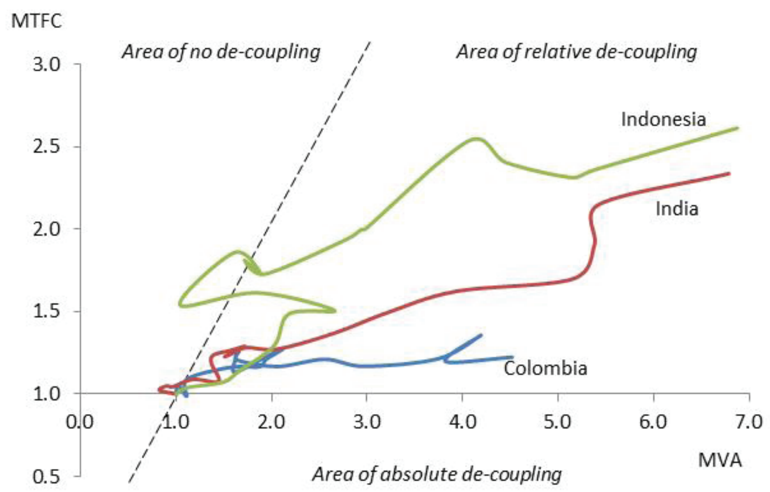
In Section 3.3, we obtained a better understanding of the exposure of specific industries to the risk of facing supply shortages due to interrupted international supply chains. As argued in the introduction, appropriate means to reduce such supply risks can be 1) an overall reduction in (the growth of) industrial energy consumption by increasing energy efficiency, and, (2) the switch from fossil energy sources or sources where vulnerabilities are particularly high, to renewable energy sources.

This analytical section focuses on the issue of energy efficiency. In the following, we take a look at two trends in the manufacturing sector over time: first, the development of production of value added, and second, the total final energy consumption by all manufacturing sub-sectors of a country. By contrasting these two trends we can analyse the extent a country has managed to increase energy efficiency over time.

Further, we illustrate the differences in energy efficiency levels between various manufacturing sub-sectors and compare the efficiency performance of manufacturing sub-sectors in the example countries with the OECD average. This allows us to identify the manufacturing sub-sectors that have the largest potential for energy efficiency improvements in the future.

Figure 12 shows the development of MTFC and MVA of the manufacturing sector in three of the example countries, namely India, Indonesia, and Colombia, between 1990 and 2010 (Tunisia is not illustrated due to a lack of data"). The lines indicate indexed values and thus illustrate percentage changes of MVA and MTFC in relation to the value of 1990.

Figure 12: Development of MTFC and MVA of three of the example countries, 1990-2010 (1990 = 1)



Sources: IEA (2014): World Energy Balances, and UNIDO INDSTAT database

The dashed line sub-divides the figure into three parts: values on the left side of the line indicate situations where MTFC grows faster than MVA. This condition is described as "no de-coupling". On the upper-right side of the dashed line (above the x-axis) MVA is growing faster than MTFC, meaning that the manufacturing sector achieves a relative decoupling of generation of value added from energy consumption, i.e. production is becoming more efficient. Finally, the lower right side of the dashed line (below the x-axis) is the area where "absolute decoupling" would occur. In such a situation, not only economic development would be decoupled from energy use, but also the overall energy use would be decreasing.

For countries aiming to achieve an improvement in energy efficiency, the policy target should be set to achieve a "relative de-coupling" (and absolute decoupling in the long run), i.e. a situation, in which MVA grows faster compared to MTFC. Looking at the three countries illustrated in Figure 12, it can be seen that from the year 1990 onwards an overall trend of relative decoupling has been taking place in all three countries. Colombia shows a specifically horizontal development, meaning that total energy consumption has not increased significantly over the 20-years period, while value added continued to increase steadily. Such a development path can be described as very positive from an energy efficiency point of view.

Likewise, in the case of Indonesia, the curve in most recent years is growing less rapidly compared to the beginning of the time period (1990). Indonesia has therefore achieved progress with regard to increased energy efficiency. The energy efficiency development path of India is less steep compared to that of Indonesia, indicating that MVA was growing more rapidly compared to MTFC.

The clear message of this type of energy efficiency analysis is that all three example countries managed to achieve a relative de-coupling of the value added being generated by manufacturing sub-sectors from their corresponding energy consumption. The pace and dynamics of this path of relative de-coupling depends on the sectoral composition, as well as the use of different energy carriers in different countries.

