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SEE Impact Study of the German MedTech Industry

Indicator-based pilot study on the social, environmnetal, and economic contributions of the German medical technology industry along the global value chains

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Appreciation

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Management Summary

Initial situation and objectives

Keywords such as resource-efficient growth, climate neutrality, fair prices, social standards, circular economy, and conservation of biodiversity shape the agenda of politics and business alike. Companies and entire industries play a crucial role in enabling sustainable and integrative value creation. Against this background, it is of great importance to know, understand and ultimately manage the manifold effects of industries on society. As the representative of the German MedTech industry, BVMed sees itself as a pioneer in identifying these economic, environmental and social effects, and advocates an open and transparent approach to the topic. For the first time, this study quantifies and presents economic, ecological, and social facts and data in a joint industry monitoring.

Methodology

The study is based on a recognized methodology – for quantifying cross-sectional industries such as the MedTech industry – and calculates the economic, environmental and social footprint of the German MedTech industry for the first time based on the results of the Health Economy Reporting (HER) of the Federal Ministry for Economic Affairs and Climate Protection (BMWK). The starting point is a "procurement list" of the MedTech industry, which contains all goods and services that the industry uses for its production process in Germany.

To create the procurement list, the results of the Health Economy Reporting (HER) of the BMWK are used. For more than a decade, the MedTech industry has been recorded uniformly and comparably year after year, and its contribution to growth and employment in Germany has been determined (Federal Ministry for Economic Affairs and Climate Protection (BMWK) 2022; Schneider, Ostwald, Karmann, et al. 2016). The uniformity and transparency of the data and statistics used is a key unique selling point offered by this monitoring, as all figures and data are based on official sources.

The study does not use any direct internal or company-specific data and facts. Rather, the study is based on the results of the Federal Statistical Office. Thereby it takes into account information that was provided to the BMWK by the companies as part of the cost structure survey.

As a result, the study represents an industry monitoring instead of a company monitoring. To finally determine the economic, environmental and social footprint of the MedTech industry, the model of input-output analysis is used, a globally recognized methodology for quantifying those economic effects that are due to the economic activity of an individual company or industry along the entire supply chain. For the development of this methodology, the economist Wassily Leontief received the Nobel Prize in 1973.

TAKE AWAYS FROM THE ECONOMIC FOOTPRINT

THE MEDTECH INDUSTRY IS ONE OF THE MOST IMPORTANT SUB-SECTORS OF THE HEALTH ECONOMY

ESPECIALLY IN THE INDUSTRIAL HEALTH ECONOMY, IT IS OF GREAT IMPORTANCE FOR THE GROSS VALUE ADDED AND EMPLOYMENT.

HOWEVER, GROWTH AND EMPLOYMENT IN THE MEDTECH INDUSTRY ARE FOLLOWING DIFFERENT PATHWAYS

2.5 BILLION EUROS IN ADDITIONAL VALUE ADDED ARE ACCOMPANIED BY A DECLINE OF 4,300 EMPLOYEES SINCE 2012.

IN CONTRAST, R&D ACTIVITIES IN THE MEDTECH INDUSTRY ARE EXTREMELY RESILIENT

SINCE 2012, THE SUB-SECTOR HAS EXPERIENCED AN AVERAGE ANNUAL GROWTH RATE OF 7.5 PERCENT.

IN ADDITION, THE MEDTECH INDUSTRY ALSO GENERATES GROSS VALUE ADDED AND EMPLOYMENT EFFECTS BEYOND ITS DIRECT ECONOMIC ACTIVITY

IN TOTAL, THE ECONOMIC FOOTPRINT OF THE GERMAN MEDTECH INDUSTRY IN 2021 AMOUNTS TO 32.2 BILLION EUROS AND AROUND 414,000 EMPLOYEES IN THE ENTIRE GERMAN ECONOMY.

TAKE AWAYS FROM THE ENVIRONMENTAL FOOTPRINT

GREENHOUSE GAS EMISSIONS ARE AMONG THE MOST IMPORTANT DRIVERS OF MAN-MADE CLIMATE CHANGE

OVER 60 PERCENT OF ALL GREENHOUSE GAS EMISSIONS IN THE MEDTECH INDUSTRY ORIGINATE INDIRECTLY IN THE GLOBAL SUPPLY CHAIN OF THE MEDTECH INDUSTRY.

AIR POLLUTION BY POLLUTANTS WITH A MAXIMUM PARTICLE SIZE OF 2 µM ($PM_{2.5}$) HAS BEEN SHOWN TO HAVE NEGATIVE EFFECTS ON HUMAN HEALTH

ALMOST 90 PERCENT OF THE MEDTECH INDUSTRY'S FINE DUST ORIGINATES IN THE MEDTECH INDUSTRY'S GLOBAL SUPPLY CHAIN.

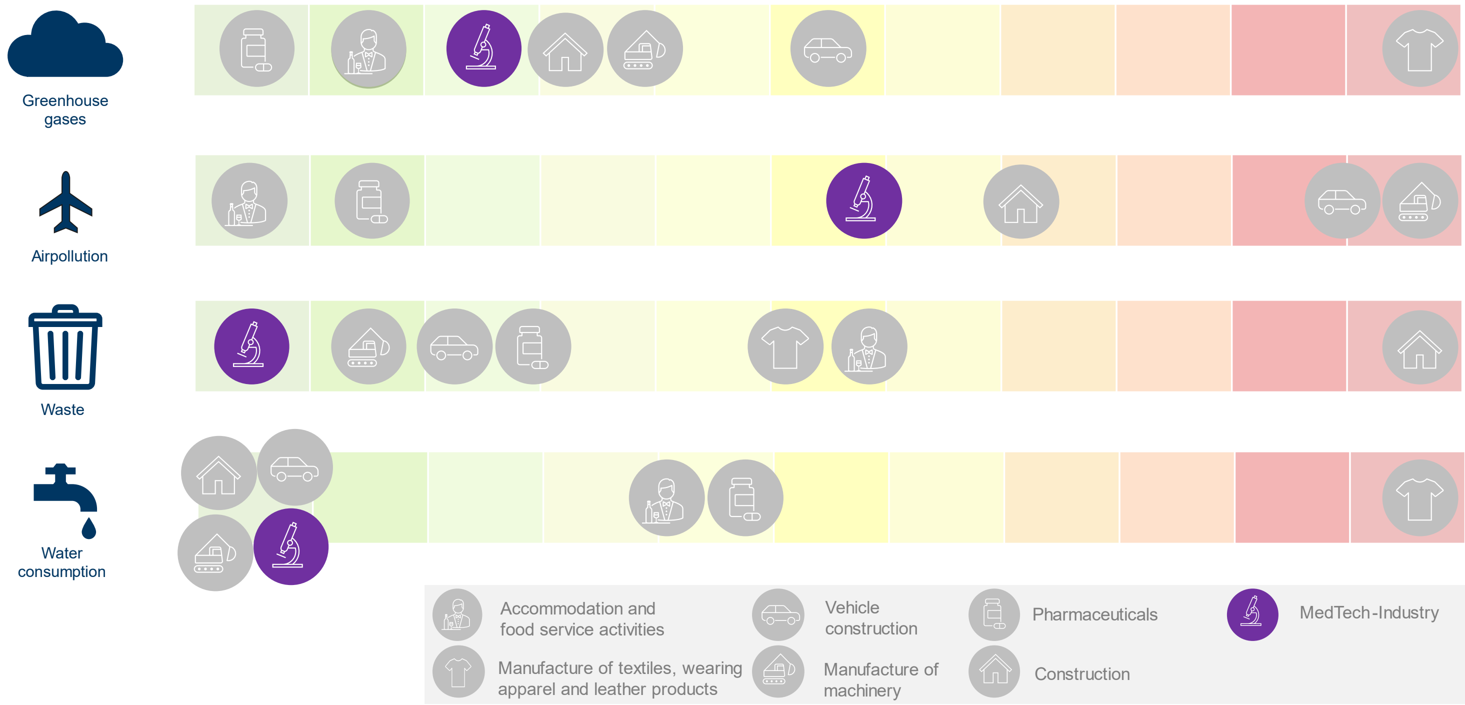
THE PRODUCTION OF WASTE IS A GLOBAL PROBLEM THAT CAN BE COUNTERED BY ON SITE RESOURCE-SAVING HANDLING IN GERMANY

IN AN INDUSTRY COMPARISON, THE MEDTECH INDUSTRY HAS THE LOWEST VOLUME OF WASTE PER 1 MILLION EUROS OUTPUT WITH ONLY 56 TONS.

THE SUSTAINABLE USE OF WATER MUST ALSO BE INCREASINGLY ANCHORED IN THE CONSCIOUSNESS OF THE POPULATION IN GERMANY

THE DIRECT AND INDIRECT WATER CONSUMPTION OF 7.9 MILLION M^3 LEAVES NO SIGNIFICANT NEGATIVE EXTERNALITIES IN GERMANY.

IN THE COMPARATIVE INDUSTRY RANKING OF THE ENVIRONMENTAL INDICATOR INTENSITIES, THE MEDTECH INDUSTRY PERFORMS ABOVE AVERAGE IN 3 OUT OF 4 INDICATORS



Source: WifOR illustration

TAKE AWAYS FROM THE SOCIAL FOOTPRINT

THE WORKPLACE IS AN IMPORTANT CENTER OF LIFE FOR MANY PEOPLE. A WORKPLACE CAN ALSO POSE RISKS TO HEALTH

WHEN IT COMES TO OCCUPATIONAL DISEASES AND INJURIES, MEDTECH TAKES A MIDFIELD POSITION IN THE INDUSTRY COMPARISON PRESENTED.

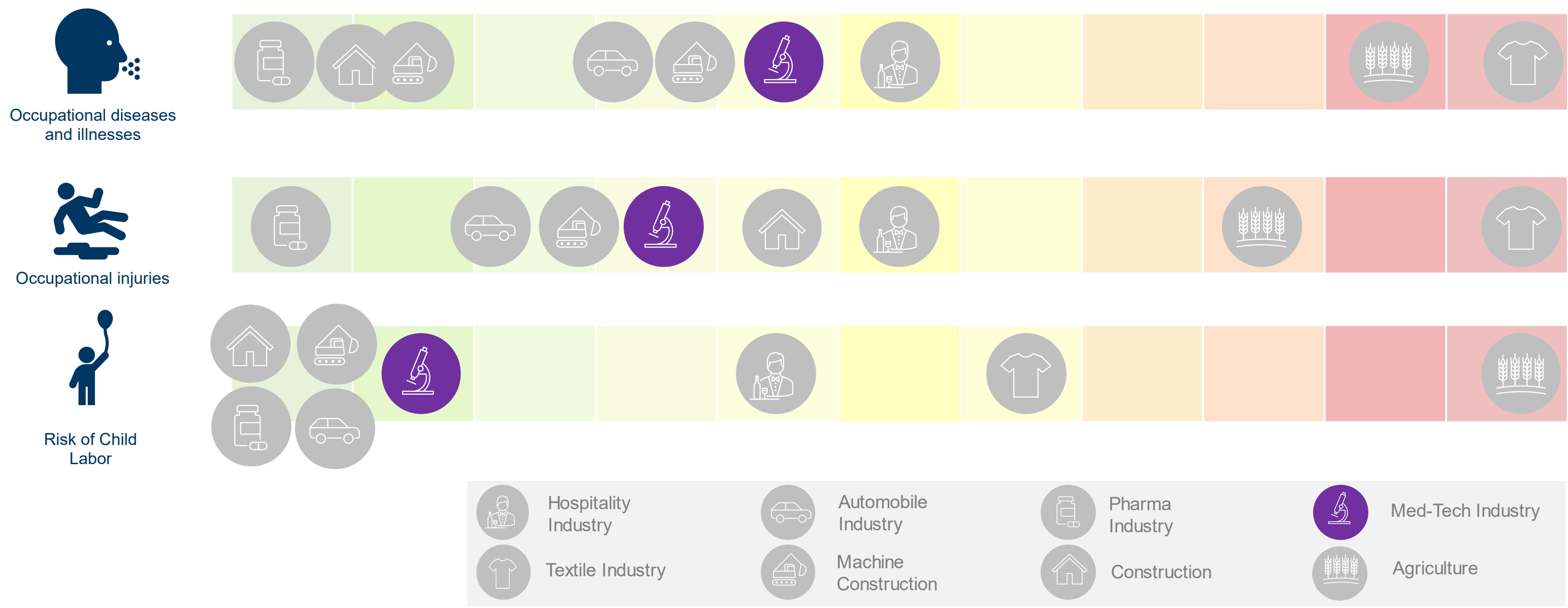
OCCUPATIONAL INJURIES HAVE A NEGATIVE IMPACT ON THE ECONOMIC DEVELOPMENT OF A COUNTRY

AROUND 62 PERCENT OF OCCUPATIONAL INJURIES IN THE MEDTECH INDUSTRY HAPPEN IN THE GLOBAL SUPPLY CHAIN.

CHILD LABOR IS NOT PROHIBITED EVERYWHERE BY LAW AND IN SOME PLACES VIOLATIONS GO UNPUNISHED

DUE TO THE GLOBAL SUPPLY CHAINS, THE ECONOMIC ACTIVITY OF THE MEDTECH INDUSTRY ALSO CREATES A RISK OF CHILD LABOR (MORE THAN 3,000 CASES).

IN THE COMPARATIVE INDUSTRY RANKING OF THE SOCIAL INDICATOR INTENSITIES, THE MEDTECH INDUSTRY PREDOMINANTLY PERFORMS AVERAGELY



Source: WifOR illustration

Outlook

The MedTech industry is already one of the most important sub-sectors of the Health Economy and is of great importance for gross value added and employment, especially in the Industrial Health Economy.

Even though there has been a slight decline in the number of employees in the sector since 2012, this fact should be considered against the background of the pandemic events of the last two years. In many places, the number of treatments in medical care still not recovered to pre-pandemic levels. In addition, the generation of “baby boomers” are retiring in increasing numbers and, due to the omnipresent shortage of skilled workers, it is becoming increasingly difficult for the industry to fill vacancies.

Overall, the MedTech industry is doing well in terms of environmental and social impact compared to other industries. Nevertheless, the industry must rise to the challenge and further minimize the industry’s footprint in the future.

The MedTech industry has a globally interconnected supply chain. This is associated with both positive and negative effects. On the one hand, the activity or length of the supply chain creates growth and employment in different regions of the world, including low-income regions.

On the other hand, with the relocation of production activities, negative environmental and social consequences are shifted abroad. As the supply chain deepens, it becomes harder for the industry in Germany to influence possible grievances along it. The industry should pursue grievances in a targeted manner, particularly in the areas of improving working conditions and preventing air pollution.

The present study combines the strengths of comparability to prior work, innovative study design, and methodology. In the future, the results and methodology can also serve as a blueprint for companies in the industry to be able to respond specifically to grievances in the supply chain and the hotspots located therein.

At the same time, however, it also offers member companies the opportunity to rank themselves along the uniform industry benchmark. In the future, subsequent in-house reporting could form the starting point for identifying further hotspots along the supply chain in order to make targeted investments in them.

1 Current Situation and Objectives

In addition to the business perspective, other topics have long played an important role in assessing the sustainability of economic activities. Keywords such as resource-efficient growth, climate neutrality, fair prices, social standards, circular economy and conservation of biodiversity should be mentioned, which will play a much stronger role in the assessment of companies in the future.

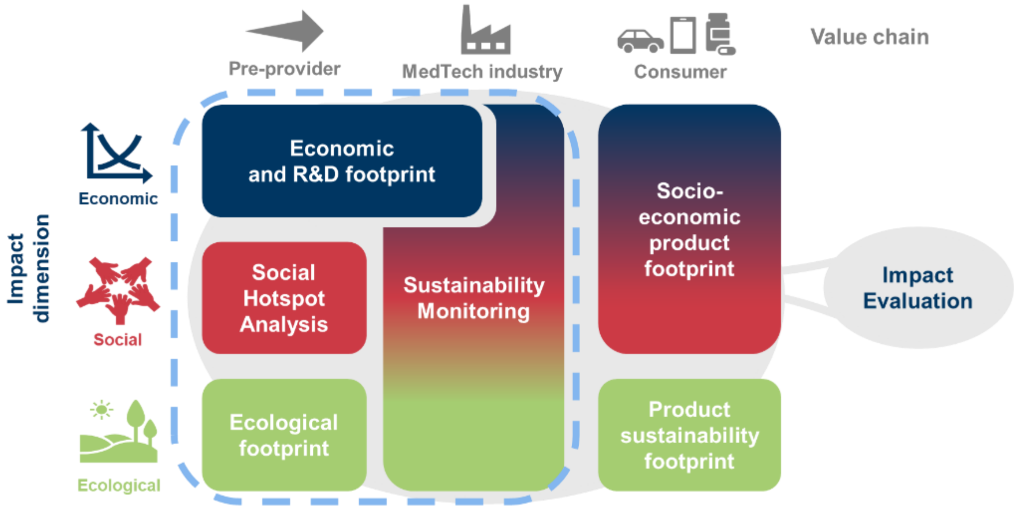
From an economic point of view, the German MedTech industry already makes a considerable contribution to the German economy with a gross value added of 15.4 billion euros while contributing substantially to public health with its medical devices. Logically, the next step in the comprehensive analysis of the industry is logically the further quantification of its environmental and social effects.

As a representative of the German MedTech industry, BVMed is a pioneer in identifying these impacts through the present analysis of its economic, environmental and social footprint and stands for an open and transparent approach to the topic. The importance of this topic has already been highlighted by the number of initiatives around the UN Sustainable Development Goals (SDGs) and ESG reporting.

This first worldwide SEE-Impact industry study enables a comprehensive sustainability measurement based on key indicators and features a direct industry comparison. The derived indicators are aligned with the UN SDGs and international standards for impact valuation such as the Value Balancing Alliance (Value Balancing Alliance 2022). This will establish a new scientific standard for industry reporting, encompassing economic, ecological, and social indicators.

In the context of the broader sustainability discussion, this study thus contributes to conducting evidence-based discussion points on the basis of current economic knowledge.

Figure 1: Impact dimensions along global value chains



Source: WifOR illustration

Germany, as the second largest MedTech location worldwide, acts as an initiator for innovative industry monitoring, i.e., the starting point is the product manufactured in Germany by the MedTech industry. The following figures therefore reflect the cross-section of all companies in the MedTech industry, but not individual companies.

The methodology of the SEE-Impact-Study needed extensive preparatory work, Thereby, the methodology is good-centered, which is internationally agreed upon with the Federal Government, the WHO and the G20 and thus also enables a coherent industry comparison.

In addition, the study is committed to the double materiality approach, i.e., the full capturement of social and environmental impacts of business activities in the global supply chain. The study only analyzes the production of the MedTech industry and its suppliers and thus focuses on the so-called upstream effects alone. This methodology is also set as a standard by the Value Balancing Alliance and is empirically recorded here for the first time for an industry.

Another prerequisite to this analysis is the comprehensive and solid database detailing on almost all countries in the world, recorded in a standardized manner. To this end, the study is based primarily on publicly available official national accounts statistics for five economic indicators, and the publicly available environmental economic accounts for four environmental indicators. The three indicators for the different social dimensions are based on publicly available statistics from various organizations, including the International Labor Organization and other international data holders.

The study thus serves as a blueprint for companies in the industry to meet future reporting obligations and to be able to address the supply chain and its hotspots in a targeted manner.

At the same time, it also offers member companies the opportunity to rank themselves along the now uniform industry benchmark. In the future, subsequent in-house reporting could form the starting point for identifying further hotspots along the supply chain in order to make targeted investments in them to counteract grievances and challenges there.

2 Methodology

2.1 Definition of the Medical Technology Industry on the Basis of the Health Economy

The following section presents the main basic concepts of the Health Economy, mainly detailing on the definition of the Health Economy and its specific characteristics. As priorly mentioned, the authors follow a goods-based approach.

The capturement of the Health Economy within the framework of the Health Economy Reporting (HER) is based on the definition of the National Industry Conference from 2005. As a result, Health Economy includes the "creation and marketing of goods and services that serve to preserve and restore health" (BioCon Valley 2015). Although this broad definition of the industry was not operational, it already took into account an essential aspect at that time, which is decisive for the quantification of the Health Economy within the framework of the HER, namely the goods-based approach instead of the institution-specific approach.

