Export as a measure of innovation performance in the clean energy sector: Assessment of indicators

Provision of technical assistance and study to support the development of a composite indicator to track clean-energy innovation performance of EU members

Independent
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Report

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Abbreviations

CAGR	Compound Average Growth Rate
CCS/U	Carbon capture, utilisation and storage
CEII	Clean Energy Innovation Indicator
CET	Clean Energy Technology
CN Code	Combined Nomenclature Code
Eurostat RAMON	Eurostat - Reference and Management of Nomenclatures
GDP	Gross Domestic Product
HS Codes	Harmonised System Codes
JRC	Joint Research Centre
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parity
RES	Renewable Energy Sources
R & D	Research and Development
R & I	Research and Innovation
SITC	Standard International Trade Classification
Solar PV	Solar Photovoltaic
TiVA	Trade in Value Added
UN	United Nations
WEC	World Energy Council

1 Introduction

This report is the deliverable *D3-1.2: Second interim data and report (Trade)*, part of the second interim data and report series designed to support the development of the Clean Energy Innovation Index (CEII), a composite indicator aimed at tracking the clean energy innovation performance of EU Member States (EU27) and Mission Innovation (MI) member countries (MI-23) (see Table 1.1)[1]. The CEII was first developed as part of the first interim data and report series, which included data for the Trade dimension of the CEII up to 2018, with a focus on exports. The Second interim data and report series is an update of the first series[2] with data for the Trade dimension of the CEII up to and including 2019, with minor methodological changes.

Table 1-1 List of EU27 and MI members

EU27 members		MI member countries	
Austria*	Italy*	Australia	Indonesia
Belgium	Latvia	Austria*	Italy*
Bulgaria	Lithuania	Brazil	Japan
Croatia	Luxembourg	Canada	Mexico
Cyprus	Malta	Chile	The Netherlands
Czechia	Netherlands	China	Norway
Denmark*	Poland	Denmark*	Saudi Arabia
Estonia	Portugal	Finland*	South Korea
Finland*	Romania	France*	Sweden*
France*	Slovakia	Germany*	United Arab Emirates
Germany*	Slovenia	India	United Kingdom
Greece	Spain		United States
Hungary	Sweden*		
Ireland			

Note: The asterisk (*) denotes countries that are members of both groups.

Cambridge Econometrics built seven datasets of exports, one for each of the core Strategic Energy Technology (SET) Plan key actions (KAs) with the exception of KA4 (Resilience & security of the energy system) for which no product-level trade codes have been attributed[3]. Furthermore, two of the KAs - KA5 (New materials & technologies for buildings) and KA6 (Energy efficiency in industry) overlap in terms of product-level trade and capture similar set of products. The table below presents the KAs covered by the Trade dimension and the clean energy technologies corresponding to each of these KAs.

[1] The Mission Innovation member countries listed in Table 1.1 and included in the analysis (referred to as MI-23) are those with MI membership as of the end of 2018 (when the CEII project was designed). Morocco also became an MI member in 2019, and in September 2021, a new phase of MI (MI 2.0) was launched, in which Indonesia and Mexico are not participating. The EU27 is also a member of MI, but EU27 data are not included in the total values of indicators estimated for the MI category to avoid double counting of seven EU Member States that are also MI members.

[2] The first report on the Clean Energy Innovation Index is available at:
https://op.europa.eu/en/publication-detail/-/publication/dbcf832a-f8b9-11eb-b520-01aa75ed71a1/language-en/format-PDF/source-search
The first report on the Trade dimension of the Clean Energy Innovation Index is available at:
https://op.europa.eu/en/publication-detail/-/publication/cddceea7-e2b8-11eb-895a-01aa75ed71a1/language-en/format-PDF/source-search

[3] The reason why data for this KA was not included is that codes related to this specific KA (mostly codes related to gas turbines) were not deemed consistent with a definition of "clean energy" based on low-carbon technologies leading to net GHG emissions reductions.