In the following, we analyse the differences in energy efficiency levels between various manufacturing sub-sectors within a country and compare these efficiency performances with the OECD average. This allows identifying the manufacturing sub-sectors that have the largest potentials for energy efficiency improvements in the future.

When studying the data for specific countries and comparing sub-sectors within a country or even the same sub-sectors of different countries among each other, caution has to be exercised, in order to avoid over simplistic conclusions. Two arguments need particular attention:

(1) The data used to calculate sub-sectoral energy efficiency has to be analysed with regard to its quality and comprehensiveness, and especially the data on sub-sectoral energy consumption (TFC) provided by the IEA. The data distinguishes different (manufacturing) sub-sectors, often containing a sub-sector called “non-specified (industry)”, which contains energy consumption that could not be allocated to specific sub-sectors. In this regard, data contained in this category could be attributed to any of the industrial sub-sectors, be it “mining and quarrying” or “construction”, or one of the different manufacturing sub-sectors. As a general rule of thumb, the higher the share of this category in total industrial energy consumption, the more cautious analyses on the sub-sector level have to be carried out. We recommend a threshold of 20% of “non-specified” energy consumption in total industrial energy consumption, above which the uncertainties on the level of single sub-sectors become too large. In a case where IEA reports more than 20% of industrial energy use as “unspecified”, we suggest to cross-check and complement IEA data with data from national sources to allow a distribution of data in the “non-specified (industry)” sub-sector to the specific (manufacturing) sub-sectors.

(2) When comparing sub-sectors and their energy efficiency, the analyst has to bear in mind that the sub-sectors are also aggregates containing a large number of industries with a high level of heterogeneity, with regard to value added created, as well as energy consumed. As a consequence, differences in sub-sectoral performances can stem not only from different energy and production technologies, but also from differences in the specialisations within a sub-sector. For example, country A might produce large amounts of iron ores, the production of which is highly energy consuming, while country B focuses on the production and refinement of silver, also characterised by high energy consumption, but with higher value added. As a consequence, country B will have a better energy efficiency performance.

In the following example, we present data for two of the four example countries – Colombia and India – and discuss to what extend a cross-sub-sectoral (or cross-country) analysis can be performed.

Table 7 illustrates data for different manufacturing sub-sectors in Colombia. For each sub-sector, value added produced, energy consumption, energy efficiency (the quotient of the first two), as well as the OECD average for this sub-sector and the distance to the OECD benchmark, are provided. Evaluation is done with three different colours: in Case 1 (green colour), Colombia performs better than the OECD average; in Case 2 (yellow colour) Colombia performs worse, but its efficiency is more than half of the OECD energy efficiency average; in Case 3 (red colour) Colombia’s performance is worse than half the OECD average. In the two rows at the bottom, energy consumption as reported for the sub-sector “non-specified (industry)” is documented, together with its share in total energy consumption as well as the comparative value of the OECD. Also for total energy consumption, i.e. including the category “non-specified”, the distance to the OECD energy efficiency target is shown.

Table 7: Detailed energy efficiency profiles by sub-sector for Colombia, including OECD benchmarks

Colombia					
	Value Added	Energy Consumption	Energy Efficiency	OECD	Distance to benchmark
Sector/Unit	[Mrd. $]	[ktoe]	[$/kg]	[$/kg]	[$/kg]
Chemical and petrochemical	8.1	1392.8	5.8	5.8	0.1
Food and tobacco	7.8	1279.2	6.1	10.9	-4.8
Iron and steel & non-ferrous metals	2.2	649.1	3.4	2.3	1.1
Machinery	1.8	147.3	11.9	36.8	-24.9
Non-metallic minerals	2.2	1462.4	1.5	2.7	-1.2
Paper, pulp and print	2.0	621.6	3.3	3.4	-0.1
Textile and leather	2.3	429.6	5.4	10.0	-4.7
Wood and wood products	0.1	50.0	2.9	5.9	-3.0
Non-specified (industry)		228.2	4%	12%	
Total	26.6	6260.2	4.2	7.2	-3.0

Sources: IEA (2014): World Energy Balances, and UNIDO INDSTAT database

Table 7 shows a 4% share of data reported for the sub-sector “non-specified (industry)” in Colombia, which is relatively small and even lower than the corresponding value for the OECD average (12%). Hence, it can be assumed that the uncertainty range in comparing sub-sectors among each other, and with OECD values, is rather small. When looking at the different manufacturing sub-sectors, we see that Colombia is performing above OECD average in two sub-sectors (“chemical and petrochemical products,” and “iron and steel and non-ferrous metals”), and below average in the other sub-sectors. However, only one sub-sector – “machinery” – shows a very large difference to the OECD average value.