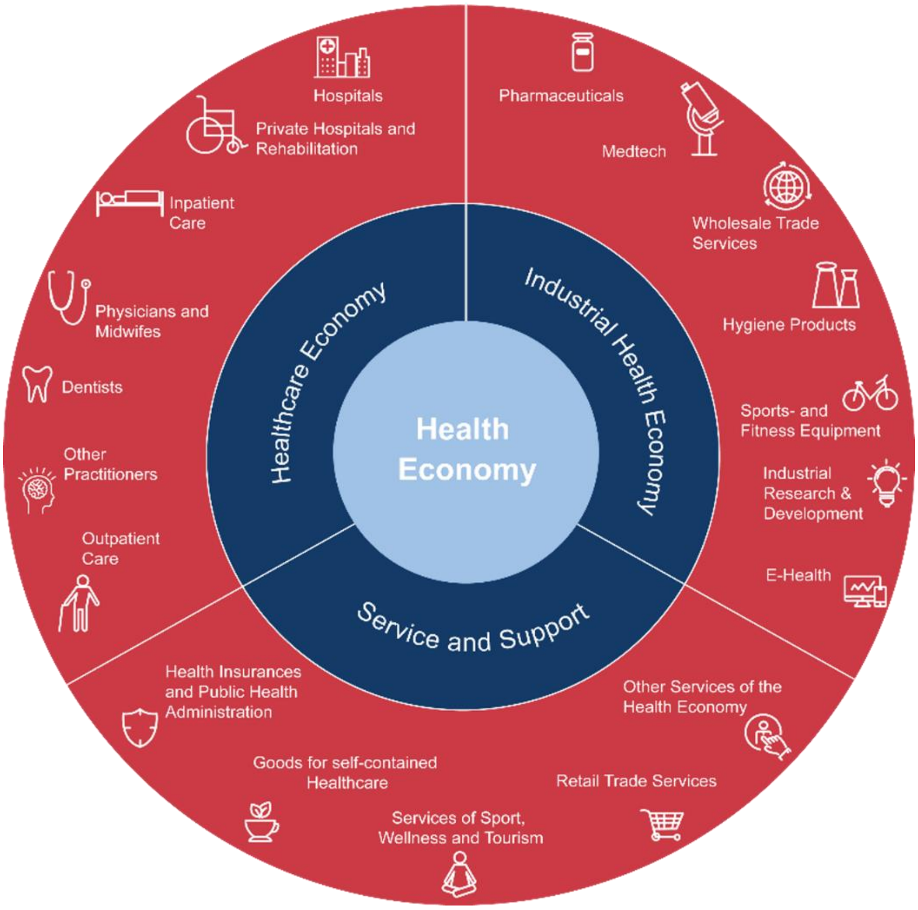
According to OECD, this also goes hand in hand with the definition of health expenditure, which is decisive for the definition of the core area of the Health Economy. This will be discussed in more detail. It basically contains the same idea as the above definition but presents the facts more explicitly. In doing so, it stresses the notion that the source of financing is not decisive for the classification of the good, but only the primary purpose of the good or service, which lies in the improvement, maintenance or preservation of health (OECD, WHO, and Eurostat 2017).

Within the framework of the HER, the main goal is the quantification of the Health Economy. This implies using calculation concepts and data bases coming from national accounts (VGR). The industry is integrated into the economic calculation concepts as a "satellite."

An essential part is keeping macroeconomic structures and volumes in the separation of the cross-sectional industry. The basic data construct is formed by supply and use tables of the national accounts.

The results offer a variety of key figures that can be used to characterize the industry (see Figure 2). The most important are the key figures gross value added, employment, exports, and imports. They all originate from the same concept of national accounts and are therefore in accordance with each other, and can be analyzed in direct comparison without having to take into account different concepts when interpreting them.

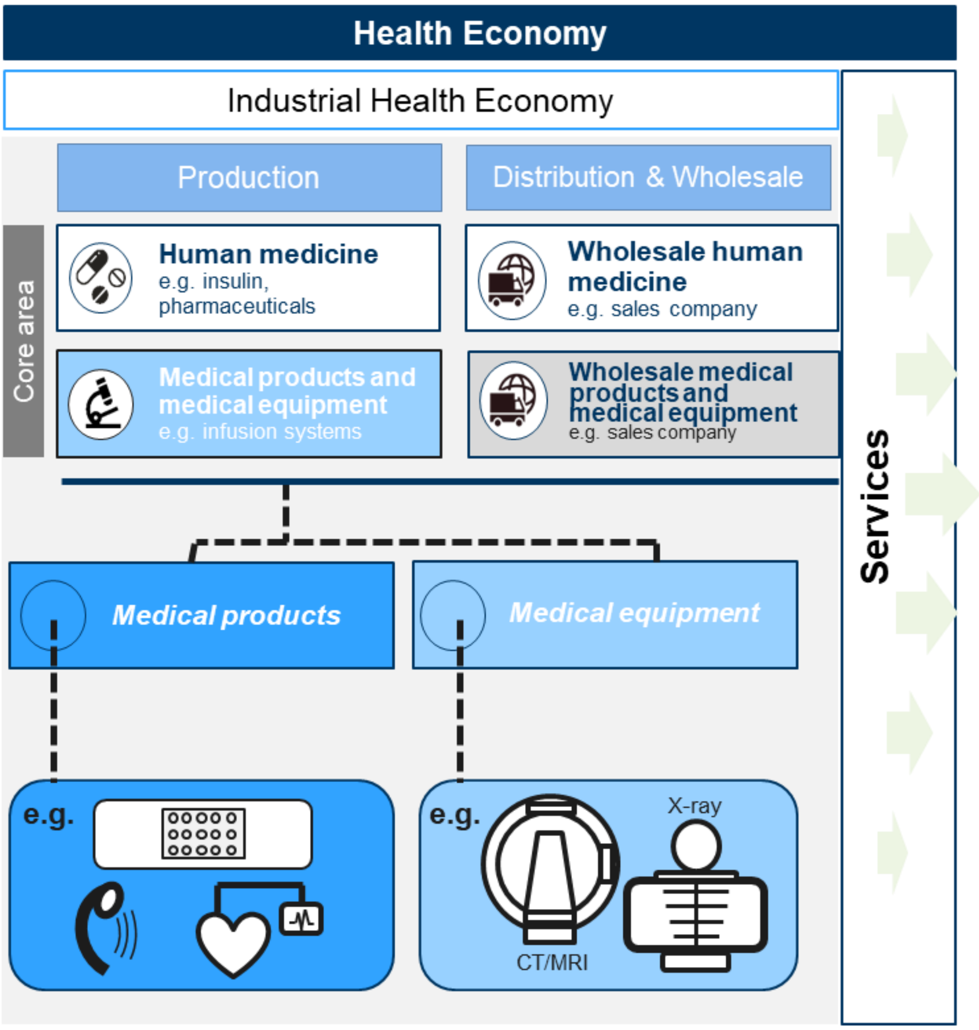
Figure 2: Overview of product groups in the Health Economy



Source: Based on: Federal Ministry for Economic Affairs and Energy (BMWi) (2018): Health Economy - Facts & Figures. Handbook on Health Economy Reporting with explanatory notes and reading aids.

The MedTech industry is one of the most important sub-sectors of the manufacturing industrial Health Economy. Current facts and figures on the industry are based on a goods-based definition of all goods and services that can be assigned to the production of medical products and medical equipment (cf. Figure 3). The field of medical products and medical equipment includes a large number of products that are used in a wide variety of areas of healthcare. A large portion of the products can be classified as "cross-sectional technology" due to a large number of industries and economic sectors involved. This is related to the fact that they have origins or sales potential in other industries. In the MedTech industry, metals, plastics, and electronic components are combined to form new products.

Figure 3: Definition of the MedTech industry as part of the Health Economy



Source: Federal Ministry for Economic Affairs and Energy (BMWi) (2017): Health Economics – Facts & Figures. Special topic Medical Products and Medical Equipment, Edition 2016.

Medical products in the sense of this definition include all goods whose focus is on patient application or personal protection (e.g., plasters or implants). They can be operated or applied independently by the patient or the medical staff – if necessary, after instruction. Since these are largely consumable goods, any maintenance or repairs by external personnel are no longer necessary. The category of medical-technical large-scale industry includes all medical equipment whose primary purpose is diagnosis. These include, in particular, X-ray and computed tomography equipment, but also centrifuges, microscopes and other laboratory supplies required for disease diagnosis. However, there are other large devices whose primary function is the maintenance of medical therapy and cannot be operated by patients without the support of competent medical or technical personnel (e.g. ventilators). These devices all require a certain amount of maintenance, which cannot be easily decoupled from the purchase or operation of the device and is therefore included as a service when calculating the economic effects.

2.2 Background to Impact Analysis

This chapter describes the calculation of the effects along the value chain and the data sources used. The method of input-output analysis (IO analysis) is based on aggregated economic macro data and goes back to the later Nobel Prize winner Wassily Leontief (Leontief 1937). IO analysis makes it possible to track value creation and associated economic, environmental, and social effects along the entire supply chain (Miller and Blair 2009).

The IO analysis is based on input-output tables collected at the national level by statistical offices. IO tables show, among other things, the extent to which economic sectors obtain intermediate consumption from each other and the output value achieved in each sector. The monetary interdependence of intermediate consumption is extended with so-called satellites. These show, for example, how many greenhouse gases, employees, or occupational injuries are generated in the production value in each sector. The satellites thus directly contain information on direct effects arising from a sector's activity, e.g. in production or through the operation of offices.

The so-called indirect or upstream effects of a sector are calculated with the IO analysis. Indirect effects are triggered by the demand for goods and services that a sector needs for its own activity. The demand impulse leads to an increase in economic activity and the associated effects on contractors and their suppliers. Using the so-called Leontief inverse, the increase in the production value triggered by the demand for intermediate consumption can first be calculated for each sector on the basis of the interconnectedness of intermediate consumption. The associated further effects per unit of production are known via the satellites.

Put simply, the indirect (upstream) effects of a sector are thus the result of multiplying three components (see Figure 4). The IO model has a number of assumptions, but there is broad agreement that it is well suited for impact analysis[1].

Figure 4: Calculation components to upstream impacts

Source: WifOR illustration

In this study, indirect effects are further subdivided according to the place where they arise. Indirect effects in the German supply chain include the effects that are triggered within Germany. In contrast, indirect effects in the global supply chain include effects that arise outside Germany.

In order to reflect the global character of value chains, this analysis is based on a multi-regional input-output table (MRIO). Unlike national IO tables, there is no official comprehensive MRIO table. The three most important tables produced by scientific consortia are[2]:

- World Input-Output Database (Gouma, Chen, Woltjer, et al. 2018; Timmer, Los, Stehrer, et al. 2016; Timmer, Dietzenbacher, Los, et al. 2015)
- EORA (Lenzen, Moran, Kanemoto, et al. 2013) and
- EXIOBASE (Stadler, Wood, Bulavskaya, et al. 2018; Tukker, de Koning, Wood, et al. 2013; Wood, Stadler, Bulavskaya, et al. 2014)

The impact of the German MedTech industry is calculated using a table created by WifOR based on the World Input-Output Database (WIOD) in conjunction with EORA. The WIOD database shows the global interconnectedness of 56 economic sectors for the year 2014. It allows the analysis of 43 countries and an aggregate that summarizes the rest of the world. To extend the analysis to

[1] The assumptions of the Leontief model are: 1) Constant economies of scale, i.e., regardless of the level of production, the same amount of inputs per unit of production is required. 2) No supply restrictions, i.e., there are no restrictions on raw materials, services, or other inputs such as employment. 3) Fixed input structure, i.e., there is no input substitution in response to a change in output.

[2] Research into the consequences of the use of the various databases has become a separate field of research. See, for example, the work of Gijum et al. or Owen (Giljum et al. 2019; Owen 2017).

other countries, the shares of this aggregate have been allocated to each country using the information from EORA. Due to the availability of different countries in EORA, a total of 188 countries with 56 sectors each can be examined. These databases already contain a large number of economic and environmental satellites. Further indicators were created by WifOR with additional research.

The 56 sectors are based on the International Standard Classification of Economic Activities ISIC Rev. 4 (United Nations Department of Economic and Social Affairs 2008). As a cross-sectional sector, the MedTech industry is not represented as such. The HER found that for 22 of the 56 sectors, the MedTech sector accounts for part of the production value. On the basis of these production values, both the direct effects were determined and aggregated proportionately and the demand for intermediate consumption for the upstream effects was calculated.

In traditional reporting, the direct and indirect effects are documented in their quantification units, e.g., tons of greenhouse gases or the number of occupational injuries. The evaluation of the effects in this report goes two steps further: First, the resulting environmental and social changes are recorded. These changes are then expressed in monetary terms. Thus, different effects can be made comparable.

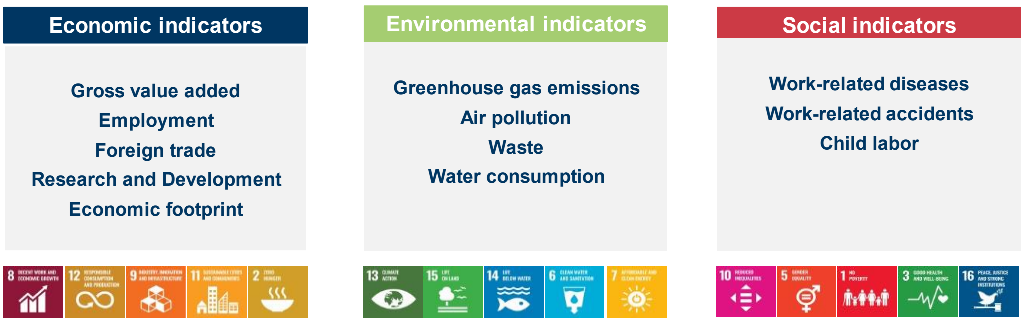
In this study, evaluation methods developed by WifOR are used for this purpose. The evaluation of each indicator should capture the damage costs incurred. For the evaluation, some decisions have to be made, which cannot be purely objective, but are partly subjective due to ethical justifications and have consequences for the economic valuation (Federal Environment Agency 2012). According to economic convention, damages incurred in the future are discounted. The discount factor of 1.5 percent reflects expectations of future economic growth. The assessment of effects affecting human health is also an important and controversial decision. In this study, a globally uniform value for a statistical human life based on studies of willingness to pay is chosen. Thus, every life is weighted equally. The value of 200,000 USD per statistical year of life corresponds to approx. 4 times the gross domestic product per capita of a high-income country. Thus, the value is located at the higher edge of the study range (Trautmann, Xu, König-Kersting, et al. 2021a; Robinson, Hammitt, Chang, et al. 2017; Schlander, Schwarz, Hernandez, et al. 2018a). Further methodological background can be found in the Appendix.

2.3 Indicator set and limitations

The selection and compilation of an indicator set is associated with limitations. Depending on available data, other research projects may have a different focus. The decisive factor for the present study was to compile an indicator set, which on the one hand ensures a broad perspective on the topic, and on the other hand is based on a database that has sufficient quality and comprehensible documentation. For the set of indicators presented here, such documentation is sufficiently available.

In order to map the aspects of the economic, environmental and social footprint of the German MedTech industry along the national and global value chain, an indicator set was compiled within the above-mentioned dimensions. This indicator set draws from the 17 Sustainable Development Goals of the UN (UN 2022) and so-called wellbeing approaches (Snowder, de Miranda, 2020). These indicators can make an important contribution to quantifying the industry effect. In the context of the present study, the indicators shown in Figure 5 are analyzed.

Figure 5: Indicator set of the study



Source: WifOR illustration

When interpreting this study, it should be noted that the MedTech sector is a cross-sectional sector that is not specifically drawn out as an industry and is therefore not directly covered by official tables. The calculated results are thus composed of the average behavior of different sectors (See Annex V). One advantage of this macroeconomic approach is the comparability of the results with other sectors.

The satellite data are important for the quality of the analysis. The availability and quality of official statistical data vary for the countries considered. This concerns, for example, the completeness and granularity, or frequency of updating. In addition, there are deviations in the recording of some indicators. In particular, occupational injuries and diseases and illnesses are recorded to varying degrees. To fill data gaps and, as in the case of injuries and illnesses, to compensate for known underreporting, secondary data, such as scientific studies, are used. The definition and sources are given in Chapter 2.3 for each indicator. It should be noted that in the interests of comparability, international databases are used for the calculation of parameters at the national level. Due to different data bases, this can lead to deviations compared to national surveys.

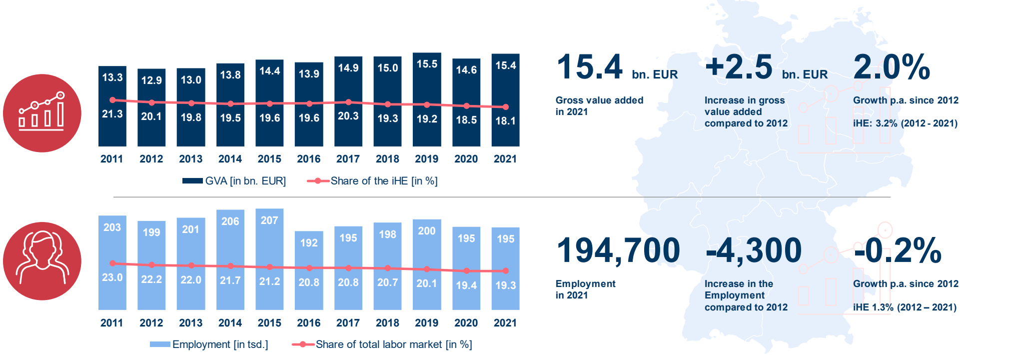
3 SEE Impact Monitoring of the MedTech Industry

In the following, selected results for the economic, economic, and social footprint of the German MedTech industry are presented in order to draw a holistic picture of the industry.

3.1 The Economic Footprint

The MedTech industry (medical products and medical equipment) is one of the most important sub-sectors of the Health Economy and is of great importance for gross value added and employment, especially in the Industrial Health Economy (IHE). As Figure 6 shows, the industry's absolute gross value added amounted to 15.4 billion euros in 2021. This corresponds to 18.1 percent of the total IHE. Compared to the previous year, the MedTech industry is thus again recording a growth of 0.8 billion euros. In last decade, gross value added in the industry constantly increased at a rate of 2.0 percentage per year, but compared to the average of the entire IHE, the growth is below average.

Figure 6: The economic development of the MedTech industry

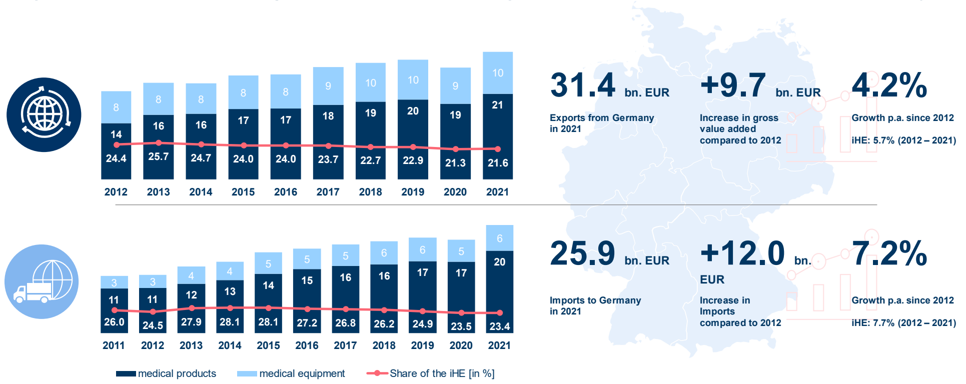


Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

A somewhat different picture can be drawn with regard to employment in the industry. With a total of 194,700 persons in employment, fewer people were employed in the sector in 2021 (-500) than in the previous year (195,200). Proportionally, the industry thus loses around 0.1 percentage points of importance within the IHE and is responsible for only 19.3 percent of the workforce. This shows that the industry is characterized by a decline in employment in the long-term. Since 2012, the number of people in employment has fallen by 0.2 percent per year. The largest sales market, which are hospitals, also recorded a strong decline in the number of treatments in the years 2020 to 2021. This resulted in corresponding adjustments for MedTech companies, which puts this decline into perspective.

