European Commission

SCIENCE FOR POLICY BRIEF

European Climate Neutral Industry Competitiveness Scoreboard 2022

HIGHLIGHTS

- → The Competitiveness Scoreboard (Figure 9) provides a snapshot of EU progress on 28 climate-neutral solutions measured against that of major global competitors.
- → The EU performs strongly in innovation-related indicators, especially high-value patents, public R&D investment and innovating companies.
- → EU production bounced back after the pandemic, but strong demand was also met with increasing imports of strategic net-zero technologies

The European Green Deal Industrial Plan for the net-zero age [1] reaffirms the leading role of industry in delivering the transformational change needed to achieve climate neutrality. Faced with the challenge of energy dependence and rising energy prices, REPowerEU [2] has underlined the urgency of accelerating this transition. The EU's industrial competitiveness, particularly with regard to strategic net-zero technologies, is therefore of utmost importance [3]. This scoreboard, measuring EU progress on climate-neutral solutions, aims to provide information on the capacity of EU industry to achieve these goals.

EU INDUSTRY COMPETITIVENESS SCOREBOARD

Approach and scope

The scoreboard builds on a framework of competitiveness indicators that monitor EU progress in key climate-neutral solutions [4 and 5], including strategic net-zero technologies [3]. It provides a snapshot of the EU's progress measured against that of major global competitors. The 2022 scoreboard (Figure 9) includes 28 climate-neutral solutions.

The solutions are chosen based on their potential to contribute to the EU climate neutrality goal, their market relevance for EU industry, and their prominence in the Member States' plans for investment under the National Energy and Climate Plans [6] and the Recovery and Resilience Plans [7].

The assessment framework builds on JRC work which monitors competitiveness in low-carbon energy industries. The framework is based on ten key indicators: public R&D[1] investment; early and later stage investment (venture capital); patenting activity; innovating companies; employment; production; turnover; imports & exports; and trade balance. Technology experts were consulted to address issues related to the availability and granularity of the datasets and to validate the selection of companies and product codes. Information on the framework and background data is available in the Methodology report [8]. Box 1 and Table 1 contain a summary of the ranking criteria. The monetary data is in current prices, including the benchmarks used for scoring criteria. This way inflation does not affect the scoring of performance. The impact of price increases is considered only qualitatively for each solution, where there is evidence.

[1] Research and development.

Joint Research Centre

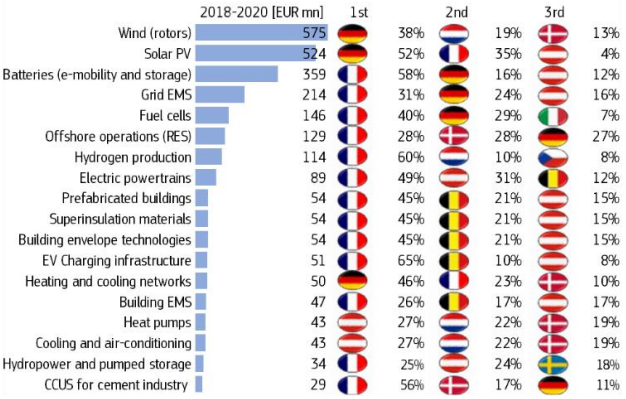
Investment is largely increasing

Public R&D investment

In 17 climate-neutral solutions, EU Member State public R&D investment increased in the period 2016-2020. **In 15 of these solutions, public R&D investment grew faster than EU GDP**. Public R&D investment increased most in batteries, offshore operations, hydrogen, grid energy management systems (EMS) and CCUS[2], in which investment grew by an average of 20-30% annually (2016-2020). Based on available data, only hydropower and pumped storage see a decrease in public R&D investment.

In absolute terms, for the period 2018-2020, wind and solar PV received the most public R&D investment: well above EUR 500 million. Germany is the biggest EU contributor in both, though as seen in Figure 1, France is the top performer for a large number of solutions, due to increasing investment reported by the country in recent years.