Table 2-2 SET Plan Key Actions covered by the Trade dimension of the Clean Energy Innovation Index and the clean energy technologies corresponding to each of them

#	SET Plan Key Action	Corresponding clean energy technology
01/02	Performant renewable technologies integrated in the system / Reduced technology costs	• Solar energy • Wind energy • Hydroelectricity • Geothermal energy
03.	New technologies & services for consumers	Smart meters
05-06.	New materials & technologies for buildings & Energy efficiency in industry	Insulation
07.	Competitive in global battery sector (e-mobility)	Energy storage
08.	Renewable fuels	• Fuel cells • Hydrogen technology
09.	Carbon capture Utilisation and Storage (CCUS)	Carbon capture, utilisation and storage (CCUS)
10.	Nuclear Safety	Nuclear energy

The CEII contributes to the overarching aim of measuring progress in clean energy innovation by analysing output-related indicators. It is a composite indicator consisting of three core dimensions (i.e. scientific publications, patents and trade), each measured with one or more indicators that capture various aspects of the innovation system. This report covers analytical work using exports as a measure of innovation performance[4]. The report aims to provide details on:

1. Insights on clean energy innovation performance from the perspective of export-related data;

2. Deliver the trade dataset for inclusion in composite indicator calculations.

The report is structured according to the above objectives. In Section 2, we discuss the main challenges of using export-related data as a measure of innovation performance, identify the most relevant export indicators, assess how they mitigate the key challenges, and finally select the most suitable trade indicator for inclusion in the CEII. Section 3 summarises the methodology for mapping clean energy technology (CET) products to the structure of the SET Plan Key Actions (KA). In Section 4, we provide insights on CET innovation performance for the selected indicator(s). Finally, Section 5 concludes and summarises the insights from the assessment of export indicators.

[4] The other two dimensions, and the index consisting of a combination of all three dimensions, are covered in separate reports. The first report on the Clean Energy Innovation Index is available at: https://op.europa.eu/en/publication-detail/-/publication/dbcf832a-f8b9-11eb-b520-01aa75ed71a1/language-en/format-PDF/source-search
The first report on the Publications dimension of the Clean Energy Innovation Index is available at: https://op.europa.eu/en/publication-detail/-/publication/9889eed4-dd3a-11eb-895a-01aa75ed71a1/language-en/format-PDF/source-search
The first report on the Patents dimension of the Clean Energy Innovation Index is available at: https://op.europa.eu/en/publication-detail/-/publication/9f1af3e9-e2ba-11eb-895a-01aa75ed71a1/language-en/format-PDF/source-search
The first report on the Trade dimension of the Clean Energy Innovation Index is available at: https://op.europa.eu/en/publication-detail/-/publication/cddceea7-e2b8-11eb-895a-01aa75ed71a1/language-en/format-PDF/source-search

2 Export flows as indicators for measuring innovation performance

In our approach, the process of innovation in clean energy technologies (CETs) can be captured in the context of a flow-concept in global markets, where the international diffusion of technological advancements has, essentially, three key stages. Scientific (basic) research forms the basis for CET innovation, a process that often results in writing research materials and publications (captured in the CEII by indicators on scientific publications). The second phase is for applied research and development activities, the success of which is often indicated by and measured in terms of classical indicators of innovation outputs (in the CEII captured by patent indicators). Finally, diffusion of the goods resulting from the innovation process takes place internationally through trade (in the CEII captured by an export-related indicator) and exports can be used as an indicator of innovation uptake or outcome, both at micro or macro level.

Export is a key dimension of the CEII, which is intended to be capable of reflecting an unbiased as possible, robust and credible picture of a country's progress in innovation in CETs vis-à-vis its own historic performance and vis-à-vis other countries. Within the CEII indicator, the trade dimension captures the ability of an economy, notably resulting from innovation, to export goods and services with high levels of value added, and successfully take part in knowledge-intensive global value chains[5].

In the first interim report on the Trade dimension, we discussed the key challenges of export-based indicators, presented several indicators and approaches to mitigate the impacts of the main challenges, and compared and assessed the results of the most relevant indicators for measuring innovation performance and for inclusion in the clean energy innovation index. The approach we took in this report was essentially the same of the previous report[6].

2.1 Identification of relevant indicators and approaches

Export of CETs[7] is one of the three dimensions of the CEII. This dimension measures the diffusion of innovation in CET through export metrics. Based on the collected and processed data, and based on the calculated indicators we identified one core indicator to include in the CEII for all the in-scope countries:

1. **CET export value added vs GDP:** Domestic value added content of Clean energy technology exports / GDP

In addition, two further supporting indicators (hereinafter referred to as 'Supporting indicators') are calculated for all the in-scope countries with a two-fold goal to include them in the supporting dashboard of the CEII, as well as to provide additional insights into country performance in these indicators.