As can be seen from Figure 7, exports of the entire MedTech industry have grown steadily since 2012. The absolute increase of around 9.7 billion euros since 2012 is accompanied by average growth of 4.9 percent p.a. in the field of medical products (approx. +50 percent) and 3.0 percent in the field of medical equipment (approx. +25 percent). In the crisis year 2020, the entire industry suffered a decline in exports. While exports in the medical products industry fell by 6.0 percent, exports of medical equipment fell by 7.9 percent compared to 2019. Both sub-areas will grow again in 2021 with 13.6 percent (medical products industry) and 14.7 percent (medical equipment) respectively.

Figure 7: The development of the foreign trade of the MedTech industry



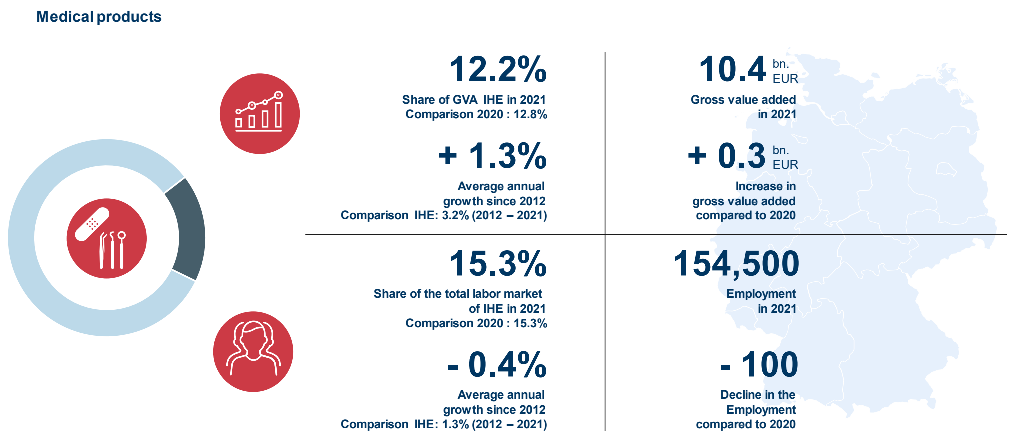
Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

The volume of imports in the MedTech industry has also been steadily increasing since 2012. The only exception is the crisis year 2020, in which the import volume fell by 500 million euros compared to the previous year. At -6.2 percent, imports of medical equipment fell more sharply than those of medical products (-1.1 percent). The current data shows that the industry is again characterized by strong import growth. At 16.6 percent, the import of medical equipment increased somewhat more strongly than that of medical products with 15.9 percent.

A closer look at the individual sub-sectors of the MedTech industry (medical products or large-scale medical devices) reveals a differentiated view of the development of the sub-sectors. Figure 8 shows that the sub-sector of medical products (as defined in the national accounts) with 10.4 billion euros of gross value added in both absolute and relative terms (12.2 percent) than the sector of large-scale medical devices with 5.0 billion euros or 5.8 percent (see Figure 9).

Compared to the crisis year 2020, the sub-sector has gained 0.3 billion euros. However, this increase is not enough to return to the pre-crisis level of 2019 of 10.5 billion euros, and since the industry is growing more slowly than the entire IHE (3.2 percent) in the long-term with annual growth of 1.3 percent, its share of it has also declined within the last decade. In view of the fact that sales of medical products and consumer goods are not dependent on consumer trends, but on the performance of hospitals, the slow growth seems understandable. Due to a shortage in skilled workers, among other things, capacities in service provision have not yet returned to the level of 2019.

Figure 8: The economic development of the medical products industry

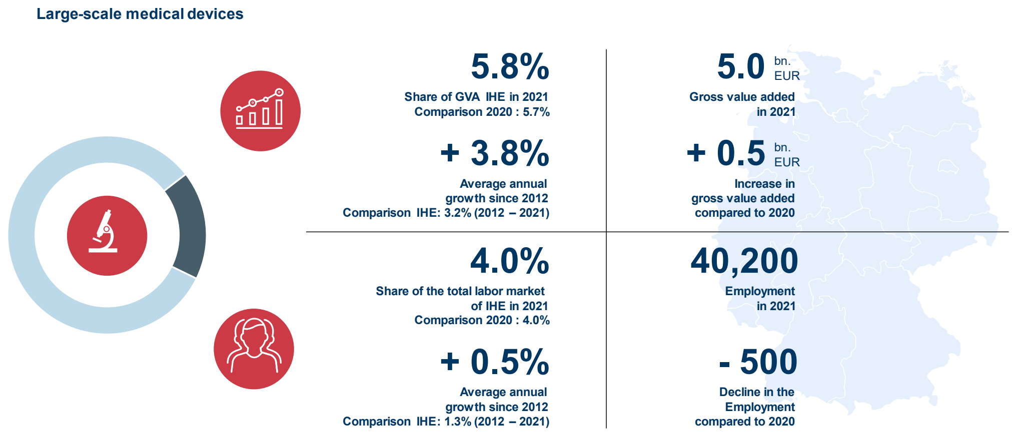


Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

On the labor market, the sub-sector has almost stagnated in the recent crisis years. With 154,500 employees in 2021, the industry employs 15.3 percent of the workforce in the IHE, but misses a trend reversal, because in the long-term, employment in the industry has continued to decline by -0.4 percent annually since 2012.

Compared to the sub-segment of medical products, the medical-technical large-scale industry has recently recorded a different development (see Figure 9). Thus, the industry left the crisis year 2020 with a growth of 0.5 billion euros gross value added and reached its pre-crisis level of 2019 with 5.0 billion euros. Here it seems understandable that the pandemic-related effect of high investments in ventilation technology had a substituting effect on declines in other areas of the industry. In the long-term, the industry has grown by 3.8 percent since 2012, 0.5 percentage points faster than IHE (3.2 percent). As a result of above-average growth, the sub-sector was able to increase its share of IHE's value added by 0.1 percentage points compared to the previous year.

Figure 9: The economic development of medical-technical large-scale industry



Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

A positive picture is also emerging on the labor market. With 40,200 employees, the medical-technical large-scale industry will be as important for the labor market in IHE in 2021 as it was in the previous year. Although the decline of around 500 persons in employment is the second in a row since 2019, the long-term employment growth of +0.5 percent since 2012 rather points to stagnation. Rising value added contributions with stagnating to slightly declining employment figures can be seen as signs of increasing automation of production processes and thus represent a productivity gain.

The fact that the medical products and large-scale medical devices sector recovered as a result of the crisis in 2021 can largely be attributed to the fact that more expenditure on medical aids and products was again made by service providers – such as health and nursing care insurance. Internal forecasts show that the growth in expenditure on aids, e.g., due to pandemic-related catch-up effects in the supply of medical aids, health crafts and retail trade increased by 5.6 percent compared to the previous year 2020. This includes, among other things, expenses for orthopedic technology, medical equipment, rehabilitation technology and aids for home use. The driving factor behind this increase is the expenditure on medical equipment aids. These alone record a forecast increase of 11.6 percent compared to the previous year[3].

In addition to statements on the growth and employment-relevant key figures of the manufacturing MedTech industry, the HER can also be used to make statements about the economically relevant contributions generated by research and

[3] Forecast WifOR based on Federal Health Reporting (GBE) 2022

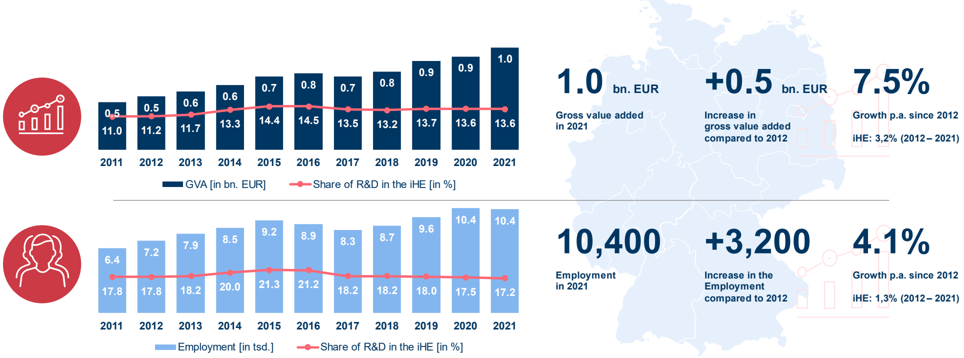
development. The process of research and development (R&D) is considered a generator of knowledge and a driver of technological progress in an economy.

It is undisputed that the MedTech industry, in addition to its role as an important value creation and employment factor in Germany, also promotes the advancing innovation process of the entire industry. R&D in the MedTech industry not only creates growth and employment, but also an important additional benefit for maintaining the health of the population through innovative medical products and solutions. In connection with the pandemic, it has become clear how important it is that the research and development of these new medical products and solutions are also available in Germany as a location for innovation. Against this background, R&D in the MedTech industry in the context of the present study sees itself as an independent sub-area that stands for the creation of new knowledge as well as for securing jobs and increasing wealth.

In addition, R&D activities are also regarded internationally as an important prerequisite for ensuring the growth and competitiveness of an industry and the entire national economy. This consensus is underpinned by one of the European Commission's headline targets from the "Europe 2020 strategy." This strategy recently stipulated that the European Union (EU) should spend three percent of its gross domestic product (GDP) on R&D by 2020. In the current coalition agreement of the Federal Government, it was raised to a value of 3.5 percent by 2025.

In 2021, R&D in the MedTech industry in Germany generated a gross value added contribution of around 1.0 billion euros and employed around 10,400 people (see Figure 10) with a share of 13.6 percent of gross value added and 17.2 percent of the workforce of total industrial R&D. This R&D share is a smaller area than, for example, the R&D of human pharmaceuticals, but it has nevertheless recorded growth more than twice as strong as gross value added in the entire IHE within the past decade.

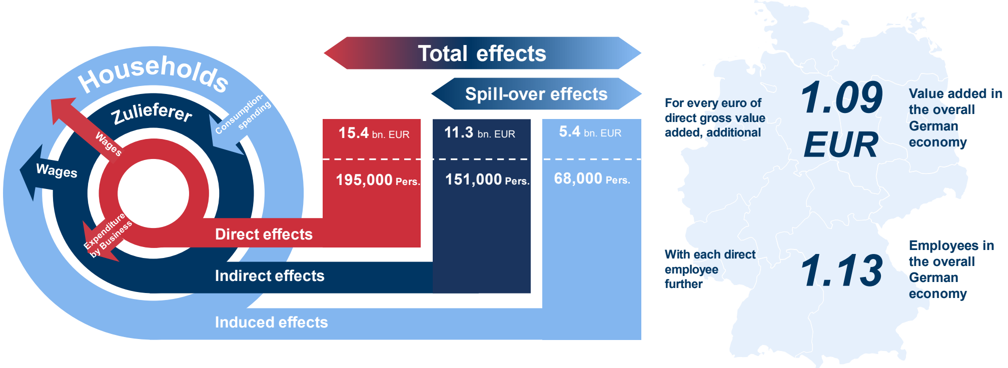
Figure 10: The economic development of R&D in the MedTech industry



Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

The fact that the German MedTech industry also generates gross value added and employment effects beyond its direct economic activity is shown in the following Figure 11.

Figure 11: The economic footprint of the MedTech industry 2021



Source: Federal Ministry of Economics and Climate Protection (BMWK) (2022): Health Economics – Facts & Figures. Health Economy Reporting results, data 2021

The economic activity of the players in the MedTech industry will initially generate 15.4 billion euros in direct gross value added and around 195,000 employment relations. In addition, the purchase of goods and services from upstream suppliers generates a further 11.3 billion euros in indirect gross value added and 151,000 employment relationships in the entire economy. Since employees in the supplier industries also consume goods and services in the economy as a whole with their wages, an induced effect of 5.4 billion euros gross value added, and 68,000 employment relations arises in a third stage. Overall, the economic footprint of the German MedTech industry amounts to 32.2 billion euros gross value added and around 414,000 employees in the entire German economy in 2021.

3.2 The Environmental Footprint

The economic activity of the German MedTech industry is associated with environmental effects. In this study, the environmental effects are quantified by the indicators greenhouse gases, air pollution, waste, and water consumption. These indicators represent the most important cornerstones for quantifying the environmental footprint of the German MedTech industry and provide information on possible hotspots.

3.2.1 Greenhouse gases

Greenhouse gases

Definition: A greenhouse gas is a gas that absorbs and emits radiant energy in the thermal infrared range, thus causing the greenhouse effect. Greenhouse gases include a total of seven gases, of which the three most important are dealt with in the present calculations: carbon dioxide (CO_2), methane (CH_4) and nitrogen dioxide (N_2O).

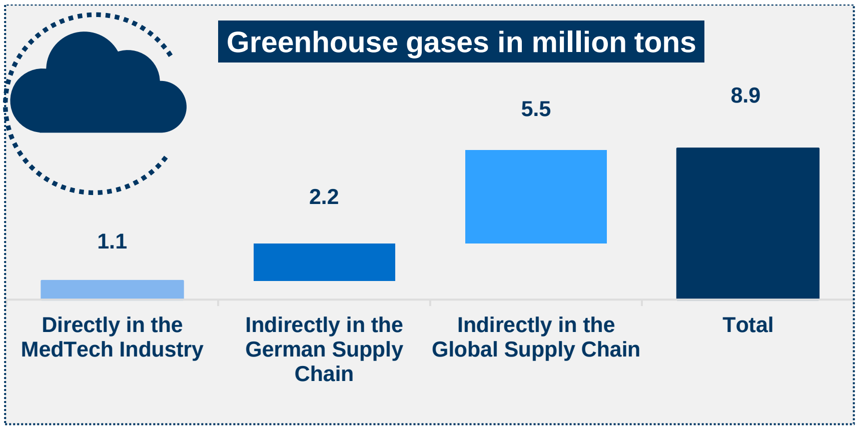
In order to unify the different gases to a universal metric, global warming potentials is used. These potentials are factors that describe the degree of atmospheric damage to a unit of a given greenhouse gas compared to a unit of CO2. As a result, so-called CO_{2e} (CO2 equivalents) are derived.

Scope: All calculated greenhouse gas emissions or associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

Sources: EXIOBASE 3.8.1. / EORA / Eurostat Air Emission Accounts (Table: env_ac_ainah_r2) / OECD Air Emission Accounts (Table “AEA”) / Global Warming Potentials from the IPCC Fifth Assessment Report AR5).

Greenhouse gas emissions are among the most important drivers of man-made climate change. The global greenhouse gas effect of the German MedTech industry arises mainly indirectly in the global supply chain. Overall, the economic activity of the German MedTech industry in 2020 was associated with the emission of 8.9 million tons of greenhouse gases. Of this, 1.1 million tons were produced directly in the MedTech industry in Germany, while a further 2.2 million tons were produced in the German supply chain. On the other hand, 5.5 million tons were emitted indirectly in the global supply chain, which represents 61.8 percent of total emissions (see Figure 12).

Figure 12: The global greenhouse gas impact of the MedTech industry 2020

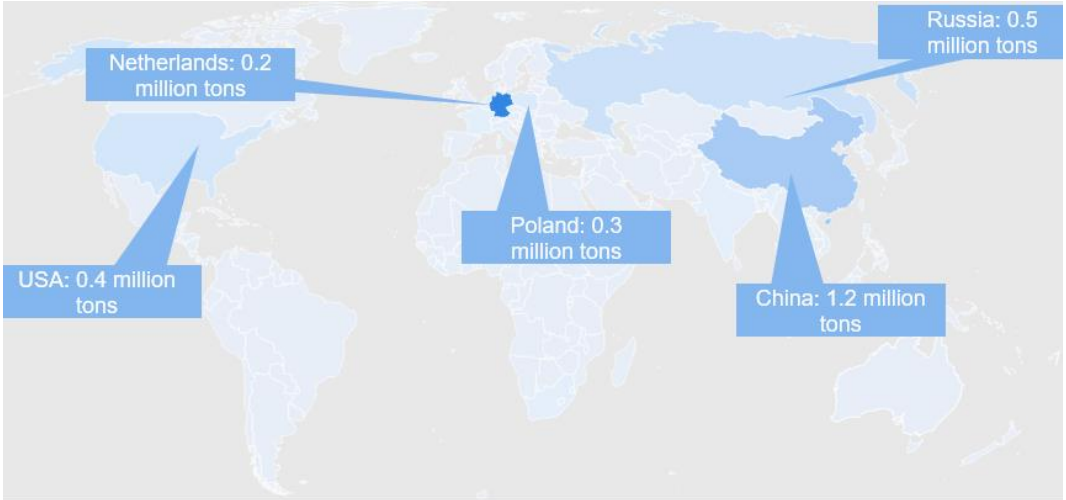


Source: Calculation and illustration of WifOR. Benchmark year 2020.

This underlines the importance of taking into account the global supply chain, as otherwise no complete picture of the greenhouse gas emissions of the MedTech industry could be generated. An exclusive consideration of the German share without integration into global supply chains would drastically underestimate the role, thus highlighting the central role of the input-output approach for the assessment of greenhouse gas emissions.

In the global supply chain, China emits by far the most greenhouse gases (1.2 million tons (see Figure 13)). As a result, more than 13 percent of the total greenhouse gas emissions of the German MedTech industry are generated in China. Russia is the second largest emitter with 0.5 million tons but lags well behind China. The large gap to China also illustrates its importance as a hotspot along the supply chain. The USA (0.4 million), Poland (0.3 million) and the Netherlands (0.2 million) follow at a further distance.

Figure 13: Global greenhouse gas hotspots of the MedTech industry in 2020



Source: Calculation and illustration of WifOR. Benchmark year 2020.

The analyzed global supply chain is on the one hand the production of preliminary and finished products, but on the other hand also the procurement of selected raw materials and metals that only occur in certain regions of the world. This raises the broader question of the extent to which a reduction of the environmental footprint through production relocations is possible in these cases.

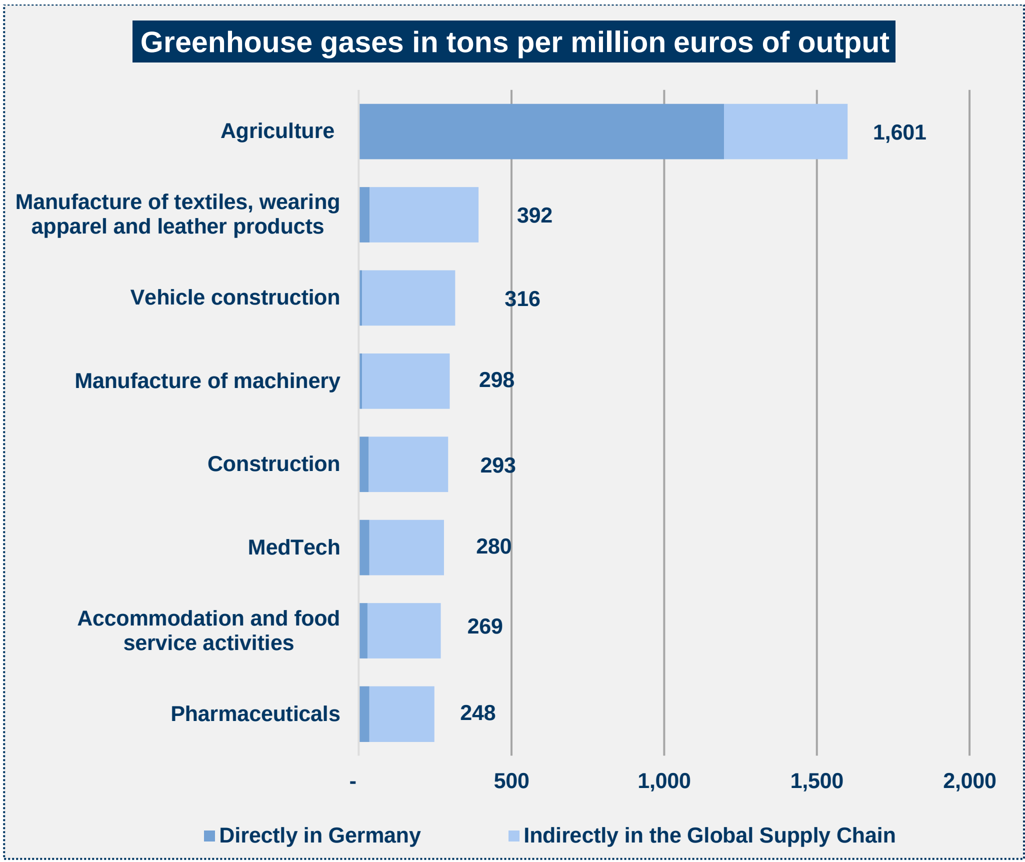
One measure for comparing different industries is greenhouse gas intensity, which scales the amount of greenhouse gases per million euros of output. This indicator makes it possible to compare different industries by indicating the amount of greenhouse gas emitted relative to output rather than in absolute indicators. As a result, industries of different sizes can also be compared with regard to their greenhouse gas emissions.