Figure 1 - EU Member State public R&D investment and top Member State based on available data



Source: JRC based on IEA data, 2023

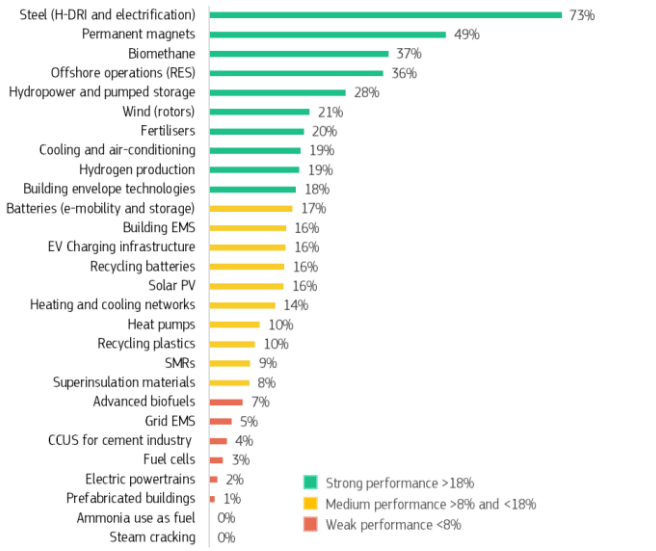
Venture capital investment

Venture capital in climate-neutral solutions is increasing overall. In early stage investment, the EU has captured a lower share globally compared to the 2015-2020 period, and is thus less competitive in batteries, solar PV and heating & cooling networks. Nonetheless, with the exception of batteries and batteries recycling, EU early stage investment is increasing and the EU has captured a significant share of all early stage investment in steel, permanent magnets, biomethane, offshore operations, hydropower, wind, bio-based circular fertilisers, cooling and air-conditioning and building envelope technologies (Figure 2).

The overall grant intensity in early stage investment in the EU (22%) is comparable to the rest of the world (21%), but the EU ranks markedly lower than the global average in three solutions: fuel cells, hydrogen production and small modular reactors.

[2] Carbon capture, utilisation and storage.

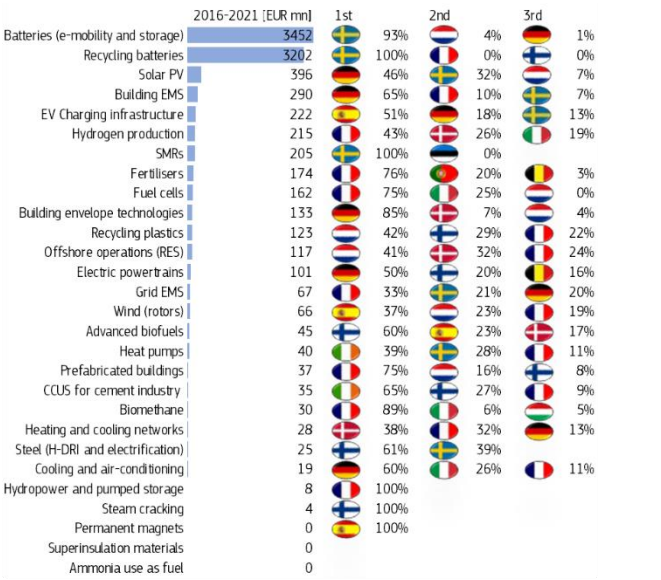
Figure 2 – EU share in global early stage investment 2016-2021



Source: JRC based on Pitchbook data, 2023

Overall, **the EU has captured a higher share of later stage investment** than in 2015-2020, doing particularly well in batteries and batteries recycling, offshore operations, heat pumps, hydrogen production, heating and cooling networks plastics recycling, building EMS and biomethane. The EU also achieved a strong performance in small modular reactors (supported by corporate investment pledges) and in steam cracking (though through a single venture capital company). In absolute terms, batteries and batteries recycling receive by far the most investment in the EU, with EUR 0.74 billion of early stage and over EUR 3 billion of later stage investment in 2016-2021 (Figure 3). Majority of this investment concentrate to Swedish Northvalt.

Figure 3 – EU later stage investment and top Member State



Source: JRC based on Pitchbook data, 2023

QUICK GUIDE – The European Climate Neutral Industry Competitiveness Scoreboard is a project carried out by the Joint Research Centre in partnership with the Directorate General Internal Market, Industry, Entrepreneurship and SMEs.

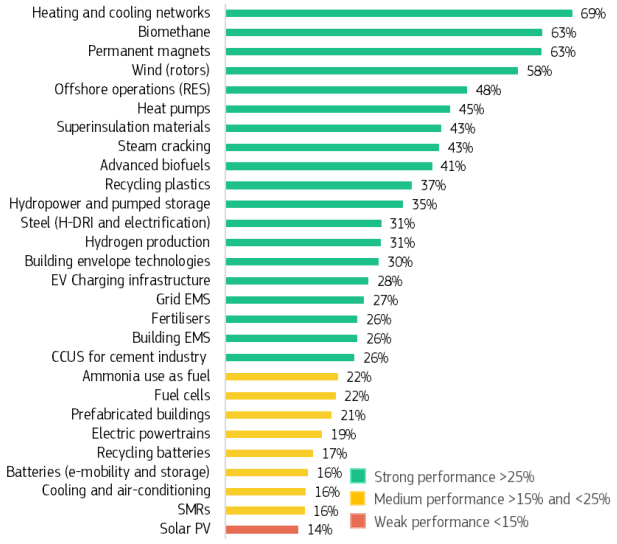
For more information about the methodology, please see Methodology Report [8], and for the preceding assessment, see European Climate Neutral Industry Competitiveness Scoreboard (CIndECS) – Annual Report 2021 [9].