2. **High-tech export:** High-tech exports / Total exports

3. **CET Export vs GDP:** Clean energy technology exports / GDP

[5] Vertesy, D (2017) The Innovation Output Indicator 2017. Methodology Report, EUR 28876 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76474-5, doi:10.2760/971852, JRC108942. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108942/jrc108942_ioi_2017_report_final.pdf

[6] For further details on the key challenges of the trade-based indicators, please consult the first interim report on the Trade dimension. The first report on the Trade dimension of the Clean Energy Innovation Index is available at: https://op.europa.eu/en/publication-detail/-/publication/cddceea7-e2b8-11eb-895a-01aa75ed71a1/language-en/format-PDF/source-search

[7] Our definition of 'clean energy technology' (CET) has been developed in accordance with the Key Actions set out in the SET Plan: https://ec.europa.eu/energy/sites/ener/files/publication/Complete-A4-setplan.pdf as per the tender specifications. This definition applied to the analysis of CET trade does not include product codes related to gas turbines, hydrogen fuel and biofuels (see section 3).

The core indicator, *CET export value added vs GDP* (Domestic value added content of Clean energy technology exports / GDP) aims to measure the extent to which the given economy provides an individual contribution to global clean energy supply chains. Pioneering new products and services can provide substantial margins for first movers, thereby securing competitive advantage in the longer run; furthermore, the agglomeration effect provides the possibility of extending the first-mover advantage in a CET to a whole ecosystem of related products and services in the future. According to the OECD Glossary of Terms,"[8]. Domestic value added in gross exports is "an estimation of value added, by an economy, in producing goods and services for export, simply defined as the difference between gross output at basic prices and intermediate consumption at purchasers' prices"[9]. In order to measure clean energy innovation performance of a country and to allow for comparison of performance between countries, some of the indicators of interest need to be normalised by the size of the economies; therefore, this indicator and the second supporting indicator are expressed relative to GDP value.

The first one of the supporting indicators, *High-tech export vs. total export*, essentially gives a measure of the actual share of high-technology[10] products' exports in a national economy within total exports and reflects the extent to which the country is currently embedded in high-technology products' global value chains. Creating, exploiting and commercialising new technologies is vital for the competitiveness of a country in the modern economy. While this indicator alone should not be considered as predictive, interpreting it in parallel with other indicators can provide insights as to the innovation capacity of a specific country, particularly on "enabling technologies" (e.g. advanced materials and robotics) that may also reinforce competitiveness in exporting CETs.

CETs and clean energy products are key drivers for the low-carbon transition, hence assessing the ability of countries to generate competitive capabilities in the production and export of low-carbon energy technologies is also of great importance – this is the key rationale behind the other supporting indicator (*CET export vs GDP*). It should be cautioned that data on "CET Exports" also include the value of intermediate products imported from other countries, such as for example when PV cells are imported and assembled into exported PV module, hence it is important to assess this metric in combination with the other two indicators.

The supporting indicators provide an overall assessment of the relative importance of high-tech and CET product exports of a country, relative to trade volumes and economic activity (total exports and GDP), thereby also reflecting technological competitiveness of a given country in these fields. It is important to highlight that while the group of high-tech products and the CET products do have overlaps in terms of products (around one-fifth of the set of 6-digit HS codes classified as CET are also present in the high-tech definition), they are not subsets of each other, nor are they disjoint sets. In this regard, the *High-tech export vs. total export* indicator, and the *CET export vs GDP* indicator both capture relevant, yet different angles of the relative export competitiveness of a country's innovative industries. It is important to note, however, that these indicators (the *High-tech export vs total export* indicator and the *CET export vs GDP* indicator) cannot account for the location of the R&D activity performed, as the export component also captures the export of manufactured products whose R&D has been performed

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[8] OECD (2022) Glossary of statistical terms. Value added – basic prices – NACE. Available at: https://stats.oecd.org/glossary/detail.asp?ID=2842

[9] OECD (2022) Domestic value added in gross exports. Available at: https://data.oecd.org/trade/domestic-value-added-in-gross-exports.htm

[10] Our definition of 'high-technology' is in accordance with Eurostat's latest classification list for High-tech products aggregation, available here: Eurostat (2020a) Eurostat indicators on High-tech industry and Knowledge – intensive services - Annex 5: High-tech aggregation of products by SITC Rev.4. Available at: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf
The classification includes technical products the manufacturing of which involved a high intensity of R&D.

elsewhere than the specific country. These indicators build upon existing approaches developed for the European Innovation Scoreboard[11] and the Innovation Output Indicator[12].