In an industry comparison (see Figure 14), the MedTech sector is behind sectors such as construction (293 tons) and vehicle construction (316 tons) with direct and indirect greenhouse gas emissions in the global supply chain of 280 tons per million euros output.

The front runner in Germany is agriculture, which with an intensity of 1,601 tons has the highest value of the analyzed industries. The comparison shows that the MedTech industry has a significantly lower greenhouse gas intensity than other sectors.

The distinction between greenhouse gases produced directly in Germany and indirectly in global supply chains is also crucial in the discussion of greenhouse gas intensity. If only the greenhouse gases emitted directly in Germany are considered, the MedTech industry would occupy one of the top places, although other sectors such as vehicle construction cause significantly higher greenhouse gas emissions from a global perspective.

Figure 14: Industry comparison along greenhouse gas intensity



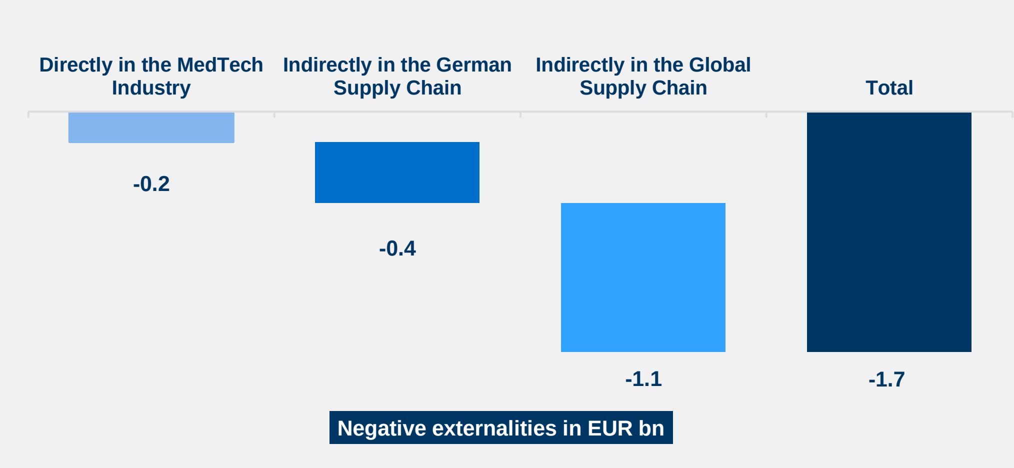
Source: Calculation and illustration of WifOR. Benchmark year 2020.

Greenhouse gases monetary valuation

Greenhouse gas emissions are global in their consequences. They are released into the atmosphere and mix there to form a global concentration of greenhouse gases, so that it does not matter for the environmental impact where it is emitted: the greenhouse gases "accumulate in the atmosphere to stores of greenhouse gases. It is the total stock of greenhouse gases that counts, not the place where they are produced" (Stern 2008). Therefore, a regional distinction is not necessary for the assessment of impacts. To calculate the monetary values associated with the emission of the aforementioned greenhouse gases, the damage cost approach of the Federal Environment Agency was used (Bünger and Matthey 2018) and inflated to the year 2020. As a result, a global damage cost value of €187 per ton of greenhouse gas released is determined.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of greenhouse gas emissions, the monetarily valued effect can also be investigated. Figure 15 shows the negative externalities along the global supply chain of the German MedTech industry. With a monetary valuation of -1.1 billion euros, the majority of negative externalities arise outside Germany and indirectly in the global supply chain. Directly within the MedTech industry itself and indirectly in the national supply chain, a total of around -0.6 billion euros in negative externalities arise. In total, the monetary valuation of greenhouse gas emissions amounts to -1.7 billion euros.

Figure 15: Global negative externalities due to greenhouse gases



Source: Calculation and illustration of WifOR. Benchmark year 2020.

3.2.2 Air pollution particulate matter of particle size $PM_{2.5}$

Air pollution $PM_{2.5}$

Definition: Air pollution refers to the emission into the atmosphere of substances that are harmful to the health of humans and other living beings or cause damage to the climate or materials. There are different types of air pollutants, such as gases, particles, and biological molecules. Both human activities and natural processes can cause air pollution. For the present calculations, the contamination by particulate matter particles not exceeding a maximum size of 2.5 µm was taken as a basis. A distinction is also made between the release environment (urban, peri-urban, rural, in traffic).

Scope: All calculated particulate matter emissions of the particle size $PM_{2.5}$ or associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

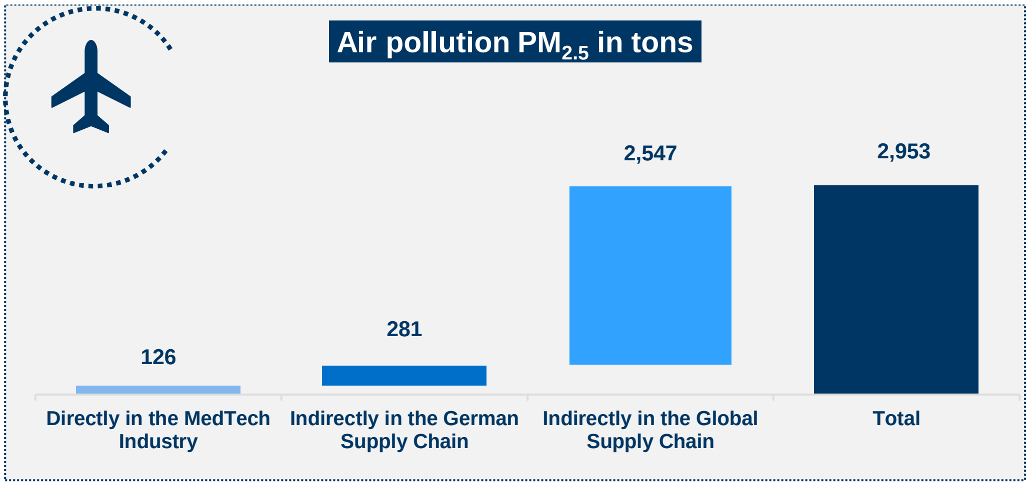
Sources: EXIOBASE 3.8.1. / EORA / Eurostat Air Emission Accounts (Table: env_ac_ainah_r2) / OECD Air Emission Accounts (Table “AEA”) / Release environment according to VBA recommendation.

Worldwide, the economic activity of the German MedTech industry causes air pollution by particulate matter of various particle sizes. Against the background of health effects in particular, particulate size $PM_{2.5}$ represents by far the most important indicator of air pollution.

The German MedTech industry causes global air pollution of $PM_{2.5}$ in the amount of 2,953 tons. Most of the air pollution (2,547 tons) originates indirectly in the global supply chain. This means that 86 percent of air pollution originates outside Germany.

Within Germany, 126 tons of particulate matter can be directly attributed to the MedTech industry, while 281 tons are produced indirectly in the German supply chain of the MedTech industry (see Figure 16).

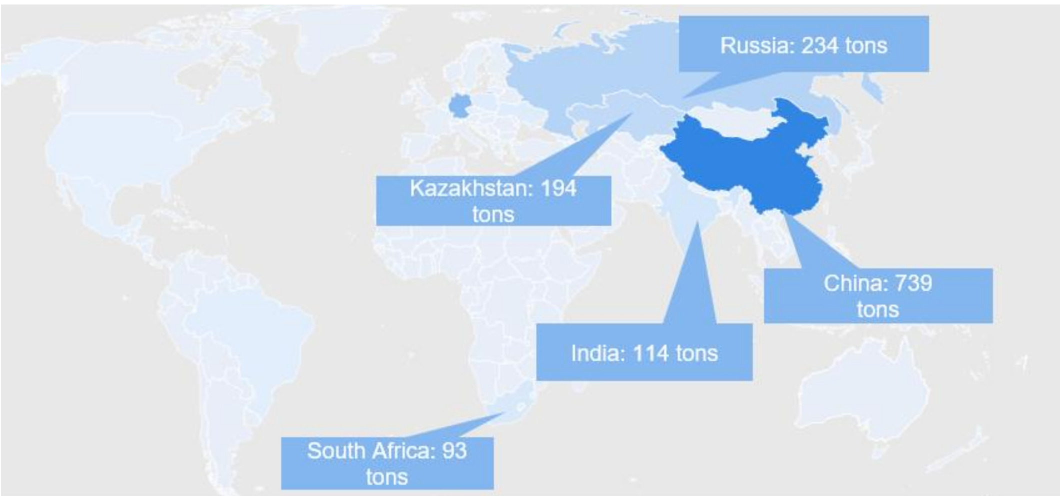
Figure 16: The global air pollution impact of the MedTech industry 2020



Source: Calculation and illustration of WifOR. Benchmark year 2020.

China is emerging as a hotspot in the supply chain in terms of air pollution, which, with 739 tons, is responsible for a quarter of the total air pollution triggered in the German MedTech industry (see Figure 17). This is followed by Russia (234 tons), Kazakhstan (194 tons), India (114 tons) and South Africa (93 tons). China's dominance is illustrated by the fact that the four countries behind it together still lag well behind China's.

Figure 17: The global $PM_{2.5}$ air pollution hotspots of the MedTech industry 2020



Source: Calculation and illustration of WifOR. Benchmark year 2020.

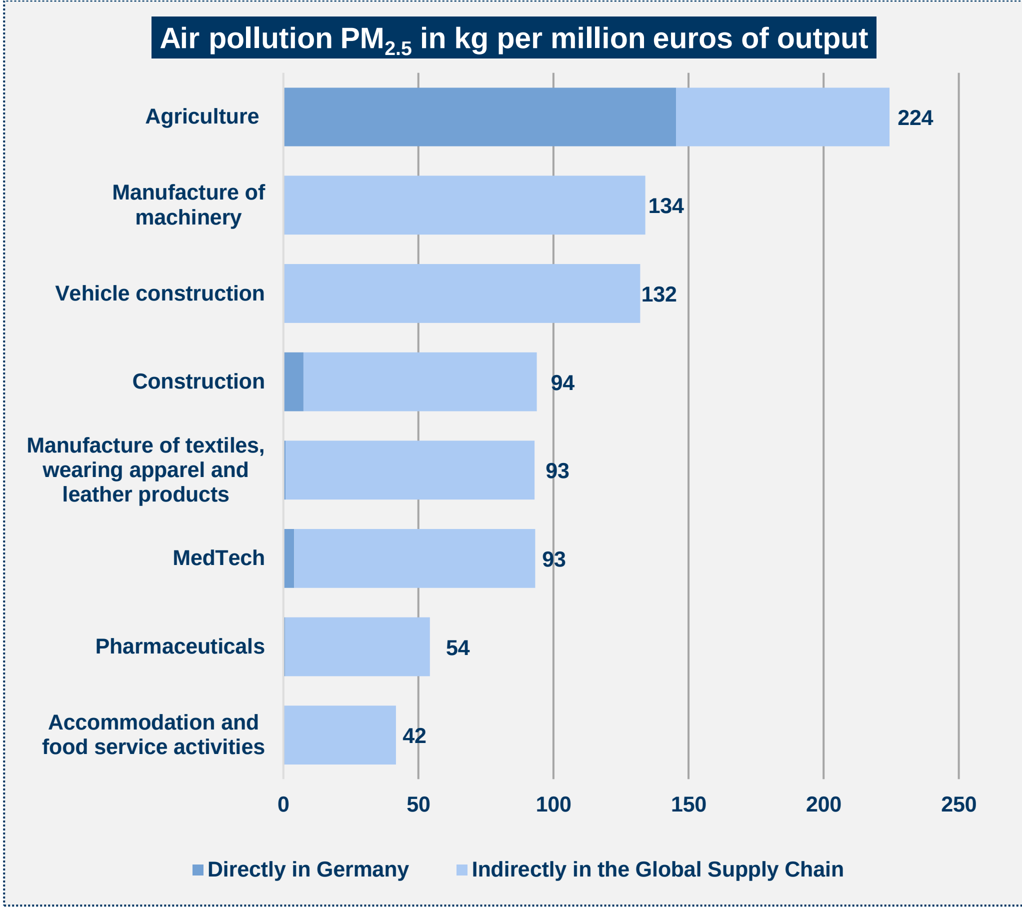
Compared to other industries in Germany, the MedTech industry in Germany occupies one of the lower places in terms of particulate matter emissions (see Figure 18).

This suggests that their economic activity is less strongly linked to the causation of particulate matter than in other industries. If the direct and indirect effects in the global supply chain are considered, the MedTech industry has a value of 93 kg of particulate matter per million euros of output. This puts it ahead of the pharmaceutical industry with 54 kg per million euros output, but still well behind other sectors such as manufacture of machinery (134 kg) or vehicle construction (132 kg).

It is striking that the MedTech industry is one of the few industries analyzed whose economic activity also directly triggers air pollution in Germany. Although this share (4 kg per million euro output) seems small compared to the indirect effects triggered in the global supply chain, this is a particularly relevant aspect from a strategic point of view. This could be explained by the fact that inputs are provided by the energy industry, which, for example, emit particles from gas and coal-fired power plants.

However, it is also interesting to note that about 60 percent of emissions in Germany result from combustion processes, with private households and road traffic accounting for the largest shares (Wilke 2013).

Figure 18: Industry comparison along $PM_{2.5}$ air pollution intensity



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Air pollution $PM_{2.5}$ monetary valuation

The calculated monetary values represent the values associated with the release of one kilogram of pollutant. Since the effects of air pollutants occur locally and vary in their extent of damage depending on the release environment (urban, suburban, rural, transport), it is necessary to estimate prices per country and differentiate them by environment.

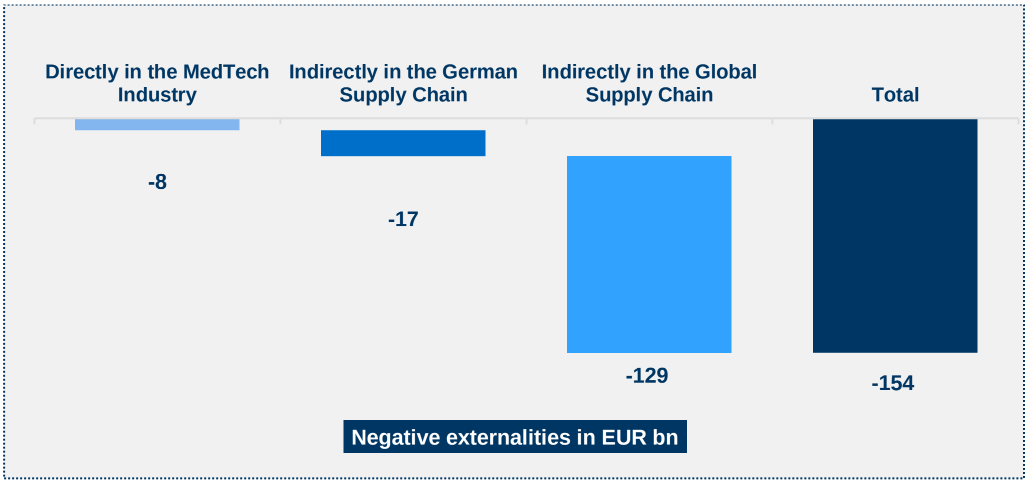
For example, at high population density, the same amount of pollutants leads to a higher concentration of pollutants and is inhaled by more people, which in turn has more serious health effects. And the closer to the ground – for example through transport – the more it is absorbed by humans or leads to pollution that must be eliminated by infrastructure costs (e.g., city cleaning).

For the calculation of the monetary values associated with the emission of the above-mentioned air pollutants in the respective environment, the damage cost rate of the Federal Environment Agency was used.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of the emission of air pollution of particle size $PM_{2.5}$, their monetarily valued effect can also be investigated. Figure 19 shows the negative externalities along the global supply chain of the German MedTech industry.

With a monetary valuation of -129 million euros, around 84 percent of negative externalities arise outside Germany and indirectly in the global supply chain. Directly within the MedTech industry itself and indirectly in the national supply chain, a total of -25 million euros in negative externalities arise. In total, the monetary valuation of $PM_{2.5}$ air pollution amounts to -154 million euros.

Figure 19: Global negative externalities due to $PM_{2.5}$ air pollution



Source: Calculation and illustration of WifOR. Benchmark year 2020.

3.2.3 Waste

Waste

Definition: The waste indicator is defined as the weight of waste generated by an enterprise. The amount is expressed in kilograms. In principle, the measured waste can be divided into the subcategories hazardous and non-hazardous waste. In addition, waste in each subcategory can also be specified by type of disposal. The waste can therefore either be disposed of in landfills or by incineration or recovered by recycling or downcycling.

Scope: The calculated waste generation or all associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

Source: EXIOBASE HYBRID / EUROSTAT Waste accounts (Table “env_wastrt”).

In addition to greenhouse gases, the consideration of waste generated by economic activity is also an important aspect in the quantification of the environmental footprint. Overall, the MedTech industry in Germany and its upstream global suppliers are responsible for 1,782,000 tons of waste (see Figure 20). This does not include the waste resulting from the consumption of the end products by the customer.

Of this, 1,464,000 tons are produced indirectly in the global supply chain, which corresponds to a share of around 82 percent. With 246,000 tons, approx. 14 percent a significantly smaller part is generated indirectly in the German supply chain. Only 72,000 tons, i.e., 4 percent of the total volume, are produced directly in the German MedTech industry. This distribution highlights the importance of waste generated indirectly in the global supply chain for the overall effect.

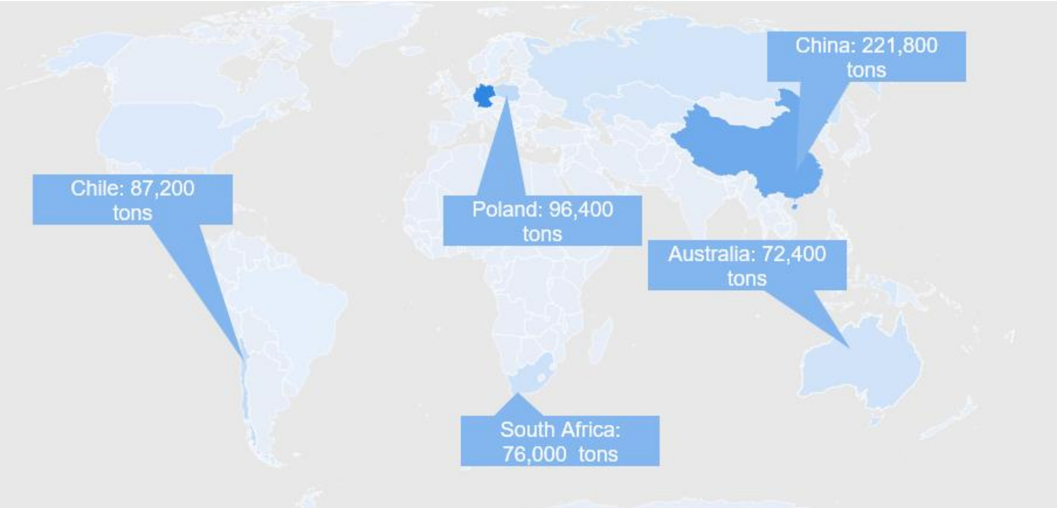
Figure 20: The global waste impact of the MedTech industry 2020

Source: Calculation and illustration of WifOR. Benchmark year 2020.

With 221,800 tons, the geographical distribution within the global supply chain once again shows China at the top of the individual countries (see Figure 21). The gap to Poland, which accounts for the second largest share with 96,400 tons, is immense and once again illustrates China's role as a hotspot in the global supply chain of the German MedTech industry.

Subsequently, Chile (87,200 tons), South Africa (76,000 tons) and Australia (72,400) are further hotspots in the global supply chain, but still well ahead of China.

Figure 21: Global waste hotspots of the MedTech industry 2020

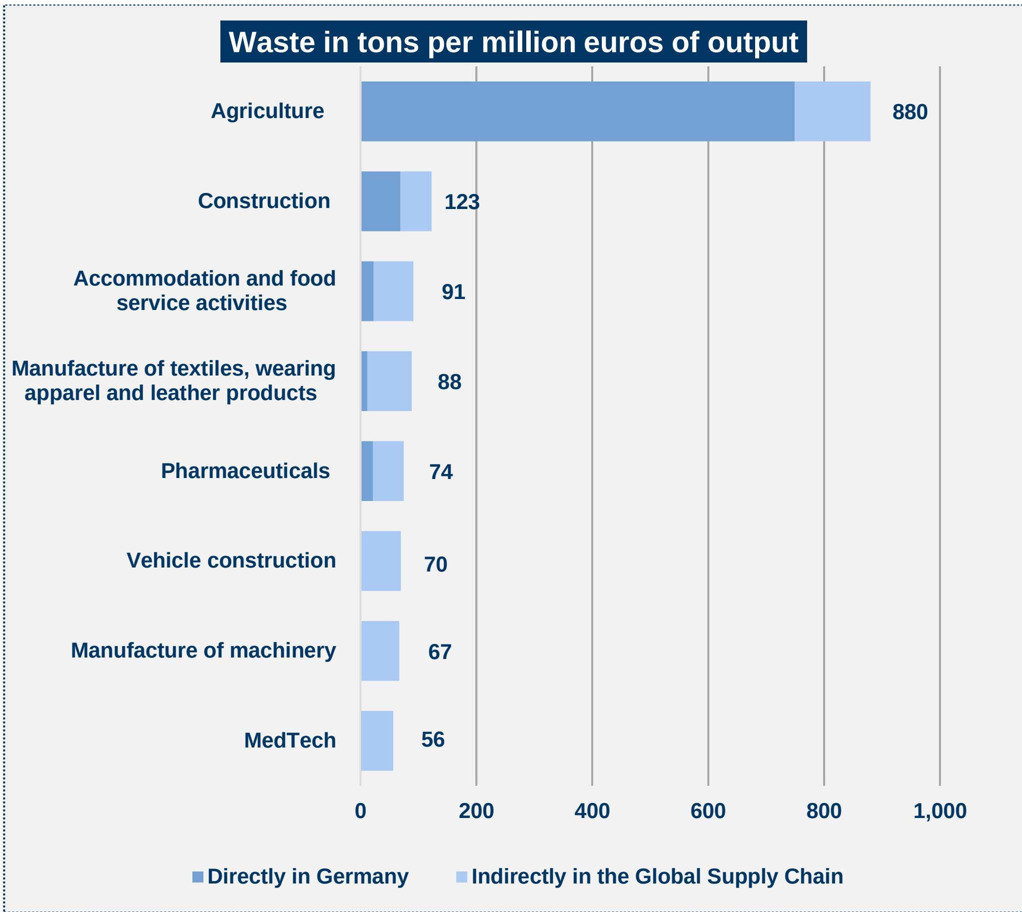


Source: Calculation and illustration of WifOR. Benchmark year 2020.

If the indirect occurrence of waste in the global supply chain is considered relative to the output of the respective industries in Germany, the MedTech industry occupies the last place in this industry selection (see Figure 22).

With 56 tons of waste per million euros of output, it is well behind other sectors such as construction or vehicle construction. This shows that value creation in the MedTech industry is less strongly linked to the generation of waste in global supply chains than a large number of other industries in Germany. It also becomes clear that only a very small proportion of waste is generated in Germany itself, and to a large extent along the global supply chains.

Figure 22: Industry comparison along waste intensity



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Waste monetary valuation

Both the collection and disposal of solid waste leads to environmental degradation, which entails various costs for society.

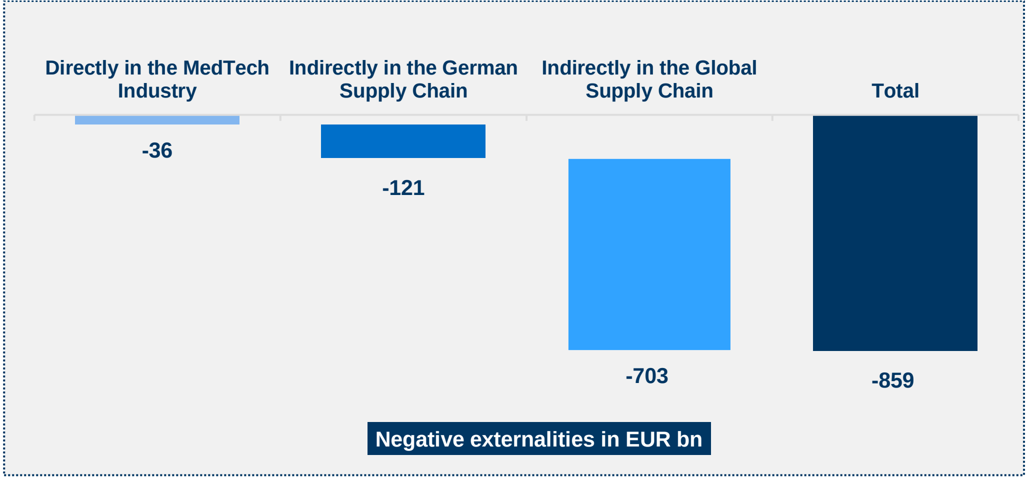
The indicator intends to measure the effect on people (health & inconvenience) and the ecosystem alike. Damage to health is an integral part of damage costs. Air pollution, contaminated leachate or greenhouse gases are causes of the resulting health effects. Prices for these environmental impacts are not directly available but must be estimated on the basis of their impact.

The damage cost estimate for waste disposal was based on a literature review. The approach was differentiated according to the type of waste, i.e., hazardous, and non-hazardous waste, and the type of treatment, i.e., incineration and landfilling. Waste that is recycled is rated zero for the company causing the waste according to the literature.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of the generation of waste, their monetarily valued effect can also be examined. Figure 23 shows the negative externalities along the global supply chain of the German MedTech industry.

With a monetary valuation of -703 million euros, more than 80 percent of negative externalities arise outside Germany and indirectly in the global supply chain. Directly within the MedTech industry itself and indirectly in the national supply chain, a total of -157 million euros in negative externalities arise. In total, the valuation of the waste amounts to -859 million euros.

Figure 23: Global negative externalities due to waste



Source: Calculation and illustration of WifOR. Benchmark year 2020.

3.2.4 Water consumption

Water consumption

Definition: Water consumption describes the proportion of water abstracted that is not returned to surface waters after use, as it is lost through evaporation in the manufacturing process or enters the final product, by-products, or solid waste. Water consumption refers to "blue water", i.e., water that comes from surface or groundwater resources.

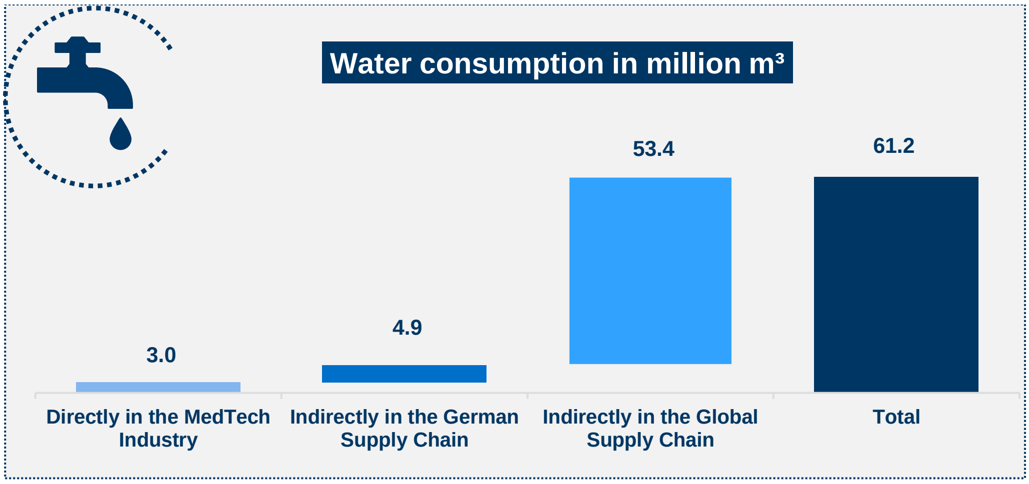
Scope: The calculated water consumption or all associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

Source: EXIOBASE 3.8.1. / EORA.

Another indicator for determining the environmental footprint is the global effect of water consumption. Its importance is particularly evident against the background of Sustainable Development Goal (SDG) 6. This formulates the goal of "ensuring the availability and sustainable management of water and sanitation for all". The importance of this becomes particularly evident against the background of the expected increasing global scarcity of water. This is made clear, for example, by a study by UNICEF, which states that about 2.2 billion people worldwide do not have secure access to clean water (UNICEF 2022a).

The economic activities of the MedTech industry in Germany are associated with a total water consumption of 61.2 million m^3 (see Figure 24). Of this, 53.4 million m^3 are consumed indirectly in the global supply chain and thus outside of Germany. In terms of share, this means that around 87 percent of the water consumption caused by the German MedTech industry takes place outside of Germany. Within Germany, 4.9 million m^3 of water are consumed indirectly in the supply chain, while 3.0 million m^3 of water are consumed directly in the MedTech industry. The majority of water consumption triggered by the German MedTech industry thus takes place outside of Germany. For comparison: The average water consumption for a person in Germany is 127 liters per day, which corresponds to about 46,500 liters per year (corresponds to about 46.5 m^3) (Federal Association of Energy and Water Industries 2020).

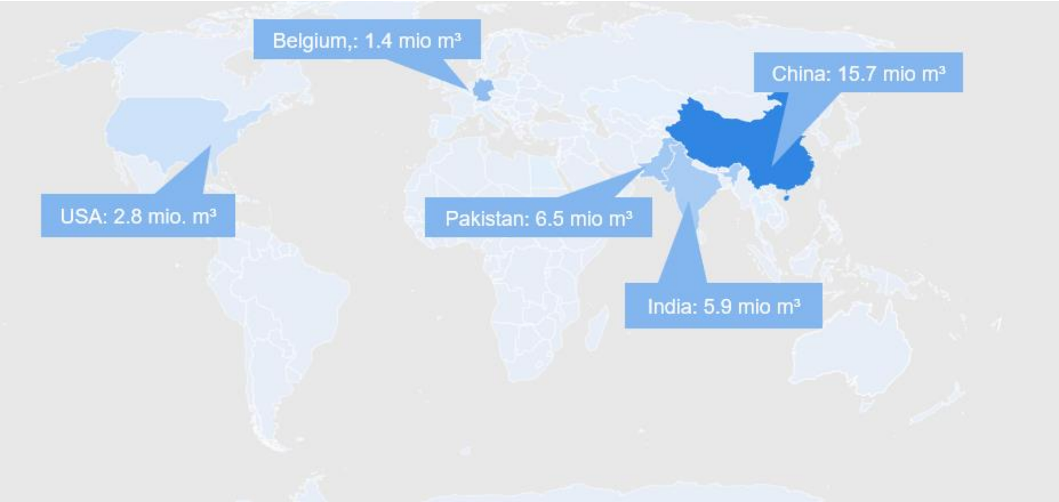
Figure 24: The global impact of water consumption in the MedTech industry 2020



Source: Calculation and illustration of WifOR. Benchmark year 2020.

In a hotspot analysis, China should once again be emphasized, which is responsible for 15.7 million m^3 of the water consumption of the German MedTech industry (see Figure 25). This is followed by Pakistan, which is responsible for 6.5 million m^3 of water consumption. The latter is followed by India (5.9 million m^3), the USA (2.8 million m^3) and Belgium (1.4 million m^3). The results show a concentration of hotspots in southern and eastern Asia. Together, China, Pakistan, and India account for approx. 46 percent of the water consumption caused by the economic activities of the German MedTech industry and represent the largest hotspots in this area.

Figure 25: Global water consumption hotspots of the MedTech industry 2020



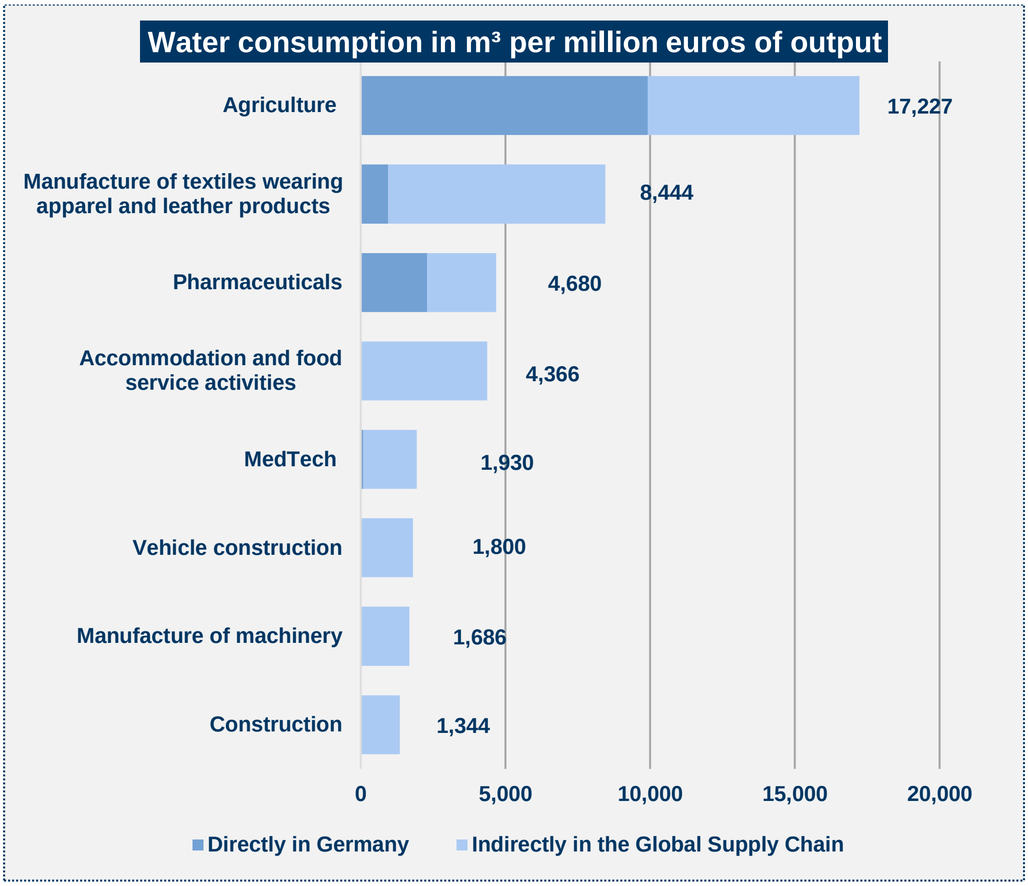
Source: Calculation and illustration of WifOR. Benchmark year 2020.

In an industry comparison, the MedTech industry is in the middle of the analyzed industries. Based on water consumption per million euros of output, this is 1.930 m^3 for the MedTech industry.

While the pharmaceutical industry and the textile industry have a significantly higher water consumption than the MedTech industry, other sectors such as vehicle construction and manufacture of machinery are comparable (see Figure 26).

In contrast to other indicators, it is striking that the economic output of the German MedTech industry is almost completely decoupled from domestic water consumption.

Figure 26: Industry comparison along water consumption intensity



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Water consumption monetary evaluation

Changes in the global water cycle pollute the environment and cause measurable damage. The impacts of water consumption vary from region to region, as they depend on water scarcity in each region.

Increasing water demand and decreasing freshwater availability in an area can led to water scarcity, causing damage to human health, the quality of ecosystems and natural resources. Damage to ecosystems is difficult to monetarize and would therefore be subject to great uncertainty, so it is not taken into account here.

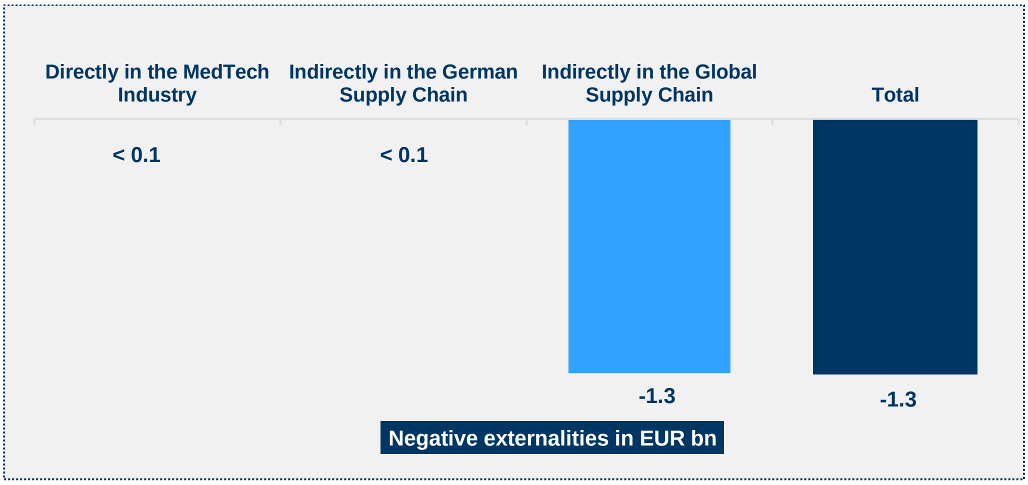
Economic damage caused by the deterioration of natural resources can be assessed as lost revenue. To assess the economic damage associated with the use of one cubic meter of water, several studies provide global and local estimates. Here, a scientifically published global value was used, which indicates the loss for agricultural goods due to the scarcity of fresh water for irrigation. Of these, local values were determined using water scarcity factors of the countries.

With a lack of household water, water-related diseases may occur more frequently, for example due to the lack of clean water for drinking and sanitation. In the literature, this relationship is measured in disability-adjusted life years ("DALYs").

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of water consumption, the monetarily valued effect can also be investigated. Figure 27 shows the negative externalities along the global supply chain of the German MedTech industry. With a monetary valuation of -1.3 billion euros, the majority of negative externalities arise outside Germany and indirectly in the global supply chain.

Directly within the MedTech industry itself and indirectly in the national supply chain, less than 0.1 billion euros of negative externalities arise each. This statistically insignificant part does not change the monetary valuation of water consumption of -1.3 billion euros.

Figure 27: Global negative externalities due to water consumption



Source: Calculation and illustration of WifOR. Benchmark year 2020.

From the analysis of the environmental indicators, various statements on the MedTech industry can be derived. The environmental effects of the economic activity of the German MedTech industry arise to a large extent outside Germany.

By far the greatest environmental effects materialize in China, which represents the largest hotspot for the German MedTech industry across all analyzed environmental indicators.

In the industry comparison of the intensities of the respective indicators, the MedTech industry occupies a lower place. The effects generated by their economic activity are therefore relatively less environmentally impactful than in other sectors.

3.3 The Social Footprint

In the following subchapter, individual social indicators will be discussed in more detail. In order to improve comparability, international definitions have been used to determine the indicators. Some of these may deviate from national definitions in Germany and therefore do not fully align. For example, the recording of occupational diseases is not uniform worldwide and is characterized by different reporting systems and definitions. However, with the addition of data from the European Agency for Safety and Health at Work and the International Labor Organization, the problem of the different reporting systems can be overcome, and comparable figures for occupational diseases and illnesses can be estimated at the national level. In addition, the risk of child labor in the supply chain of the MedTech industry indicator was also examined. For this purpose, work from the International Labor Organization and UNICEF was also used to provide estimates.

3.3.1 Occupational diseases and illnesses

Occupational diseases and illnesses

Definition: An occupational disease is any disease caused primarily by exposure at work to a physical, organizational, chemical, or biological risk factor, or a combination of these factors. Many types of diseases, including cancer, respiratory diseases, cardiovascular diseases, skin diseases, musculoskeletal disorders, and mental health problems, can be caused or aggravated by work. In the present study, occupational diseases can only be diagnosed in fatal and non-fatal cases. However, it is not possible to break down which diseases arise in the industry.

Scope: The calculated number of occupational illnesses or all associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

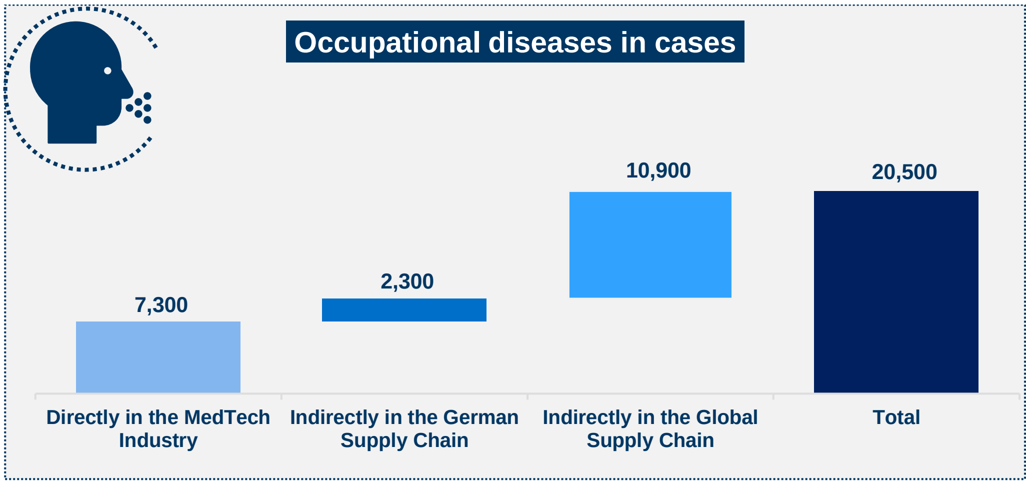
Sources: European Agency for Safety and Health at Work (2019)/ US BLS (Table SNR07)/ ILO (2008) / ILO (2015) / Eurostat (Table "nama_10_a64e") / OECD (Table "SNA_TABLE7A").

A significant part of the social footprint deals with health protection at work and all aspects of workplace health and safety. In the following, the social effects that arise in connection with diseases and illnesses due to occupational activity are discussed.

As can be seen from Figure 28, there are 7,300 cases of diseases within the MedTech industry that are related to everyday work in companies in the MedTech industry in Germany. A further 2,300 cases are also indirectly associated with the MedTech industry and arise at suppliers of the MedTech industry within Germany.

However, since the MedTech industry not only purchases goods and services from suppliers in Germany, but also operates across national borders, cases of occupational diseases also occur in the global supply chain of the German MedTech industry.

Figure 28: Global impact of occupational diseases in the MedTech industry



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Across all countries, the number of occupational diseases adds up to around 10,900 cases. The five countries with the highest number of cases (China: 1,723, India: 853; Russia: 399, Indonesia: 357 and the Czech Republic: 280) together account for around one third of the indirect effect within the global supply chain (see Figure 29).

Figure 29: Global hotspots for occupational diseases in the MedTech industry in 2020

Source: Calculation and illustration of WifOR. Benchmark year 2020.

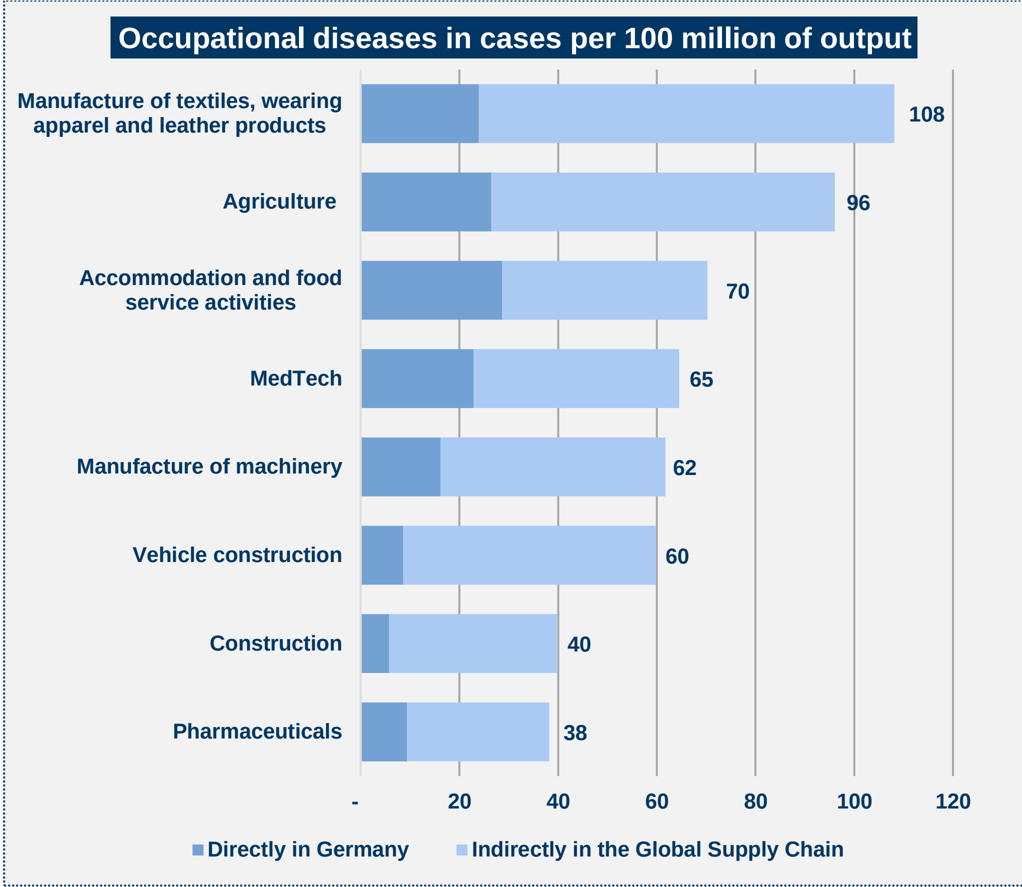
If we now look at the relationship between regional (i.e., directly, and indirectly in Germany) and global effects (i.e., indirectly in the global supply chain), it becomes clear that only slightly more than half of all occupational diseases are located outside Germany.

Occupational diseases are therefore not per se a globally outsourced effect, but also directly important in Germany. However, the reason for this is not that the protection in Germany is so low, but that the number of employees is so large compared to other countries. The ratio of occupational diseases to the number of employees in Germany is significantly lower than in the global supply chain. Specifically, the ratio within the MedTech industry is approximately 37.4 occupational diseases per 1,000 employees, while for the supply chain it amounts to approximately 39.3 occupational diseases per 1,000 employees.

If the MedTech industry is compared with other industries in Germany, normalized to the number of cases of occupational diseases per 100 million euros output, it is striking that the industry is at about the same level as the German manufacture of machinery or vehicle construction industry with 23 direct cases in the MedTech industry itself, as well as 42 indirect cases in the global supply chain (including Germany).

Unlike these, however, the MedTech industry has a much smaller impact in the global supply chain. While in the MedTech industry around 65 percent of occupational diseases (42 cases) are indirectly located in the German and global supply chain, in manufacture of machinery it is already 74 percent (46 cases) and in vehicle construction even 85 percent (51 cases).

Figure 30: Industry comparison along occupational disease intensity



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Occupational diseases monetary evaluation

Negative effects of occupational diseases arise for employers, the affected employees but also society in general. The extent of the damage depends, among other things, on the social security system and the workplace.

The nature of the damage includes, for example, production losses, costs related to health care, or the negative impact on human well-being and loss of quality of life (Safe Work Australia 2015; European Agency for Safety and Health at Work 2019).

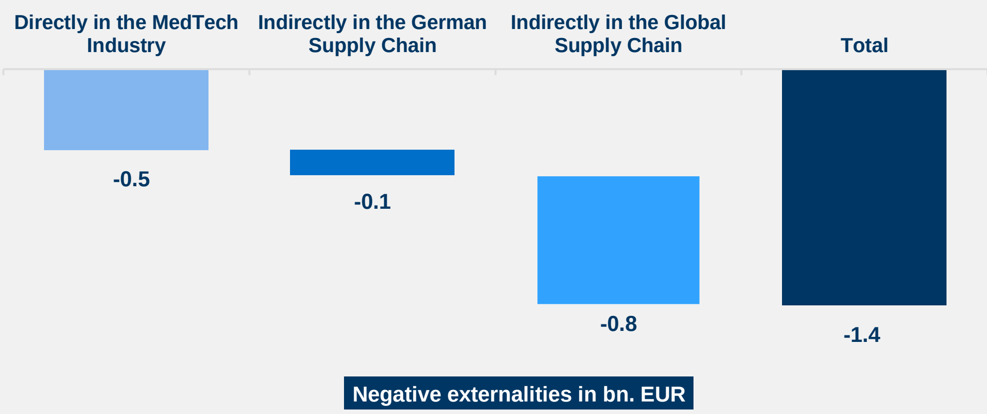
In this study, the focus is on the affected workers. In science, health impairments are usually expressed in "disability adjusted life years" (DALYs) and thus made comparable. DALYs are made up of the years of life lost and an impairment-weighted lifetime. For fatal cases, the average number of years of life lost in DALYs is estimated and valued at the global value of USD 200,000 each (See Section2.2). Likewise, for non-fatal cases, the impairment-weighted lifetime in DALYs is estimated and evaluated.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of the cause of occupational diseases, their monetarily valued effect can also be investigated. Figure 31 shows the negative externalities along the global supply chain of the German MedTech industry.

With a monetary valuation of -0.8 billion euros, unlike the environmental indicators of the previous chapter, only about half of the negative externalities arise outside Germany and indirectly in the global supply chain.

Directly within the MedTech industry itself and indirectly in the national supply chain, a total of -0.6 billion euros in negative externalities arise. The majority of this is generated directly in the MedTech industry (-0.5 billion euros). In total, the monetary valuation of occupational diseases amounts to -1.4 billion euros.

Figure 31: Global negative externalities due to occupational diseases



Source: Calculation and illustration of WifOR. Benchmark year 2020.

3.3.2 Occupational injuries

Occupational injuries

Definition: A non-fatal accident at work occurs when an employee suffers an accident at work as a result of an incident at work which does not result in death. A fatal accident at work is the result of an incident in which death occurs within one year of the date of the accident.

The calculations are based on Eurostat and ILO incidence rates for fatal and non-fatal injuries per worker at different sectoral breakdowns. In addition, average incidence rates by income region were calculated to estimate missing values. Incidence rates have recently been adjusted on the basis of scientific studies to take account of the well-known problem of under-reporting.

Scope: The calculated number of injuries at work or all associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

Sources: Eurostat (Tables “hsw_n2_01” and “hsw_n2_02”) / JOYSTATE (2021))/ Kharel (2016) / Hämäläinen et al (2017)).

As can be seen from Figure 32 there are 5,700 occupational injuries within the MedTech industry that are related to everyday work in companies in the MedTech industry in Germany.

A further 3,300 cases are also indirectly associated with the MedTech industry and arise among suppliers to the MedTech industry within Germany. However, since the MedTech industry not only purchases goods and services from suppliers in Germany, but also operates across national borders, there are also further occupational injuries in the global supply chain of the German MedTech industry.

Figure 32: Global impact of occupational injuries in the MedTech industry

Source: Calculation and illustration of WifOR. Benchmark year 2020.

Across all countries, the number of occupational injuries adds up to around 15,000 cases. The five countries with the highest number of cases (China: 4,973, India: 1,544; Indonesia: 1,326, South Africa: 824, and Nigeria: 622) together account for around 62 percent of the indirect effect within the global supply chain (see Figure 33).

Figure 33: Global hotspots for occupational injuries in the MedTech industry 2020

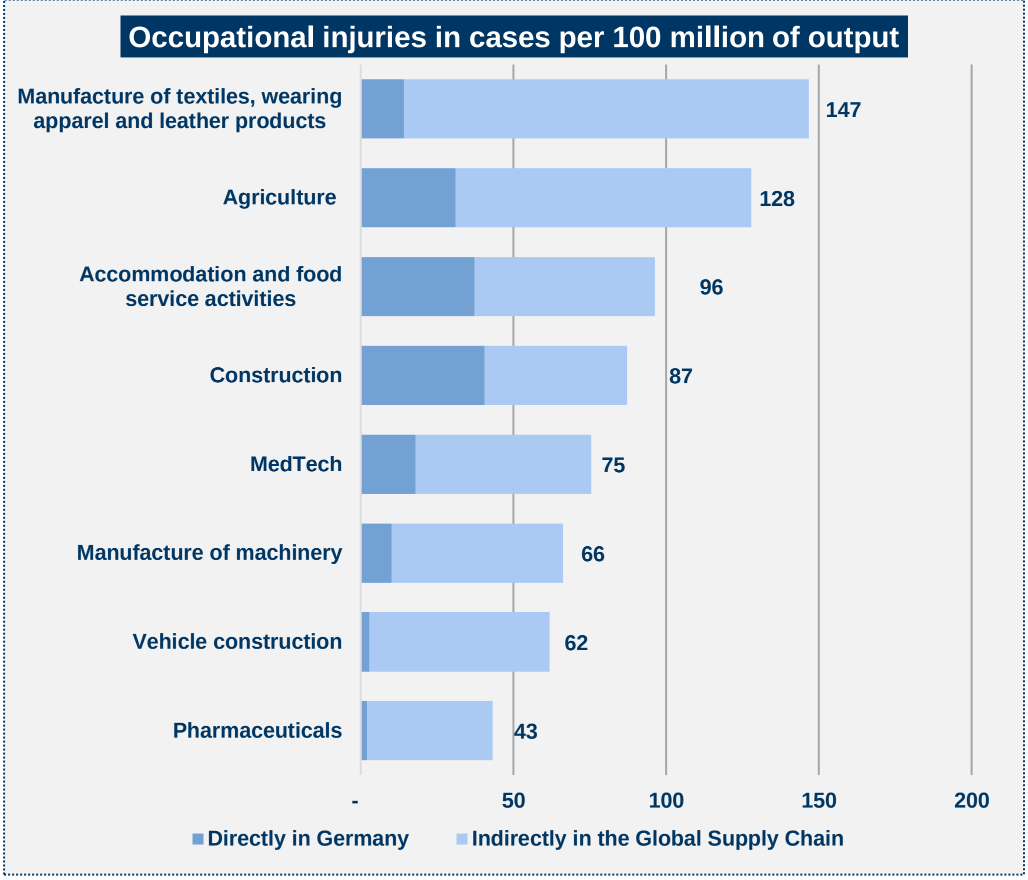
Source: Calculation and illustration of WifOR. Benchmark year 2020.

If the relationship between regional (i.e., directly, and indirectly in Germany) and global effects (i.e., indirectly in the global supply chain) is considered, it becomes clear that, unlike the previous occupational diseases, a much larger proportion of the effect of the MedTech industry arises outside Germany.

However, the reason for this is not that the industry is negligent in occupational safety and prevention of occupational injuries in Germany, but that the number of employees in Germany is again so large compared to other countries. The ratio of occupational injuries to the number of employees in Germany is significantly lower than in the global supply chain. In the MedTech sector, the ratio is approximately 29.2 occupational injuries per 1,000 employees, while in the supply chain it is approximately 54.5 occupational injuries per 1,000 employees.

If the MedTech industries are compared with other industries in Germany, normalized to the number of cases of occupational injuries per 100 million euros output, it is striking that with 18 direct cases in the MedTech industry itself, as well as 58 indirect cases in the global supply chain (including Germany), the industry is again at about the same level as the German manufacture of machinery or vehicle construction industry. Unlike these, however, the MedTech industry is once again having a relatively smaller impact in the global supply chain. While in the MedTech industry around 75 percent of occupational injuries (58 cases) are indirectly located in the German and global supply chain, in manufacture of machinery it is already 85 percent (56 cases) and in vehicle construction even 95 percent (59 cases).

Figure 34: Industry comparison along the intensity of occupational injuries



Source: Calculation and illustration of WifOR. Benchmark year 2020.

Occupational injuries - Monetary evaluation

Negative effects of occupational injuries arise for employers, the employees concerned but also society in general. The extent of the damage depends, among other things, on the social security system and the workplace.

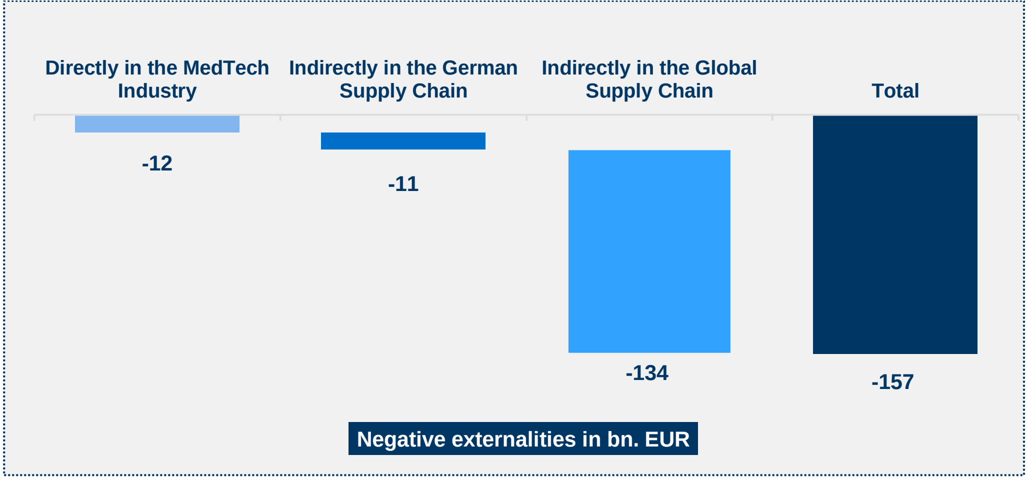
The nature of the damage includes, for example, production losses, costs related to health care, or the negative impact on human well-being and loss of quality of life (Safe Work Australia 2015; European Agency for Safety and Health at Work 2019).

In this study, the focus is on the affected workers. In science, health impairments are usually expressed in "disability adjusted life years" (DALYs) and thus made comparable. DALYs are made up of the years of life lost and an impairment-weighted lifetime. For fatal cases, the average number of years of life lost in DALYs is estimated and valued at the global value of USD 200,000 each (See Section2.2). Likewise, for non-fatal cases, the impairment-weighted lifetime in DALYs is estimated and evaluated.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of the causation of occupational injuries, their monetarily valued effect can also be examined. Figure 35 shows the negative externalities along the global supply chain of the German MedTech industry.

With a monetary valuation of -134 million euros, this time the majority of negative externalities arise outside Germany and indirectly in the global supply chain. Directly within the MedTech industry itself and indirectly in the national supply chain, a total of -23 million euros in negative externalities arise. In total, the monetary valuation of occupational injuries amounts to -157 million euros.

Figure 35: Global negative externalities due to occupational injuries



Source: Calculation and illustration of WifOR. Benchmark year 2020.

3.3.3 Risk of child labor

Risk of child labor

Definition: A case of child labor is defined as a child engaged in an economic activity for more than one hour at the age of 5 - 11 years, more than 14 hours at the age of 12 - 14 years and more than 43 hours per week at the age of 15 - 17 years. This includes, but is not limited to, dangerous work, and excludes housework. We combine country-specific estimates of the proportion of children engaged in economic activity with estimates of the number of children aged 5-17 per country to determine the absolute number of working children at the country level. We exclude the proportion of children working in the agricultural sector within the framework of family farms according to the regional estimates of ILO and UNICEF. Finally, it is assumed that there is no child labor in high-income countries.

