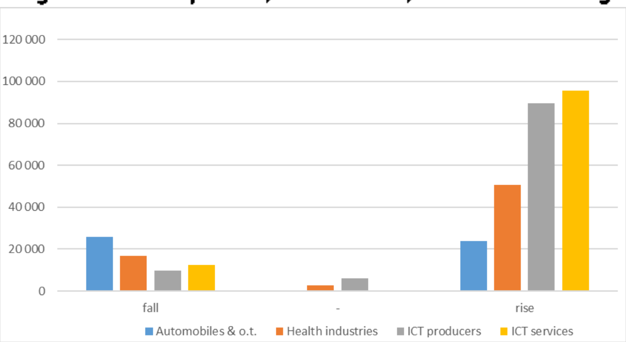
Another way to look at the dynamics is to observe the scatterplots of the 2012 and 2022 rankings (Figure Figure A 4). In the top quintile, the scatterplot of 2012 and 2022 rankings shows less volatility and a certain degree of concentration around the 45-degree line[70] meaning thus fewer and smaller changes in the ranking positions. In the lower quintiles the ranking changes are rather scattered, meaning that the probability that a company significantly changes its rank as a result of an additional amount of R&D invested is much higher in the bottom 80% of the companies. The graph on the right of Figure A 4 shows that a significant share of the common set has not managed in 10 years to enter the top quintile from any position between 501 and 2500. Indeed, there were altogether 63 companies entering the top 500 in 2022 compared to 2012. A possible future research avenue, beyond the scope of the present analysis, would be to understand why these companies have never increased their R&D investment to levels that would have made them top 500 R&D investors worldwide. The 21% share (159 out of 751) of EU companies in this group of companies adds to the interest in researching them.

Over a 10 year period it is to be expected that each industrial sector has a positive contribution to R&D, and that the increase of their R&D investment has kept the companies in the common set of 1 228, regardless of their rank changes. In the top 1000[71] the ICT services sector has contributed the most to the R&D increase[72], companies improving their ranking in this sector invested more than double on average per company than similar companies in automobiles or health sectors (**Figure 3.8 Top 1000, common set, 2012-2022 changes**Figure 3.8, and Figure A 5 in Annex 3). Out of the key sectors, the automotive sector has contributed the least and it is the only sector in the top 1000 where more companies worsened their positions than those that improved.

Figure 3.8 Top 1000, common set, 2012-2022 changes



no of comps	Fall	No change	Rise	Total
Automotive	41	1	28	41
Health	36	2	59	36
ICT producers	63	1	83	63
ICT services	22	0	55	22

Note: Left Panel: Average R&D of companies improving (rise) and worsening (fall) their ranking; right panel: Changes in R&D in the main sectors of activity by ranking change type

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Entry/exit

A total of 1272 companies entered or exited[73] the ranking between the 2012 and 2022 *Scoreboards* (Figure 3.9). The larger numbers towards the bottom cohorts indicate the increasing volatility of the tail, i.e. the turnover of companies is higher in the lowest ranks. Besides, more companies entered newly the top two quintiles than exited, because of substantial growth in R&D amongst smaller companies. The R&D shares on the right panel of Figure 3.9 reflect this development: the highest shares are those of entrants in the top two quintiles, and they are higher than those of the companies exiting these cohorts. While new entrants' R&D investments account for ca. 23% of the total R&D invested in the *Scoreboard* 2022, 16% of the *Scoreboard* 2012 R&D[74] has been lost via the exiting companies. Since the total R&D in the 2022 *Scoreboard* is about double that of 2012, the entrants have clearly added significantly to the amount of R&D investment. This can

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70 The 45-degree line indicates no change in the rank.

71 The top 1000 accounts for about 88% of R&D of the total *Scoreboard* (the top 500 for 80%). In the three lower quintiles, changes in the ranks are linked to fairly low R&D figures and changes in the rank positions of these companies may have less relevance.

72 Mergers and acquisitions may have played an important role in the increases of the ICT services R&D investments.

73 An entry means a company that is present in the ranking in a certain year (here: 2022) but absent from it in the reference year (here: 2012). An exit means a company that is present in the reference year but no longer in the other year (here: 2022). The number of entries on the level of the *Scoreboard* corresponds to the number of exits. However, in the quintile group the two are not necessarily equal, as the exit does not mean exiting the quintile, but disappearing from the full list of 2500 companies.

74 Expressed in 2022 exchange rates.

be quantified to about 30% of the total R&D in the *Scoreboard* 2012 (or 15% of 2022). It is important to note that many exits have been due to takeovers and mergers so that the R&D of the exiting company is still in the *Scoreboard* but now assigned to the acquirer. M&A is common in the health and ICT sectors.

Figure 3.9 Entries and exits between *Scoreboard* 2012 and 2022 per quintile; number of firms and R&D

Note: Left: Number of entering/exiting companies between Scoreboard 2022 and 2012 per quintile. Right: R&D share in total Scoreboard R&D (2012 for exiting, and 2022 for entering companies) of companies from the left per quintile

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Concerning geographical regions and sectors of activity, the main turnover (i.e. entry/exit) development is the increase of Chinese presence in terms of the number of companies present practically in each sector, as well as a significant and overall increase in the R&D investment (Table 3.4). China's strategy of investing in key technology sectors is clearly seen in the *Scoreboards*, via their massive investments in the automotive, health and ICT sectors. The US entrants' investment is still by far the largest in ICT services and health industries (the latter mainly in biotech and pharma), and its massive reduction of R&D investment in the ICT producers sector reflects its strategy of outsourcing a part of its R&D activity. A significant share of Chinese growth in this sector may stem from this process. For the EU, in contrast, apart from automotive, the increase in R&D in the key sectors is relatively modest. It is important to mention that the Rest of the world (RoW) figure hides the big increase in the importance of Taiwan for IT hardware R&D and production. New entrants from Taiwan in this sector invested EUR 1.4 billion in 2021.

Table 3.4 Net entries* to Scoreboard 2022 by region and sector, and net R&D changes

Sector	Number of companies						R&D, mlnEUR					
	EU	JP	CN	US	RoW	Total	EU	JP	CN	US	RoW	Total
Aerospace & Defence	-3	-1	4	-6	-4	**-10**	-248	-16	395	-510	348	**-31**
Automobiles & other transport	-10	-24	35	0	-2	**-1**	3 855	-552	6 177	2 566	1 146	**13 191**
Chemicals	-6	-27	29	-17	-12	**-33**	92	-604	3 465	-1 594	-472	**887**
Construction	-12	-17	24	-3	-3	**-11**	961	-336	11 811	-112	116	**12 440**
Energy	-8	-8	16	-3	-7	**-10**	538	-136	2 654	-206	101	**2 951**
Financial	-10	0	12	1	2	**5**	358	0	2 014	2 625	469	**5 466**
Health industries	-18	-13	79	129	3	**180**	4 573	-114	11 204	28 520	2 815	**46 998**
ICT producers	-24	-53	99	-110	-54	**-142**	-2 616	-1 375	19 080	-9 204	-1 458	**4 427**
ICT services	-13	-9	65	74	-12	**105**	722	1 317	12 808	31 208	3 722	**49 778**
Industrials	-35	-52	63	-20	-24	**-68**	-1 741	-1 142	10 910	176	936	**9 138**
Others	-24	-43	74	-9	-13	**-15**	438	-970	16 315	1 934	-407	**17 311**
Total	**-163**	**-247**	**500**	**36**	**-126**	**0**	**6 932**	**-3 928**	**96 833**	**55 404**	**7 316**	**162 557**

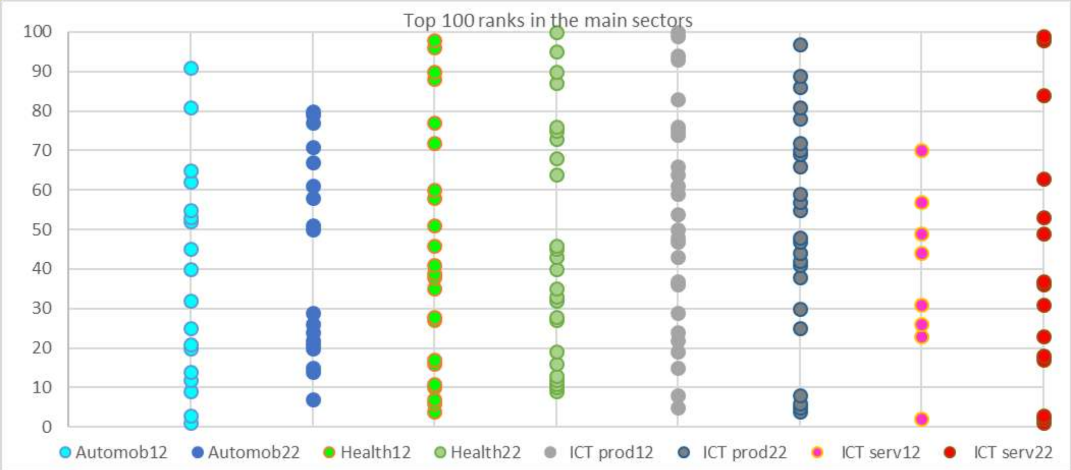
*: Difference in the number of companies that entered the 2022 Scoreboard and exited the 2012 Scoreboard

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

3.4 Now and then: World regions and sectors - comparison between the 2012 and 2022 *Scoreboards*

We compare company trends (number, volume of R&D investment) between the *Scoreboard* editions of 2012 and 2022 by main competing geographical region (China, US, EU, Japan) and by sector of activity. As we have previously seen, the automotive sector, ICT producers, ICT services and health industries are the four key industries that dominate the *Scoreboard*. Altogether, they account for around 73% (in 2012) to 78% (in 2022) of total R&D investment by the top 2 500 investors. In both years, the key sectors had the most companies in the top 100.[75] The number of ICT services companies increased more than any other sector in the top 100, followed by health firms. ICT firms tend to be higher ranked, particularly in ICT services (Figure 3.10).

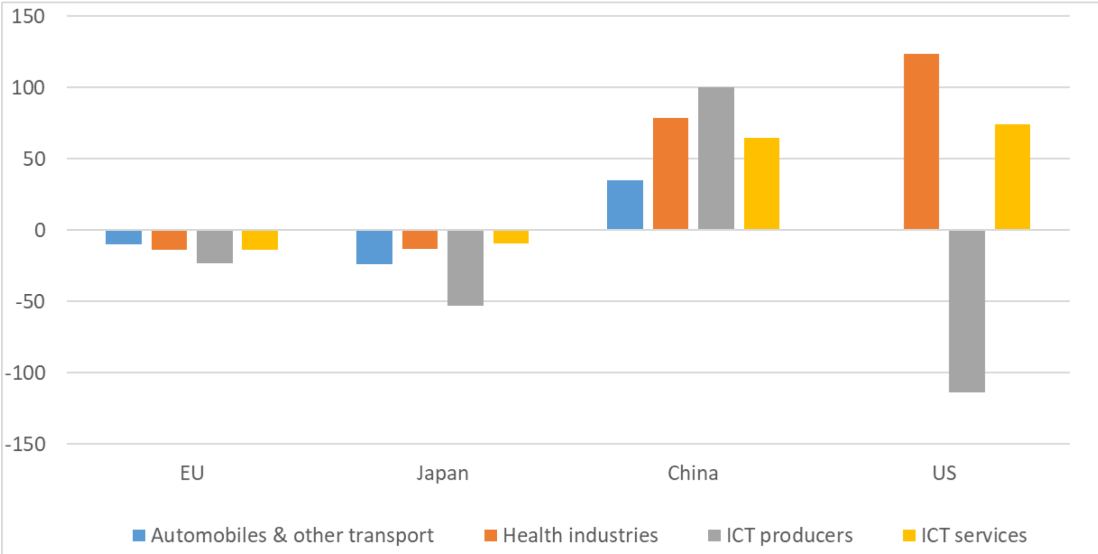
Figure 3.10 Number of companies by sector in the top 100 in *Scoreboard* 2012 and 2022



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

One of the most important development in the global R&D ranking is that more and more positions are being taken up by high-tech companies, mainly from the US and China, at the expense of more traditional manufacturing sectors, mainly from the EU and Japan. Chinese presence has significantly increased in the *Scoreboard*, with the addition of 503 companies between 2012 and 2022 (Table A1, Annex 3). The US presence increased in health industries and ICT services, thanks mainly to its sustained investment in information technology and pharmaceuticals. The US has a clear global lead in biotechnology. However, it stagnated in the automotive sector and decreased in ICT producers sector because of its massive outsourcing of computer hardware R&D, mainly to Taiwan, China, and South Korea. The number of EU headquartered companies slightly decreased in the key sectors[76]. Japanese companies are fewer in the 2022 *Scoreboard* than in 2012, with the largest decrease in the ICT producers sector (Figure 3.11).

Figure 3.11 Main changes between *Scoreboard* 2012 and 2022 in key sectors by country/region, number of companies



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

75 Although the present analysis does not focus primarily on the top 100 companies, this category shows most visibly the change in the number of companies per sector.

76 Although it is decreasing, the net decrease in the key sectors is only 61 companies between 2012 and 2022, i.e. six companies per year.

Between the 2012 and the 2022 *Scoreboards* the R&D investment of the 4 main competing regions in the *Scoreboard's* 4 key industries were the ones that increased R&D the most globally, particularly in the US and China (Table 3.5)[77]. The main difference between the regions is that while the R&D investment of the EU, Japan and US mainly targeted the key sectors, Chinese R&D investments increased somewhat more evenly across industrial sectors. Chinese investment also increased significantly in the construction, energy and industrials as it strengthened its position as a base for lower cost manufacturing. While the share of R&D of the four key sectors in the former 3 regions ranges between 87% and 99%, in China it is only 61%. Similarly to new entrants (see Table 3.3, above), the RoW figure of the changes for ICT producers includes the major increase of the R&D of Taiwanese ICT hardware production companies. These companies more than doubled their R&D investment, accounting for about 57% of the RoW-total.[78] Taiwan Semiconductors Manufacturing (TSMC) alone produces some 50% of the world's chips[79] and 90% of the advanced chips[80]. This company increased its R&D by EUR 2.9 billion between the 2012 and 2022 *Scoreboards* (i.e. 2011 and 2021).

Table 3.5 Change of R&D by country/region and sector between 2012* and 2022, EUR million

	Change between SB2022 and SB2012					
R&D invested by sector	**EU**	**JP**	**CN**	**US**	**RoW**	**Total**
Aerospace & Defence	-1,260	-16	587	-26	-134	-849
Automobiles & o.t. (key)	**26,271**	**9,804**	**15,020**	**7,513**	**5,658**	**64,266**
Chemicals	990	1,388	3,690	-1,928	743	4,883
Construction	1,457	162	22,020	-82	582	24,139
Energy	1,185	-143	4,101	-1,164	-962	3,018
Financial	3,233	0	2,014	2,954	1,628	9,829
Health industries (key)	**19,294**	**4,962**	**13,385**	**68,287**	**14,896**	**120,824**
ICT producers (key)	**5,441**	**569**	**45,055**	**40,469**	**19,694**	**111,229**
ICT services (key)	**7,333**	**4,062**	**33,351**	**108,363**	**7,299**	**160,408**
Industrials	1,027	-358	17,684	-1,481	1,381	18,254
Others	1,688	1,765	18,313	4,421	5,915	32,102
Total	**66,660**	**22,197**	**175,221**	**227,325**	**56,700**	**548,103**
Key sectors - total	58,339	19,398	106,811	224,632	47,547	456,727
Key sectors - %	88%	87%	61%	99%	84%	83%

*: 2011 R&D recalculated using 2021 exchange rates

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The EU's R&D investment has been highly concentrated in the automotive sector and rather low in ICT in the last decade compared to the *Scoreboard* average structure of number of companies (Table A 4, Annex 3) and of R&D invested (Table 3.6).

The most notable changes between the 2012 and the 2022 *Scoreboards* are:

— An increase in the share of R&D investment in health industries and ICT services, and a decrease in the share of R&D investment by ICT producers across the board and in the four competing regions, with some significant individual increases (e.g. health in China and ICT services in the US);

— The automotive sector R&D was by far the most significant for both the EU and Japan and its importance increased over the last ten years. Its share in the total R&D invested by companies headquartered in these regions is around 30% (Japan) and 32.5% (the EU). These shares are more than double of their *Scoreboard* average counterparts;

77 Note that especially for China the previously mentioned improvement in coverage may be somewhat stronger. However, China's massive technological investments of the last 10-20 years is well documented in the literature.

78 Taiwanese companies of this sector increased their R&D investment to EUR 22.3 billion in the *Scoreboard* 2022 from around EUR 10 billion[79] in 2012, meaning an increase of EUR 11.3 billion out of the EUR 19.7 billion (i.e. 57%) total increase of this sector for the RoW companies

79 https://www.cnbc.com/2021/03/16/2-charts-show-how-much-the-world-depends-on-taiwan-for-semiconductors.html – website last accessed on 8 November, 2022

80 https://www.stimson.org/2022/semiconductors-and-taiwans-silicon-shield/ – website last accessed on 8 November, 2022

— A significant share of Chinese *Scoreboard* companies invests in construction, industrials, and energy sector, the latter's share experiencing a huge decrease, although it is still somewhat higher than the *Scoreboard* average.

Table 3.6 Structure of R&D in industrial sectors by country/region

SB Sectors	SB average		EU		Japan		China		US	
	2012	2022	2012	2022	2012	2022	2012	2022	2012	2022
Aerospace & Defence	3,4%	1,6%	6,0%	3,3%	0,0%	0,0%	0,0%	0,3%	3,6%	1,7%
Automobiles & other transport	16,2%	13,9%	28,8%	32,5%	25,5%	29,2%	14,6%	9,2%	9,5%	6,3%
Chemicals	3,7%	2,3%	3,5%	2,8%	7,1%	6,9%	0,5%	1,9%	3,1%	1,1%
Construction	1,2%	2,8%	1,2%	1,5%	1,3%	1,2%	13,2%	12,6%	0,3%	0,1%
Energy	3,0%	1,8%	3,5%	2,9%	1,2%	0,9%	13,0%	3,5%	1,7%	0,6%
Financial	1,7%	1,8%	3,1%	3,7%	0,0%	0,0%	0,0%	1,0%	0,3%	0,8%
Health industries	21,0%	21,5%	15,3%	20,0%	11,3%	13,5%	1,9%	7,0%	26,2%	28,2%
ICT producers	24,8%	22,6%	18,3%	14,8%	22,3%	18,4%	33,7%	26,6%	26,8%	22,2%
ICT services	10,2%	19,8%	5,9%	7,7%	5,9%	8,3%	6,7%	17,7%	17,5%	33,1%
Industrials	6,7%	5,0%	8,3%	6,0%	10,0%	7,8%	12,8%	10,4%	4,6%	1,9%
Others	8,0%	6,9%	6,1%	4,9%	15,3%	13,9%	3,5%	9,7%	6,4%	4,1%

Note: red = lower than Scoreboard average, green = higher than Scoreboard average
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

3.5 Keys points

— The importance of the top 50 corporate R&D investors is shown by the relative stability in terms of sample composition and their large share of global R&D investment throughout the last decade. In this group of companies, the EU has a strong and stable presence in terms of number of companies; until this year, the EU companies have been the second largest R&D investors behind the US. However, the average growth rate of R&D investment of the EU companies over the past 10 years lags behind that of the top 50.

— A significant share of companies present in the *Scoreboard* nowadays has not managed to enter the top 500 from any position between 501 and 2500 in the past 10 years.

— The number of EU companies decreased by a net amount of 13 companies per year on average during the last decade. While in the top 500 the decrease was only marginal, in the lowest quintile group the number of EU companies have almost halved, from 103 companies in 2012 down to 56 by 2022. The main reasons behind these changes are mergers and company reorganisations as well as R&D being too low to reach the *Scoreboard* threshold suggesting a relatively low growth amongst small up-and-coming companies.

— The share of R&D investment in health and ICT services in the total *Scoreboard* has increased in every major investor region at the expense of ICT producers. Some sectoral increases are rather significant, such as health R&D share in China and ICT services in the US.

— The automotive sector R&D was by far the most significant for both the EU and Japan and its importance increased over the last 10 years. Its share in the total R&D invested by companies headquartered in these regions is around 30% (Japan) and 32.5% (the EU). These shares are more than double than the share of the automotive on the level of the entire *Scoreboard*.

— A significant share of Chinese *Scoreboard* companies are in the construction, industrials, and energy sectors, with the latter experiencing a strongly declining R&D share, although it is still somewhat higher than the share of the energy sector on the level of the entire *Scoreboard*.

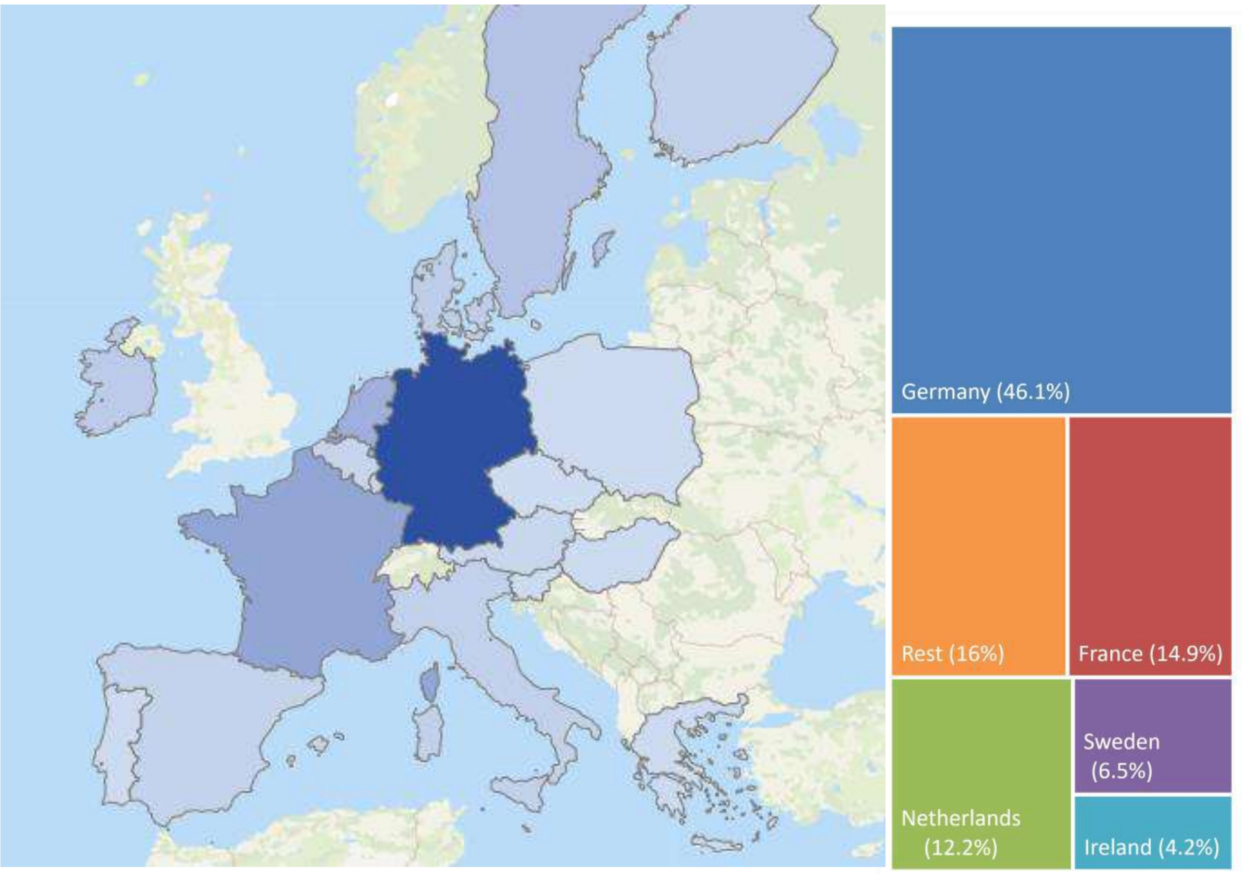
4 A closer look at the EU

This chapter provides a more detailed description of the private R&D investment across EU countries, based on data of the 1000 companies headquartered in the EU with the highest R&D investments. This includes the 361 EU headquartered companies in the global 2500. 639 additional companies spent between EUR 48.7 million (the threshold to get into the top 2500 ranking) and EUR 3.1 million in 2021. The threshold to enter the EU1000 sample increased by around 50% compared to the 2021 *Scoreboard* (which was EUR 2 million), mainly as the result of the economic recovery after the COVID-19 pandemic. This chapter is structured as follows: Section 4.1 gives a country overview, Section 4.2 provides a look at the sectors, Section 4.3 presents details on the three largest R&D sectors in the extended sample, and the final Section 4.4 gives a closer look at the top 5 R&D investing countries in the EU-27.

4.1 Top 1000 EU R&D investors – country overview

The geographical distribution of the EU1000 companies is presented in figure 4.1. Overall, the EU1000 companies are located in 19 Member States and invested EUR 202.9 billion in R&D in 2021. The 639 companies from the extended group add EUR 10.1 billion to the EUR 192.8 billion of the core 361 companies (5% of the total R&D investment by the EU1000).

Figure 4.1 Total R&D Investment by the EU1000 – Map / Treemap of the distribution of R&D investment



Note: Map - colour darkness proportional to R&D investment in 2021 by companies headquartered in the country. Treemap – Top 5 countries representing 84% of R&D in the EU1000 sample, the remaining 14 countries are responsible for 14% of the total.

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table 4.1 presents the distribution of R&D by Member State for the EU1000 firms. The top three countries in terms of R&D investment by the EU1000 sample, Germany, France, and Netherlands, represent together 50.1% of the companies with headquarters there and 73.3% of R&D investments. However, also Member States without representation in the EU1000 do have R&D investing firms but their investment either does not reach the threshold of EUR 3.1 million, they are affiliates, headquartered in other countries or not publicly listed.

Table 4.1 R&D by Member State in the EU1000 sample

Country	*Companies (core/extended)*	*R&D (EUR m)*	*Share of companies*	*Share of R&D*
Belgium	34 (12/22)	3 480.06	3.4%	1.72%
Czechia	1 (0/1)	21.84	0.1%	0.01%
Denmark	66 (25/41)	7 804.46	6.6%	3.85%
Germany	285 (114/171)	93 620.49	28.5%	46.15%
Ireland	42 (24/18)	8 575.12	4.2%	4.23%
Greece	7 (0/7)	40.18	0.7%	0.02%
Spain	27 (12/15)	4 698.73	2.7%	2.32%
France	149 (57/92)	30 306	14.9%	14.94%
Italy	45 (20/25)	5 689.19	4.5%	2.80%
Luxembourg	25 (3/22)	1 678.75	2.5%	0.83%
Hungary	1 (1/0)	165.37	0.1%	0.08%
Malta	1 (1/0)	62.62	0.1%	0.03%
Netherlands	66 (38/28)	24 755.13	6.6%	12.2%
Austria	38 (13/25)	2 446.48	3.8%	1.21%
Poland	3 (0/3)	78.72	0.3%	0.04%
Portugal	5 (2/3)	228.87	0.5%	0.11%
Slovenia	1 (1/0)	154.55	0.1%	0.08%
Finland	52 (12/40)	5 946.95	5.2%	2.93%
Sweden	152 (26/126)	13 112.85	15.2%	6.46%
Total	1000 (361/639)	202 866.4	100.0%	100.0%

Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

4.2 Top 1000 EU R&D investors – sectoral overview

The distribution R&D investment of the EU1000 companies across sectors is shown in Table 4.2. The largest sector in terms of R&D is of course automobiles and other transport, which is responsible for over 31% of R&D in the sample, followed by the health industries. From the 1000 companies, 170 are SMEs with less than 250 employees; in each sector, there is at least one SME that belongs to the 1000 largest R&D investors, and in both health industries and ICT services 2 SMEs belong to the EU core group, and one firm in construction as well. In sum, there are only few more SMEs in the extended EU sample than the US has SMEs in the global top 2500 R&D investors (156); in Europe, each 5 SMEs in the top 2500 come from the UK and Switzerland.

Table 4.2 R&D by sector in the EU1000 sample

	Countries	*Core group*	*Extended group*	*SMEs*	*R&D, EUR m*	*Share of R&D*
Aerospace & defence	7	10	5	1	6 432.8	3.2%
Automobiles & other transport	10	34	26	3	63 193	31.1%
Chemicals	9	16	21	2	5 624.6	2.8%
Construction	12	9	29	2	3 371.8	1.7%
Energy	15	26	12	2	5 794.5	2.9%
Financial	12	22	48	4	7 845	3.9%
Health industries	14	68	128	98	40 508.4	19.9%
ICT producers	12	42	74	16	29 717.8	14.7%
ICT services	14	30	78	21	15 955.5	7.9%
Industrials	12	57	95	3	13 171.7	6.4%
Others	16	47	123	18	11 251.3	5.6%

Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.