The tables (2-1 to 2-3) below provide summaries of the core indicator to be used for the construction of the trade dimension of the CEII and of the two supporting indicators.

Table 2-1 Core Indicator: Domestic value-added content of clean energy technology exports as a share of GDP.

Aspect	Description
Indicator	Domestic value-added content of energy technology-related product exports as a share of GDP
Numerator	Value of domestic value added embedded in CET products exports, in USD and current prices, reflecting value added content of exports of CET products.
Denominator	GDP, purchase power parity (PPP)
Description	The indicator measures the domestic contribution to traded CET products, measured against the value of the country's total productive capacities available (the output of which is GDP).
Rationale / relevance	The indicator gives a proxy of current embeddedness in global value chains of CETs. It also reflects the domestic value-added content of CET exports, and provides insight regarding a country's actual ability for local production and related to that, the future deployment of CETs. This indicator can provide an insight into the potential for future domestic industry development.
Comparability	The indicator allows for comparison across the selected countries (EU-27 member states and countries with Mission Innovation membership).
Data availability	CET exports: UN Comtrade database. Domestic value added content of exports: OECD Trade in Value Added (TiVA) database. GDP: World Bank. Coverage: for all requested countries, for all requested years, exports at HS 6-digit level. OECD Trade in Value Added (TiVA) database is available up to 2018, therefore, 2018 data is used to calculate the domestic value added content of exports in year 2019.
Assessment	A key advantage of the data is that it does not include re-exports by design and shows to what extent actual innovative domestic value added is created in exports.

[11] European Commission (2019) European Innovation Scorecard – Main report. Available at: https://ec.europa.eu/docsroom/documents/38781

[12] Vertesy, D (2017) The Innovation Output Indicator 2017. Methodology Report, EUR 28876 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-76474-5, doi:10.2760/971852, JRC108942. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC108942/jrc108942_ioi_2017_report_final.pdf

Table 2-2 Supporting indicator 1: High-tech exports as a share of total product exports

Aspect	Description
Indicator	Exports of high-technology product exports as a share of total product exports
Numerator	Value of high-technology products export, in USD and current prices; specifically, value of exports of the HS 6-digit product codes classified as high-technology in Table 3-2.
Denominator	Value of total product exports, in USD and current prices
Description	The indicator can be used to measure the technological competitiveness of the observed countries, i.e. the ability to commercialise the results of research and development (R&D) and innovation in international markets. In general, this indicator could reflect a country's 'potential' with respect to advanced technologies – i.e., how well developed its high-tech trade offering is. The overall expectation is that if a country tends to perform strongly in high-tech trade, this capacity could be turned towards CET production.
Rationale / relevance	High technology products are in general characterised by high value added and high-paid employment, hence are key drivers for economic growth, productivity and welfare. In addition, trade intensity of a country in these products can be considered a proxy for the country's progress in the diffusion of pioneer technologies.
Comparability	The indicator allows for proper comparison across the selected countries (EU-27 member states and countries with Mission Innovation membership).
Data availability	UN Comtrade database. Coverage: for all requested countries, for all requested years, at HS 6-digit level.
Assessment	The indicator, in general, reflects how well developed a country's high-tech trade offering is. It can be the case, however, that a country scores high in this indicator due to its strong specialisation in a very specific set of high-tech product exports, but performs poorly in trade relevant to CET, and no robust assumption can be made with regards to turning this capacity towards clean energy production in the future. This type of bias in assessing the countries' innovation performance will have to be accounted for in designing the statistical aggregation method and the weighting of the indicator in the final CEII.