Innovation trends

Patenting activity

Overall, the EU performs strongly in patenting – accounting for over 25% of high-value filings in 19 solutions. In heating and cooling networks, biomethane, permanent magnets, and wind, the EU dominates in innovating activity. The exception is solar PV, where the EU share is below 15% and on a decreasing trend (Figure 4), in contrast to surging activity in China and South Korea. Nonetheless, while the EU captures less than a 15% share globally, its patent portfolio in solar PV is one of the largest among the solutions assessed, topped by batteries and followed by fuel cells and EV charging infrastructure.

Figure 4 – EU global share of high-value inventions (2016-2019)



Source: JRC based on EPO Patstat data, 2023

EU corporates are leading global patenting activity related to superinsulation materials, heat pumps, wind, offshore operations, and decarbonising the cement industry through CCUS. In these areas, at least five EU corporates are among the global top 10.

Innovating companies

An ecosystem of patenting corporates and venture capital companies facilitates innovation and growth in future markets. The EU hosts over 25% - the threshold for strong performance – of identified innovating companies globally in 20 of the 28 solutions (Figure 5). As seen in Figure 5, the EU score is average for some strategic net-zero technologies (as defined in the Net-Zero Industry Act); these are batteries and batteries recycling, fuel cells and solar PV. Prefabricated buildings and cooling and air-conditioning are also rated as average. The EU share is low for two solutions: permanent magnets and ammonia. Overall, the composition of the innovation ecosystem in the EU is comparable to the rest of the world, with a third of innovators being venture capital companies and two thirds being corporates.

Box 1: Scoreboard ranking criteria

The scoring criteria are based on:

- EU aggregated trends in public R&D, employment, production, turnover and trade balance;
- EU share of global total in early and later stage investment, patents, innovating companies and imports & exports.

EU GDP growth is used as a benchmark for public R&D investment, production and turnover. Employment growth in the overall economy is used as a benchmark for the employment indicator.

For global comparisons, the EU share of the global economy (18%) is used as a benchmark in early and later stage investment, patents, innovating companies and extra-EU exports. In addition, objectives identified by the European Roundtable for Industry [10] are used to define the threshold of strong performance in venture capital investment, patents and exports. All thresholds are shown in Table 1.

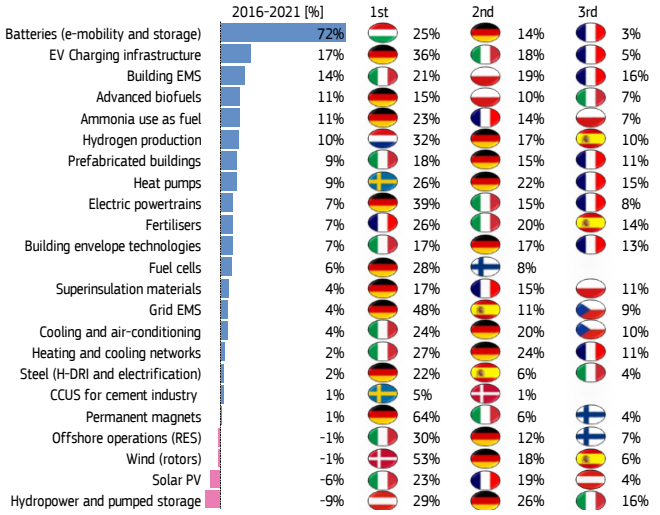
Table 1 – Scoring thresholds for 2022 assessment

Legend	High	Medium	Low
Summary of criteria			
Public R&D	>2%	0< and <2%	<0%
Early Stage	>18%	8%< and <18%	<8%
Later Stage	>18%	8%< and <18%	<8%
Patents	>25%	15%< and <25%	<15%
Companies	>25%	15%< and <25%	<15%
Employment	>1%	0%< and <1%	<0%
Production	>3%	0%< and <3%	<0%
Turnover	>2%	0%< and <2%	<0%
Imports & Exports	>25%	15%< and <25%	<15%
Trade Balance	positive / improving		negative / deteriorating

Figure 5 – EU share of innovators - VC companies and corporates (2016-2021)