From this analysis, the following conclusions can be drawn: 1) With regard to energy efficiency in the manufacturing sector and its sub-sectors, Colombia is performing relatively well. Most values are below, but relatively close, to the respective OECD averages. Additional analyses need to be performed in order to identify reasons for these differences by looking at the same sectors in specific OECD countries to find best practice examples. (2) In two sub-sectors, the performance is better than the OECD average. Additional analysis might be carried out with specific OECD countries of similar economic structure to find out where further improvement potentials are. (3) In the sub-sector machinery, Colombia’s distance from the OECD benchmark is very large. This sector is therefore a priority sector for further investigations on energy efficiency improvements. Further analysis should focus on identifying the reasons for this large difference to the average OECD value – i.e. structural (composition of the machinery sector) or technical. (4) The share of data reported under “non-specified (industry)” is relatively low and thus also uncertain.

As a comparison we present the same table (Table 8) for India. In the case of India, energy consumption reported under “non-specified (industry)” makes up almost 60% of the total industrial energy consumption. Such a high value does not allow for a well-grounded analysis, as it is not clear to which sub-sector this large amount is allocated. In cases like this, we recommend crosschecking the IEA data with data from national sources, in order to obtain more detailed information on the actual distribution of energy consumption among industrial sectors. Another option could be to analyse energy efficiencies of the same sub-sector in countries of similar industrial structure and technical advancement.

Table 8: Detailed energy efficiency profiles by sector for Colombia, including OECD benchmarks

India					
	Value Added	**Energy Consumption**	**Energy Efficiency**	**OECD**	**Distance to benchmark**
Sector/Unit	[Mrd. $]	[ktoe]	[$/kg]	[$/kg]	[$/kg]
Chemical and petrochemical	34.8	5265.1	6.6	5.8	0.9
Food and tobacco	11.3	9376.4	1.2	10.9	-9.7
Iron and steel & non-ferrous metals	24.1	20129.1	1.2	2.3	-1.1
Machinery	21.5	667.1	32.2	36.8	-4.5
Non-metallic minerals	8.8	10484.1	0.8	2.7	-1.9
Paper, pulp and print	3.5	1254.6	2.8	3.4	-0.5
Textile and leather	10.0	1287.5	7.8	10.0	-2.3
Non-specified (industry)		69830.1	59%	12%	
Total	114.1	118294.1	1.0	7.2	-6.3

Sources: IEA (2014): World Energy Balances, and UNIDO INDSTAT database

This final analytical section focused on the issue of energy efficiency of manufacturing sub-sectors. We analysed three of the four example countries with regard to trends in production of value added and total final energy consumption in the manufacturing sector over time. Such an analysis provides information to what extent a country has actually managed to increase energy efficiency over time.

Further, we illustrated the differences in energy efficiency levels between various manufacturing sub-sectors in Colombia and compared the efficiency performance of its manufacturing sub-sectors with the OECD averages. In this way, we can identify which manufacturing sub-sectors have the largest potential for energy efficiency improvements in the future. Also, by comparing countries among each other, best practice examples can be identified.

4.6. Concluding Remarks on the Analysis

The analysis described in Section 4 illustrated how a set of indicators as defined in Section 3 above can deliver a comprehensive assessment of a countries' situation regarding energy efficiency and energy vulnerability. The analysis was implemented step-wise, starting from general background information on the country level towards the specific situation in various manufacturing sub-sectors.

The analysis started with illustrating the contribution of energy use of the manufacturing sectors to total national energy consumption, thus providing decision makers with an overview of the relative importance of the manufacturing sector for energyrelated issues in a specific country. An assessment on the degree of self-sufficiency with regard to fossil fuel energy carriers followed, pointing to areas, where a country faces vulnerabilities with regard to energy supply. This provides an important background, when analysing specific patterns of energy demand of manufacturing sub-sectors.