Table 2-3 Supporting indicator 2: Clean energy technology exports as a share of GDP

Aspect	Description
Indicator	Clean energy technology-related product exports as a share of GDP
Numerator	CET product exports, in USD and current prices, specifically, value of exports of the HS 6-digit product codes classified as CET in Table 3-1.
Denominator	GDP, PPP
Description	This indicator measures the export performance of a country relative to its productive capacities available (the output of which is GDP), with a special focus on CET exports (i.e., it reflects a country's ability to commercialise results of R&D and innovation in international markets).
Rationale / relevance	The key rationale behind this indicator is a view that CET exports are an indication of successful innovation performance in the sector. The indicator shows the size of the CET exports relative to the size of the country's economy; and through reflecting the relative importance of international trade (of clean energy technologies) in the economy of a country, it is also a proxy for the country's position in global clean energy value chains.
Comparability	The indicator allows for comparison across the selected countries (EU-27 member states and countries with Mission Innovation membership).
Data availability	CET exports: UN Comtrade database. GDP: World Bank. Coverage: for all requested countries, for all requested years, exports at HS 6-digit level.
Assessment	CET exports as a proportion of GDP provides an overall measure of innovation performance in CET fields.

Approach to missing data

Since data was not available for the 'Domestic value added in Clean energy technology product exports' indicator for the United Arab Emirates, this was proxied by that of a country with similar industry structure / trade characteristics (best available proxy in selected country group: Saudi Arabia).

Potential limitations of the applied methodology

While mapping the HS codes to trade in CETs - in our approach and within the framework of the current project - is the best available methodology, it is important to note that it may not be exhaustive and multiple end-products within one product category measured by an HS code give limitations to the accuracy of the mapping exercise.

3 Mapping of traded goods classifications to the SET Plan structure

A concordance framework has been developed, linking the relevant clean energy technologies (CETs) to classifications often used in assessing trade in products data (the latest Harmonised System Codes, HS classification). Our initial mapping approach was based on discussions with the DG RTD - JRC PETTEN team involved in the project, as well as on the review of some relevant preceding sources: JRC reports[13,14], a recent academic study[15] building on these reports and expanding on their mapping structures (mostly with regards to 'Wind' energy technology), relevant studies[16,17,18] commissioned by international organisations, as well as a proposed list of goods for inclusion under the Environmental Goods Agreement (EGA), developed by the World Energy Council (WEC)[19] in 2010.

Furthermore, to discuss and validate our initially developed mapping, a workshop has been organised in May 2021 with the involvement of ~10 external topical experts from various organisations (such as the International Energy Agency - IEA, the International Renewable Energy Agency – IRENA, the World Customs Organisation and the International Institute for Sustainable Development). The workshop enabled us to collect insightful feedback on the final list of codes to be included, and ultimately led to some changes in the list of codes used for the second year of indicator calculation (compared to the codes used for the first year of indicator calculation). The most important changes are the following:

- Codes related to 'Other gas turbines' (HS 2012 841181, 841182) have been excluded as there is not substantive evidence suggesting that the majority of exported products in this category are used in natural gas power plants that would crowd out coal power plants (hence leading to net carbon emission reductions).

- Codes related to 'Ethyl alcohol' (previously used to assess trade in Biofuels, HS 2012 220710, 220720) were excluded because they most likely capture exports of first-generation biofuels, hence it is a code capturing flows of 'fuels' and not technologies.

- Hydrogen (HS 2012 280410) was also excluded because available data are most likely to capture exports of 'grey hydrogen', which is produced from natural gas without CCS.

- Several codes related to 'Electrical transformers' (HS 2012 850421, 850422, or 850423) have been excluded as they were assessed likely to capture products used in the combustion of fossil-fuels or non-energy related.

- New trade codes have been included, such as those related to 'Electric accumulators' (used for Energy storage) and 'Electrical machines and apparatus'

