The Importance of Physics to the Economies of Europe

A study by Cebr for the period 2011-2016

Report by Cebr - Centre for Economics and Business Research
for the European Physical Society

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Authorship and acknowledgements

This report has been produced by Cebr, an independent economics and business research consultancy established in 1992. The views expressed herein are those of the authors only and are based upon independent research by them.

The report does not necessarily reflect the views of the European Physical Society (EPS).

Foreword

Since its establishment in 1968, the European Physical Society (EPS) has held a dual role of learned society and federation of national member societies. After 50 years, the EPS has 42 member societies and represents a very large and varied community of physicists. One of the main objectives of the EPS is to give them a coherent voice despite the existence of many educational, scientific, social and geographic diversities.

Europe has a long lasting tradition of strength in science and technology, and today hosts many of the most important national and international physics research laboratories. Physics is vital to European culture. The new European research program Horizon Europe is being launched to reinforce the intimate link between basic science and technological applications to favour Europe's progress in research and innovation, a major challenge for the future.

Along this line, key questions arise: how important is physics to the economies of European countries? And how worthwhile is it to maintain and increase investment in physics? To address these issues the EPS has commissioned an independent economic analysis from the Centre for Economics and Business Research (Cebr), using statistics available in the public domain through Eurostat. This is the second study, following on the first which was published in 2012. It covers 31 European countries – the EU28 countries, plus Iceland, Norway and Switzerland. Under examination is the 6-year period 2011-2016, 2016 being the most recent year for which official data are simultaneously available for all these countries. The Cebr analysis is contained in a detailed report which was, while the most important results are highlighted here in this Executive Summary. Please see www.eps.org/physicsandeconomy for further details and downloads.

This 6-year snap-shot of the European economy shows that the physics-based industrial sector generated over 16% of total turnover and over 12% of overall employment within Europe's business economy. To give some context to these numbers, the turnover per person employed in the physics-based sector substantially outperforms the construction and retail sectors, and physics-based labour productivity (expressed as gross value added per employee) was significantly higher than in many other broad industrial and business sectors, including manufacturing. The European physics-based sector was also highly R&D intensive and were more resilient in comparison with the wider economy. The thorough analysis of European data, contained in the full Cebr report, can provide us with a deeper understanding of the many achievements and drawbacks within the physics-based sector in the recent past.

Our hope is that the message conveyed by the EPS through the study performed by Cebr will be inspiring for the future, both at the European and national levels, making a convincing case for the support for physics in all of its facets, from education to research, to business and industry.

Petra Rudolf

President of the European Physical Society

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Executive Summary

What is physics?

Physics is the branch of science concerned with the nature, structure and properties of matter, ranging from the smallest scale of elementary particles, to the Universe as a whole. Physics includes experi-ment and theory and involves both fundamental research driven by curiosity, as well as applied research linked to technology. Physics often provides the foundations for other disciplines, and plays a central role in many different sectors of industries.

What are physics-based industries?

Physics-based industries are defined as those sectors of the European economy where the use of physics – in terms of technologies and expertise – is critical to their existence.

This means that the industries considered are those where workers with some training in physics would be expected to be employed and where the activities would be expected to rely heavily on the theories and results of physics to achieve their commercial goals. The list of physics-based industries analysed in this report was obtained from the statistical nomenclature standard NACE (Rev. 2) that is used to classify the different economic activities of the European Union.

The analysis here was based on a subset of 72 NACE codes amongst a total of over 700. Those activities considered include to varying degrees the sectors of electrical, civil, and mechanical engineering, energy, information technology and communications, design and manufacturing, transportation, medicine and related life-science fields, and technologies used in space. These are listed on the inside back cover of this Summary. Depending on the particular datasets analysed in different parts of this study, the size and importance of physics-based industries to the wider European economy were estimated using different comparators of 'business economy' and 'whole economy'. The latter represents a larger comparator than the former which does not include, for example, agriculture, financial, public administration and other non-market services. Under NACE (Rev. 2), there are 65 broad industries categories in the 'whole economy', 49 of which are covered by the 'business economy'.

Complete details of methodology are provided in the appendices to the main report. Introduction and background

Introduction

This Summary describes an analysis of the contribution of the discipline of physics to the economies of Europe over the six-year period 2011-2016 inclusive. The analysis has been prepared by the Centre for Economics and Business Research (Cebr) in order to provide the European Physical Society with an assessment of the importance of physics to the economies of Europe.

The focus of this report is the 28 countries of the European Union (EU28), together with Iceland, Norway and Switzerland, three of the four members of the European Free Trade Association (EFTA). Unless otherwise indicated, the term Europe will be used throughout this Summary to refer to these 31 countries. The report examines the economic contributions of physics using many different measures of economic growth and prosperity, and is based entirely on data that is in the public domain, primarily through Eurostat, the European Union's Statistical Service. The research highlights the value generated by physics-based industries to the economic prosperity of Europe.

Physics-based industries contributes significantly to the economies of European countries and to the European economy as a whole

The turnover (or revenue) of the physics-based industries within Europe has exceeded €4.40 trillion in every year of the period 2011-2016. The maximum turnover of nearly €4.84 trillion was in 2015 which, despite a minor blip in 2013, has been rising steadily from €4.45 trillion

in 2011. The data suggest a slight decline in 2016 to €4.82 but other less volatile indicators suggest that this is a poor indication of performance [Figure 1 - page 9] shows the turnover in physics-based industries in Trillions €.

The physics-based sector typically accounts for 16% of the total turnover of the EU28 business economy, which is more than the gross turnover contribution of the entire retail sector. [Figure 2a] shows the percentage distribution of physics-based industries turnover between the different countries of Europe for the year 2016. The major economies of Western Europe clearly dominate. Similar geographical distributions are observed for all other years in the period of study.

Gross Value Added (GVA) is a measure of the value generated in the production of goods and services and is the official measure of how sectors of the economy contribute to GDP. The GVA of the physics-based industries within Europe has exceeded €1.45 trillion in each year of the period 2011-2016, reaching a high of €1.65 trillion in 2016 (an increase from 2015, in contrast to turnover). The physics-based sector contributes just over 12% of the total GVA of the EU28 economies, a greater fraction than either the construction, financial or retail sectors.

Physics creates over 17 million high-skilled jobs in Europe

Employment of people in physics-based industries within Europe reached 17 million people in 2014. Maximum employment of 17.8 million people was in 2016, a substantial increase from the 16.7 million estimated for 2011. The 2016 level represents more than 12% of Europe's total business economy employment.

Employment and GVA data can be combined to estimate relative workforce productivity in the physics-based sector compared with other sectors within Europe. The period 2011-2016 saw an average GVA per employee of €90,800 per annum in the physics-based industries.

This level is higher than for the manufacturing sector and substantially outperforms the construction and retail sectors. [Figure 2 – page 10] compares the GVA per employee contribution of physics with other sectors of the European economy.

Turnover per employee in the physics-based sector over the same period averaged €253,000 per annum.

This also compares very favourably to other sectors and is over twice the equivalent figure for the construction industries. The physics-based sector can therefore continue to be viewed as a highly productive part of the European economy.

Physics contributes to a broad range of economic activities in Europe

It is important to understand that different sub-sectors of physics-based industries contribute different levels of added value. Averaged over the 2011-2016 period, the three major contributions to physics-based GVA in Europe were from manufacturing (42.5%), information & communication

(14.1%), followed by professional, scientific & technical activities in physics-based fields such as architecture, engineering and R&D (14.1%). This distribution can be seen in [Figure 3 - page 11].

The distributions in employment data are broadly similar. Averaged over the period 2011-2016, the dominant areas of physics-based employment were manufacturing (48.9%), professional, scientific & technical activities (20.6%), and information & communication (9.6%).

Professional, scientific & technical activities continued to provide the area of strongest employment growth during the years 2011-16 in terms of absolute numbers, with the number of persons employed rising by over 500 thousand.

Other physics-based sub-sectors contributing to GVA and employment are transportation, energy production, oil & gas activities, and the treatment of hazardous materials.

Multiplier impacts

The activities of the physics-based sector also impact on the wider economy. For example, the production of physics-based goods and services can have a significant knock-on 'upstream' effect throughout the supply chain when, for example, a physics-based enterprise purchases other goods and services as inputs for their own business. These create a multiplier effect, impacting employment, GVA, and output.

Regarding the latter, this means that for every €1 of physics-based output, a total of €2.49 output is generated throughout the EU28 economy as a whole.

The employment multiplier is higher again at 3.34, which means that for every job in physics-based industries, a total of 3.34 jobs are supported in the economy as a whole by these industries.

Business start-ups and failures

Analysis of business start-up (birth) and failure (death) rates within the EU28 show a slight decline in physics-based enterprise creation over the period 2011-2015. In 2011, new physics-based enterprises were created at a rate of 10.8%, implying around 11 new start-ups for every 100 existing physics-based enterprises. By 2015 however, this rate had declined to 10.4%, which is closer to 10 new enterprises for every 100 already in existence.

Note that this latter figure is slightly lower than the 10.8% birth rate across all sectors of the European economy in 2015 and has been lower every year since 2011. This may suggest greater entry barriers (e.g. the need for higher initial investment) than for other sectors in the wider economy. The observed trend in the creation of physics-based enterprises over the period 2011-2015 was also accompanied by a relatively stable rate of physics-based enterprise insolvency at 8.8%.

However, it is important to note that insolvency rates amongst physics-based enterprises was markedly lower than in the total European economy in the period 2011-2013. The EU28 economy-wide death rate was almost 10% in 2011, but had dropped to 9.1% by 2015. This might suggest that physics-based industries have been more resilient in comparison to the economy as a whole, especially around the time of the European debt crisis in 2012, but that, since 2014, wider enterprise resilience has improved with the macroeconomic upturn.

Investment and R&D

Research and development (R&D) activities are an important investment function in the economy, leading to innovation in new technologies and products and generating economy-wide growth. Unsurprisingly, the European physics-based sector is highly R&D intensive. Physics-based sector expenditure on R&D within the EU28 exceeded €22 billion in every year of the period 2011-2016. The maximum R&D expenditure of €26 billion was in 2015, which accounted for over 66% of the external (B2B) spending of all sectors of the EU28 economy on scientific R&D as an intermediate input.

The absolute magnitudes presented here only provide a partial picture as they do not incorporate external spending on R&D for investment purposes – likely to be a substantial share of a recorded total of €258 billion across all sectors of the EU28 economy. Neither do the numbers capture 'in-house' R&D spending and investment, which is also likely to be significant in the physics-based industries.

International exports

It is interesting to compare how the contribution of physics-based goods and services to total exports in Europe compares with similar data for other some of the individual EU28 economies.

[Figure 4 – page 11] compares the EU28's physics-based exports with those of selected other countries, illustrating the proportion of overall exports that physics-based products and services account for.

Physics-based goods and services contributed, on average, 44% of all exports from the EU28 during the period 2011-2016, which is comparable to the levels observed for Britain, France and across the Eurozone. It is markedly lower than Germany's rate of over 53% but is a good chunk higher than Italy's average rate of less than 36%.

Concluding remarks

The detailed analysis performed by Cebr for the 2011-2016 period allows the role that physics makes to the European economy to be meaningfully compared to other sectors such as manufacturing, construction and retail. Using analysis of measures such as turnover, GVA, employment and multiplier impacts, the summary presented above clearly highlights the importance of physics to the European economy. It is clear that businesses in the physics-based sector continue to contribute significantly to employment, innovation and growth in Europe.

1 Introduction and background

The *Re-assessment of the importance of physics to the economies of Europe* is a new report examining the contribution of physics to the aggregate economy of the 28 EU nations, to its 28 individual national economies and, to the extent facilitated by the available data, the economies of the four non-EU EFTA countries.[1] We analyse how the use of physics has changed in the EU between 2011 and 2016.

This report builds on its predecessor – *The importance of physics to the economies of Europe*, published in January 2013 – and the research continues to highlight the value generated by 'physics-based industries' for the economic prosperity of Europe.[2] However, there are a number of changes since the 2013 report that are important to note at the outset. These are as follows:

- The 2013 report covered the 27 nations that were members of the EU at that time whereas this report includes the 28th member – Croatia – which joined in July 2013.
- This report builds on *The role of physics in driving UK economic growth and prosperity*, a report produced by Cebr for the UK Institute of Physics (IOP) and published in December 2016.[3] In producing that report, Cebr worked closely with IOP to exclude industry activities that can no longer be legitimately classified as 'physics-based' and to include activities that IOP opined should be classified as physics-based. The estimates contained in the 2013 report are therefore established on a different basis to those in this report.[4]

These changes have been reflected in the new set of estimates presented in this report, spanning the period 2011-2016. On some indicators, the data suggest a dramatic rise in the scale of Europe's physics-based industries between the 2010 endpoint for the 2013 report and the 2011 starting point for this report. On other measures, the increases are less dramatic. However, the estimates are not comparable because the 2007-10 estimates do not incorporate the changes above.

Over time, it is also the case that both the quantity and quality of the data available to national and European statistical authorities improve. Data on the physics-based industries that was missing at the time of the 2013 report might have since become available while data that was available at that time will have undergone retrospective revision.

A revision of Cebr's estimates for the 2007-10 period to take account of such retrospective revisions would be a significant undertaking and, as such, was beyond the scope of this study. We are, however, confident that such a revision would eliminate the dramatic increases in the scale of the physics-based industries between 2010 and 2011, observable on some measures when comparing the findings in this report with those presented in the 2013 report.

The report follows the following structure:

- Section 2 presents the results of our analysis of the jobs, turnover and value added contributions made by the physics-based industries – which, combined, we label the physics-based 'sector'.

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[1] The four non-EU European Free Trade Association countries are Iceland, Lichtenstein, Norway and Switzerland. Some data are available for three of these countries – Iceland, Norway and Switzerland – which is incorporated within the estimates for the European physics-based sector that are presented in this report. It was not possible to establish or incorporate any estimates for Lichtenstein. The estimated national-level impacts of physics are presented in tabular form in Appendix I.

[2] A 'physics-based industry' is defined as a category of industrial activities in which the use of physics – in terms of technologies or expertise – is critical to its existence. A fuller outline of this definition is available in Appendix II.

[3] This is available at the following link: https://www.iop.org/publications/iop/2017/file_70263.pdf.

[4] The changes to the list of industries that are defined as physics-based since the 2013 report are set out in Appendix II.

This is based entirely on data from Eurostat's Structural Business Statistics (SBS) database, which is based on information provided by enterprises in the European business economy.

- Section 3 provides our estimates of the direct economic contributions of physics suggested by its analysis within the official 'national' accounting framework for the EU-28 economy. The adapted version of this framework used for this study, in which physics-based industries were given an explicit role, provides the basis for our estimates of the indirect and induced multiplier impacts of physics. The underlying dataset is Eurostat's EU-28 SUIOTs (supply-use input-output tables), which were used in conjunction with assumptions developed based on our analysis of the SBS datasets in Section 2. Labour Force Survey (LFS) data were used to provide a more reliable indication of the contributions of the physics-based sector to employment.
- Section 4 examines the 'survival' of physics-based enterprises in the EU-28, in terms of birth and death rates.
- Section 5 examines the contribution of physics through international trade, investment and research & development.
- Appendix I provides a short compendium of national-level estimates underlying the aggregate results that are the focus of the report.
- Appendix II provides the updated list of industries that have been defined as physics-based for the purposes of our study. It separately identifies the changes in this list – both inclusions and exclusions.
- Appendix III provides more detail on the methodology and data sources used in this study.

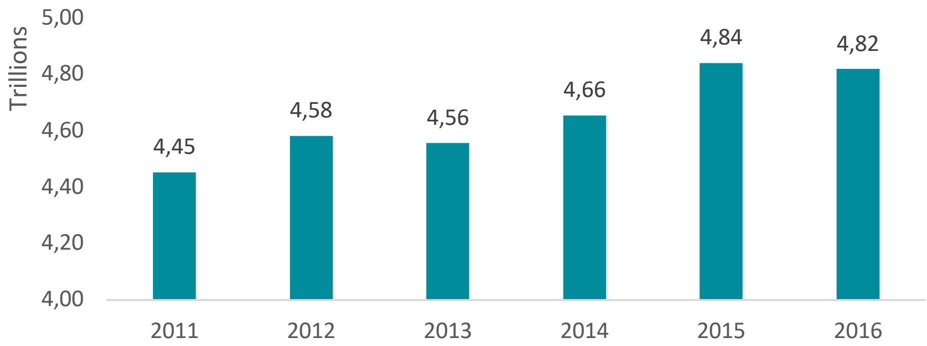
2 Jobs, turnover and value added

This section provides our re-assessment of the importance of physics-based industries to the European 'business economy' in terms of employment, turnover and gross value added over the period 2011-2016.[5] We have been able to analyse these indicators for all EU-28 countries, as well as three of the four EFTA countries – Iceland, Norway and Switzerland.[6] The Europe-wide assessment is supported by the national-level estimates in Appendix I for the most important indicators used in this section.

2.1 Turnover

Here is examined the turnover contribution of physics-based industries to the economies of Europe. Figure 1 shows that physics-based economic activities in Europe generated €4.82 trillion of turnover in 2016. Although this represents a -0.4% contraction on 2015, annual growth averaged 1.6% over the six-year period, meaning an increase in turnover of €367 billion between 2011 and 2016. The strongest year of growth was in 2015 with a 4% year-on-year increase, while the data suggest 2013 as the worst performing year with a -0.6% contraction.

Figure 1: Turnover in physics-based industries, current prices €



Source: Eurostat SBS, Cebr analysis

The strong growth observed in 2015 was helped by 3% growth in France, over 4% growth in Germany, 68% growth in Ireland, 42% growth in Greece, over 10% growth in Switzerland and 11% growth in the UK. The current data suggest that, if the 2016 contraction is to be believed, it is driven by declines in Germany (-1.4%), the Netherlands (-6.4%), Norway (-15.0%), Poland (-4.4%) and the UK (-0.8%). The declines in the latter three, but especially in Norway, can in part be attributed to exchange movements – specifically, the euro (€) has been strengthening against the national currencies of these countries.[7]

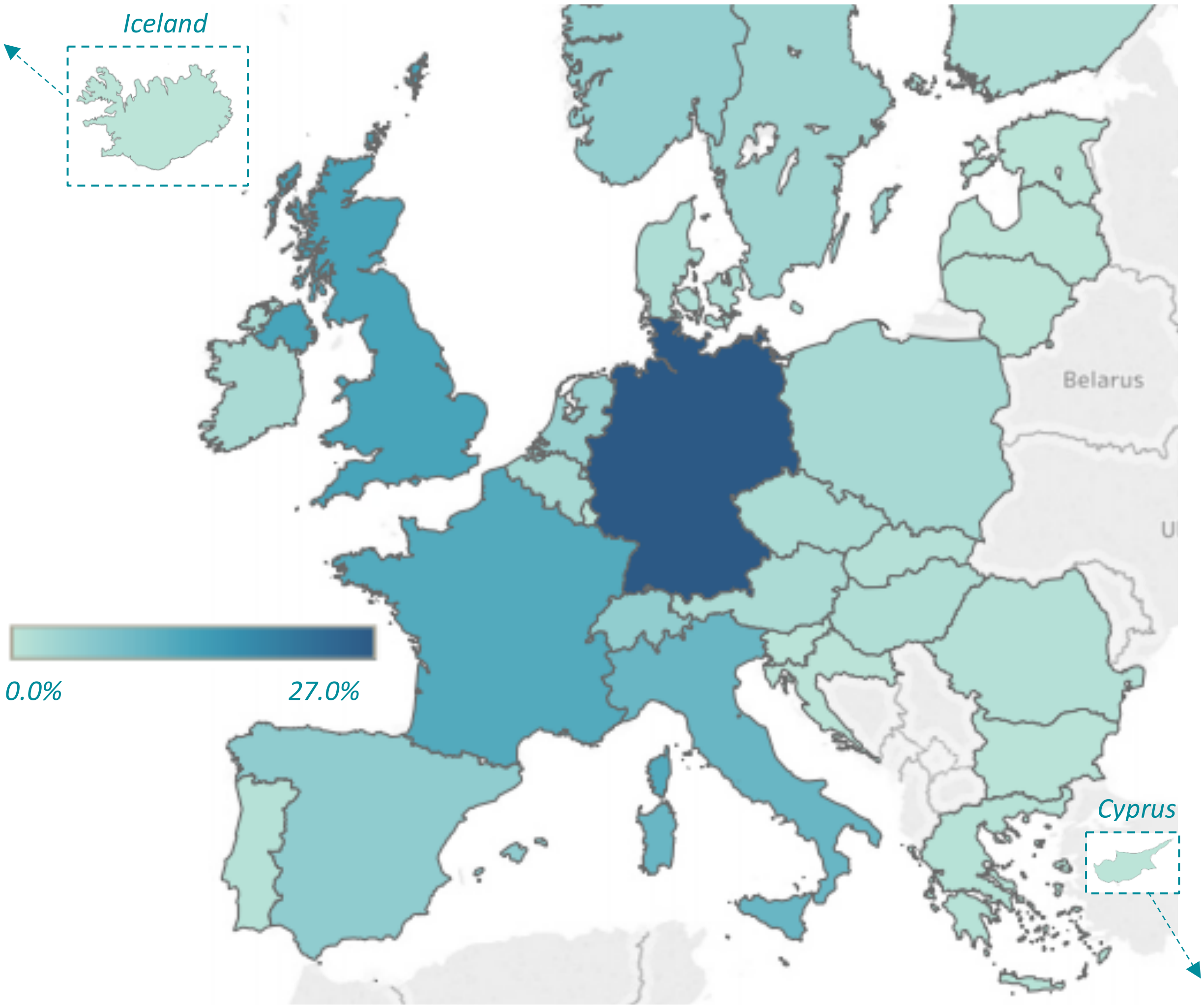
[5] The 'business economy' includes industry, construction and distributive trades and services and defines the scope covered by the Eurostat SBS database. Financial services do not feature because of their specific nature and the limited availability of most types of standard business statistics in this area. Neither does SBS cover agriculture, forestry and fishing, public administration or the (largely) non-market services like education and health.

[6] There are significant gaps in the data for the majority of non-EU EFTA countries. To fill these gaps, it was necessary to produce reasonable approximate estimates using assumptions that are based on the limited data that are available. As such, the estimates for these countries should be interpreted with caution.

[7] This means that when the contributions of these countries' physics-based industries are converted from their domestic currency to euros, they are worth less than they would have been before their currencies weakened relative to the euro.

Figure 2 illustrates each country's share of the turnover of the European physics-based sector. Aggregated over the five-year period 2011-2016, Germany contributed the largest share at 26.5% with the UK (13.0%), France (11.8%) and Italy (9.5%) also making substantial contributions.

Figure 2: Contribution to Europe's total physics-based turnover by country, aggregated 2011 - 2016



Source: Eurostat SBS, Cebr analysis

Figure 3 shows an alternative visualisation of the size of physics-based industries across Europe by turnover, and how they have fared over the years 2011-16.

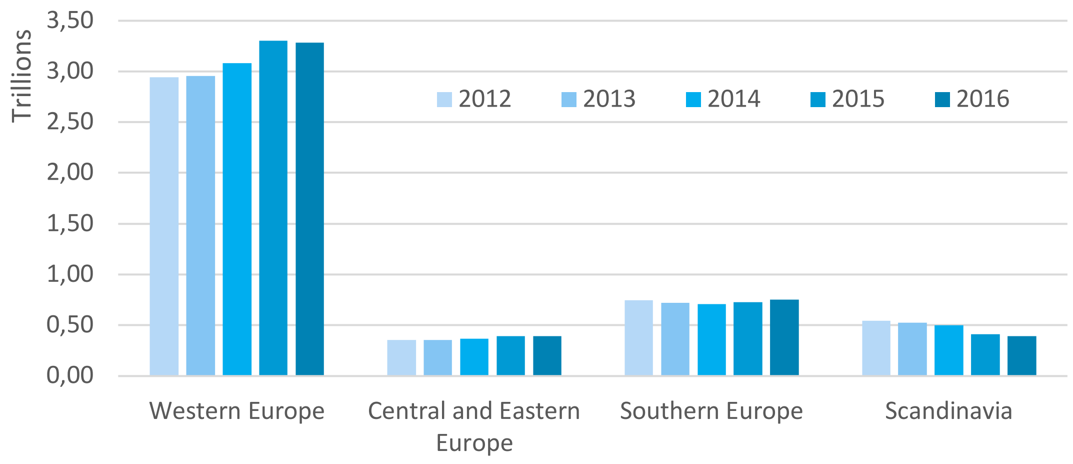
Western Europe (consisting of Austria, Belgium, France, Germany, Ireland, Luxembourg, Netherlands and the United Kingdom) continues to clearly dominate, accounting for two-thirds (66%) of the European physics-based sector's turnover over the six years, and growing faster than in any other region, with annual growth averaging 2.8%.

Southern Europe (defined as Cyprus, Greece, Italy, Malta, Portugal and Spain) is the next largest contributor, with a share of 16% over the 2011-2016 period but growth has been modest, averaging 0.2% per annum.

The four countries of Scandinavia (Denmark, Finland, Norway and Sweden) account for a larger proportion of Europe's physics-based turnover than the eleven Central and Eastern European nations (which are Bulgaria, Croatia, Czech Republic, Estonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovenia and Slovakia). Scandinavia accounts for just over 10%, while Central and Eastern

Europe accounts for 8%, but the data also suggest an annual average contraction in physics-based turnover of -4.1% in Scandinavia, in contrast to annual average growth of 2.2% in Central and Eastern Europe over the period 2011-16.

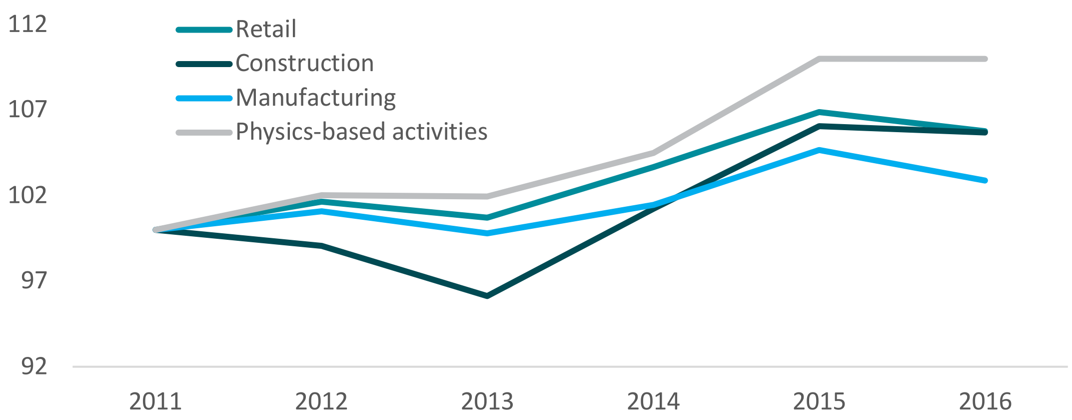
Figure 3: Physics-based turnover in regions of Europe, current prices €



Source: Eurostat SBS, Cebr analysis

Figure 4 provides further context for developments in the overall turnover generated by Europe's physics-based sector, comparing it with trends in the years 2011-16 for other selected broad sectors. From a 2011 base, growth in turnover in the physics-based sector has outperformed the growth in turnover in the comparator sectors of retail, construction and manufacturing. Physics-based turnover appears more resilient to the declines suggested by the data. During these periods, specifically 2013 and 2016 for all sectors, as well as 2012 for construction, the falls in turnover in the retail, construction and manufacturing sectors have been more severe than in the physics-based sector.

Figure 4: Physics-based turnover versus other major sectors, index (2011 = 100)

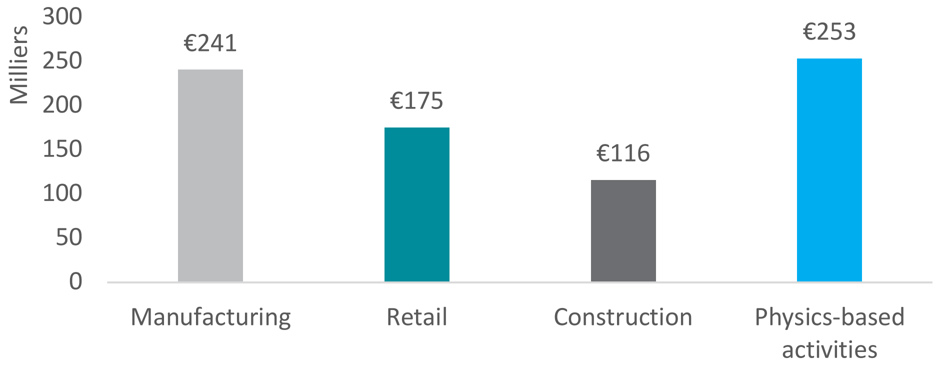


Source: Eurostat SBS, Cebr analysis

The relatively high level of turnover generated by the physics-based sector is further reflected in turnover per person employed in the sector. On this measure, the sector continues to out-perform the broader manufacturing sector.

Figure 5 illustrates that, over the six years 2011-2016, turnover averaged €253 thousand per person employed, about €13 thousand more than the €241 thousand generated in the manufacturing sector, a 'gap' that has shrunk from the €30 thousand presented for the 2007-2010 period in our 2013 report. The physics-based sector substantially outperforms the retail and construction sectors on this measure. Physics-related activities generated 44% more turnover per employee than in retail and double that in construction over the period 2011-16.

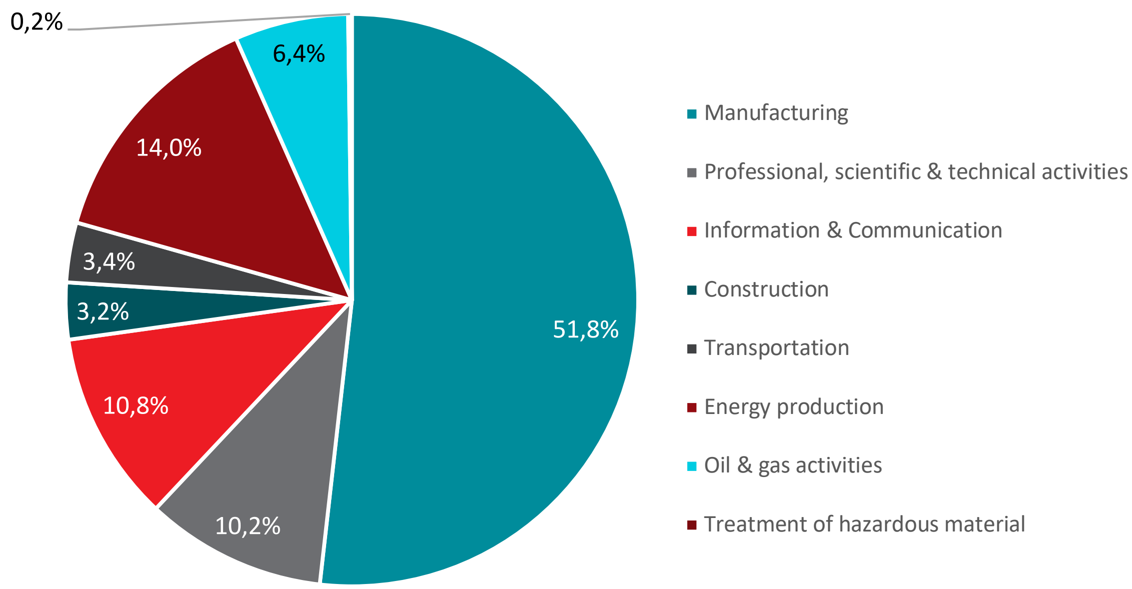
Figure 5: Annual turnover per person employed in selected sectors, average over 2011 - 2016, current prices €



Source: Eurostat SBS, Cebr analysis

The physics-based sector consists of industries that themselves form elements of other broad sectors of the economy as traditionally defined for national and international statistical purposes. Figure 6 provides a visual representation and shows that a majority of 51.8% of the turnover of the European physics-based sector is made up of physics-based manufacturing industries. Other prominent contributors are physics-based industries from the sectors of energy production (14.0%), information and communications (10.8%), and professional, scientific and technical activities (10.2%).

Figure 6: Industry shares of physics-based sector turnover



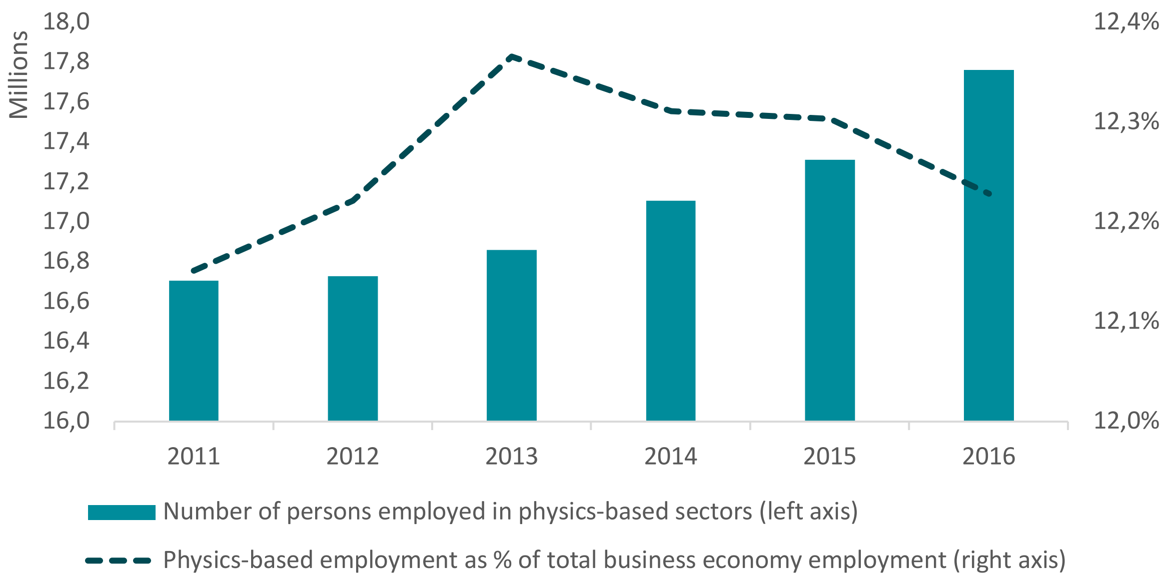
Source: Eurostat SBS, Cebr analysis

2.2 Employment

Turnover is an inherently more volatile indicator of economic importance as it is subject to the fluctuations in demand (due to changing propensities to spend and save) and supply (such as changing input costs and inventory cycles). A more stable indicator is the number of people employed.

We estimate that European physics-based industries accounted for the employment of 16.7 million people in Europe in 2011 but this figure has increased every year to just under 17.8 million in 2016. Figure 7 also shows only marginal changes in the share of physics-based employment in the total business economy. The peak of almost 12.4% in 2013 means that the decline in overall employment was greater (in relative terms) than the increase in the physics-based workforce in that year, while the 2014-16 trend is a function of the pickup in overall employment in those years given the steadily increasing size of the physics-based workforce.

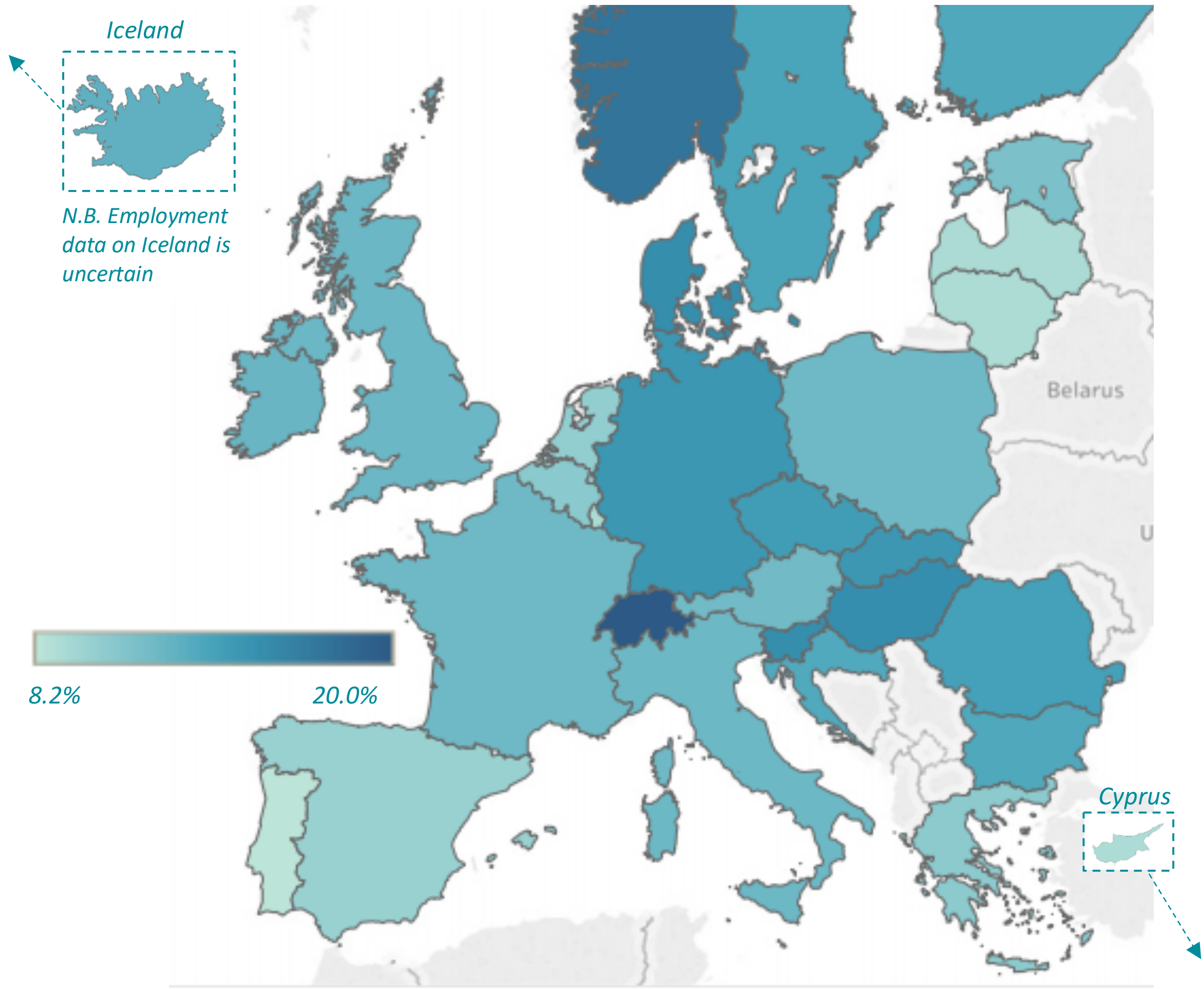
Figure 7: Physics-based employment and percentage of overall business economy employment accounted for by physics-based industries, 2011-2016



Source: Eurostat SBS, Cebr analysis

Figure 8 illustrates the variation in the proportions of employment accounted for by the physics-based industries in each country under analysis. The two nations with the highest proportion of physics-based employment are the European Free Trade Association (EFTA) members, Switzerland and Norway, with 20.0% and 16.5% of their respective workforces belonging to physics-based industries. The nations with the smallest proportions are Portugal (6.7%), Cyprus (7.4%), and Lithuania (7.5%).

Figure 8: Physics employment density: percentage of business economy employment accounted for by physics-based industries by country; 2011-2016

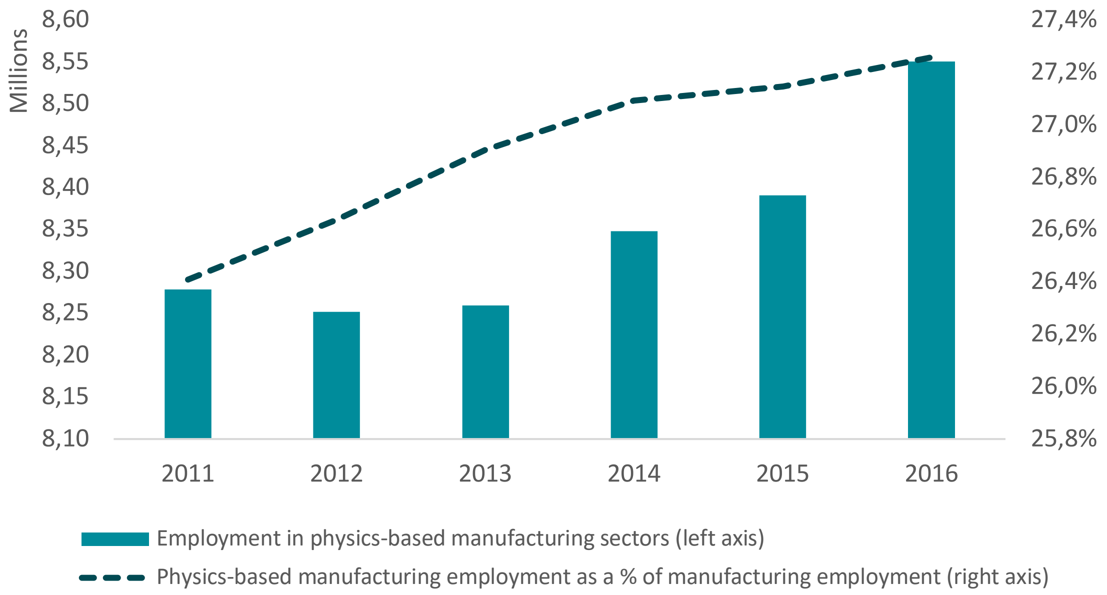


Source: Eurostat SBS, Cebr analysis

A large share (48.9%) of employment in the physics-based industries continues to be accounted for by manufacturing activities. This means that the performance of the manufacturing sector can be expected to have a bearing upon the employment levels and profiles of the physics-based industries. But, over the period 2011-16, employment within Europe's manufacturing sector has grown by only 0.7% compared to a 3.3% increase in physics-based manufacturing employment.

Figure 9 illustrates that employment within physics-based manufacturing industries increased from 8.3 million in 2011 to around 8.6 million in 2016. The share of physics-based manufacturing employment in overall manufacturing employment rose in every year. This suggests that manufacturing activities utilising some degree of physics are becoming more important in the wider manufacturing sector.

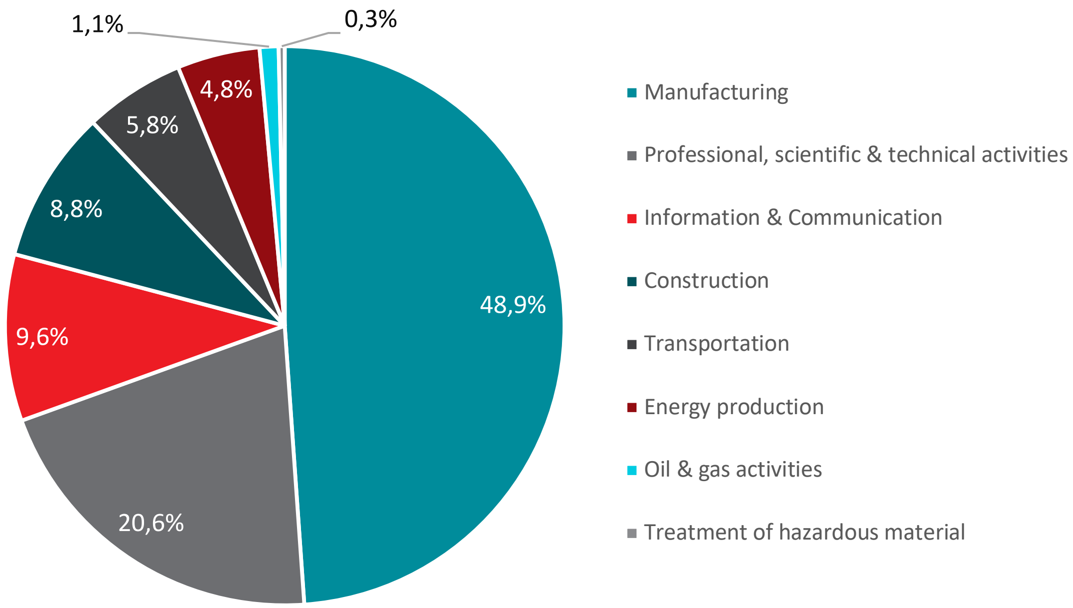
Figure 9: Physics-based manufacturing employment in Europe, 2011-2016



Source: Eurostat SBS, Cebr analysis

While manufacturing continues to account for the lion's share of physics-based employment, Figure 10 demonstrates the other broad categories of activities that are dependent on physics. These are not insignificant, with professional, scientific and technical activities accounting for employment totalling 3.8 million in 2016 in fields where physics is important like architecture, engineering and research and development. In the same year, the information and communication sector is estimated to have provided 1.7 million jobs through physics-based activities related to telecommunications.

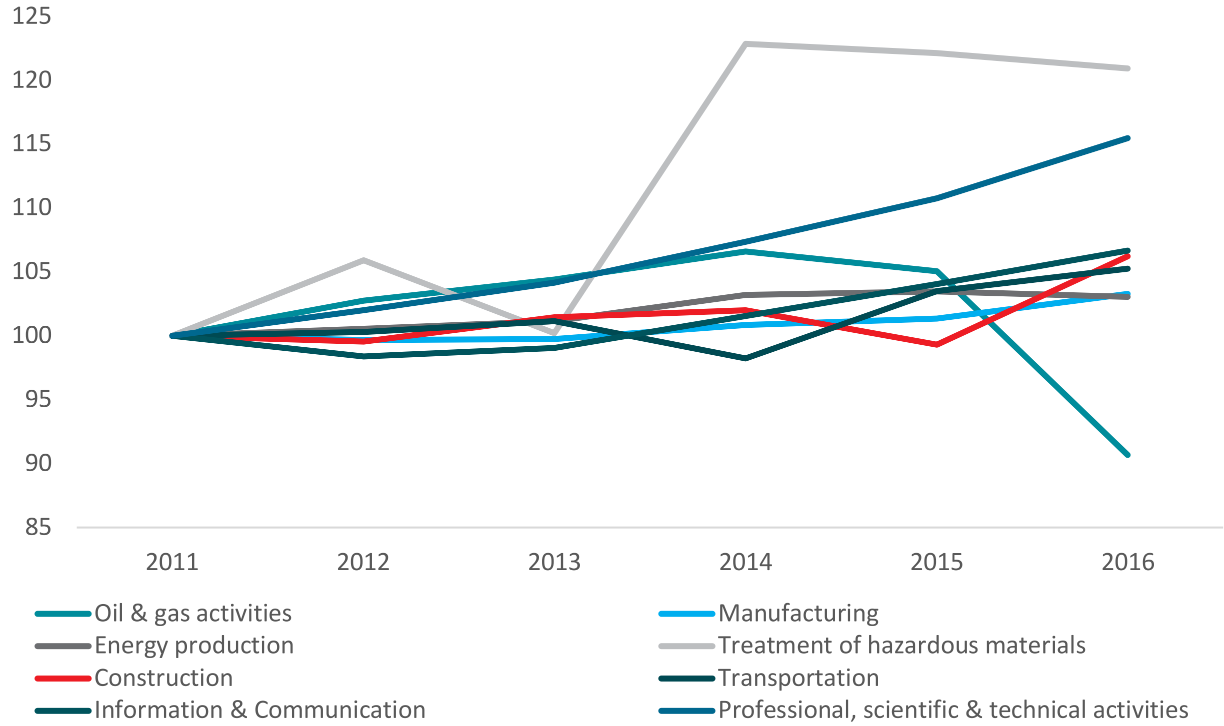
Figure 10: Physics-based employment by broad sector, average share over 2011-2016



Source: Eurostat SBS, Cebr analysis

The proportions illustrated in Figure 10 are not static when viewed across the individual years of the analysis. Some sectors have experienced growth in their share of physics-based employment, while others have undergone declines in theirs. Figure 11 indicates the development of physics-based employment from the different broad sectors, relative to 2011 levels.

Figure 11: Physics-based employment by broad sector, index (2011=100)



Source: Eurostat SBS, Cebr analysis

The starkest increase over the period is again observed in the treatment of hazardous materials sector, referring to the re-processing and/or disposal of hazardous industrial or radioactive waste. But this sector continues to be a relatively small contributor to overall physics-based employment, and the increase of 20.9% represents a rise in employment of approximately 11,000 people.

Oil and gas was the only sector seeing declines in the number of physics-dependent jobs over the period 2011-16, with a 9.3% decline. The other sectors experiencing growth in physics-based employment include construction (6.2%), energy production (3.0%), information and communications (6.7%), transportation (5.3%) and professional and technical services (15.5%). The latter, representing physics-based engineering, technical consultancy and research and development, continues to provide the area of strongest employment growth during the years 2011-16 in terms of absolute numbers, with the number of persons employed rising by over 500 thousand.

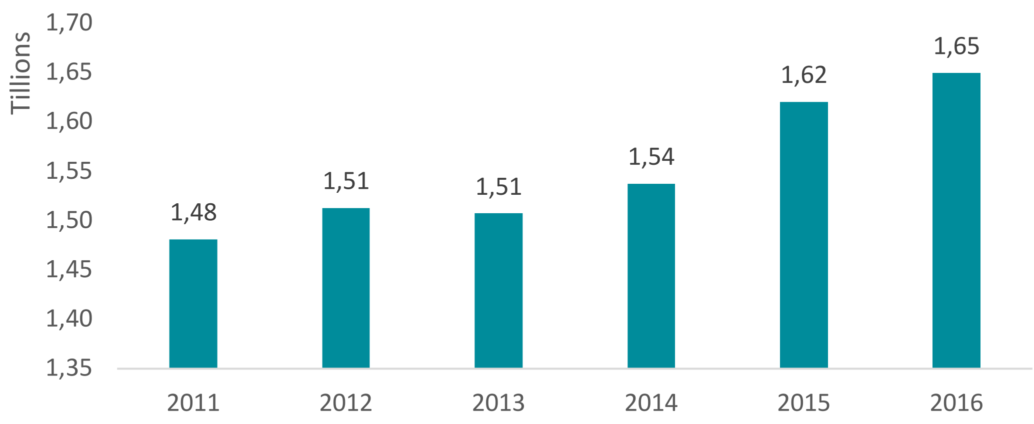
The European economy saw an increase in employment of approximately 5.6%% over the years under review, which was outperformed by the 6.3% achieved by the physics-based industries. The resilience of the physics-based industries in terms of retaining and adding jobs will have made a significant contribution to the more recent improvements in the European labour market and wider economy.

2.3 Value added

We now focus on the economic contribution of the physics-based industries (or sector) to the European economy in terms of their *value added*. This is a measure of the economic output of a sector, industry or economy, having subtracted from turnover the cost of the inputs of goods and services that were required to generate it. Value added captures how much value is added to these inputs in the production process by labour – physics-based employees – and capital – the tangible and non-tangible assets available to the industries – and is the formal representation of how industries contribute directly to GDP (the formal measure of the size of an economy).

Figure 12 shows that the value added contribution of the European physics-based sector stood at €1.48 trillion in 2011, but was 11.4% larger at €1.65 trillion by 2016. The only year of decline was in 2013, but it rebounded in 2014 to exceed the 2012 level and grew strongly (by 5.4%) in 2015. Growth in 2016 of 1.8% is in stark contrast to the apparent decline in turnover reported above.

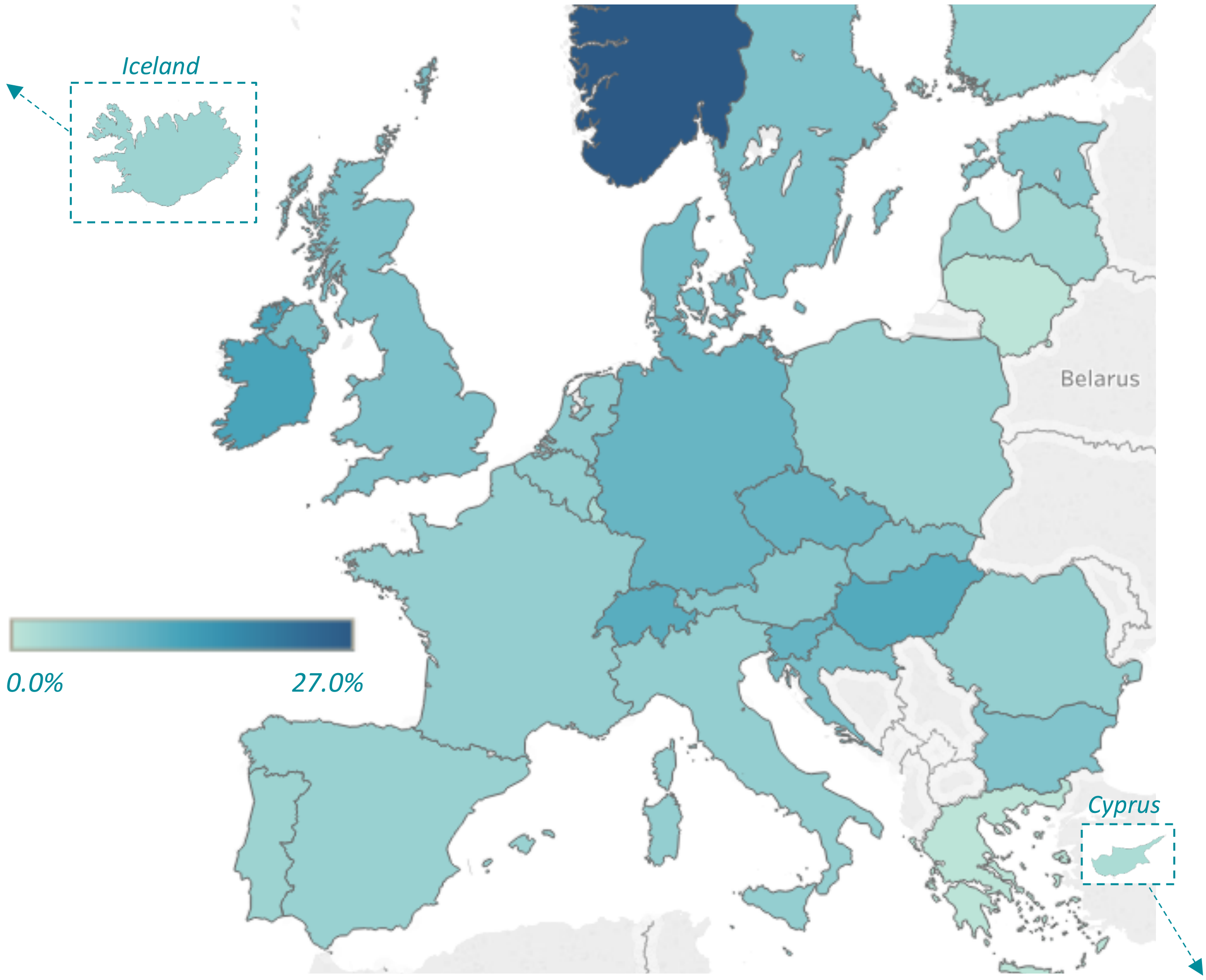
Figure 12: Value added in physics-based industries, current prices €



Source: Eurostat SBS, Cebr analysis

Figure 13 illustrates the differences in the importance of the physics-based industries in different countries across Europe in generating value and thereby contributing to overall domestic economic performance. This was achieved through a measure of the physics-based sector's value added contribution as a share of national GDP.

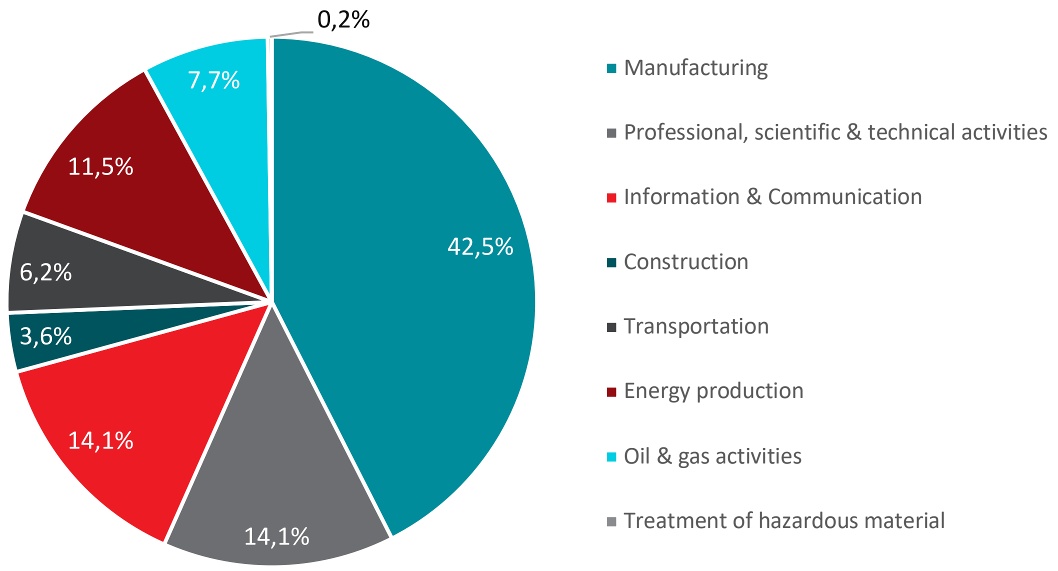
Figure 13: Physics density: Map illustrating physics-based sector value added as a proportion of GDP within nations, average 2011-2016



Source: Eurostat SBS, Cebr analysis

Each industry within the physics-based sector does not, however, contribute value added at the same rate. The majority share again continues to be accounted for by physics-based manufacturing, as illustrated in Figure 14. Between the years 2011 and 2016, physics-based manufacturing contributed an average share of 42.5% of the physics-based sector's value added. The other significant contributors are the information and communications (14.1%), professional, scientific & technical (14.1%) and energy production (11.5%) sectors.

Figure 14: Physics-based value added accounted for by category of physics-based industry, average 2011-2016

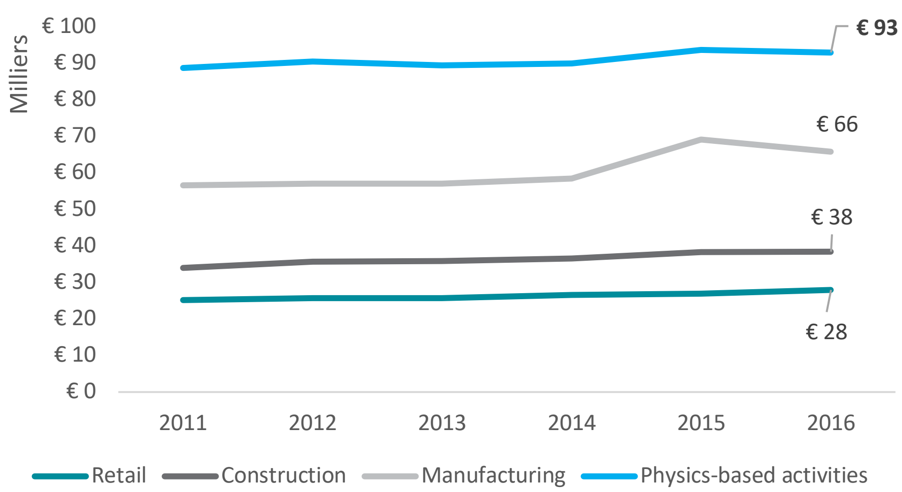


Source: Eurostat SBS, Cebr analysis

These value added data can, in conjunction with the corresponding employment data, be used to provide a comparative measure of labour productivity in the physics-based sector relative to other sectors. Figure 15 compares this measure – value added per person employed – for the physics-based sector relative to the same sectors we have been using up to now. This suggests that the physics-based sector's labour productivity continues to measure significantly higher than any of these other broad sectors.

Throughout the period under consideration, an employee in the physics-based sector contributed an average of €90,800 per annum in value added. This is markedly above the manufacturing sector's productivity, which averaged €60,600, is over twice the equivalent figure of €39,500 in the construction industry and more than triple that of the retail sector at €26,300 per worker. Figure 15 shows the equivalent values for 2016, the latest year in the period under review.

Figure 15: Apparent labour productivity (value added per person employed per year), 2011-2016,



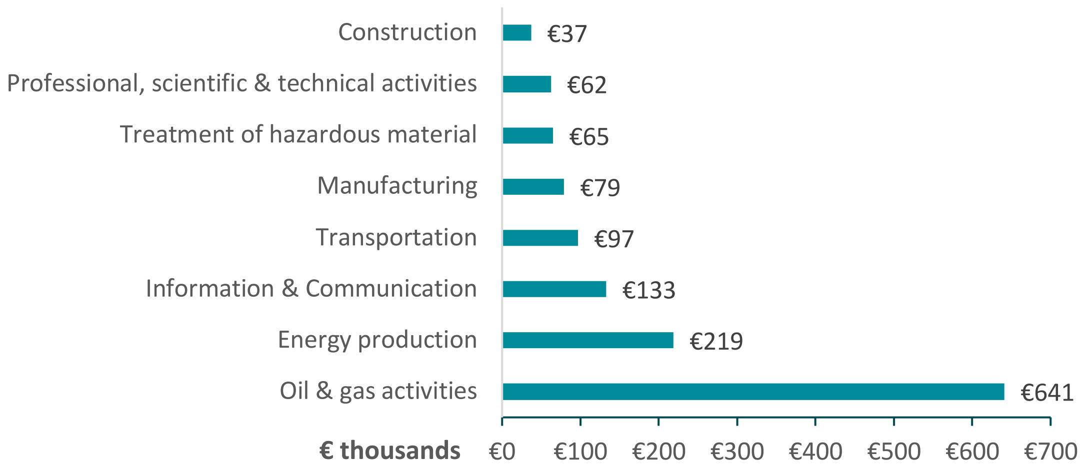
Source: Eurostat SBS, Cebr analysis

We would continue to suggest, as we did in our 2013 report, that the technology-intensive nature of physics-dependent activities produces greater labour productivity than is observed on average based on this value added per worker measure. Physics-based activities are not, of course, homogeneous and within the physics-based sector, significant disparities can be observed between the productivity levels of different types of physics-based activity.

Figure 16 illustrates the large divergences between the value added per person employed generated amongst the different categories of physics-based activities. Employees in the physics-based industries that are part of the oil and gas sector provide a significant boost to the physics-based sector's overall productivity levels. Without it, the physics-based sector's average GVA per person employed would have been £84,750 for the 2011-16 period.[8] But, as we also reported in 2013, this would still be markedly above the other broad sectors considered above. In other words, even if the mining and quarrying outlier is excluded, the physics-based sector outperforms the productivity of the manufacturing, construction and retail sectors (as per Figure 15 above.

Another interesting finding is the extent to which the inclusion of Norway drives the €641,000 figure for the European physics-based oil & gas sector in Figure 16. Taking the EU-28 in isolation, the equivalent figure is €384,000. Furthermore, physics-based manufacturing activities generate more value added per person employed (approximately €79,100 in the years 2011-16) than the wider manufacturing sector (€60,600 as noted above). It is still possible to suggest, as we did in 2013, that those production processes that draw more heavily upon physics sustain a greater level of labour productivity relative to the average for manufacturing as a whole.

Figure 16: Average labour productivity (value added per person employed) within categories of physics-based industries, average 2011-2016, current prices (categorisation by traditional broad sector)



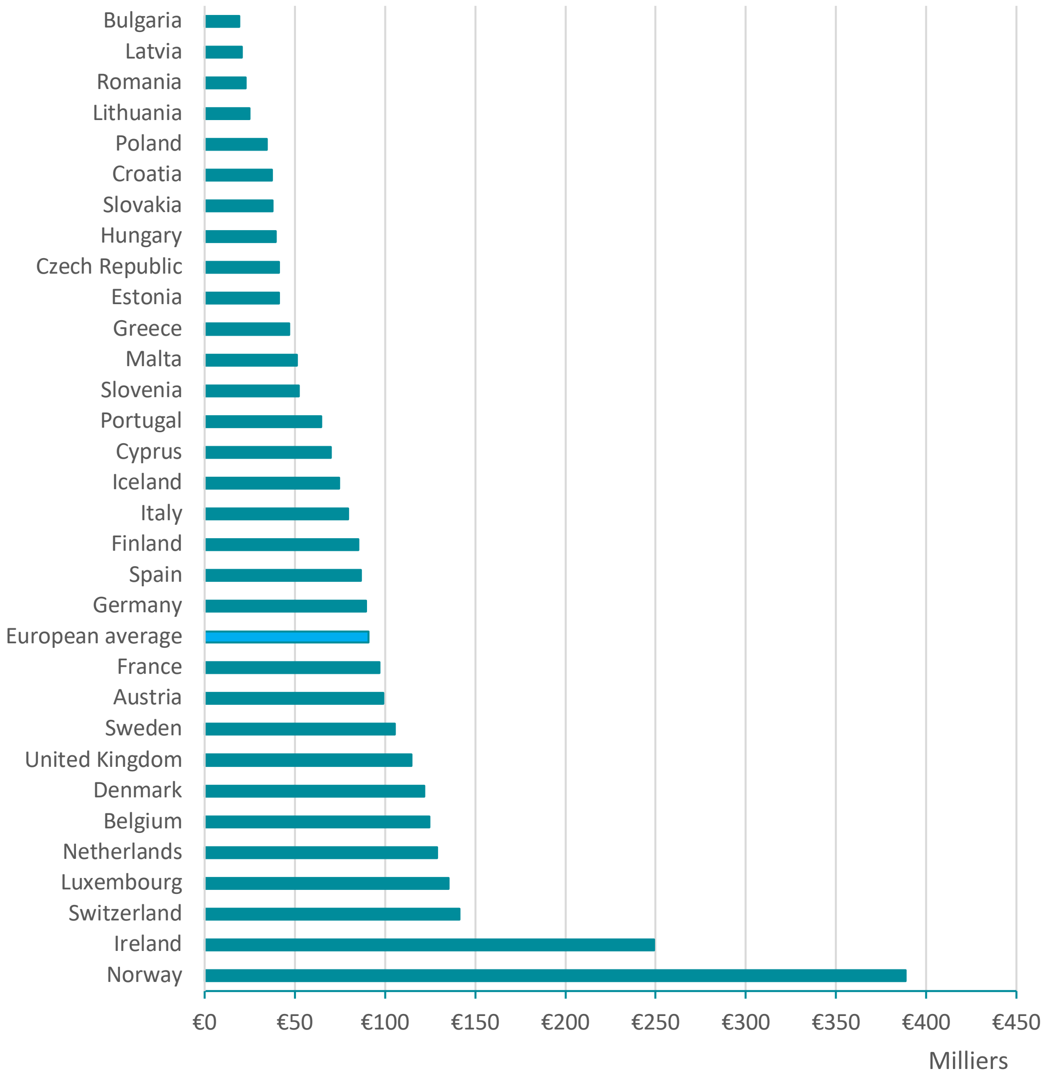
Source: Eurostat SBS, Cebr analysis

Figure 17 offers some insight into the country-by-country variation in labour productivity that is also clear in Figure 18. Norway continues to have the highest rate of value added per person employed across all physics-based activities, averaging €388,400 over the six-year period under review, which shows the impact of its extremely productive oil and gas activities on this productivity measure for its national physics-based sector. This is despite the significant depreciation by 15% in the value of

[8] The exclusion of energy production, as well as oil and gas, would mean an average GVA per person employed in the physics-based sector of £78,000 across the period. This is also still higher than the broad construction, manufacturing and retail sectors.

Norway's national currency relative to the euro, the denomination for the statistics presented in this report.

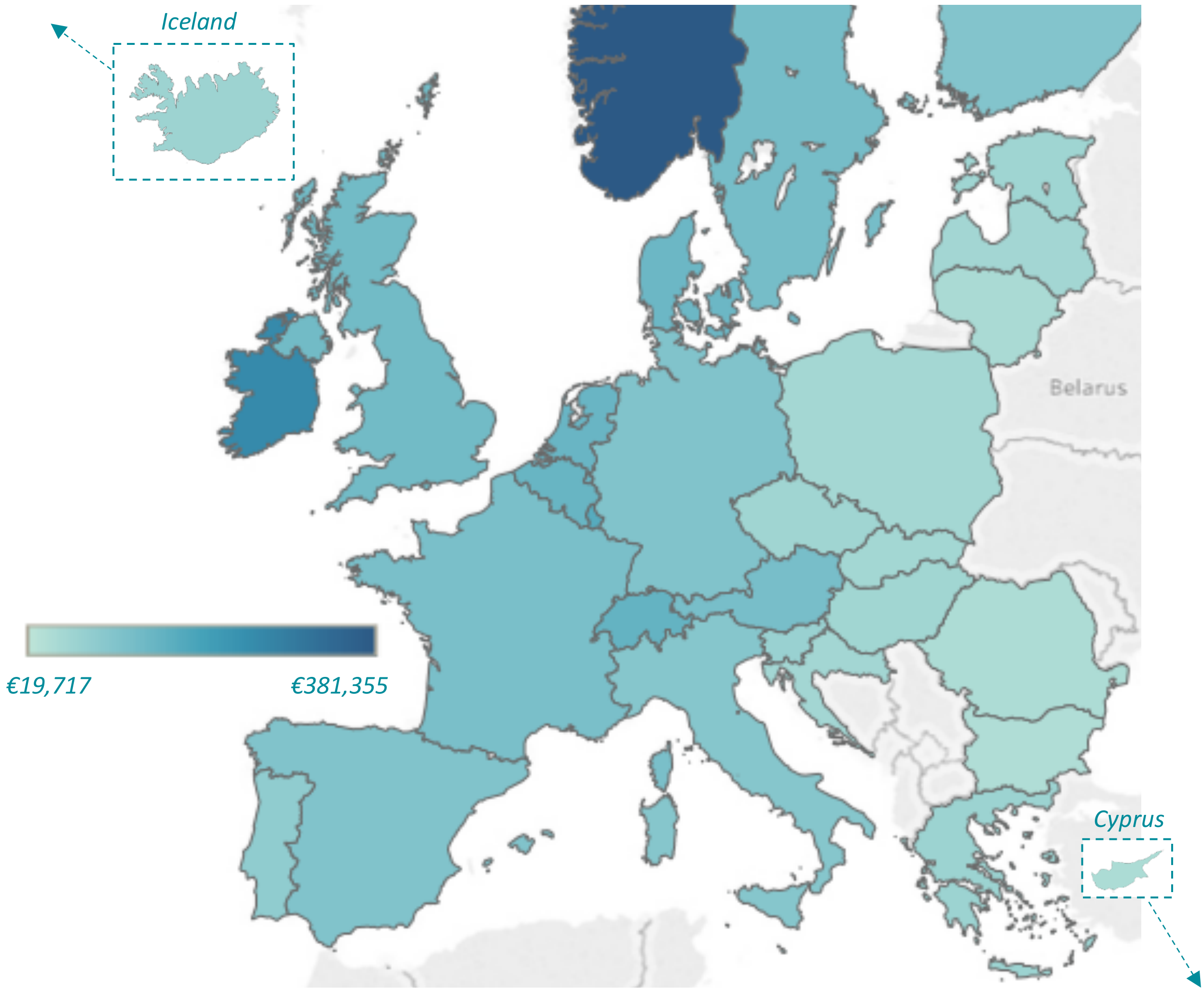
Figure 17: Comparison of country-level physics-based productivity, GVA per worker per year, average 2011-2016



Source: Eurostat SBS, Cebr analysis

An alternative visualisation of the same country-by-country comparison is offered by the heat map in Figure 18 below.

Figure 18: Productivity in physics-based sectors, value added per person per year, average 2011-2016



Source: Eurostat SBS, Cebr analysis

3 Direct economic contributions and multiplier impacts

This section provides our estimates of the direct economic contributions of Europe's physics-based industries suggested by their analysis within a formal 'national' accounting framework. This framework, which is adapted to give physics-based industries an explicit role, also provided the basis for our estimates of the indirect and induced multiplier impacts of physics.

For this analysis, we used the EU-28 SUIOTs (supply-use input-output tables) in conjunction with assumptions developed based on our analysis of the SBS datasets in Section 2. The set of consolidated national accounts drawn upon is limited to the EU-28, so the estimates in this section are limited to the EU-28, rather than to our broader definition of Europe used in Section 2, which included Iceland, Norway and Switzerland. The latest year for which a complete set of national accounting data covering the entire EU-28 is currently 2015 and, as such, the estimates presented are based on 2015 data.

3.1 Output at basic prices

The estimates of output in this section can be considered analogous to the turnover data presented in Section 2.1 above. There are differences between output at basic prices and turnover, with the latter data requiring adjustments to be made for:

- the transition from producers' prices (the basis of turnover) to basic prices, which means accounting for things like the value of unsold inventories and indirect taxes other than VAT (which is already excluded from turnover) such as excise and other duties (see Appendix III); and
- the fact that all of the production activities of the physics-based industries (and businesses that make up those industries) may not be physics-based and that some non-physics-based industries might be engaged in activities that are physics-based.

These estimates of output at basic prices are presented immediately below, followed by the indirect and induced impacts of physics-based activities on output in the wider economy.

Direct impact

According to our estimates, aggregate output at basic prices of the physics-based sector was €4.15 trillion in 2015. This compares with an SBS-based turnover estimate of €4.48 trillion for the EU-28, the difference amounting to Cebr's estimate of the impact of the aforementioned adjustments to SBS-based turnover data (at producers' prices) to arrive at estimates of output at basic prices. Of the €4.15 trillion of the sector's output, over 95% is estimated to be output of physics-based goods and services.[9]

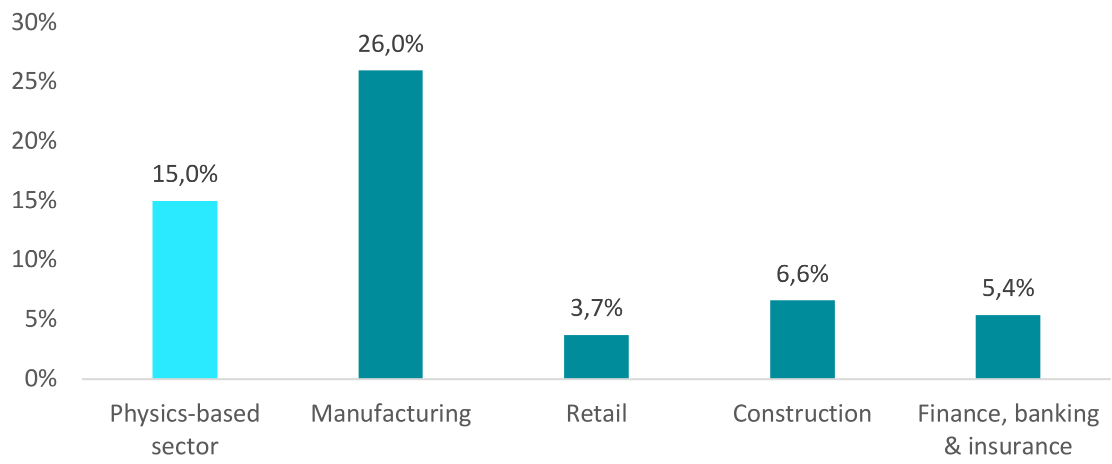
This equates to €3.96 trillion of supply of physics-based goods and services produced by the physics-based sector in 2015. This, in turn, constitutes 76% of total EU-wide output of physics-based goods and services, that is, including the production of physics-based goods and services by industries that

[9] This means that €194 billion of the physics-based sector's output in 2015 was non-physics based. In adapting the EU-28 supply table, we assumed that the detailed 3-4-digit physics-based industries' production of non-physics-based output followed the same pattern as the broader 2-digit industry of which they formed part. This allows for the expectation that it is unlikely that the physics-based industries would limit themselves to the sale of physics-based goods and services that is their primary concern if commercial opportunities also arose for any by-products, which could include anything from, for example, scrap metal to highly valued expertise that can be sold to others.

are not classified as physics-based. We estimate the total output of physics-based goods and services in the EU-28 in 2015 was €5.22 trillion.

Figure 19 shows how the physics-based sector has continued to contribute more than the combined output contributions of the construction and retail sectors and over half the size of the share of EU-28 output contributed by the entire manufacturing sector (which includes many physics-based industries).

Figure 19: Selected sectors' shares of EU-28-wide output at basic prices, 2015



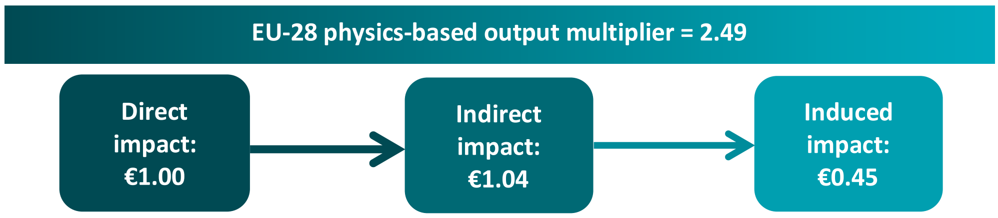
Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

However, whereas the contribution of the physics-based sector is estimated at 15% of output across all industries and sectors of the EU-28 economy, the output of physics-based goods and services is estimated to constitute 19% of the output across all categories of goods and services produced in the EU-28 economy.

Indirect and induced multiplier impacts

Figure 20 illustrates our estimate of the indirect and induced multiplier impacts of every €1 of production of physics-based goods and services.

Figure 20: The EU-28 physics-based output multiplier, 2015



Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

From Figure 20 can be derived two types of physics-based output multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.04. That is, for every €1 of physics-based output, the economy-wide output due to direct and indirect supply chain impacts is €2.04. Note that the indirect impact of €1.04 is equivalent to the upstream impact of every €1 of physics-based production, that is, a valuation of the economic activity supported in the industries from which the providers of physics-based goods and services purchase other goods and services as inputs for their own production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.49. That is, for every €1 of physics-based output, the economy-wide increase in output due to direct, indirect and induced impacts is €2.49. Note also that the induced impact of €0.45 represents the employee spending impact of physics-based production.

On this basis, the physics-based sector's direct contribution of €4.15 trillion in output at basic prices in 2015 multiplies to a €10.33 trillion aggregate output 'footprint' once these additional indirect and induced impacts are accounted for.

Downstream impacts

By supplying goods and services to other industries, producers of physics-based goods and services help to support the economic activity carried out by these other industries. We estimate that other industries relied on physics-based goods and services (as intermediate inputs) valued at €1.93 trillion in 2015, with €0.63 trillion being consumed by the physics-based industries themselves.

The latter figure, along with €1.52 trillion of intermediate inputs supplied by other non-physics-based industries, supported the production of the €4.15 trillion of the physics-based and non-physics-based goods and services output of the physics-based sector.

The remainder of the €1.93 trillion of physics-based intermediate inputs that are not used by the physics-based industries themselves will have supported the production of significant amounts of output in a wide range of other industries as well. Other than presenting the entirety of the output of these other industries, the evidence does not exist to be able to measure the extent to which the output of any sector is reliant (and could not be produced without) the relevant set of physics-based inputs.

Final demand

The use of the remainder of the estimated €5.22 trillion of physics-based goods and services output (produced by the physics-based sector and non-physics-based sectors) comes from sources of final demand, including household and government consumption expenditure (approximately 15.5%), purchases for investment purposes (17.9%) and exports (18.1%).

3.2 Gross value added (GVA) contributions to GDP

This section re-visits the contribution of the physics-based sector in terms of its *value added*. In a national accounting setting, the term used is *gross value added* or GVA which, as already noted, is the formal measurement of how industries contribute to GDP.[10]

Direct impact

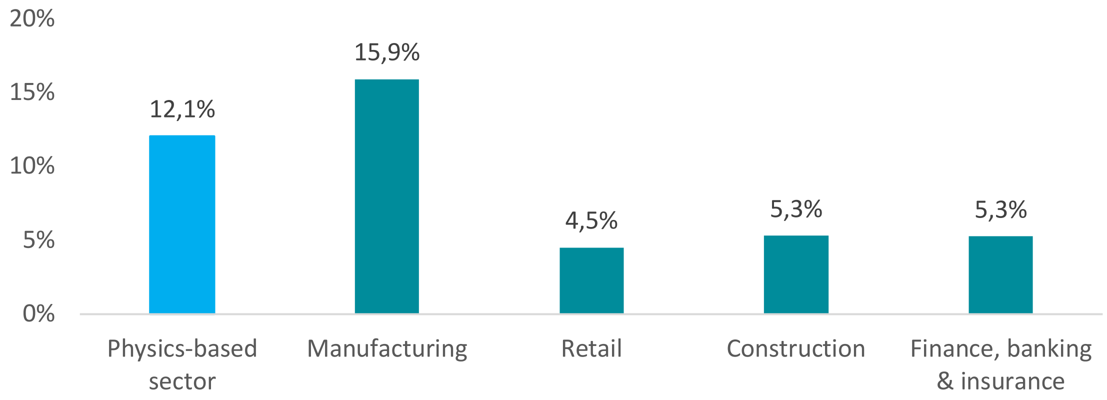
According to our new estimates, the aggregate GVA of the physics-based sector was €1.59 trillion in 2015. This compares with a SBS-based estimate of €1.45 trillion for the EU-28. The difference for the

[10] GVA, or gross value added, is a measure of the value from production in the national accounts and can be thought of as the value of industrial output less intermediate consumption. That is, the value of what is produced less the value of the intermediate goods and services used as inputs to produce it. GVA is also commonly known as income from production and is distributed in three directions – to employees, to investors and to government. GVA is linked as a measurement to GDP – both being a measure of economic output. Formally, that relationship is (GVA + Taxes on products - Subsidies on products = GDP). Because taxes and subsidies on individual product categories are only available at the whole economy level (rather than at the sectoral or regional level), GVA tends to be used for measuring things like gross regional domestic product and other measures of economic output of entities that are smaller than the whole economy, such as the physics-based sector. As noted in Section 2, GVA in the national accounts is valued at basic prices, as distinct from the value added concept used in section 2.3, which is based on producers' prices.

EU-28 is larger than in the 2013 report, but still amounts to Cebr's estimate of the impact of the adjustments to SBS-based data introduced above and outlined in Appendix III.

This €1.59 trillion of GVA constitutes a 12.1% share of EU28-wide GVA. This is compared with the same selection of other sectors in Figure 21 below.

Figure 21: Broad sector shares of EU-28 wide GVA, 2015



Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

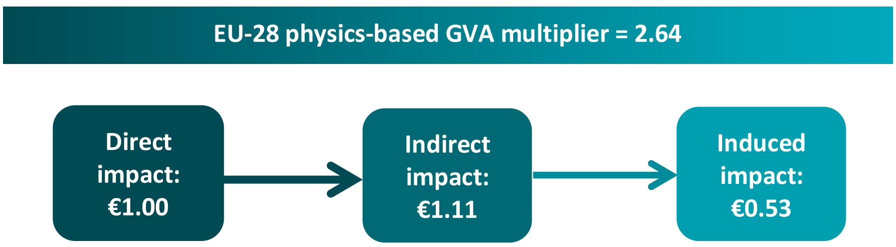
As this figure shows, the physics-based sector continues to contribute a greater share of EU-28 GVA than either the construction, financial or retail sectors.

But it also shows that the gap between the physics-based and manufacturing sectors is significantly smaller than was observed in the case of output (or turnover). This means that the physics-based sector generates more GVA per €1 of output (on average) than the manufacturing sector which is, in turn, a reflection of the productivity differential between these sectors (see Figure 15 above).

Indirect and induced multiplier impacts

Figure 22 illustrates our estimates of the indirect and induced GVA multiplier impacts of production in the physics-based sector.

Figure 22: The EU-28 physics-based GVA multiplier, 2015



Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

From Figure 19 can be derived two types of physics-based GVA multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.11. That is, for every €1 of physics-based GVA, a further €1.11 of GVA is generated by the physics-based sector's supply chain. This indirect impact of €1.11 is equivalent to the upstream impact of every €1 of GVA generated from physics-based production. That is, the gross value added generated as a result of the economic activity in the industries from which the physics-based sector purchases other goods and services as inputs for their production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.64. That is, for every €1 of physics-based GVA, a total economy-wide impact of €2.64 on GVA is produced as a result of direct, indirect and induced impacts. The induced impact of €0.53 represents the employee spending impact of physics-based production and is generated in the sectors that provide final goods and services to households when physics-based employees and their supply chain counterparts spend their earnings, thus supporting the wider economy.

On this basis, the physics-based sector's direct GVA contribution of €1.59 trillion in 2015 multiplies to an aggregate €4.21 trillion GVA 'footprint' once these additional indirect and induced impacts are accounted for.

We note that the sector's GVA multipliers continue to be higher than the corresponding output multipliers. The logic here is that the upstream industries supported by physics-based production have, on average, relatively high GVA-to-output ratios, so that the indirect GVA impact is proportionately greater than the indirect output impact.

It is also worthy of note that both multipliers have increased since the 2013 report – in the case of output, from 2.28 to 2.49 and, in the case of GVA, from 2.49 to the 2.64 above. In both cases, this is driven by an increase in the induced multiplier impacts that is to some extent counteracted by reductions in the estimates of the indirect multiplier impacts. The former is the result of a more robust input-output modelling approach that required fewer adjustments to the raw data and, as such, produced less conservative estimates of induced impact than those produced for the 2013 report.

The indirect impact estimates are less likely to have been affected by the modelling adjustment, but would be difficult to explain further without deeper investigation. A 'cold' reading of the numbers would lead to the suggestion that the European physics-based sector has become less reliant on its supply chain.

This is possible but such a simple interpretation would risk ignoring what is likely to be a complex set of industry dynamics – such as rising and falling input prices, technological developments that impact on the number or type of inputs required in physics-based production as well as the supply chain dynamics that can characterise production 'life-cycles'. Another contributing factor would be if the physics-based sector is itself succeeding in achieving relatively high (by historical standards) prices for its own output, thus increasing the size of the sector's direct impacts relative to its indirect and induced impacts.[11]

3.3 Employment

The results presented in this section draw on data from the 2015 Labour Force Survey (LFS). As we first noted in our 2013 report, SBS does not provide employment data for sectors that sit outside the business economy covered by SBS, whereas the LFS is economy-wide. Because the LFS is the dedicated survey for the labour market, it is also likely to be more robust and accurate than SBS. Furthermore, to estimate employment multipliers, we required employment data for all sectors that can only be sourced from LFS and so, for consistency purposes, the estimates in this section are all based on LFS data.

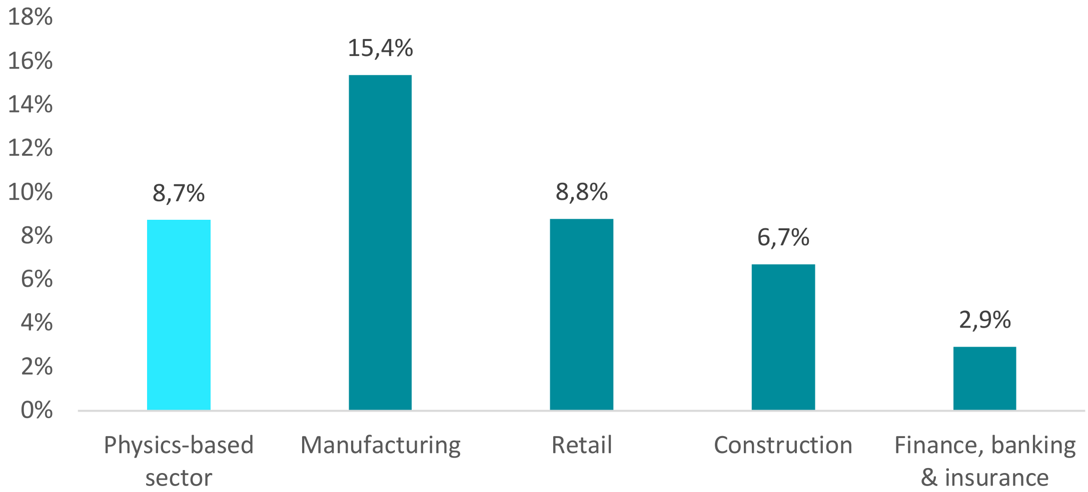
Direct impact

According to our LFS-based estimates, the physics-based industries provided employment for 19.3 million people across the EU-28 in 2015. This is about 2 million higher than the SBS-based estimate

[11] The multiplier can be understood as a ratio between aggregate contribution (incl. direct, indirect and induced impacts) – the numerator – and direct contribution – the denominator. A relative increase in the size of the direct contribution of an industry increases the denominator, thus pulling down the multiplier ratio.

presented above. This means that the physics-based sector accounted for an 8.7% share of EU28-wide employment.[12] This is compared with the same selection of other sectors as considered previously in Figure 23 below.

Figure 23: Selected sectors' shares of total EU-28 employment, 2015



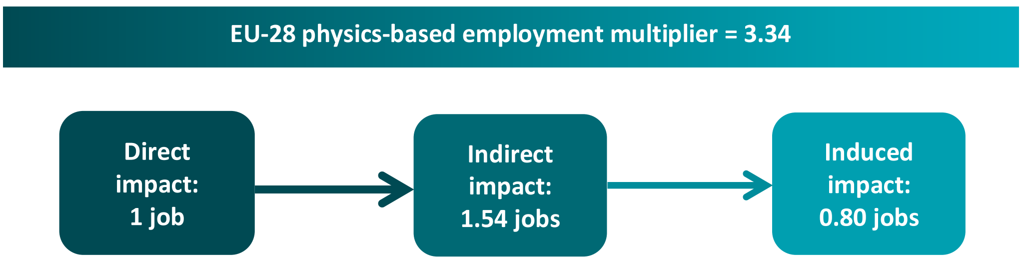
Source: Eurostat ESA2010 Input-Output Tables, LFS, Eurostat SBS; Cebr analysis

This suggests that the physics-based sector makes a contribution to EU-28 employment equivalent to almost 99% of that of the retail sector and 130% of that of the construction sector. This contrasts with the analysis of output and GVA, which shows the physics-based sector making substantially greater output and GVA contributions than retail or construction. This is a function of the relatively higher labour intensities and lower labour productivity levels of these other sectors. As with GVA, the evidence presented in section 2 on comparative labour productivity further supports these conclusions.

Indirect and induced multiplier impacts

Figure 24 illustrates our estimate of the indirect and induced employment multiplier impacts associated with physics-based production.

Figure 24: Employment multipliers for physics-based activities, 2015



Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

From Figure 24 can again be derived two types of physics-based employment multiplier. The Type I multiplier is the sum of direct and indirect impacts and equals 2.54. That is, for every job in the physics-based sector, there are a further 1.54 jobs in the physics-based sector's supply chain. That is,

[12] This is a smaller share than when physics-based employment is expressed as a proportion of total employment in the business economy as above (section 2.2) because the business economy excludes sectors that are included in the LFS.

the jobs that are supported as a result of the economic activity in the industries from which the physics-based sector purchases other goods and services as inputs for their production processes and in the industries that provide inputs to these suppliers and so on.

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 3.34. That is, for every physics-based job, there are a further 2.34 jobs supported in the economy as a whole as a result of the sector's indirect and induced impacts. The induced impact of 0.80 represents the employee spending impact of physics-based production and consists of the jobs supported in sectors that provide the final goods and services required by households.

On this basis, the physics-based sector's direct employment contribution of 19.3 million people in 2015 multiplies to an aggregate 64.5 million jobs 'footprint' once these additional indirect and induced impacts are accounted for.

The employment multiplier has increased since the 2013 report – from the 2.73 estimate presented then to the 3.34 estimate presented here. This, as with output and GVA, is driven by an increase in the induced multiplier impact that is partially counter-balanced by a reduction in the indirect employment multiplier impact. The former is the result of a more robust input-output modelling approach that required fewer adjustments to the raw data and, as such, produced less conservative estimates of induced impact than those produced for the 2013 report. The indirect impact estimates are less likely to have been affected by the modelling adjustment, but can be expected to reflect the same complex array of influences outlined in section 3.2, with the added complication of changes over time in how labour intensive either physics-based industries or their supply chains have become.

3.4 Incomes from employment

In any industry and across the economy as a whole, the most significant element of GVA contributions to GDP is the remuneration of employees. This section quantifies the physics-based sector's contributions to incomes from employment in the EU-28 economy.

Direct impact

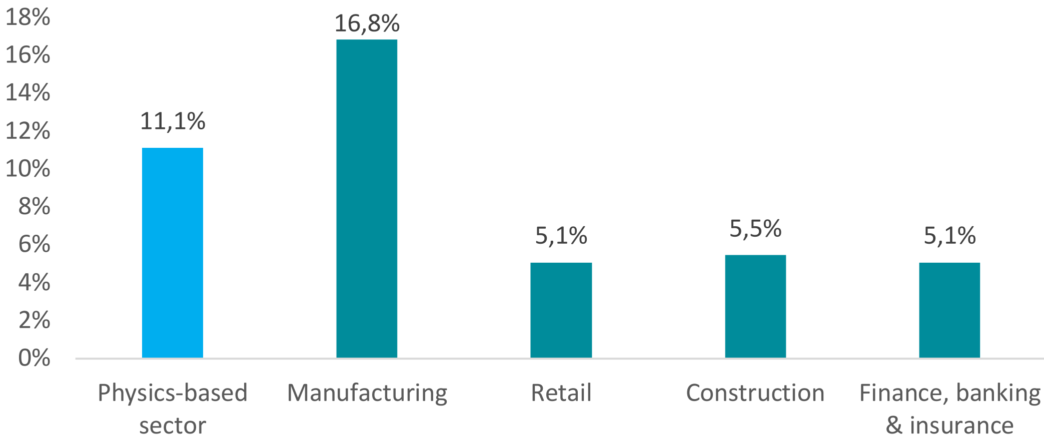
Our estimates suggest that the physics-based industries generated €0.77 trillion of employee compensation in 2015, including €0.62 trillion of wages and salaries. This constitutes a share of 11.1% of EU-28-wide employee compensation.

This is compared with the same selection of other sectors in Figure 25 below. As we noted first in our 2013 report, the differential between the physics-based sector's share of employee compensation and manufacturing's share is significantly smaller than the differential in employment. The logical explanation for this is higher average levels of pay in the physics-based industries than in manufacturing as a whole.

The differentials in employment between the physics-based sector and the construction and retail sectors is smaller than the differentials in employee compensation. The same logical explanation applies - higher average levels of pay in the physics-based industries than in these other sectors.

Although the financial sector generates less employee compensation than the physics-based sector, the differential in employment is larger. This means average levels of pay that are higher in the financial than in the physics-based sector.

Figure 25: Selected sectors' shares of total EU-28 employee compensation, 2015



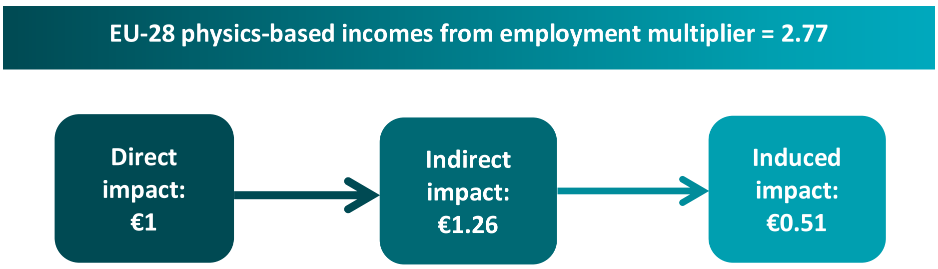
Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

Indirect and induced incomes from employment multiplier impacts

Figure 26 illustrates our estimate of the indirect and induced multiplier impacts of physics-based production for incomes from employment.

From this can be derived two types of physics-based multipliers for incomes from employment. The Type I multiplier is the sum of direct and indirect impacts and equals 2.26. That is, for every €1 of physics-based employee compensation, a further €1.26 of employee compensation is paid by the physics-based sector's supply chain. This indirect impact of €1.26 is equivalent to the upstream impact of every €1 of income from employment paid as part of physics-based production. That is, the income from employment paid as a result of the economic activity in the industries from which the physics-based sector purchases other goods and services as inputs for their production processes and in the industries that provide inputs to these suppliers and so on.

Figure 26: Employee compensation multipliers for physics-based activities, 2015



Source: Eurostat ESA2010 Input-Output Tables, Eurostat SBS; Cebr analysis

The Type II multiplier is the sum of the direct, indirect and induced impacts and equals 2.77. That is, for every €1 of physics-based income from employment, a total economy-wide impact of €2.77 on income from employment is produced as a result of direct, indirect and induced impacts. The induced impact of €0.51 represents the employee spending impact of physics-based production and is generated in the sectors that provide final goods and services to households, thus supporting employee earnings in the wider economy beyond its supply chain.

The fact that the employee compensation multipliers are lower than the corresponding employment multipliers reflects, as first noted in our 2013 report, the relatively lower average levels of employee compensation in the industries that supply the physics-based sector relative to the physics-based sector itself and of the industries that meet the demands generated by physics-based employee spending.

On the basis of this estimate, the physics-based sector's direct employee compensation contribution of €0.77 trillion in 2015 multiplies to an aggregate €2.15 trillion employee compensation 'footprint' once these additional indirect and induced impacts are accounted for.

The income from employment multiplier has increased since the 2013 report – from the 2.46 estimate presented then to the 2.77 estimate presented above. This is consistent with what was observed above for output, GVA and employment and is driven by the same factors – the change in modelling approach and, in terms of explaining reductions in the estimates of the indirect supply chain impacts, the same complex array of influences that were outlined in section 3.2, including the added complication of changing labour intensities from section 3.3 and the additional complication of changes in how and how much people are paid.

4 The survival of physics-based businesses

This section discusses enterprise demography within the EU-28 physics-based sector of Europe as it was not possible to source equivalent data for the non-EU EFTA countries. The analysis measures trends in business inceptions and insolvencies within physics-based industries, with a view to assessing the endurance and survival of physics-based businesses during a period in which the European economic landscape has shifted dramatically.

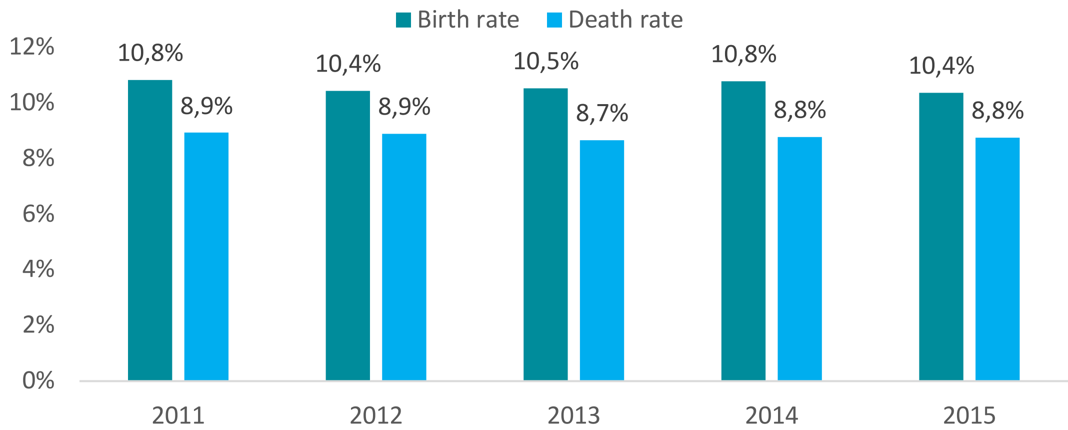
4.1 Physics-based enterprise birth and death rates

Figure 27 illustrates that physics-based enterprises in the EU-28 economies had a birth rate of 10.8% in 2011, implying roughly 11 start-ups for every 100 physics-based enterprises active in that year. This enterprise birth rate declined marginally over the period under consideration to 10.4% by 2015, suggesting closer to 10 start-ups for every 100 physics-based businesses already in existence.

The sharper upswing in the rate of enterprise deaths over the years 2007-2009, as reported in 2013, appears to have abated. Insolvencies in physics-based enterprises occurred at a rate of 8.9% in 2011 and have since declined marginally to 8.8% by 2015.

In contrast to 2009, for which we presented in our 2013 report a physics-based enterprise death rate that exceeded the birth rate, the rate of start-up has consistently exceeded the death rate by a comfortable margin across the period covered by this report.

Figure 27: EU-28 birth and death rates for enterprises in physics-based sectors; 2011-2015



Source: Eurostat Business demography statistics, Cebr analysis

4.2 Comparison with the wider economy

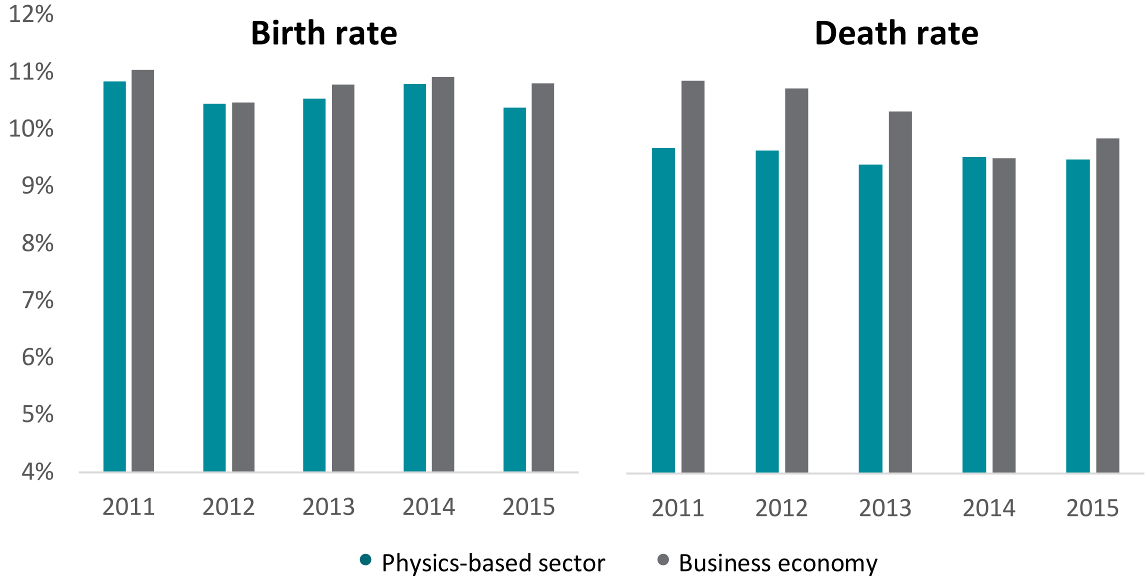
Figure 28 illustrates a comparison between the rates of enterprise births and deaths in the physics-based sector and the wider EU business economy.[13] This suggests that, in the period under analysis, the rate of business births within the physics-based sector was broadly equivalent to, but has usually been slightly lower than, that of the wider business economy. The 2015 birth rate was 10.8% across all sectors of the European economy and has been higher than for the physics-based sector in every year since 2011. This may suggest greater barriers to entry (e.g. the need for higher initial

[13] Due to a lack of data for some sectors, the coverage of the business economy for the purposes of this section is industrial production (incl. manufacturing) and construction, wholesale & retail, food & accommodation, transport, information & communications, finance (excluding holding companies), real estate, professional and business services.

Cebr

investment) to setting up a physics-based enterprise than for the average enterprise in the economy.

Figure 28: Comparison between enterprise demography trends in the EU-28 physics-based sector and business economy, 2011-2015



Source: Eurostat Business demography statistics, Cebr analysis

It is important to note however that, while insolvency rates amongst physics-based enterprises was markedly lower than in the total European economy in the period 2011-2013, the EU-28 economy-wide death rate had dropped from almost 10% in 2011 to 9.1% by 2015. The continued suggestion is that businesses utilising physics in their operations have been more resilient in comparison to the economy as a whole, especially around the time of the European debt crisis in 2012, but that, since 2014, wider enterprise resilience has improved with the improvements in macroeconomic conditions.

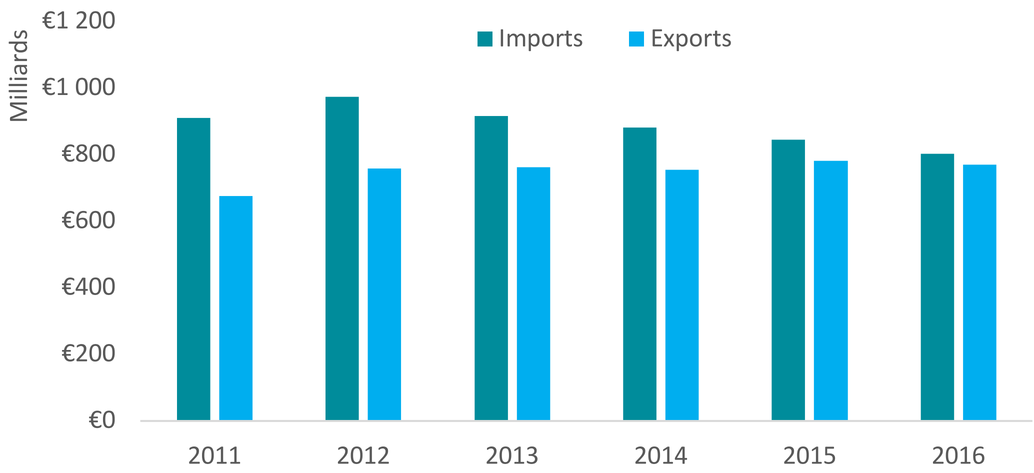
5 International trade, investment and research & development

This section assesses the economic importance of physics through the 'lens' of a number of other well-known indicators – international trade, foreign direct investment and research & development. The data on these indicators is not as comprehensive or, in some cases, as up-to-date as for some of the indicators presented thus far. As such, the findings should be interpreted as more indicative than in Sections 2 and 3 above.

5.1 International trade

Figure 29 illustrates that the EU had a trade deficit in physics-based goods and services over all years under review. However, the differential between imports and exports has diminished for five consecutive years since 2012. Physics-based imports into the EU peaked at €973 billion in 2012 but had dropped to €801 billion by 2016. Exports of physics-based goods and services have, in contrast, increased over the period, from €675 billion in 2011 to €770 billion in 2016. These trends could only be explained through further investigation of the dynamics of international import and exports markets for physics-based goods and services, not least the influence of exchange rate movements.

Figure 29: EU-28 imports and exports of physics-based goods and services to extra-EU trade partners, current prices, 2011-2016

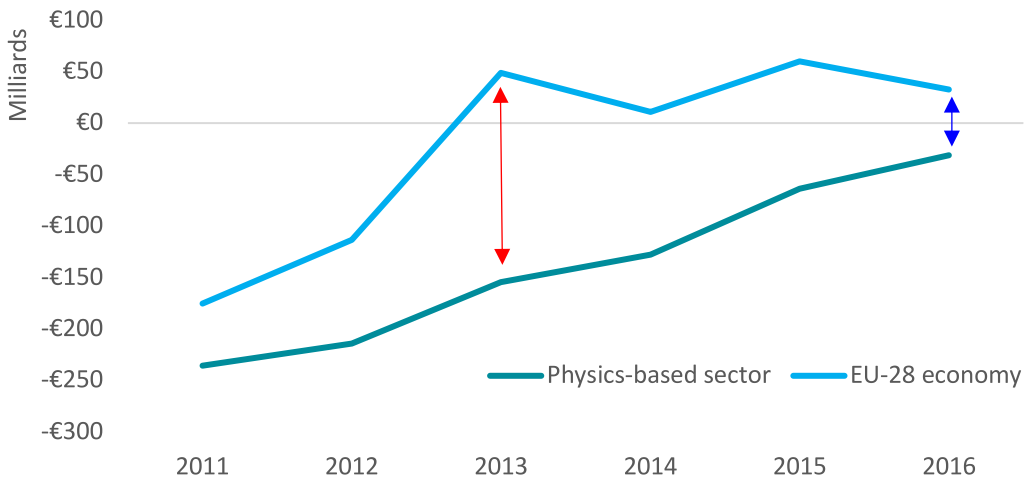


Source: Eurostat Input-Output tables, Eurostat international trade statistics, Cebr analysis

Figure 30 compares the EU-28's trade balance in physics-based goods and services with the overall EU-28 external trade balance with extra-EU countries. The gap between the two that we reported in 2013 as widening in the period 2007-10 appears to have continued to widen until 2013, when the entire EU-28 external trade balance went into surplus by nearly €49 billion, compared to a deficit of €155 billion in physics-based goods and services.

Since then, the EU-28 overall trade surplus has remained broadly steady, with a decline to €33 billion in 2016 from a high of €60 billion in 2015. This is in contrast to a rapidly declining trade deficit in physics-based goods and services, which had fallen to only €31 billion by 2016. As such, from a gap of over €200 billion between the EU-28's overall and physics-based external trade balances in 2013 (the red arrow in Figure 30), these trends mean the gap had been reduced to about €64 billion by 2016 (the blue arrow).

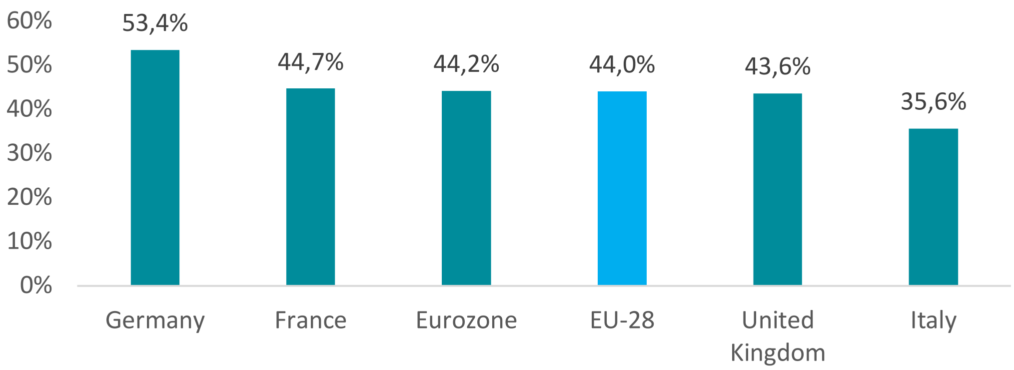
Figure 30: EU-28 External trade balance, calculated as value of exports minus imports, current prices, 2011-2016



Source: Eurostat Input-Output tables, Eurostat national accounts, Cebr analysis

Figure 30 compares the EU-28's physics-based exports as a share of overall exports with Cebr's estimates of the same indicator for the Eurozone and the four largest EU nations. These new estimates draw on the latest available data from Eurostat's international trade statistics and are more reliable and consistent than those presented in the 2013 report. These suggest that 44% of EU-28 exports are physics-based.

Figure 31: Physics-based exports to extra EU-28 nations as a share of each economy's total exports, aggregated 2011-2016



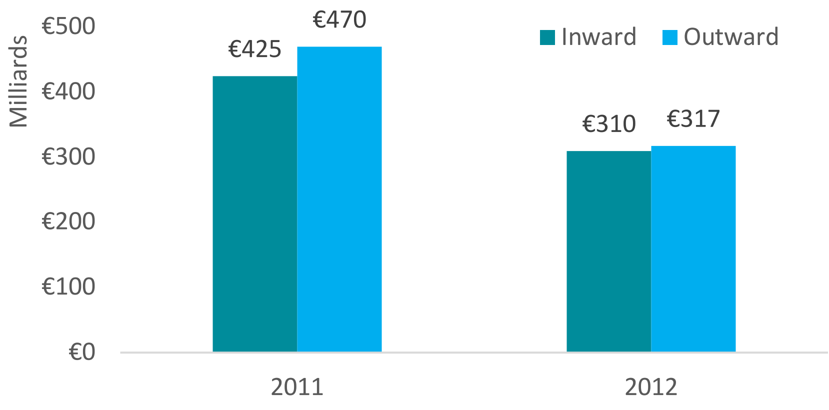
Source: Eurostat Comext, Cebr analysis

The share in the Eurozone and in France and the UK is broadly equivalent but the share of physics-based exports in Germany is significantly higher at 53.4% and in Italy is significantly lower at 35.6%.

5.2 Investment

When taken in aggregate, the European Union business economy invests more in economies outside of the EU-28 than it receives in investment from such economies. This is illustrated in Figure 32 below for the years 2011 and 2012, the latest available. We observe a net FDI outflow flow that is, however, significantly smaller than that found in Cebr's previous report, standing at just €7.7 billion in 2012, compared to the net outward flow of €78.9 billion recorded for 2010 in the 2013 report.

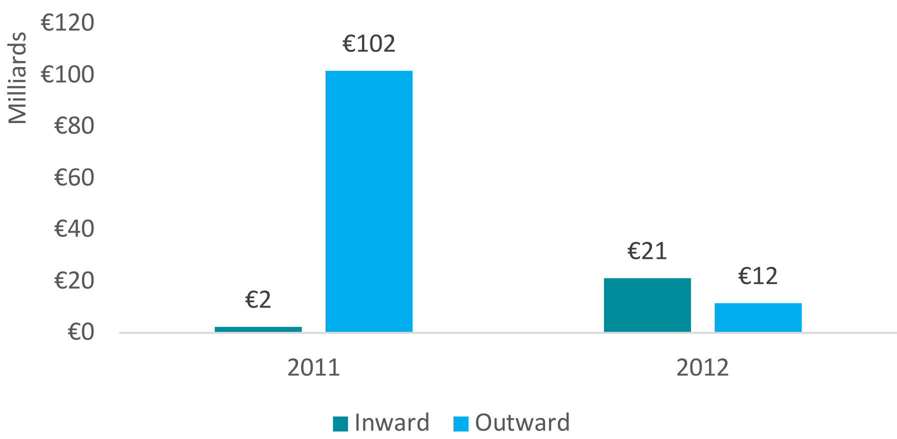
Figure 32: Extra-EU foreign direct investment flows in and out of the EU, 2011-2012



Source: Eurostat Direct Investment statistics, Cebr analysis

The feature of outward investment being higher than inward continued to also be observed in our physics-based sector in 2011, as it has done in the 2008-2010 period. But the trend was broken in 2012 when EU-28 investment in physics-based sectors outside of the EU fell dramatically and below inward investment into the EU-28 physics-based sector. This is illustrated in Figure 33.

Figure 33: Extra-EU physics-based FDI flows in the EU, 2011-2012

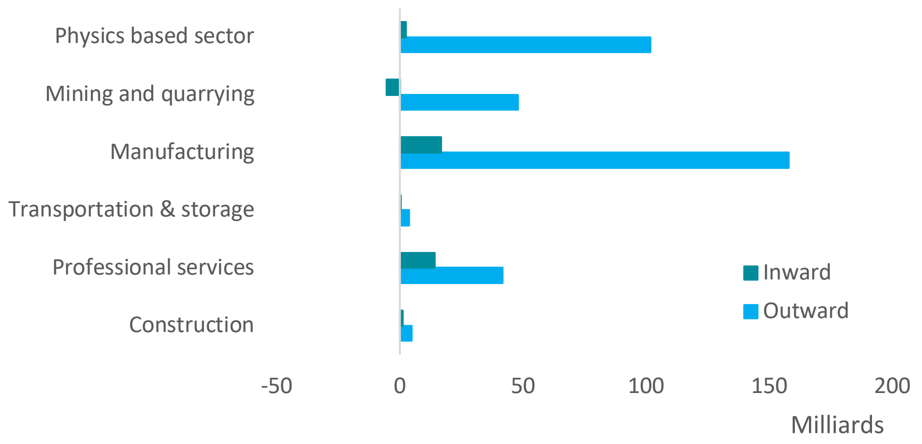


Source: Eurostat Direct Investment statistics, Cebr analysis

This also suggests that the EU28's physics-based sector benefited from only €2 billion of investment from extra-EU28 countries in 2011. This figure increased ten-fold in 2012 to €21 billion, constituting a tenfold increase. Outward investment into physics-based sectors abroad was €102 billion in 2011 but this dropped to only €12 billion in 2012, less than inward investment. These findings should however be interpreted with caution - the limited number of years for which new Eurostat data are available were at the height of the Eurozone debt crisis, a time of considerable financial uncertainty and a retrenchment in capital flows.

The extent to which Europe's physics-based sectors are inter-linked with the global economy is illustrated in Figure 34 below, at least in respect of outward flows. The figure compares FDI flows in 2011 across various EU-28 broad sectors. The manufacturing sector – of which physics-based activities are an important part – is the only sector in which higher levels of both extra-EU inward and outward investment flows are observed than in the physics-based sector. But professional services also performed better on the inward investment measure.[14]

Figure 34: Net extra-EU foreign direct investment flows among selected EU sectors, 2011



Source: Eurostat Direct Investment statistics, Cebr analysis

5.3 Research & development

Research and development (R&D) activities are an important investment function in the business economy, with continuing innovation of new technologies, processes and products contributing much to improving efficiency and generating economy-wide productivity growth. The EU's physics-based sector is unsurprisingly a highly R&D-intensive industry.

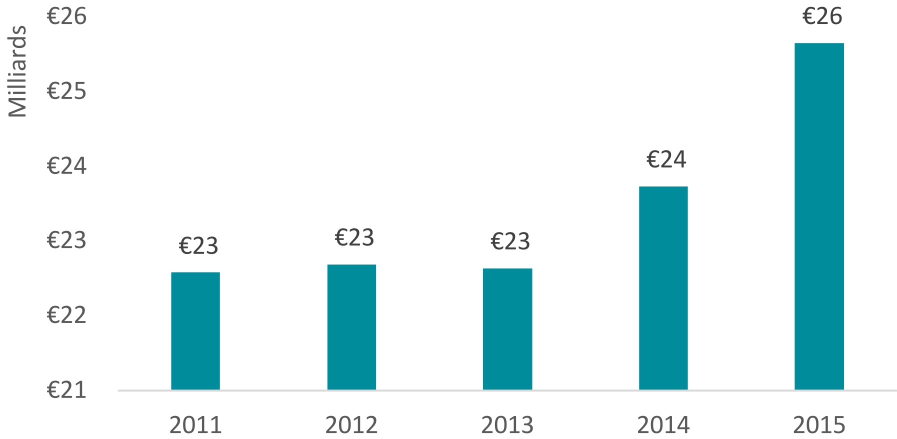
The overall picture

To measure the extent to which the physics-based sector undertakes R&D activities, we once again drew upon our customised EU-28 national accounting framework for 2015. This was used to calculate each physics-based industry's consumption of scientific R&D services as an intermediate input. We then drew on Eurostat's Business Enterprise R&D expenditure (BERD) dataset to infer comparable estimates for 2011-2014.

The results are presented in Figure 35 below, but the magnitudes are significantly lower than those featured in the 2013 report, in which levels of between €47 and €49 billion were recorded in all years 2007-10, compared to €23 billion in 2011 and £26 billion in 2015.[15] Nonetheless, the £26 billion in 2015 accounts for a 66.3% of the spending of all sectors of the EU-28 economy on scientific R&D as an intermediate input.

[14] Note that the negative inward figure for the Mining and Quarrying sector reflects a net return of outward capital from the EU to its origins. This can be attributed to depreciation – that is, the value of the investment falling – and from withdrawal of investment – taking cash out of the EU, selling off factories, shrinking operations etc.).
[15] BERD measures trends in R&D expenditure in different sectors under the NACE Rev. 2 classification, disaggregating mainly to a 2-digit NACE level, with a minority of sectors disclosed at the 3- or 4-digit level. Hence, we used the expenditure trends revealed in the BERD data – at the deepest level of disaggregation possible – to interpolate from the physics-based industries' intermediate consumption of R&D services in 2015.

Figure 35: EU-28 physics-based sector expenditure on scientific research & development, 2011-2015



Source: Eurostat Direct Investment statistics, Cebr analysis

These new estimates still only capture the physics-based industries' external expenditure on scientific R&D and it is likely that higher proportions of intermediate R&D spend has been brought (back) 'in-house' over the period. This would explain the lower levels of external intermediate R&D spend in the period 2011-2015. It is even more likely, under these circumstances, that the estimates above could be significantly higher if it were possible to also estimate internal R&D expenditure.

Nonetheless, all of this only tells a partial story. The official accounts for the combined EU-28 economy suggest a further €36 billion of spending on scientific R&D by governments and charities and a further €258 billion of spending for investment purposes. This €258 billion can be expected to capture elements both external and internal (involving subsidiaries) R&D expenditures that are capitalised as investments. The data are not available that would make it possible to isolate the share that is attributable to R&D investment spending by physics-based industries. But, given that the sector accounts for over 66% of the intermediate spend of all sectors, it is very likely that it also accounts for a substantial proportion of the €258 billion investment number. At least some of the €36 billion of government spending on scientific R&D is also likely to be physics-based.

Global R&D inter-linkages

We estimate that, in 2015, 85.9% of EU-28 economy-wide external intermediate expenditure on scientific R&D was made within the EU-28, thus supporting European providers. The share for the physics-based sector was lower at 78.7%, but this is still higher than the equivalent share for the EU-28 business economy, which was 75.8%. This is a better comparator for the physics-based industries, especially when one considers that EU-28 governments sourced 97.6% of their external expenditure on scientific R&D from within the union. However, at the same time, only 5% of the €258 billion spend on R&D for investment purposes (across all sectors) was imported.

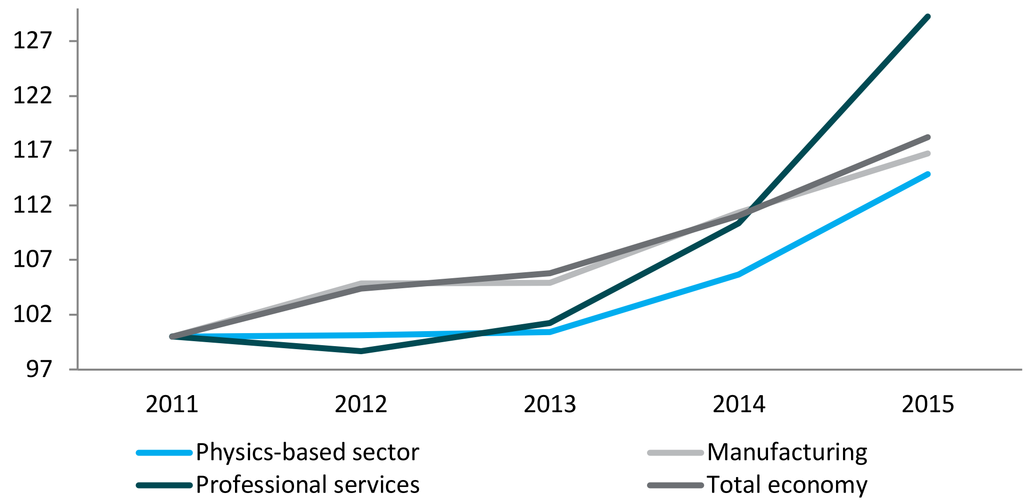
The physics-based sector sourced about €5.5 billion in scientific R&D services from economies outside the EU-28 in 2015, which demonstrates strong interlinkages between the EU-28 and the global economy in the area of physics-based R&D. The sector that itself provides for all of the above scientific R&D requirements, some of which includes physics-based activity, exported €31.5 billion of scientific R&D services to the world beyond the EU28's borders. The data are not available that would make it possible to isolate the physics-based share, but it will be captured within the physics-based trade data presented in Figure 29 above.

Cross-sectoral comparisons

Figure 36 compares trends in scientific R&D spending by the physics-based sector with the equivalent trends for manufacturing and professional services – both of which include some physics-based industries – and for the total economy. With the exception of professional services, the physics-based sector has, on this measure, been outperformed by the comparators over the period 2011-15. However, the estimates do not include internal R&D which, if it were possible to estimate, could alter the picture dramatically, given the likely higher prevalence of dedicated R&D functions, subsidiaries etc. within physics-based companies.

Nonetheless, external spending on scientific R&D by the physics-based sector has grown by almost 14.9% over the 2011-15 period, compared with 16.7% in manufacturing, 29.2% in professional services and 18.2% across the EU-28 economy. Within the physics-based sector, significant increases in the physics-based communications industries were offset by declines in the measure for physics-based industries from the transport sector.

Figure 36: R&D expenditure in broad sectors, Index (2011 = 100)



Source: Eurostat Direct Investment statistics, Cebr analysis

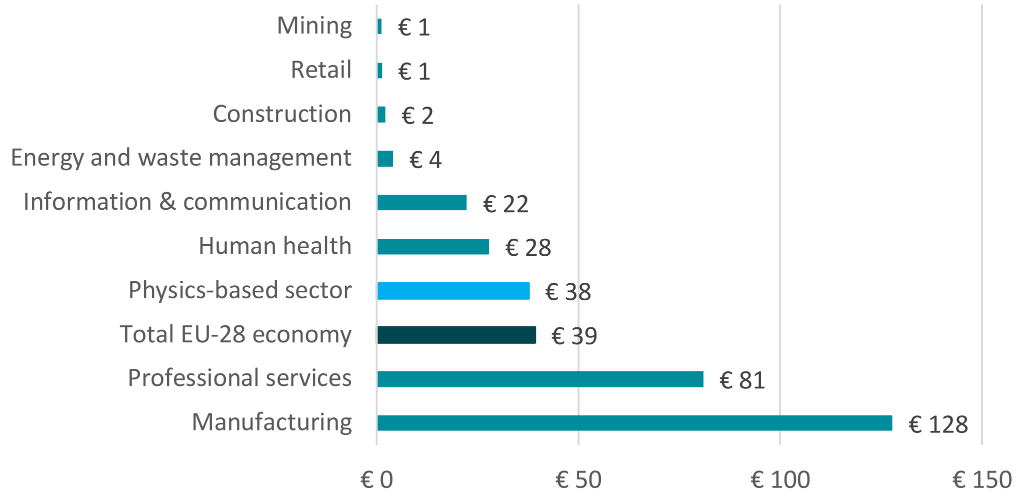
However, while these indices reveal developments in R&D expenditure in various segments of the economy over the years under review, they do not reveal the relative importance of R&D activities to each sector.

Figure 37 compares the degree of external scientific R&D services consumption among selected sectors that typically undertake a relatively high degree of R&D, analysed in terms of expenditure as a proportion of gross operating surplus (GOS), which is broadly akin to the accounting concept of gross profit (or EBITDA, earnings before interest, tax, depreciation and amortisation). The measure still excludes internal R&D, but offers some insight into the rate at which sectors re-invest profits in R&D. The picture is still only partial given the difficulties in establishing internal R&D expenditures and in isolating sector shares of R&D spending for investment purposes. We would however reiterate that comparisons like this between estimates of what are likely to be a very small element of overall R&D outgoings for many industries, particularly those in the physics-based sector, are of limited usefulness.

In 2015, EU-28 physics-based industries spent approximately €38 per £1,000 of GOS on externally sourced scientific R&D as an intermediate input. This is similar to the comparable rate of R&D

expenditure in the overall EU economy, in which approximately €39 of R&D services €1,000 of GOS were consumed. The rate of R&D expenditure by the physics-based sector is exceeded in our sample only by the overall manufacturing sector, which in 2015 spent around €128 per €1000 of GOS, and by the professional services sector at €81 per €1,000 GOS. But note that the latter comparator itself includes the scientific R&D sector, and both include several physics-based industries.

Figure 37: EU-28 expenditures by sector on externally sourced (EU + non-EU) on scientific R&D services, per €1000 of gross operating surplus, 2015



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

The mining, retail, construction and energy & waste management sectors all spent significantly less than a tenth of the amount spent by the physics-based sector.

Appendix I: Compendium of national-level results

Here we present our estimates of turnover, employment and GVA in each of the countries analysed as part of this study. Please note that the column totals may not sum due to rounding.

	Turnover in physics-based industry, € million, current prices					
	2011	2012	2013	2014	2015	2016
Austria	78,825	81,107	83,077	80,666	82,356	85,656
Belgium	109,209	109,288	114,482	112,669	113,041	111,290
Bulgaria	10,110	10,776	10,667	10,845	12,258	12,880
Croatia	10,115	9,623	9,260	9,521	9,826	9,613
Cyprus	2,496	2,444	2,273	2,429	2,397	2,460
Czech Republic	77,678	79,873	77,924	80,435	84,349	88,506
Denmark	67,873	69,297	69,237	70,673	74,524	79,474
Estonia	5,807	6,065	6,551	6,336	6,131	6,317
Finland	69,484	68,730	67,688	64,036	58,567	56,152
France	544,670	548,878	547,011	540,733	556,088	560,988
Germany	1,137,553	1,169,996	1,189,339	1,268,581	1,325,371	1,307,483
Greece	20,372	23,642	24,255	22,152	31,414	30,933
Hungary	58,463	55,432	55,294	58,566	64,694	61,511
Ireland	77,678	73,209	71,047	77,394	129,898	135,383
Italy	452,436	454,630	436,294	427,118	428,427	451,051
Latvia	4,095	4,542	4,532	4,300	4,278	4,261
Lithuania	4,518	4,666	4,934	4,956	5,145	5,536
Luxembourg	8,893	8,496	8,678	8,250	10,717	11,491
Malta	1,498	1,605	1,749	1,963	2,144	2,377
Netherlands	178,751	182,368	181,248	193,010	199,435	186,669
Poland	98,338	97,293	97,272	101,386	110,503	105,603
Portugal	37,676	35,132	33,862	33,408	33,340	33,654
Romania	35,939	34,699	37,512	38,509	41,033	40,650
Slovakia	34,454	37,914	39,122	39,272	42,389	43,921
Slovenia	13,746	13,732	13,759	14,399	14,326	14,593
Spain	233,760	226,284	223,731	218,765	232,326	234,369
Sweden	121,421	145,035	145,085	142,256	135,504	133,533
United Kingdom	541,127	573,145	567,888	603,965	671,526	666,016
Iceland	3,334	3,401	3,364	3,605	3,872	4,054
Norway	230,345	255,738	238,291	217,922	137,651	116,945
Switzerland	182,964	195,115	191,439	197,322	217,987	216,376
Total	**4,453,627**	**4,582,156**	**4,556,863**	**4,655,442**	**4,841,517**	**4,819,747**

Source: Eurostat SBS, Cebr analysis

	Number of persons employed in physics-based industry					
	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Austria	306,139	312,030	320,436	307,295	310,669	319,070
Belgium	292,802	290,761	294,889	254,722	255,495	263,544
Bulgaria	217,464	219,688	217,780	223,353	234,622	248,512
Croatia	141,154	132,817	131,405	124,856	129,802	123,457
Cyprus	16,791	16,154	15,387	15,927	16,102	17,188
Czech Republic	489,170	501,705	500,051	512,866	527,609	530,451
Denmark	237,907	234,690	240,251	250,558	254,268	248,627
Estonia	41,938	42,496	42,824	43,509	45,883	45,426
Finland	199,504	201,520	199,268	199,758	198,734	185,595
France	1,757,929	1,828,092	1,817,686	1,870,282	1,772,766	1,876,584
Germany	3,858,166	3,908,479	3,992,748	4,167,651	4,192,928	4,250,986
Greece	184,688	176,363	165,635	169,771	201,765	204,073
Hungary	373,608	373,653	371,537	372,086	394,470	414,568
Ireland	124,116	122,266	125,446	131,331	137,640	145,470
Italy	1,755,606	1,732,620	1,695,557	1,665,587	1,663,307	1,707,075
Latvia	74,345	77,586	78,836	81,771	82,068	82,501
Lithuania	59,442	61,538	64,752	69,932	70,370	72,484
Luxembourg	22,425	22,556	22,131	22,845	23,616	24,063
Malta	11,401	11,634	11,810	12,618	13,724	14,263
Netherlands	459,959	463,029	467,218	466,679	474,363	476,911
Poland	926,882	913,323	911,825	921,983	935,991	969,955
Portugal	206,454	196,684	192,609	196,435	205,018	209,251
Romania	519,334	513,627	521,733	530,847	540,214	550,964
Slovakia	210,279	204,639	205,744	195,408	200,913	214,917
Slovenia	88,824	91,681	93,188	93,836	95,016	92,240
Spain	976,466	938,957	909,923	937,684	969,270	1,005,397
Sweden	428,236	432,631	429,410	420,372	423,504	433,444
United Kingdom	1,963,252	1,923,717	2,007,095	2,013,513	2,093,347	2,212,847
Iceland	12,216	12,549	13,195	14,361	17,296	17,607
Norway	245,087	250,666	263,884	269,719	263,218	241,774
Switzerland	504,236	519,340	534,245	548,945	566,735	559,866
Total	**16,705,819**	**16,727,490**	**16,858,497**	**17,106,499**	**17,310,722**	**17,759,110**

Source: Eurostat SBS, Cebr analysis

	GVA in physics-based industry, € million, current prices					
	2011	2012	2013	2014	2015	2016
Austria	29,640	31,120	31,664	29,724	30,502	33,229
Belgium	33,237	33,111	36,244	33,178	32,850	36,203
Bulgaria	3,877	4,011	4,230	4,327	4,909	4,878
Croatia	5,097	4,758	4,816	4,960	4,682	4,850
Cyprus	1,222	1,168	1,071	1,071	1,163	1,123
Czech Republic	19,996	20,493	20,769	20,139	21,775	22,748
Denmark	28,364	28,731	29,462	29,474	31,067	31,428
Estonia	1,622	1,661	1,823	1,913	1,800	2,016
Finland	16,585	15,454	16,725	17,094	17,067	17,634
France	168,477	171,678	173,135	176,943	183,683	182,652
Germany	335,362	341,192	349,181	376,409	385,481	396,284
Greece	9,206	8,817	8,233	7,687	9,517	8,105
Hungary	14,563	14,060	14,444	15,201	16,285	16,324
Ireland	26,272	25,268	23,953	26,648	53,097	43,163
Italy	138,253	137,678	132,492	131,076	132,775	138,955
Latvia	1,424	1,623	1,617	1,603	1,843	1,805
Lithuania	1,354	1,477	1,600	1,774	1,958	1,852
Luxembourg	3,013	2,955	2,852	3,247	3,311	3,249
Malta	515	568	617	666	727	776
Netherlands	60,580	62,144	60,385	57,643	57,924	63,473
Poland	31,905	30,928	30,872	31,871	33,198	33,681
Portugal	13,426	13,085	12,644	12,679	12,646	13,622
Romania	11,348	10,749	12,045	12,103	11,744	13,851
Slovakia	7,296	7,768	7,374	7,629	8,078	8,298
Slovenia	4,498	4,559	4,656	4,970	5,004	5,184
Spain	84,684	81,107	79,704	79,691	84,302	87,660
Sweden	43,605	44,553	45,175	44,760	44,018	48,739
United Kingdom	212,294	221,119	218,817	233,433	261,362	252,460
Iceland	863	907	955	1,064	1,245	1,496
Norway	103,139	116,800	107,279	94,215	83,050	90,063
Switzerland	69,462	73,582	72,562	74,577	83,297	84,074
Total	**1,481,180**	**1,513,127**	**1,507,393**	**1,537,770**	**1,620,361**	**1,649,874**

Source: Eurostat SBS, Cebr analysis

Appendix II: NACE Rev. 2-based definition of physics-based activities

List of industries defined as physics-based

Code	Description	Code	Description
6.1	Extraction of crude petroleum	**27.12**	Manufacture of electricity distribution and control apparatus
6.2	Extraction of natural gas	**27.2**	Manufacture of batteries and accumulators
9.1	Support activities for petroleum and natural gas extraction	**26.8**	Manufacture of magnetic and optical media
20.13	Manufacture of other inorganic basic chemicals	**27.11**	Manufacture of electric motors, generators and transformers
21.2	Manufacture of pharmaceutical preparations	**27.31**	Manufacture of fibre optic cables
23.44	Manufacture of other technical ceramic products	**27.32**	Manufacture of other electronic and electric wires and cables
24.46	Processing of nuclear fuel	**27.33**	Manufacture of wiring devices
25.4	Manufacture of weapons and ammunition	**27.4**	Manufacture of electric lighting equipment
25.99	Manufacture of other fabricated metal products n.e.c.	**27.51**	Manufacture of electric domestic appliances
26.11	Manufacture of electronic components	**27.9**	Manufacture of other electrical equipment
26.12	Manufacture of loaded electronic boards	**28.11**	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
26.2	Manufacture of computers and peripheral equipment	**28.23**	Manufacture of office machinery and equipment (except computers and peripheral equipment)
26.3	Manufacture of communication equipment	**28.25**	Manufacture of non-domestic cooling and ventilation equipment
26.4	Manufacture of consumer electronics	**28.29**	Manufacture of other general-purpose machinery n.e.c.
26.5	Manufacture of instruments and appliances for measuring, testing and navigation	**28.49**	Manufacture of other machine tools
26.6	Manufacture of irradiation, electro-medical and electrotherapeutic equipment	**28.99**	Manufacture of other special-purpose machinery n.e.c.
26.7	Manufacture of optical instruments and photographic equipment	**29.1**	Manufacture of motor vehicles
26.8	Manufacture of magnetic and optical media	**29.31**	Manufacture of electrical and electronic equipment for motor vehicles
27.11	Manufacture of electric motors, generators and transformers	**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
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
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
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: Methodology and data Sources

This appendix provides details of the data sources, modelling and analytical methodologies used to produce this study.

Jobs, Turnover and Value Added

Section 2 presented our analysis of employment, turnover and value added in the physics-based sector of the EU-28 economies along with three of the four EFTA nations. The data in this section were drawn entirely from Eurostat's Structural Business Statistics (SBS). These data are gathered directly from enterprises operating within the target economies and, once gathered, 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 particular industries according to the principal activity they undertake in the economy. Effectively, all the jobs, all the turnover and all the value added that these enterprises create are attributed to a particular industry.[16]

The SBS database provides information on the structure, conduct and performance of businesses across the European Union. The statistics are broken down to a highly detailed sectoral level – several hundred economic activities – and are more detailed than national accounting data. Under NACE Rev. 2, the EU-28 'national' accounts contain data[17] for 65 divisions (categories of economic activities or industries), of which 49 are within the 'business economy' covered by SBS.[18]

As previously noted, the level of detail offered by the SBS extends well beyond these 49 "divisions", with further categorisations into "groups", then "classes", and finally "subclasses", all supplemented with descriptions of the relevant economic activities. This allows for accurate analysis of economic indicators at the required level of industry disaggregation for the relevant physics-based activities (see Appendix II).[19]

Adjustments were made to some industries to estimate the proportion of these industries that are physics-based. The adjustments drew upon our estimates of the physics-based share of turnover, value added and employment across the wider division. For example, we sometimes used the average share of turnover that was physics-based in a certain class as a proxy for a missing share in the relevant subclasses. This then allowed us to estimate the extent to which other indicators were generated by physics-based activities at a more nuanced level than the data would have otherwise allowed.

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[16] A basic rule of thumb to determine the "principal activity" of a given enterprise is to identify the activity that generates the most value added. The vast majority of enterprises are assigned their industry according to this measure.

[17] These national accounting data – provided in Eurostat's supply-and-use and input-output tables - are used in conjunction with the Structural Business Statistics for the analysis in Section 3. Note that the national accounting data have other advantages relative to SBS, which are explained further in the subsection on direct, indirect and induced impacts below.

[18] Financial services do not feature because of their specific nature and the limited availability of most types of standard business statistics in this area. Neither does SBS cover agriculture, forestry and fishing or public administration and (largely) non-market services like education and health.

[19] Note that the 65 NACE Rev. 2 divisions that feature in the national accounts are at the 2-digit level of industrial classification. SBS data for the 2011-2016 period are provided at the 4-digit level of industrial classification. Our tailored 'physics-based sector', detailed in Appendix II, includes a range of industries classified at the 3-digit and 4-digit levels. Some data for certain indicators were incomplete at the required level of detail, especially at the national level (see Appendix I), which necessitated the estimation of values drawing on wider European trends in the detailed (4-digit) industries, trends in related variables that provided a reasonable proxy for the statistic being measured, or trends observed at higher levels of industrial aggregation. These assumptions were generally applied to only the smallest national economies, as data for smaller countries was generally patchier, and as such did little to affect our aggregated European analysis.

Direct, indirect and induced impacts

Section 2 of the report presents our estimates of the *direct* impacts of physics on the business economy as derived from the SBS datasets, which are based on information gathered directly from enterprises. These 'raw' estimates of the indicators for physics-based economic activity (namely employment, turnover and value added) are subject to a number of caveats. Meanwhile, our analysis of indirect and induced impacts (presented in Section 3) drew on different data to that of the SBS – that is, the EU national accounting framework. This subsection of Appendix III explores the discrepancies that exist between our SBS estimates (in Section 2) and our national accounting framework estimates (in Section 3).

The use of a different framework inevitably means the derivation of alternative estimates of some of the same (or closely related) indicators of direct economic impact featured in Section 2. That much is guaranteed by sample variation; two surveys that draw samples from the same population are bound to yield at least slightly different results. That being said, the national accounting framework should offer a more accurate picture of the economic contribution of Europe's physics-based sector.

Direct impacts aside, EU national accounting data certainly provides a robust framework for the analysis of the *indirect* and *induced* multiplier impacts of the physics-based industries in Europe. This begins with Eurostat's supply, use and input-output datasets.[20] We use this important part of the national accounting framework in conjunction with the Leontief matrix multiplier approach as the basis for our estimates of the indirect and induced impacts of physics on the EU economy.[21]

Section 3 focuses then on the direct, indirect and induced impacts of the physics-based industries on output, gross value added (GVA), employment and incomes from employment across the EU-28. These indirect and induced contributions are also examined in the context of the following impacts:

- **Upstream** through the economic activity supported in sectors that supply goods and services to the physics-based industries;
- **Employee spending** through the economic activity supported in the economy through the incomes and resultant spending of employees within the physics-based industries;
- **Downstream** through the economic activity supported in sectors that use goods and services provided by the physics-based industries.

The new data underlying the analysis in Section 3 are drawn from Eurostat's supply, use and input-output datasets (or SUIOTs for short). These provide detailed information for a given year on production activities, the supply and demand for goods and services, intermediate consumption, primary inputs (factors of production) and foreign trade. We noted above that national accounting data are less detailed than the SBS statistics, containing data for only 65 NACE Rev. 2 divisions (categories of economic activities or broad industries). However, the national accounting data are broader in scope because, as already described, 16 of the 65 SBS divisions are not within the business economy covered by SBS.

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[20] See https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/methodology for further details and https://ec.europa.eu/eurostat/web/esa-supply-use-input-tables/data/database for the datasets.

[21] Supply-use tables provide the most detailed official record of how sectors of the economy interact with other sectors, with consumers and with international markets in producing GDP and national income. Input-output analysis, due largely to the work of Wassily Leontief (see, for example, Leontief, Wassily W. Input-Output Economics. 2nd ed., New York: Oxford University Press, 1986.), while macroeconomic in the sense that it involves analysing the economy as a whole, owes its foundations and techniques to the microeconomic analysis of production and consumption. (See ten Raa, Thijs (2005), The Economics of Input-Output Analysis, Cambridge University Press.) According to ten Raa (2005), some people argue that input-output analysis is at the interface of both, defining it as the study of industries or sectors of the economy.

The supply-use tables are matrices by product and industry showing the production processes and transactions of industries in respect of products (goods or services). The input-output tables are product-by-industry or product-by-product matrices that present the same data having extracted imports and government taxes in order to isolate the domestic economy (in this case, the economy of the EU-28). In such a *closed economy* product-by-industry input-output table, for instance, industries' intermediate consumption of domestically produced inputs, net of taxes, are shown. In the supply-use tables, which are generally prepared in *open economy* form, industries' intermediate consumption of all inputs, including imports, is shown and the data still include non-VAT government taxes on such inputs.

We used these 2015 NACE Rev. 2 based SUIOTs for the EU-28 to estimate the direct and indirect and induced multiplier impacts of the physics-based industries. These are consolidated by Eurostat from the tables transmitted by the Member States for their national economies, which is a compulsory requirement (every 5 years) under the European System of Accounts (ESA2010, formerly ESA95). The tables offer valuable insights that SBS datasets cannot. For example, the SUIOTs contain:

- the structure of the costs of production and the value added generated in the production process;
- the inter-industry dependencies within the economy;
- the flows of goods and services produced within the national economy; and
- the flows of goods and services with the rest of the world.

There are also, as previously noted, caveats associated with the 'raw' estimates of economic activity provided by the SBS datasets. These relate principally to the methods used to value the economic indicator under consideration and are given due consideration in Box 1 below.

The other principal reason to expect variability between the direct economic impact estimates based on SBS and those based on ESA2010 is the fact that businesses' and, therefore, SBS industries' employment, turnover and *value added* contributions are based on all of their economic activities, regardless of whether they are physics-based or not. Likewise, businesses classified in industries that do not fall within our NACE-based definition of the physics-based industries may produce goods and services that are physics-based, even though their principal activity may not be physics-based (the factor that would have led to their classification as non-physics-based industries in the first place).

Meanwhile, the SUIOTs allow us to exclude the economic activities of physics-based industries that are not strictly physics-based (e.g. hiring of cleaners within an engineering firm) and the inclusion of activities that are physics-based but carried out by non-physics-based industries. These tables are thus used in conjunction with the results of our analysis of the SBS datasets in the previous section to produce estimates of the economic contribution of physics that are consistent with EU-wide and national accounting frameworks. Specifically, we acknowledged that each of the more detailed NACE 3-4-digit physics-based industries belonged to one of the 65 broader 2-digit industries in the NACE Rev. 2 based ESA2010 framework. To assign the physics-based industries –collectively the physics-based 'sector' – an explicit role within the supply, use and input-output framework, we isolated and attributed shares of supply-use 2-digit industries to the 3-4-digit physics-based industries.

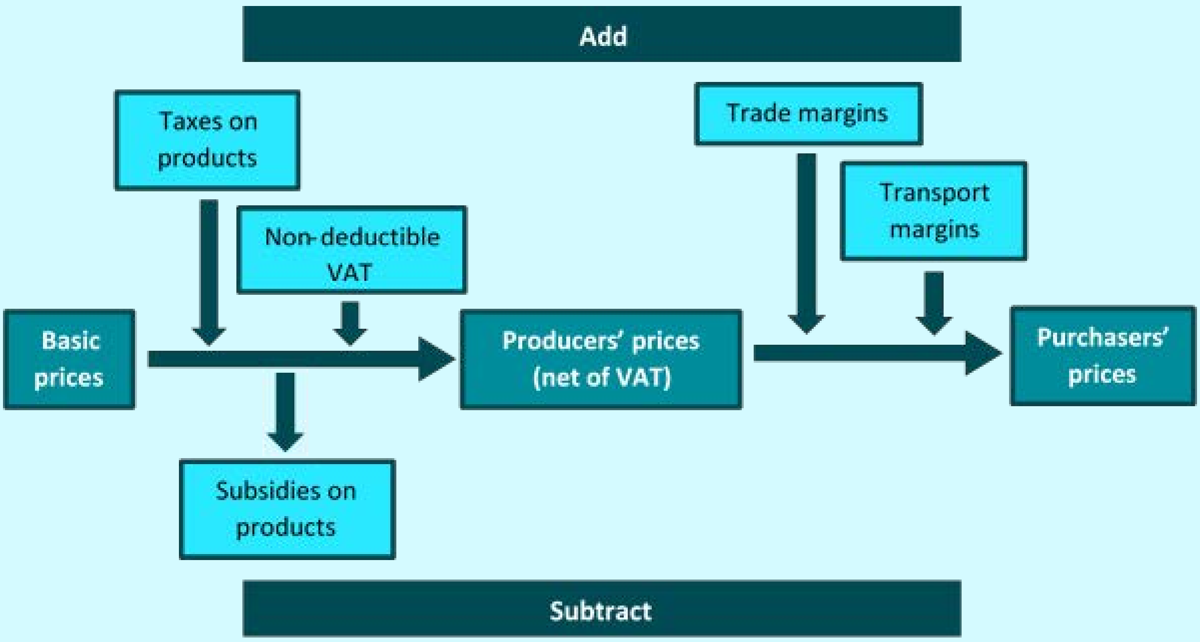
Box 1: Valuing economic indicators under SBS vs. ESA2010

The EU-wide and national accounting methodologies represented by ESA2010 combine different types of valuation for the same variable or transaction, thereby showing different actual prices depending on the type of unit involved in the transaction. For example, a household that purchases a consumer good in a retail shop does not perceive its price in the same way as the producer who produced the good in question. Different types of valuation of economic indicators like production and contribution to national product (GDP) are, therefore, borne out of different definitions of the price paid in different types of transaction.

The flowchart below shows that production (or 'industrial' output) can be valued according to two principal criteria, namely whether the price is one paid by a purchaser (what the buyer has to pay) or set by a producer. The basic price strips away all government taxes, while a producer price is an intermediate concept that is closer to the basic price but which includes taxes and subtracts subsidies on products and adds non-deductible VAT. ESA2010 and national accounts use basic prices and purchasers' prices and do not explicitly define "producer price".

Business turnover is generally thought of as being recorded at producers' prices, but is stated net of non-deductible VAT, unlike the ESA2010 producer price concept. The SBS datasets therefore value production by the hundreds of NACE economic activities at producers' prices. But it is evident that the basic price is the best option from a theoretical point of view (that is, in terms of more accurately measuring economic impacts), reflecting more exactly than other price concepts the costs of the elements inherent in the product. In other words, the other price concepts disguise the real costs of the product and may be influenced by changes in fiscal policy or in trade and transportation. ESA2010 and therefore the consolidated EU-28 supply use and input-output tables (SUIOTs) value production at basic prices, thus providing a bridge between the 'raw' estimates of the economic impact of physics from and the true costs and value of production of the physics-based sector.

Flowchart – Valuation of output



Source: Eurostat input-output methodology

The economic impacts presented in this report are, as such, expressed in terms of basic prices unless otherwise indicated.

These attributions were based on the ratio of SBS turnover, intermediate consumption, GVA and other indicators at the 3-4-digit industry level to the equivalent SBS metrics at the 2-digit industry level.[22]

This amounts to a simplifying assumption that all 3-4-digit physics-based industries are levied (or endowed) with the same proportions of taxes (or subsidies) on products and are subject to the same proportions of non-deductible VAT as the broader 2-digit industries to which they belong (which often include non-physics-based, as well as the physics-based, elements). To the extent that the physics-based industries are levied with less taxes and in receipt of less subsidies on products[23] and are subject to lower proportions of non-deductible VAT, the ESA2010-based estimates of the economic contribution of the physics-based industries presented in Section 3 could be considered underestimates.

The sum of the attributions across the detailed 3-4-digit physics-based industries together constitute the physics-based sector within the ESA2010-based EU-wide and national accounting frameworks.

Through this mapping exercise between the SBS relationships and the SUIOTs, we produced the estimates of the direct output and GVA contributions (at basic prices) of the physics-based sector, as well as estimates of the direct contribution to EU-wide income from employment. The EU-28 input-output model is then used to produce Leontief matrix multipliers that estimate the monetary scale of the upstream impacts of the physics-based sector as well as the physics-based employee spending (or induced) impacts. This analysis is presented in Section 3 of the report.

Section 3 presents the finding that the increases in the overall multiplier estimates for the physics-based sector since the 2013 report are partly the result of a more robust input-output modelling approach. This involved switching from the use of a symmetric product-by-product input-output table to use instead of a product-by-industry 'domestic use' table. This meant fewer adjustments to the raw SBS data for physics-based industries when mapping them into the national accounting framework. This has resulted in less conservative estimates of the induced impacts of the physics-based sector than those presented in the 2013 report and that are more in line with what would normally be expected.

Employment is examined using SBS data in Section 2 and more reliable Labour Force Survey (LFS) data in Section 3. The LFS data are used in conjunction with the SUIOTs to produce estimates of the physics-based sector's multiplier impacts on employment in the EU-28 economy.

Physics-based businesses and their survival

Section 4 draws upon the business demography statistics provided by Eurostat, which measure the numbers and rates of enterprise births and deaths on an annual basis.[24] The demography dataset extends only to 2015, so the analysis covers the period 2011-2015 period of analysis.

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[22] The SBS turnover data are, as outlined in Box 1, based on producers' prices whereas the ESA2010 data are valued at basic prices. The former could not, therefore, be supplanted on the latter without significant adjustment first. Undertaking such adjustments for self-styled categories of industries or products, such as the physics-based sector, was beyond the scope of this research. This is why we used proportional relationships between variables in the detailed physics-based industries and their corresponding broader 2-digit industries for the purposes of incorporation in the ESA2010 framework.
[23] This would certainly be the case in respect of, for example, on the tax side industries like tobacco and alcohol and, on the subsidy side, like agriculture, forestry and fishing.
[24] Some demographic events leading to creations or closures of enterprises are not classified as births or deaths: these include firm 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.

These data are largely presented at a 2-digit level under the NACE Rev. 2 framework (with only a few sectors presented at a 3- or 4-digit level), necessitating an estimation procedure in order to measure demographic trends within the more detailed physics-based industries.

In order to estimate the business populations that can be characterised as physics-based under our definition, we utilised ratios derived from the SBS datasets. Within each 2-digit aggregate sector, we measured the proportion of enterprises that are defined as physics-based at the constituent 4-digit levels, and applied these proportions to the lesser-disaggregated business register data. Once these physics-based populations had been isolated, we applied the birth and death rates at the greatest level of disaggregation available (as noted previously, in most cases this was at the 2-digit level) in order to derive the count of physics-based enterprise births and deaths in each time period.

Where birth or death rates were not available, we utilised the total count of enterprise births or deaths in each sector, and applied the SBS-derived proportions in order to estimate the demographic events that are accounted for by physics-based enterprises.

International Trade

Section 5 analyses the value of trade in physics-based goods and services. From our adapted SUIOTs, in which the EU-28 physics-based sector is assigned an explicit role, we are able to measure the level of extra-EU imports and exports of physics-based goods and services in 2015. To measure trade developments since 2011, we used goods trade statistics classified in the SITC framework, which we have mapped to the NACE Rev. 2 classification of physics-based goods as defined in our Appendix II. For trade in physics-based services, we have drawn on data from the SUIOTs and other more general services industry trends.

FDI

This analysis, the results of which are also presented in Section 5 of the report, draws upon direct investment statistics provided by Eurostat, which detail financial investment flows into and out of the EU economy, broken down according to the NACE Rev. 2 activity of the businesses being invested in. While the FDI dataset does not disaggregate fully to the many 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 NACE level), and the assumption made that the physics-based businesses received proportions of these investments equivalent to their share of the 2- or 3-digit sector's turnover.

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