Source: JRC compilation of sources, 2023

Figure 6 – EU production compoung annual growth rate (CAGR) and top Member State



Source: JRC based on Prodcom data, 2023

The EU in today's markets

EU production

The production value provides an indication of EU manufacturing capacity for key components of the solutions in focus. EU production grew fastest in batteries, EV charging infrastructure, building EMS, advanced biofuels, ammonia and hydrogen production, for which the compound annual growth rate (CAGR) reached double digits in 2016-2021, see Figure 6. The EU's battery production[3] increased by CAGR of 72%, but more effort is needed to keep the EU on track for self-sufficiency, since there is still a significant, and increasing, trade deficit. In the same period, the production of heat pumps, building envelope technologies, offshore operations for renewable energy (RES) and cooling & air-conditioning grew faster than EU GDP, which had a CAGR of 3% in 2016-2021. The Figure 6 also includes the largest EU producers as a share of total disclosed production value.

The production indicator has largely improved compared to 2015-2020, indicating a strong bounce back from the pandemic. Nonetheless, the production of offshore operations and wind generating sets in 2021 was 7% smaller in value than in 2016. The production of solar PVs almost doubled from 2020 to 2021, but was still a quarter of the 2016 value. The production value of hydroturbines witnessed a decreasing trend in 2016-2021, but this was due to an exceptional peak in 2016.

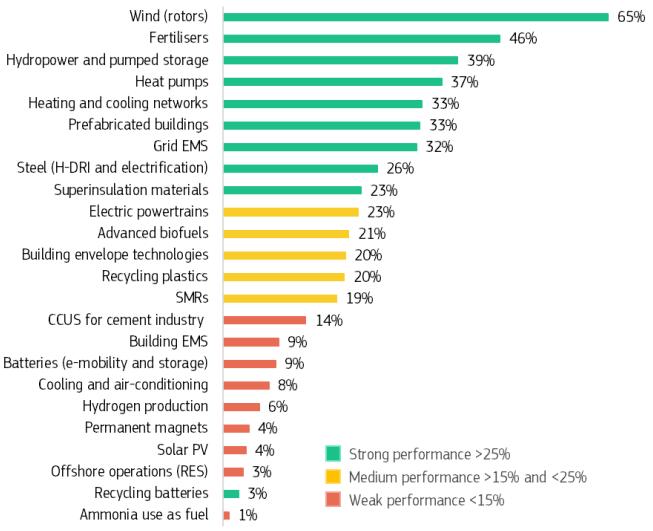
EU imports and exports

In terms of global presence, the EU largely maintained its position, compared to 2018-2020. In 2019-2021, the EU accounted for over 25% of global exports in eight solutions: wind, bio-based circular fertilisers, hydropower, heat pumps, heating and cooling networks, prefabricated buildings, grid EMS and steel (H-DRI & electrification), thus performing strongly. EU export performance was average in superinsulation materials, electric powertrains, advanced biofuels, building envelope technologies and small modular reactors (SMRs). In the remaining solutions, the EU share in global exports is less than 15%, which is considered weak, as it is significantly lower than the EU's economic weight globally (Figure 7).

In the majority of solutions, EU Member State imports were covered by internal trade except for five solutions: 73% of permanent magnets and 65% of solar PV were imported from China, and 70% of ammonia from Algeria and Russia. In addition, in offshore operations and SMRs about two thirds is imported from outside the EU. The largest share of intra-EU imports is seen in hydrogen (98%), bio-based circular fertilisers (86%), prefabricated buildings (84%) and building envelope technologies (83%).

[3] The Prodcom code associated with Li-ion batteries is only available from 2019. Due to reclassification, other types of battery are therefore included. However, the share of Li-ion grew from 74% in 2019 to 94% in 2021, constituting most of the reported production value.

Figure 7 – EU share of extra-EU exports (2019-2021)



Source: JRC based on Comext and Comtrade data, 2023

The performance criteria for the trade of spent batteries and scrap plastics are reversed, because exports are seen as a loss of raw materials. Since 2014, the EU has significantly reduced the export of scrap plastics, thus indicating improving circularity. Nevertheless, the EU share of global exports still stands at 20%, which is higher than its economic weight. In spent batteries, the EU share is only 3% and in fact, the EU imports more than it exports.