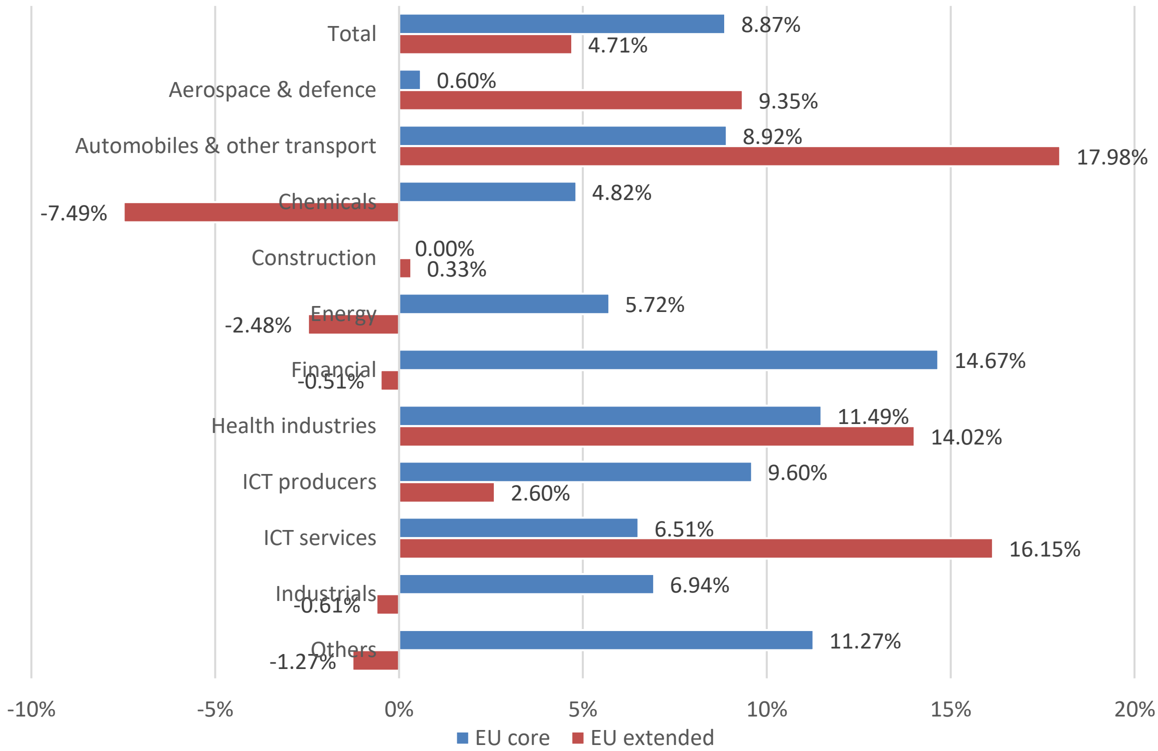
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 4.2 displays the growth of R&D investment across sectors for the core and the extended group. Overall, the R&D investment of the core companies increased by 8.87%, significantly higher than for the extended group (4.71%) but six percentage points lower than the growth of total R&D investment by the top 2500. In sum, the core group spent EUR 15.69 billion more on R&D in 2021 than in the previous year – an amount that exceeds the total R&D of the remaining 639 companies by 50%.

The growth rates of R&D investment vary considerably across sectors and also between the two groups. The core companies in aerospace and defence report only a marginal increase of 0.6% after the massive decline of 22.6% in 2020 - the total R&D investment by these ten companies in 2021 therefore remains almost EUR 1.8 billion below the level of 2019. In contrast, the extended group companies continue their positive growth trajectory from the past year with an increase of 9.35%, but their total R&D amounts to only EUR 74 million.

In the chemicals sector, the growth of R&D investment in the core group was strong enough to reach the 2019 level, while in the extended group the decline observed in 2020 continued in a similar magnitude. While the companies in construction raised their R&D investment only by little (if at all), a dynamic development is observed for the other sectors. Particularly positive is the development of the core companies in the financial and energy sector – however, these sectors, as aerospace and defence, comprise only small shares of total R&D of the EU1000 companies (compare Table 4.2, Figure 4.3)

Figure 4.2 1-year R&D growth rates by sector- EU core vs EU extended group



Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The most significant increase for the total R&D investment of the EU1000 comes from the companies in automobiles and other transport – the core group invested over EUR 5 billion more in 2021 and thereby slightly surpassed the R&D investment of 2019, and the extended group companies report the largest relative increase in R&D investment across all sectors. Given the high weight of this sector in the EU (31.3% of the total R&D in the EU1000), this development is a significant driver of the EU total.

The core firms in health industries continue their expansion, and also the extended group companies significantly raised their R&D investment after the decline in 2020 (-5.3%). Overall, the 68 EU health companies in the core group spent EUR 38.5 billion on R&D in 2021, the second most important R&D sector in the EU. This positive development is to a large extent determined by the European companies in biotechnology and pharmaceuticals that developed vaccines and treatments against COVID-19; overall, the sector's R&D investment increased by EUR 4 billion compared to 2020 (plus EUR 6 billion compared to 2019).

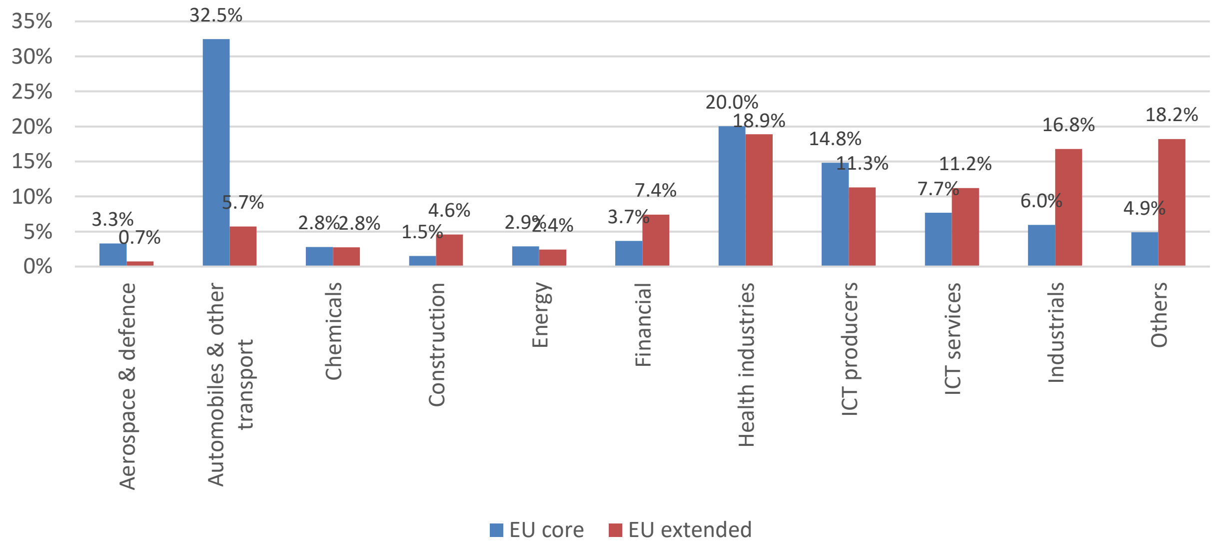
For the ICT producers and ICT services, both groups raised their R&D investment in the previous year, but while the core group of ICT producers expanded almost three times more than the extended group, the extended group of ICT services increased their R&D much stronger than the core group. Overall, this implies for ICT producers that they slightly surpassed the level of R&D in 2019 (after the reduction in 2020), while for ICT services, which continued its expansion form 2020, the 2021 R&D investment exceeds the 2019 level by EUR 2.2 billion.

Finally, the core companies in industrials and the group "others" both increased their R&D investment in 2021. However, for the industrial core companies, this increase was not enough to reach the R&D investment from the year 2019, while the core companies in "others" continued their expansion path. The companies of the extended group in these two sectors reduced their R&D in 2021 compared to 2020 and thereby perpetuate the negative development of the past year, albeit at a slower pace.

Figure 4.3 displays the distribution of R&D across sectors for the core and extended group of the EU headquartered SB companies. The R&D investment distribution across sectors between the core and the extended sample firms differs considerably. While in the core group, the automobile and other transport sector dominates the distribution, the extended group distribution has more weight in the high-tech sectors health industries, ICT services and ICT producers, as well as in "others" and industrials. Taken together, ICT services and ICT producers constitute the largest sector in the extended sample with 22.5% of R&D investment.

The extended group shares of R&D in ICT services and industrials are higher than the corresponding ones of the core group. The largest share of R&D in the extended sample is attributed to companies in health industries – with 18.9% of the total the sector ranks first, followed by "others" with 18.2%. Bearing in mind the small amount of R&D the extended group represents, the analysis of the sectoral distribution of R&D in the extended group can give insights into the role of small R&D investors in important high-tech sectors where the EU lags behind its competitors.

Figure 4.3 R&D share by sector - core EU vs extended EU



Note: *"Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.* The percentages are the shares of R&D by sector of the core (blue bars) and extended (orange bars) groups.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

4.3 Top 3 Sectors in the Extended Group

The three largest sectors in term of R&D investment in the extended group of the EU1000 are health industries, the group of "others" and industrials; these three sectors comprise 346 of the 639 extended group companies and EUR 5.44 billion of the total of EUR 10.1 billion R&D investment of this group (54.1% of companies, 53.9% of R&D). The analysis of these sectors of the extended sample of R&D investors in the EU allows obtaining a deeper understanding of the most important sectors beyond the well-known top R&D investors.

Table 4.3 displays how the number of firms and the R&D investment of the three sectors is distributed across EU Member States, as well the growth rate of R&D investment of those firms compared to 2020. The companies in the sectors health industries and "others" come from 11 Member States, and from 15 for industrials. While the companies in health increased their R&D investment considerably (see above), the companies in the other two sectors reduced their R&D (compare Figure 4.2). It is important to note that the growth rates in R&D investment by country and sector can be driven by actions of a few firms.

Table 4.3 EU extended group – Top 3 sectors: Country overview

	Health industries			*Others*			*Industrials*		
	n	R&D, EUR m	Growth	n	R&D, EUR m	Growth	n	R&D, EUR m	Growth
Belgium	7	128.61	2.98%	4	46.15	29.87%	4	65.11	-2.81%
Denmark	9	131.56	31.89%	7	140.88	-9.72%	3	86.93	7.13%
Germany	13	170.91	-12.91%	36	564.40	-7.21%	32	599.88	3.18%
Ireland	7	65.93	-16.58%	5	62.98	12.56%	0		
Greece	0			1	6.58	15.10%	0		
Spain	4	50.06	12.87%	2	11.66	11.74%	2	29.30	-0.46%
France	33	532.80	8.50%	12	187.12	-1.07%	12	217.58	-15.69%
Italy	4	63.23	14.86%	6	84.37	12.39%	5	146.62	7.34%
Luxembourg	0			4	64.41	1.52%	6	91.80	4.85%
Netherlands	11	315.96	60.53%	4	70.50	3.64%	4	105.33	11.49%
Austria	3	17.11	3.57%	5	88.51	14.02%	3	39.11	7.35%
Poland	0			2	52.11	-52.13%	0		
Portugal	0			1	16.47	34.50%	0		
Finland	3	31.64	20.27%	12	160.00	16.93%	6	95.35	-9.08%
Sweden	34	401.92	16.54%	22	284.39	10.40%	18	221.08	-4.68%
Total	128	1 909.73	14.02%	123	1 840.51	-1.27%	96	1 698.09	-0.61%

Note: Health industries comprise the subsectors pharmaceuticals & biotechnology and health care equipment & services; Industrials comprise general industrials, industrial engineering, industrial transportation, industrial metals & mining, and the sector "others" contains leisure goods, household goods & home construction, forestry & paper, support services, food producers, general retailers, personal goods, food & drug retailers, media, travel & leisure, tobacco, mining, and beverages.

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

75% of the companies in health industries are SMEs with less than 250 employees, while this share is only 3.2% for industrials, and 14.6% for "others". Out of all 170 SMEs in the EU1000, 96 are in the extended group in the health sector. In health industries, France, Sweden and the Netherlands are by far leading in terms of R&D investment and number of companies; overall, 60 Swedish companies are SMEs, and 29 of them in the health sector, France has 40 SMEs with 28 being in health. The growth of R&D investment in this high-tech sector and the large number of SMEs is an encouraging sign of a deepening of this important sector in the EU.

The group "others" contains a heterogeneous set of firms: 69 of the 123 companies are in high- or medium-high tech segments[81], in particular in fields such as leisure goods, (business) support services or personal goods. The small decrease in R&D compared to 2020 is the results of reduced investment of several larger firms in this group, while the majority of firms increased their R&D relative to the previous year. There are 18 SMEs in this group and they spread proportionally across the different fields of activity.

The third largest sector of the EU extended sample in terms of R&D is industrials that contains firms in medium-high (74 firms) and low-tech (21 firms) segments. While the companies in the medium-high tech segments increased their R&D investment compared to the previous year, those in low-tech decreased it, leading to an overall reduction in this sector.

Even if the R&D investment of the selected three sectors is similar, the remaining financial indicators displayed in Table 4.4 show how different they are. The companies in health so far serve only a small market in terms of net sales, and relating this to their R&D investment results in an R&D intensity close to 100%; aggregate profits are negative for this group as 96 out of the 128 companies marked a loss in 2021. At the same time, capital expenditures increased by 18.39%, employment by close to 14% and market capitalisation

[81] We follow the OECD technology classification based on R&D intensity: Galindo-Rueda, F. and F. Verger (2016), 'OECD Taxonomy of Economic Activities Based on R&D Intensity', *OECD Science, Technology and Industry Working Papers*, No 2016/04, OECD Publishing, Paris, https://doi.org/10.1787/5jlv73sqqp8r-en.

by almost 60%. The strong development of this SME dominated nascent group of R&D intensive companies in the extended sample of the EU1000 is a positive sign for a growing biotechnology and pharmaceutical sector in the EU.

Table 4.4 EU extended group – Top 3 sectors: Financial indicators

	Health industries	*Others*	*Industrials*
Net sales (EUR m)	11 054	196 609	291 790
One-year change	10.47%	10.54%	21.23%
R&D intensity	99.95%	2.30%	2.28%
Operating profits (EUR m)	-665	8 924	27 291
One-year change	29.58%	456.69%	141.14%
Profitability	-6.02%	4.54%	9.34%
Capex (EUR m)	568	7 622	10 064
One-year change	18.39%	8.50%	16.87%
Capex/net sales	5.14%	3.87%	3.45%
Employment	44 400	740 469	1 231 303
One-year change	13.89%	0.12%	3.31%
R&D per employee, EUR	42 774	2,522	1,387
Market capitalisation (EUR m)	59 156	187 002	249 766
One-year change	58.36%	38.71%	51.15%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Very much in contrast are the figures for industrials. Net sales of the EU extended group industrial companies amounted to over EUR 291 billion in 2021, a strong increase of 21% compared to 2020 that mainly relates to effects connected to COVID-19 and the economic recovery process, in particular for transport and logistics services. As an example, the net sales of Deutsche Post (industrial transportation) increased from EUR 63.3 billion in 2019 to EUR 81.7 billion in 2021; another example is the Danish logistics provider DSV that doubled its net sales since 2019 to EUR 24.5 billion. Also the companies in industrial metals and mining saw both their net sales and profits increase with the economic upswing and the demand- and supply-driven price increases of their products in 2021. A positive development is also the growth in employment of this labour-intensive sector – over 1.2 million people work for these 96 companies.

The companies collected in the group "others" also recovered from the COVID-19 pandemic, but developed in a less positive way than industrials. The at first sight almost unrealistic increase of profits by 456% is a result of the sector composition: The sector "others" encompasses the large travel providers such as Lufthansa or TUI that made significant losses in 2020 due to COVID-19 which could be reduced in 2021 but profits remained negative. Similarly, related leisure good providers such as Samsonite recorded massive losses in 2020 that were recovered in 2021. Also, producers of food and beverages, tobacco and forestry and paper recorded increased net sales and profits in 2021 and in many instances, the 2021 values exceeded those for 2019.

Combining the ICT services and ICT producers sector into one ICT sector, these 152 companies cover 22.5% (EUR 2.2 billion) of the R&D investment of the extended group and thereby constitute the largest R&D investing sector in this group. Their combined R&D investment grew by 8.9% relative to the previous year and is thus in line with the EU1000 sample. The top 5 countries in the ICT sector, Germany (50 firms), France (27), Sweden (27), Finland (14) and Denmark (8) headquarter 82% of the companies as well as of R&D investment. Here again an already familiar pattern emerges: Germany has the largest number of companies and the highest R&D investment (EUR 676 million), and Sweden has the most SMEs (13 out of 27 companies).

4.4 Country Focus – Top 5 EU Countries

Table 4.5 presents the main financial indicators for the companies headquartered in the top 5 countries in terms of R&D investment in the EU1000 sample. The number of companies in the top 1000 per country changed slightly: Germany lost 9 companies, Netherlands gained 3, Ireland gained 2, and Sweden and France each gained one company compared to 2020.

Companies headquartered in Germany are by far the largest R&D investors: as an example, the German automotive and other transport sector invested EUR 45.79 billion in R&D in 2021, while in France - the number two R&D investor in the EU-27 – all companies in the ranking together spent EUR 30.3 billion. With this value, France is the only country of this selection in which the level of R&D investment in 2021 is below its pre-COVID value (EUR 34.07 billion, see *Scoreboard* 2020).

Table 4.5 Main economic indicators for the EU1000 – Top 5 Member States

	Germany	***France***	***Netherlands***	***Sweden***	***Ireland***
Companies	285	149	66	152	42
R&D investment (EUR m)	93 620	30 306	24 755	13 112	8 575
One-year change	7.99%	2.67%	21.93%	5.62%	10.46%
Net sales (EUR m)	2 174 800	1 176 955	563 486	250 006	252 865
One-year change	14.07%	17.07%	24.81%	8.70%	11.28%
R&D intensity	4.87%	7.51%	6.03%	5.94%	4.08%
Operating profits (EUR m)	171 452	115 211	66 545	39 242	33 311
One-year change	219.53%	97.15%	185.52%	53.33%	67.30%
Profitability	7.88%	9.79%	11.81%	15.3%	13.17%
Capex (EUR m)	111 453	83 158	21 167	10 139	8 320
One-year change	1.93%	8.69%	-12.03%	30.34	-3.49%
Capex/net sales	5.12%	7.07%	3.76%	4.06%	3.29%
Employment	6 891 788	4 173 099	1 387 693	871 984	1 387 693
One-year change	-0.92%	-3.84%	9.91%	4.56%	10.27%
R&D per employee, EUR	13 5848	7 262	15 495	15 037	6 179
Market capitalisation (EUR m)	1 632 977	1 464 341	902 013	455 060	847 367
One-year change	29.65%	30.72%	61.64%	38.14%	37.61%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The most striking figure in Table 4.5 is the strong increase of R&D investment in the Netherlands by 21.94% – almost 40% of the increase is linked to Stellantis, which raised its R&D in 2021 by over EUR 2 billion. Also, Curevac (mRNA therapies, COVID-19 vaccine development) raised its R&D from EUR 87.5 million to EUR 722.5 million. The influence of the registration of the Stellantis headquarter in the Netherlands is visibile also in the other indicators: the close to EUR 4 billion reduction of capital expenditures (Capex) and the increase in market capitalisation by EUR 12 billion drive the overall strong decline in Capex and the strong increase in market capitalisation for the Netherlands. The same holds for employment – the almost 10% increase compared to 2020 is driven by the merger of Stellantis; with this bookkeeping transfer it increased employment by 100 000 full time equivalents. Overall, if Stellantis had not registered its headquarter in the Netherlands, R&D investment in Netherlands would have still grown by over 14%, and employment by around 3% (compare Chapter 2).

The second noticeable observation is the increase in profits in all five countries, and in particular in Germany and the Netherlands. The total profits of the German R&D investors increased by 219% compared to 2020, those of the Dutch companies by 185%. While an increase in profits is observed for all selected countries and is natural after the strong contraction due to COVID-19, the German numbers require a more detailed look (compare also section 4.3).

The German car producers realized massive profits in 2021: Mercedes-Benz profits increased from EUR 7 billion in 2020 to EUR 28 billion in 2021; from this, EUR 12.4 billion profit was gained solely from discontinued operations that comprised the profit from the spin-off and hive-down of the former Daimler Trucks & Buses segment. Volkswagen doubled its profits from EUR 9 billion to EUR 18 billion, and BMW almost tripled it from EUR 4.8 billion to EUR 13.4 billion. Not only the German luxury car producers had a golden year 2021, also companies such as Rheinmetall AG, Deutsche Bank, Deutsche Telekom, Deutsche Post, BASF and Infineon saw massive increases in profits that partly by far exceeded any of the past ten years. Last but not least, the German COVID-19 vaccine developer BioNTech earned profits of EUR 14.9 billion in 2021 after a loss of EUR 82 million in 2020. Nevertheless, the profitability of the German top R&D investors was considerably lower than of the companies in the other economies presented in Table 4.5.

A closer look at France reveals why the aggregate R&D investment is below the 2019 level, even if more French companies are in the EU1000 than in 2019, when UK companies were still included in the *Scoreboard*. For 4 out of the 5 largest French R&D investors Sanofi, Renault, Valeo, Schneider and Faurecia, the R&D investment in 2021 was considerably lower than in 2019 (except for Schneider). The large French Aerospace and defence sector raised its R&D by 3.12%, but the automotive sector reduced its investment by over 5%. Even if R&D investment in France is not as concentrated as in Germany with the all-dominating automotive sector, the growth in R&D investment by 87 out of the 149 firms in 2021 was not enough to reach the aggregate of 2019.

As mentioned above, the group of French firms in the top 1000 contains many companies from the health sector (41), and 28 of them are SMEs. The health sector is a driving force for the increase in net sales of the French companies, even if many of these companies were not yet profitable, their market capitalisation increased in 2021.

Sweden, the third largest R&D investing country in the EU-27, has three large R&D investors that spent over EUR 1 billion in R&D; at the same time the largest number of SMEs in the EU1000 is located in Sweden. While in aggregate, the Swedish companies show the lowest growth rates in terms of net sales and operating profits, they have the largest increase in capital expenditures of the 5 countries. Vattenfall (energy) and Volvo (automobiles) are the companies that drive the increase of almost 18%. Also SSAB, the largest steel manufacturer in Scandinavia, contributed significantly to the increase in profits and market capitalisation. Many of the small Swedish companies in health industries significantly increased their R&D compared to 2020 (and also relative to 2019), but given their relatively low amounts this has only a minor effect on aggregate R&D investment in Sweden.

With 10.46%, Ireland experienced the second largest increase in R&D investment of the 5 top R&D investing countries in the EU-27. Strong and quantitatively important contributions to R&D growth came from companies in health industries, i.e. Medtronic (which is responsible for over a quarter of Irish R&D in the SB), Jazz Pharmaceuticals or Horizon Pharma, but also Accenture raised its R&D investment by over EUR 200 million compared to 2020. Market capitalisation of the 42 companies increased by over 38% since 2020 – this is mainly the result of Johnson Controls (American Irish-domiciled multinational conglomerate for equipment, controls and services for energy efficiency of buildings) that witnessed a EUR 20 billion increase in market capitalisation to currently over EUR 47 billion. Finally, the strong growth in employment of the Irish top R&D investors of 10.27% relates almost entirely to Accenture that increased its number of employees from 506 000 to 624 000, worldwide.

4.5 Key points

- In 2021, the largest 1000 corporate R&D investors in the EU spent EUR 202.8 billion on R&D; 95% of this amount was invested by the 361 companies that belong to the group of the global top 2500 R&D investors. In addition, 639 companies that spent between EUR 48.7 million (the threshold to get into the top 2500 ranking) and EUR 3.1 million in 2021, are included in the EU1000. The threshold to enter the EU1000 sample increased by around 50% compared to the 2021 *Scoreboard*, mainly as the result of the economic recovery from COVID-19.
- The sample of the EU1000 displays the large variety of innovative companies in the EU-27. The traditional stronghold of EU corporate R&D lies in the automotive sector, 31.2% of the total corporate R&D was realised in this sector. On the other end of the scale, the *Scoreboard* identifies a significant number of smaller R&D investors in important and fast-growing high-tech sectors such as health or ICT.
- Both, the largest R&D investors and the smaller ones increased their R&D investment in 2021 compared to the previous year: the 361 EU companies that are also in the top 2500 raised their R&D by 8.87%, while the additional 639 companies increased their R&D by only 4.71%. Along with the recovery from COVID-19 in terms of R&D investment, also profits, sales and employment developed favourably in 2021.
- The pace of growth of the EU1000 aggregate R&D investment was again slower than for the other world major R&D investing regions - the US and China. The analysis of the top EU1000 R&D investors revealed that policy support for this heterogeneous group of companies, spanning from very large global corporations to high-tech SMEs, requires a broad mix of policies, ranging from investments into specific technologies (e.g. EU Battery Alliance) to scale-up support for small, growing firms.

5 Patenting trends in Green and Circular Economy Technologies

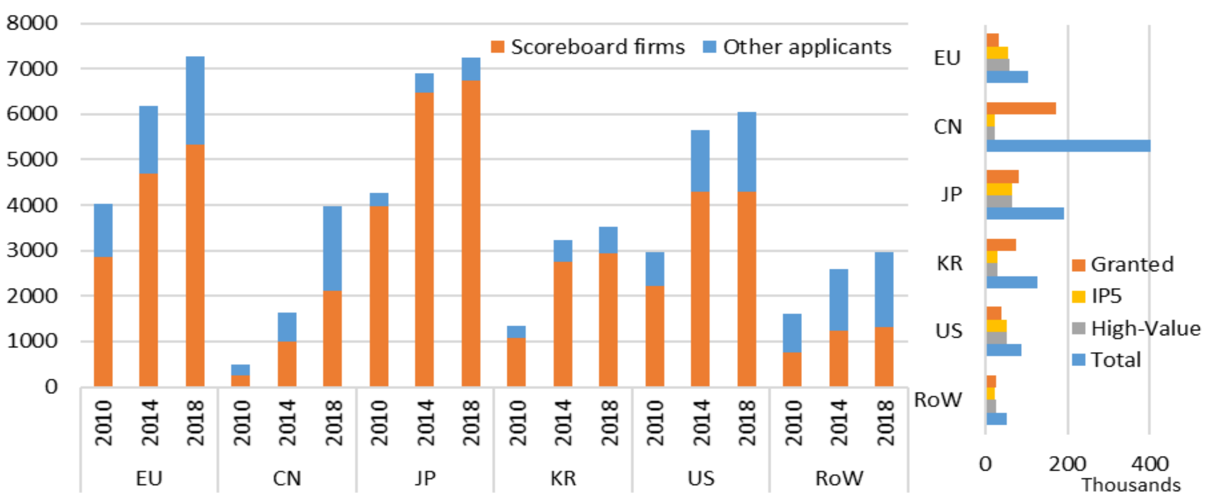
The 2021 EU Industrial R&D Investment Scoreboard provided an update on general patenting trends in climate change mitigation technologies (CCMTs), also referred to as 'green' patents, and an extensive analysis of green inventions for energy-intensive industries (EII). This year's chapter continues the review on general trends in CCMTs and focuses on patenting trends in the circular economy, one of the main building blocks of the European Green Deal[82]. The chapter provides an analysis of circular economy technologies (CETs) for the EU, a comparison with other major economies, and insights on the performance of EU *Scoreboard* companies and their subsidiaries in comparison with the leading R&D investors of other major economies.

We identify the CETs through CCMT patent classes[83] and aggregate them into industry groups. Table 5.2 in Box 5.1 shows the industries analysed and the concordance of codes used in the analysis. Section 5.1 provides an update on trends in CCMTs. Section 5.2 presents an analysis of global trends in CET inventions, provides further insights on the patenting activity of EU Member states, and examines the activity of global and EU *Scoreboard* companies.

5.1 Update on overall trends in CCMTS

The global share of green inventions has increased consistently to 9% of all filings in 2018, driven by very high numbers of Chinese inventions patented domestically. Globally, green high-value inventions have a share of 10% of all high-value patent filings in 2018. At 58%, the US and the EU have the highest shares of high value patents (patents filed at several patent offices, indicating international protection) among their green patents. The EU and the US also have a more diverse contribution to green innovation from applicants beyond the Scoreboard. By contrast, most of the high-value green filings in Japan and South Korea come from Scoreboard investors (Figure 5.1). The Scoreboard companies have a share of around 73% of green high-value inventions in 2018. Overall, the EU is among the leaders in high-value green inventions, having caught up with Japan. However, Japan remains in the lead in high-value green inventions by Scoreboard companies.

Figure 5.1 Trends in high-value green inventions: Scoreboard firms and other applicants



Note: On the left: trend of annual fillings of high-value green inventions for major economies for the years 2010, 2014 and 2018.
On the right: Green inventions in the period 2010-2018: total number of inventions, high-value inventions, IP5 inventions and granted inventions for major economies.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[82] Factsheets on the European Green Deal: https://ec.europa.eu/info/publications/factsheets-european-green-deal_en
[83] Section Y02 of the CPC classification. https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions

Box 5.1 Methodology

Patenting trends are produced following the methodology developed by the JRC[84] to derive indicators on global inventions in clean energy technologies[85]. Patent data are retrieved from PATSTAT 2022 Spring Edition. As data are not as complete from 2019 onwards; the analysis relies on 2018 annual figures to compare across major economies and to compute the specialisation index.

The analysis is restricted to Climate Change Mitigation Technologies (CCMTs)[86]. CCMTs – referred to as green technologies in the context of this study - are identified through the Y02 and Y04 schemes of the Cooperative Patent Classification (CPC).