On the specific level of sub-sectors, the analysis revealed the absolute energy use of various manufacturing sub-sectors and its composition by energy carriers, thus pointing decision makers to those sub-sectors, which provide the "hot-spots" in terms of energy use. Developing a strategy towards "greening industries" should focus on the sub-sectors identified with the highest energy demand. We illustrated how the data on absolute energy use of sub-sectors can be contrasted with the energy self-sufficiency data, in order to identify those sub-sectors that potentially face the highest energy vulnerability.

Finally, we illustrated how energy efficiency in manufacturing sub-sectors can be calculated and analysed, and how developing countries can be compared to the OECD countries as a benchmark. This comparison is important for implementing a “greening industry” agenda, as these actions should target those sub-sectors, i.e. those which show the highest potentials for energy efficiency improvements.

5. Possible Extensions: Resource Efficiency Assessments for Raw Materials and Water

The indicators and methods presented in this tool can, in principle, also be applied to other types of natural resources. However, in a number of cases there is a need for further work regarding indicator development and/or data compilation, as data on the level of manufacturing sub-sectors is more difficult to obtain compared to that of energy.

5.1. Raw Materials

In general, the same indicators can be applied for energy and raw material use, as a standardised methodology has been developed by the European Statistical Office (EUROSTAT) in cooperation with the OECD, on how to assess material flows used by national economies and industrial sectors. However, the data situation is generally more complicated in the case of materials compared to energy use. Some data on material extraction need to be estimated, as it is not reported by official statistics (e.g. construction minerals). To improve this situation, increased efforts should focus on capacity building in statistical institutions and in compiling data on raw materials. Furthermore, for the case of materials, no international database is available that reports on the material inputs for various economic sectors, comparable to the IEA for the energy data. Therefore, calculations need to be performed in order to generate data on material use and material efficiency at the sub-sector level, for example, using data from economic input-output tables.

5.2. Water

In the case of water, the situation is even more complicated. Water statistics and water accounting are rather young fields in environmental analyses, and therefore accounting standards have not yet been internationally harmonised. Additionally, the availability of water use data at the national level, and even more so at the sectoral level, is very poor not only in developing countries, but also in industrialised countries. Until robust statistical data are available, environmental analysis can be built on modelled or estimated data being published in great detail for the global level, especially for the agricultural sector. Estimates for water use in industrial production exist, but have to be treated with care, as variations between industries, countries and years can be considerable. Still, as with the case of materials, pilot assessments can be performed using environmental-economic calculation methodologies, such as input-output analysis.

6. Linkages to Other Areas

Enhanced energy efficiency and energy self-sufficiency is possibly linked to and has potential impacts on other areas of industrial development that are covered in the EQuIP toolbox. In terms of **industrial competitiveness and growth** (see Tool 1), energy efficiency can be regarded as a driver of economic growth, as it reduces production costs and thereby potentially increases the international competitiveness of manufacturing companies. This is particularly important for SMEs, which often have a larger productivity gap to international productivity benchmarks compared to larger companies, thus improving energy efficiency is a powerful mechanism to close that gap.

Efforts to improve energy efficiency can have positive effects on the general level of technological sophistication in a country's manufacturing sector since the adoption (or even domestic development) of new production technologies with higher energy efficiency can be a driver and a positive stimulus for **technological upgrading and deepening** (see Tool 3). Moreover, various European countries have demonstrated through their experience that renewable energy policies and investing in renewable energy technologies can trigger larger technological development.

Enhancing energy efficiency also bears the potential of helping **employment creation** (see Tool 5) by reducing production and operation costs for firms. These potential job-generating effects of higher energy efficiency have been discussed in UNIDO's *Industrial Development Report 2011*. Similarly, investments into the building up of renewable energy systems can also have a positive effect on employment and wage generation. In European countries, this is often discussed under the banner of "green jobs".

Improving energy efficiency can also contribute to **poverty alleviation** (see Tool 5). For example, if energy efficiency in households improves through the use of more energy efficient appliances, this can lower household spending on energy, thereby increasing the purchasing power of their incomes. In a similar vein, establishing or expanding local and low-cost renewable energy systems can also lower the energy costs of households, e.g. with solar cooking systems.

7. References and Further Reading

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v. 1.0 - April 2015

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