EU trade balance

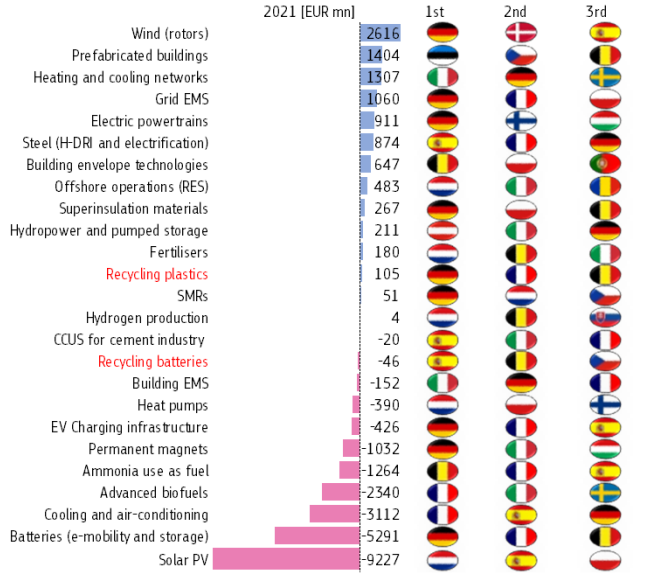
In 2021, the EU had a positive trade balance in 14 solutions and a trade deficit in 11. The biggest trade surpluses were in wind (EUR 2.6 billion), prefabricated buildings (EUR 1.4 billion), heating and cooling networks (EUR 1.3 billion), and grid EMS (EUR 1 billion). Germany had the biggest trade surpluses in wind and grid EMS, Estonia in prefabricated buildings and Italy in heating and cooling networks (Figure 8).

In 2021, the EU had the biggest trade deficit in solar PV (EUR 9 billion), **batteries** (EUR 5 billion), cooling and air-conditioning (EUR 3 billion) and advanced biofuels (EUR 2 billion). At Member State level, the Netherlands had the biggest trade deficit in solar PV, cooling and air-conditioning and advanced biofuels and Germany in batteries. China was the main exporter to the EU in seven solutions where the EU has a trade deficit (solar PV; batteries; cooling and air-conditioning; permanent magnets; EV charging; heat pumps; and buildings EMS). The EU imported biofuels mainly from Argentina and China, ammonia mainly from Algeria and Russia and solvents for CCUS from Saudi Arabia and the US.

[4] In circular solutions (in red), trade surplus indicates a lost opportunity for recycling.

The EU trade balance has deteriorated for many of the solutions since 2020, including the strategic net-zero technologies, solar PV, batteries and heat pumps. In 2020, the heat pumps trade balance turned negative (EUR 40 million) for the first time, and in 2021, the deficit increased almost tenfold (EUR 390 million) due to the fast-growing EU market.

Figure 8 – EU trade balance and top Member State by trade surplus/deficit[4]



Source: JRC based on Comext data, 2023

A strong recovery from the pandemic

Venture capital investment, unaffected by the pandemic, continued to rise and enjoyed a record year in 2021. Clean energy and climate technologies are witnessing a new wave of venture capital, which is broader in terms of the spectrum of solutions funded compared to the first boom that took place prior to the 2008 financial crisis. Venture capital companies can play an important role in challenging incumbents and catalysing breakthrough innovations in sectors such as steel, fertilisers, buildings and construction. Strong policy support and demand for these solutions may help these ventures to succeed.

The green recovery boosted EU manufacturing in 2021, with many key sectors such as batteries, electric powertrains, prefabricated buildings and hydrogen production experiencing accelerated growth. Nevertheless, the recovery was accompanied by supply chain disruptions and employment shortages, coupled with price volatility. Increasing material, energy and labour costs have a differentiated effect on the

assessed technologies. For instance technologies, in which bigger part of the value chain is produced within the EU, such as wind and heat pumps, face the pressure of internalising the bigger share of the increased costs in the EU.

Moreover, at the same time, the EU trade balance deteriorated in all but wind, offshore operations, hydrogen and steel (H-DRI and electrification). This indicates that EU demand for climate-neutral solutions is growing to the extent that domestic manufacturing is not able to satisfy it, and an increasing share is met with imports.

As the EU aims to accelerate the deployment of climate-neutral solutions, it is important to maintain and improve the competitiveness of the EU manufacturing industry. The Green Deal Industrial Plan [1] addresses skills gaps and, through the Critical Raw Materials Act [11], focuses on improving the resilience of supply chains by ensuring access to (critical) materials vital for the manufacturing of many of the climate-neutral technologies featured in this study. The Net-Zero Industry Act [3] provides a regulatory framework to streamline and speed up permitting, improve access to markets and promote a range of tools for net-zero technologies such as one-stop shops, net-zero strategic projects, net-zero academies for skills and regulatory sandboxes.

EU industry champions and challengers

Areas of strength

The EU continues to perform well in **wind (rotors), scoring high in all innovation-related indicators for this solution**. The EU is well-placed to capture future growing markets and maintain its technological leadership. However, circularity may require further R&I efforts. **The EU also performs well globally**, capturing 65% of all extra-EU exports, and reaching 79% if intra-EU trade is included. EU Member States host a substantial proportion of the global wind energy supply chain and are the leading suppliers for the EU onshore and offshore wind rotor market. Concerns include the availability of raw materials, permitting and skills bottlenecks, reflected in the decline in EU employment and turnover in 2021. The Green Deal Industrial Plan [1], along with its Net-Zero Industry Act [3] and Critical Raw Materials Act [11] address these issues, for wind and other strategic technologies.

The EU **heat pump** market continued its strong growth in 2021, with employment and turnover growing by nearly 20% and 30% respectively against 2020 values. The industry maintains its **strong performance on innovation indicators**, with the exception of early stage investment, where the EU only captures a 10% share. In addition, imports from China are increasing, resulting in a rapidly increasing EU trade deficit (over EUR 3 billion in 2021). There is a risk that while EU manufacturers are not able to scale up fast enough, large Asian and North-American air conditioner manufacturers could saturate the growing EU market with less efficient products. In this respect, cooling also deserves attention, as cooling needs are likely to increase in the EU and are coupled with an emerging ecosystem of VC companies and a growing EU manufacturing base, which can offer spillovers and transferable skills between the technologies.

The EU **performs well in all innovation-related indicators for offshore operations for renewable installations**. As a first mover, the EU hosts 42% of identified innovating companies, especially in offshore wind, but also in ocean energy. The EU has a strong industrial base for offshore vessels and infrastructures, and European offshore operators are well represented globally, e.g. in the Asia-Pacific region. However, **rapid developments in turbine sizes are causing bottlenecks for operators** in terms of up-to-date vessels and overcapacity. **Ports will require major upgrades** to meet the offshore renewable energy targets, along with significant investment in fuel infrastructures to be able to supply zero-emission fuels for maritime transport. Action is also needed to avoid an imminent shortage of skilled workers.

The EU has maintainted its positioning in heating and cooling networks. While performance in early stage investement has dropped, it remains strong in the later stages. Production rebounded in 2021 and the trade balance remained positive. Nevertheless, more infrastructure development is required for district heating and cooling networks, to achieve a higher share of renewable energy and deeper energy system integration as envisioned in the proposed revision of the Renewable Energy Directive [12].

High expectations in strategic areas

There are signs of **improvement in batteries, solar PV and hydrogen production**. EU Member State public R&D investment in batteries increased at a compound annual growth rate of nearly 40% in 2016-2020, mainly due to a signficant increase in investment by France. The scale-up of Swedish battery manufacturer, Northvolt, is solely responsible for nearly half of all EU venture capital investment. Nevertheless, other countries such as the Netherlands, France and Germany have attracted investment, indicating that start-ups are emerging in other regions of the EU. The EU is also catching up with Japan and South Korea in patenting activity. While the EU is largely dependent on imports, its production of batteries is growing very fast, with many industry announcements being made about new manufacturing projects.

In solar PV, EU Member State public funding has remained stable against a globally decreasing trend. In 2021, which was a record year, EU companies did not attract venture capital to the same extent as the rest of the world. Nevertheless, the EU production value increased in 2021 for the first time since 2016. Moreover, with new announcements by industry and the EU Solar energy strategy [13], the EU has the potential to improve its position in upstream activities and capture a larger share of the value chain as the global PV industry is undergoing technological change. Growing employment and turnover (which both increased by over 30% on 2020 values) show that the EU deployment market is growing fast and solar PV became the third biggest renewable employer.

As one of the main pathways for decarbonisation, the renewable hydrogen production and electrolysers sector has high potential for growth and is attracting increasing amounts of venture capital investment. The EU is strong on innovation aspects, performing well in terms of public R&D investment and patenting output. As **host to 40% of global electrolyser capacity, and half of the manufacturers of large-scale electrolysers, the EU has a good industrial basis to take advantage of future market opportunities**. However, it could face competition, particularly from the deployment drive and cost reductions in China. Other issues to address include ensuring demand for green hydrogen or low carbon hydrogen, and dependence on (critical) raw material imports, and thus supply disruption and price volatility. A closely connected solution is **green ammonia as a sustainable alternative fuel** for maritime transport. While still at a very nascent stage, it **represents a first mover opportunity for the EU**, as 75% of pilots and demonstration projects currently identified are either located in Europe or rely on solutions provided by leading EU corporate innovators.

The EU lead in circularity offers many benefits

Bio-based circular fertilisers, batteries and plastics recycling mitigate climate and environmental impacts, while offering new business opportunities and improving security of supply.

In bio-based circular fertilisers, the EU performs strongly in innovation. Supported by an enabling policy framework, including the Fertilising Product Regulation [14], EU production is gradually increasing, serving an emerging global market. In terms of plastics recycling, the EU leads in patenting activity and innovating companies, thus being well positioned to capture future opportunities. The EU has already reduced waste export significantly, yet there is still room to improve, as the EU is responsible for 20% of global plastic waste exports. Battery recycling is still a nascent area, but extremely important for the development of an EU-based battery supply chain and access to critical raw materials.

Areas in need of attention

There are some concerning trends, particularly in terms of venture capital investment, where EU companies have attracted less venture capital than competitors, **in transport-related solutions** (fuel cells, electric powertrains, EV charging infrastructure, ammonia as a fuel and advanced biofuels). EU companies also capture less than the EU average in climate tech (less than 9%), in grid EMS and prefabricated buildings, which are both very important, the former for ensuring smart grids and the latter for decarbonising the building sector. In building EMS, which is closely connected to both, the EU trade deficit is gradually increasing, reflecting the EU's reliance on imports when it comes to digital components and assemblies.

Another concern relates to neodymium magnets (Nd-Fe-B), which are high-performance permanent magnets, indispensable for the production of wind turbines (aerogenerators) and electric vehicles (electric traction motors), as well as a number of other advanced technologies. The EU's increasing trade deficit (EUR 1 billion in 2021) demonstrates the magnitude of the import dependency for this crucial technology. It also raises questions about the role of China as the most important exporter to the EU (export value of EUR 2.5 billion in the period 2019-2021). The future legislative framework, based on the European Critical Raw Materials Act [11], will provide incentives to diversify supply and increase the EU's self-sufficiency in this domain. This can be reinforced by the ongoing EU R&D projects, funded by Horizon Europe, which focus on improving circularity and developing rare earth-free magnets.

Emerging solutions

The EU has the potential to take the lead in green hydrogen-based steelmaking. The EU is already a leader in energy- and CO_2-efficient steel production, and with a 30% share of high-value inventions and 34% share of innovating companies, the EU also leads in breakthrough technologies. Thanks to a mega-deal with a Swedish start-up in 2021, the EU captures nearly three quarters of all early stage investment. In addition, the **majority of global steel decarbonisation projects via the H-DRI route are based in Europe**. Nevertheless, deep decarbonisation of steel production will depend on the accelerated development and adoption of supporting technologies, such as electrolysers and hydrogen infrastructure, and the availability of renewable energy.

There have been unprecedented advances in CCUS technologies in recent years. While the EU lags behind the US and the rest of the world on some indicators, the situation is

improving. EU Member State public R&D funding grew at a CAGR of 18% in 2016-2020, and CCUS received the highest share of EU R&D funding for the decarbonisation of the cement industry.

Steam cracking is the key process in the decarbonisation of the chemical industry, the electrification of which could not only drastically reduce emissions but also improve product yield. Several innovative ideas are being developed by the industry and academia, and the EU is a clear leader in patenting activity. The only venture capital deal so far has gone to an EU-based start-up, which develops technology that, if successful, could be groundbreaking for the chemical and other energy-intensive industries.

Biomethane can substitute for natural gas, decarbonising a range of sectors, while improving waste management and sustainable agriculture. It can thus contribute to the goals of REPowerEU to reduce the EU's dependence on imported fossil fuels and diversify its energy supply. The EU performs strongly in investment and innovation, but weakly in employment and turnover. Nevertheless, if current scale-up plans are realised, the sector has significant job creation potential.

Small modular (nuclear) reactors can significantly improve nuclear safety performance and lower capital cost requirements, thus offering a solution that can be built closer to industrial sites, while enabling new delivery and business cases (such as scalable sources of zero-carbon heat and electricity applications), that would make them more affordable and faster to deploy than large traditional reactors. As such, they are attracting increasing amounts of investment worldwide, with the US largely leading the way. Several EU countries have shown interest and allocated public funding to the development of SMRs, supported by the EU SMR Pre-Partnership Initiative.

Box 2: Connection to other work

This project has contributed to the Clean Energy Technology Observatory, underpinning the Clean Energy Competitiveness Progress Report [15 and 16], which accompanies the annual State of the Energy Union Report.

The solutions chosen for assessment feature in Member States' National Energy and Climate Plans [6] as well as the Recovery and Resilience Plans [7] and are aligned with the EU's long-term decarbonisation needs and with the targets of REPowerEU [2]. All technologies featuring in the Net-Zero Industry Act [3] are addressed in the report.

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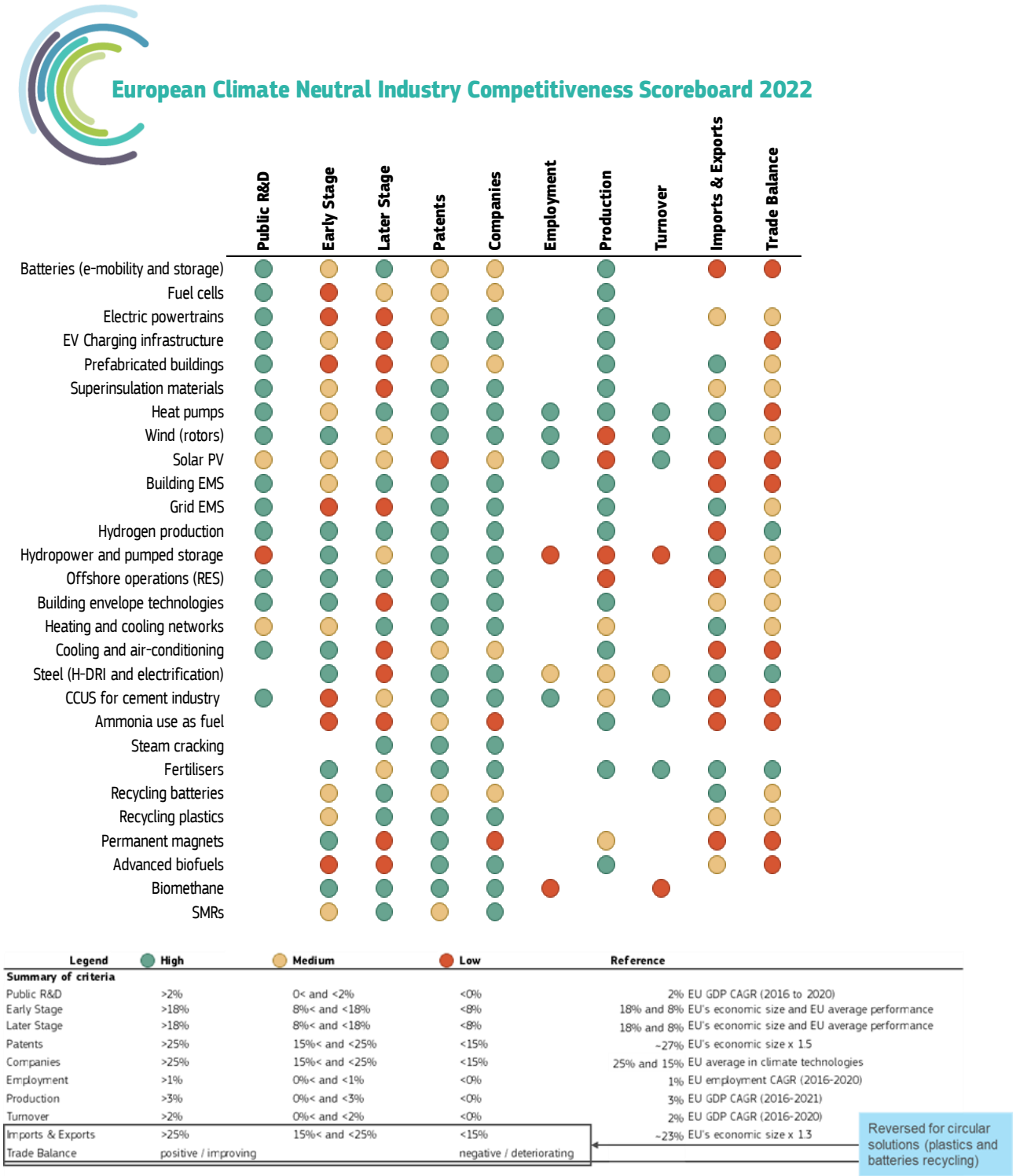
DISCLAIMER OR OTHER FINAL DETAILS

Public R&D data is subject to Member States' reporting to the IEA. Production figures represent the value of production sold during the reported period. There is very limited information on

the physical volumes of production, therefore, only the monetary value is tracked. Not all EU Member States disclose their data. In all solutions, production and trade aim to track those flows that are specific enough to the solution in question, e.g. electric furnaces and graphite electrodes are used as proxies in steel (H-DRI), and solvents used for CCUS are tracked in decarbonisation of cement (CCUS). Full list of product codes used is reported in the Methodology Report. Employment and turnover are based on Eurobserv'ER investment-based modelling, which is sensitive to the input data and, as figures are allocated to the year when projects are commissioned, can cause statistical peaks.

Figure 9 – European Climate Neutral Industry Competitiveness Scoreboard 2022



Source: JRC, 2023

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