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[13] Pasimeni, F (2017) EU energy technology trade: Import and export. EUR 28652 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-69670-1, doi:10.2760/607980, JRC107048.
[14] Fiorini, A et al (2017) Monitoring R&I in Low-Carbon Energy Technologies. Methodology for the R&I indicators in the States of the Energy Union Report – 2016 edition. EUR 28446 EN. doi: 10.2760/447418
[15] Read, E A (2019) The technology transfer reality behind Costa Rica's renewable Electricity. EKHS34 Master's Thesis, Lund University, School of Economics and Management, Sweden. Available at: http://lup.lub.lu.se/luur/download?func=downloadFile&recordOId=8993611&fileOId=8993612
[16] Wind, I (2010a) HS Codes and the Renewable Energy Sector. International Centre for Trade and Sustainable Development. Available at: https://www.files.ethz.ch/isn/111414/2010_01_hs-codes-and-the-renewable-energy-sector.pdf
[17] Wind, I (2010b) HS Codes and the Transport Sector. International Centre for Trade and Sustainable Development. Available at: https://www.files.ethz.ch/isn/139135/hs-code-study-transport.pdf
[18] Jacob, A – Møller, M K (2017), Policy landscape of trade in environmental goods and services. ARTNeT Working Paper Series No. 166, April 2017, Bangkok, ESCAP. Available at: https://www.unescap.org/sites/default/files/AWP%20No.%20166.pdf
[19] World Energy Council (2010) Proposed list of goods for inclusion under the Environmental Goods Agreement (EGA). Available at: https://www.worldenergy.org/assets/images/imported/2012/09/20100914_wec_envtl_goods_list.pdf

(used for Hydrogen technology), such as HS 2012 850750, 850780, 854330, 854370. Overall, 50 HS codes have been selected and mapped to the assessed clean energy technologies for the second year of indicator calculation.

While it should be noted that some of the sources mentioned above are not recent (e.g., the WEC report) and therefore might be considered as outdated, the changes in the technologies and related products have not been that substantial to the extent where the actual insights from of these sources cannot still be considered valid. However, it might be the case that some categories, which were not included in earlier works, are now included in our analysis, mostly as an outcome of the workshop and continued discussions with the DG RTD – JRC PETTEN team.

Where needed, harmonisation of different HS code classifications was based on the concordance tables available in Eurostat's RAMON[20] metadata.

It should also be highlighted that there is no clear one-to-one mapping between the investigated SET Plan KAs and the product-level 6-digit HS codes. Certain product categories, while being highly relevant for the assessed CETs, capture trade in products which are also relevant to other non-CET product categories. The clearest example of this appears to be in the SET Plan KA '*CCS/U*' where some of the key products identified for the concordance table are likely to capture trade in natural gas and chemical industry, too, for example. Furthermore, some of the codes (e.g., HS 2012 841861, 841950, or 850431) might apply to more than one CET. However, for the sake of consistency and additivity (for the calculation of the 'total' indicator, based on the sub-indicators per different CETs and per different SET Plan KAs), in these cases the HS codes have been exclusively allocated to one CET. This way the indicators, when aggregated up to SET Plan KA level and to 'total', show a comprehensive picture of a country's progress in CET trade and there is no risk of double-counting a specific product category under more than one CET. In these cases, i.e. where one product (as defined by a specific HS code) might have been relevant to more than one technology or SET Plan KA, the final allocation of the code was based on a) the reviewed literature sources (listed in the footnotes) and b) the observed relative importance of the HS code in question within all the HS codes associated with the specific CET (in terms of the share of export value captured by the HS code in question compared to total export value of all HS codes associated with the specific CET)[21].

The concordance between the Energy Union R&I and Competitiveness priorities, the SET Plan KAs, the selected CETs and the corresponding HS codes (to assess trade) is summarised in Table 3.1 below.

[20] Eurostat (2020b) Reference And Management Of Nomenclatures. Available at: https://ec.europa.eu/eurostat/ramon/index.cfm?TargetUrl=DSP_PUB_WELC

[21] The final judgement made based on the insights from continued discussions with DG Research and on the inputs from external experts collected at a workshop held in 2021 Spring.

Table 3-1 Concordance between topics within the Energy Union R&I and Competitiveness priorities, SET key actions and HS product codes for clean energy technologies

Energy Union R&I priority	SET Plan Key Actions	Corresponding clean energy technology	HS code (6- or 4-digit)	HS code description
Number 1 in Renewables	Performant renewables	Geothermal	840681	Steam turbines and other vapour turbines - Other turbines - Of an output exceeding 40 MW
			840682	Steam turbines and other vapour turbines - Other turbines - Of an output not exceeding 40 MW
			841869	Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15 - Other refrigerating or freezing equipment; heat pumps - Other
			841861	Refrigerators, freezers and other refrigerating or freezing equipment, electric or other; heat pumps other than air conditioning machines of heading 84.15 - Other refrigerating or freezing equipment; heat pumps - