A refreshed assessment of the importance of physics to the European economy

A CEBR REPORT FOR THE EUROPEAN PHYSICAL SOCIETY (EPS)

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European Physical Society

DISCLAIMER

AUTHORSHIP AND ACKNOWLEDGEMENTS

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London, July 2025

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PREFACE

Physics plays a foundational role in the world's economy because it underpins both technological innovation and industrial competitiveness.

There is a need to drive innovation and technology. Even though Europe has a long tradition in science and technology, there is now a fierce competition from other parts of the world, which have a major impact on Europe competitiveness. Millions of jobs in Europe depend directly or indirectly on physics-based sectors, from R&D to manufacturing and technical services.

Physics-driven technologies (quantum computing, space science, nuclear energy) are critical for Europe's sovereignty in defence, security, and digital infrastructure. By developing its own capacity in these fields, Europe reduces reliance on external suppliers, especially in sensitive technologies.

The European Physical Society (EPS), with its national member societies, acts as a federating body in Europe. Education and research are the primary concerns of EPS, and the European Union has provided continued support in both these directions, with programmes like Horizon and the establishment of international research infrastructures like CERN, ITER, and synchrotron light sources that attract talent and investment globally.

The EPS has commissioned the Centre for Economics and Business Research (CEBR) to produce an updated analysis after the previous report (published September 2019). The report analyses data and impact on the physics-based sector within the 27 countries of EU, the United Kingdom and the three of the four EFTA members (Iceland, Norway, Switzerland).

What the report shows is the sustained increase of the turnover of the physics-based sector over the period with the notable exception of the year 2020, a direct impact of the Covid pandemic affecting EU and non-EU countries. The recovery from that period is solid, even if the nominal increase may be partially attributed to the inflationary spike, as is rightfully noted in the report.

Global turnovers have a direct impact on the employment, with major differences between different sectors: energy production and construction experienced growth while oil and gas activities as well as treatment of hazardous materials declined. This may be related to both the central role that energy has played, and the geopolitical uncertainty we are experiencing.

Finally, as far as productivity is concerned, physics-based activities show an increase largely superior to the other branches of economy (with again the marked effect of the Covid pandemic for year 2020).

We hope that such a report produced by an independent organism (CEBR) can contribute helping organise policy briefings in Brussels, Strasbourg, and national capitals, translating physics research into economic and societal benefits and advocate for sustained funding in physics research as a strategic investment, not a cost.

Mairi Sakellariadou, President EPS.

EXECUTIVE SUMMARY

This research demonstrates the scale and significance of physics throughout Europe. To achieve this, we quantify the impact of physics-based sectors and the overall physics-based sector, presenting estimates of physics' contribution to the European economy. Impacts are assessed under the dimensions of physics-based business population and employment, core business metrics such as turnover and value added, aggregate economic impacts and wider trade and investment variables.

We utilise a refined and comprehensive sector classification to define and scope physics throughout the European economy. Geographically, our analysis covers the 27 European Union economies, the United Kingdom and three of the four EFTA countries.

DIRECT IMPACTS OF PHYSICS-BASED ACTIVITIES

• Physics-based activities in Europe generated over **€7.07tn of turnover in 2022, growing by 46.8% since 2016**. The EU-27 economy specifically generated **€5.59tn of this turnover in 2022**. Western Europe is the greatest contributor to Europe's physics-based turnover, with Germany contributing the largest share of any European economy, having **generated over a quarter (€1.96tn)** of the whole continent's physics-based turnover in 2022.

• The physics-based sector **employed 20.13m people in Europe, with specifically 17.00m people in the EU-27 economy in 2022. This overall figure across Europe represents growth of 10.0% or 1.83m employees since 2016.** We estimate that **12.5% of European jobs were physics-based in 2022.** Physics-based manufacturing accounts for the largest share **(47.4%)** of physics-based employment across Europe.

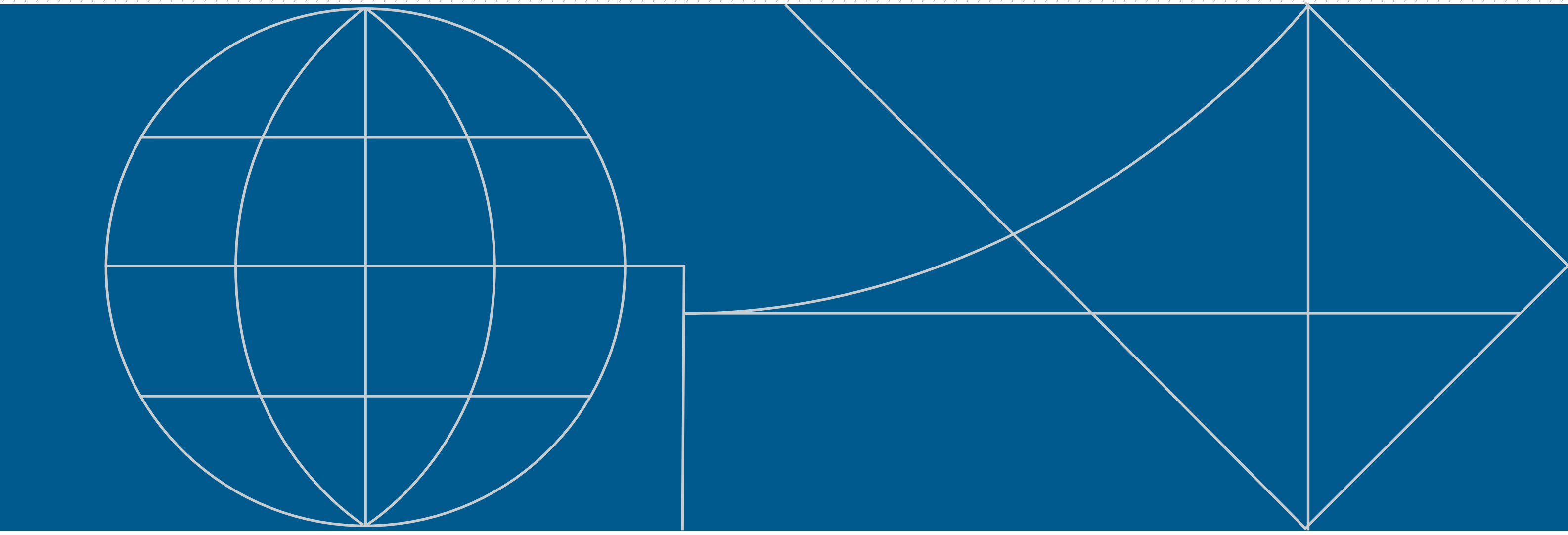
• Germany was also the largest contributor to European physics-based employment, constituting **a quarter of the total**, likely due to its role as a manufacturing hub in Europe. However, Switzerland leads Europe in terms of the share of business economy employment stemming from the physics-based sector, with **more than one in six** Swiss workers employed around physics-related activity in 2022.

• The European physics-based sector and its production processes generated **€2.30tn in direct value added in 2022**, which is **44.1% higher** than the value-added contribution of **€1.60tn recorded in 2016**. The EU-27 economy's contribution was **€1.62tn in 2022**.

• Manufacturing activities generate the most physics-based turnover and value added out of all physics-based sectors. However, the physics-based energy production sector is significantly more productive, where the average worker generated **€254,400** GVA per employee in 2022. This was **1.8 times** the next most productive physics-based information and communication sector.

• Productivity in the physics-based sector of Europe is significantly higher than in all other comparable sectors in our analysis. The average physics-based sector worker added **more than double the value of the average construction sector worker and nearly double the average retail sector worker** in 2022.

• The average physics-based sector worker was more than two-thirds more productive than the average worker in Europe, generating **€114,340** in GVA in 2022.



AGGREGATE IMPACTS OF PHYSICS-BASED SECTORS

• According to our estimates, the EU-27 physics-based sector generated **€4.91tn of direct output in 2022**, constituting **15.5% of total EU-27 economy-wide output**, behind only the manufacturing sector.

• For every €1 in physics-based output, a further **€1.41 is generated through indirect and induced impacts**, supporting **€2.41 on aggregate** throughout the EU economy.

• Aggregate output at basic prices of the EU-27 physics-based sector was **€11.85tn in 2022**, with nearly half of this comprised of indirect supply chain impacts at **€5.75tn**.

• For every €1 in physics-based sector GVA, the **EU-27 economy-wide GVA supported due to direct, indirect and induced impacts is €2.50.**

• Our estimates indicate that on aggregate, physics-based sectors contributed a total of **€4.06tn** in GVA to the EU economy in 2022, incorporating **€1.62tn of direct GVA contributions** of the physics-based sector in EU-27 countries.

• For every direct physics-based job, the physics-based sector supported a **further 1.78 jobs throughout the EU-27 economy** through its indirect and induced activity.

• On aggregate, the physics-based sector supports over **47.2m** jobs throughout the EU-27 economies.

• We estimate that total direct employee compensation in the physics-based sector **measured €913bn in 2022**, accounting for **17.2% of total EU-27 employee compensation.**

• For every €1 of physics-based employee compensation, the economy-wide increase in employee compensation due to direct, indirect and induced impacts is **€2.50**. This implies that the physics-based sector, on aggregate, supports **€2.34tn in total incomes from employment throughout the EU economy.**

EXECUTIVE SUMMARY

PHYSICS-BASED BUSINESS POPULATION & SURVIVAL

- There has been gradual, sustained growth in the number of physics-based enterprises in Europe, **increasing by 18.4% between 2016 and 2022 to reach 2.91m total enterprises.**

- Approximately **one in ten total European businesses** were operating within the physics-based sector throughout the six-year period.

- Professional and technical activities accounted for **52.7% of the physics-based business population in 2022**, by far the largest proportion out of all sectors.

- Italy, Germany and France contributed the highest proportions (**16.2%, 11.0% and 10.3% respectively**) of total physics-based enterprises in Europe in 2022.

- The enterprise birth rate **fell significantly in 2020 by 1.3 percentage points** due to the COVID-19 pandemic, but despite this, throughout the six-year period it increased by **0.1 percentage points, standing at 8.3% in 2022.**

- Business death rates also remained largely unchanged over the period, starting at **6.0% in 2016 and ending at 6.3% in 2022**, with a decline observed in 2020, perhaps due to government initiatives reducing business closures.

- The physics-based sector exhibited consistently lower birth and death rates than the whole business economy from 2016-2022. In terms of creation rates (birth rates minus death rates), **net business creation was stronger in the physics-based sector** than the whole business economy in all years assessed apart from 2020 and 2021.

PHYSICS-BASED INTERNATIONAL TRADE, FDI & R&D

• Physics-based trading volumes increased consistently between 2016 to 2022. Physics-based sector **imports increased by 24.9%** throughout the time period to **€887bn in 2022**, whilst **exports increased by 12.6% to €1.29tn**.

• The physics-based sector constitutes a substantial proportion of total EU trading volumes, **exceeding 30% for both imports and exports** for all years, also far more than equivalent shares for turnover and value added. This demonstrates significantly greater trade intensity in the physics-based sector than whole business economy.

• The EU-27's trade surplus in physics-based goods and services surpassed the overall business economy trade surplus in 2022, **measuring €398bn**.

• Net Foreign Direct Investment (FDI) from the EU varies significantly from 2016 to 2022, reaching a low of **-€25bn in 2020** (signifying a net FDI inflow), and a high of **€122bn in 2022** (signifying a net FDI outflow).

• This remarkable post-COVID-19 rebound was primarily driven by increases in outward FDI from the physics-based manufacturing industry, which invested **€105bn** in countries outside of the EU in 2022.

• Scientific research & development (R&D) in the physics-based sector grew by **36.5%** from 2016 to 2022, reaching **€24.8bn**. This growth was primarily driven by the manufacturing and professional activities sector, which accounted for an average **99%** of the total physics-based R&D over the period.

INTRODUCTION

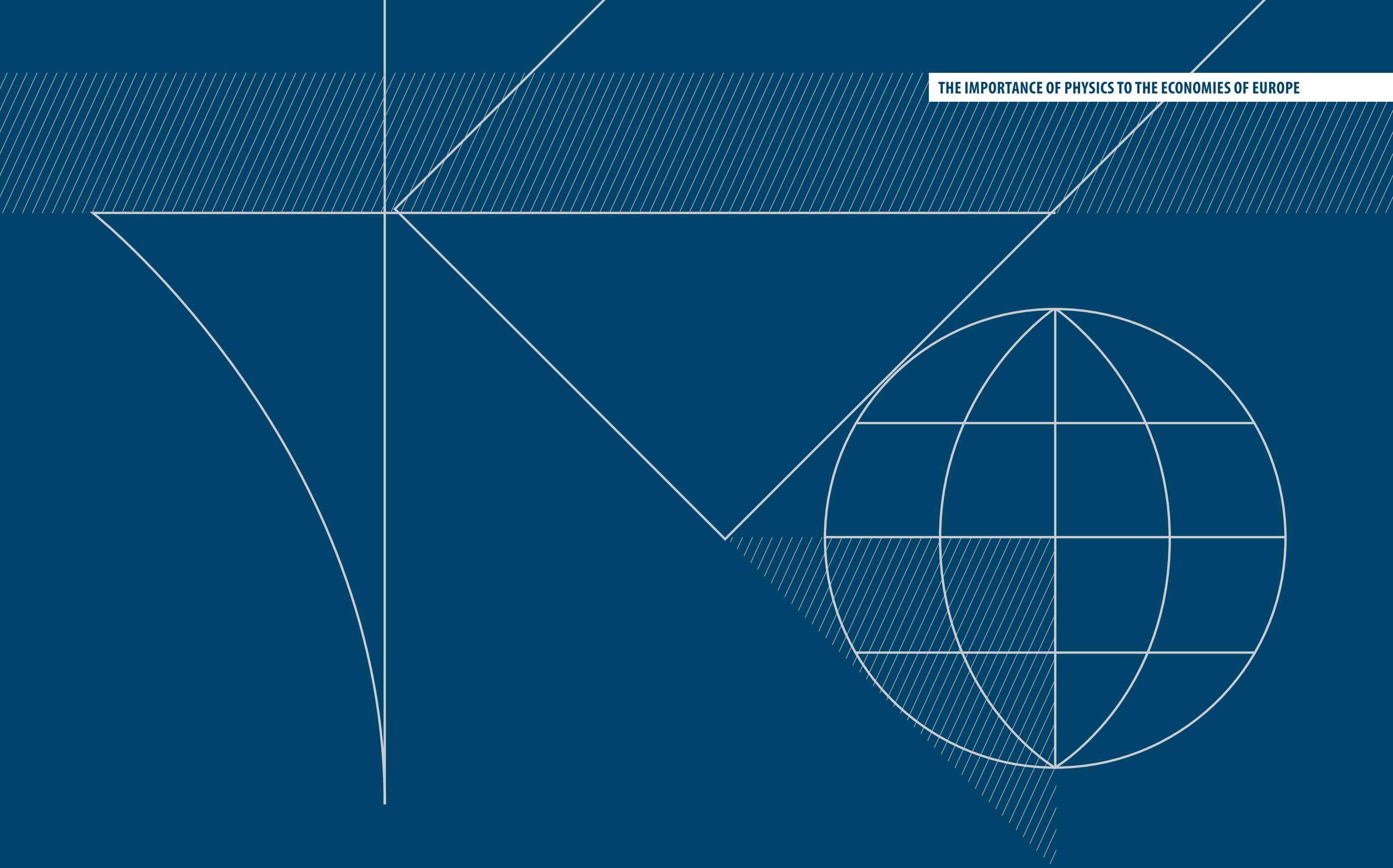
This report has been produced by the Centre for Economics and Business Research (Cebr) on behalf of the European Physical Society (EPS). It presents the findings of comprehensive research and analysis into the significance and scale of physics throughout the European economy, through quantifying the physics-based sector and its economic contributions throughout the continent, across a broad range of dimensions. Our work updates two previous iterations of this research delivered for the EPS over the last decade, along with similar research produced in the UK context for the Institute of Physics.

Most recently in September 2018, EPS commissioned a report by Cebr entitled "A refreshed assessment of the importance of physics to the economies of Europe". The 2018 report examined the contribution of physics to the aggregate economy of the then 28 nations of the European Union (EU), to its 28 individual national economies, and to the economies of three of the four EFTA nations[1]. It also highlighted the value generated by "physics-based sectors" for the economies of Europe[2].

This report seeks to update and extend the research in this space, reviewing the data over more recent years in light of the updated sector definition and changing geopolitical landscape. Given the United Kingdom has now completed its exit from the EU, we now assess the physics-based sector within the 27 individual countries of the EU, the United Kingdom, and the same three EFTA nations. This constitutes Cebr's updated assessment of the importance of physics to the European economy.

1. The four non-EU European Free Trade Association countries are Iceland, Norway, Liechtenstein and Switzerland. Iceland, Norway and Switzerland were analysed in the 2018 report.

2. "Physics-based sectors" are defined as sectors where the use of physics – in terms of technologies or expertise – is critical to its existence. The appendix lists these industries in detail.



THE REMAINDER OF THIS REPORT FOLLOWS THE STRUCTURE SET OUT BELOW:

Section 2 outlines the methodologies, data sources and modelling approaches employed to derive all indicators of the physics-based sector in this research;

Section 3 examines the total physics-based business population in Europe and the survival of physics-based enterprises, in terms of business birth and death rates, in aggregate and disaggregated form;

Section 4 presents the direct impacts of the physics-based sector through the core indicators of employment, turnover, value-added, and productivity. This analysis covers physics-based activity at the aggregated level along with specific breakdowns by more granular sectors and individual countries;

Section 5 contains our estimates of the aggregate economic impacts of the physics-based sector, comprising both indirect and induced impacts. This analysis leveraged input-output modelling and the EU national accounting framework, combined with direct impact results from Section 4 as data inputs;

Section 6 examines some additional indicators of the physics-based sector, particularly in the context of international and innovation activity, through international trade flows, foreign direct investment, and research & development expenditure;

Appendix I provides a short compendium of national-level results in more detail for the four core indicators, that underpin the aggregate results in the main body of the report;

Appendix II details the updated industry-based definition of physics-based activities used for the purposes of our study. It outlines the inclusions as a result of the updated definition and also lists those activities which are no longer considered to be physics-based; and

Appendix III provides further methodological details around sector classification and some of the technical definitions utilised in the report.

2. METHODOLOGY

Before delving into our detailed estimates of the European physics-based sector, this section sets out the methodology that was utilised to derive them. Our analysis drew exclusively from Eurostat data, primarily the Structural Business Statistics (SBS) and National Accounts (ESA2010) datasets. Modelling and calculation approaches varied between different indicators and are detailed in turn below.

2.1 DEFINING THE PHYSICS-BASED SECTOR

The definition of the physics-based industry used throughout this report was developed in collaboration with the European Physical Society and the Institute of Physics. This iterative process allowed both organisations to scrutinise and refine the definition of the physics-based sector until a comprehensive list of four-digit NACE Rev.2 codes was agreed upon. These codes are particularly relevant for European analysis due to their use in Eurostat datasets and their one-to-one mapping onto the UK's equivalent SIC codes. As such, the resulting definition reflects agreement between both European Union and UK physics bodies. A full list of the industries included in the analysis is provided in Appendix II.

The sector was defined from the bottom up. First, by identifying relevant four-digit industries where the use of physics is integral and critical to their activity, and then by aggregating this into the overall physics-based sector. Four-digit physics-based industries were also aggregated to broader industry groupings for presentation purposes[3]. We did not adopt a top-down approach that begins with entire sectors (e.g., manufacturing – Section C) and apportions a share to physics-based activity. Therefore, all physics-based industries are included and captured in their entirety, and our highly granular approach means that no industries are partially physics-based.

2.2 DIRECT IMPACTS OF THE PHYSICS-BASED SECTOR

Section 4 of this report presents our analysis of the direct impacts of the physics-based sector, through the core indicators of total turnover, value added and employment. These indicators cover the physics-based sector of the EU-27 economies, along with three of the four EFTA nations and the United Kingdom[4].

Data for this analysis were drawn entirely from Eurostat's Structural Business Statistics (SBS). This data is gathered directly from enterprises operating within the business economy and are categorised according to the type of economic activity being undertaken by the enterprise. This categorisation system is known as NACE. Under the system, enterprises are assigned to sectors according to the principal activity they undertake in the economy. Essentially, all the jobs, turnover and value added that these businesses create are attributed to a particular sector[5].

The SBS database provides information on the structure, conduct, and performance of businesses across the European Union, with statistics broken down to a highly detailed sectoral level (hundreds

3. For example, where our analysis refers to physics-based activity within broader sectors, this is the refers to the aggregation of all physics-based four-digit industries within the broader sector, rather than an apportionment of the broader sector.

4. The three EFTA nations include Switzerland, Iceland and Norway. Lichtenstein was excluded due to data availability constraints.

5. To determine the "principal activity" of a given enterprise, the activity that generates the most value added is identified. Most enterprises are assigned their industry according to this measure.

of economic activities)[6]. This allows for accurate analysis of economic indicators at the required level of sector disaggregation for the relevant physics-based activities (see Appendix II).

Adjustments were made to some sectors to estimate the proportion of economic activity that was physics-based. These adjustments were implemented in some granular subsectors where data availability was more sparse and drew upon our estimates of the physics-based share of turnover, value added, employment, and number of enterprises across the wider sector. For subsectors, countries and years in which core indicator data was missing, we applied the average subsector proportion of wider sector activity to impute missing values.

This therefore reflects the assumption that the ratio between the economic activity in physics-based subsectors and their wider sector is relatively consistent across the time period of our analysis. Missing data in granular subsectors for EU total values were then imputed as the sum of economy activity in individual EU-27 countries. These processes allowed us circumvent issues with missing Eurostat SBS data, estimating the extent to which all four indicators were generated by physics-based activities at a more granular level than the data would have otherwise allowed.

Given labour productivity data was not directly available within the Eurostat SBS like the other three core indicators, this was derived as a function of two of these variables. Both in individual physics-based subsectors and the sector as a whole, total gross value added was divided by total employment to generate gross value added per worker. As an extension of gross

6. SBS data for the 2016-2022 period are provided at the 4-digit level of industrial classification. Our defined "physics-based sector" includes a range of industries classified at the 3-digit and 4-digit levels.

value added and employment data our productivity figures therefore also reflect the adjustment used for these two indicators.

2.3 AGGREGATE IMPACTS OF THE PHYSICS-BASED SECTOR

Having generated direct physics-based sector impacts we employed a comprehensive modelling approach to derive aggregate impacts from this. This approach drew from the initial Eurostat SBS data, Eurostat ESA2010 national accounts tables and Cebr's in-house input-output modelling capacity. Input-output modelling leverages these data sources, specifically supply, use and input-output tables to analyse the physics-based sector within the EU's "national" accounting framework, exhaustively mapping its transactions between all other sectors of the EU economy[7].

Our analysis employs these datasets in conjunction with a Leontief matrix multiplier approach to derive multipliers that capture the broader impacts of direct physics-based activity throughout the entire economy. Multipliers cover indirect impacts through the upstream supply chain of the physics-based sector (Type I multiplier) and induced impacts from the consumption of employees both within the physics-based sector and its supply chain (Type II multiplier). Impact categories and multipliers are explained in further detail in Section 5.

It is also crucial to note the data sources employed within our aggregate impacts analysis and the scope this captures. Direct impacts (methodology detailed in Section 2.2) are underpinned by SBS data, as the sector granularity and geographic coverage it provides facilitates a detailed, accurate estimate of the physics-based sector. However, our modelling framework here means that aggregate impact analysis draws from national accounts and Labour Force Survey data. This data covers the entire EU economy, a slightly broader scope than the SBS that focusses on the business economy, including household activity, public administration and non-market services such as education and healthcare. Given the broader scope, some of our estimates in this analysis exceed the equivalent measures in the direct impacts section.

2.4 PHYSICS-BASED BUSINESSES AND THEIR SURVIVAL

Section 3 draws heavily upon the business demography statistics provided within Eurostat SBS data, measuring the total number of active enterprises on an annual basis. Analogously to the core impact indicators covered in Section 2.1, these number of enterprises statistics required equivalent estimates and adjustments to impute values in subsectors, countries and years that contained missing data.

This section also utilised data around numbers of enterprise births and deaths, sourced from

7. EU national accounts data merges all EU-27 economies to capture them as an overall economic unit, analogous individual country national accounts, such that trade between different EU-27 economies is not treated as exports or imports, but transactions within the economic unit.

broader Eurostat business demography datasets[8]. This data was predominantly presented at a 2-digit level under the NACE Rev. 2 framework, with some selected sectors presented at a 3- or 4-digit level, thus broader sector values were adjusted to reflect the more granular physics-based subsectors. Number of enterprise data was crucial in this process as this variable exhibited good granularity and availability down to 4-digit sector level. To estimate physics-based business births and deaths in granular subsectors, we apportioned wider sector values using the distribution of number of enterprises across physics-based subsectors. Having derived physics-based numbers of births and deaths, we transformed this to birth and death rates by expressing them relative to the total number of physics-based enterprises, across granular subsectors and aggregated for the overall physics-based sector.

2.5 TRADE, FOREIGN DIRECT INVESTMENT AND R&D EXPENDITURE

Section 6 analyses the impacts of the physics-based sector through three additional metrics – trade, net FDI flows and total business R&D expenditure. Trade indicators were first computed by employing a combination of national accounting data and raw SBS trade data. Within our physics-based EU-27 national accounting framework, constructed in full from our input-output modelling and estimation of aggregate impacts, we measured the level of extra-EU trade in physics-based goods and services in the base year of 2022. This comprised imports covered within the supply table framework, exports within the domestic use table and exports from imported use, covered by the imported use table.

Eurostat SBS trade data was then used to adjust 2022 trade values and derive trading volumes throughout the preceding years in our time period. Raw import and export data was reported at a higher level of 2-digit NACE sectors in the SBS, which we collected and apportioned across granular physics-based subsectors using physics-based turnover data. Apportioned physics-based trade data was aggregated to a physics-based total trading volumes for imports and exports, from which indexes were constructed throughout the period (2017-2022)[9], with 2022 as the base year. SBS-based trade indexes were applied to the 2022 national accounts-based trade data to deduce imports and exports for all other years. This approach represents an improvement on purely utilising SBS trade data, circumventing potential inaccuracies generated by apportionment and ensuring import and export volumes accurately reflect the physics-based sector.

Section 6 of our analysis also draws upon foreign direct investment (FDI) of the physics-based sector in the EU. FDI data is provided by directly by Eurostat, through a single indicator that details net financial investment flows out of the EU economy, according to the NACE Rev. 2 activity of the business involved in the investment. While the FDI dataset does not disaggregate fully to the granular 4-digit NACE sectors in our physics-based definition, statistics were sourced at the greatest level of disaggregation possible, predominantly at the 2 and 3-digit sector level, with some sectors being grouped. Wider sector values were then apportioned to granular physics-based subsectors using equivalent proportions of turnover, therefore operating under the assumption FDI in the physics-based sector was distributed proportionately to total business turnover. Granular subsector FDI was then aggregated to the whole physics-based sector.

8. Some demographic events leading to creations or closures of enterprises are not classified as births or deaths: these include firms' break-ups, split-offs, mergers, takeovers and restructurings; as well as the re-activation of businesses which closed down within the previous two years. In addition, creations of enterprises solely for the provision of one production factor or an ancillary activity (such as real estate or personnel) are excluded from these measures, as are enterprises with governmental legal forms.

9. Data for 2016 was very limited, and so we do not include this year in our analysis of trade.

Finally, Section 6 also explores physics-based business expenditure on research and development (R&D). Our approach in modelling this across the physics-based sector was rather analogous to that of trade, utilising a combination of Eurostat national accounts and SBS data to do so. Firstly, we drew upon our adapted physics-based EU supply-use framework to derive estimates for R&D expenditure, leveraging the physics-based sectors' consumption of scientific research and development services and intermediate inputs. We then employed Eurostat's Business Enterprise R&D expenditure (BERD) dataset to derive estimates of whole economy R&D expenditure between 2016 to 2022 and constructed indexes for all years, with 2022 as the base year. Whole economy R&D indexes were transformed using physics-based subsector turnover indexes to generate R&D indexes in granular physics-based subsectors. These indexes were applied to 2022 R&D expenditure values in each physics-based subsector aggregated to total physics-based R&D spend.

3. THE EUROPEAN PHYSICS-BASED BUSINESS POPULATION

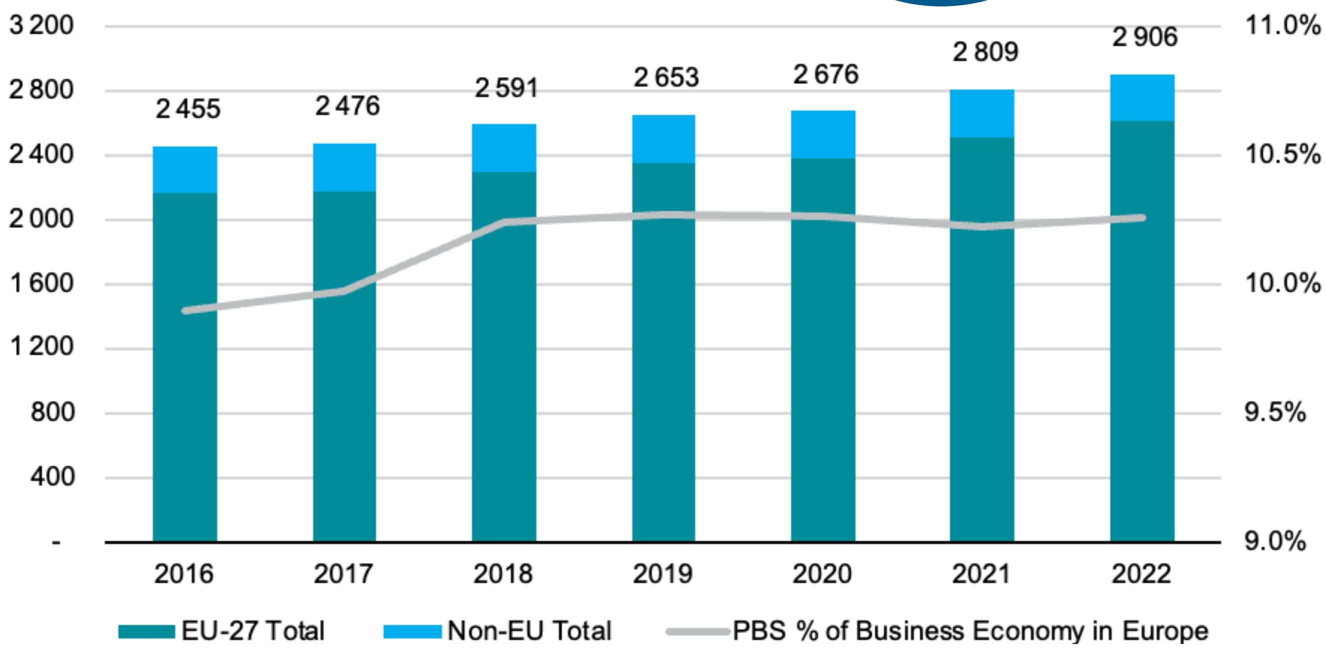
In this section, we examine the total number of enterprises that belong to the physics-based sector in the EU-27, the EFTA nations and United Kingdom. Specifically, we examine how the number of physics-based enterprises evolves over time, the breakdown of the main industries that make up the physics-based sector in Europe and a comparison of the physics-based sector to other key sectors in Europe.

3.1 PHYSICS-BASED BUSINESS POPULATION

This subsection sets out the number and characteristics of physics-based businesses in Europe. Full data from this section broken down by country is also provided in Appendix I. **Figure 1 provides a breakdown of the total enterprise population of the physics-based sectors by the number belonging to the EU-27 countries and non-EU countries.** The total enterprise number is displayed above each bar chart which sums the EU-27 and non-EU countries to form the total physics-based sector in Europe. In 2022 the total physics-based business population across our European sample measured 2.91m enterprises.

Between 2016 and 2022, there has been a consistent upward trend in physics-based enterprises in Europe throughout the time period. This signifies gradual, sustained growth of the business population, as the total number of physics-based enterprises increased by 18.39% between 2016 and 2022. The strongest growth across the six-year period was experienced

FIGURE 1.
Breakdown of total physics-based enterprises in Europe between EU-27 and non-EU countries and proportion of total business economy, thousands and %, 2016-2022



between 2020 and 2021, when the number of physics-based enterprises in Europe climbed from 2.68 million to 2.81 million, representing annual growth of 4.96%. Growth in the physics-based business population was also particularly strong in 2019 and 2022 at 4.6% and 3.5% respectively. Two consecutive years of robust growth in enterprises numbers in both 2021 and 2022 is indicative of a strong post-pandemic recovery of the physics-based sector business population.

Figure 1 also visualises the physics-based business population as a proportion of the whole European business economy. Approximately one in ten European businesses operate within the physics-based sector, a proportion which remained relatively consistent over the period, increasing slightly from 9.9% in 2016 to 10.3% in 2022.

Figure 2 details the proportion of the total physics-based enterprises by constituent industry in 2022.

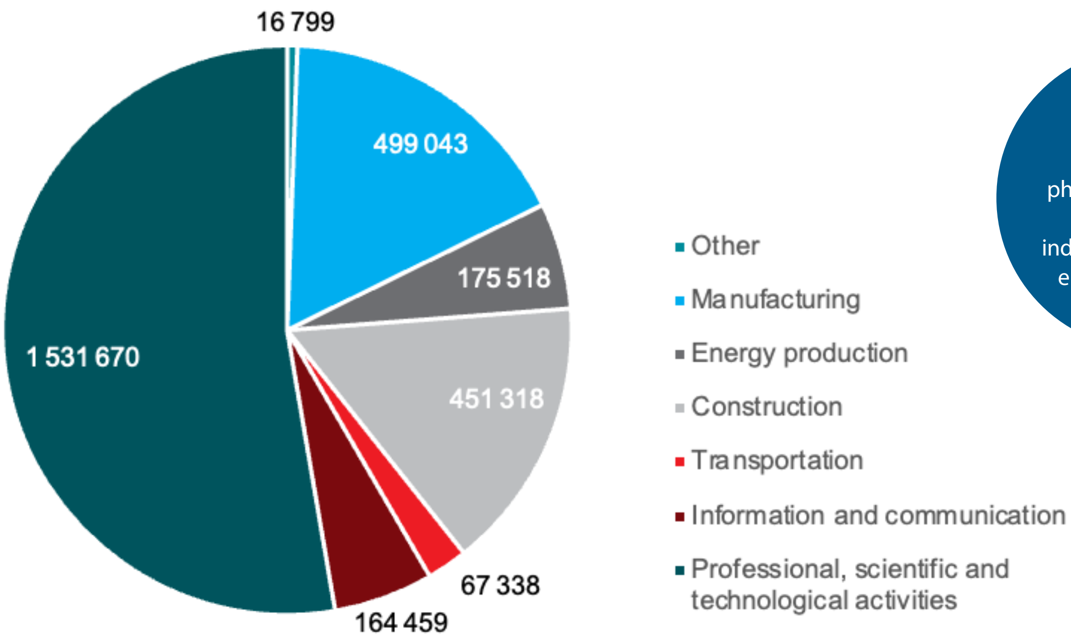


FIGURE 2. Composition of physics-based sector across different industries , number of enterprises[10], 2022

Source: Eurostat SBS, Cebr analysis

Clearly, the distribution of enterprises is uneven across the different industries, as by far the largest number of enterprises are accounted for by physics-based professional, scientific and technological activities at 1.53 million enterprises, constituting 52.7% of the physics-based business population in 2022 (2.9 million). This is followed by manufacturing (17.2%), construction (15.5%) and energy production (6.0%). Combined, the total enterprise contribution of these sectors (38.7%) still amounts to less than that of the professional, scientific and technological activities sector alone (52.7%). Other lesser-represented sectors within the physics-based industry include energy production, accounting for approximately 1 in 16 (6%) of physics-based enterprises, and transportation, accounting for just under 1 in 40 (2.3%)

10. Other includes oil and gas activities, treatment of hazardous material and the repair of personal and household goods. They have been grouped as each industry make up less than 1.0% of the total physics-based enterprises in Europe.

Figure 3 illustrates the share of the total 2.9 million European physics-based enterprises that are contributed by each country in 2022. The full underlying data for this graphic, along with all other heatmaps throughout the report, is listed in Appendix I.

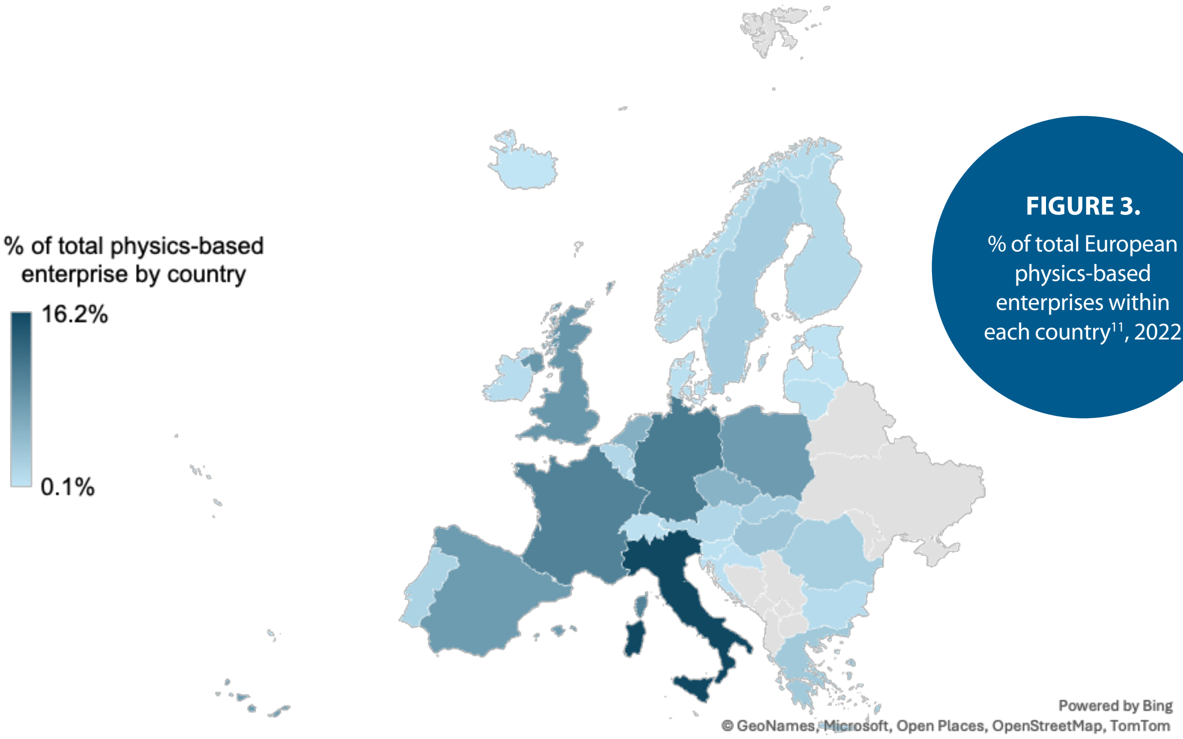


FIGURE 3.
% of total European physics-based enterprises within each country[11], 2022

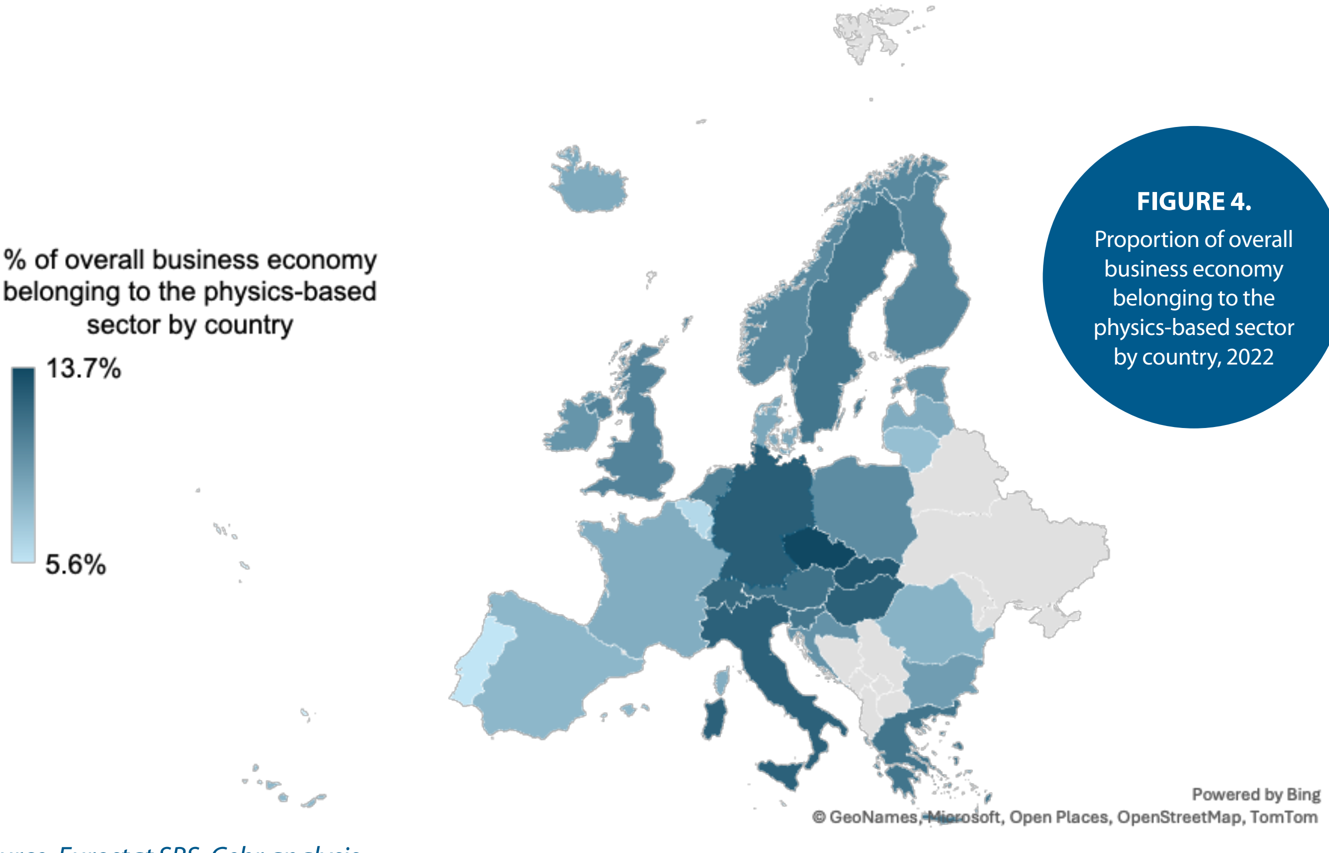
Source: Eurostat SBS, Cebr analysis

The countries with the highest proportion of total physics-based enterprises are Italy (16.2%), Germany (11.0%) and France (10.3%). No other country accounts for 10.0% or more of the total physics-based enterprises in Europe. There is also a marked divide between the physics-based business populations in Western and Central and Eastern Europe, as the former comprises a far greater proportion of total European physics-based enterprises. Western European countries account for two-fifths (40.0%) of the total European physics-based business population and have an average national share of the European business population of 4.4%. This compares to Central and Eastern Europe that account for one quarter (25.0% of all European physics-based businesses with an average share of 2.3%). A detailed breakdown of the total physics-based enterprise per country is provided in Appendix I.

11. Cyprus is not included in our heatmaps throughout due to scale and formatting constraints. However, for Figure 3 specifically Cyprus only accounts for 0.2% of the total physics-based enterprises in Europe, thus no key countries are excluded.

Figure 4 visualises the share of the overall business economy within each European country comprised of the physics-based sector in 2022. This therefore presents a more relative perspective around the significance of the physics-based sector in each economy, as opposed to the more absolute perspective offered by Figure 3.

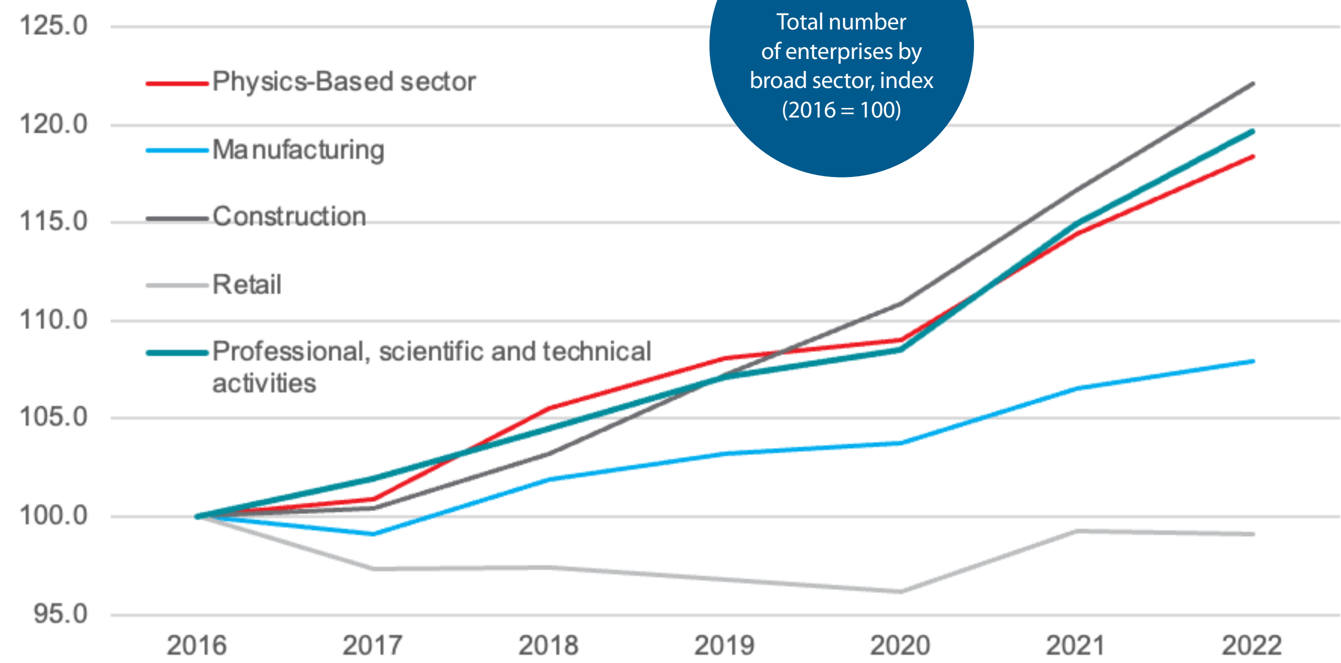
FIGURE 4.
Proportion of overall business economy belonging to the physics-based sector by country, 2022



Source: Eurostat SBS, Cebr analysis

Findings here also diverge from the previous perspective with Western Europe proving less dominant. The three countries with the highest proportions of physics-based business population are the Czech Republic (13.7%), Slovakia (13.0%) and Germany (12.5%), closely followed by other Eastern and Southern European economies such as Hungary (12.4%) and Italy (12.4%). Figure 4 illustrates that Central and Eastern Europe is the area with the highest average concentration of physics-based sector enterprises as a share of their total enterprises. This is potentially a function of smaller overall business populations in Central and Eastern Europe, and a stronger focus on wider sectors that contain a higher concentration of physics-based activity, such as manufacturing.

FIGURE 5.
Total number of enterprises by broad sector, index (2016 = 100)



Source: Eurostat SBS, Cebr analysis

Figure 5 presents an indexed comparison of enterprise growth across the physics-based sector and other key sectors of the European economy, with 2016 acting as the baseline. The number of enterprises in the physics-based sector increased by 18% between 2016 and 2022, reiterating the growth figures observed in Figure 1. Notably, business population growth in the physics-based sector outpaced that in both the manufacturing and retail sectors, the former of which contains a substantial volume of physics-based activity. This potentially indicates that physics-based manufacturing activity is more heavily concentrated within the high-growth portion of the sector. Overall manufacturing business growth measured 8% over the six-year period, whilst retail enterprise numbers shrank by 1%.

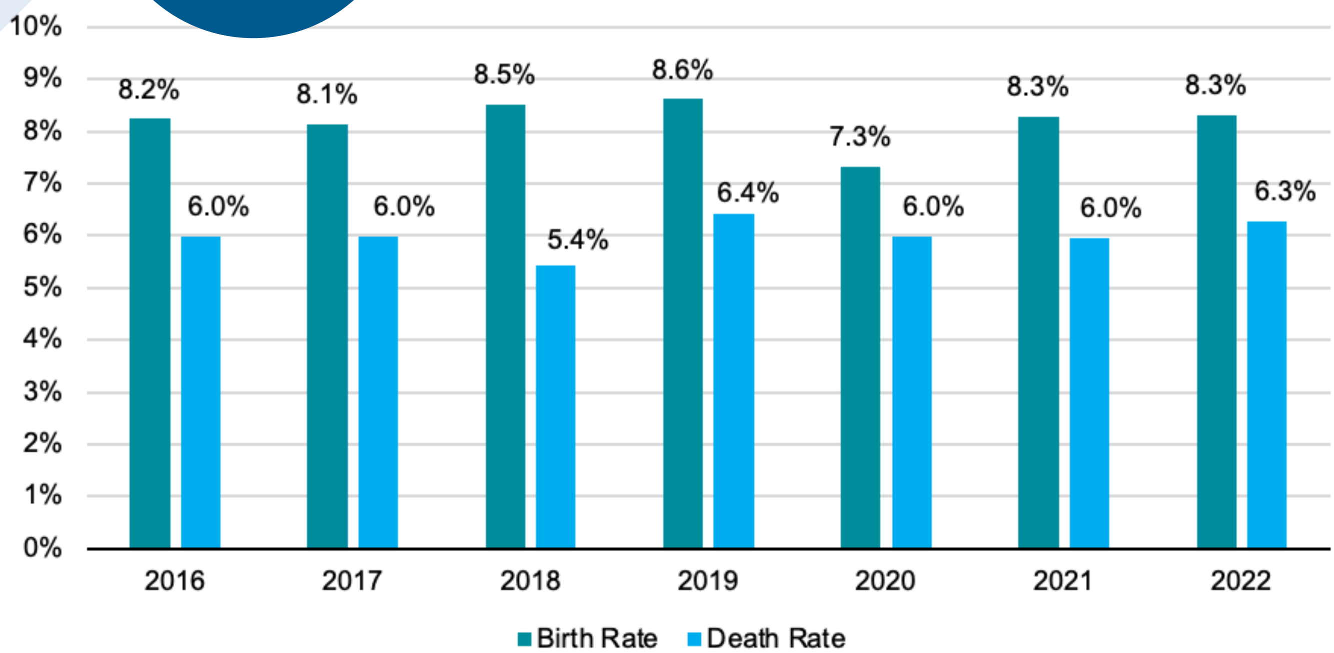
Conversely, physics-based business population growth was outpaced by construction and professional, scientific and technical activities, which increased by 22% and 20% respectively. These trends reflect structural shifts in European business demographics towards construction and professional services, but growth in these sectors only outpaced the physics-based equivalent very marginally. Physics-based activity therefore ranks amongst the strongest sectors of the European economy in terms of business creation.

3.2. PHYSICS-BASED ENTERPRISE BIRTH AND DEATH RATES

This section assesses the change and evolution in enterprise demography within the physics-based sector of the EU-27 economies. The decision to only cover these 27 nations is motivated by a lack of coverage of business births and deaths of the EFTA nations and the UK within Eurostat, facilitating challenges in utilisation of consistent data sources. Specifically, our analysis focuses on analysing trends in business "births" and "deaths" between 2016 and 2022, allowing us to assess the resilience of the of physics-based enterprises during this period.

Our data indicates robust, active business creation within the European physics-based sector. **Figure 6 illustrates that in 2016, physics-based enterprises in the EU-27 economies exhibited a birth rate of 8.2%, implying there were roughly eight physics-based start-ups for every 100 existing physics-based enterprises in that year.** This birth rate increased modestly to 8.6% in 2019, representing growth of the business birth rate by 0.4 percentage points between 2016 and 2019. However, this upward trend was interrupted in 2020, when the birth rate declined to 7.3%, a 1.3 percentage point fall from 2019. This decline can primarily be attributed to the COVID-19 pandemic which curtailed economic activity in the European Union through government-mandated lockdowns and policies limiting business operations.

FIGURE 6.
EU-27 birth and death rates for enterprises in physics-based sectors, 2016-2022



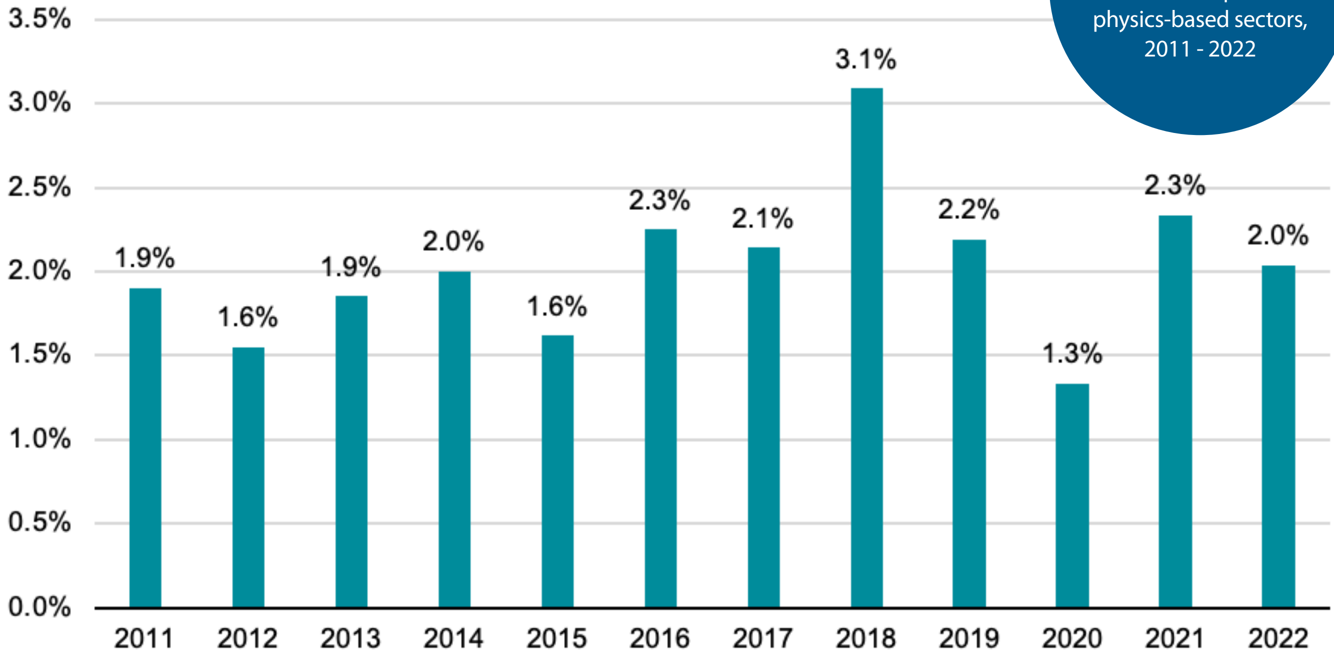
Source: Eurostat SBS, Cebr analysis

Although a fall in the business birth rate of the physics-based industries was experienced in 2020, the downward trend in business birth rate did not persist, with the business birth rate among the physics industry recovering to pre-pandemic levels by 2021 and remaining at this level into 2022. Throughout the whole six-year period business birth rates averaged 8.2%.

Business death rates were broadly also stable over the assessed period, at between 6.0% and 6.4% in all years other than 2018 (5.4%). The relative stability of business death rates between 2020 and 2022, suggests that government initiatives during the pandemic to reduce business closures in the EU may have been effective in supporting business survival during the height of the crisis, particularly in the physics-based sector.

When comparing longer-term averages, the average birth rate between 2011 and 2015 measured 10.6%, while the average death rate was 8.8%. In the more recent period, between 2016 and 2022, the average birth rate declined to 8.2%, while the death rate fell more significantly to 6.0%. As a result, the net enterprise creation rate improved, from an average of 1.8% during 2011–2015 to 2.2% in 2016–2022, indicating stronger enterprise sustainability in the latter period, despite a slowdown in new business formation. **Figure 7 visualises net business creation rates throughout the extended time period, accounting for both birth and death rates.** As established, there is a general increase in the business creation rate between 2016 and 2022, particularly when compared to the lower net business creation rate experienced between 2011 and 2015.

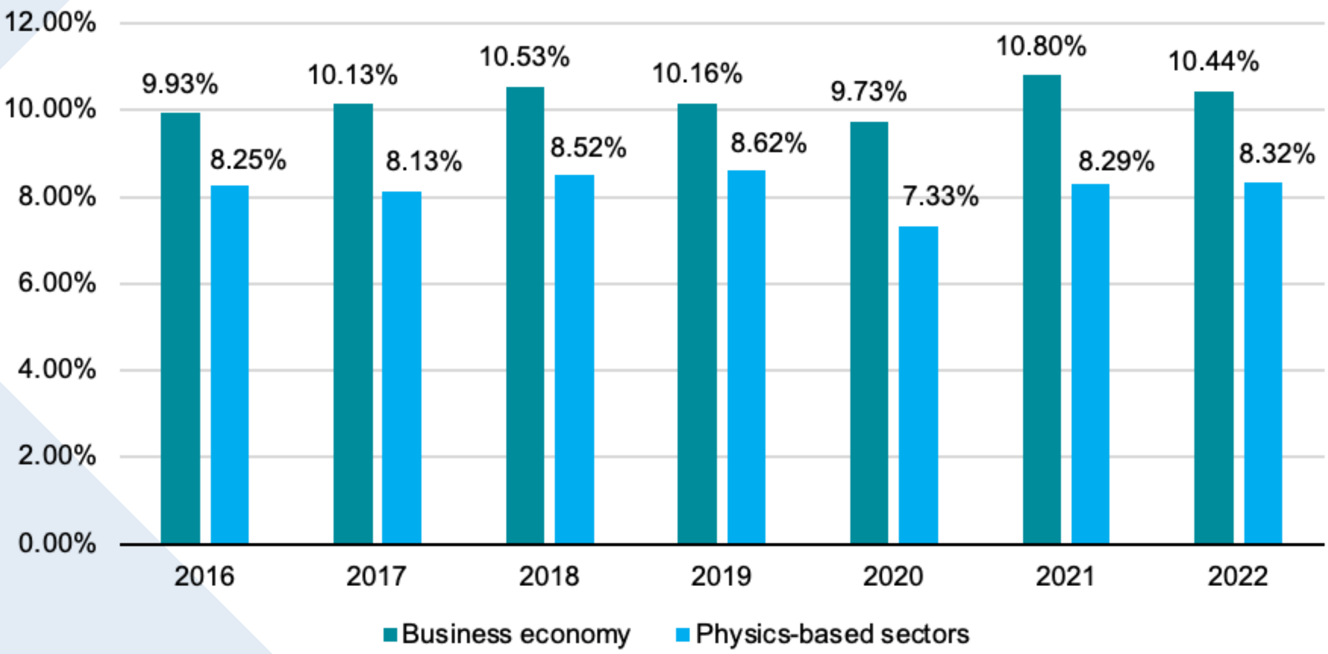
FIGURE 7.
EU-27 business creation rate for enterprises in physics-based sectors, 2011 - 2022



Source: Eurostat SBS, Cebr analysis

FIGURE 8.
Comparison between the enterprise birth rates in the EU-27 physics-based sectors and the business economy, 2016-2022

Figure 8 compares business birth and death rates between the physics-based sector and the overall business economy from 2016 to 2022. Over this period, the physics-based sector exhibited a consistently lower birth rate than the whole business economy. On average, the physics-based sector had a birth rate of 8.2% while the wider business economy exhibited an average birth rate of 10.2%.

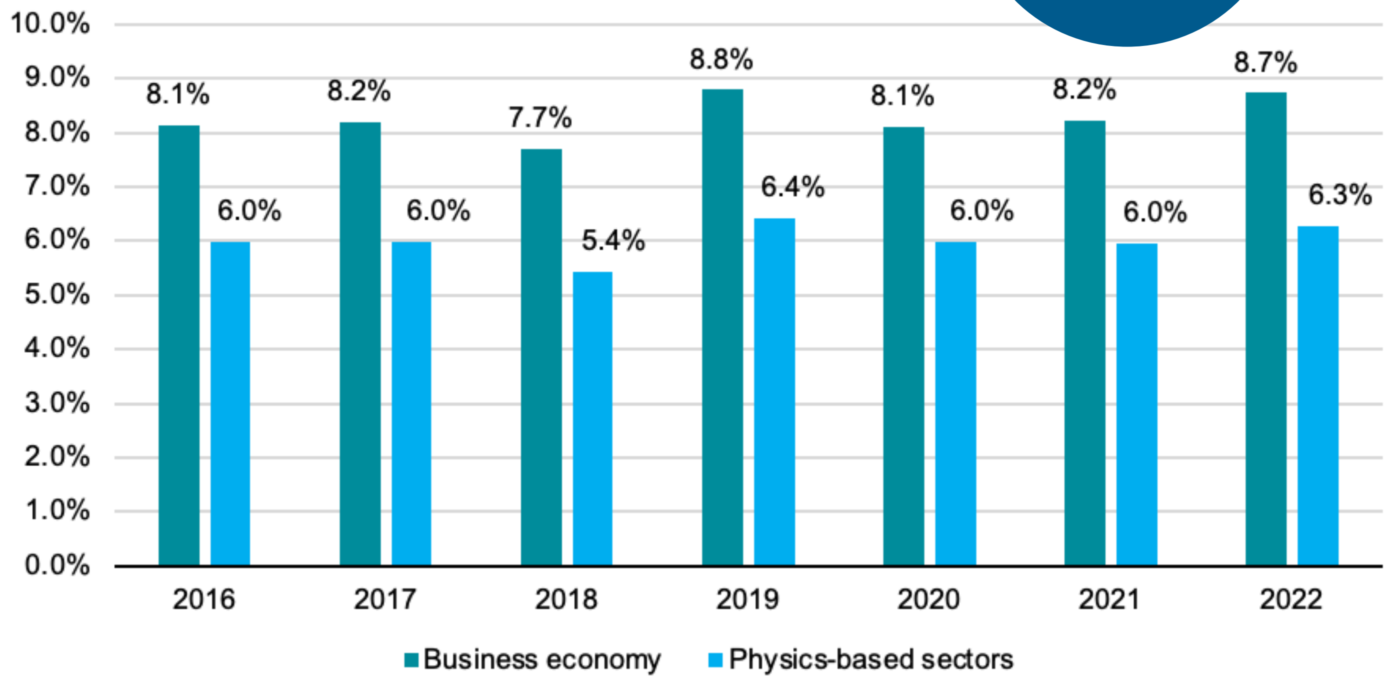


Source: Eurostat SBS, Cebr analysis

The largest disparity in birth rates is observed in 2020 when the business economy experienced a birth rate of 9.7% while the physics-based sector equivalent measured 7.3%, resulting in a business birth rate deficit of 2.4%. Although both sectors experienced a decline in business formation during the pandemic, the fall was more pronounced in the physics-based sector. This suggests that the COVID-19 crisis had a more substantial impact on the creation of new enterprises in physics-based industries than in the broader economy. The disparity in business birth rates between the physics-based sectors and the wider economy can partially be explained by the relatively high barriers to entry for start-ups in the physics-based sector. High levels of start-up capital and a skilled workforce are common requirements for firms in the physics-based sector, which could pose significant disincentives and barriers to entry for potential new entrants.

In the case of business deaths, displayed in Figure 9, we observe a similar disparity between the physics-based sectors and the wider business economy. Between 2016 and 2022, an annual average of eight out of every 100 existing enterprises went insolvent within the whole business economy. In the physics-based sector however, six out of every 100 on average annually suffered insolvency. Over the period, the gap in death rates of the two sectors grew modestly, reaching a peak of 2.5% in 2022. This indicates that physics-based businesses are notably less likely to cease operations relative to the wider business economy, with physics-based business death rates waning and the difference in likelihood of insolvency widening throughout the time period.

FIGURE 9.
Comparison between enterprise death rates in the EU-27 physics-based sector and the business economy, 2016-2022



Source: Eurostat SBS, Cebr analysis

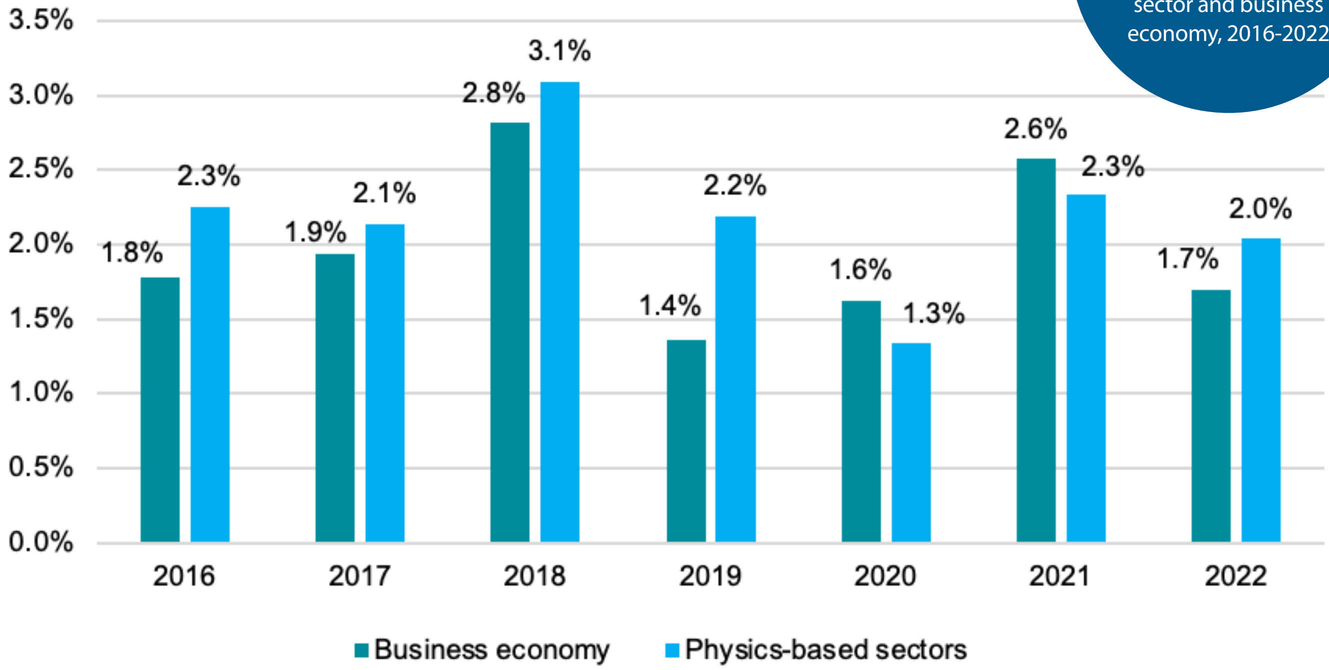
On balance, these findings demonstrate that although the physics-based sector consistently exhibits a lower business birth rate, in part due to structural barriers, it also exhibits a lower business death rate.

Combining birth and death rates, **Figure 10 compares the net business creation rate of the EU-27 physics-based sectors and the wider business economy**. Between 2016 and 2022, the physics-based sectors consistently outperform the wider business economy in terms of net business creation, except in 2020 and 2021. On average, the physics-based sectors report a net business creation rate of 2.20% between 2016 and 2022, while the wider business economy reports a net business creation rate of 1.97%. The difference is most pronounced in 2019, when the physics-based sectors posted a net creation rate of 2.19%, significantly surpassing the wider economy's 1.36%.

The highest business creation rates during the period were recorded in 2018, when both the physics-based sectors and the wider business economy peaked at 3.09% and 2.82%, respectively. This surge was driven by a combination of rising business births and declining business deaths. However, between 2019 and 2022, business creation rates never rebounded to the peak experienced in 2018.

Notably, 2020 and 2021, the two years most affected by the COVID-19 pandemic, were the only two years in which the business creation rate was lower amongst the physics-based sectors than the wider business economy. In 2020, the physics-based sectors grew at 1.34%, compared to 1.62% in the wider business economy. This supports earlier findings that the growth of the physics-based business population was more severely impacted by COVID-19 than the wider business economy.

FIGURE 10.
Comparison of the business creation rate in EU-27 physics-based sector and business economy, 2016-2022



Source: Eurostat SBS, Cebr analysis

4. THE DIRECT IMPACT OF THE PHYSICS-BASED SECTOR IN EUROPE

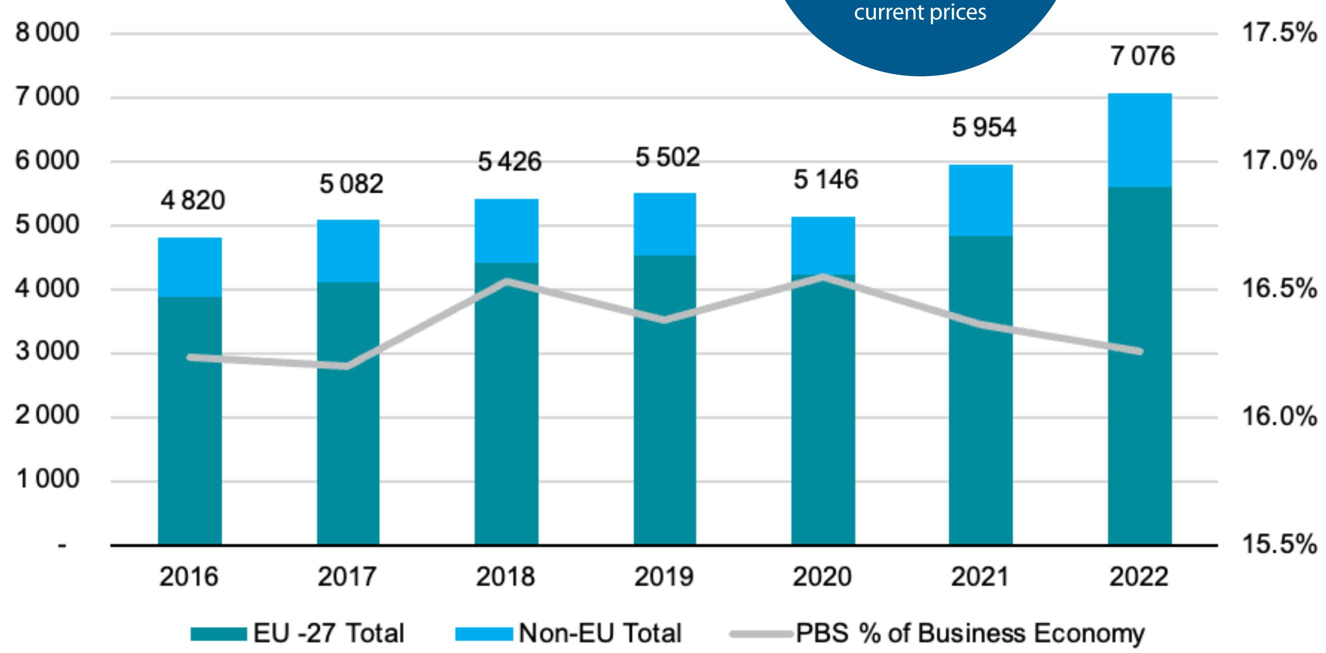
This section sets out the direct impacts of physics-based activity on the European economy, throughout 2016-2022. Direct impacts are encapsulated through the turnover, gross value added and employment generated by physics-based industries, whilst this section also covers productivity within the sector. We analyse these metrics for all EU-27 countries, as well as the United Kingdom and three of the four EFTA countries (Switzerland, Iceland, and Norway; Liechtenstein was again excluded due to data availability). Figures within this analysis are supported by the full national-level estimate tables in Appendix I that cover all main indicators assessed in this section. All monetary indicators (turnover, value added and productivity) are presented in nominal prices.

As detailed in Section 2.1, the estimates throughout this section are underpinned by data from Eurostat's Structural Business Statistics. This data is employed as its comprehensive sector granularity and geographical coverage enable accurate and detailed estimates of the physics-based sector. However, its scope covers only the business economy, excluding households, public administration and non-market sectors such as healthcare and education. In the context of the physics-based sector these exclusions are not particularly consequential, but the figures presented in this section should nonetheless be interpreted with this caveat in mind.

4.1. TOTAL TURNOVER

Figure 11 below shows that the European physics-based sector generated substantial, robust turnover that has grown markedly throughout the period of this analysis.

FIGURE 11.
Turnover in physics-based sectors and proportion of business economy turnover, €bn and%, 2016-2022, current prices



Source: Eurostat SBS, Cebr analysis

Physics-based economic activities in Europe generated over €7.07tn in turnover during 2022, exhibiting substantial growth of 46.8% from 2016 turnover levels. This is equivalent to an increase of €2.26tn in total physics-based turnover in Europe over the six-year period, attributed to a €1.72tn[12] increase in EU physics-based turnover and a €532bn total increase for non-EU countries.

Unsurprisingly, weakest annual growth was observed in 2020, when turnover in physics-based sectors significantly contracted by 6.5% or approximately €356bn in absolute terms. This reflects the COVID-19 pandemic that dampened economic activity and therefore turnover throughout the business economy. Nonetheless, physics-based turnover grew in all other years over the period, with 2021 and 2022 exhibiting the strongest years of growth (15.7% and 18.8% respectively), representing a very robust recovery from the pandemic in both EU and non-EU countries. This strong post-pandemic recovery exceeds trends observed in physics-based business population, although part of this strong upward trend in the nominal data could be attributed to the impact of inflationary spikes across much of Europe in 2022[13].

Figure 11 also illustrates the evolution of physics-based turnover as a share of total turnover in Europe.

12. Throughout this research, 'tn' refers to the short scale trillion, which is defined as 1×10^{12}.

13. According to Eurostat data in 2022, EU annual inflation reached 9.2%, which was more than triple the 2.9% inflation in 2021.

Turnover of physics-based businesses has constituted a very consistent proportion of the overall economy equivalent, remaining between 16.2% and 16.5% throughout the period, peaking in 2018 and 2020. This signifies that strong turnover growth within the physics-based sector was matched by and likely reflective of equally strong growth throughout the European business economy. Additionally, physics-based turnover proportions consistently exceed the equivalent business population proportions, indicating per-business turnover is greater in the physics-based sector than the wider economy.

Comparing the physics-based sector with other major sectors allows us to place it in the context of the wider European business economy. The much broader retail and manufacturing sectors made up larger shares of European turnover over the whole period by a wide margin, at 35.1% and 25.4% in 2022 respectively. In absolute terms, the European manufacturing sector's turnover measured €11.07tn in 2022, 1.6 times greater than the physics-based turnover. Nonetheless, physics-based turnover was more than double that of both the construction sector and professional, scientific and technical activities.

Examining the intersection between sectors and physics-related activity, **Figure 12 below sets out the composition of physics-based turnover across broad sectors of the European economy in 2022.**

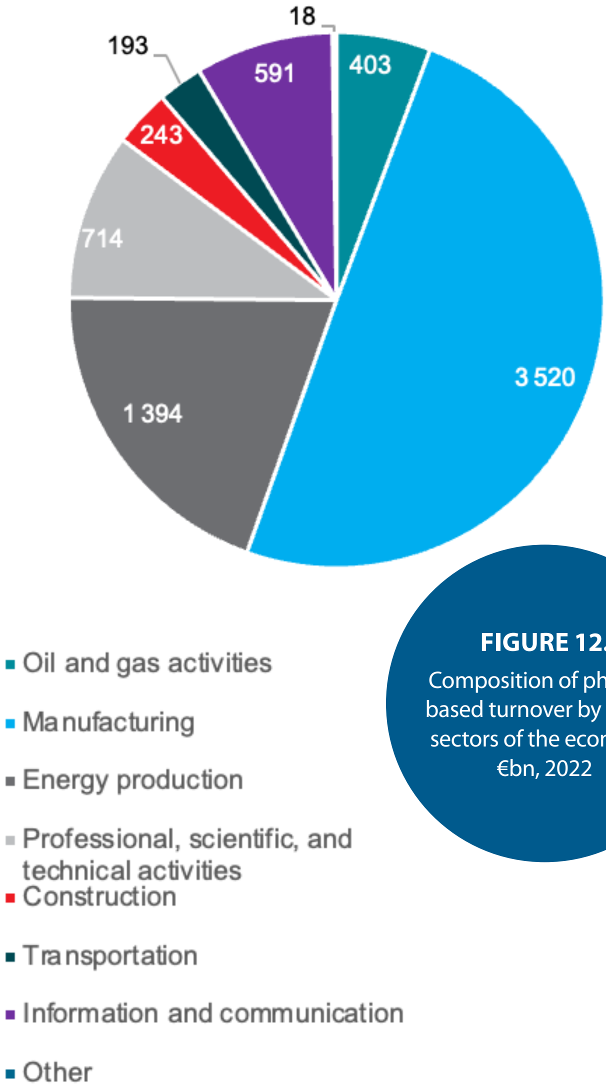


FIGURE 12.
Composition of physics-based turnover by broad sectors of the economy, €bn, 2022

Source: Eurostat SBS, Cebr analysis

After manufacturing, which accounts for nearly half of turnover from physics-related activity in Europe, energy production contributes the second highest share of physics-based turnover, generating a relatively modest 19.7% of the total[14]. Professional, scientific, and technical activities and the information and communication sector together make up around one fifth of total physics-based turnover. Modest shares of the total also originate from the oil and gas activities, construction, and transportation sectors[15].

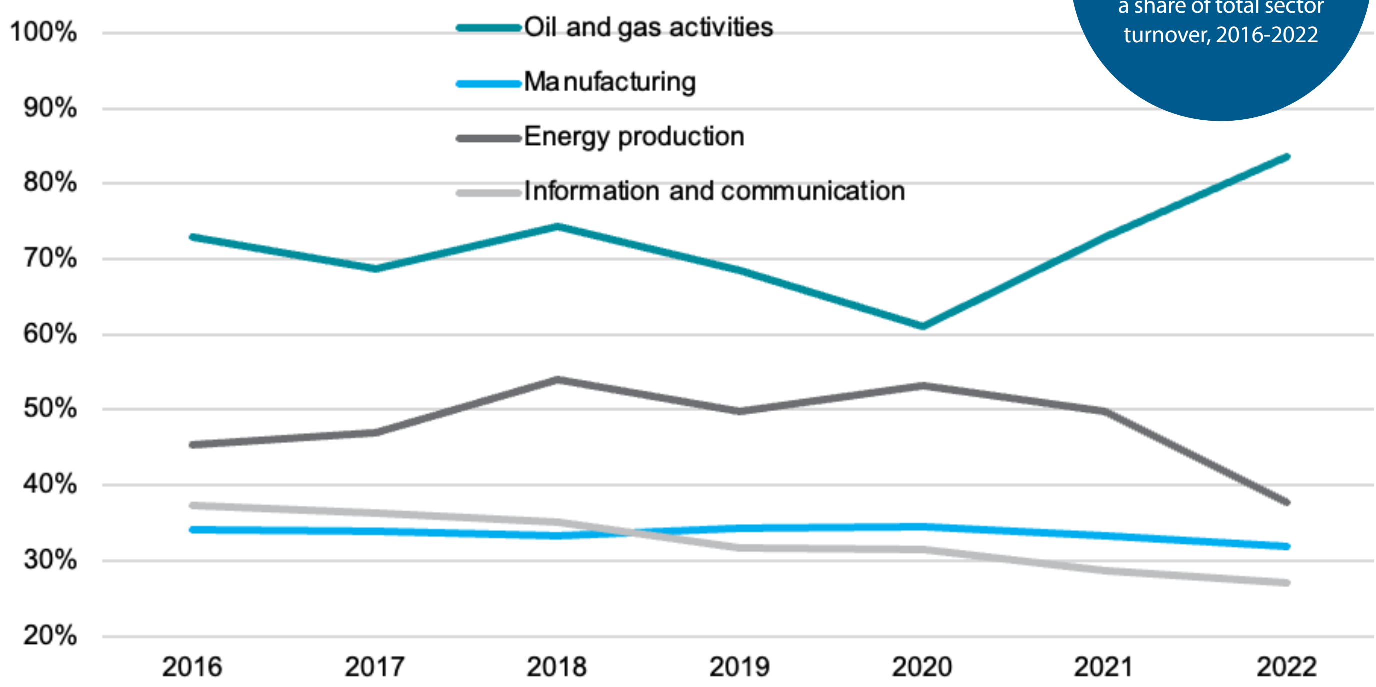
14. The energy production industry is made up of the production of electricity, the transmission of electricity and the distribution of electricity. The energy production industry is the physics-based subset of the wider electricity, gas, steam and air conditioning supply sector.

15. The oil and gas industry is made up of the extraction of petroleum and the extraction of natural gas. The oil and gas industry is the physics-based subset of the wider mining and quarrying industry.

To further explore the evolution of physics-based activity across different sectors, **Figure 13 below illustrates the evolution of physics-based turnover in selected sectors as a proportion of total sector turnover.** This therefore indicates the relative prominence of physics in each sector from 2016 to 2022.

Throughout the period, shares of physics-based turnover were most concentrated in oil and gas activities, with a physics-based share of 83.6% in 2022 exceeding any other sector proportion by more than 45 percentage points. The sector's proportion was quite volatile over the period, with significant falls year-on-year from 2018 to 2020 of 5.9 and 7.4 percentage points respectively, contrasting with the relatively stable proportions of other sectors during those years. This volatility is likely due to the concentrated impact of the COVID-19 pandemic on physics-related activity in this sector. Interestingly, other sectors saw declines in their proportions post-pandemic, whereas oil and gas activities demonstrated strong recovery.

FIGURE 13.
Physics-based turnover in sectors as a share of total sector turnover, 2016-2022



Source: Eurostat SBS, Cebr analysis

Figure 14 below illustrates the contribution of each individual country to Europe's total physics-based turnover in 2022.

In line with its status as the largest economy in Europe, Germany contributed the largest share of any European economy by a significant margin, generating 27.6% of Europe's physics-based turnover, equivalent to €1.96tn in absolute terms. This was more than 2.5 times the share of any other country, with France and the United Kingdom representing the next two major contributors, generating turnover worth €779bn and €754bn, or shares of 14.2% and 13.9% respectively.

In relative terms, however, Germany no longer leads Europe in physics-based turnover. **Figure 15 below shows countries with the highest physics-based turnover as a share of their whole business economy total.** Norway, Hungary, and Slovenia had the highest shares throughout the whole period, with the former leading Europe in every year between 2016 and 2022. Norway's share of 37.9% in 2022 was far higher than any other country, followed by Hungary and Slovenia with shares of 26.4% and 22.1% respectively, surpassing Germany by over 15 percentage points[16].

FIGURE 14. Contribution to Europe's total physics-based turnover by country, 2022

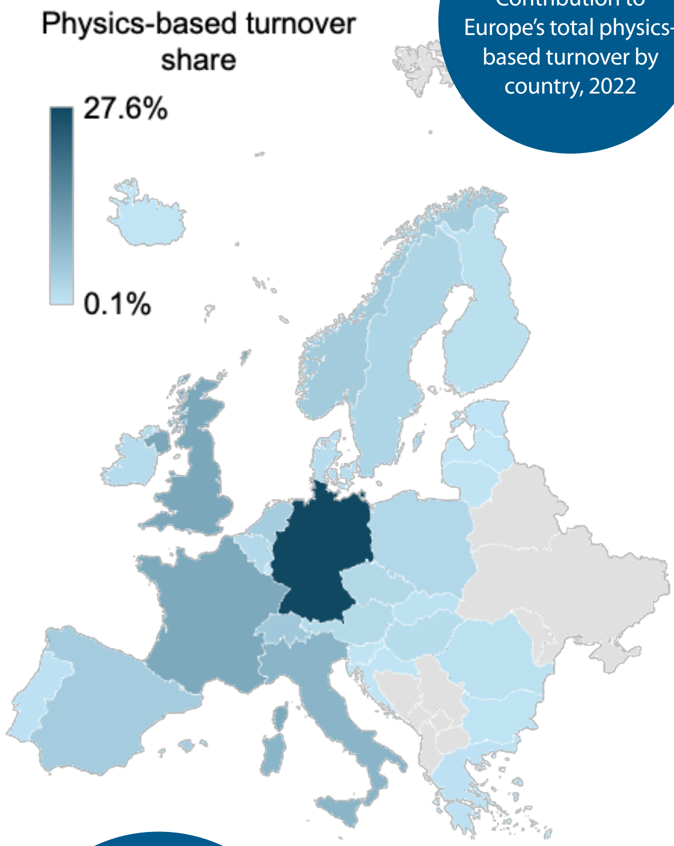
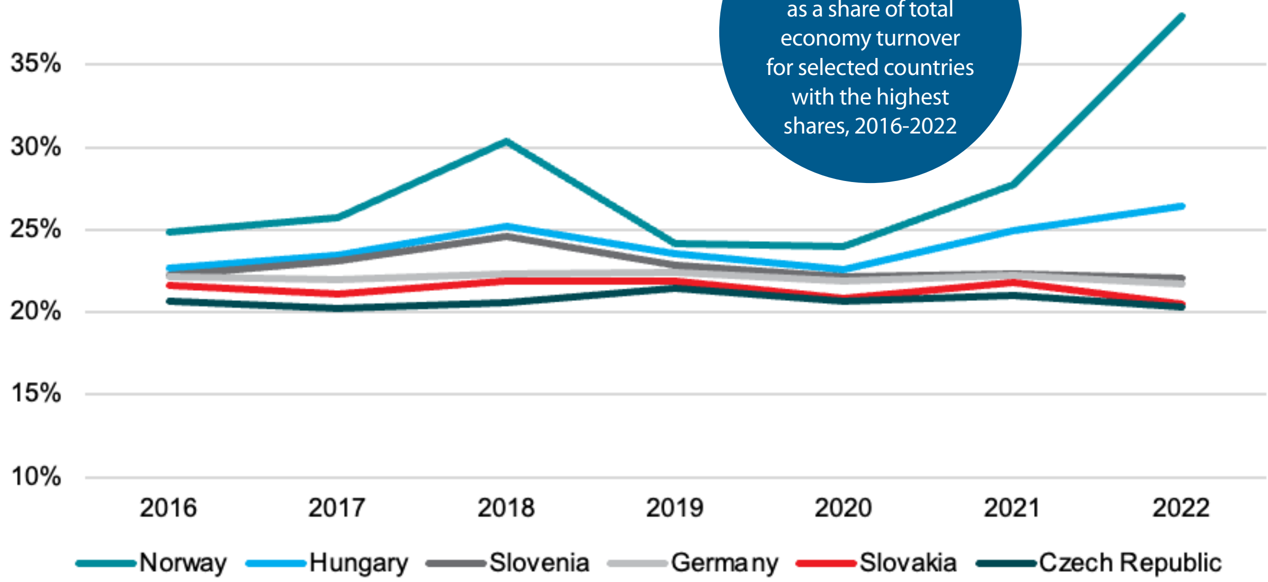


FIGURE 15. Physics-based turnover as a share of total economy turnover for selected countries with the highest shares, 2016-2022



Source: Eurostat SBS, Cebr analysis

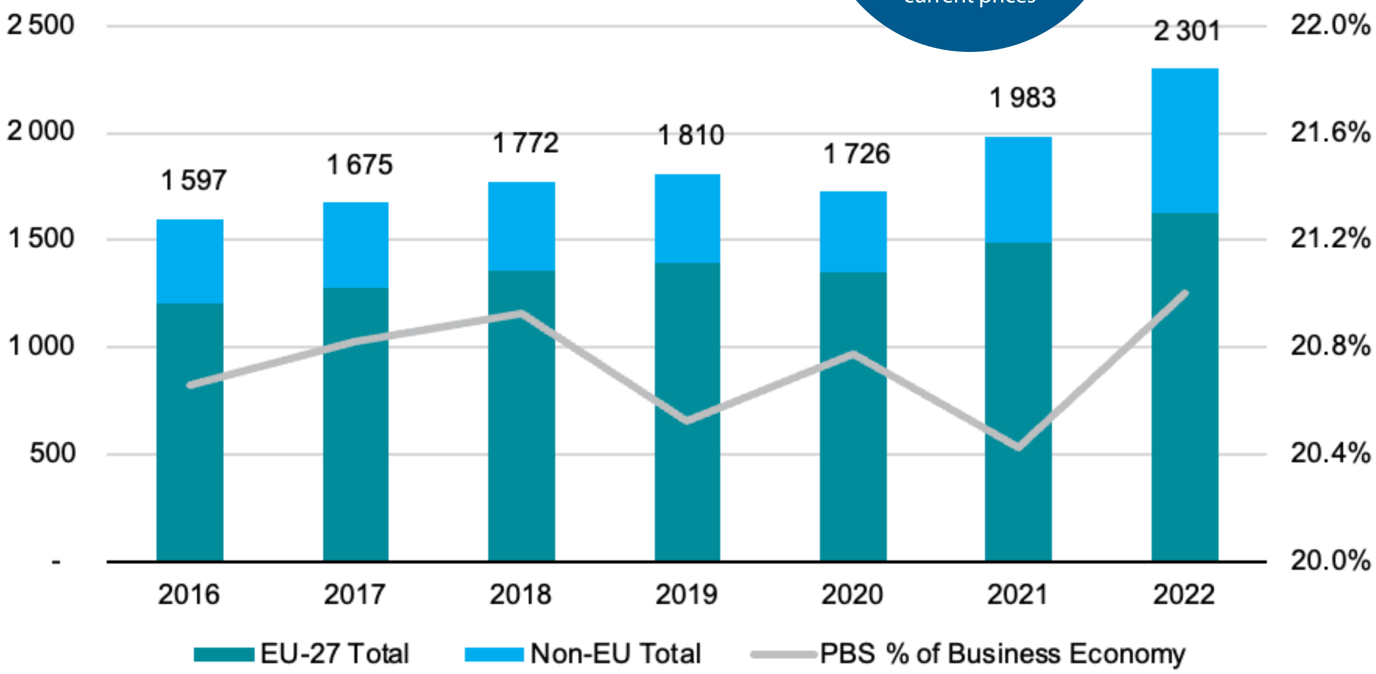
16. *All absolute values of physics-based turnover for individual countries can be found in Appendix I.*

4.2. GROSS VALUE ADDED

Here we present the economic contributions of physics-based sectors to the European economy in 'gross value added' (GVA) terms. This is a measure of the total output of a sector, industry, or economy, having subtracted the inputs of goods and services that were required to produce this output. Therefore, it captures how much value is added in the production process. It is often used as the proxy for the contribution of a sector to GDP.

Figure 16 below illustrates the European physics-based sector total GVA between 2016 and 2022.

FIGURE 16.
Value added in physics-based sectors and proportion of whole economy value added, €bn and %, 2016-2022, current prices



Source: Eurostat SBS, Cebr analysis

In 2016, value added contributions of EU and non-EU physics-based activity amounted to €1.21tn and €390bn respectively, generating just under €1.6tn of value added throughout Europe. Over the next six years, this figure grew by €704bn (44.1%) to stand at €2.30tn, asmost interestingly the value added of the non-EU physics-based sector grew almost double that of its EU counter part (73.4% versus 34.6%)[17]. Similar to turnover,

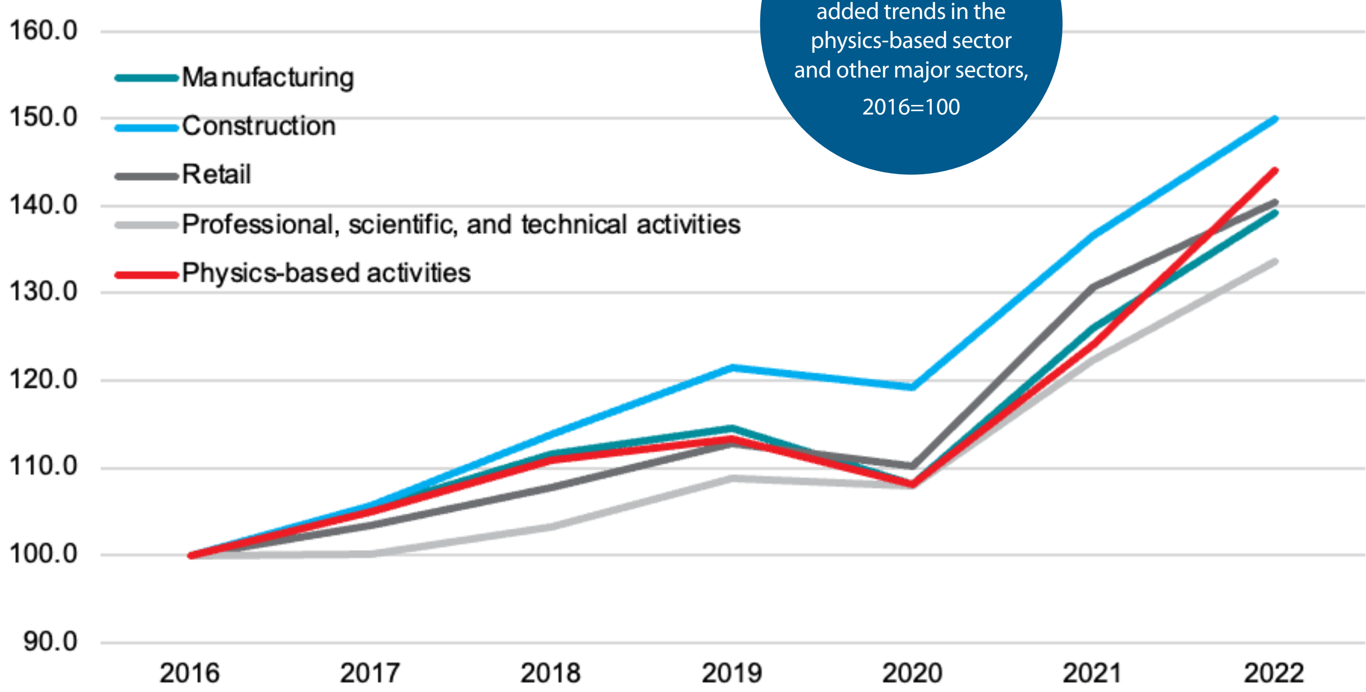
17. Non-EU countries have relatively large shares of high-value industries, such as Norway's oil and gas sector, which have grown rapidly in recent years and driven value added growth. However, it is important to note that this nominal data may be capturing the effect of, for example, high global energy prices that boost Norway GVA through its oil and gas sector.

the only year that diverged from GVA growth trends was 2020, declining by €84bn (4.6%). Nevertheless, recovery in value added was also strong post-pandemic, rebounding by 14.9% and 16.1% in nominal terms, in 2021 and 2022 respectively. Again, it is important to set 2022 figures in the context of the broader high-inflation environment throughout Europe, which could be driving a large portion of nominal GVA growth.

Figure 16 also depicts trends in physics-based value added as a share of total value added across the European business economy. Continuing trends in previous indicators, physics-based value added as a proportion of the whole economy was extremely consistent, increasing marginally by 0.3 percentage points throughout the period to reach 21.0% in 2022. It is worth noting that this proportion represents a notable increase on the turnover equivalent though (16.3%). This indicates a significantly greater GVA per unit of turnover in the physics-based sector versus the overall economy, thus more value is added in physics-based production processes than the whole economy average.

To examine GVA growth through a more comparative lens, **Figure 17 below contextualises the growth performance of physics-based GVA against other major sectors of the European economy[18].**

FIGURE 17.
Indexed gross value added trends in the physics-based sector and other major sectors, 2016=100



Source: Eurostat SBS, Cebr analysis

18. We have selected the manufacturing, construction, retail, and "professional, scientific, and technical activities" sectors to make this comparison.

Physics-based activities saw strong growth of 44.1% from 2016 to 2022, only surpassed by the construction sector which grew by nearly 50%. Interestingly, physics-based value added growth up to 2019 before the pandemic was slower than both the manufacturing and construction sectors, but post-pandemic, the physics-based sector experienced the most rapid growth of all selected sectors at 33.3% between 2020 and 2022. This points to the physics-based sector's ability to rebound stronger from external crises compared to other sectors, and also drives the growth in physics-based GVA as a proportion of the whole business economy in 2022, as visualised in Figure 16 above.

Looking within the physics-based sector, **Figure 18 below illustrates the contributions of broad sectors to physics-based GVA in 2022.**

Similar to the turnover perspective, manufacturing makes the greatest contribution (43.0%) to total value added from physics-based activities in Europe, with the professional, scientific and technical activities sector following with the second highest share of 13.7%. The oil and gas, energy production, and information and communication sectors together make up around a third of total physics-based value added, whilst the construction and transportation sectors have modest shares of the total.

At the country level, **Figure 19 below visualises the contribution of each individual country to Europe's physics-based gross value added in 2022.**

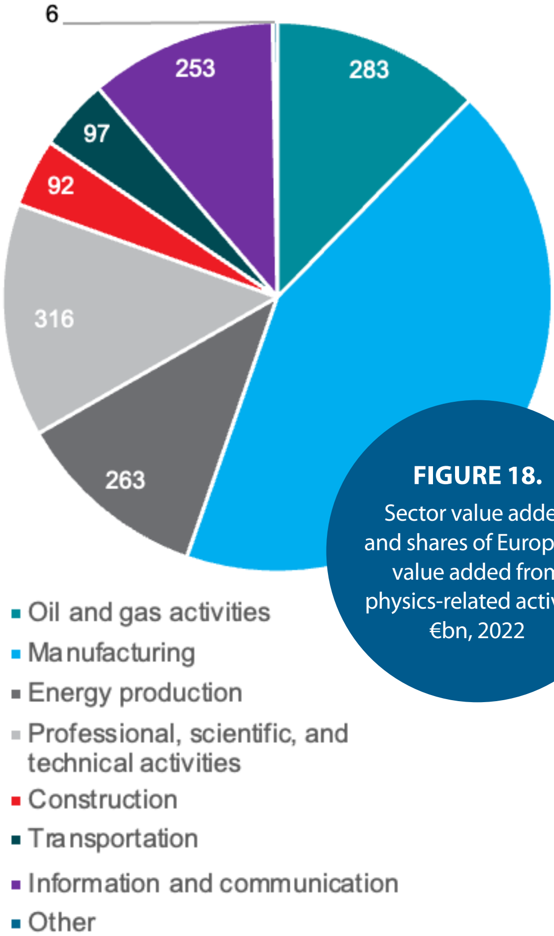


FIGURE 18.
Sector value added and shares of European value added from physics-related activity, €bn, 2022

Source: Eurostat SBS, Cebr analysis

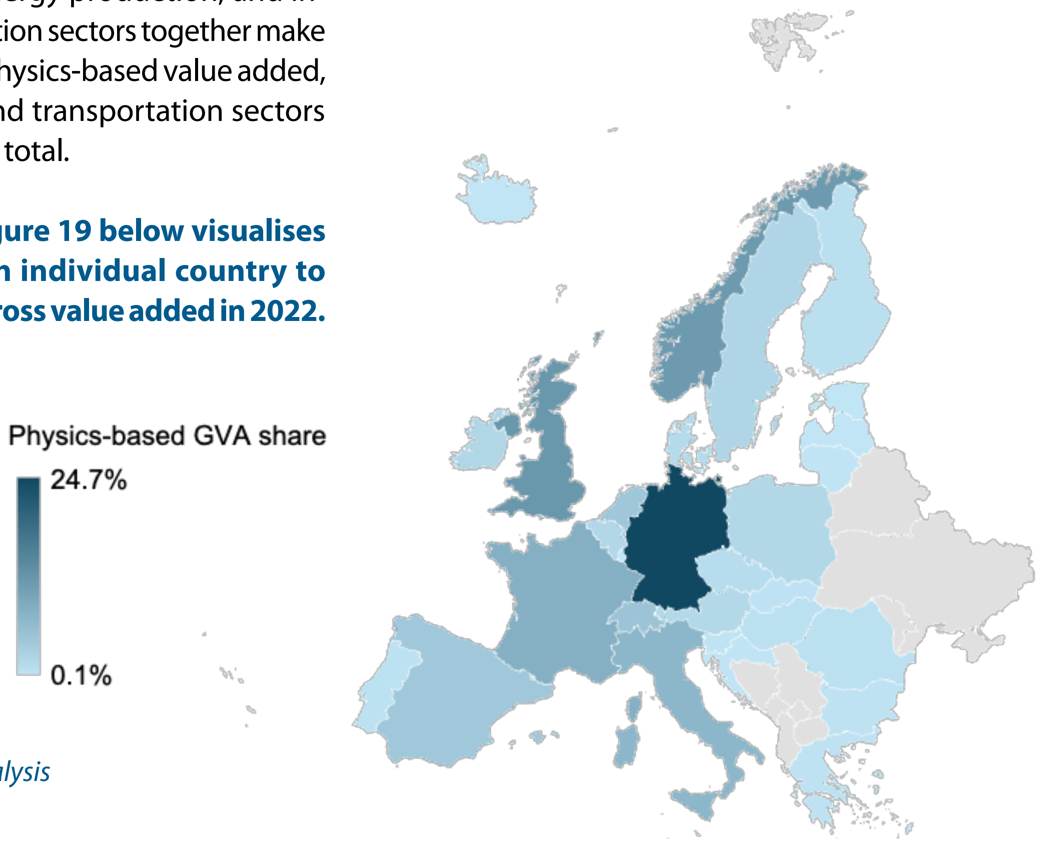


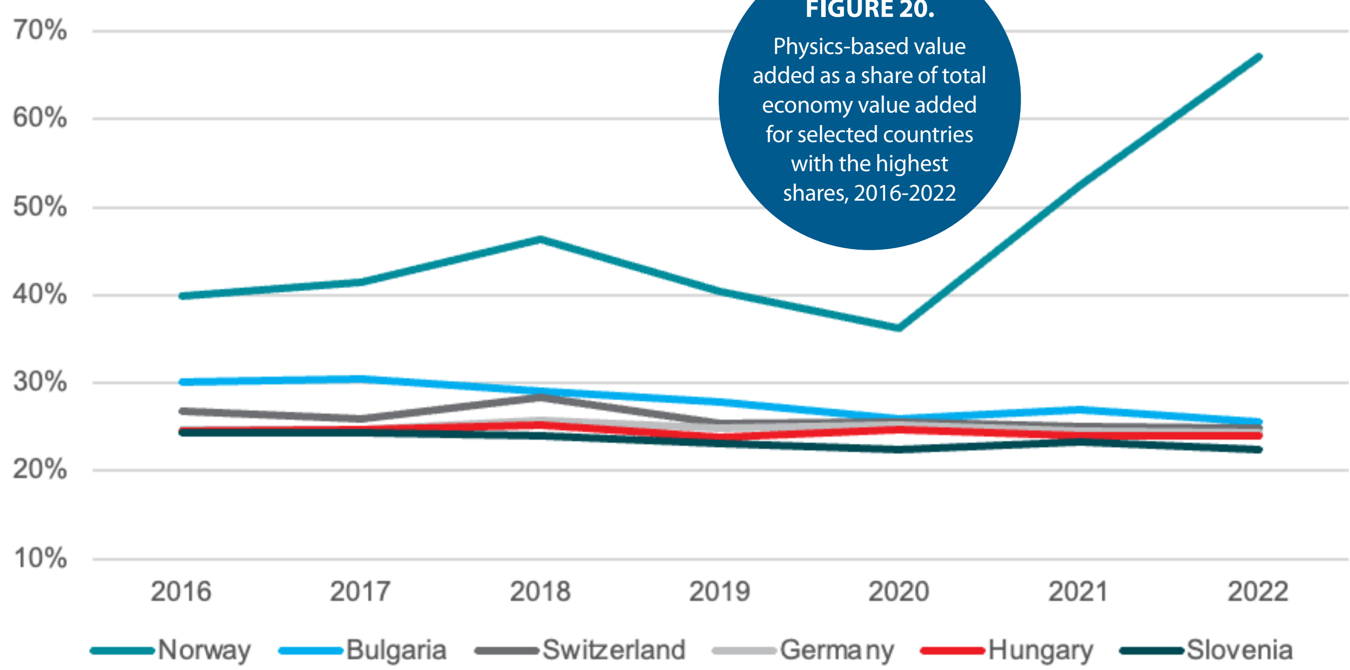
FIGURE 19.
Contribution to European physics-based gross value added by country, 2022

Source: Eurostat SBS, Cebr analysis

Similar to turnover, Germany exhibited the greatest share again, contributing 24.7% of the total value added from physics-based activities in Europe, worth €568bn. The United Kingdom, Norway, and France were the next three major contributors, but Germany's physics-based value added was double that of the United Kingdom's contribution of €284bn (12.3% share) and nearly three times the €193bn contribution of France (8.4% share). This difference is also impressive in relative terms, given the German economy is less than double the size of France and the United Kingdom.

As seen in **Figure 20**, Norway leads the country-specific perspective in relative GVA terms. Physics-based value added as a proportion of total Norwegian economy value added was consistently highest across the entire period, peaking in 2022 with a substantial share of 67.1%, which is more than 40 percentage points higher than the shares of any other nation. Bulgaria, Switzerland, and Germany followed with much smaller shares of 25.6%, 24.9% and 24.4% in 2022 respectively. These shares were relatively stable throughout the period.

FIGURE 20.
Physics-based value added as a share of total economy value added for selected countries with the highest shares, 2016-2022



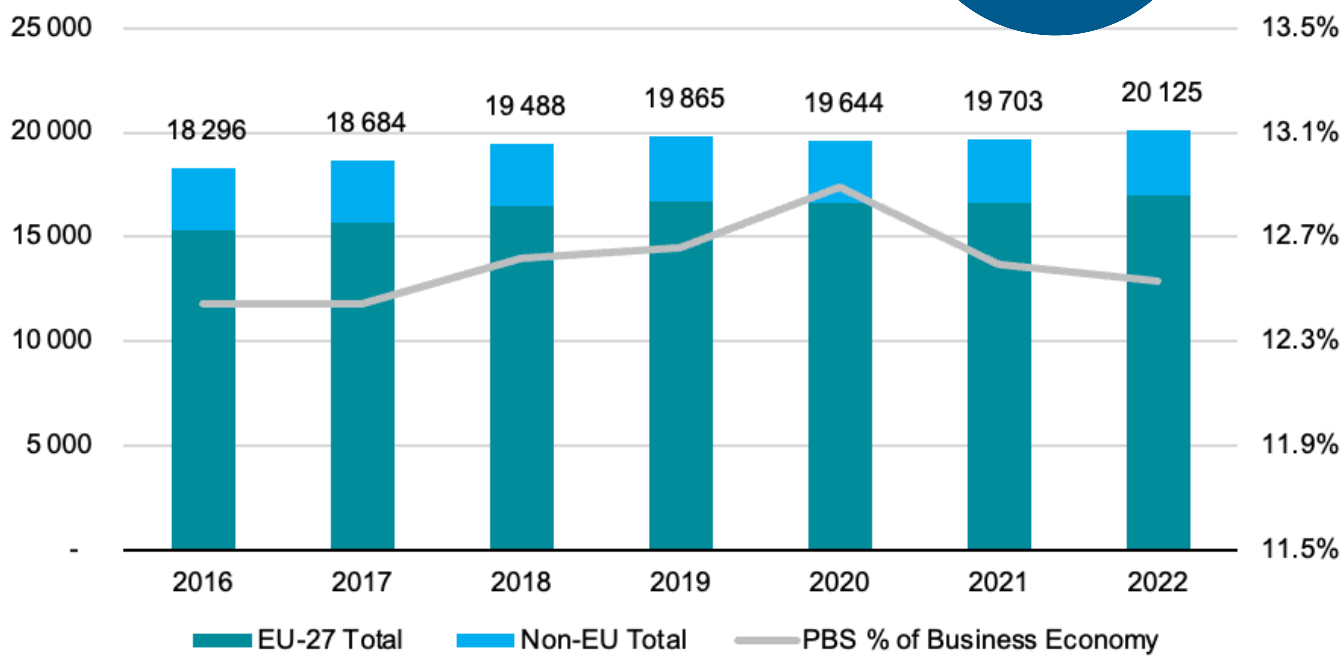
Source: Eurostat SBS, Cebr analysis

4.3. TOTAL EMPLOYMENT

The physics-based sector is a substantial employer of high-skilled workers throughout the European economy. **Figure 21 displays the total physics-based employment in Europe from 2016 to 2022 by the total employment in the EU-27 and non-EU countries.** In addition, this figure depicts the evolution of physics-based employment as a proportion of the total employment in Europe.

We estimate that physics-based industries accounted for total headcount employment of around 20.1 million people in Europe in 2022. This is an increase of 1.8 million employees from 2016, which represents physics-based employment growth of 10.0% over the six-year period.

FIGURE 21.
Total employment in the physics-based sector broken down by EU-27 and non-EU countries, 2016-2022



Source: Eurostat SBS, Cebr analysis

Employment growth proved slightly stronger in the physics-based sectors than the 9.3% growth observed across the whole business economy throughout Europe. As a result of this relatively tempered differential, physics-based employment as a share of total employment grew moderately from 12.4% in 2016 to 12.5% in 2022, with a peak of 12.9% in 2019.

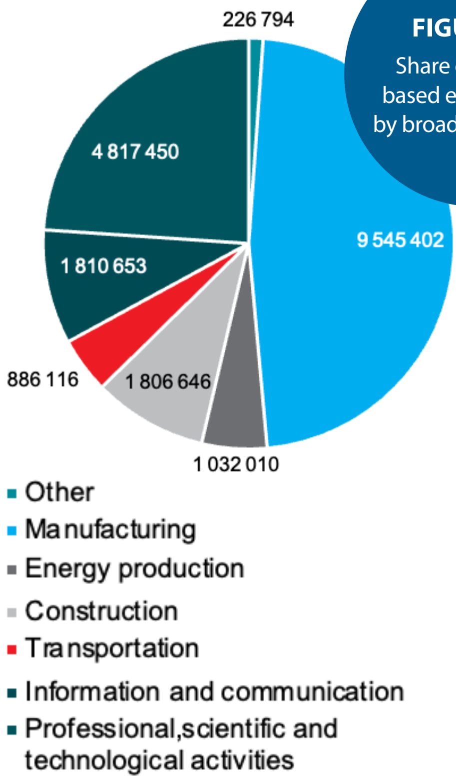
Delving into the composition of employment in the physics-based sector, we examined the physics-based employment across major constituent industries in Europe in 2022.

Figure 22 provides a breakdown of the share of total physics-based employment by the physics-based industries in 2022.

Figure 22 identified manufacturing, professional, scientific and technological activities and information and communication as the three sectors with the largest share of physics-based employment in 2022. These sectors constituted 47.4%, 23.9% and 9.0% of physics-based employment respectively, or over four-fifths (80.4%) of total physics-based employment on aggregate. Emulating trends from Section 3.1 around enterprise numbers across the broad physics-based sectors, Manufacturing dominates the physics-based employment share. This sector accounts for a higher proportion of employment (47.4%) than the next three largest sectors by employment share combined (42.0%).

Figure 23 displays an indexed comparison of physics-based employment by the broad physics-based sector, with 2016 acting as a baseline.

FIGURE 22.
Share of physics-based employment by broad sector, 2022



Source: Eurostat SBS, Cebr analysis

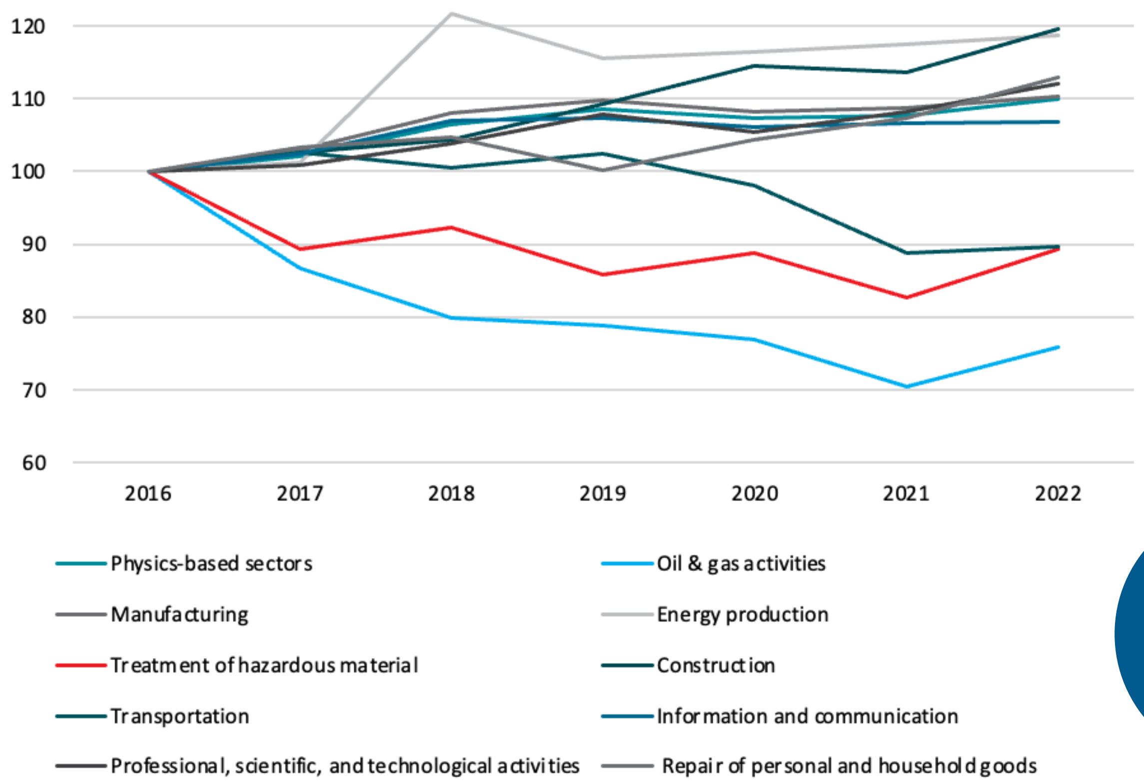


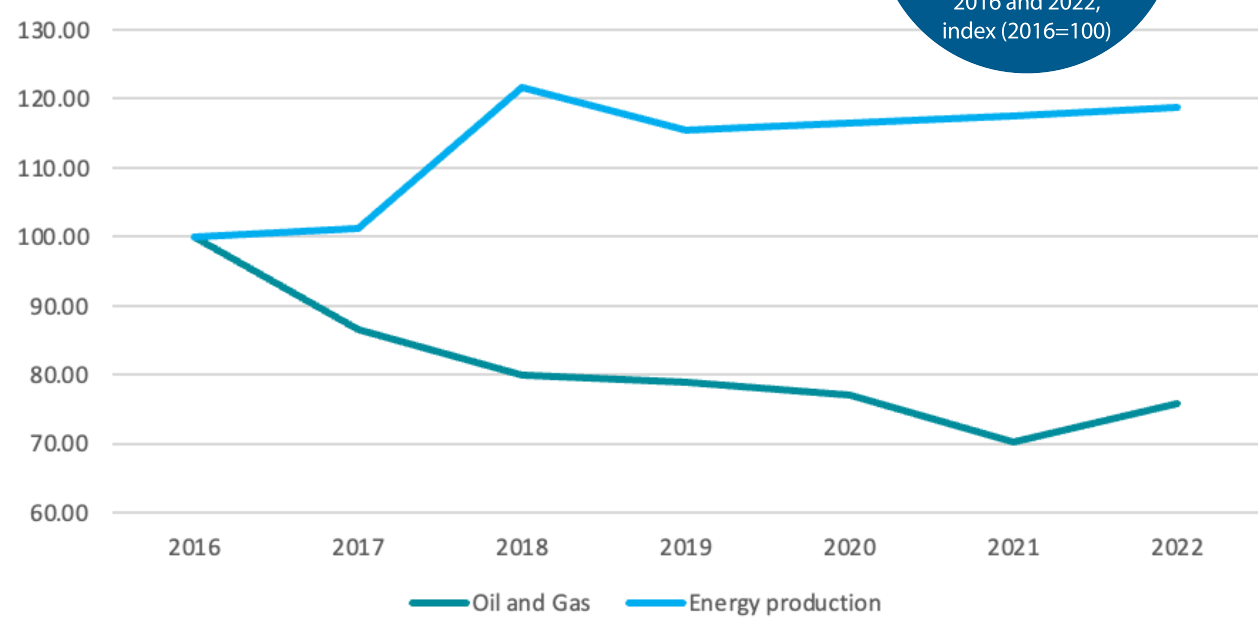
FIGURE 23.
Physics-based employment by broad sector, index (2016=100)

The two key takeaways from this analysis are that two sectors have experienced by far the largest growth in physics-based employment. Energy production[19] employment grew 19% over the period, whilst construction employment grew 20%. In comparison, oil and gas activities [20] experienced a 24% decline in physics-based employment and the treatment of hazardous materials experienced a 10% decline over the period. This points to the shifting dynamic of employment within the physics-based sector, away from oil and gas towards energy production and construction, reflecting broader economic and environmental trends throughout Europe.

Building on this insight, we explored further the differing employment trends between the energy production and the oil and gas activities sectors in Europe. This analysis is motivated by the central role energy has played in Europe over the last decade – from the shift to renewable energy sources to the energy disruptions experienced in the continent due to conflict and geopolitical uncertainty over recent years. We focus on how employment in the physics-based energy industry compares to the wider energy sector between 2016 and 2022, offering potential explanations for the trends observed.

Figure 24 is an indexed comparison of solely the employment in the energy production and oil and gas activities industry between 2016 and 2022, with 2016 acting as a baseline. Although these industries are displayed in Figure 23, they are isolated here so that they can be compared.

FIGURE 24.
Comparison of employment in the oil and gas activities and energy production industries between 2016 and 2022, index (2016=100)



Source: Eurostat SBS, Cebr analysis

19. In 2022, the electricity production sector made up 90% of the wider electricity, gas and steam sector in Europe.
20. In 2022, the oil and gas industry made up 26.2% of the wider mining and quarrying sector in terms of employment.

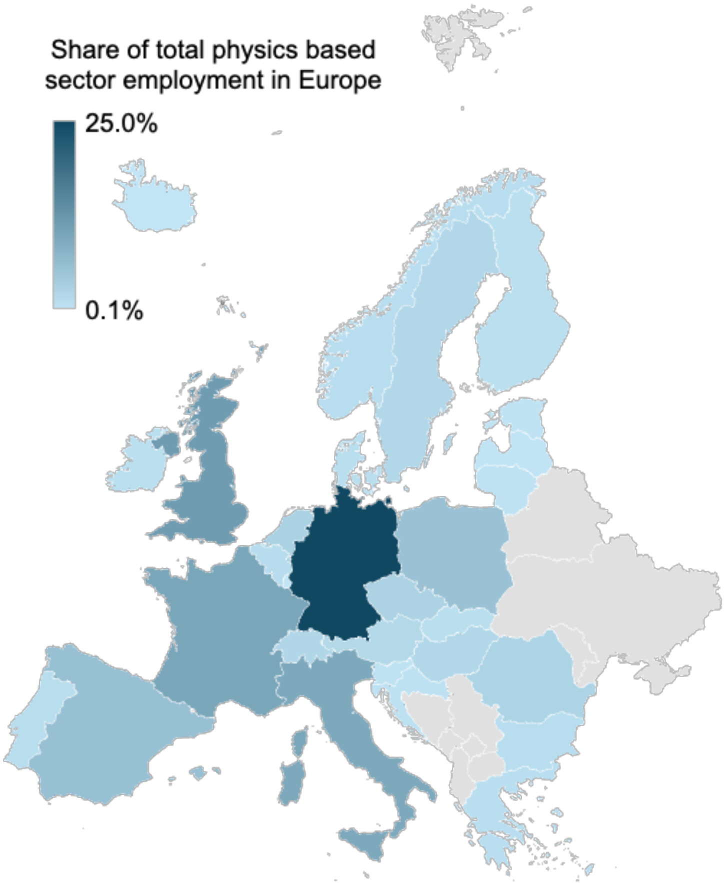
Employment in the energy production industry grew from 869,710 in 2016 to 1,032,010 in 2022, representing an 18.7% increase over the period. In contrast, employment within the oil and gas activities industry fell from 169,627 in 2016 to 129,700 in 2022, representing 24.1% fall in employment over the period while the overall business economy saw a smaller decline of 14.8%.

Considering the trends displayed in Figure 24, we see a clear shift in physics-based employment in Europe away from the oil & gas sector towards other sources of energy production. The trend in decreasing oil and gas employment and increasing energy production employment could potentially be explained by Europe's move towards the use of renewable energy sources in line with the broader energy transition. Shifting employment patterns are particularly important to Europe due to its strategic implications as this demonstrates the adaptability of physics-based employment to both long-term policy goals and unpredictable geopolitical shocks. This adaptability highlights the importance of the sector in supporting economic stability and energy security in Europe.

Moving from sectoral trends to country trends, **Figure 25 displays the share of total physics-based employment in Europe attributed to each European country in 2022, excluding Cyprus.**

Consistent with wider trends in other variables, Germany stands out considerably in this perspective. Germany is by far the largest contributors to physics-based employment in Europe, constituting a quarter (25.0%) of the total workforce. The next two largest contributors, the United Kingdom and France, account for 11.7% and 10.1% respectively. Germany's dominance likely owes to its role as a manufacturing hub in Europe. Manufacturing accounts for the largest share of physics-based employment across Europe as shown in Figure 22, and Germany employs more people in this sector than any other country by a large margin.

FIGURE 25.
Share of the total physics-based employment in Europe by country, 2022



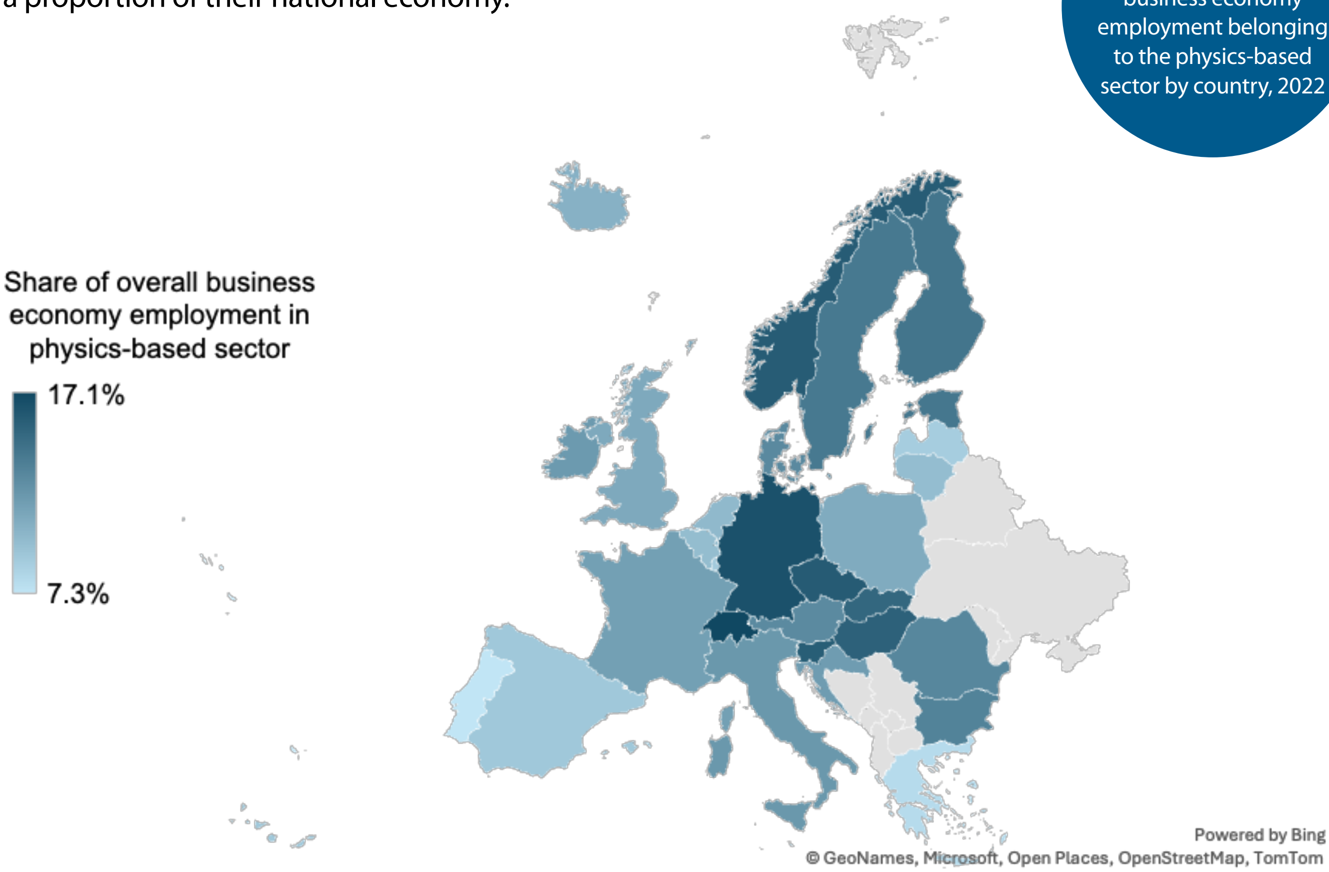
Source: Eurostat SBS, Cebr analysis

Figure 26 illustrates the share of each economy's total business economy employment belonging to the physics-based sector in Europe in 2022.

Switzerland leads Europe with 17.1% of the business economy employment stemming from its physics-based sector, followed by Germany and the Czech Republic with 16.5% and 15.9% respectively. Other Central and Eastern European countries, including Slovenia and Slovakia, report similarly high shares of over 15% in both.

Notably, Switzerland accounts for just 2.5% of total physics-based employment in Europe yet has the highest share of its own business economy employed in the physics-based sector at 17.1%. This illustrates that countries with a smaller absolute contribution to Europe's physics-based employment can still have relatively large physics-based sectors when measured as a proportion of their national economy.

FIGURE 26.
Proportion of overall business economy employment belonging to the physics-based sector by country, 2022



Source: Eurostat SBS, Cebr analysis

4.4. PRODUCTIVITY

By combining total GVA and total employment measures, we can construct estimates of labour productivity across different sectors and countries, including the physics-based sector. **Figure 27 below illustrates how this measure of productivity (GVA per person) in the physics-based sector compares with other broad sectors, as well as the overall productivity in the European economy.**

Productivity in the physics-based sector in Europe is distinctly higher than overall productivity in Europe, where the average worker in this sector generated €46,125 more GVA (67.6% more productive), amounting to €114,340 in GVA per employee in 2022[21]. Comparable sectors also exhibit far inferior productivity to physics-based activities. The second highest productivity was observed in the manufacturing sector in 2022, €30,018 GVA per worker (26.3%) lower than the physics-based equivalent, followed by the professional, scientific, and technical activities sector, which was €43,489 (38.0%) lower. Despite this, these two sectors still demonstrated higher productivity than the whole European economy in 2022, at €84,322 and €70,851 for manufacturing and professional, scientific and technical activities respectively.

In terms of evolution in productivity throughout the period, physics-based sectors again ranked significantly better than other areas of the economy in this regard. Retail represented the only selected sector that experienced faster growth than the physics-based sector between 2016 and 2022, growing at 36.1% versus 31.0% for physics-based activities. Compared to other sectors and the overall European economy, higher productivity growth from a higher base in physics-based activities generates overwhelmingly superior valued added per employee. These trends are also emulated at the country-specific level. The physics-based sector exhibited the highest productivity of all major sector in every European country in our sample apart from Ireland[22].

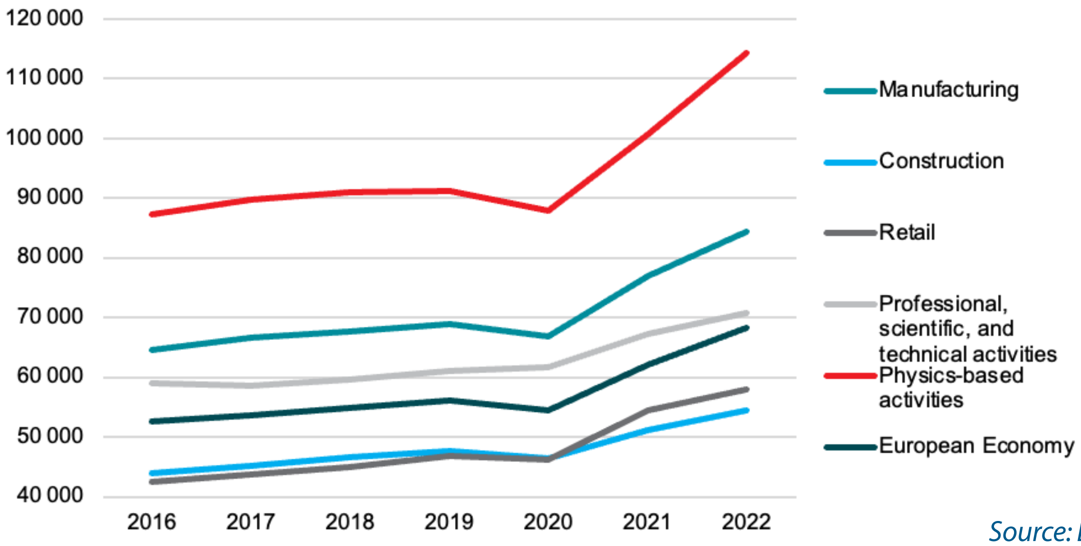


FIGURE 27. Productivity, GVA per person employed per year, €, 2016-2022, current prices

Source: Eurostat SBS, Cebr analysis

21. Turnover per worker as a measure of productivity has slightly different results, with the physics-based sector having the second highest productivity after the retail sector over the six-year period. However, we choose to focus on GVA per worker, as GVA isolates the net economic contribution of labour and more accurately reflects the value added by each employee.

22. The average worker's value added contribution in the manufacturing sector of Ireland in 2022 exceeds the physics-based contribution per worker.

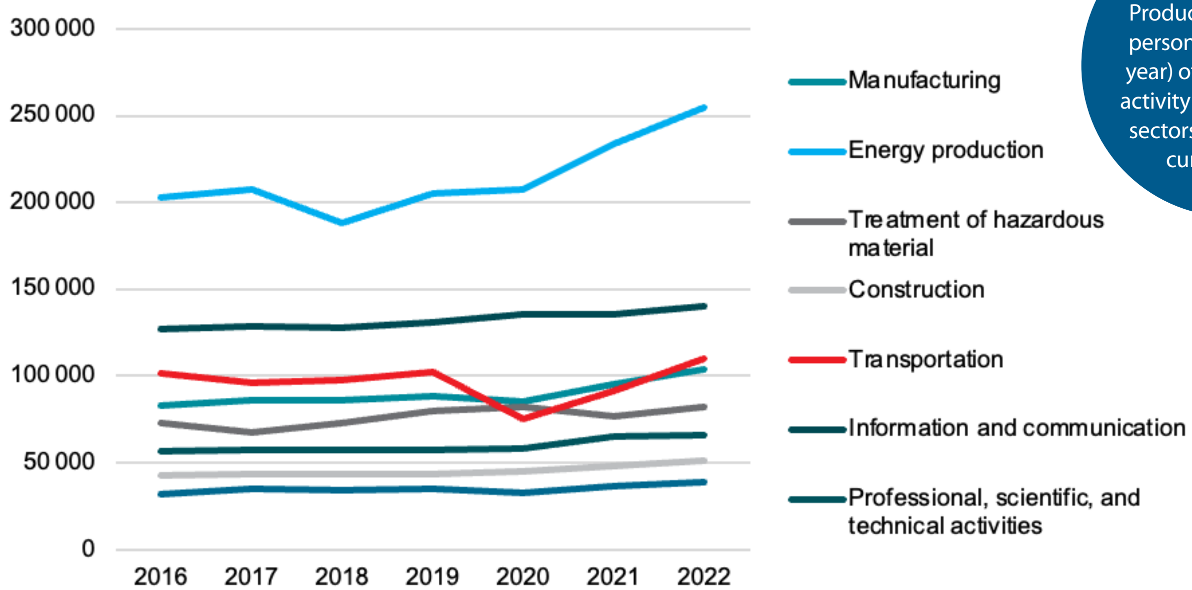
Findings around superior value added productivity in physics-based sectors are rather intuitive. The technology- and capital-intensive nature of production processes in the physics-based sector enhances productivity, thus significantly more value can be added per worker than in more labour-intensive sectors such as retail and construction. These two sectors displayed the lowest productivity in all years, with GVA per worker of €57,944 and €54,477 in 2022 in retail and construction respectively.

We now turn to more granular productivity trends within physics-based activity, as **Figure 28 below illustrates the significant disparities in the productivity of different industries within the physics-based sector**[23].

Physics-based productivity enjoyed moderate growth in the majority of sectors over the sixyear period. The principal exception is energy production that experienced notable productivity growth and led the selected sectors. Physics-based productivity in this sector grew by over 25% during the period to reach €254,428 GVA per employee in 2022. Consistent, albeit much more gradual, growth in physics-based productivity was also observed in information and communication, the next most productive of the physics-based sectors. GVA per worker in this sector grew by over 10% to reach €139,832 in 2022.

Interestingly, physics-based manufacturing activities generate more value added per person employed than the wider manufacturing sector, at €103,739 versus €84,322 in 2022. This suggests that production processes implemented within the physics-based sectors generally sustain greater levels of productivity than typical manufacturing production processes. This reinforces the point made previously that workers with expertise in physics-based activities have higher productivity, likely reflecting greater skill requirements of the roles and sectors.

FIGURE 28.
Productivity (GVA per person employed per year) of physics-based activity within different sectors, €, 2016-2022, current prices

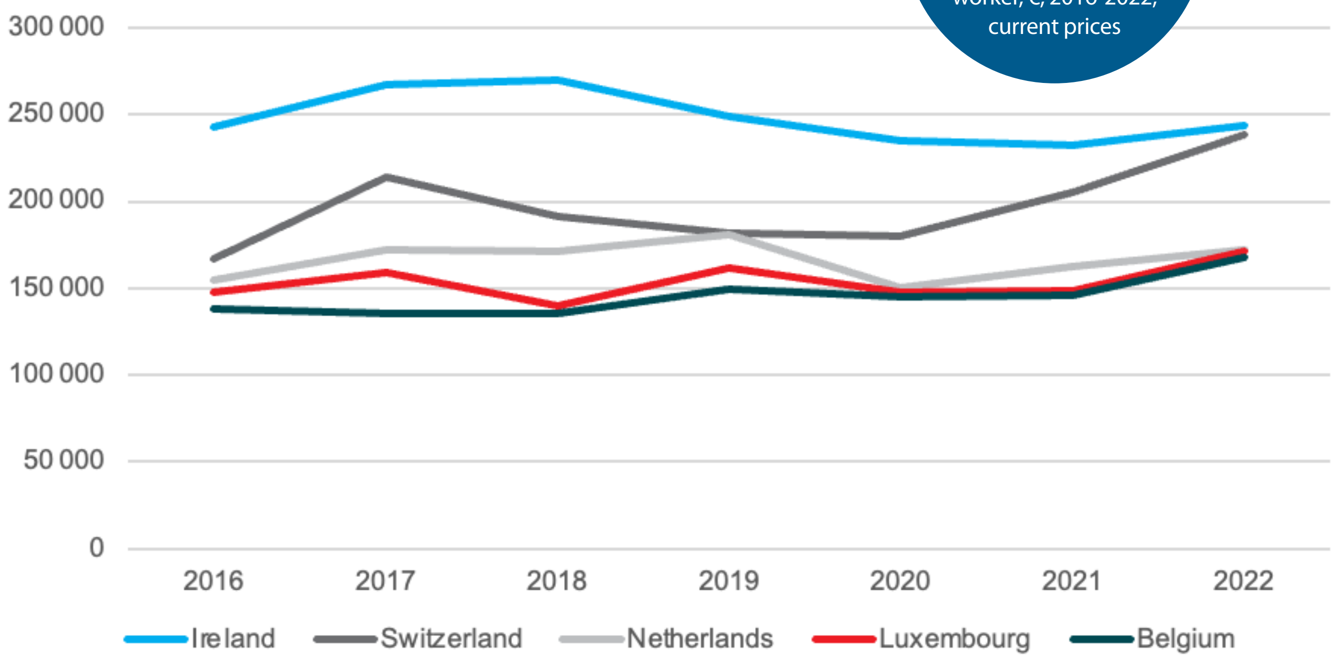


Source: Eurostat SBS, Cebr analysis

23. Not included within this graph, is productivity in the physics-based oil and gas sector. This is a sector with extremely high and increasing productivity, which grew from €425,241 in 2016 to €2,200,452 in 2022. The data has not been presented on the graph, to prevent visually distorting smaller trends in other physics-based industries.

The country-level findings below in Figure 29 further emphasise the high productivity of workers in the physics-based sector in some countries.

FIGURE 29.
Evolution of country-level physics-based productivity in selected countries, GVA per worker, €, 2016-2022, current prices



Source: Eurostat SBS, Cebr analysis

The countries that saw the highest productivity in physics-based activities in 2022 were Ireland, Switzerland, the Netherlands, Luxembourg, and Belgium. Additionally, the average worker in the physics-based sectors of these countries (except for Ireland) was at least 1.5 times more productive than the average worker in the overall economy. Further to this, the average physics-based sector worker was more productive across all European countries studied.

5. THE AGGREGATE IMPACT OF THE PHYSICS-BASED SECTOR IN EUROPE

Having delved into the direct impacts and contribution of the European physics-based sector, here we develop our assessment of the sector under a broader perspective. Specifically, we estimate "aggregate economic contributions" (defined below) through analysis of the physics-based sector within the EU's 'national' accounting framework. This analysis enables us to understand the impacts associated with the physics-based supply chain, and impacts generated through the consumption of physics-based employees, known as indirect and induced impacts respectively. These are explained further below:

INDIRECT IMPACTS:

The upstream impacts generated within the supply chain of the physics-based sector, arising from the purchase of inputs by businesses in the sector, and by extension the further purchase of inputs of suppliers to the sector to facilitate this. Impacts and extend and multiply the longer the supply chain as new economic activity is required at every stage. In our analysis, this is captured by a Type I multiplier that reflects both direct and indirect impacts.

INDUCED IMPACTS:

Impacts associated with increased expenditure and consumption of physics-based employees. Increased output induces increases in employment, profits and other income sources, which enable greater consumption of goods and services both in the physics-based sector and throughout its supply chain. This is captured by a Type II multiplier, reflecting direct, indirect and induced impacts.

Combined, the direct economic impact of the physics-based sector (as assessed in Section 4) and these indirect and induced impacts, represent the aggregate economic contribution of physics to the European economy. Our analysis leverages input-output modelling to generate estimates of the indirect, induced, and hence aggregate, impacts of the EU physics-based sector. Input-output modelling draws from national accounts data, specifically the supply, use and input-output tables published by Eurostat for the EU-27 area as an overall economic unit[24]. Given that national accounts data only pertains to the EU-27 economies, our analysis excludes the four additional non-EU countries that have been covered thus far. It also focusses primarily on the most recent year within the time period of this research (2022).

Finally, it is crucial to note the scope and data source of measures used throughout our aggregate impact analysis. Our direct impact analysis in Section 4 drew on SBS data for all core indicators, for the reasons of data granularity and coverage specified in this section, as some of this data also formed inputs into our modelling of aggregate impacts. Our aggregate impact modelling however was undertaken and presented consistent with national accounts data. SBS and national accounts data differ fundamentally in their scope, as the former focuses purely on the business economy, whilst the latter adopts a more comprehensive coverage of the entire economy. This allows us to supplement the previous businessfocussed scope with a more comprehensive perspective of the EU economy, and therefore our measures of direct output, GVA and employment here exceed the equivalent figures in Section 4. The main differences are explained further below:

1. Differing scope: the SBS covers purely the business economy (excluding financial services) and market producers, whilst the national accounts and Labour Force Survey data covers the entire economy, including households, public administration and most non-market services such as education and healthcare;

2. Differing datasets and methods: the two differing data frameworks are derived from different methodologies, data collection and sampling, thus these differences inevitably generate variation in their estimates; and

3. Differing price measures: this applies for SBS turnover versus national accounting output only. Whilst the two indicators can be considered largely equivalent to one another, a key nuance and difference between them is that turnover is expressed in producer prices whilst national accounting output is expressed in basic prices. Basic prices exclude net taxes on products, this is explained further in Appendix III.

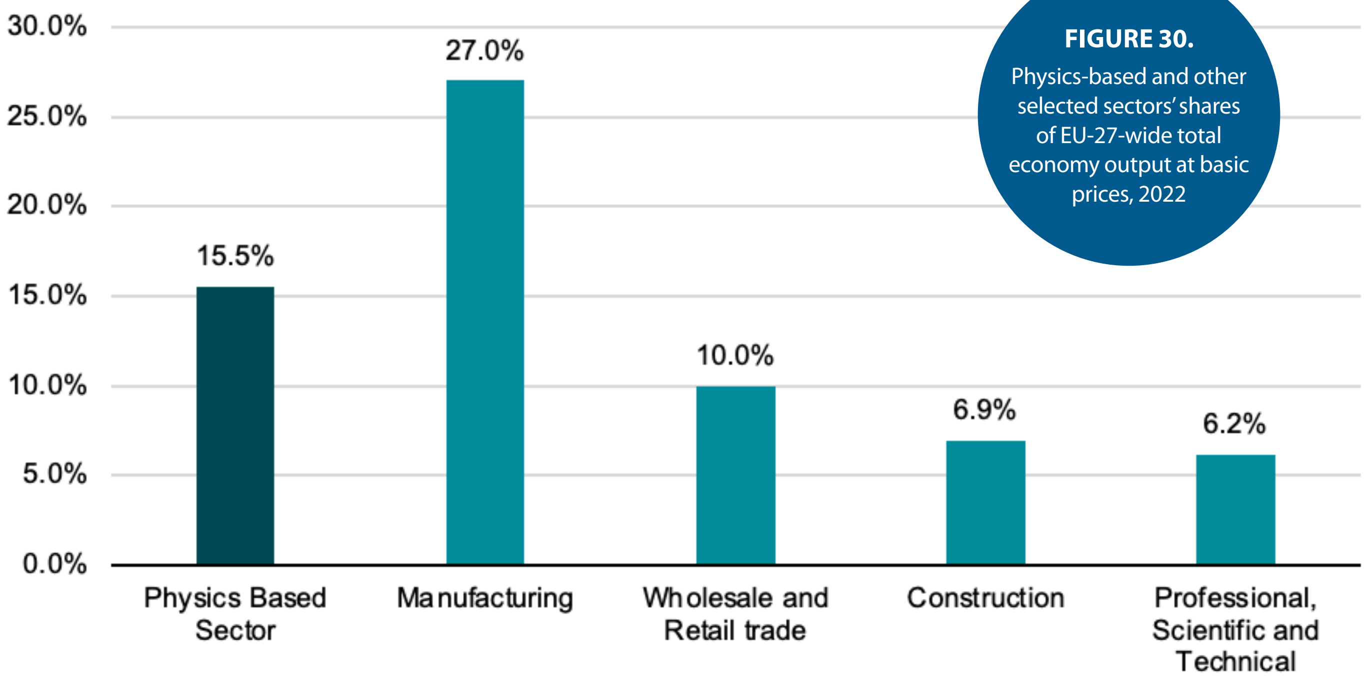
24. EU national accounts data merges all EU-27 economies to capture them as an overall economic unit, equivalent to the structure and scope of national accounts data within an individual country. This means that trade between different EU-27 economies is not treated as exports or imports, but transactions within the overall economic unit.

5.1. TOTAL OUTPUT AT BASIC PRICES

We estimate that the EU-27 physics-based sector generated €4.91tn of direct output in 2022. This compares with an equivalent EU-27 turnover figure of €5.59tn in 2022, as the €677bn difference between output and turnover estimates reflects the differences in measures and data sources detailed above. The €4.91tn output constitutes 15.5% of total EU-27 economy-wide output, as **Figure 30 visualises the output share of the physics-based sector in comparison to other selected sectors**.

The manufacturing sector, that includes a substantial volume of physics-based activity itself, generates 27.0% of total EU-27 output and represents the most substantial sector selected here. Nonetheless, output generated in the physics-based sector exceeds that in the wholesale and retail sector, another substantial element of the EU economy, by a factor of over 1.5. Physics-based sector output is also more than 2.2x greater than that generated in both the construction and professional, scientific and technical sectors.

FIGURE 30.
Physics-based and other selected sectors' shares of EU-27-wide total economy output at basic prices, 2022



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Input-output modelling uncovers a significant volume of additional output supported by the supply chains and employee consumption of physics-based sectors. Accounting for all impact layers, physics-based activities contributed €11.85tn of aggregate output in 2022, as **Figure 31 illustrates the composition of this contribution.** In addition to the €4.91tn direct output detailed above, increased activity throughout the physics-based supply chain generates a further €5.75tn in indirect output impacts. Increased incomes, profits and employment in the physics-based sectors stimulates employee spending and consumption that supports a further €1.19tn in induced impacts.

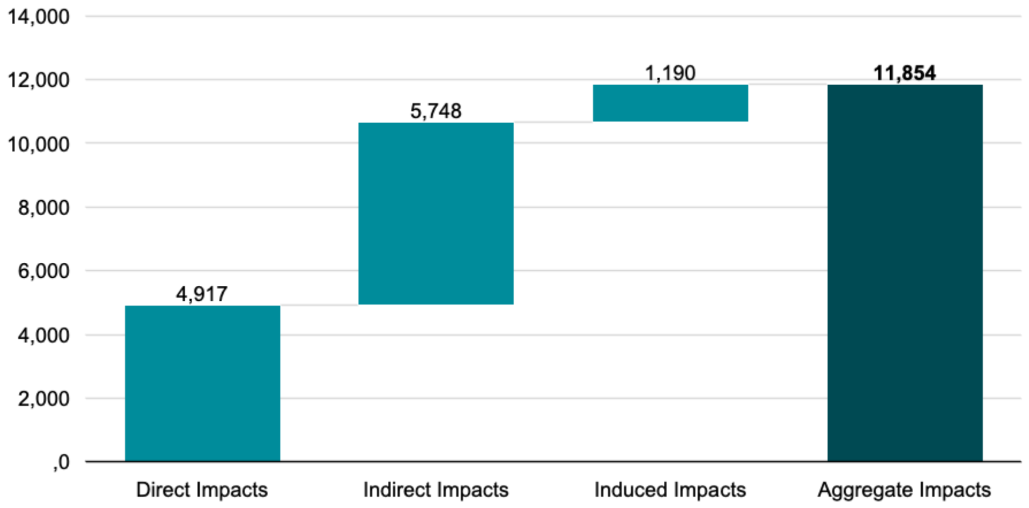
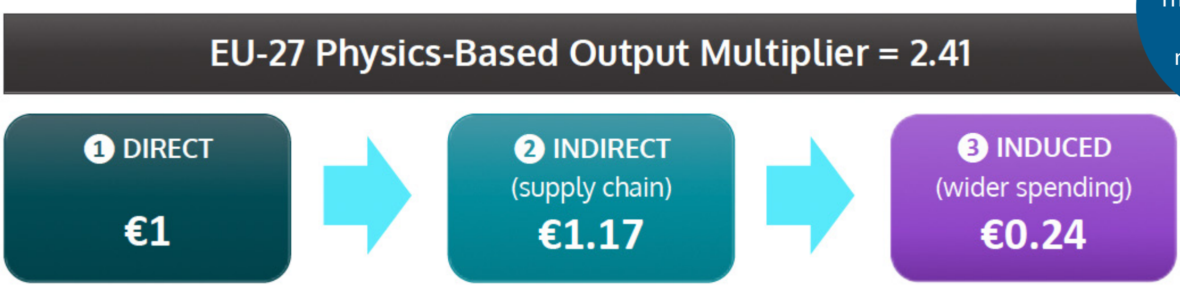


FIGURE 31. Aggregate output impacts of the EU-27 physics-based sector, €bn, 2022

Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Indirect and induced impacts are reflective of significant output multiplier effects observed within physics-based activity. **This is visualised in Figure 32, as for every €1 of output in the physics-based sector, a further €1.41 is generated through indirect and induced impacts, supporting €2.41 on aggregate throughout the EU economy.** This figure embodies the Type II multiplier that accounts for direct, indirect and induced impacts. The physics-based Type I multiplier is also substantial, with every €1 in physics-based output generating a further €1.17 in indirect impacts. This quantifies the upstream supply chain activity supported by physics-based activity, whilst induced employee spending increases amount to €0.24

FIGURE 32. The EU-27 physics-based output multiplier, 2022



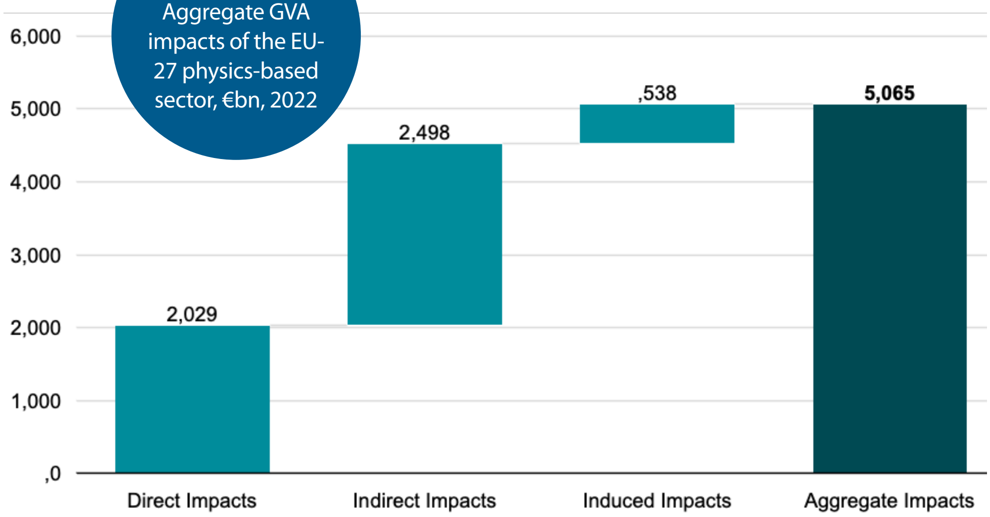
Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

5.2. AGGREGATE GROSS VALUE ADDED (GVA) AND CONTRIBUTION TO GDP

Under the entire economy perspective, our modelling dictates that the physics-based sector contributed €2.03tn in direct GVA to the EU-27 economy in 2022. This compares to an equivalent direct GVA figure of €1.62tn for the EU-27 economies presented in Section 4.2, capturing the different data sources and broader scope of the national-accounts based estimates, captured within the direct impacts throughout this section.

Substantial aggregate impacts and even stronger multiplier effects were observed for GVA relative to the output perspective. Our estimates indicate that on aggregate, physics-based sectors contributed a total of €5.07tn to the EU economy in 2022. As shown in **Figure 33, aggregate impacts are a product of substantial indirect and induced impacts generated within the physics-based sector.** On top of their direct impacts specified above, physics-based activities generate €2.50tn in further GVA throughout their supply chain, and support an additional €538bn of GVA through the expenditure and consumption of their employees.

FIGURE 33. Aggregate GVA impacts of the EU-27 physics-based sector, €bn, 2022



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

FIGURE 34. The EU-27 physics-based GVA multiplier, 2022

Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

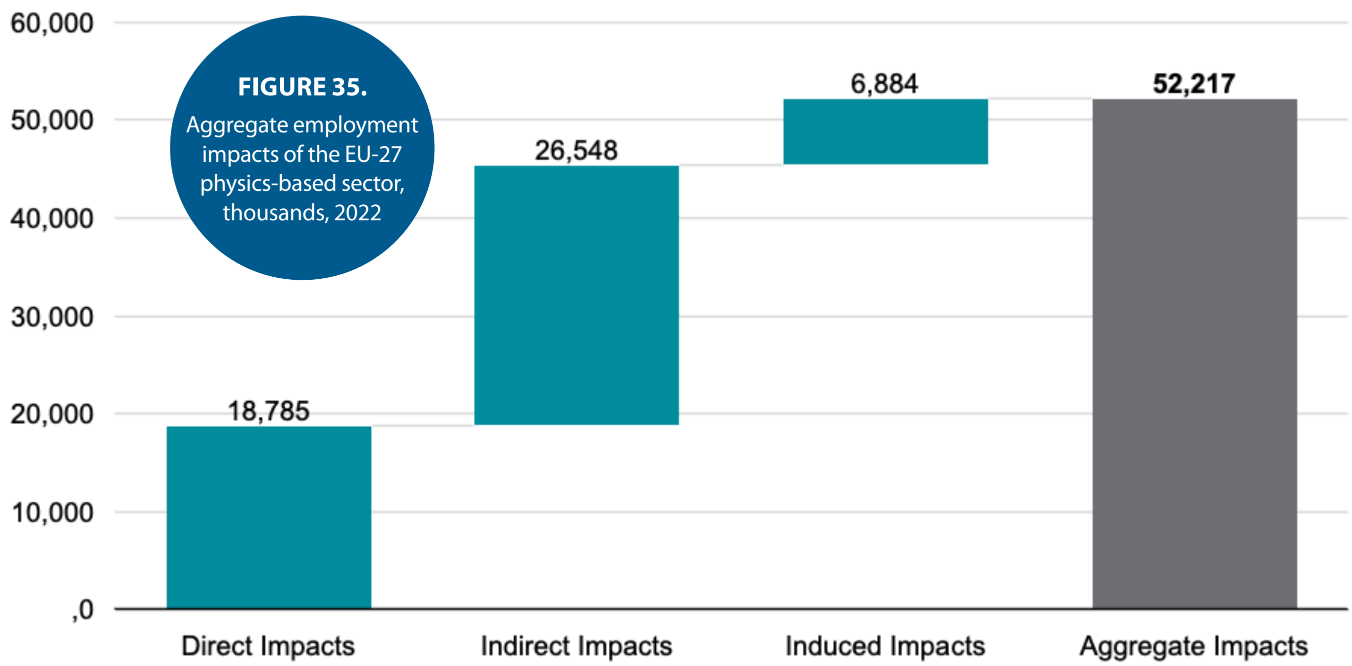
Aggregate GVA impacts are a result of substantial Type I and II GVA multipliers that exceed the equivalent observed for output. **Figure 34 visualises these GVA multipliers, as for every €1 of GVA in the physics-based sector a further €1.23 is generated upstream throughout the supply chain, constituting a Type I multiplier of €2.23**. Further to this, every €1 of physics-based GVA induces an additional GVA impact of €0.27 through the consumption of employees throughout the physics-based sector and its supply chain. Every €1 of GVA generated directly by physics-based activities therefore supports a total of €2.50 throughout the EU economy.

5.3. AGGREGATE EMPLOYMENT

Multiplier effects extend beyond just output and GVA to employment, as total aggregate impacts of physics-based activities support a far greater number of jobs than just those employed directly in the sector. Primarily, we estimate that the physics-based sector directly supported 18.8m jobs throughout the entire EU-27 economy. This exceeds the SBS-based employment estimates presented in Section 4.3 by approximately 10.5%, again reflecting the broader scope captured by the Labour Force Survey that underpins these employment figures.

On aggregate, the physics-based sector supports over 52.2m jobs throughout the EU-27 economies. Displayed in **Figure 35, this aggregate employment figure encompasses the 26.5m jobs supported indirectly through the economic activity and impacts generated upstream in the physics-based supply chain.** The consumption of employees both directly within the physics-based sector and its wider supply chain supports a further 6.9m jobs throughout the EU economy.

FIGURE 35.
Aggregate employment impacts of the EU-27 physics-based sector, thousands, 2022



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Figure 36 sets out the employment multipliers from which aggregate jobs impacts have been derived. For every physics-based job, a further 1.41 jobs are supported by the activity generated upstream throughout the supply chain, resulting in a Type I multiplier effect of 2.41. Interestingly, this multiplier effect exceeds the GVA multiplier specified above (2.23), signifying that a greater volume of jobs than GVA is supported by physics-based indirect impacts, relative to direct impacts. This is indicative of the fact that indirect productivity throughout the physics-based supply chain is inferior to direct productivity within the sector itself. Moving to broader impacts, every job in the physics-based sector supports a further 0.37 jobs through the induced impacts and consumption of physics-based employees. This generates a rather substantial Type II employment multiplier of 2.78.

FIGURE 36. The EU-27 physics-based employment multiplier, 2022

Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

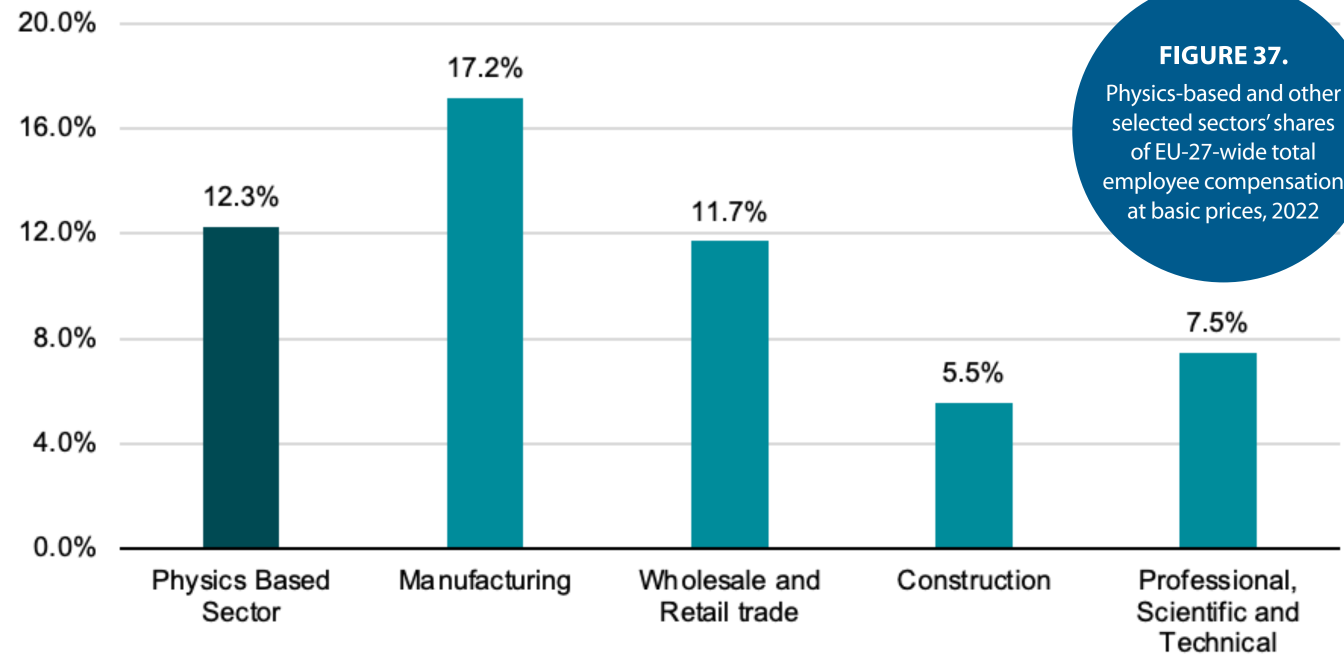
5.4. TOTAL INCOMES FROM EMPLOYMENT

Input-output modelling also facilitated analysis of total employee compensation in the physics-based sector. This measures the total remuneration paid to physics-based employees, comprising both wages and employer social contributions, and represents a key component of physics-based GVA. We estimate that total employee compensation in the physics-based sector measured €913bn in 2022.

Figure 37 expresses this relative to the EU economy total, as this analysis uncovers some interesting trends in employee compensation by sector. Once again, manufacturing proves the most substantial of the selected sectors and constitutes 17.2% of total employee compensation, but its size difference over the physics-based sector has shrunk from both the output and employment perspective. As mentioned in Section 4.3, manufacturing employment exceeds physics-based sector employment by 77%, at 30.0m versus 17.0m, but under the employee compensation perspective manufacturing outweighs the physics-based sector by just 40% (€1.28bn versus €913m). This indicates significantly stronger employee compensation and thus average wages in the physics-based sector.

In a similar vein, the difference between the physics-based sector and wholesale and retail trade narrows considerably between the output and employee compensation perspectives. Total wholesale and retail output lags the physics-based equivalent by 55% but this deficit drops to just 5% for employee compensation. Conversely to manufacturing though, this is indicative of differences in labour intensity as opposed to average wages and employee compensation. Physics-based industries prove far more capital intensive than wholesale and retail trade, thus strong employee compensation in the latter is reflective of a larger volume of labour required, a conclusion that is verified by the employment data.

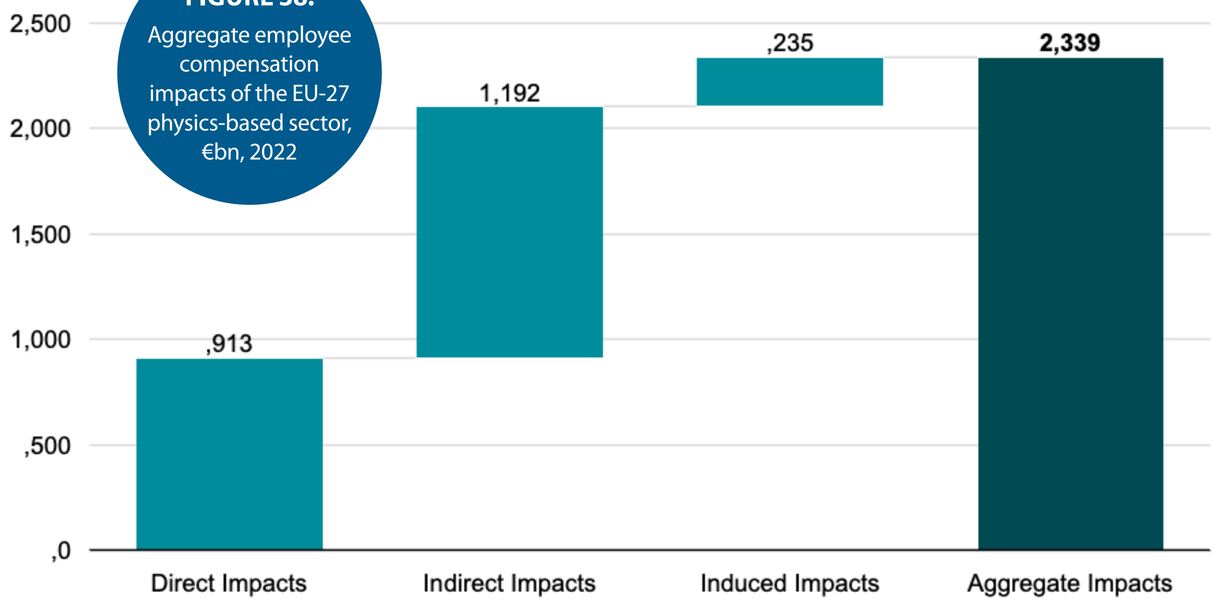
FIGURE 37.
Physics-based and other selected sectors' shares of EU-27-wide total employee compensation at basic prices, 2022



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Aggregate employee compensation can also be estimated analogously to the other impact indicators. Our input-output modelling suggests that in total, the physics-based sector supports €2.34tn in total incomes from employment throughout the EU economy. **Figure 38 illustrates employee compensation impacts in more detail.** In addition to the €913bn in direct income mentioned above, physics-based industries generate a further €1.19tn in employee compensation through the upstream activity throughout their supply chain. On top of this, a further €235bn of employment incomes are supported by the consumption and expenditure of employees, both within the physics-based sector directly and indirectly within its supply chain.

FIGURE 38.
Aggregate employee compensation impacts of the EU-27 physics-based sector, €bn, 2022



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

Figure 39 visualises the multiplier effects that drive the aggregate employee compensation impacts. For every €1 of income earned by physics-based employees, a further €1.31 is generated indirectly throughout the physics-based supply chain. It is worth noting that this multiplier effect is weaker than the equivalent multiplier for employment. This signifies a greater ratio between indirect and direct physics-based employment than for incomes from said employment, indicative of weaker average employee compensation and wages in the supply chain of physics-based industries, as opposed to within the sector itself. Beyond indirect impacts, for every €1 of physics-based employee compensation a further €0.25 of incomes are induced through the consumption of employees throughout the sector and its supply chain. This generates a type II employee compensation multiplier of 2.50.

FIGURE 39.
The EU-27 physics-based employee income multiplier, 2022

Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

6. INTERNATIONAL TRADE, INVESTMENT AND RESEARCH & DEVELOPMENT

In addition to the core indictors, direct and aggregate impacts of the physics-based sector, our analysis also covers three further metrics that capture the international dynamics and innovation environment in the EU-27 physics-based sector. Assessment of international trade, foreign direct and investment and R&D expenditure provide a more holistic and comprehensive perspective of physics-based activities in the EU.

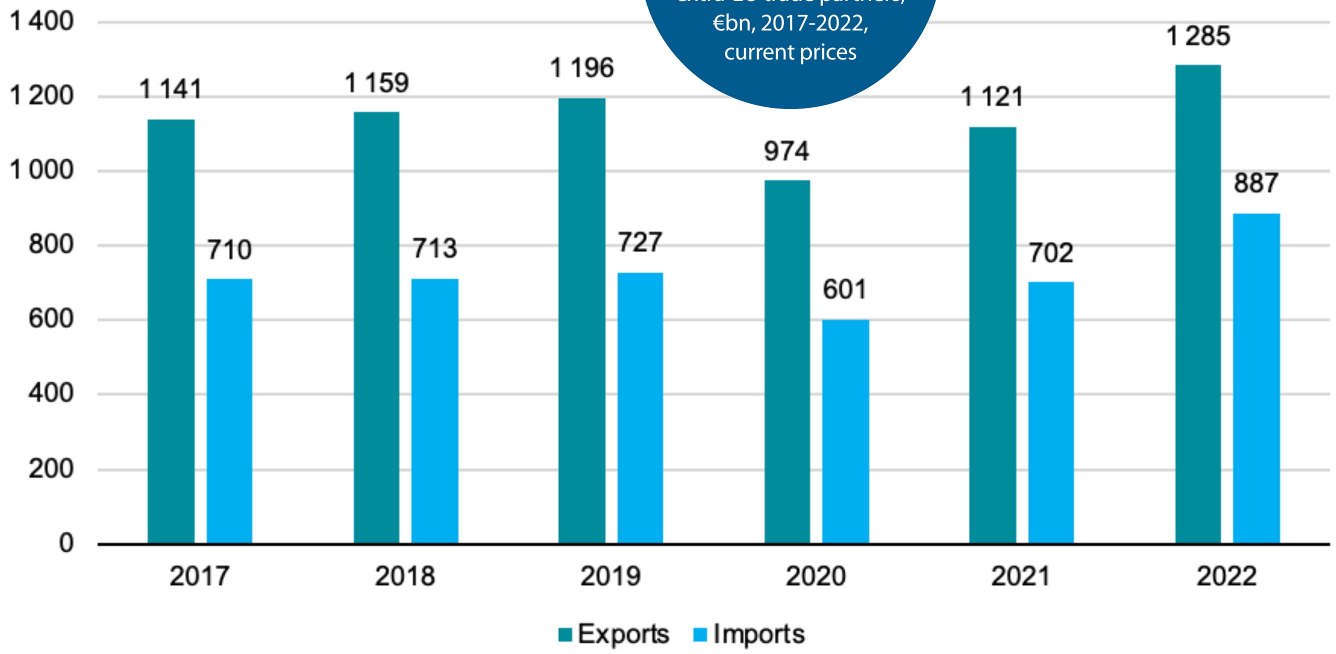
Due to data availability and our modelling framework in calculating these indicators, like the aggregate impacts here we only present findings for the EU on an aggregate level, excluding the four non-EU countries covered in earlier sections. However, unlike the aggregate impacts our findings here span throughout the research time period. This facilitates more detailed, trend analysis around the evolution of these indicators of the physics-based sector.

6.1. INTERNATIONAL TRADE

Overall, physics-based trade exhibited gradual growth throughout our time period, with imports and exports increasing by 24.9% and 12.6% respectively between 2017 and 2022[25]. **Figure 40 illustrates slight volatility in physics-based imports and exports between 2017 and 2022.** Total trade volumes[26] fell as low as €1.58tn in 2020, but demonstrated a strong post-pandemic recovery and robust growth of 37.8% from 2020 onwards, peaking at €2.17tn in 2022. This growth is attributed to strong rises of €311bn and €286bn in exports and imports respectively, from 2020 to 2022. Again, it is important to caveat the high-inflation environment throughout Europe in this period that is likely driving a portion of nominal trade growth.

The physics-based sector exhibited a consistent, strong trade surplus in goods and services over all years of our analysis. Physics-based imports peaked at €887bn in 2022, but exports also peaked in this year at €1.28tn, generating a substantial physics-based trade surplus of €398bn[27]. Interestingly, this reverses the findings observed in the previous 2018 report, where a physics-based trade deficit was consistently observed, a testament to very strong physics-based export volumes since 2017. The previous report did highlight a consistently narrowing trade deficit throughout the time period though, implying that this narrowing continued to reverse the physics-based current account deficit into a surplus.

FIGURE 40.
EU-27 imports and exports of physics-based goods and services to extra-EU trade partners, €bn, 2017-2022, current prices



Source: Eurostat Input-Output Tables, Eurostat SBS, Cebr analysis

25. Throughout this section, trade figures and analysis are based on overall EU-27 trade with countries outside the trading bloc.
26. Total trade volumes here refers to the sum of import and export volumes.
27. Trade balance is calculated as the value of exports minus imports.

Figure 41 below compares the EU-27's trade balance in physics-based goods and services with the overall business economy. We observe broadly similar trends in both measures up until 2021, where the physics-based trade surplus lagged the overall economy equivalent between €100bn to €200bn. The whole economy trade surplus deteriorated more sharply in 2022, leading to the physics-based sector's trade surplus marginally surpassing the overall economy by €12.4bn. This is a testament to the trade surplus of the physics-based sector given significantly smaller total trading volumes than the overall business economy. Over the five-year period, the physics-based sector's trade surplus declined slightly by 7.6%, whilst the overall economy surplus fell by a much greater 34.1%, leading to this convergence in 2022.

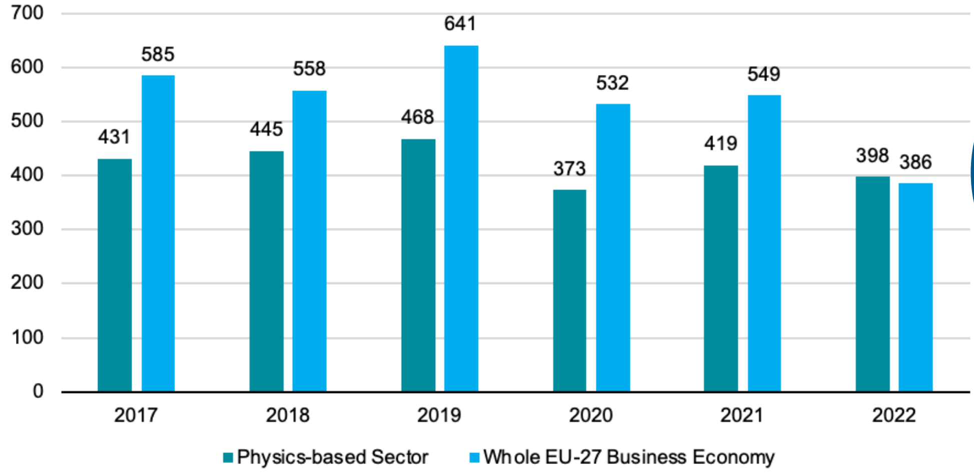


FIGURE 41.
EU-27 external trade balance for the physics-based sector and whole business economy, €bn, 2017-2022, current prices

Source: Eurostat National Accounts, Eurostat SBS, Cebr analysis

When examining trading volumes in relative terms we find that physics-based sectors make a disproportionately strong contribution to EU trade. **Figure 42 illustrates the imports and exports contribution of the physics-based sector to the overall EU-27 business economy.** The physics-based sector's imports and exports shares follow similar trends over the fiveyear period, declining notably from 2021 to 2022 due

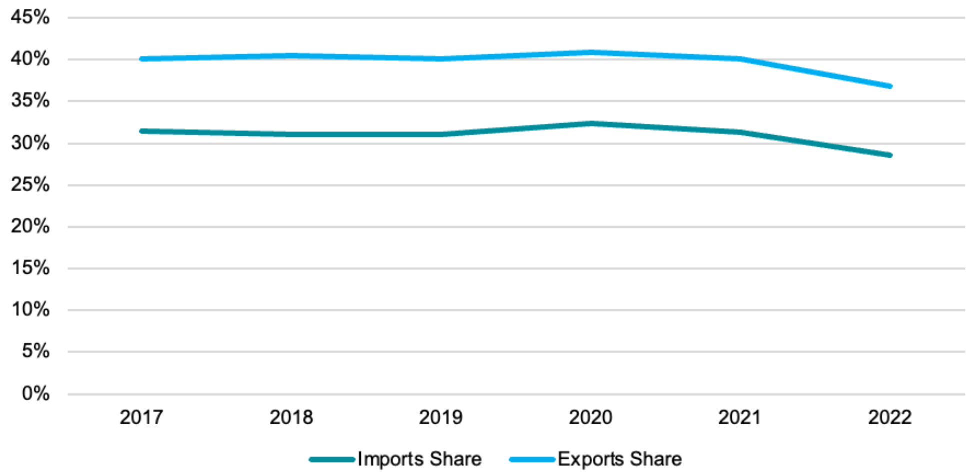


FIGURE 42.
Imports and exports in the physics-based sectors as a proportion of the total economy, 2017-2022

Source: Eurostat National Accounts, Eurostat SBS, Cebr analysis to a large increase in both imports and exports in the overall economy. Despite dropping off slightly towards the end of the period, the physics-based sector still constitutes a substantial proportion of total EU trading volumes, exceeding 30% for both imports and exports throughout all years of the time period. Comparing this to relatively lower shares for turnover and GVA, this reveals that the EU physics-based sector has a significantly greater trade intensity than the broader business economy.

Compounding this, the physics-based exports share remains consistently higher throughout, with the differential peaking in 2018 at 9.5 percentage points and narrowing to 8.2 percentage points in 2022. Nonetheless, this trend demonstrates the importance of the physics-based sector in driving trade surpluses in the EU-27 economy, owing to the consistently greater contributions of physics-based exports to the overall economy compared to imports.

Figure 43 below illustrates the trade surpluses of the physics-based sector and the overall economy as a proportion of total trade in each[28]. We observe very similar trends in the two proportions, with the physics-based sector proportion significantly higher for all years in our analysis, reinforcing the previous point on the physics-based sector driving the sizeable trade surplus in the EU-27 economy. Notably, the physics-based sector proportion saw a decline in 2022 by 4.7 percentage points, and the overall economy also experienced a nearequivalent decline (5.0 percentage points) in the same year, potentially reflecting influence of physics-based trade on overall trade dynamics in the EU business economy.

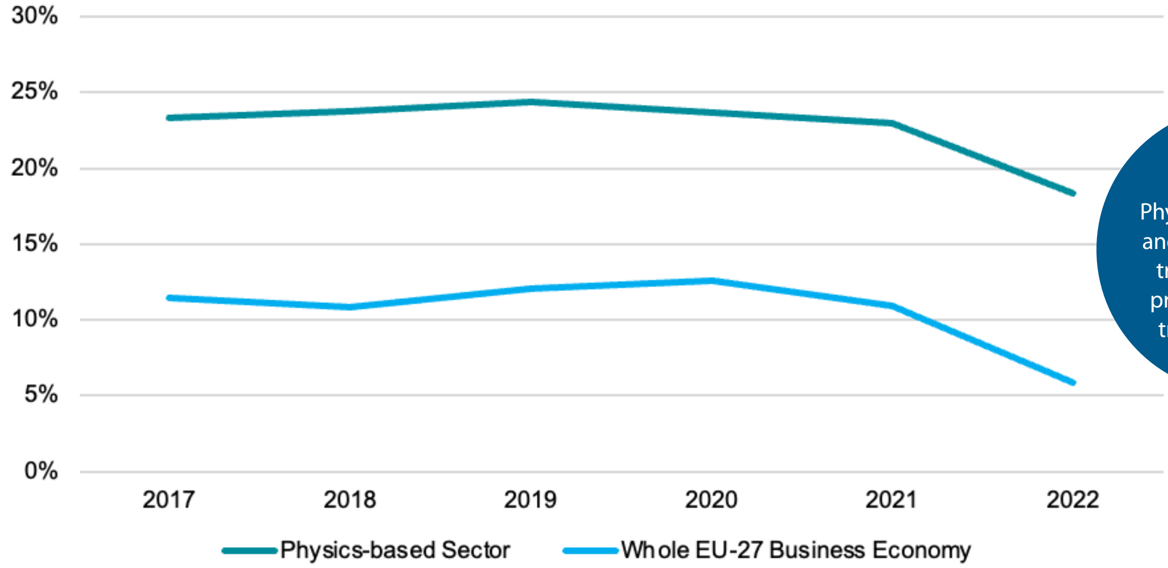


FIGURE 43.
Physics-based sector and EU-27 economy trade surplus as a proportion of total trade, 2017-2022

Source: Eurostat National Accounts, Eurostat SBS, Cebr analysis

28. This proportion is calculated as the difference in exports and imports divided by the sum of imports and exports.

6.2. FOREIGN DIRECT INVESTMENT FLOWS

Foreign Direct Investment (FDI) occurs when one country invests in a business or enterprise in another country with the intention of establishing a lasting presence within the country. These investment activities can benefit both the host country by providing job opportunities and new technologies, and the investing country by providing access to new markets. In turn, this can contribute to growth in both economies.

As in our 2018 report, we are unable replicate the analysis undertaken in the 2013 report, which examined both FDI inflows and outflows from the EU separately. The dataset used to conduct the analysis was discontinued after 2012, therefore instead we employ a dataset that covers FDI more broadly through net FDI outflows, from the physics-based sector in the EU-27 countries to the rest of the world[29]. Therefore, our analysis in this section still encapsulates both FDI outflows and inflows, but lacks the granularity of previous studies to distinguish between the two and their composition of the net total. Positive values represent a net outflow of FDI whilst negative values represent a net inflow of FDI

Figure 44, shows that for almost all years, except 2020, the a net outflow of FDI was observed from the EU-27 physics-based sector. The highest outflow occurred in 2022, when a total of €122bn was invested by the physics-based sector in EU in the rest of the world.

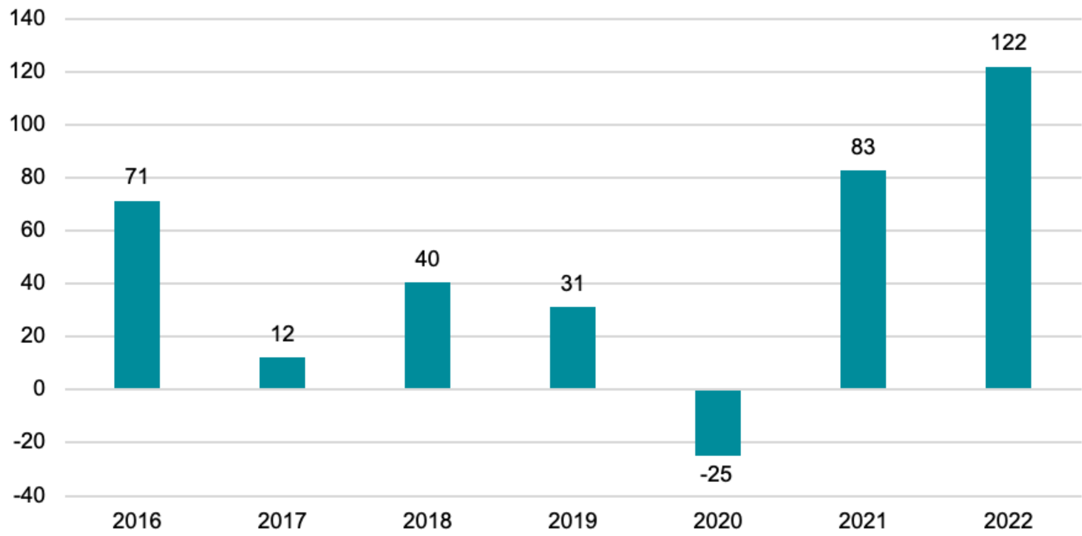


FIGURE 44.
Net FDI outflows from the physics-based sector of the EU-27 nations, €bn, 2016-2022, current prices

Source: Eurostat Direct Investment statistics, Eurostat SBS, Cebr analysis

Since net FDI varies largely for the same industries over different years, it is difficult to establish a long-term time trend in net FDI flows from the EU physics-based sector between 2016 and 2022. However, one notable trend we observe is that net FDI flows in the postpandemic period are higher than any of the pre pandemic years, indicating that net FDI flows experienced a strong rebound after the pandemic caused it to fall to €-25bn. This rebound is consistent with global FDI flows, which experienced a 135% increase between 2020 and 2021[30]. It is worth caveating these findings with the broader high-inflation environment in Europe though, that could be driving a portion of nominal FDI flows growth.

29. This variable is calculated as total FDI outflows net of total FDI inflows.

30. Taken directly from the OECD website dedicated to measuring foreign direct investment, available: https://www.oecd.org/en/topics/foreign-direct-investment-fdi.html

The volatility in the EU net FDI flows displayed in Figure 44 stem from the Manufacturing sector, which has consistently been the largest contributor to physics-based investment in almost every year. A prime example of this occurs in 2020, when COVID-19 curbed FDI from the EU (and indeed globally) resulting in net Manufacturing FDI to fall to -€39.9bn, indicating that the EU received €39.9bn in investment from foreign countries. This large inflow offset the outward FDI in Energy production (€12.7bn) and Information and Communication (€11.0bn), highlighting the importance of Manufacturing on the net FDI flows of the EU.

To further explore the relative importance of each physics-based industry to the net FDI flow of the EU, **Figure 45 provides a breakdown of the net FDI from the EU in 2022 by each industry**. As previously noted, Manufacturing is the physics-based industry with the largest net FDI flow, investing €105.1bn in foreign countries in 2022, more than eight times larger than the second largest absolute contributor (energy production at €13.1bn). The only EU physics-based industries that experienced net inflows of investment from foreign countries were oil & gas Activities, and the treatment of hazardous materials.

Net FDI flows across sectors are slightly at odds with trends and theories posited within Section 4.3 of this research. Employment trends here implied a changing structure and reallocation of resources within the physics-based sector, from oil and gas activities to energy production, in light of the broader energy transition. Physics-based FDI data for 2022 however indicates net inflows of FDI to the oil and gas sector amounting to €11.6bn, along with net outflows of FDI from the energy production sector of €13.1bn. This could however reflect greater capital expenditure within physics-based businesses in the energy production sector and expansion of activities overseas, and oil and gas activities being supported by foreign capital expenditure and investment. It could also potentially capture a short-term pivot to more traditional energy sources in efforts to sure up energy security post-pandemic issues.

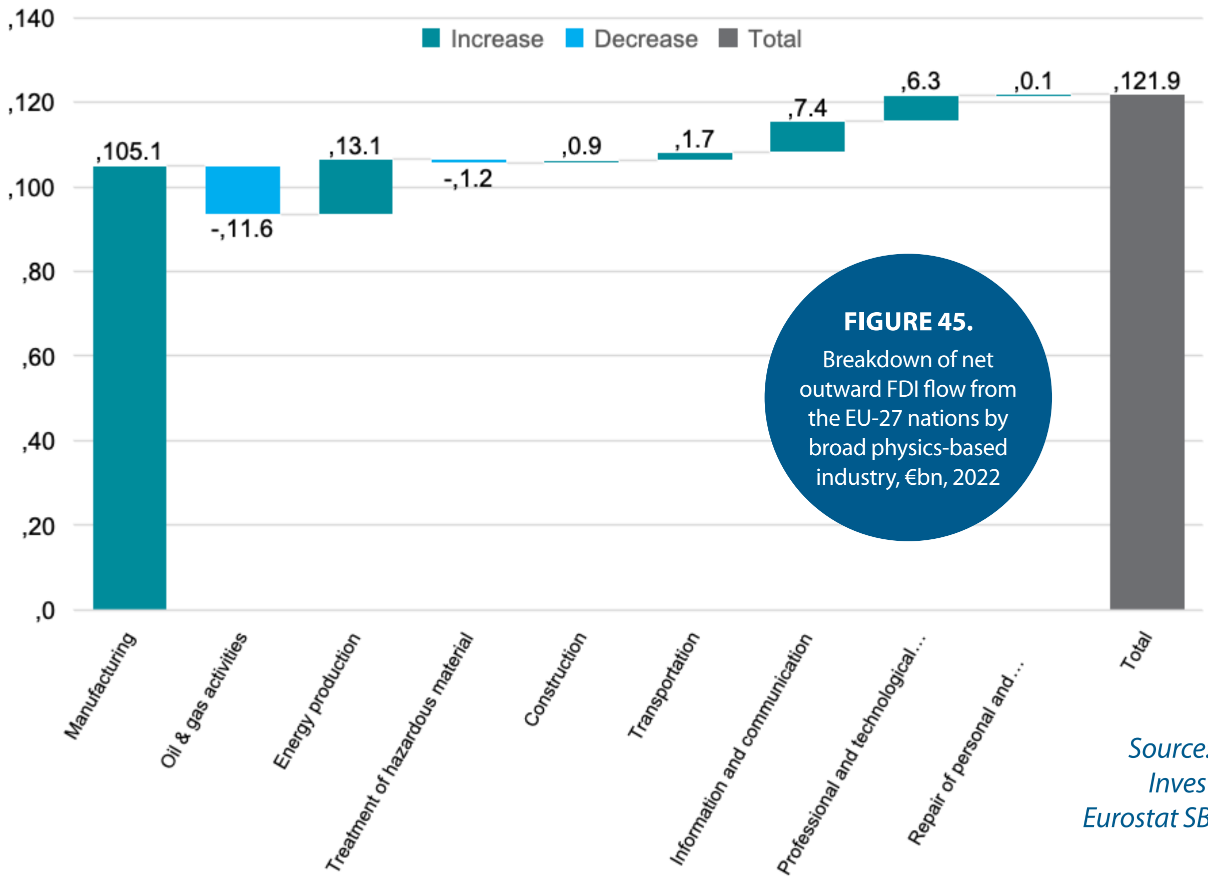


FIGURE 45.
Breakdown of net outward FDI flow from the EU-27 nations by broad physics-based industry, €bn, 2022

Source: Eurostat Direct Investment statistics, Eurostat SBS, Cebr analysis

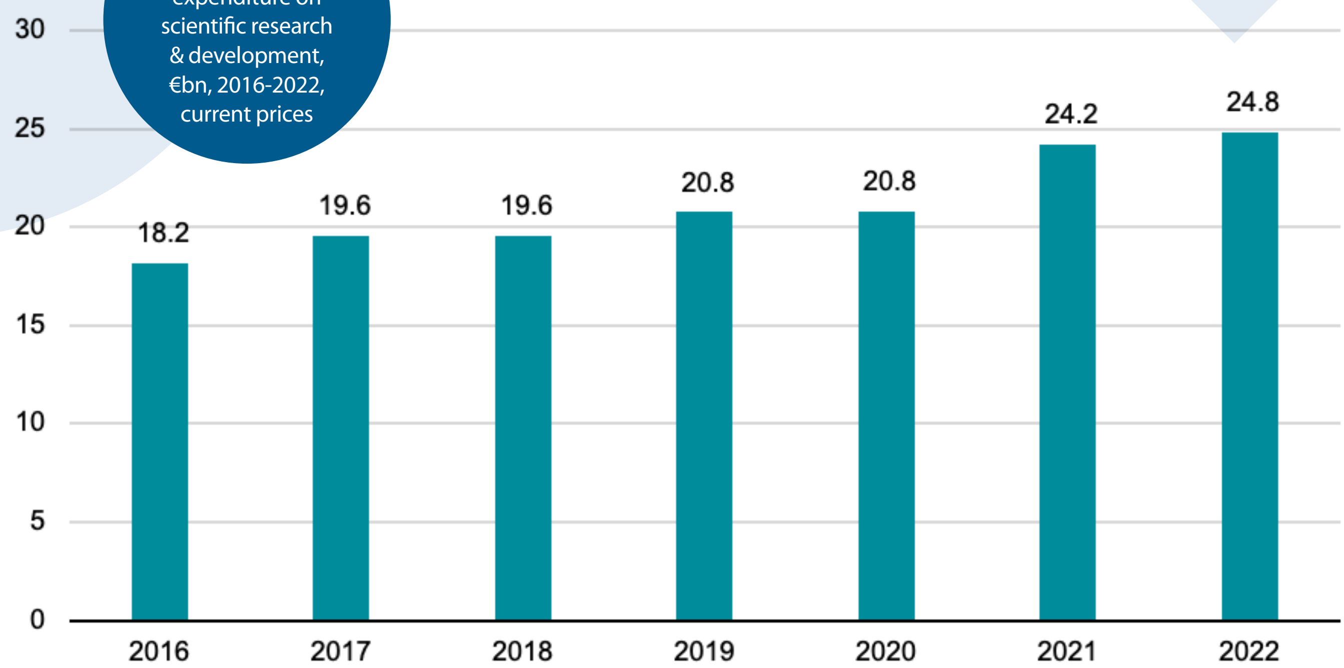
6.3. RESEARCH AND DEVELOPMENT EXPENDITURE

Research and development (R&D) activities are essential for innovation of new technologies, production processes and products. This, in turn, contributes to economy-wide productivity growth. As discussed in Section 4.4, the physics-based sector in Europe is capital-intensive, that is, it uses a relatively large amount of machinery and technology as inputs in the production process. The following analysis validates this and demonstrates that physics-based businesses spend relatively large amounts on R&D.

It is important to note, however, that our national accounts-based estimates capture the physics-based industries' external expenditure on scientific R&D only. Given our estimates are based upon the consumption of services from the scientific research and development sector as intermediate inputs, they capture R&D expenditure that is cross-sectoral or flows to providers and organisations that are external to physics-based businesses. This therefore excludes internal R&D that physics-based businesses conduct in-house using their own employees and capital. As described in the earlier reports, the estimates presented in this section could be expected to be significantly higher if it were possible to also estimate internal R&D expenditure.

We estimate that total external business R&D expenditure in the EU-27 physics-based sector totalled €24.8bn in 2022, covering both domestic R&D spending of physics-based organisations and imported R&D services. As shown in **Figure 46**, expenditure increased consistently throughout the time period. Business R&D expenditure measured €18.2bn in 2016, signifying total growth of 36.5% throughout the time period, with particularly sharp increases in 2017, 2019 and 2021. Growth towards the latter years in the time period at least partially reflects the broader high-inflation environment throughout Europe following the pandemic, with this a contributing driver of increases in nominal R&D spending.

FIGURE 46.
EU-27 physics-based expenditure on scientific research & development, €bn, 2016-2022, current prices



Source: Eurostat Direct Investment statistics, Eurostat SBS, Cebr analysis

The steepest rise in R&D expenditure was experienced in 2021 where expenditure increased by 16.3% from the year before. Again, broader inflation likely constitutes a large portion of this nominal growth, but it also potentially reflects an economic rebound following the COVID-19 pandemic, prompting industry to invest in R&D due to a rise in income. This aligns with strong post-pandemic growth we observed in other major indicators of the physics-based sector, such as turnover, business population and GVA, with R&D expenditure likely a function of these variables. Following the significant increase in 2021 R&D expenditure grew far more modestly at 2.4% in 2022, representing a slight real terms decline given very strong inflation at the time.

The EU physics-based sector also invests in research and development from countries outside the European Union. Overseas R&D expenditure amounted to €5.3bn, representing 21.4% of the total €24.8bn physics-based expenditure on scientific R&D in 2022.

Upon examining the contributions of different sectors to total physics-based R&D expenditure, we find that it is weighted significantly towards two sectors in particular. Manufacturing and professional, scientific and technical activities drive a substantial proportion of R&D spend, as on average throughout our time period, these two industries accounted for approximately 99% of total physics-based R&D expenditure. Although manufacturing and professional, scientific and technical activities also make up a large proportion of the physics-based sector in turnover and GVA terms, R&D expenditure is significantly more concentrated towards the two sectors. This indicates that physics-based activities in these industries is far more R&D-intensive than other sectors such as energy production and oil and gas activities. **Figure 47 illustrates this, comparing total physics-based R&D expenditure and that in the physics-based manufacturing and professional, technical and scientific activities sectors**.

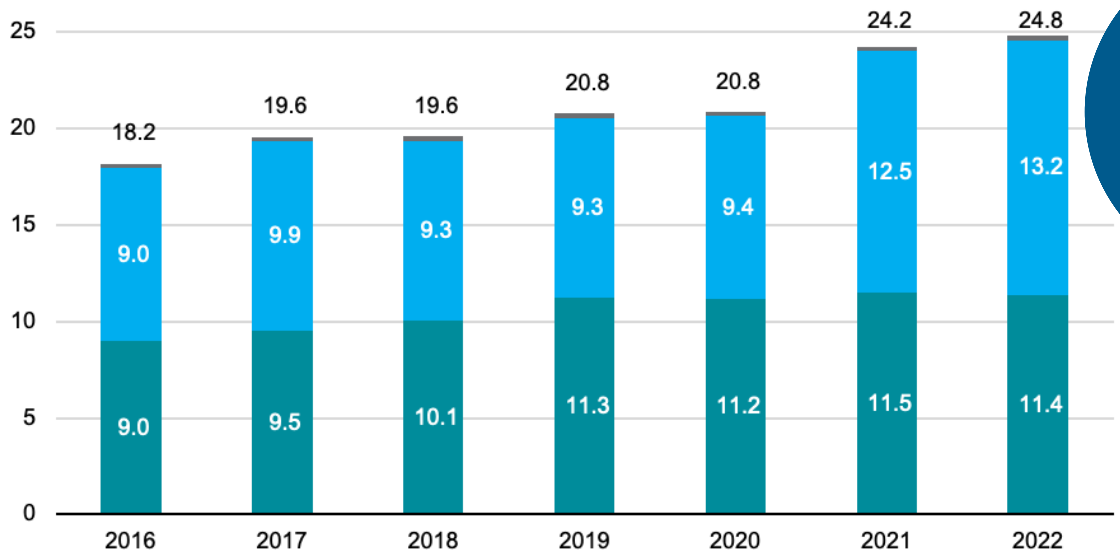
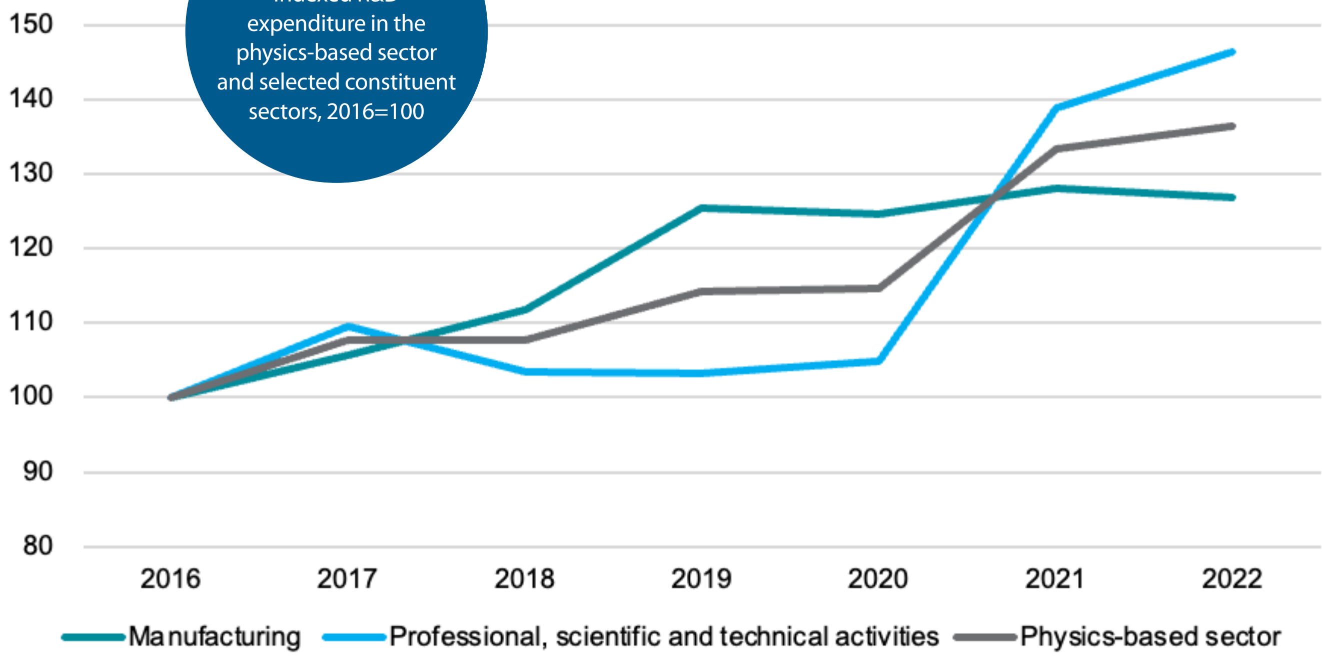


FIGURE 47.
Total physics-based R&D expenditure, composition across manufacturing, professional, scientific and technical activities and all other sectors, €bn, 2016-2022, current prices

Source: Eurostat Direct Investment statistics, Eurostat SBS, Cebr analysis

FIGURE 48.
Indexed R&D expenditure in the physics-based sector and selected constituent sectors, 2016=100



Source: Eurostat Direct Investment statistics, Eurostat SBS, Cebr analysis

Given the dominance of manufacturing and professional, scientific and technical activities, **Figure 48 presents the growth trends of physics-based R&D expenditure in these two industries and the overall physics-based sector**.

Relative to 2016 as the baseline, R&D expenditure across the overall physics-based sector grew 36.5% up to 2022. Interesting trends are observed in R&D expenditure of the two driving sectors, with a clear divergence in growth trajectories, that reverses following the pandemic. Physics-based R&D expenditure in manufacturing grows rather steadily by total of 26.8% throughout the time period. However, physics-based R&D expenditure in professional, scientific and technical activities stagnates from 2016 to 2020, before rebounding significantly following the pandemic to outpace the manufacturing sector. Physics-based R&D expenditure in professional, technical and scientific activities therefore grows by 46.5% throughout the whole time period. R&D expenditure growth in the overall physics-based sector essentially functions as an average of these two constituent sectors, given the significant proportion of physics-based R&D spend that they constitute.

APPENDIX I: FULL RESULTS TABLES

DIRECT IMPACT RESULTS

Here we present the results tables in full, across all European countries studied and years of the analysis. This captures the direct impacts from Sections 3 and 4 for total business population, employment, turnover and gross value added, sourced from Eurostat SBS.

Table A1

NUMBER OF ENTERPRISES IN THE PHYSICS-BASED SECTOR, 2016-2022							
COUNTRY	2016	2017	2018	2019	2020	2021	2022
Austria	30,813	31,919	31,143	34,255	34,341	47,519	47,051
Belgium	35,200	35,748	36,870	40,410	39,976	42,737	46,870
Bulgaria	27,175	27,680	28,325	29,299	29,449	29,403	31,902
Switzerland	16,508	16,624	16,580	16,754	17,017	17,144	17,195
Cyprus	3,259	3,486	3,809	4,100	4,222	4,356	4,571
Czech Republic	143,427	146,709	152,446	152,620	151,697	150,403	153,854
Germany	259,492	266,915	332,407	333,435	317,560	317,390	320,213
Denmark	19,760	20,011	20,081	20,351	20,218	20,463	21,952
Estonia	6,348	7,000	7,091	7,572	7,920	10,561	11,590
Greece	80,026	72,160	71,107	72,955	76,066	82,246	87,502
Spain	199,199	200,538	204,221	212,752	209,245	219,279	224,539
Finland	21,773	22,009	21,960	22,522	22,891	35,127	36,124
France	251,211	233,985	240,321	253,015	259,124	272,431	299,474
Croatia	13,759	14,165	14,542	17,075	17,285	18,378	19,538
Hungary	66,331	69,894	74,329	81,275	84,009	92,333	95,335
Ireland	23,342	24,454	24,507	25,413	27,059	27,367	29,724
Iceland	2,263	2,351	2,358	2,474	2,568	2,892	2,967

NUMBER OF ENTERPRISES IN THE PHYSICS-BASED SECTOR, 2016-2022							
COUNTRY	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Italy	433,853	434,735	438,417	425,541	436,074	455,227	471,237
Lithuania	14,995	15,584	16,095	17,011	17,544	18,622	20,303
Luxembourg	2,410	2,503	2,576	2,659	2,683	2,718	2,899
Latvia	8,798	8,935	9,257	9,238	9,295	8,878	9,275
Malta	1,524	1,589	1,725	1,887	1,845	2,544	2,694
Netherlands	124,991	126,442	134,329	142,766	149,994	152,112	162,980
Norway	28,328	28,427	28,090	29,944	30,357	33,052	33,940
Poland	166,949	171,126	190,260	199,270	205,293	217,603	222,234
Portugal	45,887	47,577	48,442	49,885	50,550	53,019	57,158
Romania	36,163	38,251	40,171	42,315	43,926	66,030	68,795
Sweden	83,242	82,030	75,240	75,903	76,571	77,606	74,214
Slovenia	16,506	16,922	17,154	17,484	17,505	17,750	18,295
Slovakia	47,082	52,466	58,172	63,155	64,403	68,597	74,414
United Kingdom	243,895	254,145	248,700	249,835	249,475	245,075	237,305
EU TOTAL	**2,163,693**	**2,174,831**	**2,294,997**	**2,354,164**	**2,376,748**	**2,510,699**	**2,614,737**
NON UE TOTAL	**290,994**	**301,546**	**295,728**	**299,007**	**299,417**	**298,163**	**291,407**
TOTAL	**2,454,687**	**2,476,377**	**2,590,725**	**2,653,171**	**2,676,165**	**2,808,862**	**2,906,144**

Table A2

TURNOVER IN PHYSICS-BASED SECTOR, € M, 2016-2022, CURRENT PRICES							
COUNTRY	2016	2017	2018	2019	2020	2021	2022
Austria	85,237	92,882	103,239	106,473	103,138	115,363	145,674
Belgium	112,624	118,842	117,751	123,059	125,098	129,160	167,736
Bulgaria	16,084	16,732	15,942	16,899	17,220	23,208	32,944
Switzerland	212,543	236,625	236,394	258,764	255,115	297,175	366,526
Cyprus	2,597	2,748	3,113	3,319	3,947	4,582	7,021
Czech Republic	92,498	100,528	118,362	122,848	112,166	111,992	159,452
Germany	1,375,797	1,444,439	1,682,220	1,694,345	1,608,801	1,867,350	1,955,470
Denmark	75,540	81,335	82,812	86,877	84,138	90,147	110,437
Estonia	6,606	7,015	7,189	7,688	7,298	9,431	10,808
Greece	28,533	29,949	28,772	30,099	28,678	37,192	49,915
Spain	232,277	248,179	255,598	270,036	241,128	265,206	315,584
Finland	56,358	58,676	62,563	67,671	64,076	71,642	84,957
France	593,567	612,138	634,469	660,915	589,362	635,530	754,125
Croatia	10,624	11,122	11,727	11,256	11,115	11,982	15,046
Hungary	59,861	64,240	66,597	73,207	72,292	82,838	118,745
Ireland	113,867	129,577	99,904	129,950	106,206	116,742	128,083
Iceland	2,497	2,922	3,067	3,229	2,834	3,125	4,020
Italy	422,404	477,346	481,818	472,676	384,301	481,529	607,836

TURNOVER IN PHYSICS-BASED SECTOR, € M, 2016-2022, CURRENT PRICES							
COUNTRY	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Lithuania	8,840	9,308	6,838	11,683	8,867	11,618	13,211
Luxembourg	13,022	15,245	8,976	11,429	9,786	12,295	12,276
Latvia	3,608	4,031	4,972	4,716	4,432	7,133	7,604
Malta	1,842	1,990	2,606	3,241	1,842	4,115	5,845
Netherlands	163,006	168,922	189,022	194,642	186,384	215,735	299,988
Norway	118,254	127,296	146,945	131,330	105,974	180,292	333,105
Poland	115,143	121,174	121,927	130,238	134,679	149,720	179,285
Portugal	40,915	42,785	39,418	40,969	37,815	41,616	49,435
Romania	40,445	44,807	46,133	47,980	44,192	51,621	65,470
Sweden	133,576	141,793	143,875	146,570	173,247	213,155	208,664
Slovenia	18,979	24,476	31,054	24,707	17,393	25,820	31,969
Slovakia	46,153	46,648	47,373	48,286	44,340	47,613	56,284
United Kingdom	616,360	598,290	625,150	566,801	560,339	639,524	778,777
EU TOTAL	**3,870,002**	**4,116,928**	**4,414,270**	**4,541,779**	**4,221,942**	**4,834,337**	**5,593,864**
NON-EU TOTAL	**949,653**	**965,133**	**1,011,556**	**960,124**	**924,261**	**1,120,116**	**1,482,428**
TOTAL	**4,819,655**	**5,082,061**	**5,425,826**	**5,501,903**	**5,146,203**	**5,954,453**	**7,076,292**

Table A3

GVA IN PHYSICS-BASED SECTOR, € M, 2016-2022, CURRENT PRICES							
COUNTRY	2016	2017	2018	2019	2020	2021	2022
Austria	31,817	34,095	36,299	37,162	36,159	39,509	45,900
Belgium	36,265	35,971	38,811	43,354	42,153	46,481	50,471
Bulgaria	5,402	6,240	6,319	7,298	7,239	7,936	10,921
Switzerland	80,027	84,026	83,705	90,428	90,036	102,597	120,126
Cyprus	1,367	1,385	1,428	1,527	1,812	1,840	1,989
Czech Republic	23,106	24,586	31,878	29,968	25,284	33,896	32,236
Germany	403,268	428,313	467,859	475,309	457,597	521,101	567,768
Denmark	32,257	35,726	43,460	37,387	33,811	34,055	41,405
Estonia	2,346	2,354	2,431	2,487	2,006	2,226	2,780
Greece	10,307	9,862	9,151	6,717	10,472	12,893	12,042
Spain	84,233	89,334	93,680	97,507	87,977	94,289	107,330
Finland	18,565	19,400	19,288	19,651	20,352	21,493	24,022
France	174,632	179,012	189,285	198,367	189,362	198,309	192,910
Croatia	4,244	4,294	4,901	5,193	5,067	4,977	5,335
Hungary	15,114	16,519	17,189	17,834	17,808	18,414	20,852
Ireland	40,326	46,071	50,446	49,989	52,271	48,062	53,290
Iceland	1,404	1,453	1,742	1,717	1,378	1,572	2,045

GVA IN PHYSICS-BASED SECTOR, € M, 2016-2022, CURRENT PRICES							
COUNTRY	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Italy	137,692	146,281	147,098	151,200	135,929	157,068	170,239
Lithuania	2,881	3,226	3,576	4,014	3,812	4,670	5,077
Luxembourg	3,797	6,252	3,784	5,075	3,646	3,864	4,787
Latvia	1,646	1,895	1,590	1,826	1,888	1,897	2,407
Malta	1,367	884	927	976	928	1,046	1,232
Netherlands	53,874	55,799	61,975	65,865	65,251	76,729	107,961
Norway	69,992	78,631	94,352	76,913	60,142	129,240	270,405
Poland	35,773	39,674	38,145	41,484	42,942	44,803	49,924
Portugal	15,966	15,905	14,445	15,220	14,051	14,622	16,079
Romania	11,932	13,573	13,766	14,901	15,740	15,567	19,866
Sweden	44,157	45,785	46,392	49,327	60,056	68,377	59,654
Slovenia	6,181	6,884	7,012	7,122	6,568	7,490	7,386
Slovakia	8,696	9,210	9,003	9,632	9,163	10,317	10,626
United Kingdom	238,714	232,807	231,954	244,417	225,083	257,430	284,032
EU TOTAL	**1,207,210**	**1,278,531**	**1,360,138**	**1,396,394**	**1,349,345**	**1,491,931**	**1,624,490**
NON-EU TOTAL	**390,137**	**396,917**	**411,752**	**413,475**	**376,638**	**490,839**	**676,608**
TOTAL	**1,597,347**	**1,675,447**	**1,771,890**	**1,809,869**	**1,725,983**	**1,982,769**	**2,301,098**

Table A4

NUMBER OF PERSONS EMPLOYED IN PHYSICS-BASED SECTOR, 2016-2022							
COUNTRY	2016	2017	2018	2019	2020	2021	2022
Austria	328,078	336,812	358,836	368,590	373,146	397,265	409,857
Belgium	262,254	265,439	286,684	290,147	281,119	286,777	300,226
Bulgaria	241,809	254,739	263,772	264,551	263,474	257,520	262,501
Switzerland	479,701	487,378	489,447	500,723	500,992	499,369	503,390
Cyprus	19,118	20,473	20,903	22,131	22,818	22,827	23,538
Czech Republic	581,132	599,548	612,408	604,880	595,419	607,787	614,269
Germany	4,484,594	4,651,142	5,103,334	5,180,036	5,014,816	4,961,399	5,030,886
Denmark	218,999	224,539	227,042	231,225	228,992	233,261	250,059
Estonia	49,132	51,349	51,781	62,441	51,939	66,543	69,066
Greece	223,119	208,427	221,740	216,154	219,183	229,377	229,112
Spain	1,061,135	1,097,078	1,150,622	1,200,084	1,199,163	1,149,615	1,191,090
Finland	208,027	205,488	212,655	221,181	221,596	207,979	216,414
France	1,843,964	1,845,576	1,933,892	1,924,866	1,994,990	1,968,988	2,029,925
Croatia	126,875	129,736	131,981	138,361	138,027	129,555	134,546
Hungary	415,252	427,979	451,073	464,989	463,303	446,239	466,455
Ireland	166,137	172,654	186,883	200,655	203,973	206,494	218,764
Iceland	12,465	13,443	13,098	13,117	12,522	13,058	14,188

NUMBER OF PERSONS EMPLOYED IN PHYSICS-BASED SECTOR, 2016-2022							
COUNTRY	2016	2017	2018	2019	2020	2021	2022
Italy	1,801,611	1,835,376	1,817,731	1,822,464	1,818,320	1,865,564	1,925,838
Lithuania	84,465	88,177	92,514	93,928	98,652	105,105	109,896
Luxembourg	24,595	29,165	27,116	27,931	25,197	26,065	28,011
Latvia	59,412	59,884	56,491	54,668	53,943	53,422	52,785
Malta	12,278	13,374	15,890	19,408	14,196	14,717	15,411
Netherlands	525,470	539,846	565,770	587,772	595,375	604,660	627,014
Norway	252,720	246,179	251,087	258,998	255,913	253,483	266,884
Poland	1,033,741	1,059,990	1,072,031	1,096,003	1,117,924	1,115,857	1,125,138
Portugal	226,962	237,687	240,192	251,496	252,300	261,109	277,115
Romania	552,623	560,114	567,519	571,064	555,126	576,464	568,966
Sweden	438,140	455,025	468,158	478,016	463,294	491,729	457,184
Slovenia	94,293	99,037	102,434	105,331	104,247	107,670	110,562
Slovakia	222,448	233,394	236,935	241,602	234,071	247,603	250,676
United Kingdom	2,245,076	2,234,798	2,258,106	2,352,424	2,270,313	2,295,842	2,345,306
EU TOTAL	**15,305,663**	**15,702,049**	**16,476,387**	**16,739,974**	**16,604,602**	**16,641,591**	**16,995,304**
NON-EU TOTAL	**2,989,962**	**2,981,798**	**3,011,738**	**3,125,262**	**3,039,740**	**3,061,752**	**3,129,767**
TOTAL	**18,295,626**	**18,683,847**	**19,488,125**	**19,865,236**	**19,644,342**	**19,703,343**	**20,125,071**

Table A5

PHYSICS-BASED EMPLOYMENT WITHIN BROAD SECTOR GROUPS, 2016-2022							
PHYSICS-BASED SECTORS	2016	2017	2018	2019	2020	2021	2022
B - Mining and quarrying	169,627	147,006	135,658	133,752	130,617	119,386	128,700
C - Manufacturing	8,657,913	8,918,485	9,345,408	9,511,617	9,367,969	9,408,837	9,545,402
D - Electricity, gas, steam and aur conditioning supply	869,710	880,001	1,058,217	1,004,946	1,012,256	1,021,639	1,032,010
E - Water supply activities	64,232	57,415	59,287	55,123	56,999	53,114	57,340
F - Construction	1,511,743	1,552,359	1,576,547	1,652,804	1,732,098	1,718,514	1,806,646
H - Transportation and storage	988,562	1,013,560	994,156	1,012,822	969,440	878,166	886,116
J - Information and Communication	1,696,453	1,737,064	1,814,947	1,820,524	1,800,224	1,809,522	1,810,653
M - Professional, scientific and technical activities	4,301,279	4,340,674	4,466,088	4,637,501	4,537,032	4,655,425	4,817,450
S95 - Repair and computers and personal and household goods	36,106	37,284	37,817	36,148	37,707	38,740	40,754

APPENDIX II: PHYSICS-BASED SECTOR CLASSIFICATION

CODE	DESCRIPTION
6.1	Extraction of crude petroleum
6.2	Extraction of natural gas
9.1	Support activities for petroleum and natural gas extraction
20.13	Manufacture of other inorganic basic chemicals
21.2	Manufacture of pharmaceutical preparations
23.44	Manufacture of other technical ceramic products
24.46	Processing of nuclear fuel
25.4	Manufacture of weapons and ammunition
25.99	Manufacture of other fabricated metal products n.e.c.
26.11	Manufacture of electronic components
26.12	Manufacture of loaded electronic boards

CODE	DESCRIPTION
27.12	Manufacture of electricity distribution and control apparatus
27.2	Manufacture of batteries and accumulators
26.8	Manufacture of magnetic and optical media
27.11	Manufacture of electric motors, generators and transformers
27.31	Manufacture of fibre optic cables
27.32	Manufacture of other electronic and electric wires and cables
27.33	Manufacture of wiring devices
27.4	Manufacture of electric lighting equipment
27.51	Manufacture of electric domestic appliances
27.9	Manufacture of other electrical equipment
28.11	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines

CODE	DESCRIPTION
26.2	Manufacture of computers and peripheral equipment
26.3	Manufacture of communication equipment
26.4	Manufacture of consumer electronics
26.5	Manufacture of instruments and appliances for measuring, testing and navigation
26.6	Manufacture of irradiation, electro-medical and electrotherapeutic equipment
26.7	Manufacture of optical instruments and photographic equipment
26.8	Manufacture of magnetic and optical media
27.11	Manufacture of electric motors, generators and transformers

CODE	DESCRIPTION
28.23	Manufacture of office machinery and equipment (except computers and peripheral equipment)
28.25	Manufacture of non-domestic cooling and ventilation equipment
28.29	Manufacture of other general-purpose machinery n.e.c.
28.49	Manufacture of other machine tools
28.99	Manufacture of other special-purpose machinery n.e.c.
29.1	Manufacture of motor vehicles
29.31	Manufacture of electrical and electronic equipment for motor vehicles
30.11	Building of ships and floating structures

CODE	DESCRIPTION
30.2	Manufacture of railway locomotives and rolling stock
30.3	Manufacture of air and spacecraft and related machinery
30.4	Manufacture of military fighting vehicles
30.91	Manufacture of motorcycles

CODE	DESCRIPTION
52.21	Service activities incidental to land transportation
52.22	Service activities incidental to water transportation
52.23	Service activities incidental to air transportation
60.1	Radio broadcasting

CODE	DESCRIPTION
32.5	Manufacture of medical and dental instruments and supplies
33.11	Repair of fabricated metal products
33.12	Repair of machinery
33.13	Repair of electronic and optical equipment
33.14	Repair of electrical equipment
33.15	Repair and maintenance of ships and boats
33.17	Repair and maintenance of other transport equipment
33.2	Installation of industrial machinery and equipment
35.11	Production of electricity
35.12	Transmission of electricity
35.13	Distribution of electricity
38.12	Collection of hazardous waste
38.22	Treatment and disposal of hazardous waste

CODE	DESCRIPTION
61.1	Wired telecommunications activities
61.2	Wireless telecommunications activities
61.3	Satellite telecommunications activities
61.9	Other telecommunications activities
62.1	Other information technology and computer service activities
71.12	Engineering activities and related technical consultancy
71.2	Technical testing and analysis
72.11	Research and experimental development on biotechnology
72.19	Other research and experimental development on natural sciences and engineering
74.2	Photographic activities
74.9	Other professional, scientific and technical activities n.e.c.
84.2	Defence services
95.12	Repair of communication equipment

AMENDMENTS TO THE DEFINITION OF PHYSICS-BASED ACTIVITIES

CODE	EXCLUDED SINCE 2013 REPORT
25.21	Manufacture of central heating radiators and boilers
25.30	Manufacture of steam generators, except central heating hot water boilers
28.21	Manufacture of ovens, furnaces and furnace burners
28.92	Manufacture of machinery for mining, quarrying and construction
32.99	Other manufacturing n.e.c.
33.16	Repair and maintenance of aircraft and spacecraft
60.2	Television programming and broadcasting activities
71.11	Architectural activities
72.2	Research and experimental development on social sciences and humanities

CODE	INCLUDED SINCE 2013 REPORT
35.12	Transmission of electricity
35.13	Distribution of electricity
43.22	Plumbing, heat and air-conditioning installation

APPENDIX III: FURTHER METHODOLOGICAL DETAIL

SECTOR NOMENCLATURE

Below we set out the sector codes and descriptions of all the broad sectors that contain physics-based sectors, and are therefore cited throughout this research as "broad sectors", and used as comparator sectors. These sectors are consistent with the NACE classification.

- **B:** Mining and Quarrying
- **C:** Manufacturing
- **D:** Electricity, gas, steam and air conditioning supply
- **E:** Water supply, sewerage, waste management and remediation
- **F:** Construction
- **G:** Wholesale and retail trade
- **H:** Transportation and storage
- **J:** Information and communication
- **M:** Professional, scientific and technical activities
- **S95:** Repair of computers and personal and household goods

It is worth noting that in the interest of brevity, some sector names are abbreviated within our reporting: "wholesale and retail trade" is referred to as "retail", "transportation and storage" is referred to as "transportation". As it relates to the physics-based sector, we also refer to "mining and quarrying" as"oil and gas activities", as this describes the activities of the physics-based subsectors within this wider sector. The same applies for "electricity, gas, steam and air conditioning supply" which we refer to as "energy production" as again this describes the physics-based activities within this wider sector.

PRODUCER VERSUS BASIC PRICES

Basic prices and producer prices are two valuation concepts used in national accounts to measure output, differing in how they treat taxes and subsidies on products. Basic prices reflect the amount retained by producers per unit of output, and crucially they exclude any taxes on products (like VAT or excise duties) but including subsidies on products. We consider this the exclusion of net taxes on products. This makes basic prices the preferred measure for valuing output in national accounts, as they isolate the producer's true earnings from market distortions.

Producer prices, on the other hand, represent the amount receivable by the producer including any product taxes and excluding product subsidies (including net taxes on products). They reflect the price paid by purchasers before trade and transport margins are added, and are more common within turnover data.

Producer prices = Basic prices + Product taxes – Product subsidies

NOTES

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