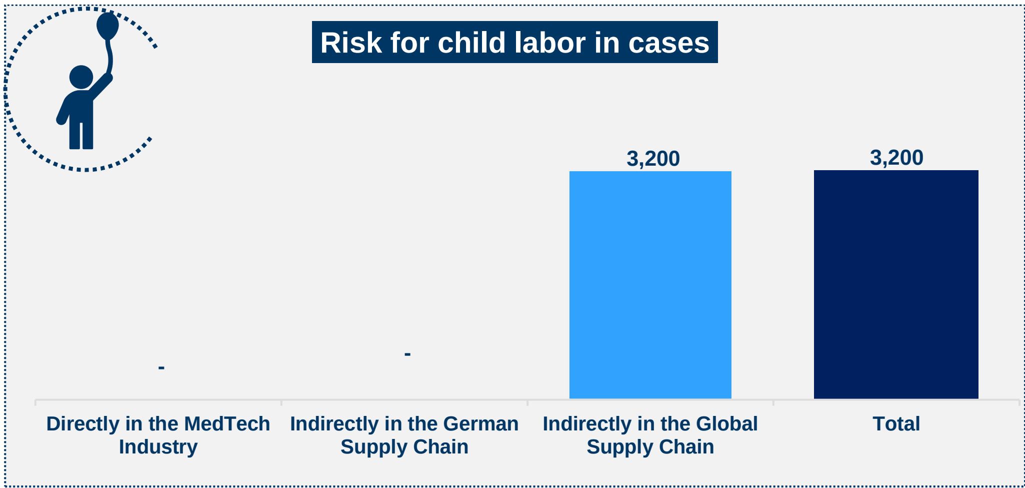
Scope: The calculated number of cases of child labor or all associated externalities refer exclusively to those effects that are located in the industry itself (directly) or in the upstream supply chain (indirectly).

Sources: ILOSTAT (2021) / UNICEF (2021) / ILO and UNICEF (2021).

The United Nations writes in Article 32 of the Conventions on the Rights of the Child that "every child has the right to be protected from economic exploitation and not to be involved in work that involves danger. Likewise, he has the right not to perform work that may hinder his education and damage his health and physical, mental, emotional and social development." Nevertheless, according to the International Labor Organization, about 160 million children worldwide are affected by child labor (UNICEF 2022b).

When analyzing this indicator, it should be noted that there is no case of child labor in Germany. However, due to the multi-stage, international supply chain of the German MedTech industry, cases from other countries are attributed to the economic activity of the German MedTech industry. In doing so, it is important to assess the overall 3.200 cases in this context. As mentioned earlier, none of these cases exist in Germany.

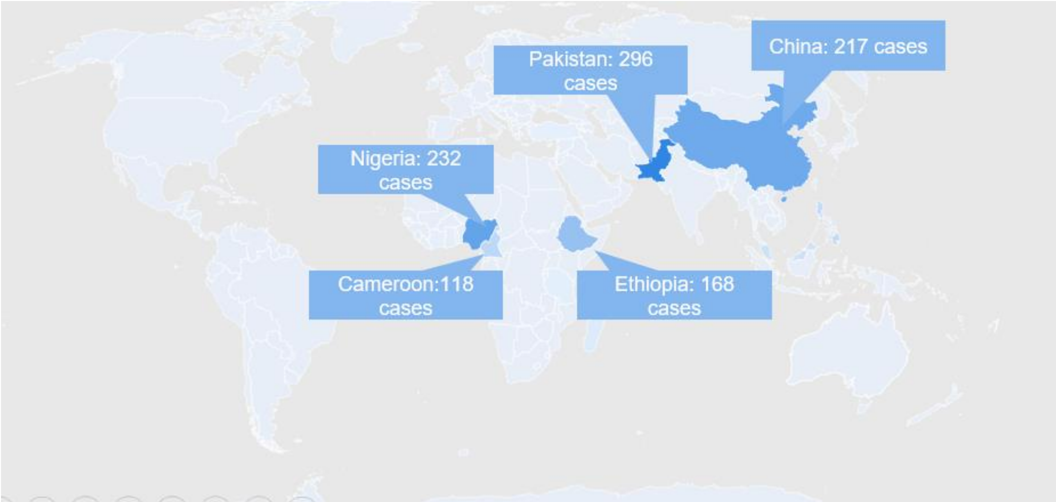
Figure 36: Global impact of child labor in the MedTech industry



Source: Calculation and illustration of WifOR. Benchmark year 2020.

With 296 cases, Pakistan is the country where most cases of child labor are observed in the supply chain. Nigeria with 232 cases and China with 217 cases also have a significant share. Ethiopia with 168 cases and Cameroon with 118 cases are also among the hotspots for this indicator (see Figure 37). The increased incidence of child labor in agricultural and mining sectors suggests that these cases also occur in the mining of certain raw materials. These are often without alternative for the production of goods but can therefore play a strong role in the occurrence of child labor in the supply chain of the MedTech industry.

Figure 37: Global hotspots for child labor risk in the MedTech industry 2020

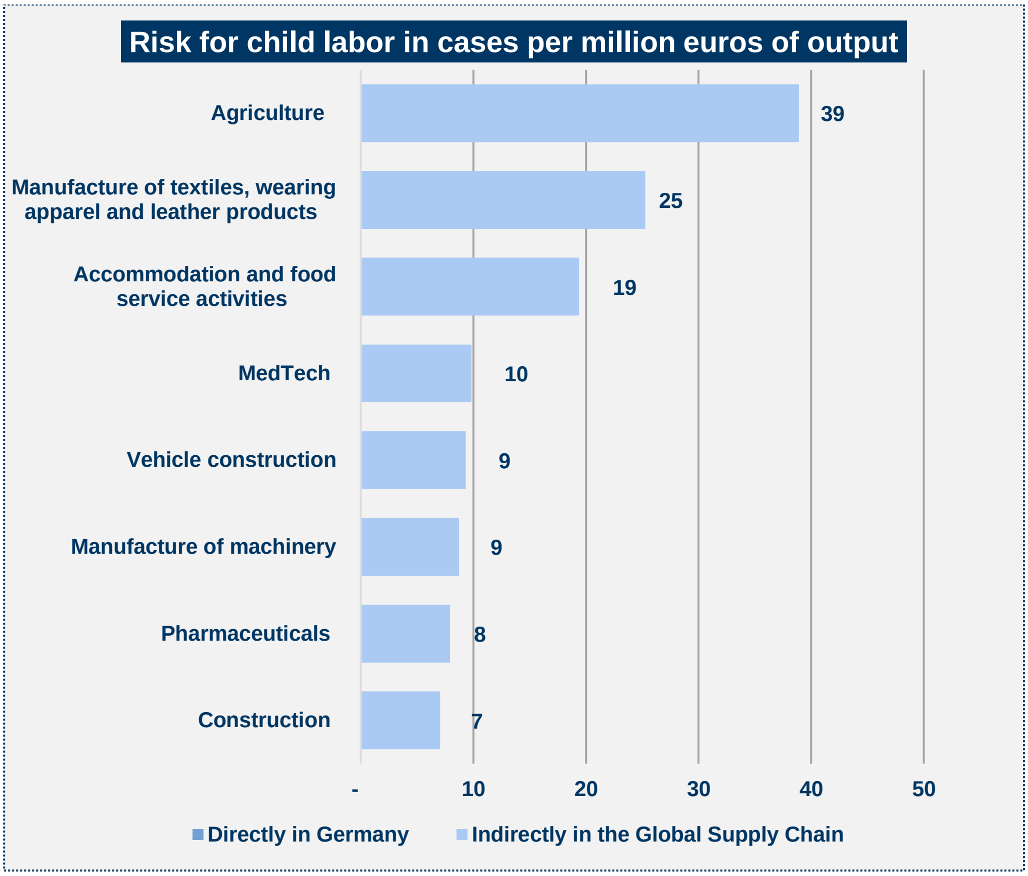


Source: Calculation and illustration of WifOR. Benchmark year 2020.

As with other indicators, it should be borne in mind that the absolute number of cases allows only an indirect conclusion to be drawn about the relative incidence of child labor compared to workers in these countries.

In comparison with other industries, it becomes clear how the results for the German MedTech industry can be classified. The agricultural sector in Germany has an intensity of 39 cases of child labor per million euros of output. On the other hand, the MedTech industry with 10 cases, which puts it in the middle of the analyzed industries, is at a comparable level with the manufacture of machinery and vehicle construction industry and significantly behind the textile industry (25 cases).

Figure 38: Industry comparison along child labor intensity



Source: Calculation and illustration of WifOR. Benchmark year 2020.

None of the German industries has a proportion of child labor as a result of their direct economic activity in Germany. This underlines that child labor occurs primarily indirectly in the global supply chain. The intensity of child labor in an industry comparison shows the slightly below-average intensity of the MedTech industry for this indicator.

Risk of child labor

Child labor has a variety of negative effects on children and society. For example, children have a higher risk of injury or death if they work in low-skilled areas, or they may suffer psychological damage from, for example, violence. This damage can have a potential long-term impact on their health not only in the short term. However, they are difficult to quantify due to a lack of data (Vionnet, Friot, Haut, et al. 2021; Edmonds 2016; Pereznieto, Montes, Langston, et al. 2014).

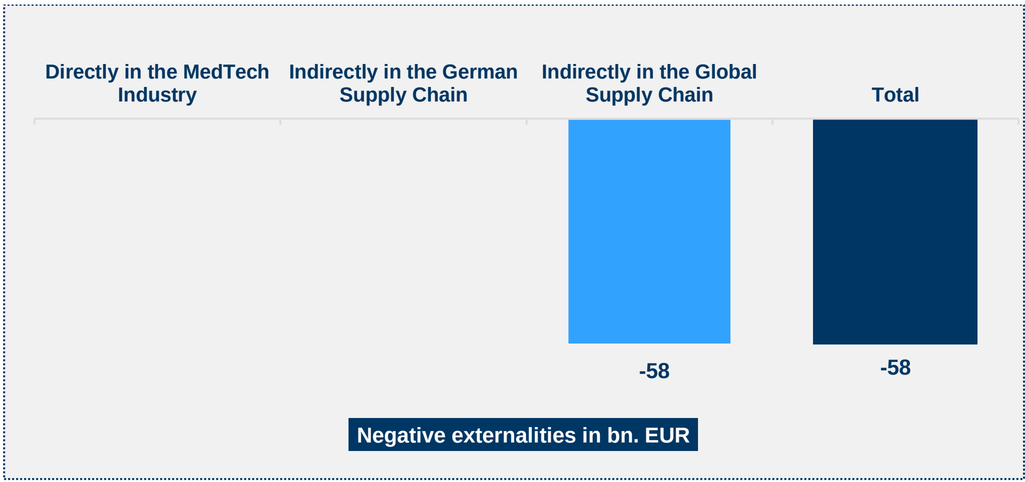
Nevertheless, child labor also has longer-term negative effects on children and society when children are deprived of education, thereby losing future productivity and income opportunities. Using returns on education, the loss of income and productivity due to one year of child labor is estimated.

This approach to quantifying the cost of child labor is widely used in the literature (Pereznieto, Montes, Langston, et al. 2014; World Vision 2016). The assessment factors for child labor are country-specific according to the return on education and the level of productivity.

In addition to the previous interpretation of the physical effects and effects associated with economic activity of the MedTech industry in the context of child labor, their monetarily valued effect can also be investigated. Figure 39 shows the negative externalities along the global supply chain of the German MedTech industry.

With a monetary valuation of -58 million euros, the negative externalities arise exclusively outside Germany and indirectly in the global supply chain. Directly within the MedTech industry itself as well as indirectly in the national supply chain, no negative externalities arise as child labor is prohibited in Germany.

Figure 39: Global negative externalities due to risk of child labor



Source: Calculation and illustration of WifOR. Benchmark year 2020.

4 Conclusion and Outlook

Sustainable management requires the internalization of economic, ecological, and social factors. This approach is already realized by concepts such as resource-efficient growth or the circular economy and will continue to gain in importance in the coming decades, not least in view of the goal of climate neutrality. For this transformation, it is crucial to know the economic, environmental, and social effects of economic activities on society. This knowledge can be used in the further course to better understand one's own situation, and thus also the upcoming transformation, and ultimately to actively control it.

The aim of the study was to quantify and present these economic, ecological, and social effects for the first time in a joint industry monitoring. The study uses the acknowledged methodology of input-output calculation to quantify the MedTech industry. Based on the results of the health economics of the Federal Ministry for Economic Affairs and Climate Protection, the "Economic, Environmental and Social Footprint of the German MedTech Industry" was measured for the first time.

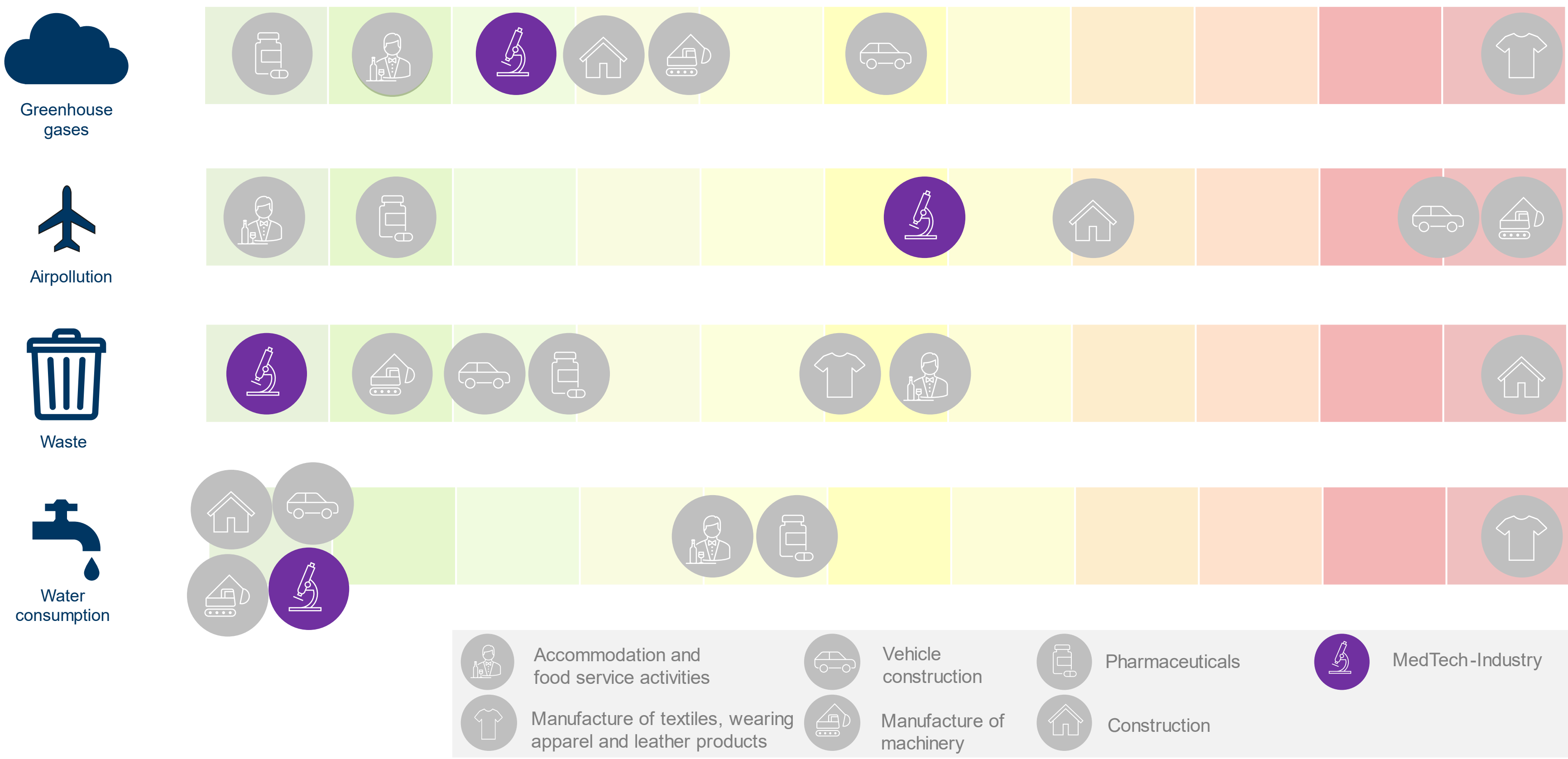
The results of the economic footprint can be summarized as follows:

- The MedTech sector is one of the most important sub-sectors of the Health Economy and is of great importance for gross value added and employment, especially in the industrial Health Economy.
- However, growth and employment in the MedTech industry are following different pathways: 2.5 billion euros in additional added value are offset by a decline of 4,300 employees since 2012.
- In contrast, R&D activities in the MedTech industry are extremely resilient. The sub-sector has contributed to sustainable growth with an average of 7.5 percent GVA growth since 2012.
- In addition, the MedTech industry also generates gross value added and employment effects beyond its direct economic activity: In total, the economic footprint of the German MedTech industry amounts to 32.2 billion euros and around 414,000 employees in the entire German economy.

The results of the environmental footprint can be summarized as follows:

- Greenhouse gas emissions are among the most important drivers of man-made climate change. Over 60 percent of all greenhouse gas emissions in the MedTech industry originate indirectly in the global supply chain of the MedTech industry.
- Air pollution by pollutants with a maximum particle size of 2 µm ($PM_{2.5}$) has been shown to have a negative effect on human health. Almost 90 percent of the particulate matter in the MedTech industry originates in the global supply chain of the MedTech industry.
- The production of waste is a global problem that can be countered by resource-saving handling on site in Germany. In an industry comparison, the MedTech industry has the lowest waste volume per 1 million euros output with only 56 tons.
- The sustainable use of water must also be increasingly anchored in the consciousness of the population in Germany. The direct and indirect water consumption of the MedTech industry amounting to 7.9 million m^3 does not leave any significant negative externalities in Germany.
- In the comparative industry ranking of environmental indicators and intensities, the MedTech industry scores above average in 3 out of 4 indicators (see Figure 40).

Figure 40: Industry ranking of environmental indicator intensities

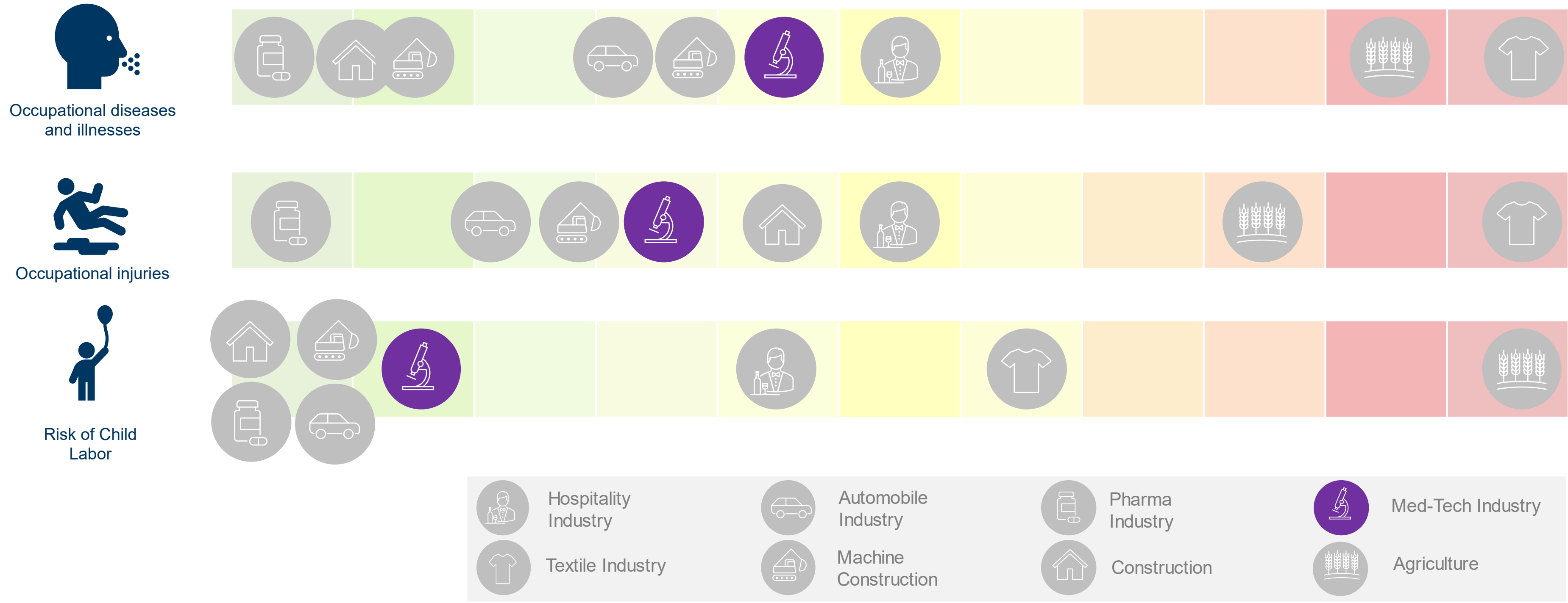


Source: WifOR illustration

The results of the social footprint can be summarized as follows:

- For many people, the workplace is an important center of life. A workplace can also pose risks to health. When it comes to occupational diseases, the MedTech industry is in the middle of the field in an industry comparison.
- Occupational injuries have a negative impact on the economic development of a country. Around 62 percent of occupational injuries in the MedTech industry occur in the global supply chain.
- Child labor is not prohibited everywhere in the world by law and in some places goes unpunished. Due to global supply chains, there is also a risk of child labor in the MedTech industry.
- In the comparative industry ranking of social indicators intensities, the MedTech industry predominantly performs average (see Figure 41).

Figure 41: Industry ranking of social indicator intensities



Source: WifOR illustration

The MedTech sector is already one of the most important sub-sectors of the Health Economy and is of great importance for gross value added and employment, especially in the industrial Health Economy. Even if there has been a slight decline in the number of employees in the sector in the long-term, this fact should be considered in perspective against the background of the past pandemic events of the last two years. In many places, the number of cases in medical care is still not back to the level it was before the pandemic. In addition, the baby boomers are increasingly retiring and, due to the prevailing shortage of skilled workers, it is becoming increasingly difficult for the industry to fill vacancies.

In terms of environmental and social factors, the MedTech industry is also in a good position overall compared to the rest of the industry. Nevertheless, the industry must rise to the challenge and further minimize the footprint of the industry in the future. The MedTech industry has a globally interconnected supply chain. This is associated with both positive and negative effects. On the one hand, the activity of the supply chain creates growth and employment in the most diverse – sometimes underdeveloped – regions of the world. On the other hand, with the relocation of production activities, the negative consequences – environmental and social – are shifted abroad.

It is true that the deeper the supply chain, the greater the challenge for the industry in Germany to influence possible grievances in the supply chain. In doing so, the industry should focus particularly on the improvement of working conditions and the prevention of air pollution. Whether this must necessarily be related to "Onshoring" can be discussed in this context, especially in view of partly stationary raw material deposits.

These developments are important because Europe intends to become the first climate-neutral continent by becoming a modern, resource-efficient economy. Against the background of the "Green Deal" of the European Commission and the political goal of the German Federal Government to create a climate-friendly healthcare system, the sustainable transformation of the economy and society will take on an increasingly important aspect for the MedTech industry in Germany.

The first legal obligations have already been adopted or are available as drafts. In the future, non-financial company reports must be based on the Corporate Sustainability Reporting Directive (CSRD). The Corporate Sustainability Due Diligence Directive (CSDDD) is being intensively prepared at European level. In Germany, the Supply Chain Due Diligence Act (LkSG) has already been passed. From 1 January 2023, transparency will be mandatory by law. From then on, suppliers and industry itself must promote transparency in their supply chain and may be sanctioned.

The present study results combine the strengths of comparability, innovative character, and proven methodology. In the future, the results and methodology can serve as a blueprint for companies in the industry to be able to specifically address grievances in the supply chain and the hotspots located therein.

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Appendix

I. Classification of Input-Output Modelling within the Topic of Supply Chain Analysis

Effects of economic activities that arise from purchases in the supply chains, i.e., upstream of the company under consideration, can be evaluated using both “bottom-up” and "top-down" methods. Well-known bottom-up approaches are process-based life cycle assessment (LCA) or the collection of suppliers and/or sales data. One advantage of bottom-up approaches is the heavy use of primary data. However, the results are mostly product or supplier specific, represent only parts of the overall impact of the company, and are very labor-intensive in the collection.

In contrast, top-down approaches usually use secondary data. Input-output analysis is one such methodology based on macroeconomic activity data. It differs decisively in the scope of the analysis from bottom-up methods. Input-output modeling can take into account the entire value chain of the company and analyze a variety of indicators. The estimates are based on primary financial data (A detailed list of region-specific information on the quantity and type of goods and services purchased), which are then translated into economic, socio-economic, and environmental indicators. The results are to be interpreted as statistical effects of an average company or an entire sector. It is therefore not possible to make any statements about individual actors and their individual efforts. Also, structural changes within a sub-area of a sector can remain hidden due to the low granularity.

Since both approaches provide valuable results, an attempt is made to align bottom-up and top-down approaches (Beylot, Corrado and Sala 2019). This makes it possible to insert results from bottom-up analyses into the top-down Output framework to improve data quality without limiting the scope of the analysis. However, this is beyond the scope of this study.

When interpreting this study, it should be noted that the MedTech industry is a cross-sectional sector that is not specifically defined as an economic sector and is therefore not directly covered in IO tables. The calculated results are therefore composed of the average behavior of the relevant ISIC sectors. However, one advantage of the macroeconomic approach is the comparability of the results with other sectors.

The satellite data are important for the quality of the analysis. The availability and quality of official statistical data vary for the 188 countries considered. This concerns, for example, the completeness and granularity, or frequency of updating. In addition, there are deviations in the recording of some indicators. In particular, occupational injuries and occupational diseases and illnesses are recorded to varying degrees. In order to fill data gaps and, as in the case of injuries and illnesses, to compensate for known underreporting, secondary data, such as scientific studies, are used. The definition and sources are given in Chapter 2.3 for each indicator.

II. Mathematical Specification

The calculation of indirect effects is based on the following equilibrium equation:

$$x = Ax + y \leftrightarrow x = (I - A)^{-1}y \qquad (1)$$

This is the vector of the x total output value of a sector and y the vector of final demand, which includes domestic final consumption expenditure, capital, changes in stocks and exports. A represents the matrix of intermediate consumption per unit output value.

Equation (1) with "$L = (I - A)^{-1}$" as the Leontief-inverse is derived with the following mathematical transformation:

$$x = Ax + y$$

$$y = x - Ax$$

$$y = (1 - A)x$$

Since $(I - A)^{-1} * (I - A) = 1$ holds, where I is the identity matrix, $x = \frac{y}{1-A}$ is equivalent to

$$x = (1 - A)^{-1}y$$

III. On the Assessment of Human Health and Effects in the Future

Assessment of Human Health

Can and should a human life be assigned a monetary value? And if so, how can the "value" of a human life be determined? These questions are controversially debated within and outside the research on impact assessment. Once human lives are affected by different choices, these impacts must be weighed against each other – implicitly, human lives are always given value. In the impact assessment, this value is made explicit, which allows and even requires a debate on the – essentially ethical – assessment.

There are two basic approaches to evaluating human life. The *productivity-based perspective* assesses a year of life with a person's productivity within a year in terms of paid and unpaid work. The *willingness to pay perspective*, on the other hand, determines the "Value of Statistical Life" (VSL), from which the "Value of Statistical Life Year" (VSLY) is derived.

The value of statistical life essentially reflects the willingness to pay for the avoidance of a death. The VSL approach, for example, is used in policy to assess whether regulations to reduce the likelihood of deaths are worth the cost of their implementation. Since this approach takes the perspective of the affected persons, the WifOR assessment method applies a VSLY approach.

VSLY estimates depend on the country, the age of the population, the method and the level of wealth (Schlander, Schaefer and Schwarz 2017). While the WHO recommends an order of magnitude of one to three times the gross domestic product per capita, a large number of studies criticize this value on the basis of the empirically determined values, which are between 3.5 and 6.5 times (Trautmann, Xu, König-Kersting, et al. 2021b; Robinson, Hammitt, Chang, et al. 2017; Schlander, Schwarz, Hernandez, et al. 2018b). As an example, about six times the median GDP per capita in a meta-analysis of over 120 VSLY studies between 1995 and 2015.

The aim of this study is to give equal value to every human life for ethical reasons. VSLY is assumed to be 5 times the GDP per capita of a high-income country. Since an exact number cannot be determined and would suggest false accuracy, the value is rounded smoothly to $200,000. This value is also in the order of magnitude used in another valuation methodology (Value Balancing Alliance 2021).

Valuation of Effects in the Future

Many of the social and environmental effects manifest themselves not only in the present, but also in the future. For a comprehensive assessment of the effects of entrepreneurial activity, these effects must be taken into account for future generations. In economics, discounting is common to convert future costs and benefits into their present value. Discounting can be justified by the fact that (1) people tend to weight the present more than the future, (2) consumption growth is expected in the long-term, and thus a unit of wealth is worth less in the future than it is today, and (3) the benefits of additional consumption diminish as consumption levels increase. These three aspects are discussed in the social discount rate (SDR), which is known as the Ramsey rule, e.g. Federal Environment Agency (2012):

$$SDR = \gamma + \eta * g$$

where γ is the pure time preference rate (1), the η elasticity of the marginal utility of consumption (3) and the g growth rate of per capita consumption (2). Social discount rate limits how far into the future the effects are measured. For example, at a rate of 2 percent, impacts that are 50 years in the future have a present value of ~37 percent, and at 2 percent it is ~61 percent.

Assumptions about the value of the social discount rate and its components are the subject of intense scientific debate, especially in the environmental economics literature on climate change. This method follows the approach of the Federal Environment Agency (2012) with the assumption of a long-term growth rate of $g = 1.5\ Percent$ (See also World Bank (2022)) and $\eta = 1$. The equal assessment of the well-being of present and future generations is set as an ethical imperative and is in line with the ideas of intergenerational justice widely established in the climate change literature. This results in a social discount rate of 1.5 percent.

IV. Overview of the sources of the physical satellites

	Indicators	Sub-indicators	Specification	Sources		
				Main data source (MRIO databases)	**Additional Sources**	**Coverage Commentary**
Economy	**Gross value added**	-	-	WIOD, EORA	Eurostat, OECD, Health Economy Reporting (HER) of the BMWK	Full coverage by existing MRIO satellites
	Employees	-	-			
	Foreign trade	-	-	Health Economy Reporting (HER) of the BMWK	-	-
Environ-ment	**Greenhouse gases**	Total greenhouse gases in CO_2 equivalents	-	EXIOBASE, EORA	Air Emission Accounts (Eurostat, OECD), GHG protocol to get actual GWPs	Full coverage by existing MRIO satellites
	Air pollution	Particulate matter $PM_{2.5}$	urban, peri-urban, rural, traffic	EXIOBASE, EORA	Air Emission Accounts (Eurostat, OECD)	Full coverage by existing MRIO satellites
	Water consumption	-	-	EXIOBASE, EORA	-	Full coverage by existing MRIO satellites

	Waste	Hazardous & non-hazardous waste	Landfill, incineration, recycling	EXIOBASE HYBRID	EUROSTAT (env_wastrt)	Specification partial. Not covered in existing MRIO satellites
Social affairs	**Occupational health and safety**	Accidents	Deadly & Non-Fatal	-	EUROSTAT(hsw_n2_01, hsw_n2_02), ILOSTAT (2021), Kharel (2016), Hämäläinen, Takala, and Kiat (2017)	*In-house research: no coverage in existing MRIO satellites*
		Occupational Diseases	Deadly & Non-Fatal	-	European Agency for Safety and Health at Work. et al. (2019), US BLS (TABLE SNR07), (ILO 2011), (ILO 2015).	
	Child labor	-	-	-	(ILOSTAT 2021), UNICEF (2021), ILO and UNICEF (2021)	*In-house research: no coverage in existing MRIO satellites*

V. Composition MedTech Industry

ISIC Rev. 4 -	English name	MedTech share of production value
A01	Crop and animal production, hunting and related service activities	0,0%
A02	Forestry and logging	0,0%
A03	Fishing and aquaculture	0,0%
B	Mining and quarrying	0,0%
C10-C12	Manufacture of food products, beverages, and tobacco products	0,0%
C13-C15	Manufacture of textiles, wearing apparel, and leather products	0,1%
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0,0%
C17	Manufacture of paper and paper products	0,0%
C18	Printing and reproduction of recorded media	0,0%
C19	Manufacture of coke and refined petroleum products	0,0%
C20	Manufacture of chemicals and chemical products	0,6%
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	3,1%
C22	Manufacture of rubber and plastic products	2,9%
C23	Manufacture of other non-metallic mineral products	2,3%
C24	Manufacture of basic metals	0,3%
C25	Manufacture of fabricated metal products, except machinery and equipment	0,1%
C26	Manufacture of computer, electronic and optical products	21,1%

C27	Manufacture of electrical equipment	0,1%
C28	Manufacture of machinery and equipment n.e.c.	0,3%
C29	Manufacture of motor vehicles, trailers, and semi-trailers	0,1%
C30	Manufacture of other transport equipment	1,0%
C31_C32	Manufacture of furniture; other manufacturing	61,5%
C33	Repair and installation of machinery and equipment	0,8%
D35	Electricity, gas, steam, and air conditioning supply	0,0%
E36	Water collection, treatment, and supply	0,0%
E37-E39	Sewerage; waste collection, treatment, and disposal activities; materials recovery; remediation activities and other waste management services	0,0%
F	Construction	0,1%
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	0,0%
G46	Wholesale trade, except of motor vehicles and motorcycles	0,1%
G47	Retail trade, except of motor vehicles and motorcycles	1,1%
H49	Land transport and transport via pipelines	0,0%
H50	Water transport	0,0%
H51	Air transport	0,0%
H52	Warehousing and support activities for transportation	0,0%
H53	Postal and courier activities	0,0%
I	Accommodation and food service activities	0,0%
J58	Publishing activities	0,0%

J59_J60	Motion picture, video and television program production, sound recording and music publishing activities; programming and broadcasting activities	0,0%
J61	Telecommunications	0,0%
J62_J63	Computer programming, consultancy, and related activities; information service activities	0,0%
K64	Financial service activities, except insurance and pension funding	0,0%
K65	Insurance, reinsurance, and pension funding, except compulsory social security	0,0%
K66	Activities auxiliary to financial services and insurance activities	0,0%
L68	Real estate activities	0,0%
M69_M70	Legal and accounting activities; activities of head offices; management consultancy activities	0,0%
M71	Architectural and engineering activities; technical testing and analysis	0,0%
M72	Scientific research and development	0,0%
M73	Advertising and market research	0,0%
M74_M75	Other professional, scientific, and technical activities; veterinary activities	0,0%
N	Administrative and support service activities	4,3%
O84	Public administration and defense; compulsory social security	0,0%
P85	Education	0,0%
Q	Human health and social work activities	0,1%
R_S	Other service activities	0,0%
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0,0%

U	Activities of extraterritorial organizations and bodies	0,0%

Note: Deviations in the total are due to rounding.

Indicators Glossary

Waste	Economic activities lead to the generation of solid waste at almost all levels of the supply chain. Both the collection and disposal of this solid waste leads to environmental degradation, which entails economic costs (or external costs) to society.
Occupational Diseases and ill-nesses/occupational injuries	Occupational diseases and injuries are health incidents arising in connection with work activity. A distinction is made between fatal and non-fatal cases. Negative effects arise for employers, the affected employees but also society in general. The extent of the damage depends, among other things, on the social security system and the workplace. The nature of the damage includes, for example, production losses, costs related to health care, or the negative impact on human well-being and loss of quality of life (Safe Work Australia 2015; European Agency for Safety and Health at Work 2019).
Foreign trade	Foreign trade takes into account all exports and imports of goods and services of German economic entities that have their permanent seat (domicile) within Germany. The foreign trade activities of the Health Economy are reported within the framework of the HER according to the national accounts concept and acquisition prices.
Gross value added	Gross value added (GVA) is the total value of the goods and services produced in the production process (production value) minus the intermediate consumption used for this purpose. GVA thus corresponds to the services provided in the individual sectors. GVA makes it possible to highlight the economic importance of an industry within the national economy or in comparison with other sectors. The sum of the GVA of all branches or sectors plus taxes on products minus subsidies on products gives the gross domestic product (GDP). GVA thus reflects the contribution to GDP.
Employed	Persons in employment include all persons who, as employees (workers, employees, civil servants, marginally employed persons, soldiers) or as self-employed persons or family workers,

	pursue an activity in Germany with a view to economic gain, irrespective of the extent of this activity. Persons with several simultaneous employment relationships are recorded only once with their main activity. The data basis for the calculation of persons in employment is the employment statistics of the Federal Statistical Office.
Research and development	Research and development (R&D) are regarded as a decisive factor for long-term economic growth and is particularly important in a resource-poor economy like Germany. Within the Health Economy, a large part of R&D takes place in IHE and its industrial research and development. In addition to the R&D activities of companies and institutions outside universities, such as private research institutes, R&D also takes place in the areas of human pharmaceuticals, biotechnology and, last but not least, the MedTech industry.
Risk of child labor	A case of child labor is defined as a child who works more than one hour per week when they are 5-11 years old, more than 14 hours per week when they are 12-14 years old, and more than 43 hours per week when they are 15-17 years old. Although the working children may experience some benefits (e.g., better nutrition, greater control over the use of resources in their favor) (Edmonds 2016), there are a variety of negative effects on the children and society that overall outweigh the potential benefits (Gordon 2008).
Air pollution	Air pollution is the contamination of indoor or outdoor air by chemical, physical or biological substances that alter the natural properties of the atmosphere. Domestic incinerators, motor vehicles, industrial plants, and forest fires are common sources of air pollution. Pollutants of particular concern to public health include particulate matter, carbon monoxide, ozone, nitrogen dioxide and sulfur dioxide. Outdoor and indoor air pollution causes respiratory and other diseases and is a major cause of morbidity and mortality (WHO 2022).
Economic footprint	The term "economic footprint" refers to the overall economic importance of an industry. The economic footprint is the sum of direct, indirect, and induced value added or employment effects. The direct effects first describe the direct effects of an industry on the German economy. They can refer to the contribution of an industry to the overall economic production value, to gross value

	added or to the number of persons in employment. Since the production activities of an industry require intermediate goods, the purchase of these goods in turn results in higher production from suppliers, who in turn demand intermediate goods for their production processes. The resulting effects (e.g., employment) are called indirect effects of an industry. Finally, the induced effect quantifies the contribution resulting from the re-spending of wages and salaries. This is, for example, the number of persons in employment in the economy as a whole, who produce consumer goods for employees in the Health Economy and their suppliers.
Greenhouse gases	Emissions of greenhouse gases cause climate change by creating a greenhouse effect in the Earth's atmosphere. These emissions mainly include carbon dioxide, methane, and nitrogen dioxide, which are therefore the main cause of climate change. As a result of climate change, we will see an increase in extreme weather events and a rise in sea levels, as well as a decline in surface and groundwater resources due to warming. This, in turn, will lead to additional economic and social damage for present and future generations.
Water consumption	The changes in the global water cycle pollute the environment and cause measurable damage. Increasing water demand and decreasing freshwater availability in an area can led to water scarcity, causing damage to human health, the quality of ecosystems and natural resources. The impacts of water consumption vary from region to region, as they depend on water scarcity in each region.

WifOR is an independent economic research institute that originated from a spin-out of the Department of Public Economics and Economic Policy at the Technical University of Darmstadt, Germany. We see ourselves as an academic partner and think tank on a global scale. WifOR's fields of research include Economic, Environmental and Social Impact Analyses as well as Labor Market and Health Economy research.

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