Table B 5.1 Y02 and Y04 schemes of the CPC classes

CCMT	Y scheme	Y02 and Y04 description
Adaptation	Y02A	Technologies for adaptation to climate change
Buildings	Y02B	CCMTs related to buildings
CCS	Y02C	Carbon capture storage (CCS), sequestration or disposal of greenhouse gases
ICT	Y02D	CCMTs related to information and communication technology (ICT)
Energy	Y02E	Reduction of greenhouse gas emissions, related to energy generation, transmission or distribution
Production	Y02P	CCMTs in the production or processing of goods
Transport	Y02T	CCMTs related to transportation
Waste	Y02W	CCMTs related to wastewater treatment or waste management
Systems	Y04S	Systems integrating technologies related to power network operation, communication or information technologies, i.e. smart grids

The JRC methodology uses patent families as a proxy for inventions. Patent families include all documents relevant to a distinct invention, including patent applications to multiple jurisdictions as well as those following regional, national and international routes. Statistics are produced based on applicants only (as the owners of the patent and, thus, directly financing R&D activities) and considering different categories of applicants, namely companies, universities and government non-profit organisations. In case of multiple documents per invention, and when more than one applicant or technology code is associated with an application, fractional counting is used to proportion effort between applicants or technological areas, thus preventing multiple counting. An invention is considered of high-value when it contains patent applications to more than one office, as this entails longer processes and higher costs and thus indicates a higher expectation of the prospects in international markets[87,88]. Within a patent family, only patent applications protected in more than one office and in one of the largest five offices are considered as IP5[89]. High-value considers all countries separately, while IP5 requires at least one application to the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the National Intellectual

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84 JRC publications:
- Pasimeni, F., Fiorini, A., and Georgakaki, A. (2021). International landscape of the inventive activity on climate change mitigation technologies. A patent analysis. Energy Strategy Reviews, 36, 100677. https://doi.org/10.1016/j.esr.2021.100677
- Pasimeni, F. and Georgakaki, A. (2020). Patent-Based Indicators: Main Concepts and Data Availability. JRC121685, https://setis.ec.europa.eu/patent-based-indicators-main-concepts-and-data-availability_en
- Pasimeni, F., Fiorini, A., and Georgakaki, A. (2019). Assessing private R&D spending in Europe for climate change mitigation technologies via patent data. World Patent Information, 59, 101927. https://doi.org/10.1016/j.wpi.2019.101927
- Pasimeni, F. (2019). SQL query to increase data accuracy and completeness in PATSTAT. World Patent Information, 57, 1-7. https://doi.org/10.1016/j.wpi.2019.02.001
- Fiorini, A., Georgakaki, A., Pasimeni, F. and Tzimas, E. (2017). Monitoring R&I in Low-Carbon Energy Technologies. EUR 28446 EN, Publications Office of the European Union, Luxembourg. ISBN 978-92-79-65591-3, https://doi.org/10.2760/434051

85 SETIS Research & Innovation data: https://setis.ec.europa.eu/publications/setis-research-innovation-data

86 CPC classification. https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions

87 Dechezleprêtre, A., et al., (2011) Invention and transfer of climate change–mitigation technologies: a global analysis. *Review of environmental economics and policy.*

88 Dechezleprêtre, A. et al., (2015) Invention and International Diffusion of Water Conservation and Availability Technologies. *OECD Environment Working Papers, No. 82.*

89 Daiko, T. et al., (2017). World top R&D investors : industrial property strategies in the digital economy, Publications Office, https://data.europa.eu/doi/10.2760/837796

Property Administration of the People's Republic of China (CNIPA) or the United States Patent and Trademark Office (USPTO). A granted invention only sums fractional counts of the patent family related to granted patent applications.

Fractional counting is also used to quantify international collaborations in patenting activity. Co-inventions are calculated based on a matrix of all combinations among co-applicants, for inventions that have been produced by at least two entities resident in two different countries. Shares of co-inventions in the same country are not considered.

The analysis of EU *Scoreboard* companies focuses on the companies headquartered in the EU. The portfolio of inventions of these companies includes the inventions produced by all subsidiaries, irrespective of their location. The matching of subsidiaries to applicant names in PATSTAT currently covers 60% of the *Scoreboard* companies, which however account for 97% of R&D investments.

The selection of CCMTs relevant to Circular Economy Technologies (CETs) is done using relevant codes from the CPC classification shown in Table B 5.2, focusing on reuse and recycling aspects of inventive activities. Patent classes are aggregated as construction, chemicals & plastics, fertilisers, glass, metals, pulp & paper, food, fuel from waste, textiles, batteries & fuel cells, electrics & electronics, packaging, vehicles and waste water & sludge. Chemicals & plastics, fertilisers, glass, metals and pulp & paper are the subgroups of EII. To facilitate the illustration of results, in certain instances we group textiles, batteries & fuel cells, electrics & electronics, packaging, vehicles and waste water & sludge in the "other" category due to low levels of patent applications in corresponding technology classes.

Table B 5.2 Concordance of circular economy technologies and CPC classes

Industry		Technology	
Level 1	**Level 2**	**Y02 scheme codes**	**Description**
Construction	Construction	Y02W 30/58; Y02W 30/78; Y02W 30/91	Construction, demolition, wood and furniture recycling, and the use of waste
EII	Chemicals & Plastics	Y02P 20/143; Y02P 20/582; Y02P 20/584; Y02W 30/52; Y02W 30/62; Y02W 30/74	Plastics and chemicals recycling, and the use of recycled materials
	Fertilisers	Y02A 40/20; Y02W 30/40	Fertilizers of biological origin, and the use of waste or refuse in fertilisers
	Glass	Y02W 30/60	Glass recycling
	Metals	Y02P 10/20; Y02W 30/50	Reuse, recycle and recovery of metals
	Pulp & Paper	Y02W 30/64	Paper recycling
Food	Food	Y02P 60/87	Re-use of by-products of food processing for fodder production
Fuel from Waste	Fuel from Waste	Y02E 50/30	Fuel from waste, e.g. synthetic alcohol or diesel
Other	Textiles	Y02W 30/66	Disintegrating fibre-containing textile articles to obtain fibres for re-use
	Batteries & Fuel Cells	Y02W 30/84	Recycling of batteries or fuel cells
	Electrics & Electronics	Y02W 30/82	Recycling of waste of electrical or electronic equipment
	Packaging	Y02W 30/80	Packaging reuse or recycling, e.g. of multilayer packaging
	Vehicles	Y02W 30/56	Solid waste management of vehicles
	Wastewater & Sludge	Y02W 10/40	Valorisation of by-products of wastewater, sewage or sludge processing

Note: Technology descriptions adapted from the Y02 scheme descriptions of the CPC.

Table 5.1 shows the specialisation index[90] for the nine sub-classes of green technologies in major economies and changes over the period 2010-2018. Green sub-classes (in rows) relate to the patent classification of CCMT (Table B 5.1 in Box 5.1). In 2018, the EU had the highest specialisation index in all green technologies and the strongest increase in specialisation over the reference period among major economies. The EU has a positive specialisation index in every sub-class except for the green technologies related to ICT, and has experienced an increase in its specialisation in every technological category except for Adaptation technologies.

Table 5.1 Specialisation index in CCMT by technological categories and major economies (2018)

	EU		CN		JP		KR		US		RoW	
CCMT	Index	Change	Index	Change	Index	Change	Index	Change	Index	Change	Index	Change
Adaptation	0.1	0.0	-0.3	0.0	-0.5	0.1	-0.1	0.3	0.4	-0.2	0.6	0.1
Buildings	0.2	0.1	0.1	0.2	-0.1	-0.1	-0.1	-0.4	-0.2	0.1	0.1	-0.1
CCS	0.3	0.1	-0.6	0.2	-0.4	0.1	0.1	0.5	0.4	-0.3	0.3	0.0
ICT	-0.5	0.0	0.8	-0.5	-0.5	-0.5	0.7	0.0	0.3	0.1	-0.2	-0.3
Energy	0.1	0.1	-0.1	0.2	0.2	0.1	0.9	0.4	-0.4	-0.3	-0.3	-0.1
Production	0.2	0.2	-0.2	0.1	0.0	0.0	0.1	-0.1	0.0	0.0	-0.1	-0.1
Transport	0.6	0.3	-0.7	0.1	0.1	-0.1	-0.2	0.2	0.1	0.1	-0.3	0.3
Waste	0.5	0.2	-0.2	0.0	-0.3	0.0	-0.4	-0.1	-0.1	-0.2	0.5	0.2
Systems	0.2	0.3	-0.3	0.2	-0.2	0.0	0.0	-0.5	0.2	-0.1	0.2	0.0

Note: Based on high-value inventions.
For each economy, the index in 2018 is listed in the 1st column and the change with respect to 2010 is listed in the 2nd column.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The matrix in Figure 5.2 shows the dispersion of the nine sub-classes of green technologies across the Scoreboard industries. Green sub-classes (in columns) relate to the patent classification of climate change mitigation technologies (Table 1 in Box 1). In the period 2010-2019, ICT producers lead in green inventions with a share of 30% of green inventions, followed by Automobiles & other transport industry. Not surprisingly, ICT producers have the major share of green inventions related to ICT (76%). Similarly, the Scoreboard companies in Automobiles & other transport industry have the major share of green inventions related to Transport. Energy and Transport are the technology areas that dominate green inventions with shares of 33% and 28%, respectively.

Figure 5.2 Matrix of patent applications of the *Scoreboard* companies' green inventions (2010-2019)

	Adaptation	Buildings	CCS	ICT	Energy	Production	Transport	Waste	Systems	
Aerospace & Defence	2%	2%	3%	1%	2%	4%	15%	2%	2%	6%
Automobiles & other transp	15%	8%	5%	2%	18%	8%	56%	5%	9%	25%
Chemicals	14%	1%	24%	0%	9%	10%	1%	18%	1%	6%
Health industries	27%	1%	4%	1%	3%	3%	0%	4%	1%	3%
ICT producers	15%	46%	16%	76%	32%	33%	8%	17%	42%	30%
ICT services	2%	2%	1%	11%	2%	2%	0%	1%	10%	2%
Industrials	13%	15%	26%	2%	19%	25%	15%	19%	19%	17%
Others	12%	23%	20%	8%	16%	15%	3%	35%	17%	12%
	4%	7%	1%	9%	33%	14%	28%	1%	1%	100%

Note: Share of high-value green inventions labelled simultaneously with CPC codes related to technologies (rows) and ICB industries (columns).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[90] The share of inventions in the area of interest among all inventions within a country's portfolio, compared to the respective global average share.

5.2 Patenting trends in Circular Economy Technologies

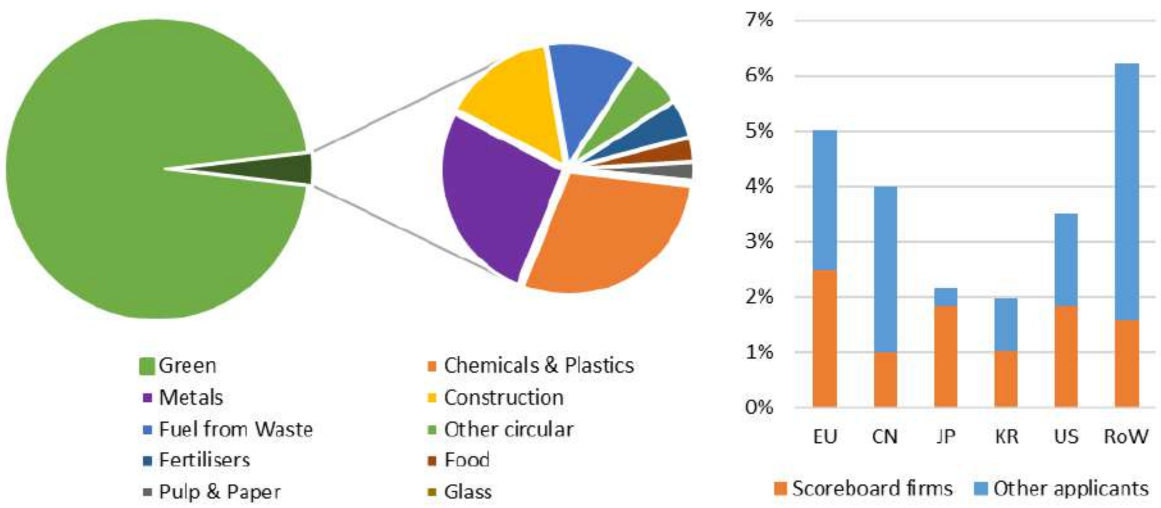
The innovative capacity of the leading EU companies in CETs is crucial to remaining competitive and leading the global transition towards a circular economy. In 2015, the EU announced the First Circular Economy Action Plan to transform the EU economy by creating new business opportunities and remaining competitive in the transition towards a circular economy[91]. The New Circular Economy Action Plan was adopted in 2020[92] and is one of the main building blocks of the European Green Deal. The plan is designed to reduce the use of natural resources by recycling and reducing waste, to create sustainable growth and jobs, and to lead global efforts on the circular economy.

The current section presents, using high-value patent statistics, the state of play in CETs for the EU in comparison with other major economies. It also provides insights on the performance of the EU Scoreboard companies and their subsidiaries alongside the leading R&D investors of other major economies, as these companies are the applicants of around 49% of the CET patents.

Global trends

Globally, patenting activity in CETs accounts for only about 4% of total green inventions between 2010 and 2019 (Figure 5.3). The share is the highest for the EU (5%), followed by China (4%) and the US (4%). The share of CETs in green inventions is around 2% in Japan and South Korea.

Figure 5.3 Share of CETs over green inventions in major economies. (2010-2019)



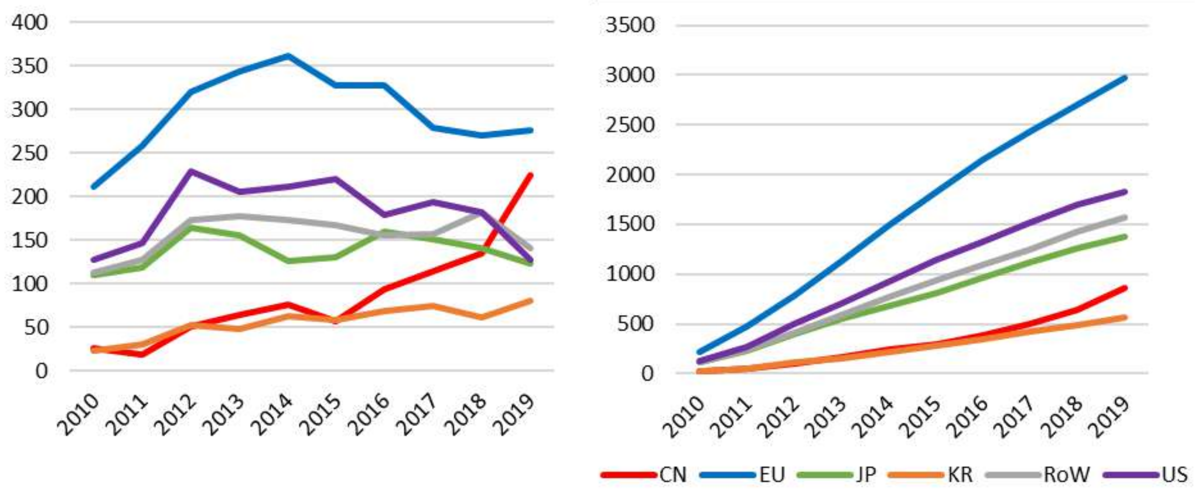
Note: On the left: Share of CETs in green inventions and the split of share by industrial categories for circular economy technologies.
On the right: Share of CETs in green inventions for major economies and the split of share between the Scoreboard firms and other applicants.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Between 2010 and 2019, the EU is the leader in CET inventions, both in absolute terms and as a share of overall green inventions (Figure 5.4**Error! Reference source not found.**). During this period, the EU's share of CETs in green inventions remains between 28% and 37%, despite a decreasing patenting trend between 2014 and 2018. The US is the second largest economy in terms of CET patenting activity, with a share fluctuating from 18% to 23%. In the US, similarly to the EU, there has been a decline in annual inventions after 2015. China had the highest growth rate over the same period; starting from a much lower level of activity, annual CET inventions more than quadrupled until 2018 and the latest figures for 2019 indicate an increase of more than seven times with respect to 2010.

91 Press release: https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6203

92 European Commission, Directorate-General for Communication, Circular economy action plan : for a cleaner and more competitive Europe, Publications Office of the European Union, 2020, https://data.europa.eu/doi/10.2779/05068

Figure 5.4 High-value inventions in CETs in major economies (2010-2019[93])



Note: On the left: Yearly high-value CET inventions. On the right: Cumulative trend of high-value CET inventions.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

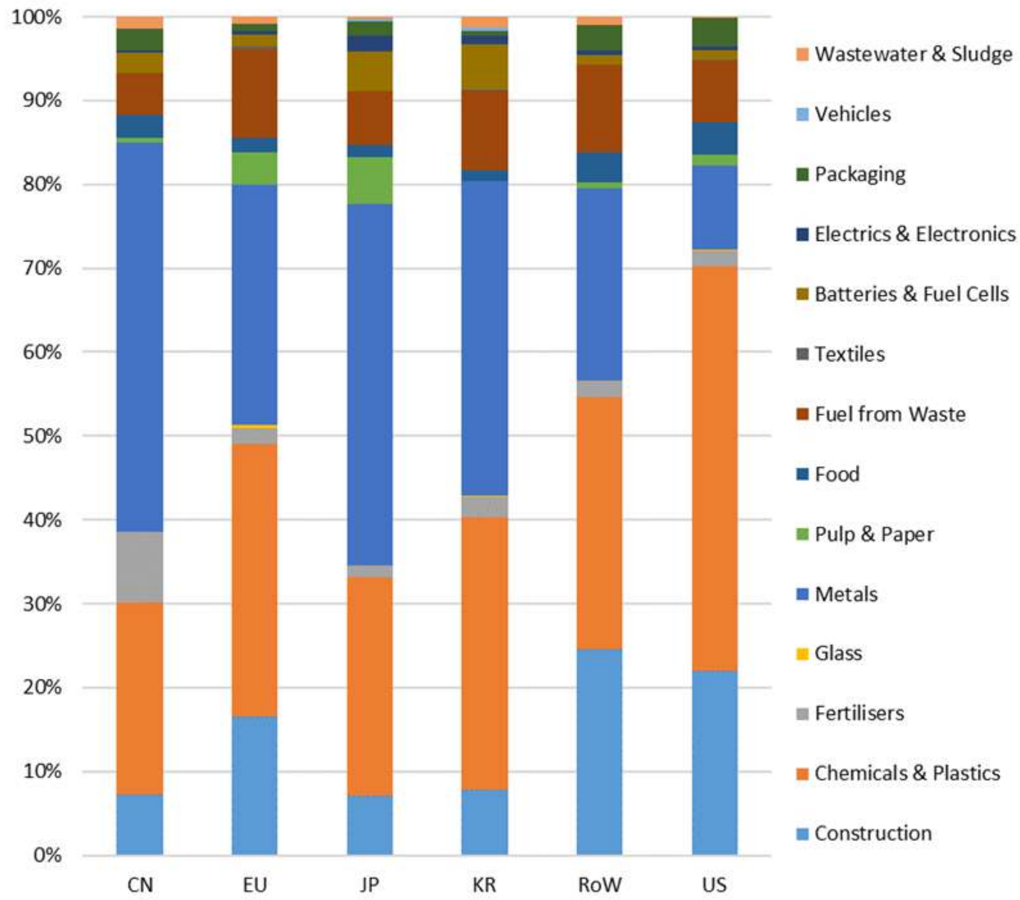
In the period 2010-2019, CET inventions are concentrated in chemicals & plastics (29%), metals (27%), construction (15%) and fuel from waste (12%) as shown in Figure 5.3. The involvement of *Scoreboard* companies in CET inventions is lower than their contribution to green inventions. The *Scoreboard* companies are responsible for around 50% of the CET patents in the EU, South Korea and the US, and around 25% in China in the period 2010-2019. Similar to the trend in green inventions, the share of the *Scoreboard* companies in CET inventions remains high (around 85%) in Japan. The public sector and universities are together responsible for 15% of global CET inventions.

Figure 5.5 provides a breakdown of the CET patent filings of major economies. The distribution varies across economies. The largest industrial categories are chemicals & plastics, metals, construction and fuel from waste, while in China there is more focus on fertilisers. For the EU and the US, the chemicals & plastics category accounts for the largest share in their portfolio. The metals category comes top in Asian economies followed by chemicals & plastics, the two major subcategories of EIIs. Construction is the second largest category of CET inventions in the US (22%) but comes third or fourth in the portfolios of other economies. In China, CETs in fertilisers account for 8%, the highest share among major economies.

For all of the economies except for the US, the CET patent portfolio is largely composed of the two major subcategories of EIIs: Chemicals & plastics and metals industries. Construction comes third for the EU, with a share in its CET portfolio second only to the US. CET inventions related to fuel from waste are the fourth largest category in the EU's portfolio; the EU has the highest portfolio share for this category (11%).

93 Data not as complete for 2019.

Figure 5.5 **Industrial distribution of CET inventions in major economies (2010-2019)**



Note: Industrial categories are aggregated at Level 2 categories of Table B 5.2.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Among major economies in 2018, the EU is the only economy with a positive specialisation index[94] in most of the industrial categories for CETs except for those related to packaging (Table 5.2). Nine industrial categories have seen an increase in specialisation since 2010, the strongest of which is glass, one of the EII subcategories. Among the major economies, the EU leads the specialisation in CETs related to construction, chemicals & plastics, glass, food, fuel from waste, textiles and waste water & sludge. China is leading in metals and has seen a substantial increase in specialisation in textiles since 2010. Japan leads in the pulp & paper and electrics & electronics industries, and is highly specialised in vehicles. South Korea leads in batteries & fuel cells as well as vehicles, and has experienced a positive trend in its specialisation in all industries except for packaging. The US leads in specialisation in CETs in packaging and has increased its specialisation in pulp & paper.

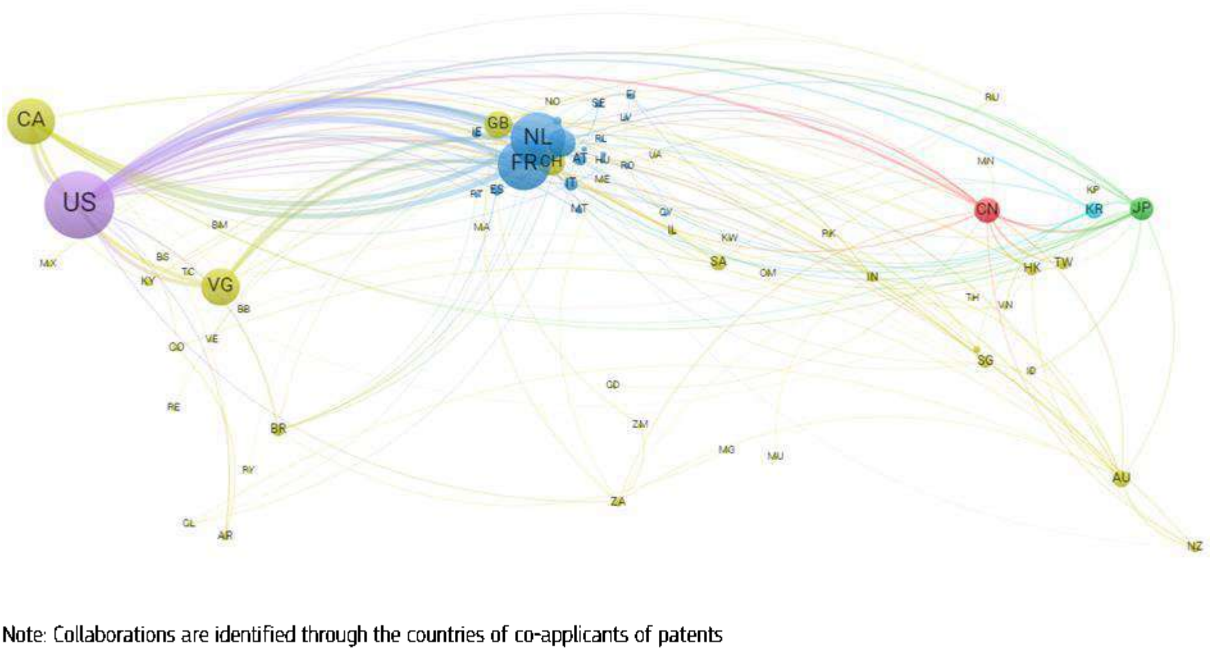
[94] The share of CET inventions among other technologies within a country's portfolio, compared to the global average share.

Table 5.2 Specialisation index in circular economy technologies (2018)

Industry	EU Index	EU Change	CN Index	CN Change	JP Index	JP Change	KR Index	KR Change	US Index	US Change	RoC Index	RoC Change
Construction	0.6	↗ 0.1	-0.4	↗ 0.1	-0.5	↗ 0.1	-0.3	↗ 0.1	-0.1	↘ -0.4	1.1	↗ 0.7
Chemicals & Plastics	0.6	↗ 0.3	-0.4	↘ -0.4	-0.5	↘ -0.2	-0.5	↗ 0.2	0.3	↘ 0.0	0.3	↗ 0.4
Fertilisers	0.3	↘ -0.2	-0.1	↘ -1.1	-0.7	↘ 0.0	0.3	↗ 0.7	-0.3	↘ -0.2	1.3	↗ 0.9
Glass	4.2	↗ 3.9	-1.0	0.0			-1.0	0.0	-1.0	↘ -0.7		
Metals	0.0	↘ -0.1	0.4	↗ 0.2	-0.3	↘ 0.0	-0.2	↗ 0.1	-0.4	↘ 0.0	0.8	↘ -0.3
Pulp & Paper	0.3	↘ -0.5	-0.8	↗ 0.2	1.4	↗ 1.5	-1.0	0.0	-0.2	↗ 0.5	-1.0	↘ -1.8
Food	0.5	↗ 0.7	0.0	↘ -0.9	-0.8	↘ -0.4	-0.8	↗ 0.2	0.4	↘ -0.6	0.8	↗ 0.6
Fuel from Waste	1.3	↗ 0.6	-0.6	↗ 0.1	-0.6	↘ -0.1	0.0	↗ 0.4	-0.2	↘ -0.3	0.3	↗ 0.1
Textiles	1.3	↗ 0.3	0.8	↗ 1.8			1.0				-0.3	
Batteries & Fuel Cells	0.2	↗ 0.5	-0.2	↘ -0.2	0.0	↘ -0.7	0.8	↗ 0.7	-0.5	↘ -0.6	0.3	↗ 1.2
Electrics & Electronics	0.6	↗ 1.1	-0.4	↘ -3.0	1.4	↗ 0.9	-1.0	0.0	-0.9	↘ -0.4	-1.0	↘ -1.1
Packaging	-0.1	↘ -0.2	-0.8	↗ 0.2	-0.6	↗ 0.0	-0.6	↘ 0.0	1.0	↗ 0.3	1.1	↗ 0.3
Vehicles			-1.0		2.1		2.3					
Wastewater & Sludge	0.6	↗ 0.1	0.2	↘ -0.9	-0.7	↘ -1.1	0.3	↗ 1.3	-0.9	↘ -0.5	1.6	

Note: Specialisation index in circular economy technologies by industrial categories and major economies. For each economy, the index in 2018 is listed in the 1st column and the change with respect to 2010 is listed in the 2nd column.
Data is not available for glass, textiles and vehicles for all years/countries, as the codes are not widely assigned
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Figure 5.6 Collaboration network in CETs inventions (2010-2019)

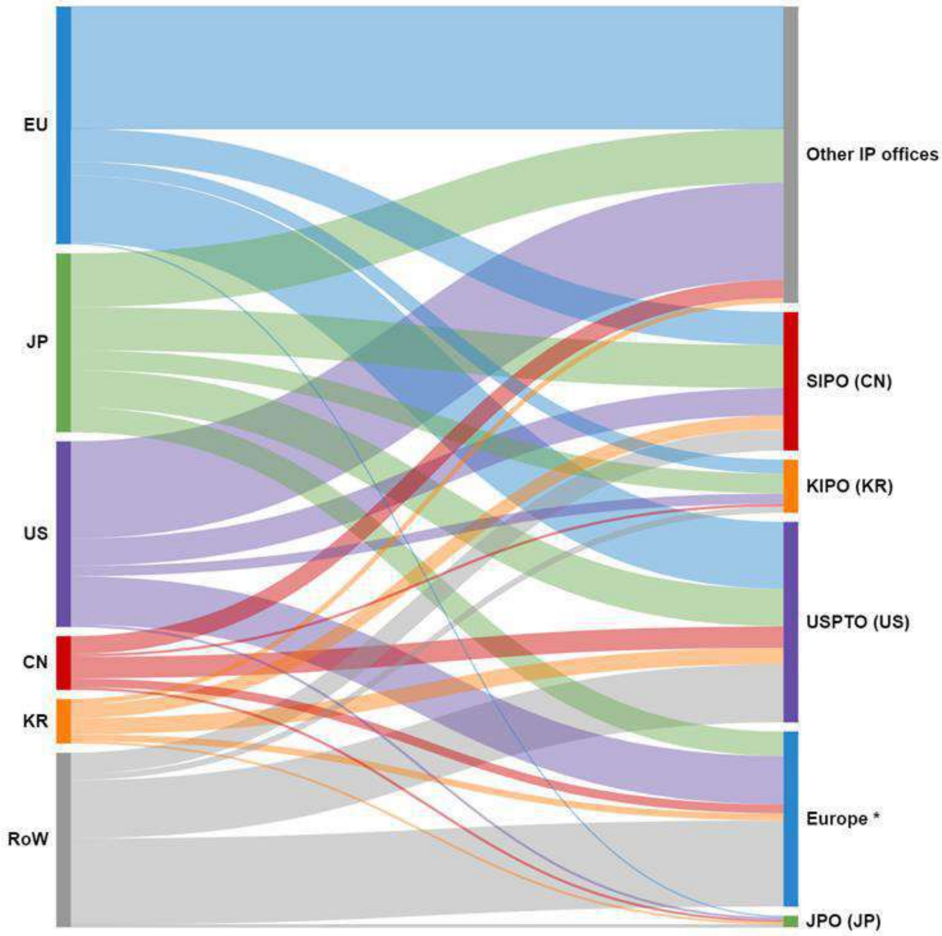


Note: Collaborations are identified through the countries of co-applicants of patents
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

At country level, the US has the highest number of international collaborations (Figure 5.6) on CET inventions in the period 2010-2019, however, the EU taken as a whole would surpass this. The Netherlands and France are the leading EU countries when it comes to international collaboration, and second and third in the world, after the US. The US has the highest number of countries involved in its international alliances, with 43 in total, including 13 EU Member States. The Netherlands and France are the primary partners in US-EU CET patent applications. Patent applicants in EU Member States primarily construct alliances with US applicants, followed by other Member States. China and Japan collaborate with 18 and 20 other countries respectively. Among EU Member States, patent applicants in France, Germany, Italy and Netherlands collaborate with counterparts in China. Applicants in Austria, Denmark, Finland, Germany, Italy and Latvia have formed alliances with counterparts in Japan.

Figure 5.7 shows that the US (23%) and the EU (20%) are the most targeted economies for international CET inventions, followed by China (16%). As with the general trend in overall green inventions, Japan attracts only a small share of international applications. As mentioned in the previous *Scoreboard*, the strong industry and technology base in Japan, coupled with very specific regulations, tend to make it a rather difficult and insular market for foreign technology providers. EU applicants tend to favour the US, with a share of 28% of its non-European applications, followed by China, with a share of 14%. The rest of the world (RoW) and the US applicants target European jurisdictions as their first foreign destination. Among the major economies in Asia, China and South Korea file their foreign patent applications primarily in the US, whereas Japanese applicants primarily target China.

Figure 5.7 International flow of CET inventions by major economies (2010-2019)



Note: Country of applicant (left) and foreign authorities targeted for protection (right).

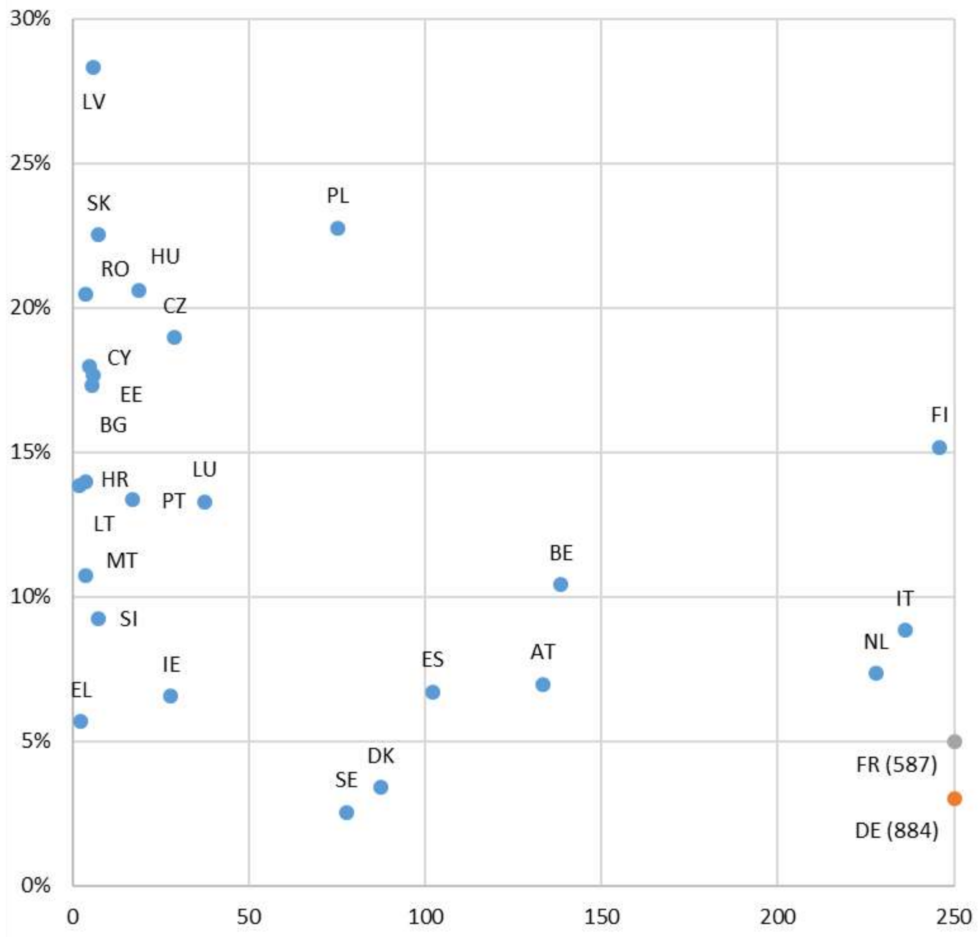
* Europe: EPO and national IP offices of EPO members

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Trends in the EU Member States

In line with overall green invention levels, over the period 2010-2019, Germany and France have by far the highest number of CET inventions. However, these represent only 3% and 5% of the overall green inventions produced by German and French applicants, respectively (Figure 5.8). Among the countries with a high number of inventions, Finland has the highest share of CET inventions in its green patent portfolio at 15%. On the left side of Figure 5.8, Latvia, Slovakia, Hungary and Romania are the four countries with the highest shares of CET inventions in their green patent portfolios, at above 20%.

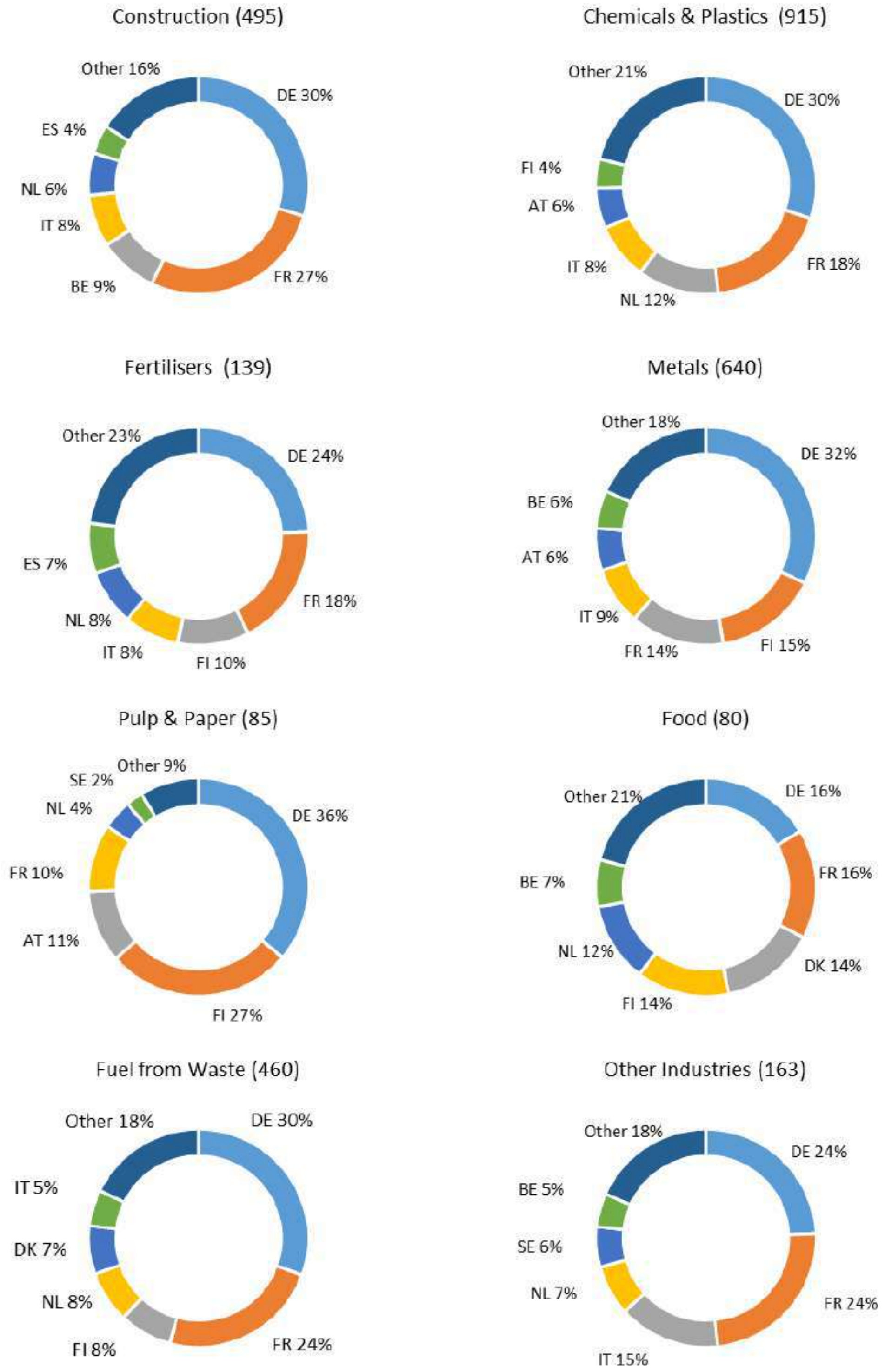
Figure 5.8 **Inventive activity in CETs of the EU Member States (2010-2019)**



Note: Number of CET inventions (horizontal axis), and share of CET inventions over green inventions (vertical axis).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

In accordance with Figure 5.8, Germany and France always rank among the top five inventing countries in each of the industrial subcategories for CETs (Figure 5.9). Germany is first in all of the eight subcategories, and followed by France except for metals and pulp & paper categories. Finland has the second highest share in EII categories related to metals and pulp & paper. Other EU Member States that appear among the top five countries by industry are the Netherlands in all categories except metals; Italy in construction, chemicals & plastics, fertilisers, metals and others; Austria in chemicals & plastics, metals and pulp & paper; Denmark in food and fuel from waste; Belgium in construction and Sweden in others.

Figure 5.9 Share of CET inventions per industry and EU member state (2010-2019)



Note: Total number of CET inventions in the EU for each industrial category is given in parenthesis.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

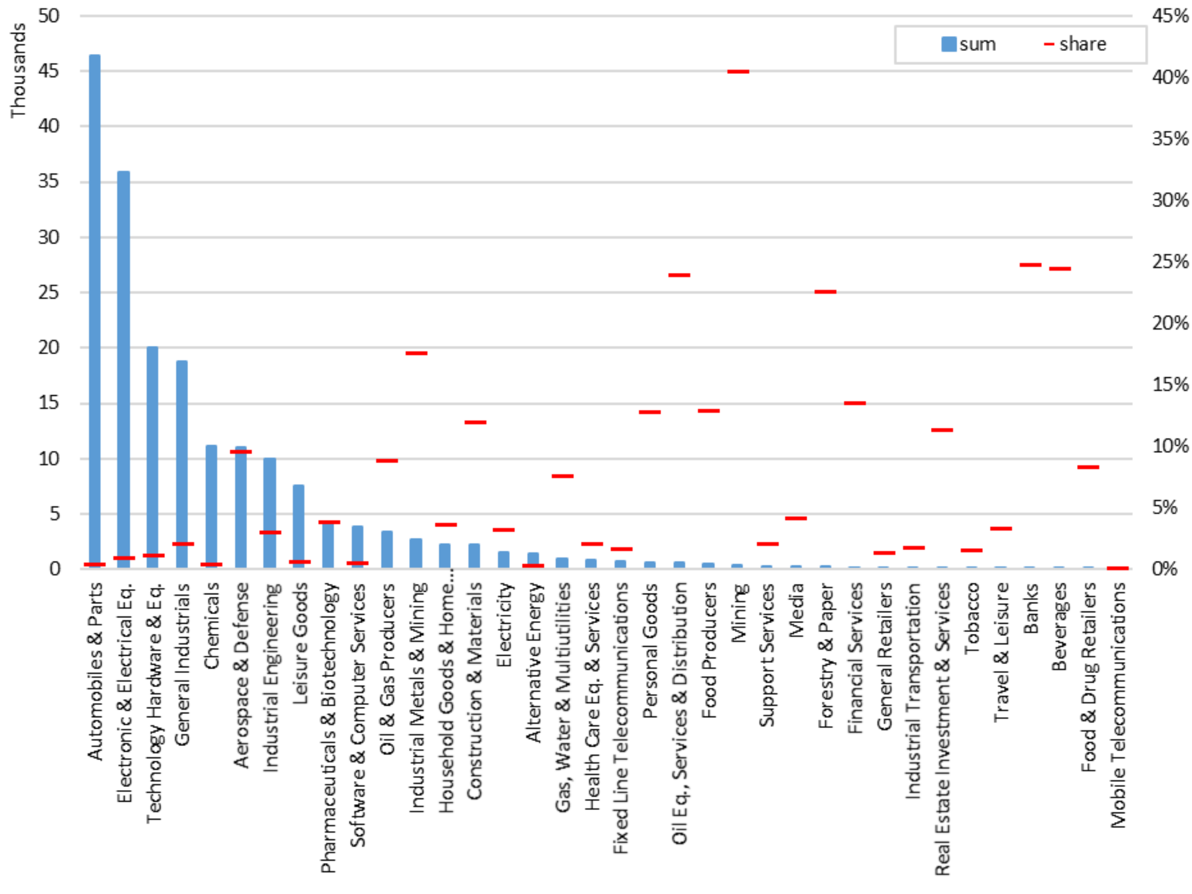
5.3 Global Scoreboard and the EU Scoreboard

In the following, the activity of subsidiary companies has been aggregated and attributed to the Scoreboard parent company. This introduces differences in the resulting performance and location (headquarters) of some companies, which are now referred to as a group and not as the subsidiaries which may have been referenced above.

Sector-level trends

Since 2010, the CET inventions of *Scoreboard* companies have accounted for 51% of the global total. Figure 5.10 presents their sectorial distribution. In general, companies active in sectors with high levels of green inventions also have a large patent portfolio for CETs. The top five sectors in absolute numbers are automobiles & parts, electronic & electrical equipment, technology hardware & equipment, general industrials and chemicals. In relative terms, however, the five sectors with the highest share of CET inventions are mining, oil equipment, services & distribution, forestry & paper, beverages and industrial metals & mining sectors. These ICB sectors are directly related to EIIs except for beverages, where efforts in CETs are related to the food industry, as well as the metal cans, plastics and glass bottles in packaging. The patenting statistics do indeed indicate that, in the period 2010-2019, CET inventions in the beverages sector concentrate on food (44%), followed by packaging (31%).

Figure 5.10 Scoreboard companies' inventive activity in CETs by ICB sectors (2010-2019)

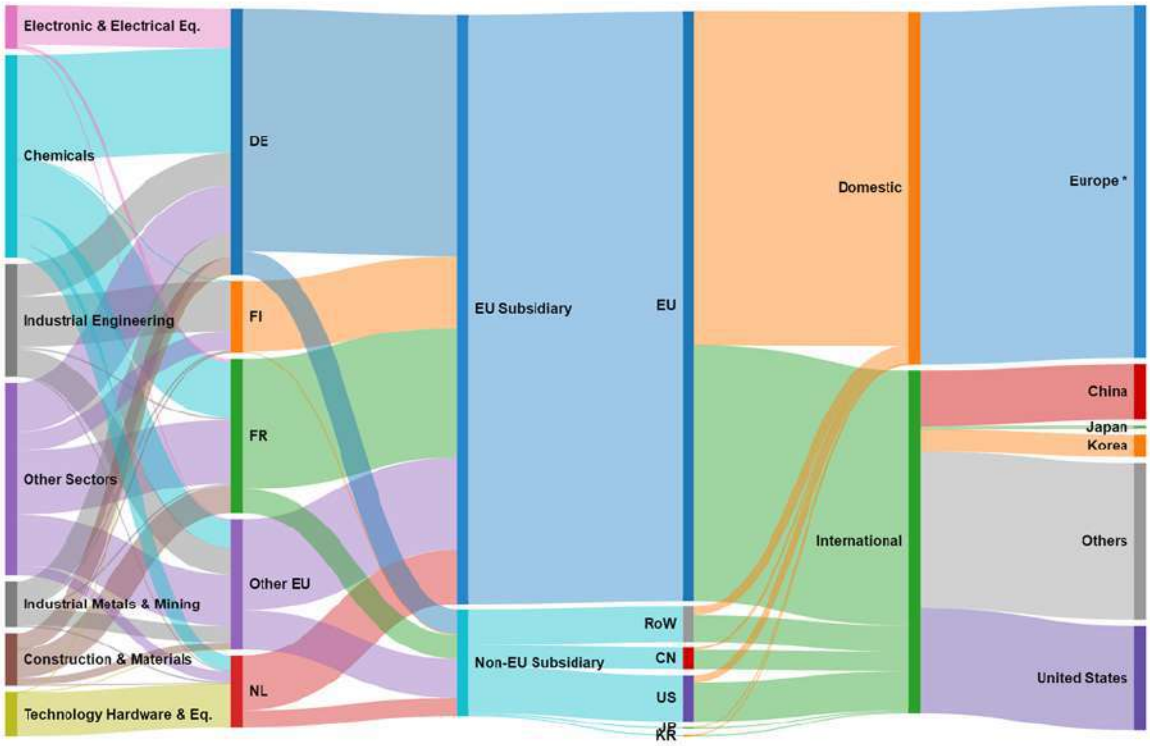


Note: Number of inventions (blue, left axis), and share in green inventions (red, right axis).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The EU companies active in the chemicals sector account for about 29% of the total CET inventions produced by EU *Scoreboard* companies (Figure 5.11), followed by industrial engineering (16%) and construction & materials (8%). In line with patterns shown for the EU Member States in Figure 10, German, French, Finnish and Dutch companies have the highest amount of filings among the EU *Scoreboard* firms, accounting for 81% of all EU *Scoreboard* CET inventions. The German and French companies active in CET patenting are mostly in the chemicals sector, the Finnish in industrial engineering and the Dutch in technology hardware & equipment.

About 85% of EU *Scoreboard* CET inventions are produced by EU subsidiaries, of which 43% are protected internationally, mostly in the US and Other jurisdictions. Among the inventions produced by non-EU subsidiaries of EU *Scoreboard* companies, 44% originate from the US, followed by 18% produced by companies located in China. Overall, 51% of CET inventions produced by EU *Scoreboard* companies are protected in Europe, while the rest flow to other international jurisdictions, primarily to the US at about 15%.

Figure 5.11 EU *Scoreboard* companies' patenting activity in circular economy technologies by sector, country of headquarter and subsidiary, and targeted jurisdiction (2010-2019)



Note: Inventions by ICB sectors (1st column), country of headquarters (2nd column), country where subsidiaries are domiciled (3rd and 4th columns) and IPO jurisdictions targeted (5th and 6th columns).

* Europe: EPO and national IP offices of EPO members

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Top Scoreboard Companies in CET inventions

Globally, the Japanese *Scoreboard* companies lead patenting activity in CETs related to metals, pulp & paper and batteries & fuel cells, while the Chinese *Scoreboard* companies outperform in circular fertilisers (Table 5.3). EU *Scoreboard* companies are present among the top five companies in each category. EU *Scoreboard* companies lead in the number of CET inventions related to fuel from waste, and US *Scoreboard* companies lead in CET inventions related to construction and chemicals & plastics.

Table 5.3 Top five *Scoreboard* companies inventing in CETs per industry (2010-2019)

	GLOBAL SCOREBOARD				EU SCOREBOARD			
Rank	Company	Country	inventions	Share	Company	Country	inventions	Share
Construction								
1	Halliburton	US	95	51%	Saint-Gobain	FR	30	11%
2	LafargeHolcim	CH	35	39%	BASF	DE	30	3%
3	Sika	CH	33	65%	HeidelbergCement	DE	30	51%
4	USG	US	33	82%	Weatherford International	IE	11	5%
5	Saint-Gobain	FR	30	11%	Siemens	DE	9	0%
Chemicals & Plastics								
1	Dow Chemical	US	93	19%	BASF	DE	54	5%
2	BASF	DE	54	5%	Arkema	FR	45	22%
3	Honeywell	US	47	5%	STMicroelectronics	NL	24	1%
4	Saudi Basic Industries	SA	45	16%	Solvay	BE	22	10%
5	Arkema	FR	45	22%	Siemens	DE	20	0%
Fertilisers								
1	Guangzhou Pharmaceutical	CN	7	22%	BASF	DE	3	0%
2	Whirlpool	US	5	3%	SUEZ	FR	3	3%
3	Kingfa Science & Technology	CN	4	36%	Veolia Environnement	FR	2	3%
4	Procter & Gamble	US	4	2%	Altana	DE	2	6%
5	BASF	DE	3	0%	STMicroelectronics	NL	2	0%
Metals								
1	Sumitomo Metal Mining	JP	120	39%	Metso Outotec	FI	77	52%
2	Metso Outotec	FI	77	52%	SMS Holding	DE	44	46%
3	JFE	JP	74	35%	STMicroelectronics	NL	42	2%
4	JXTG	JP	72	23%	Siemens	DE	37	1%
5	Nippon Steel	JP	69	15%	BASF	DE	23	2%
Pulp & Paper								
1	Seiko Epson	JP	43	10%	Voith	DE	21	14%
2	Voith	DE	21	14%	Valmet	FI	8	13%
3	Unicharm	JP	12	27%	Andritz	AT	7	11%
4	Valmet	FI	8	13%	Altana	DE	6	19%
5	Andritz	AT	7	11%	Siemens	DE	3	0%
Fuel from Waste								
1	L'Air Liquide	FR	16	2%	L'Air Liquide	FR	16	2%
2	Novozymes	DK	12	7%	Novozymes	DK	12	7%
3	Veolia Environnement	FR	11	14%	Veolia Environnement	FR	11	14%
4	Suez	FR	10	12%	Suez	FR	10	12%
5	BP	UK	10	2%	Siemens	DE	10	0%
Batteries & Fuel Cells								
1	Toyota Motor	JP	13	0%	STMicroelectronics	NL	5	0%
2	JXTG	JP	11	4%	Johnson Controls	IE	3	1%
3	SK Innovation	KR	8	2%	BASF	DE	2	0%
4	Sumitomo Metal Mining	JP	7	2%	Robert Bosch	DE	2	0%
5	STMicroelectronics	NL	5	0%	Daimler	DE	2	0%

Note: The total number of CET inventions per company is represented in blue and the share of CETs in overall green inventions per company is represented in green. Industrial categories are selected according to the total number of inventions per category.

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

CET inventions related to the construction industry

US companies lead in CET inventions related to the construction industry, followed by Swiss and French companies. This is in line with the significant country-level shares of CET inventions related to the construction industry in the US and the EU shown in Figure 5.5. The US company Halliburton is the global leader among the *Scoreboard* firms in the period 2010-2019. In the EU, the top inventing companies are mostly from Germany, while Saint-Gobain from France leads in the number of inventions.

CET inventions related to the chemicals & plastics industry

Although the EU leads in CET inventions related to the chemicals & plastics industry, with a 29% share in total CET inventions, Dow Chemical from the US is the leading *Scoreboard* company. Among the EU *Scoreboard* firms, the CETs related to chemicals & plastics account for 33% of CET inventions – the largest share together with metals. The top inventing companies are from Germany, France, Belgium and the Netherlands; and BASF from Germany leads despite a small share for CETs related to chemicals & plastics in its overall green portfolio.

CET inventions related to the fertilisers industry

CET inventions related to the fertilisers industry represent a small share in the patent portfolio of the *Scoreboard* firms from all regions except for China, with a share of around 13% circular fertilisers over all CET inventions. At firm level, companies from China and the US have the largest numbers of CET inventions related to fertilisers. In the EU, German, French and Dutch firms lead in the period 2010-2019.

CET inventions related to the metals industry

Despite the large share of metals-related inventions in the CET inventions of all major economies, those of Japanese and EU *Scoreboard* firms account for 73% of total CET inventions in the period 2010-2018, with a share of 40% and 33% respectively. The top five inventing firms are mainly from Japan, with the single exception of Metso Outotec from Finland. Other leading EU companies in CET inventions related to metals are from Germany and the Netherlands.

CET inventions related to the pulp & paper industry

As with the metals industry, the Japanese and EU *Scoreboard* firms lead in CET inventions related to the pulp & paper industry, with shares of 46% and 43%, respectively. The top five inventing firms are from Japan and the EU, and the top five EU companies in CET inventions related to pulp & paper are from Germany, Finland and Austria.

CET inventions related to the fuel from waste industry

In the period 2010-2019, EU *Scoreboard* companies lead in CET inventions related to fuel from waste, with a share of 42% of all *Scoreboard* company inventions. In both the global and the EU *Scoreboard*, Áir Liquide, Veolia Environnement and Suez from France, and Nonozymes from Denmark, are the top four inventors in the industry. Globally, Japanese companies come second, with 24% of *Scoreboard* company inventions.

CET inventions related to the batteries & fuel cells industry

In the period 2010-2019, CET inventions related to the batteries & fuel cells industry do not account for more than 5% of total CET inventions for any of the regions in the *Scoreboard*. Japanese companies lead, with a global share of 53% of CET inventions related to the batteries & fuel cells industry. The top five companies are mostly from Japan, with Toyota Motors in the lead. In Europe, companies from the Netherlands, Ireland and Germany lead the inventions, despite the very small share in their overall green patent portfolios.

5.4 Key Points

- In 2018, the EU and Japan lead in green high-value patents, with the US in third place. The EU also has the highest specialisation index in green technologies among major economies. While *Scoreboard* companies dominate patenting efforts in Japan, the EU and the US have a more diverse contribution to green inventions from applicants beyond the *Scoreboard*.
- In the period 2010-2019, ICT producers lead in green inventions, followed by automobiles & other transport. Energy and transport are the largest technology areas in global high-value green inventions.
- In the period 2010-2019, CET inventions represent just 4% of overall green inventions. The EU leads in CET inventions both in absolute terms and as a share of green inventions globally. China ranks first in terms of the growth rate of CET inventions.

- In the period 2010-2018, global CET inventions are concentrated in chemicals & plastics, metals, construction and fuel from waste. CET inventions related to chemicals & plastics account for the highest share in the EU and US, while CET inventions related to metals account for the highest share in major Asian economies.
- In 2018, the EU is the only major economy with a positive specialisation index in most industrial categories related to CETs.
- In the period 2010-2018, the US and EU are the most targeted economies for international CET inventions.
- The Netherlands and France are the leading EU countries in international alliances and second and the third in the world after the US.
- In the period 2010-2018, Germany and France always rank among the top five inventing EU Member States in the industrial categories for CETs. The Netherlands, Finland, Italy Austria, Belgium, Denmark and Sweden are among the others.
- *Scoreboard* companies are the applicants of around 49% of global CET patent filings of high-value; i.e. a smaller contribution in these technologies compared to their contribution in global high-value green inventions.
- Globally, the five *Scoreboard* sectors with the highest shares of CET inventions are mining, oil equipment, services & distribution, forestry & paper, beverages and industrial metals & mining. In the EU, the chemicals sector accounts for the highest share of CET inventions, followed by industrial engineering and construction & materials.
- In the period 2010-2019, EU *Scoreboard* companies are among the top five inventing companies globally in all of seven major categories related to CETs, and leading in fuel from waste.

6 Top R&D investors and the UN sustainable development goals

Achieving sustainable development through the UN's 17 Sustainable Development Goals (SDGs)[95] of the 2030 Agenda is a priority for EU in the Political Guidelines of the von der Leyen Commission[96], which link most of the transformative policies to specific SDGs[97]. Commissioners are expected to implement the 2030 Agenda together and ensure that policies under their responsibility reflect one or more SDGs[98]. Several policy documents have been developed to better integrate SDGs into EU policies[99] to assure a timely monitoring of the implementation of SDGs in the EU[100] and, more importantly for this chapter, to highlight opportunities and challenges of linking SDGs to the competitive advantage of European industry[101].

EU institutions support the achievement of SDGs by directly investing in projects and developing appropriate monitoring and policy tools. For example, in 2021, the European Investment Bank supported projects that foster SDGs and contribute to the EU's competitive advantage with EUR 491 million in the year 2021[102]. In Member States, the capacity to monitor SDG progress increased thanks to the adoption of comprehensive monitoring tools and accurate reporting[103]. Methodological tools have also been developed to address SDGs' contribution to smart specialisation strategies[104,105], evaluate the potential for scenario analysis with available simulation tools[106], develop roadmaps relevant to policy formulation[107], and overcome potential conflicts across multiple SDGs when designing effective economic policies[108].

This chapter focuses on the analysis of SDG commitments of the top R&D investors, using reputation and disclosure scores calculated at the firm level. Focusing on *Scoreboard* (SB) companies is particularly relevant for two reasons. First, *Scoreboard* companies are global players due to their economic, innovative, social, and environmental impact: SB companies account for approximately 90% of the world's business-funded R&D and own nearly two thirds of the patents filed at the world's five largest intellectual property offices. Large multinational companies, such as those in the *Scoreboard*, play a key role in strengthening the innovation environment given their large (direct and indirect) market and innovation powers. They are also an entry point

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95 https://sdgs.un.org/

96 Ursula von der Leyen (2019), A Union that strives for more — My agenda for Europe. Political Guidelines for the next European Commission 2019-2024.

97 For example, the European Green Deal, the circular economy action plan, the 2030 climate target plan, and the European Climate Law. SDGs also play an important role in the European Semester country reports and the national recovery and resilience plans. For a more comprehensive overview, see EUROSTAT (2022), Sustainable development in the European Union. Monitoring report on progress towards the SDGs in an EU context. Luxembourg: Publications Office of the European Union.

98 European Commission (2020), Delivering on the UN's Sustainable Development Goals — A comprehensive approach, SWD(2020) 400 final, Brussels.

99 European Commission (2016), Next steps for a sustainable European future: European action for sustainability, COM(2016) 739 final, Brussels.

100 https://ec.europa.eu/eurostat/web/sdi/overview

101 European Commission (2019), Reflection Paper 'Towards a Sustainable Europe by 2030', COM(2019)22, Brussels.

102 Mostly on affordable and clean energy (SDG 7), industry and innovation infrastructure (SDG 9) and sustainable cities and communities (SDG 11). See European Investment Bank (2011). Sustainability report. European Investment Bank. DOI: https://doi.org/10.2867/50047.

103 EUROSTAT (2022), Sustainable development in the European Union. Monitoring report on progress towards the SDGs in an EU context. Luxembourg: Publications Office of the European Union and OECD (2022), The Short and Winding Road to 2030: Measuring Distance to the SDG Targets, OECD Publishing, Paris, https://doi.org/10.1787/af4b630d-en.

104 Fuster Martí, E., Massucci, F., Matusiak, M., Quinquilla, A., Bosch, J., Duran Silva, N., Amador, R., Multari, F. and Iriarte Hermida, M., Pilot methodology for mapping Sustainable Development Goals in the context of Smart Specialisation Strategies, Matusiak, M. and Fuster Martí, E. editor(s), EUR 30901 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-44398-8 (online),978-92-76-44397-1 (print), doi:10.2760/400836 (online),10.2760/940431 (print), JRC126846.

105 Siragusa, A., Stamos, I., Bertozzi, C. and Proietti, P., European Handbook for SDG Voluntary Local Reviews - 2022 Edition, EUR 31111 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-53390-0, doi:10.2760/218321, JRC129381.

106 Barbero Vignola, G., Acs, S., Borchardt, S., Sala, S., Giuntoli, J., Smits, P. and Marelli, L., Modelling for Sustainable Development Goals (SDGs): Overview of JRC models, EUR 30451 EN (main) 30453 EN (annex), Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25326-6 (main) 978-92-76-25330-3 (annex) (online),978-92-76-25327-3 (main) 978-92-76-25331-0 (annex) (print), doi:10.2760/697440 (main) 10.2760/108956 (annex) (online),10.2760/228158 (main) 10.2760/2726 (annex) (print), JRC122403.

107 European Commission, Joint Research Centre, Matusiak, M., Ciampi Stancova, K., Dosso, M., et al., Overview of the existing STI for SDGs roadmapping methodologies: background paper, Publications Office, 2021, https://data.europa.eu/doi/10.2760/2100.

108 Basheer, M., Nechifor, V., Calzadilla, A., Ringler, C., Hulme, D., & Harou, J. J. (2022). Balancing national economic policy outcomes for sustainable development. Nature Communications, 13(1), pp. 1-13.

to local upgrading through collaboration and internationalisation[109]. By adopting sustainable business practices and technologies (for example, addressing gender inequality in the workplace, reducing greenhouse gas emissions), SB companies produce significant spillover effects along their value chain: they can show the positive impact to customers and pressure competitors to adopt similar practices and technologies. The second reason is that SB companies are key players that can contribute to tackling SDG-related challenges with new technological and organisational solutions.

In fact, Industry has increased recently its commitment to the SDGs by being more transparent on sustainability matters. Notably, private companies are putting more and more effort into capturing and reporting key performance indicators (KPIs). They are also experimenting and adopting more sustainable business models, which is important to achieve SDG-related milestones[110]. In this respect, the Non-Financial Reporting Directive[111] requires companies with more than 500 employees to report relevant non-financial information about environmental, social and governance issues[112].

Following the past two editions of the *Scoreboard*, this chapter deepens our understanding of top R&D investors' commitments to sustainable development. Sections 6.1 and 6.2 provide an overview of the adoption of new internal business practices and technologies to tackle SDG-related challenges. In particular, Section 6.1 provides an update on how the efforts of top R&D investors to progress on sustainability and social issues changed in 2021 compared with the previous 5 years (2016-2020) by employing scores comprising a quantitative (non-financial data reporting) and a qualitative component (corporate communications). Section 6.2 analyses the climate action SDG (13) and the affordable and clean energy SDG (7) and focuses on core data disclosed by SB companies. The focus is on CO_2 emissions and energy use, which are quantifiable targets for the green transition to a climate-neutral EU, from different points of view (e.g. direct vs indirect emissions) and across sectors of activity and regions of the world. Section 6.3 investigates the association between the outcome of R&D investment of SB companies and innovation for the SDGs. Notably, it focuses on the development of new scientific and technological solutions addressing the SDGs. It does so by gauging the ability of top R&D investors to develop relevant and potentially breakthrough research and innovation that directly tackles SDG-related challenges. It resonates with the importance of deep tech highlighted in the new European innovation agenda[113]. Overall, the results of the analysis in this chapter should inform policymakers about the strengths and weaknesses of EU companies in sustainable competitiveness.

Not all SDGs are tackled in the chapter. We leave out of the analysis the following SDGs: No poverty (SDG 1), Zero hunger (SDG 2), Quality education (SDG 4), Reduced inequalities (SDG 10), Sustainable cities and communities (SDG 11), Peace, justice and strong institutions (SDG 16) and Partnerships for the goals (SDG 17). We do so because of their lack of relevance to the corporate sector, which is often reflected in the lack of reliable data reported by SB companies for these SDGs.

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109 Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters?. Regional studies, 36(9), pp. 1017-1027.

110 Scheyvens, R., Banks, G., & Hughes, E. (2016). The private sector and the SDGs: The need to move beyond 'business as usual'. Sustainable Development, 24(6), pp. 371–382. https://doi.org/10.1002/sd.1623

111 Directive 2014/95/EU of The European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. http://data.europa.eu/eli/dir/2014/95/oj

112 Pizzi, S., Rosati, F., & Venturelli, A. (2021). The determinants of business contribution to the 2030 Agenda: Introducing the SDG Reporting Score. Business Strategy and the Environment, 30(1), pp. 404-421.

113 European Commission (2022). A New European Agenda. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Brussels, European Commission COM(2022) 332, 5 July.

6.1 Environmental and socio-economic practices of top R&D investors – 2021 update

Box 6.1 Methodology for computing SDG scores

The SDG scores used for the analysis are based on data collected by Covalence SA[114]. The scores produced by Covalence aim to measure the extent to which companies' practices affect their compliance with Environmental, Social and Governance (ESG) targets and report on the contribution these practices bring to solving SDG challenges[115]. The data retrieved by Covalence comprise two different scores: reputation and disclosure.

Reputation scores cover qualitative data published by company stakeholders, such as governments, international organisations, NGOs, the media, and other third-party sources. This data are sourced mainly from news and media content covering specific activities or practices of a company (e.g. web pages, news articles). Covalence applies sentiment analysis techniques to the gathered data. Content whose sentiment is deemed positive increases the reputation score of a company, while content whose sentiment is deemed negative reduces the score[116].

Disclosure scores originate from self-reported information published by the companies. Such information is extracted from quantitative and qualitative data.[117] The disclosure score aggregates the qualitative and quantitative information in a composite index from 0 to 100.

Finally, for each SDG, Covalence calculates a global score ranging from 0 to 100 combining the disclosure and reputation indicators. These global scores are used in this analysis. A score of 50 is a neutral value; if a company scores above 50 in an SDG, it means that the assessment of its contribution to that SDG in positive. Conversely, a score below 50 means that a company is not doing enough or has performed poorly on that SDG[118].

The EU Industrial R&D Investment Scoreboard report already covered SDG scores calculated by Covalence in previous editions. The 2021 report focused on the performance of the top R&D investing companies worldwide in a subset of 10 SDGs, grouped into environmental and socio-economic categories119. In this edition we take a deeper dive into two environmental SDGs (7 and 13) that are closely related to emissions and energy consumption.

Before moving to this analysis, we show how the environmental and socio-economic SDG scores presented in the 2021 Scoreboard have evolved over the past year for those companies covered between 2016 and 2021 (679 companies in total). We first analyse the overall trend of each SDG and then present regional and sectoral breakdowns of the scores. Table 6.1 contains a breakdown by sector and region of the number of Scoreboard companies included in the analysis. The rightmost columns containing the totals by region shows that the EU, the US and Japan are by far the most represented regions in the sample; companies based in China reporting SDG scores instead are still a minority. From a sectoral viewpoint, the sample is dominated by

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[114] Covalence SA, based in Geneva (Switzerland) since 2001, is specialised in environmental, social and governance research and ratings. For more information, see https://www.covalence.ch/.

[115] The Covalence approach is not the only way to analyse SDG compliance at company level. An interesting overview is given in the following report: OECD, 2021, Industrial Policy for the Sustainable Development Goals – Increasing the Private Sector's Contribution, https://doi.org/10.1787/2cad899f-en.

[116] For a more detailed discussion about Covalence SDG scores and their computation, see Chapter 5 of the 2021 EU industrial R&D Scoreboard: https://op.europa.eu/en/publication-detail/-/publication/02ab5f6a-c9bd-11ec-b6f4-01aa75ed71a1/language-en/format-PDF/source-257925010.

[117] This comes from combining environmental, social and governance indicators (e.g. water consumption, percentage of women in executive positions), which are sourced from external providers (e.g. Refinitiv) and sustainability-related corporate communications.

[118] For a detailed explanation of the data sources and methodologies employed by Covalence to compute reputation, disclosure and global scores, see https://www.covalence.ch/docs/Covalence_SDG_Mapping_Methodology.pdf.

[119] The composition of the two groups was the following. Socio-economic SDGs: good health and well-being, gender equality, decent work and economic growth, industry, innovation and infrastructure; Environmental SDGs: Clean water and sanitation; Affordable and clean energy; Responsible consumption and production; climate action; Life below water life on land.

companies operating in ICT, followed closely by companies from the Industrials[120] and the Health sectors. The sectoral composition of the sample differs considerably across regions: EU-based companies operate mostly in the Industrials, Health, and Energy sectors; Japan-based companies operate mostly in ICT, Industrials, and Automotive; US-based companies are mostly active in ICT, ICT services, and Health.

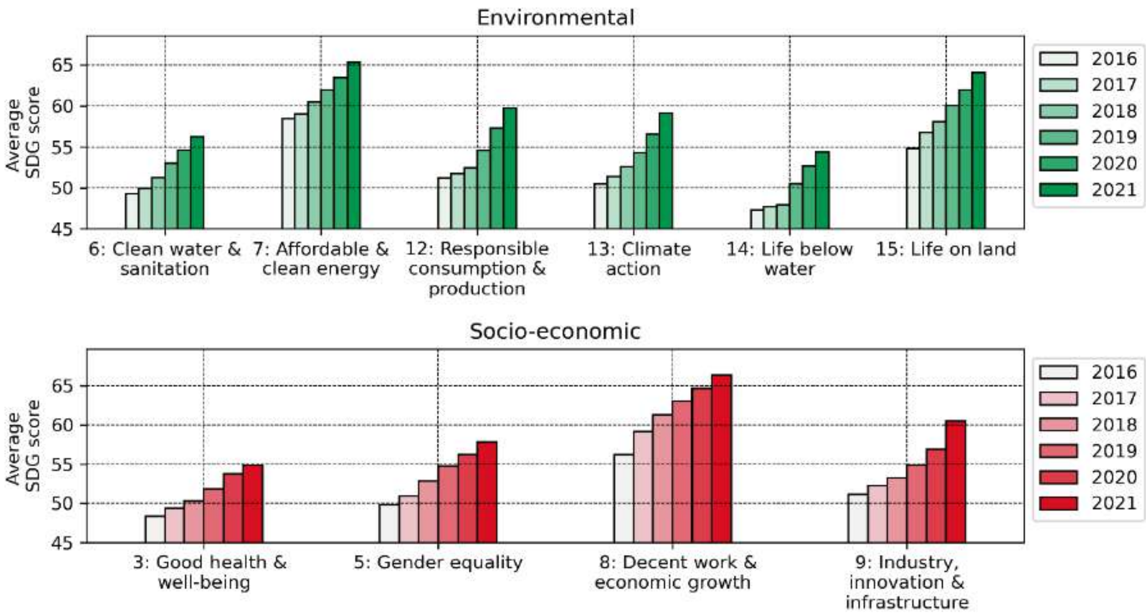
Table 6.1 Number of *Scoreboard* companies included in the SDG analysis by region and sector

	Aerospace & Defence	*Automobiles & oth. transport*	*Chemicals*	*Construction*	*Energy*	*Financial*	*Health industries*	*ICT producers*	*ICT services*	*Industrials*	*Others*	***Total***
China	0	5	1	3	4	0	1	5	2	7	3	**31**
EU	7	12	12	8	22	16	23	16	13	28	33	**190**
Japan	0	20	13	8	12	1	11	30	7	23	28	**153**
US	5	13	10	2	7	4	31	31	26	13	34	**176**
RoW	5	13	12	4	6	4	13	21	14	19	18	**129**
Total	**17**	**63**	**48**	**25**	**51**	**25**	**79**	**103**	**62**	**90**	**116**	**679**

Source: JRC own compilation based on data from R&D Scoreboard and Covalence.

Figure 6.1 presents the overall change in SDG scores between 2016 and 2021 of the 679 SB companies for which complete data are available. It shows that the commitment of the top R&D investing companies to social and environmental responsibility continued in 2021. In line with the past, clean and affordable energy (SDG 7), decent work and economic growth (SDG 8), and life on land (SDG 15) achieve the highest absolute scores, suggesting that they are still the SDGs on which the top R&D investors are focusing their efforts the most. In terms of overall growth, all indicators are stable: all scores increased by 10% or more over the entire period, and some grew by almost 20% (e.g. climate action - SDG 13). Industry innovation and infrastructure (SDG 9) is particularly striking, which increased by 7% in 2021 alone. The regional and sectoral breakdown of the scores presented later in this section attempt to make sense of this evidence.

Figure 6.1 Average SDG scores by year – 2016-2021



Source: JRC own compilation based on data from R&D Scoreboard and Covalence.

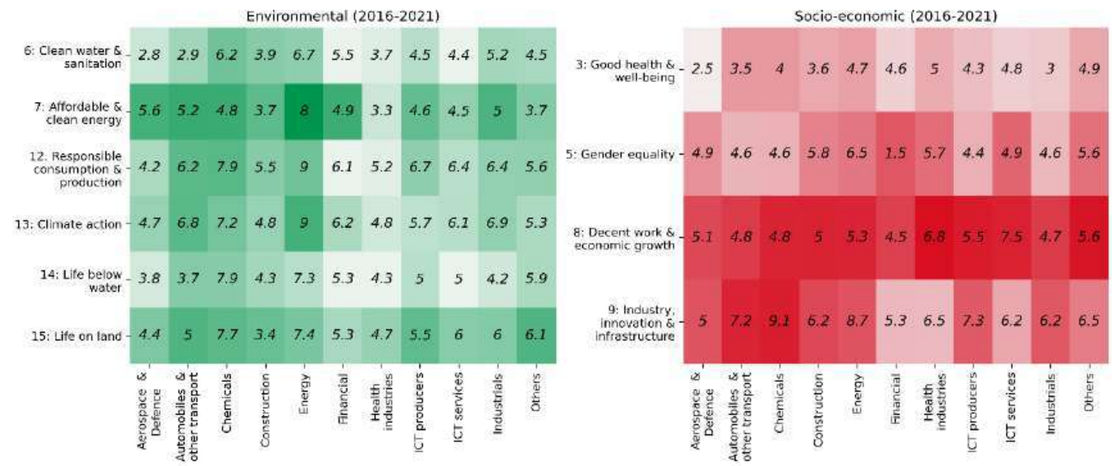
The rest of this section, working with the same companies as above, looks at the sectoral and regional dimensions. For readability, in both exercises we present a separate heat map for environmental scores and

[120] Industrials group includes the following industries: general industrials, industrial engineering, manufacturing of metals and mining, industrial transportation

for socio-economic scores. We assign a green colour palette to environmental SDG scores and a red palette to socio-economic scores.

Figure 6.2 illustrates the progression in each SDG of the *Scoreboard* companies belonging to the same industrial sector, based on a score comparing the average 2016-2020 values with the 2021 values. Similarly to what we observed in last year's *Scoreboard* report, the results show some differences across industries. Companies from the energy, chemicals, and transport sectors scored the highest (darker colour), especially in the environmental SDGs. However, companies in the health sector had, on average, lower SDG progression scores compared with the rest of the sample, especially in the environmental scores (as suggested the very light green vertical strip corresponding to the health sector in the left heatmap). We observe a similar pattern in financials, which, however, has a remarkably high score in SDG 7 (affordable & clean energy), but achieved relatively low scores in the socio-economic SDGs. On the contrary, companies in the automotive sector and the chemicals sector achieve on average high SDG progression scores in almost all of the environmental SDGs as well as in the socio-economic SDGs 8 (decent work and economic growth) and 9 (industry, innovation & infrastructure).In terms of changes over time, we see improvements across the board but also some interesting differences between sectors. The energy sector witnessed an average increase of at least 6.5 points in all but two SDGs, namely SDGs 3 (good health) and 8 (decent work), and up to 9 points in SDGs 12 (responsible consumption) and 13 (climate action). We observe a similar pattern also in the chemicals sector, whose scores in the environmental SDGs increased by 6.2 points or more in all SDGs except SDG 6 (clean water) and whose score in SDG 9 (industry, innovation and infrastructure) increased by 9.1 points in 2021 with respect to the average for the period 2016-2020. At the opposite end of the spectrum, the health sector and the aerospace sector show positive, yet considerably more moderate increases in both the socio-economic and environmental SDGs.

Figure 6.2 SDG progression scores - sectoral comparison: 2016-2020 vs 2021

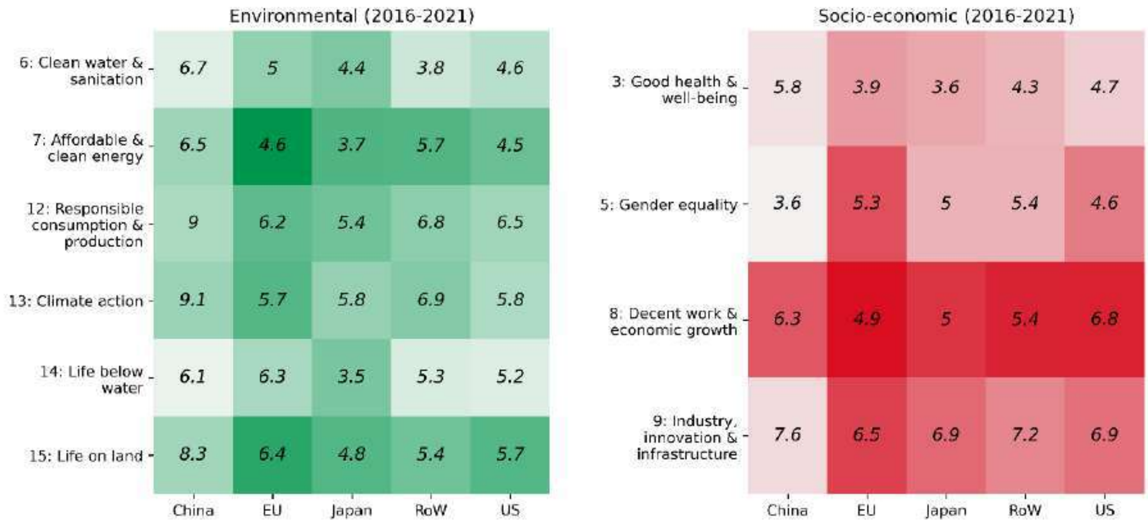


Note: Each cell refers to a unique combination of industrial sector SDG. The number and the colour of each cell convey different information. The colour represents the average score achieved in 2021 in a given SDG (see row) by companies from a given sector (see column); darker colour shades correspond to a higher score in 2021. The number in the cell is the difference between the average score achieved in a given SDG by *Scoreboard* companies from a given industry computed in 2021 and in 2016-2020; the number in the cell is the growth in the score achieved in 2021 with respect to 2016-2020.

Source: JRC own compilation based on data from R&D Scoreboard and Covalence.

Figure 6.3 shows the average SDG performance of *Scoreboard* companies headquartered in the same region. *Scoreboard* companies based in the EU and Japan have higher SDG scores compared with other regions, as shown by the darker shade of colour in the cells belonging to the columns corresponding to those two regions. Looking at environmental scores, the EU clearly led in 2021 in affordable and clean energy (SDG 7) and life on land (SDG 15). EU-headquartered SB companies also perform remarkably well in responsible consumption & production (SDG 12) and climate action (SDG 13). The same holds for the socio-economic SDGs – the colour pattern suggests they had the highest score in 2021. In terms of changes over time, we observe solid improvements in both environmental and socio-economic scores in all regions. For instance, SDG 9 (industry, innovation, and infrastructure) increased by 6.5 points or more on average in every regions, with companies from China (+7.6 points) and the Rest of the world (+7.2 points) performing significantly better than average along this dimension. The ongoing positive development of EU-based companies signals a strong commitment to pursue the objectives set by the EU to move towards a more just and climate-neutral society. Chinese-headquartered companies improved the most, especially in the environmental SDGs; it is too soon to tell whether this is an early sign of catching up with other major economies, but it is certainly worth monitoring in the future.

Figure 6.3 SDG progression scores. Regional comparison: 2016-2020 vs 2021



Note: Each cell refers to a unique combination of area SDG. The number and the colour of each cell convey different information. The colour average score achieved in 2021 in a given SDG (see row) by companies from a given region (see column); darker colour shades correspond to a higher score in 2021. The number in the cell is the difference between the average score achieved in a given SDG by *Scoreboard* companies from a given region computed in 2021 and in 2016-2020; the number in the cell is the growth in the score achieved in 2021 with respect to 2016-2020.
Source: JRC own compilation based on data from R&D Scoreboard and Covalence.

6.2 Environmental impact of the top R&D investors – analysis of climate action (SDG 13) and affordable and clean energy (SDG 7)

This section examines the performance of top R&D investors across industries, regions, and time in targeting climate action (SDG 13) and affordable and clean energy (SDG 7) by reducing carbon dioxide (CO_2) emissions and increasing energy efficiency. Reducing greenhouse gas emissions and dependence on non-fossil fuel-based energy sources is crucial in the current climate and energy crises. The 2030 climate target plan[121] and the European Climate Law[122] set ambitious targets for CO_2 emissions by 2030 and expect the EU to be climate-neutral by 2050.

We focus on some of the most pressing environmental SDGs by using data collected at company level.[123] In particular, the amount of total (direct and indirect) CO_2 emissions is one of the main KPIs to measure the ability of *Scoreboard* companies to achieve climate action goals (SDG 13). To gauge these companies' abilities

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121 European Commission (2020), Stepping up Europe's 2030 climate ambition — Investing in a climate-neutral future for the benefit of our people, COM(2020) 562 final, Brussels.

122 Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law').

123 To this respect, the analysis in this chapter differs from the approach taken in related studies looking at emissions at the country level. Nevertheless, general trends reported here are in line with country-level macro-dynamics. See for example, Crippa M., Guizzardi D., Banja M., Solazzo E., Muntean M., Schaaf E., Pagani F., Monforti-Ferrario F., Olivier, J.G.J.,Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Grassi, G., Rossi, S., Oom, D., Branco, A., San-Miguel, J., Vignati, E. CO2 emissions of all world countries – JRC/IEA/PBL 2022 Report, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/07904, JRC130363; The European Round Table for Industry (ERT), European Competitiveness and Industry Benchmarking Report 2022; Enerdata – Global Energy and Climate Trends 2022 Edition

to address affordable and clean energy (SDG 7), we use the amount of total energy consumed by the company[124]. Box 6.2 describes the main data source and methods used in the analysis.

Box 6.2 Data and methods for the analysis of climate action (SDG 13) and affordable and clean energy (SDG 7)

The measures used in the analysis are based on data in the Eikon database from Refinitiv[125]. We focus on data reported by *Scoreboard* companies on their CO2 emissions and energy use. CO2 emissions include total CO2 and CO2 equivalent emissions in tonnes. Data are collected following the greenhouse gas (GHG) protocol[126] for all emission classification types and, therefore, refer to CO2, methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCS), perfluorinated compound (PFCS), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3). Total CO2 emissions are further separated into direct and indirect emissions. Direct emissions refer to emissions coming from sources that are owned or controlled by the company while indirect emissions come from purchased electricity, heat or steam. Energy use is defined as total direct and indirect energy consumption in gigajoules. It includes the total amount of energy consumed (both purchased and produced) as part of the company's operations[127].

We derive a number of indicators to better characterise emissions and energy use by relevant dimensions. First, we compute CO2 intensity to weigh a company's emissions by the scale of its operations:

$$Carbon\ intensity = \frac{CO_2\ emissions\ (thousand\ tonnes)}{Net\ sales\ (EUR)}$$

This measures a company's carbon footprint better as it associates the generation of emissions to the company's size. We also provide two breakdowns of carbon intensity. The first one refers to direct vs indirect emissions:

$$\frac{CO_2\ emissions\ (thousand\ tonnes)}{Net\ sales\ (EUR)} = \frac{Direct\ CO_2\ emissions\ (thousand\ tonnes)}{Net\ sales\ (EUR)} + \frac{Indirect\ CO_2\ emissions\ (thousand\ tonnes)}{Net\ sales\ (EUR)}$$

The second breakdown helps shed light on the efficiency of energy use compared with how clean the energy source used is:

$$\frac{CO_2\ emissions\ (thousand\ tonnes)}{Net\ sales\ (EUR)} = \frac{CO_2\ emissions\ (thousand\ tonnes)}{Energy\ use\ (thousand\ joules)}\ x\ \frac{Energy\ use\ (thousand\ joules)}{Net\ sales\ (EUR)}$$

The first term on the right-hand side of the equation above (carbon energy intensity) measures how clean the energy sources used by a company are. A decrease in this term implies that a company has adopted breakthrough carbon-saving technologies / production processes (e.g. circular economy principles) or deployed new green energy sources (e.g. renewables, hydrogen). The second term (energy intensity) is an indicator of a company's energy efficiency. A fall in this term suggests the adoption of (mostly incremental) energy-saving technologies / operational practices (e.g. low energy light bulbs, energy-saving machinery).

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124 These measures are used for monitoring countries' achievements of SDGs by, among others, the UN and Eurostat. See https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20refinement_Eng.pdf and https://ec.europa.eu/eurostat/web/sdi.

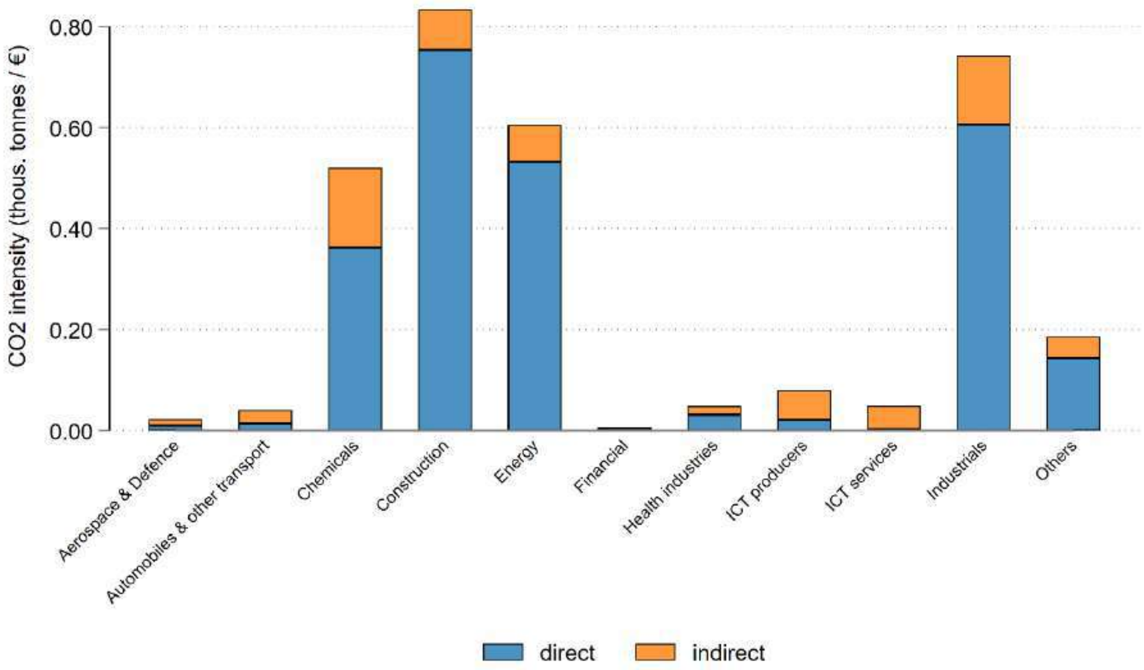
125 Refinitiv's Eikon is a well-known database used extensively for financial analysis, academic work, and policy reporting. It provides transparent, objective, and auditable extra-financial information based on public disclosures from companies. Refinitiv offers a transparent rating methodology and facilitates the understanding of how the data are aggregated from different information sources. It includes more than 12 000 global companies across 76 countries, covering more than the 85% of global market capitalisation and has data going back to 2002.

126 See https://ghgprotocol.org/.

127 For companies in the utility sector, transmission / grid loss resulting from business activities is considered as total energy consumed. Electricity produced to satisfy demand by third parties is not included (i.e. utility companies producing energy for sale). Furthermore, raw materials such as coal, gas or nuclear used in the production of energy are not considered.

Figure 6.4 reports CO_2 intensity for 2020 (the last year available) across sectors of activity of *Scoreboard* companies. The figure also provides a breakdown by emission sources (direct or indirect). Companies in the construction, industrials, energy, and chemical sectors are the most carbon-intensive and account for 76% of the overall carbon emissions from *Scoreboard* companies[128]. Within industrials, steel and aluminium manufacturers account for the largest share of carbon emissions with nearly 40%, while the second largest contributors – manufacture of coke and refined petroleum products – accounts for a mere 3%. Moreover, these sectors (together with the health sector) are characterised by a disproportionate amount of direct emissions compared with indirect ones. Aerospace and defence, automobile, financial, and ICT (services and producers) sectors have a higher share of indirect emissions, which means that most of their emissions come from purchased energy rather than from internal production processes.

Figure 6.4 Average direct and indirect carbon intensity by sector in 2020



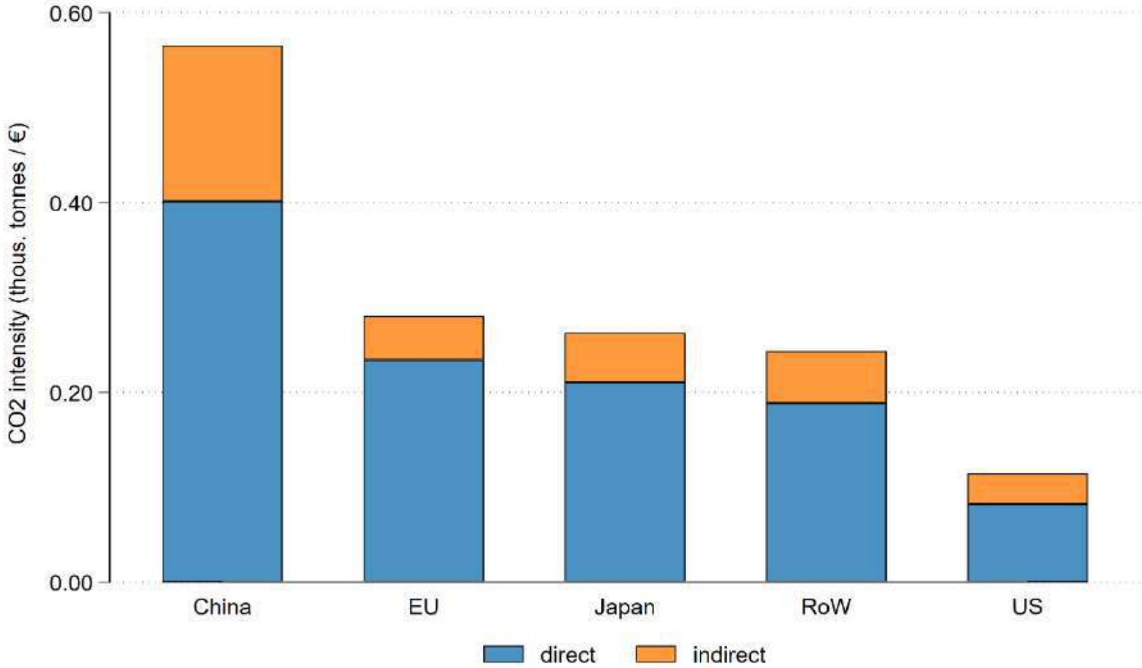
Notes: Data refers to 1 045 companies for which data on carbon emissions is available, representing 70% of the R&D invested in the whole sample.

Source: JRC own compilation based on data from R&D Scoreboard and Refinitiv.

Figure 6.5 shows carbon intensity across regions of the world. US-headquartered *Scoreboard* companies have the lowest carbon footprint, followed by companies in the rest of the world, Japan and the EU. Those headquartered in China have the highest carbon footprint. The EU (jointly with US) leads in indirect emissions with one of the lowest values.

[128] This is calculated as the ratio of the weighted sum of total emissions for the four sectors over the total weighted sum

Figure 6.5 Average direct and indirect carbon intensity by region in 2020



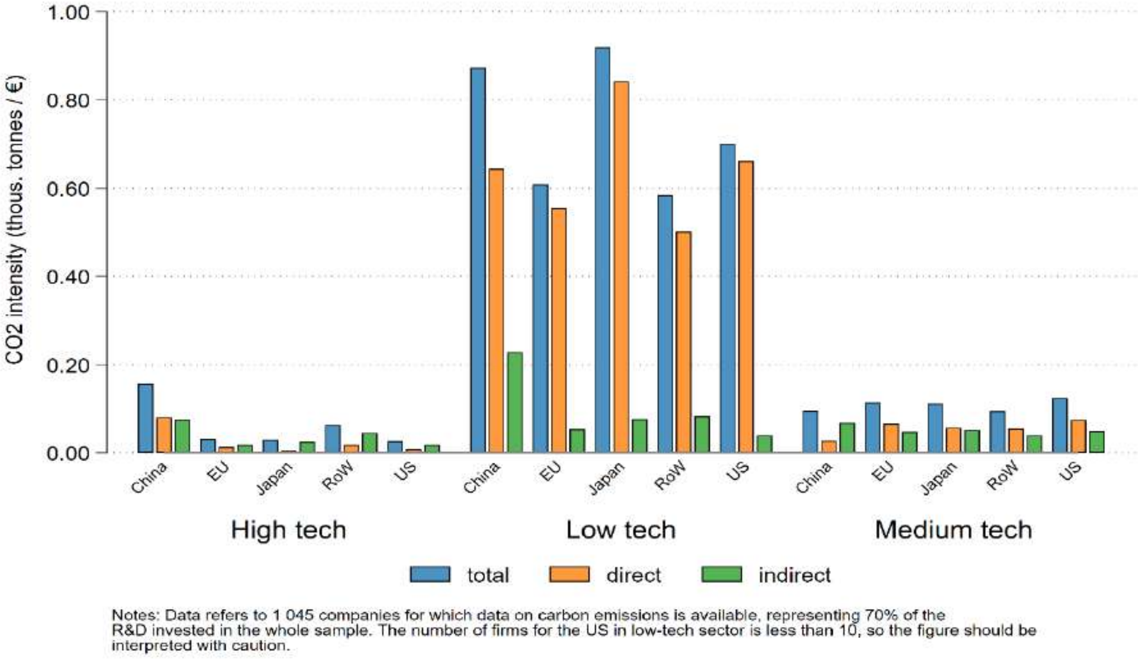
Notes: Data refers to 1 045 companies for which data on carbon emissions is available, representing 70% of the R&D invested in the whole sample.

Source: JRC extraction from EIC working paper "Identification of emerging technologies and breakthrough innovations." Available online at: https://eic.ec.europa.eu/system/files/2022-02/EIC-Emerging-Tech-and-Breakthrough-Innov-report-2022-1502-final.pdf".

Figure **6.6** presents a further breakdown by world region and type of industry[129] and illustrates the big differences of top R&D investors' carbon footprints. As expected, low technology sectors are those with the highest CO_2 intensity, irrespective of where the companies are headquartered. Japanese companies show the highest score in the low-tech group. Low- and medium-tech Chinese companies have high carbon-intensity scores, and high-tech companies have the highest CO_2 intensity. EU companies fare well across all three types of industry and lead or co-lead for both direct and indirect carbon intensity.

[129] This classification takes into account the average R&D intensity of all companies aggregated by ICB 3-digits sectors: high is above 5%; medium between 1% and 5%; and low below 1%. To compensate for the insufficient representativeness of the Scoreboard in some sectors, they are adjusted using the OECD definition of technology intensity for manufacturing sectors. For simplification, in this report the three groups are also referred to as high tech, medium tech and low tech.

Figure 6.6 Average direct and indirect carbon intensity by world region and industry in 2020



Source: JRC own compilation based on data from R&D Scoreboard and Refinitiv.

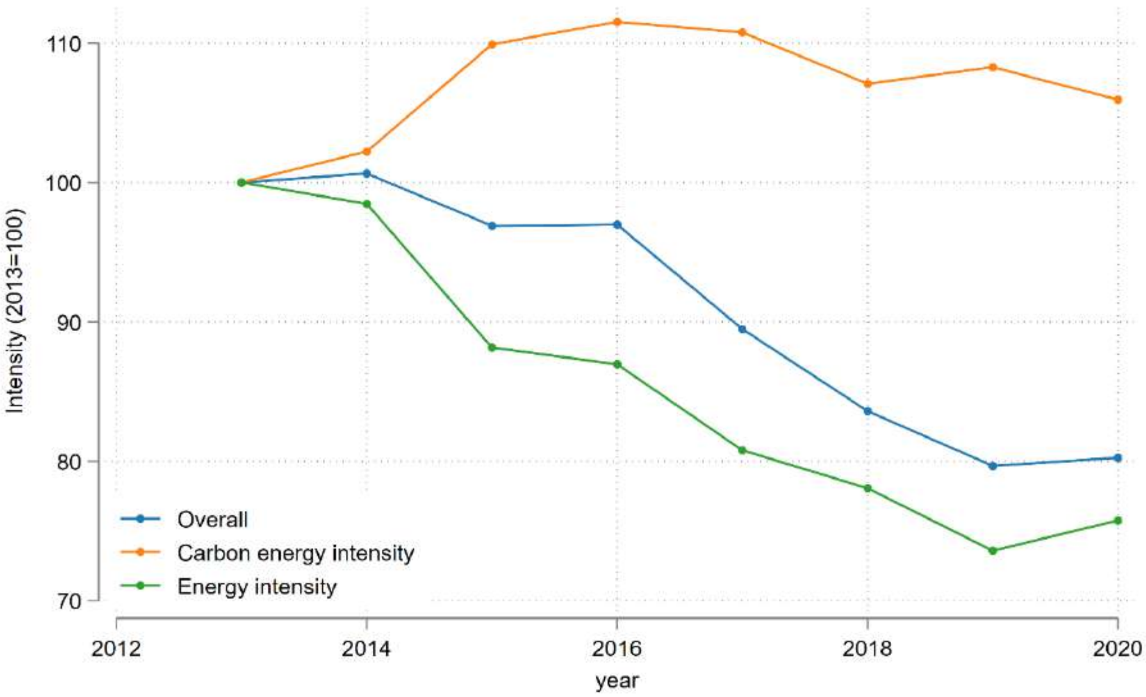
Figure 6.7 presents the trend in carbon intensity and its two main dimensions (carbon energy intensity and energy intensity) between 2013 and 2020 for the *Scoreboard* companies for which the relevant data are available for at least 6 years (627 companies)[130]. The figure shows that carbon intensity fell sharply for *Scoreboard* companies. On average, carbon intensity decreased by 20% between 2013 and 2020, with the sharpest fall taking place between 2016 and 2019[131]. The main driver reducing SB companies' carbon footprints is the drop in energy intensity, which in 2020 was 25% lower than in 2013. On the contrary, carbon energy intensity is over 5% higher than in the base year although it has been falling since 2016. The sharp decrease in energy intensity reflects the adoption of energy-saving technologies by top R&D investors as well as organisational change due to, for example, increased servitisation of energy-intensive manufacturing processes[132]. Comparatively less effort has been made in reducing emission intensity in energy production (carbon energy intensity). This reflects attempts to substitute fossil fuels with alternative energy sources (e.g. renewables, biomass, hydrogen), which has improved but contributed less to the overall decrease in carbon emissions. Overall, *Scoreboard* companies have improved meeting the emission target for climate action (SDG 13) and the energy efficiency target for affordable and clean energy (SDG 7). They have also contributed to reducing their primary energy consumption for affordable and clean energy (SDG 7), albeit to a lesser extent.

[130] Similar results are obtained when companies with data on all years (2013-2020) are retained (541 companies).

[131] Figures 6.7, 6.8 and 6.9 do not point to a significant drop in emissions in 2020 following closures due to the COVID-19 pandemic. This is because we represent indexes where both emissions and sales were heavily affected by health restrictions. When looking at absolute numbers, there are decreases overall and in relevant sectors.

[132] Servitisation is where companies pay for a service rather than buying the equipment or machinery and it goes hand in hand with the increasing relevance of the service sector in major economies. This can be a major contributor to decarbonisation. Mulder, P., & De Voigt, S., De Cian, E., Schymura, M., & Verdolini, E. (2014). Energy intensity developments in 40 major economies: structural change or technology improvement?. Energy Economics, 41, pp. 47-62.

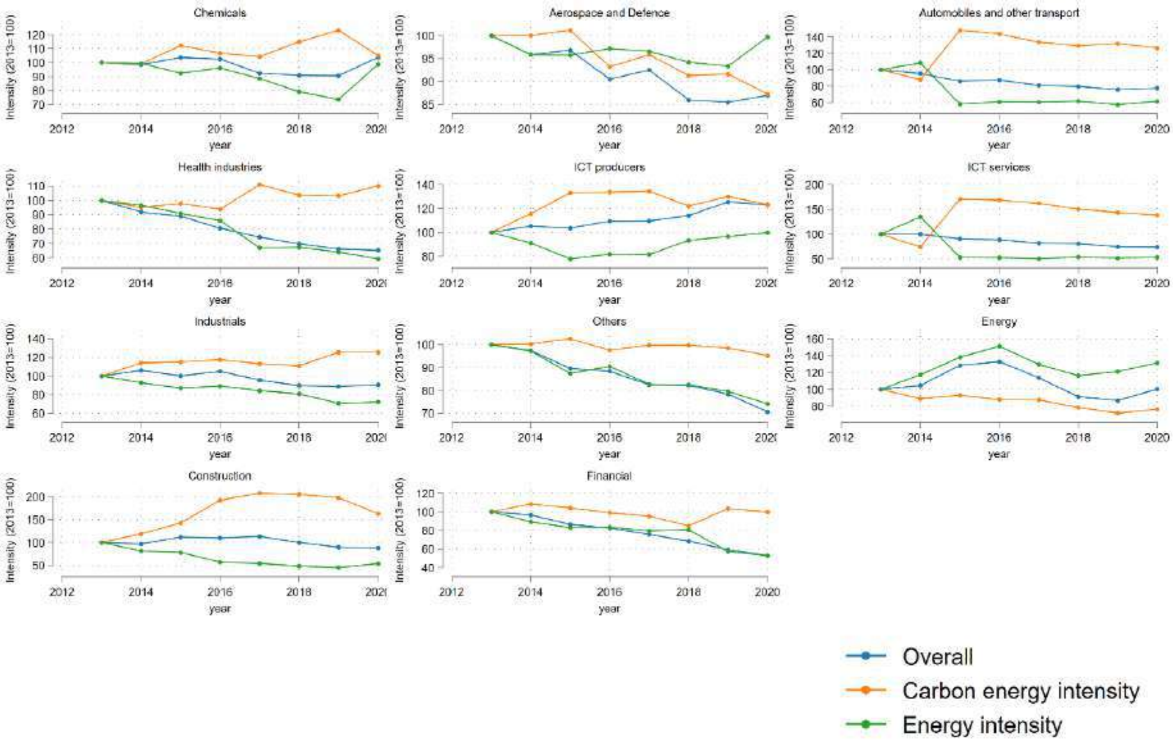
Figure 6.7 Carbon intensity by year – 2013-2020 (2013 base year = 100)



Source: JRC own compilation based on data from R&D Scoreboard and Refinitiv

Figure 6.8 and Figure 6.9 present a breakdown of carbon scores by industry and world region and illustrate the difference in SB companies' responses to SDG 13 and SDG 7. Figure 6.8 shows that the sectors contributing the most to the fall in carbon intensity between 2013 and 2020 were *Scoreboard* companies from the financial (-47%), health (-34%), ICT services (-27%) and automobile (-22%) sectors. Companies from the aerospace (-13%), construction (-12%) and industrial (-9%) sectors also contributed but to a lesser extent. Carbon intensity increased in the energy (+0.5%) and chemical (+4%) sectors, but the largest increase came from ICT producers (+23%). In contrast, all sectors saw a drop in energy intensity between 2013 and 2020. The financial, ICT services, construction, health, and automobile sectors reduced their energy intensity by 40% or more. The main exception were *Scoreboard* companies in the energy industry, which increased their energy intensity by more than 30%. This was counterbalanced by a comparable decrease in carbon energy intensity (-24%), which indicates progress in decarbonising energy production. *Scoreboard* companies in other sectors (aerospace and financial, with -13% and -0.23% respectively) witnessed a decline in carbon energy intensity while most other industries experienced an increase of 20% or more.

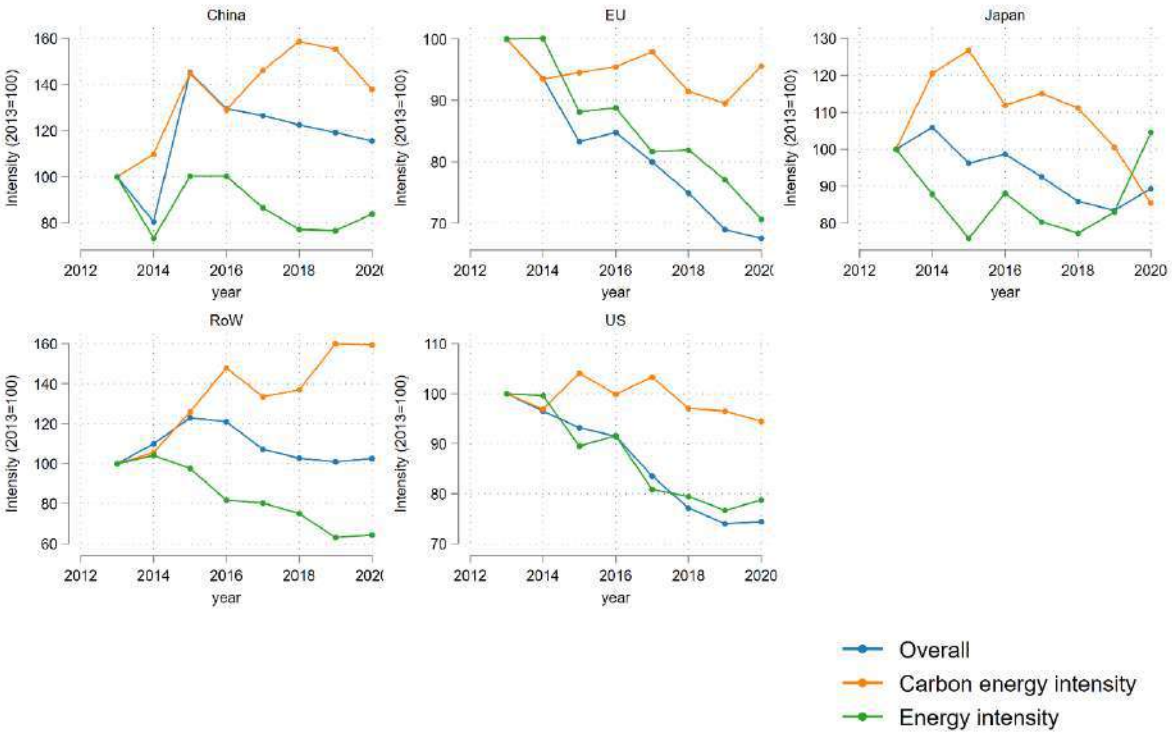
Figure 6.8 Carbon intensity by industry – 2013-2020



Source: JRC own compilation based on data from R&D Scoreboard and Refiniti.

Figure 6.9 shows average carbon-intensity scores by world regions where the *Scoreboard* companies are headquartered. *Scoreboard* companies based in the EU and the US had the largest drop in overall carbon intensity over the period. EU-headquartered companies lead this reduction with a 32% decrease compared with 2013 levels. Companies based in the US and Japan have a similar trend albeit less steep, with reductions in carbon intensity of 25% and 10% respectively. *Scoreboard* companies headquartered in the rest of the world and China increased their overall carbon intensity (+3% and +16% respectively). Similar to the industry breakdown, most carbon-intensity reduction comes from the steep decline (-15% or higher) in the energy intensity of *Scoreboard* companies in all world regions, except for those from Japan, which experienced a sharp increase in the last year alone. Companies based in Japan, the US and the EU also witnessed a decrease in carbon energy intensity (-14%, -5.5% and -4.5% respectively), while China and the rest of the world experienced a huge increase (+37% and +60%). This highlights a significant divide between world regions in achieving targets for climate action (SDG 13) and affordable and clean energy (SDG 7). On one hand, SB companies headquartered in EU, US and Japan have been able to reduce their carbon footprints by: i) adopting energy-saving technologies; and ii) substituting fossil fuels in energy consumption (to a lesser extent). On the other hand, companies based in China and the rest of the world saw an increase in their carbon footprints mainly due to their inability to counterbalance a steep increase in carbon energy intensity with improved energy efficiency.

Figure 6.9 Carbon intensity by world region – 2013-2020



Source: JRC own compilation based on data from R&D Scoreboard and Refinitiv.

6.3 SDG-related innovative output by top R&D investors

In this section, we keep the focus on affordable and clean energy (SDG 7) and climate action (SDG 13). However, we now look at specific scientific outputs and technological innovations of the top R&D investing companies that signal their ability and commitment to engage in breakthrough research that helps achieve SDGs. The new European innovation agenda[133] places great importance on deep technologies (deep tech), which are expected to 'drive innovation across the economy and society addressing the most pressing societal challenges, including by achieving the SDGs'[134]. In line with this, we sharpen our focus on the technological and scientific outputs that fall under the deep-tech category.

Box 6.3 Identifying innovation in deep technologies by *Scoreboard* companies

Identifying the technological and scientific outputs that fall under the deep-tech category involves two steps:

1. Linking *Scoreboard* companies to technological and scientific outputs that are relevant to SDGs;

2. Selecting deep-tech outputs from among the SDG-relevant outputs of the *Scoreboard* companies above.

[133] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_4273
[134] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0332&from=EN

For the first step, we relied on an exploratory study[135] conducted by SIRIS Acedemic[136] (SIRIS) that produced a database identifying patents, scientific publications and Horizon 2020 (H2020) projects carried out by *Scoreboard* companies that are relevant to one or more SDGs. To do so, the study first used tailored string matching techniques to retrieve *Scoreboard* companies and the associated records in Elsevier's abstract and citation database Scopus[137] (to collect scientific publications by authors affiliated to *Scoreboard* companies) and in CORDIS[138] (to collect H2020 projects in which *Scoreboard* companies participate).

To identify the patents of SB companies, SIRIS used the 2021 edition of the JRC/OECD COR&DIP database, which lists international patents filed between 2016 and 2019 by the companies listed in the 2019 *Scoreboard* report. After retrieving the records associated with the *Scoreboard* companies from the above databases, SIRIS applied natural language processing techniques to the textual descriptions (H2020 project descriptions, abstracts of patents and scientific publications) to determine which records had a meaningful connection to one or more SDGs. The final output of the SIRIS project consisted of:

> the list of *Scoreboard* companies involved in SDG-relevant R&D related outputs (patents, publications or H2020 projects) between 2017 and 2020;

> the unique identifier of all selected R&D outputs (Patent application ID[139], the Scopus ID, and the CORDIS ID, respectively);

> the list of SDG(s) for which each selected R&D related output was deemed relevant.

With this information, we retrieved the titles and abstracts (project descriptions for H2020 projects) of the database items identified by SIRIS. In parallel, a way to identify technologies that we could classify as deep tech was developed. This is not a trivial task because there is not a clear consensus yet on what exactly should be considered deep tech. A guiding principle is that deep tech concerns cutting-edge physical, biological and digital advances, which entail long development phases, massive R&D and capital investment, and have a significant societal impact. This principle is close to a recent working paper published by the European Innovation Council (EIC) identifying several emerging technologies and breakthrough innovations of high interest to the EIC because of their 'potential for future technological, economic and social impacts'[140].

The report describes several breakthrough technologies related to the European Green Deal, health, and the digital domain. It also provides a set of associated keywords for each technology. The EIC report identifies technologies that fit the current definition of deep tech, and, by leveraging the keywords, it was possible to look for deep-tech technologies in the description of the SDG-related outputs listed in the exploratory study data.

Table 6.2 EIC breakthrough technologies and keywords

No	Dimension	Deep-tech	Keywords
1.1	Green deal	Energy harvesting, conversion, and storage	aluminium-based energy; molten salt reactors; hydrogen fuel; airborne wind turbine; bioelectronics; artificial photosynthesis
1.2	Green deal	Cooling and cryogenics	nanowires; optoelectronics; flexible electronics; hydrogels; metamaterials
1.3	Green deal	Industry and agriculture decarbonisation and pollution abatement	artificial photosynthesis; bioplastic; microbial fuel cells; precision farming; automated indoor farming; plant communication

135 See Massucci, F. and Seri, A.: 'Exploratory study understanding the SDG alignment along research activities and technological innovation of *Scoreboard* companies', JRC Technical Report, October 2022.
136 https://sirisacademic.com/
137 https://www.scopus.com
138 https://cordis.europa.eu/projects
139 As recorded in the COR&DIP and in the European Patent Office's worldwide patent database, Patstat (https://www.epo.org/searching-for-patents/business/patstat.html)
140 European Commission, European Innovation Council and SMEs Executive Agency, Lopatka, M., Pólvora, A., Manimaaran, S., et al. 2022:, Identification of emerging technologies and breakthrough innovations https://op.europa.eu/en/publication-detail/-/publication/7c1e9724-95ed-11ec-b4e4-01aa75ed71a1

1.4	Green deal	Environmental intelligence and monitoring systems	artificial intelligence; geoengineering: precision farming; molecular recognition; flexible electronics; plant communication
1.5	Green deal	Water-energy nexus	energy harvesting; water splitting; desalination; precision farming; tidal power technologies; wastewater nutrient recovery
1.6	Green deal	Sustainable, safe and regenerative buildings	energy harvesting; smart windows; nanoleds; self-healing materials; 3D printing of glass; wastewater nutrient recovery;
2.1	Digital & industry	Next-generation computing devices and architectures	computing memory; quantum computers; graphene transistors; neuromorphic chip; spintronics
2.2	Digital & industry	Chip-scale frequency combs	high-precision clock; optoelectronics; quantum computers; quantum cryptography
2.3	Digital & industry	Photon, phonon, electron triangle	2D materials; metamaterials; optoelectronics; spintronics; quantum computers; computing memory
2.4	Digital & industry	DNA-based digital data storage	bioelectronics
2.5	Digital & industry	Alternative approaches to quantum computation	flexible electronics; computing memory; quantum computers; optoelectronics; spintronics
2.6	Digital & industry	AI-based local digital twins	local digital twin; artificial intelligence (AI)
2.7	Digital & industry	New uses of space	asteroid mining
2.8	Digital & industry	2D materials for low-power electronics	2D materials; carbon nanotubes; graphene transistors
2.9	Digital & industry	Sustainable electronics	flexible electronics; biodegradable sensors; bioelectronics; self-healing materials; graphene transistors; artificial photosynthesis;

Note: The first column contains a numerical index used as a shorthand for the deep tech in this section. The last column in the table contains a sample of the keywords associated to each deep tech in the EIC report.

Source: JRC own compilation based on data from R&D Scoreboard and Refinitiv.

Table 6.1 presents a list of all deep tech selected from the EIC report[141]. We performed a string search with all the keywords in the abstracts and project descriptions linked to SDGs 7 and 13 in the exploratory study. We were able to associate 70 H2020 projects, 734 scientific articles, and 206 patents with one or more deep technologies. These associations are found in 234 *Scoreboard* companies, revealing a base of real corporate activities in deep tech. In the rest of this section, we first provide a general overview of the relevance of each deep tech for the SDG-related R&D outputs (publications, patents and research projects) developed by top

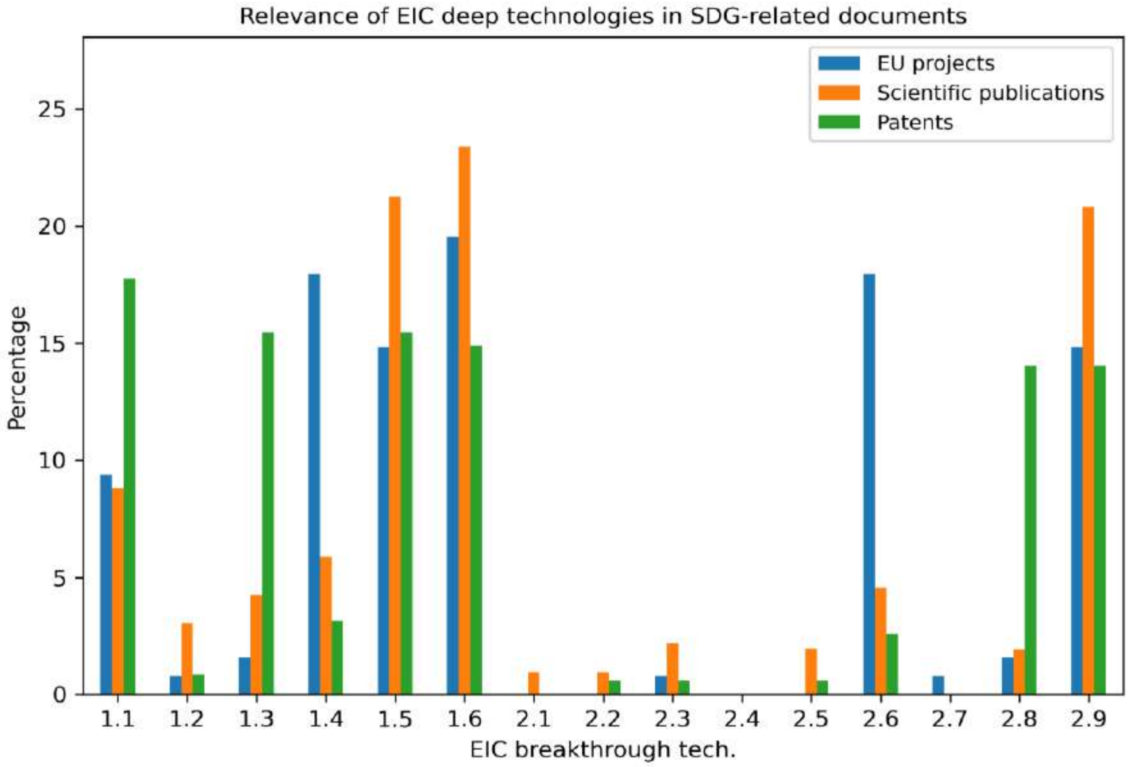
Figure 6.10 presents the percentage of H2020 projects (blue bars), scientific articles (orange bars) and patents (green bars) that we link to each EIC technology. The figure clearly shows that technologies are not equally relevant in the exploratory dataset. For instance, technology 1.2 (cryogenics) and most of the digital deep technologies (2.1 to 2.5, 2.7) are either marginal or missing, irrespective of the type of output considered[142]. Moreover, the relevance of deep tech varies with the type of output. For instance, the deep techs that are associated to a large number of documents are rather evenly distributed across patents. The same is not true for H2020 projects, in which technologies 1.4 (environmental monitoring) and 2.6 (local

[141] The EIC report identifies technologies related to the Green Deal, health, and the digital domain. However, due the focus on environmental SDGs, we ruled out health-related deep techs and focused on the other two categories.

[142] For technologies 2.4, 2.6, and 2.7, the very short list of associated keywords could be driving the result.

digital twins) are the most represented. For scientific articles, keywords associated to deep-techs 1.5 (water-energy nexus), 1.6 (sustainable buildings), and 2.9 (sustainable electronics) are the most common.

Figure 6.10 Percentage of H2020 projects, scientific articles and patents associated with SDG 7 or SDG 13 and linked to each EIC deep technology



Source: JRC own compilation based on data from R&D Scoreboard, EIC, and SIRIS.

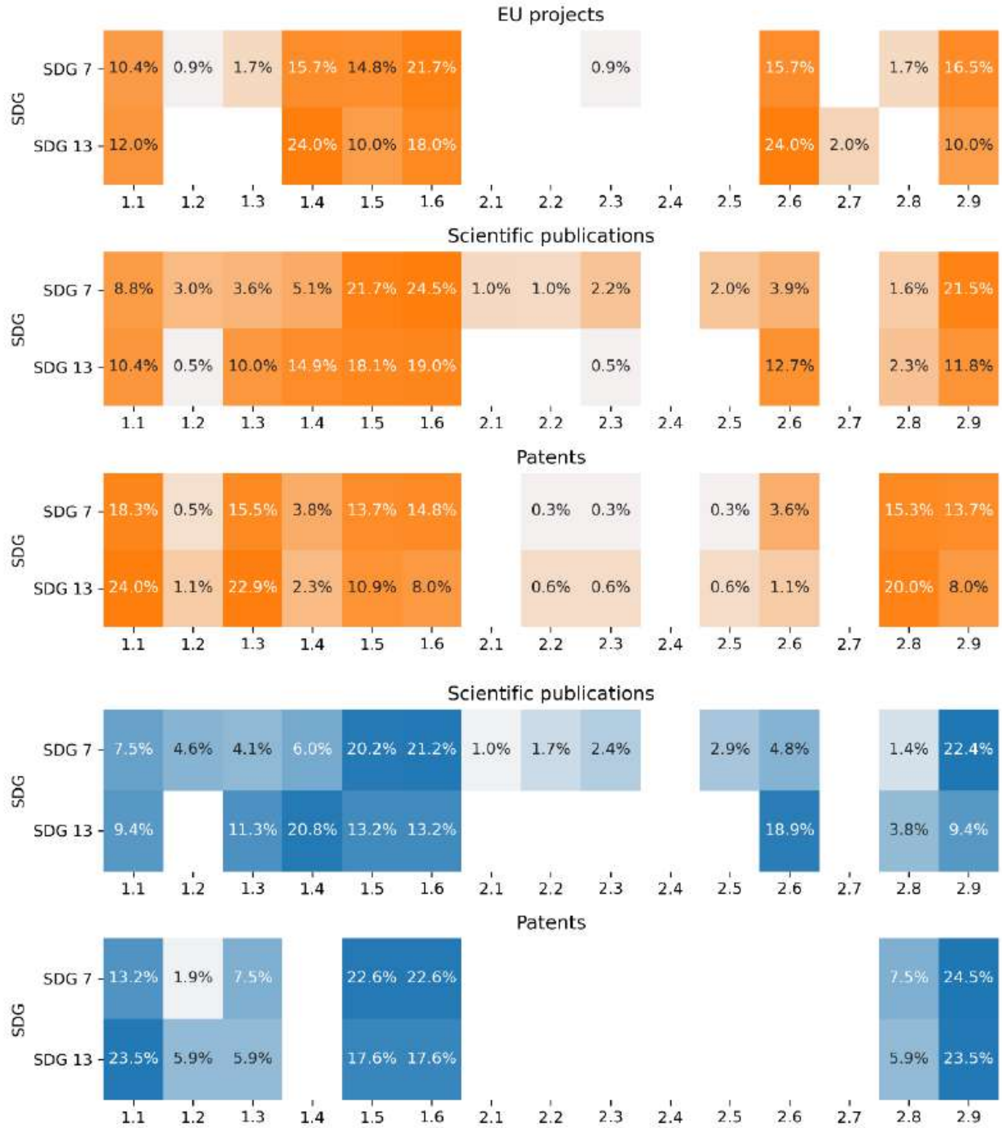
Figure 6.11 breaks the relevance of deep tech down by SDG and document type. The orange heat maps refer, respectively, to H2020 projects, scientific articles, and patents involving any of the *Scoreboard* companies; the blue heat maps only refer to those scientific articles and patents involving EU-based companies. A darker colour shade in a cell indicates a higher percentage of documents linked to the corresponding technology.

In the data on all SB companies (orange heat maps), patenting linked to SDG 13 is concentrated in deep technologies 1.1 (energy storage), 1.3 (decarbonisation) and 2.8 (2D materials for low-power electronics). The same set of technologies are also relevant for SDG 7; however, technological innovation in 1.5 (water-energy nexus), 1.6 (green buildings) and 2.9 (sustainable electronics) is also relevant in this case.

In contrast, scientific research relevant to SDG 7 is relatively concentrated in deep technologies 1.5 (water-energy nexus), 1.6 (sustainable buildings) and 2.9 (sustainable electronics). Scientific research related to SDG 13 is spread among a wider range of technologies: most of the Green Deal related deep technologies as well as technologies 2.6 (local digital twins) and 2.9 (sustainable electronics). Patenting and scientific articles in technologies 2.1 to 2.7 are not relevant to either SDGs, with the notable exception of technology 2.6 (AI-based local digital twins), which shows a high percentage of scientific publications linked to SDG 13.

For EU-based companies (blue heat maps), the relevance of deep technologies in scientific publications follows a similar pattern to the one observed for all SB companies (in the orange heat map). However, patenting in deep technologies by EU-based *Scoreboard* companies shows some obvious specificities. Comparing patents for all SB companies with patents for EU-based companies, we observe EU-based companies seem to mostly specialise in technologies 1.5 (water-energy nexus), 1.6 (sustainable buildings), and 2.9 (sustainable electronics). At the same time, patenting in technologies 1.3 (decarbonisation) and 2.8 (2D materials) appears to be less relevant to EU-based companies than in SB companies in general.

Figure 6.11 Breakdown of the relevance of each EIC deep technology by SDG and document type



Note: The orange heat map shows outputs of all Scoreboard companies while the blue heat map only shows outputs by EU-based Scoreboard companies. The colour shading and the number in the cells convey the same information: a darker shade corresponds to a higher percentage of documents linked to a given technologies.

Source: JRC own compilation based on data from R&D Scoreboard, EIC, and SIRIS.

To better illustrate the evidence above, **Table 6.3 Examples of breakthrough research projects, patents and publications for achieving SDG 13 and 7**Table 6.3 provides examples of breakthrough EU-funded collaborative projects, technological advances and scientific discoveries. There is an example of each of the three different output types (projects, patents and scientific publications) for each SDG along with other information (the number of breakthrough categories, year of publication, region of the headquarters of the corresponding Scoreboard company, name of the company and a brief description). For example, Airbus has received EU funding to lead a consortium in the aviation industry with the aim of reducing the industry's environmental footprint, which has significant implications for achieving SDG 13. Similarly, Fujifilm contributed to a scientific discovery in the area of radiative cooling, which brings the promise of harvesting the coldness of the universe as a thermodynamic resource and is thus relevant to achieving both SDG 13 and SDG 7. Also for SDG 7, LG CHEM filed a patent application protecting an AI fuel cell system, which can generate energy more efficiently thanks to the feedback received by an AI unit processing relevant data gathered through sensors.

Table 6.3 Examples of breakthrough research projects, patents and publications for achieving SDG 13 and 7

SDG	Breakthrough categories	Year	Type	Region	Company name	Short description of output
SDG 13	Environmental intelligence and monitoring systems; AI-based local digital twins	2020	EU-funded project	EU	AIRBUS	Albatross is a modernisation programme for European air traffic control infrastructure. It is managed by major European aviation stakeholders and aims to reduce aviation's environmental footprint.
SDG 7; SDG 13	Energy harvesting, conversion, and storage; Cooling and cryogenics; Chip-scale frequency combs; Photon, phonon, electron triangle; Alternative approaches to quantum computation; Sustainable electronics	2018	Patent	US	BIOGEN	Transparent wood composite able to yield an improvement in overall energy conversion efficiency and emission abatement with a range of applications in biodegradable electronics and optoelectronics.
SDG 7; SDG 13	Water-energy nexus; Sustainable, safe and regenerative buildings; Sustainable electronics	2018	Publication	Japan	FUJIFILM	Self-adaptive radiative cooling based on phase-change materials.
SDG 7	Environmental intelligence and monitoring systems; Water-energy nexus; Sustainable, safe and regenerative buildings; AI-based local digital twins; Sustainable electronics	2020	EU-funded project	EU	THALES	Nanomaterials enabling smart energy harvesting for next-generation internet-of-things.
SDG 7	Environmental intelligence and monitoring systems; AI-based local digital twins	2018	Patent	Rest of the world	LG CHEM	AI fuel cell system comprising fuel cell stack for generating electric energy, sensors to gather real time data and AI unit to process the data to provide feedback on optimal and efficient operation of the fuel cell stack.
SDG 7	Energy harvesting, conversion, and storage; sustainable, safe and regenerative buildings	2018	Publication	EU	DAIMLER	Batteries and fuel cells for emerging electric vehicle markets.

Source: JRC own compilation based on data from R&D Scoreboard, EIC, and SIRIS.

6.4 Key points

— The clear upward trend across SDG scores between 2016 and 2020 is confirmed by the 2021 data. This signals an ongoing commitment of the top R&D investing companies to social and environmental responsibility. In line with past evidence, clean and affordable energy (SDG 7), decent work and economic growth (SDG 8) and life on land (SDG 15) achieve the highest absolute scores. Overall, the scores increased by 10% or more between 2016 and 2021, with some growing by almost 20% (e.g. climate action - SDG 13).

— In 2021, EU-based companies led in many environmental SDGs: affordable and clean energy (SDG 7), life on land (SDG 15), responsible consumption & production (SDG 12) and climate action (SDG 13). These companies also achieved the highest scores across the board in the socio-economic SDGs.

— On adopting new processes and technologies to tackle SDG challenges, Scoreboard companies reduced carbon intensity by more than 20% compared with 2013, which is relevant to both climate action (SDG 13) and clean and affordable energy (SDG 7). This decrease is entirely due to increased energy efficiency by top R&D investors, while the adoption of clean energy production technologies still lags behind. EU companies are leading the way with a decrease of more than 30% in energy intensity and 5% in carbon energy intensity.

— Companies operating in the automotive sector and the chemicals sector achieve on average high SDG progression scores in almost all of the environmental SDGs as well as in the socio-economic SDGs 8 (decent work and economic growth) and 9 (industry, innovation & infrastructure). Notably, SDG 9 (industry, innovation and infrastructure) increased by 9.1 points in 2021 with respect to the average for the period 2016-2020 for companies in the chemicals sector. It also increased by 6.5 points or more on average in every region, with companies from China (+7.6 points) and the Rest of the world (+7.2 points) performing significantly better than average along this dimension.

— *Scoreboard* companies are central in developing breakthrough technological and scientific solutions to tackle SDG-related challenges. Patenting linked to climate action (SDG 13) is concentrated in technologies related to energy storage, decarbonisation, and materials for low-power electronics. These technologies are also relevant to clean and affordable energy (SDG 7) as are technologies in the water-energy nexus, green buildings, and sustainable electronics. In contrast, scientific research relevant to SDG 7 is concentrated in relatively few technologies, while scientific research linked to SDG 13 is spread across a much wider range of fields. This indicates the potential for deep technologies to help achieve green and energy policy goals as well as SDG targets.

7 Policy implications

Since the establishment of the EU Industrial R&D Investment *Scoreboard* in 2003[143], private R&D investment has captured substantial attention by policy-makers. EU innovation and industrial policy initiatives highlight the importance of monitoring and analysing the state of overall innovation activity in Europe, including private R&D investment (ERA Policy agenda, Digital Compass, European Education Area, and New European Innovation Agenda).[144] The *Scoreboard* is being developed to contribute to policy monitoring, in particular combining R&D investment data with other data and indicators.

The war in Ukraine has no impact on the 2022 *Scoreboard* data due to the earlier cut-off dates for financial accounts in 2021, but statements by EU firms are available in the *2022 Survey on EU Industrial R&D Investment Trends*, which has been taken between June-September 2022 and is published together with this report.[145] The 100 EU-based *Scoreboard* firms participating therein indicated that, despite generally worsening economic prospects during the surveyed period due to the Russian war in the Ukraine, they expect their sales, profits and employment to increase in 2022 and 2023. This indicates the resilience of innovative EU companies, especially in high-tech segments, such as ICT and health. During the surveyed time until autumn 2022, the war in Ukraine did not cause any change in R&D investment for 86% of the respondents with little effect on the research portfolio of these rather large firms. Delay of existing R&D projects participants are expected most frequently by respondents in aerospace and defence, construction, health industries and automobiles and parts. But respondents also report that they started new R&D projects that were inspired by the war: this is the case for 80% of the companies in aerospace and defence – which are also the ones facing the most interruptions. Also several respondents in the energy sector and in ICT services report new R&D projects that were influenced by the war context. Overall, the impact of the war on R&D was still limited at the time of this *Survey* and mostly for the above sectors.

Despite COVID-19, the 2022 *Scoreboard* data show strong global growth of industrial R&D investments for the 12th consecutive year, revealing the strategic nature of such investments. However, the growing differences between the R&D investment levels and growth rates for EU companies and those from the US and China are a cause for concern and action to be taken in both the private sector and public policy domains. Here, also population size enters the equation raising the question why the EU and the US, which are comparable in population size, have taken such different paths in sector specialisation in the past decades and how the EU can create and grow more key players in the ICT and health sectors.

The following EU-level policy measures could be considered to accelerate growth in private R&D investment:

- **Support reindustrialisation of Europe.** Innovation policies need to be promoted to harness the broad industrial base in Europe including particularly the medium and low-tech sectors. The Industrial Strategy includes the establishment of transition pathways for the identified industrial ecosystems[146] and initiatives with industry and Member States which will benefit from links with ERA policy instruments (common industrial technology roadmaps, industrial alliances, and Horizon Europe missions and partnerships). This can benefit from enhanced coordination and directionality of regional, national and EU innovation policies, which can mobilise and accelerate sustainability-oriented economic growth.
- **Promote Corporate Open Innovation to advance industrial transformation.** Although large players, such as top R&D investors, play a key role in R&D investment worldwide due to their size and centrality, radical and game-changing innovations often come from young and innovative companies which were able to grow and scale-up quickly. The EU has an existing base of smaller firms in key

[143] Under the ERA 2003 with a direct mandate from the 3% Action Plan COM(2003) 226 final; Action 6.6: "Set up an industrial research monitoring activity, including a score-board, to analyse trends and facilitate benchmarking of research investment and research management practices between firms, building on experience in Member States (Implementation: Commission support; first report early 2005)".

[144] September 2020 ERA Communication COM (2020) 628 final, May 2021 updated Industrial Strategy for Europe COM (2020) 102 final, 2030 Digital Compass COM (2021) 118 final, and European Education Area COM (2020) 625 final, and the New European Innovation Agenda COM (2022)332 final. The data have been used in SRIP reports and lately in the McKinsey report "Securing Europe's competitiveness – Addressing its technology gap" of September 2022.

[145] The aim of the 2022 Survey on Industrial R&D Investment Trends is to gain further insight on the trends in R&D and innovation and to address factors and policies that influence these investment decisions from the EU-1000 subsample of *Scoreboard* firms. The 2022 questionnaire addresses R&D investment expectations, financing and collaboration, technology transfer & open innovation, as well as short assessments of the effects of the COVID-19 pandemic and the war in Ukraine. See: https://iri.jrc.ec.europa.eu/rd_monitoring

[146] These 14 industrial ecosystems are: aerospace and defence, agri-food, construction, cultural and creative industries, digital, electronics, energy intensive industries, energy-renewables, health, mobility – transport – automotive, proximity, social economy and civil security, retail, textile and tourism (see https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en).

sectors, such as ICT and health, and excellent technology capacities across Member States. The EU policy objective in the medium-term could be to provide incentives to retain home-grown technologies and firms, and to facilitate their growth into emerging sectors, particularly green and/or digital.[147] This concerns policies to integrate digital talent and technologies better in traditional manufacturing sectors, support growth strategies of start-ups as well as midcap companies (e.g. to grow beyond SME status, go on international markets), and to increase industrial capacities where more/most of the added value in value chains is produced (e.g. "down" the value chain). Also the New European Innovation Agenda inter alia addresses firm creation and growth in emerging technologies to trigger spill overs between sectors. This would have the effect of reducing both EU R&D investment and R&D intensity gaps vis-à-vis its main global competitors.[148]

— **Explore start-up and scale-up measures in relation to Corporate Venture Capital (CVC) activities of existing European and global lead firms**. On a general level, CVC investments of EU-headquartered *Scoreboard* companies are 2.4% of own-funded internal R&D, compared to 4% of their US-headquartered peers. CVC by EU *Scoreboard* companies is just around half of that by US ones. However, 80% of funds from EU-based companies goes to US-based start-ups. A positive regard is that this already produces spill overs, which are also at the heart of the New European Innovation Agenda. Potential measures to close the gap to the higher developed US VC capital market[149] could include better exit opportunities (e.g. facilitating easier floating on the stock market), the promotion of VC networks, or to enhance the visibility of European start-ups, especially outside the country of the headquarters of the mother company to increase the deal flow across national borders and sectors of activity. On a sectoral level, ICT producers and ICT services and health sector have shown a particularly strong positive correlation and high complementarity between R&D and CVC investments. This indicates potential to explore further firms' CVC portfolios towards understanding where to focus the start- and scale-up funding of the New Innovation Agenda,[150] e.g. via the European Innovation Council (EIC) Fund.

— **Strike the right balance between the objectives of strategic autonomy/technological sovereignty, industrial transformation (green and digital) and industrial competitiveness/welfare, together with international key partners.**[151] In the currently challenging geopolitical and global competition context, the question arises on how to boost industrial innovation, while achieving a proper balance between these three objectives, and in particular the potential trade-offs between Open Strategic Autonomy and the transformative agenda, on one hand, and global industrial competitiveness, on the other.[152] From the point of view of industrial innovation, digital, trade and competition policies, this brings new requirements for key sectors and technologies.[153] The more than tripling number of Chinese *Scoreboard* firms over the past decade benefited from a favourable globalisation context and came mostly from organic growth and growth via acquisition of R&D investing companies. These Chinese M&A peaked until around 2018,[154] and are now at a 10-year low.[155] This contributed to a higher sensitivity for the possible impact of foreign takeovers and their innovation

147 Diodato D., P. Moncada-Paternò-Castello, F. Rentocchini and A. Tübke (2022) 'Industrial innovation for sustainable competitiveness: Science-for-policy insights'. Science for Policy Brief – Industrial Innovation & Dynamics Series. JRC 128430. European Commission, Joint Research Centre – Directorate for Growth and Innovation, Seville (Spain), February 2022.

148 Moncada-Paternò-Castello, P. Top R&D investors, structural change and the R&D growth performance of young and old firms. Eurasian Bus Rev 12, 1–33 (2022). https://doi.org/10.1007/s40821-022-00206-3.

149 Available venture capital investment in the EU is about one sixth of the amount it is in the US with a particularly worrying situation for scale-ups in their growth or later stage phases. These figures are from JRC analysis based on Dealroom data that was presented at the expert webinar "Tackling the Scale-Up Gap" on 5 October 2021. This webinar was introduced by Commissioner Mariya Gabriel and was organised by the JRC together with DG-R&I and EISMEA to better quantify the scale-up financing gap, establish what is known about the causes of the gap and its negative economic consequences and to identify how best to address the gap, see: https://publications.jrc.ec.europa.eu/repository/handle/JRC127232).

150 COM (2022) 332 final.

151 Technology Sovereignty as an Emerging Frame for Innovation Policy - Fraunhofer ISI Discussion Papers, July 2021.

152 2022 Strategic Foresight Report: Twinning the green and digital transitions in the new geopolitical context COM (2022) 289 final, and Communication on the Global Approach to Research and Innovation COM (2021) 252 final.

153 See Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F., Towards a green and digital future, EUR 31075 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52452-6, doi:10.2760/54, JRC129319

154 Chinese Mergers and Acquisitions (M&A) in the EU grew strongly (21% between 2017-2019 vs. 2013-2016) and faster than inbound deals from any other strategic partner country (such as the US or Japan), in the EU targeting mostly manufacturing firms (45%). Technology-oriented Chinese companies prefer to acquire radically new technologies not already in their portfolios compared to their European peers that engage in a higher share of coherently diversified (i.e. technologically related) M&As deals. See: Alves Dias, P., Amoroso, S. et al. China: Challenges and Prospects from an Industrial and Innovation Powerhouse, Preziosi, N., Fako, P., Hristov, H., Jonkers, K. and Goenaga Beldarrain, X. editor(s), EUR 29737 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02997-7, doi:10.2760/445820, JRC116516.

155 See the Second Annual Report on the Screening of Foreign Direct Investments into the Union, COM(2022)433.

dimension, e.g. also reflected in the new referral possibility to the Commission of smaller take-overs under the Merger Regulation.

— **Build global partnerships.** In the current geopolitical and competition context, the Global Approach to R&D aims at building stronger partnerships with like-minded countries and at adopting a modulated approach with non-EU countries based on reciprocity, a level-playing field and respect of fundamental and shared values and principles. The application of Article 22 (5) of Horizon Europe is one of the tools that help the EU to safeguard its assets, interests, technological autonomy or security. The overall new geopolitical situation affects also EU strategies for stepping up science diplomacy, strategic partnerships with countries that share EU values, standard-setting or capitalising on leadership in technological circularity. Maintaining strong EU input at international level, such as standard-setting, circularity or Mission Innovation 2.0 as important channels to demonstrate Europe's "green tech" leadership.

— **Take into account the "glocal" nature of innovation ecosystems.** Innovation ecosystem have both a global and a local dimension. Global lead companies, such as those in the *Scoreboard*, play a key role in vitalising innovation ecosystems given their large (direct and indirect) market and innovation power, and an as entry point towards regional and local upgrading via collaboration and internationalisation.[156] Presence of such large companies or their subsidiaries in regional innovation ecosystems could leverage the New Innovation Agenda's connected regional innovation valleys[157] or other territorial policies.[158] The Partnerships for Regional Innovation (PRI)[159] enhance the coordination and directionality of regional, national and EU innovation policies, bringing the above aspects into policy implementation.

— **Pursue the policy strategies rooted in the renewed ERA strategy and the (updated) Industrial Strategy**. This includes *transition pathways* for some of the 14 identified *industrial ecosystems*, *ERA Common industrial technology roadmaps* (a key tool to help accelerating transfer of R&I results into the economy through R&I investment agendas developed with Member States and stakeholders), *industrial alliances* (to mobilise and build industrial capacities in key industrial and technological areas) and *Horizon Europe partnerships* with industry (as a stepping-stone for such alliances to develop industrial investment plans, and to provide the starting basis for ERA technology roadmaps.) Focus should be on the effective implementation of the agreed actions, and careful selection and design of possible new ones, based on a co-creation approach with Member States and stakeholders. Some industrial eco-systems benefit from a combination of initiatives, e.g. Horizon partnerships with industry and industrial alliances, which is a good basis for effective public-private synergies building on complementarity, relevant R&I results and mutual input.

More information, including activities and publications surrounding the *Scoreboard*, is available at:

https://iri.jrc.ec.europa.eu/home/ and
https://research-and-innovation.ec.europa.eu/strategy/support-policy-making_en.

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156 Home-bases of *Scoreboard* firms drive the knowledge flows of their home regions on the international scene, see Dosso, M. and Lebert, D.: "A geography of corporate knowledge flows across world regions: evidence from patent citations of top R&D-investing firms", JRC Working Papers on Corporate R&D and Innovation No 03/2019, JRC 118006, https://iri.jrc.ec.europa.eu/sites/default/files/2019-10/TR%20Geografy% 20of% 20corporate_0.pdf

157 These valleys will bring together less with more innovative regions by building on strategic areas of regional strength and specialisation in support of key EU priorities. For this purpose, 3-4 inter-regional innovation projects will be launched by the end of 2023 building on Smart Specialisation Strategies and, where applicable, on the participation in the Partnerships for Regional Innovation (PRIs), see: https://s3platform.jrc.ec.europa.eu/pri

158 Such as 13 start-up villages under Cohesion Policy as part of the long-term vision for rural areas policy; Euroclusters under the Single Market Programme; and Horizon Europe, including European Innovation Ecosystems, Start-up Europe, Widening Participation and Strengthening the ERA, Missions, and the work of the European Institute of Innovation and Technology's Knowledge and Innovation Communities and the regional innovation scheme.

159 See https://s3platform.jrc.ec.europa.eu/pri.

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Annexes

Annex 1 Background information

Investment in research and innovation is at the core of the EU policy agenda. The Europe 2020 growth strategy includes the Innovation Union flagship initiative[160] with a 3 % headline target for intensity of research and development (R&D)[161]. R&D investment from the private sector plays also a key role for other relevant European initiatives such as the Industrial Policy[162], Digital Agenda and New Skills for New Jobs flagship initiatives.

The project "Global Industrial Research & Innovation Analyses" (GLORIA)[163] supports policymakers in these initiatives. The *Scoreboard*, as part of the GLORIA project, aims to improve the understanding of trends in R&D investment by the private sector and the factors affecting it. The *Scoreboard* identifies main industrial players in key industrial sectors, analyse their R&D investment and economic performance and benchmark EU companies against their global counterparts.

This report describes and analyses the *Scoreboard* data and provides additional information on the positioning of Scoreboard companies in relation to other key indicators of relevance for industrial innovation policy and industrial R&D positioning. The annual publication of the *Scoreboard* intends to raise awareness of the importance of R&D for businesses and to encourage firms to disclose information about their R&D investments and other intangible assets.

The data for the *Scoreboard* are taken from companies' publicly available audited accounts. As in more than 99% of cases these accounts do not include information on the place where R&D is actually performed, the company's whole R&D investment in the *Scoreboard* is attributed to the country in which it has its registered office[164]. This should be borne in mind when interpreting the *Scoreboard*'s country classifications and analyses.

The *Scoreboard*'s approach is, therefore, fundamentally different from that of statistical offices or the OECD when preparing business enterprise expenditure on R&D data, which are specific to a given territory. The R&D financed by business sector in a given territorial unit (BES-R&D) includes R&D performed by all sectors in that territorial unit[165]. **Therefore, the *Scoreboard* R&D figures are comparable to BES-R&D data only at the global level.**

The *Scoreboard* data are primarily of interest to those concerned with private sector R&D investments and positioning and benchmarking company commitments and performance (e.g. companies, investors and policymakers). BES-R&D data are primarily used by economists, governments and international organisations interested in the R&D performance of territorial units defined by political boundaries. The two approaches are therefore complementary. The methodological approach of the *Scoreboard*, its scope and limitations are further detailed in Annex 2 below.

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160 The Innovation Union flagship initiative aims to strengthen knowledge and innovation as drivers of future growth by refocusing R&D and innovation policies for the main challenges society faces.

161 This target refers to the EU's overall (public and private) R&D investment approaching 3 % of gross domestic product (see: http://ec.europa.eu/europe2020/pdf/targets_en.pdf).

162 The Industrial Policy for the Globalisation Era flagship initiative aims to improve the business environment, notably for small and medium-sized enterprises, and support the development of a strong and sustainable industrial foundation for global competition.

163 GLORIA builds on the IRIMA project (Industrial Research and Innovation Monitoring and Analysis). See: http://iri.jrc.ec.europa.eu/home /. The activity is undertaken jointly by the Directorate General for Research (DG R&I R&I A; see: http://ec.europa.eu/research/index.cfm?lg=en) and the Joint Research Centre, Directorate Growth and Innovation (JRC-Seville; see: https://ec.europa.eu/jrc/en/science-area/innovation-and-growth).

164 The registered office is the company address notified to the official company registry. It is normally the place where a company's books are kept.

165 The *Scoreboard* refers to all R&D financed by a company from its own funds, regardless of where the R&D is performed. BES-R&D refers to all R&D activities funded by businesses and performed by all sectors within a particular territory, regardless of the location of the business's headquarters. The sources of data also differ: the *Scoreboard* collects data from audited financial accounts and reports whereas BES-R&D typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. Additional differences concern the definition of R&D intensity (BES-R&D uses the percentage of R&D in value added, while the *Scoreboard* considers the R&D/Sales ratio).

Scope and target audience

The *Scoreboard* is a benchmarking tool which provides reliable up-to-date information on R&D investment and other economic and financial data, with a unique EU-focus. The 2500 companies listed in this year's *Scoreboard* account for more than 90%[166] of worldwide R&D funded by the business enterprise sector and the *Scoreboard* data refer to a more recent period than the latest available official statistics. Furthermore, the dataset is extended to cover the top 1000 R&D investing companies in the EU.

The data in the *Scoreboard*, published since 2004, allow long-term trend analyses, for instance, to examine links between R&D and business performance.

The *Scoreboard* is aimed at three main audiences.

- **Policy-makers, government and business organisations** can use R&D investment information as an input to industry and R&D assessment, policy formulation or other R&D-related actions such as R&D tax incentives.
- **Companies** can use the *Scoreboard* to benchmark their R&D investments and so find where they stand in the EU and in the global industrial R&D landscape. This information could be of value in shaping business or R&D strategy and in considering potential mergers and acquisitions.
- **Researchers, investors, and financial analysts** can use the *Scoreboard* to assess investment opportunities and risks, as well as analyse investment trends.

Furthermore, the *Scoreboard* dataset has been made freely accessible to encourage further economic and financial analyses and research by any interested parties.

Annex 2 Methodological notes

The data for the 2022 *Scoreboard* have been collected from companies' annual reports and accounts by Bureau van Dijk – A Moody's Analytics Company (BvD). The source documents, annual reports & accounts, are public domain documents and so the *Scoreboard* is capable of independent replication. In order to ensure consistency with our previous *Scoreboards*, BvD data for the years prior to 2012 have been checked with the corresponding data of the previous *Scoreboards* adjusted for the corresponding exchange rates of the annual reports.

Main characteristics of the data

The data correspond to companies' latest published accounts, intended to be their 2021 fiscal year accounts, although due to different accounting practices throughout the world, they also include accounts ending on a range of dates between late 2020 and mid-2022. Furthermore, the accounts of some companies are publicly available more promptly than others. Therefore, the current set represents a heterogeneous set of timed data. However, around 70% of companies closed their accounts in December 2021.

In order to maximise completeness and avoid double counting, the consolidated group accounts of the ultimate parent company are used. Companies which are subsidiaries of another company are not listed separately. Where consolidated group accounts of the ultimate parent company are not available, subsidiaries are included.

In the case of a demerger, the full history of the continuing entity is included. The history of the demerged company can only go back as far as the date of the demerger to avoid double counting of figures.

In case of an acquisition or merger, pro forma figures for the year of acquisition are used along with pro-forma comparative figures if available.

The R&D investment included in the *Scoreboard* is the cash investment which is funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share of any associated company or joint venture R&D investment

[166] According to latest Eurostat statistics.

when disclosed. However, it includes research contracted out to other companies or public research organisations, such as universities.

Where part or all of R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated.

Companies are allocated to the country of their registered office. In some cases this is different from the operational or R&D headquarters. This means that the results are independent of the actual location of the R&D activity.

Companies are assigned to industry sectors according to the NACE Rev. 2[167] and the ICB (Industry Classification Benchmark). In the *Scoreboard* report we use different levels of sector aggregation, according to the distribution of companies' R&D and depending on the issues to be illustrated. In Chapter 1.2, paragraph 1.2.2 typical levels of the industrial classification applied in the *Scoreboard*.

Limitations

Users of the *Scoreboard* data should take into account the methodological limitations, especially when performing comparative analyses (see summary of main limitation in Box A2.1 below)

The *Scoreboard* relies on disclosure of R&D investment in published annual reports and accounts. Therefore, companies which do not disclose figures for R&D investment or which disclose only figures which are not material enough are not included in the *Scoreboard*. Due to different national accounting standards and disclosure practice, companies of some countries are less likely than others to disclose R&D investment consistently. There is a legal requirement to disclose R&D in company annual reports in some countries.

In some countries, R&D costs are very often integrated with other operational costs and can therefore not be identified separately. For example, companies from many Southern European countries or the new Member States are under-represented in the *Scoreboard*. On the other side, UK companies could be over-represented in the *Scoreboard*.

For listed companies, country representation will improve with IFRS adoption.

The R&D investment disclosed in some companies' accounts follows the US practice of including engineering costs relating to product improvement. Where these engineering costs have been disclosed separately, they are excluded from the *Scoreboard*. However, the incidence of non-disclosure is uncertain and the impact of this practice is a possible overstatement of some overseas R&D investment figures in comparison with the EU. Indeed, for US companies, the GAAP accounting standards are always used because they are the official, audited ones, however non-GAAP results may give a more realistic view of true R&D investments.

Where R&D income can be clearly identified as a result of customer contracts it is deducted from the R&D expense stated in the annual report, so that the R&D investment included in the *Scoreboard* excludes R&D undertaken under contract for customers such as governments or other companies. However, the disclosure practise differs and R&D income from customer contracts cannot always be clearly identified. This means a possible overstatement of some R&D investment figures in the *Scoreboard* for companies with directly R&D related income where this is not disclosed in the annual report.

In implementing the definition of R&D, companies exhibit variability arising from a number of sources: i) different interpretations of the R&D definition; ii) different companies' information systems for measuring the costs associated with R&D processes; iii) different countries' fiscal treatment of costs. Some companies view a process as an R&D process while other companies may view the same process as an engineering or other process.

Interpretation

There are some fundamental aspects of the *Scoreboard* which affects the interpretation of the data. The focus on R&D investment as reported in group accounts means that the results do not indicate the location of the R&D activity. The *Scoreboard* indicates rather the level of R&D funded by companies, not all of which is carried out in the country in which the company is registered. This enables inputs such as R&D and Capex

[167] NACE is the acronyme for "Nomenclature statistique des activités économiques dans la Communauté européenne".

investment to be related to outputs such as Sales, Profits, productivity ratios and market capitalisation only at the group and the at global level.

The data used for the *Scoreboard* are different from data provided by statistical offices, e.g. the R&D expenditures funded by the business enterprise sector and performed by all sectors within a given territorial unit (BES-R&D). The *Scoreboard* refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. In contrast, BES-R&D refers to all R&D activities funded by businesses and performed within a particular territory, regardless of the location of the business's headquarters. ***Therefore, the Scoreboard R&D figures are directly comparable to BES-R&D data only at the global level, i.e. the aggregate of the 2500 companies R&D investment can be compared with the global total BES-R&D.***

Further, the *Scoreboard* collects data from audited financial accounts and reports. In contrast, BES-R&D typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. An additional difference concern the definition of R&D intensity, BES-R&D uses the percentage of value added, while the *Scoreboard* measures it as the R&D/Sales ratio because value added data is not available at a micro-level

Sudden changes in R&D figures may arise because a change in company accounting standards. For example, the first time adoption of IFRS[168], may lead to information discontinuities due to the different treatment of R&D, i.e. R&D capitalisation criteria are stricter and, where the criteria are met, the amounts must be capitalised.

For many highly diversified companies, the R&D investment disclosed in their accounts relates only to part of their activities, whereas sales and profits are in respect of all their activities. Unless such groups disclose their R&D investment additional to the other information in segmental analyses, it is not possible to relate the R&D more closely to the results of the individual activities which give rise to it. The impact of this is that some statistics for these groups, e.g. R&D as a percentage of sales, are possibly underestimated and so comparisons with non-diversified groups are limited. By allocating all companies to a single sector, the R&D of diversified companies is allocated to one sector only leading to overstatement of R&D in that sector and under-statement of it in other sectors.

At the aggregate level, the growth statistics reflect the growth of the set of companies in the current year set. Companies which may have existed in the base year but which are not represented in the current year set are not part of the *Scoreboard* (a company may continue to be represented in the current year set if it has been acquired by or merged with another but will be removed for the following year's *Scoreboard*).

For companies outside the Euro area, all currency amounts have been translated at the Euro exchange rates ruling at *31 December 2021* as shown in Table A2.1[169]. The exchange rate conversion also applies to the historical data. The result is that over time the *Scoreboard* reflects the domestic currency results of the companies rather than economic estimates of current purchasing parity results. The original domestic currency data can be derived simply by reversing the translations at the rates above. Users can then apply their own preferred current purchasing parity transformation models.

Glossary

1. **Research and Development (R&D) investment** in the *Scoreboard* is the cash investment funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share of any associated company or joint venture R&D investment. However, it includes research contracted out to other companies or public research organisations, such as universities. Being that disclosed in the annual report and accounts, it is subject to the accounting definitions of R&D. For example, a definition is set out in International Accounting Standard (IAS) 38 "Intangible assets" and is based on the OECD "Frascati" manual. **Research** is defined as original and planned investigation undertaken with the prospect of gaining new scientific or technical knowledge and understanding. Expenditure on research is

[168] Since 2005, the European Union requires all listed companies in the EU to prepare their consolidated financial statements according to IFRS (International Financial Reporting Standards, see: http://www.iasb.org/).

[169] Companies from some countries report their data in US dollars, e.g. in this edition, most companies based in Israel present their results in US dollars.

recognised as an expense when it is incurred. **Development** is the application of research findings or other knowledge to a plan or design for the production of new or substantially improved materials, devices, products, processes, systems or services before the start of commercial production or use. Development costs are capitalised when they meet certain criteria and when it can be demonstrated that the asset will generate probable future economic benefits. Where part or all of R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated.

2. R&D expenditures funded by the business enterprise sector (**BES-R&D**), provided by official statistics, refer to the total R&D performed within a territorial unit that has been funded by the business enterprise sector (private or public companies).
3. **Net sales** follow the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures & associates. For banks, sales are defined as the "Total (operating) income" plus any insurance income. For insurance companies, sales are defined as "Gross premiums written" plus any banking income.
4. **R&D intensity** is the ratio between R&D investment and net sales of a given company or group of companies. At the aggregate level, R&D intensity is calculated only by those companies for which data exist for both R&D and net sales in the specified year. The calculation of R&D intensity in the *Scoreboard* is different from that in official statistics, e.g. BES-R&D, where R&D intensity is based on value added instead of net sales.
5. **Operating profit** is calculated as profit (or loss) before taxation, plus net interest cost (or minus net interest income) minus government grants, less gains (or plus losses) arising from the sale/disposal of businesses or fixed assets.
6. **One-year growth** is simple growth over the previous year, expressed as a percentage: 1 yr growth = 100*((C/B)-1); where C = current year amount and B = previous year amount. 1yr growth is calculated only if data exist for both the current and previous year. At the aggregate level, 1yr growth is calculated only by aggregating those companies for which data exist for both the current and previous year.
7. **Capital expenditure (CAPEX)** is expenditure used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings. In accounts capital expenditure is added to an asset account (i.e. capitalised), thus increasing the asset's base. It is disclosed in accounts as additions to tangible fixed assets.
8. **Number of employees** is the total consolidated average employees or year-end employees if average not stated.

Box A2.1 Methodological caveats

Users of Scoreboard data should take into account the methodological limitations summarised here, especially when performing comparative analyses:

A typical problem arises when comparing data from different currency areas. The Scoreboard data are nominal and expressed in Euros with all foreign currencies converted at the exchange rate of the year-end closing date (31.12.2021). The variation in the exchange rates from the previous year directly affects the ranking of companies, favouring those based in countries whose currency has appreciated with respect to the other currencies. In this reporting period, the exchange rate of the Euro appreciated by 9.8%, 3.8% and 5.8% against the US dollar, the Japanese Yen and the pound sterling respectively. However, ratios such as R&D intensity or profitability (profit as % sales) are based on the ratio of two quantities taken from a company report where they are both expressed in the same currency and are therefore not affected by currency changes.

The growth rate of the different indicators for companies operating in markets with different currencies is affected in a different manner. In fact, companies' consolidated accounts have to include the benefits and/or losses due to the appreciation and/or depreciation of their investments abroad. The result is an 'apparent' rate of growth of the given indicator that understates or overstates the actual rate of change. For example, this year the R&D growth rate of companies based in the Euro area with R&D investments in the US is partly understated because the 'losses' of their overseas investments due to the depreciation of the US dollar against the Euro (from $1.12 to $1.23). Conversely, the R&D growth rate of US companies is partly overstated due to the 'benefits' of their investments in the Euro area. Similar effects of understating or overstating figures would happen for the growth rates of other indicators, such as net sales.

When analysing data aggregated by country or sector, in many cases, the aggregate indicator depends on the figures of a few firms. This is due, either to the country's or sector's small number of firms in the Scoreboard or to the indicator dominated by a few large firms.

The different editions of the Scoreboard are not directly comparable because of the year-on-year change in the composition of the sample of companies, i.e. due to newcomers and leavers. Every Scoreboard comprises data of several financial years (8 years since 2012 and 10 years since 2017) allowing analysis of trends for the same sample of companies.

In most cases, companies' accounts do not include information on the place where R&D is actually performed; consequently the approach taken in the Scoreboard is to attribute each company's total R&D investment to the country in which the company has its registered office or shows its main economic activity. This should be borne in mind when interpreting the Scoreboard's country classification and analyses. In some cases where company are headquartered in countries for fiscal reasons with little R&D or other activity in that country, a misleading impression may be received.

Growth in R&D can either be organic, the outcome of acquisitions or a combination of the two. Consequently, mergers and acquisitions (or de-mergers) may sometimes underlie sudden changes in specific companies' R&D and sales growth rates and/or positions in the rankings.

Other important factors to take into account include the difference in the various countries' (or sectors') business cycles, which may have a significant impact on companies' investment decisions, and the initial adoption or stricter application of the International Financial Reporting Standards (IFRS)[170].

[170] Since 2005, the European Union requires all listed companies in the EU to prepare their consolidated financial statements according to IFRS (see: EC Regulation No 1606/2002 of the European Parliament and of the Council of 19 July 2002 on the application of international accounting standards at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002R1606:EN:HTML).

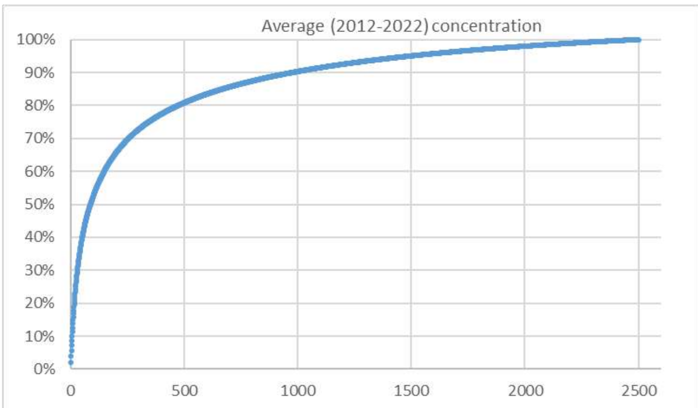
Table A 1 Euro exchange rates applied to *Scoreboard* data for companies reporting in different currencies (as of 31 Dec 2021)

Country	As of 31 Dec 2020	**As of 31 Dec 2021**
Australia	$ 1.59	**$ 1.56**
Brazil	6.38 Brazilian real	**6.32 Brazilian real**
Canada	$ 1.58	**$ 146**
China	8.02 Renminbi	**7.22 Renminbi**
Czech Republic	26.24 Koruna	**24.86 Koruna**
Denmark	7.43 Danish Kronor	**7.43 Danish Kronor**
Hungary	364.83 Forint	**368.87 Forint**
Hong Kong	9.51 HKD	**8.83 HKD**
India	89.65 Indiana Rupee	**84.15 Indiana Rupee**
Israel	3.95 Shekel	**3. 25 Shekel**
Japan	127.16 Yen	**129.35 Yen**
New Zealand	1.70 NZD	**1.66 NZD**
Norway	10.47 Norwegian Kronor	**9.99 Norwegian Kronor**
Poland	4.61 Zloty	**4.60 Zloty**
Russia	90.65 Rouble	**84.15 Rouble**
Singapore	1.62 SGD	**1.53 SGD**
South Korea	1335.11 Won	**1344.09 Won**
Sweden	10.03 Swedish Kronor	**10.24 Swedish Kronor**
Switzerland	1.08 Swiss Franc	**1.03 Swiss Franc**
Taiwan	$ 34.98 New dollar	**$ 31.36 New dollar**
Turkey	9.02 Turkish lira	**14.71 Turkish lira**
UK	£0.91	**£0.84**
US	$ 1.23	**$ 1.13**
United Arab Emirates	4.51 Dirham	**4.16 Dirham**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

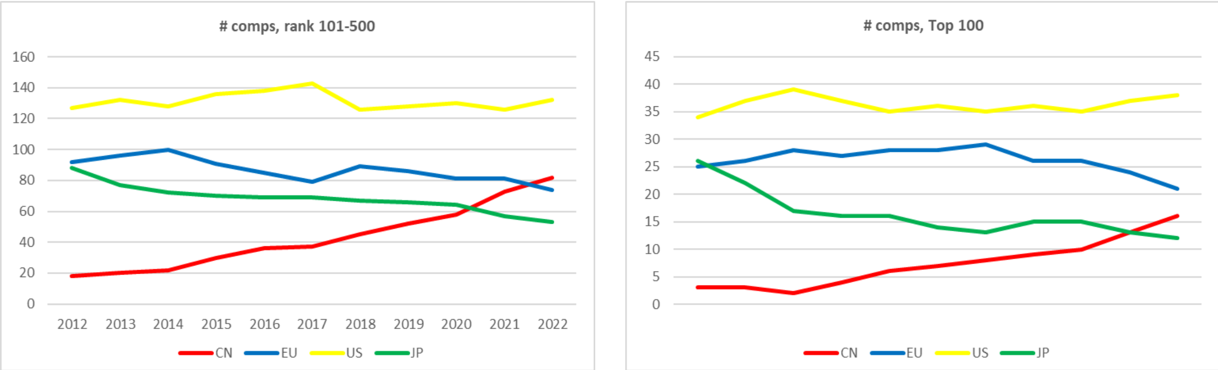
Annex 3 Chapter 3 - additional tables

Figure A 1 Average of the cumulated shares of R&D investments companies of *Scoreboard* 2012 and 2022



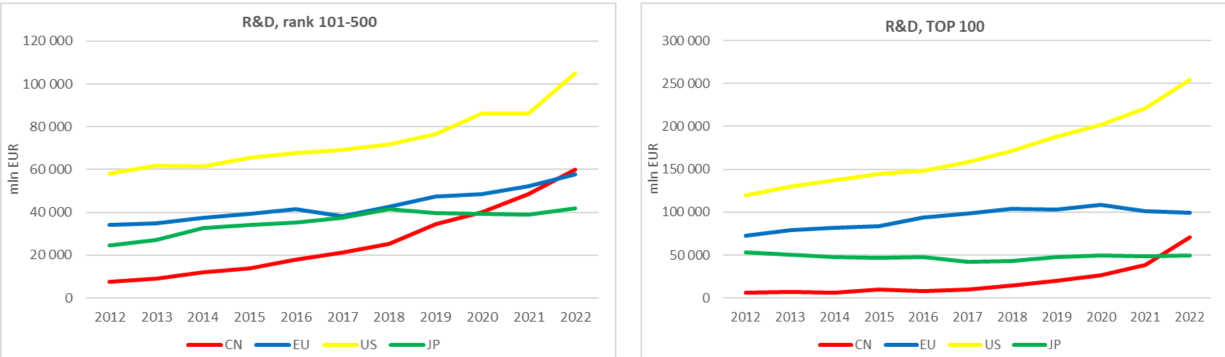
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A 2 Main developments in the number of companies in the *Scoreboard* by the four main geographical regions



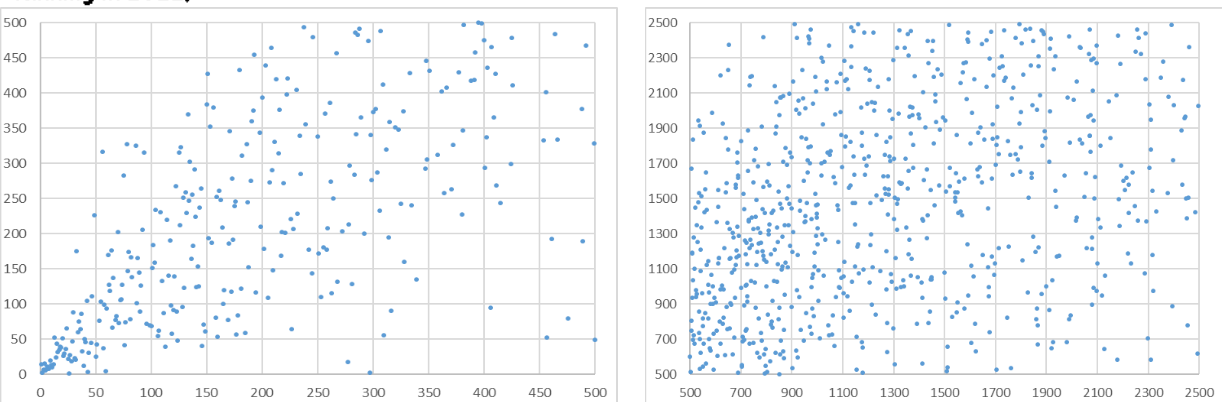
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A 3 Main developments in R&D investment in the *Scoreboard's* four main geographical regions, EUR million



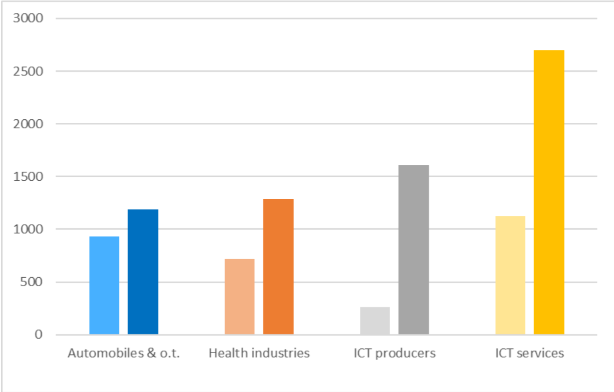
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A 4 Scatterplot of rankings in *Scoreboard* 2012 and 2022 (horizontal: ranking in 2012, vertical: ranking in 2022)



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A 5 Average R&D of companies improving (rise) and worsening (fall) their ranking



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A 2 Number of companies by region and by sector of activity between *Scoreboard* 2012 and 2022

Number of companies	SB2012						SB2022					
	EU	JP	CN	US	RoW	Total	EU	JP	CN	US	RoW	Total
Aerospace & Defence	13	1	0	21	18	53	10	0	5	15	14	44
Automobiles & other tr	**44**	**52**	**19**	**37**	**29**	**181**	**34**	**28**	**54**	**37**	**27**	**180**
Chemicals	23	55	4	38	28	148	16	28	33	21	17	115
Construction	21	27	11	7	10	76	9	10	35	4	7	65
Energy	32	18	5	12	24	91	26	10	20	10	14	80
Financial	31	0	0	9	17	57	22	0	12	9	18	61
Health industries	**82**	**44**	**13**	**185**	**65**	**389**	**68**	**31**	**92**	**309**	**67**	**567**
ICT producers	**65**	**98**	**53**	**226**	**157**	**599**	**42**	**45**	**153**	**112**	**102**	**454**
ICT services	**44**	**15**	**18**	**129**	**53**	**259**	**30**	**6**	**83**	**203**	**40**	**362**
Industrials	92	87	36	55	58	328	57	36	99	35	35	262
Others	72	83	17	77	70	319	47	39	92	67	65	310
Total	**519**	**480**	**176**	**796**	**529**	**2 500**	**361**	**233**	**678**	**822**	**406**	**2 500**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A 3 Top 50 R&D investment per company in *Scoreboard* 2012 and 2022, EUR million

	2012						2022					
	EU	US	JP	CN	RoW	Total	EU	US	JP	CN	RoW	Total
Automotive	4 616	5 926	3 916			4 600	8 729	6 843	6 303			7 624
Health industries	3 452	5 478	2 179		6 086	4 982	5 110	7 876	4 065		8 464	7 266
ICT producers	3 721	4 434	2 784	3 122	5 550	4 032	4 441	8 969		19 534	10 395	8 955
ICT services		5 508	1 957			4 324	5 168	14 474	5 732	7 439		11 262
Others	3 249	3 614	3 322			3 407			4 902	5 509		5 206

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A 4 R&D invested by region and by sector of activity between *Scoreboard* 2012 and 2022, EUR million

R&D invested	SB2012						SB2022					
	EU	JP	CN	US	RoW	Total	EU	JP	CN	US	RoW	Total
Aerospace & Defence	7 618	16	0	7 666	3 248	18 548	6 359	0	587	7 640	3 114	17 699
Automobiles & o.t.	36 343	23 385	3 017	20 076	5 321	88 141	62 614	33 189	18 037	27 588	10 979	152 407
Chemicals	4 356	6 460	97	6 660	2 682	20 255	5 346	7 848	3 787	4 733	3 425	25 138
Construction	1 453	1 211	2 730	672	647	6 714	2 910	1 374	24 750	590	1 228	30 852
Energy	4 365	1 134	2 691	3 641	4 649	16 480	5 550	991	6 792	2 477	3 688	19 498
Financial	3 861	0	0	557	4 898	9 316	7 095	0	2 014	3 511	6 525	19 145
Health industries	19 305	10 386	397	55 611	28 815	114 515	38 599	15 349	13 783	123 897	43 712	235 339
ICT producers	23 137	20 392	6 961	56 969	28 120	135 579	28 578	20 962	52 016	97 438	47 814	246 808
ICT services	7 487	5 435	1 381	37 138	4 410	55 852	14 821	9 498	34 732	145 501	11 709	216 260
Industrials	10 446	9 189	2 643	9 820	4 444	36 543	11 474	8 831	20 328	8 339	5 825	54 797
Others	7 722	13 998	719	13 544	7 830	43 814	9 411	15 763	19 032	17 965	13 745	75 916
Total	**126 096**	**91 606**	**20 637**	**212 355**	**95 064**	**545 757**	**192 756**	**113 802**	**195 858**	**439 680**	**151 763**	**1 093 860**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A 5 Structure of company presence in *Scoreboard* industrial sectors by main geographical regions – # of companies included (red = lower than the *Scoreboard* average, green = higher than the *Scoreboard* average)

SB Sectors	SB average		EU		Japan		China		US	
	2012	2022	2012	2022	2012	2022	2012	2022	2012	2022
Aerospace & Defence	2,1%	1,8%	2,5%	2,8%	0,2%	0,0%	0,0%	0,7%	2,6%	1,8%
Automobiles & other transport	7,2%	7,2%	8,5%	9,4%	10,8%	12,0%	10,8%	8,0%	4,6%	4,5%
Chemicals	5,9%	4,6%	4,4%	4,4%	11,5%	12,0%	2,3%	4,9%	4,8%	2,6%
Construction	3,0%	2,6%	4,0%	2,5%	5,6%	4,3%	6,3%	5,2%	0,9%	0,5%
Energy	3,6%	3,2%	6,2%	7,2%	3,8%	4,3%	2,8%	2,9%	1,5%	1,2%
Financial	2,3%	2,4%	6,0%	6,1%	0,0%	0,0%	0,0%	1,8%	1,1%	1,1%
Health industries	15,6%	22,7%	15,8%	18,8%	9,2%	13,3%	7,4%	13,6%	23,2%	37,6%
ICT producers	24,0%	18,2%	12,5%	11,6%	20,4%	19,3%	30,1%	22,6%	28,4%	13,6%
ICT services	10,4%	14,5%	8,5%	8,3%	3,1%	2,6%	10,2%	12,2%	16,2%	24,7%
Industrials	13,1%	10,5%	17,7%	15,8%	18,1%	15,5%	20,5%	14,6%	6,9%	4,3%
Others	12,8%	12,4%	13,9%	13,0%	17,3%	16,7%	9,7%	13,6%	9,7%	8,2%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Annex 4 Access to the dataset

The 2022 *Scoreboard* comprises two data samples:

— The world's top 2500 companies that invested more than EUR 48.5 million in R&D in 2021

— The top 1000 R&D investing companies based in the EU with R&D investment exceeding EUR 3.1 million.

For each company, the following information is available:

— Company identification (name, country of registration and sector of declared activity according to the *Scoreboard* sector classification).

— R&D investment

— Net Sales

— Capital expenditure

— Operating profit or loss

— Total number of employees

— Market capitalisation (for listed companies)

— Main company indicators (R&D intensity, Capex intensity, Profitability)

— Growth rates of main indicators over one year.

The following link provides access to the page of the two *Scoreboard* data samples, which contain the main economic and financial indicators and main statistics:

https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard

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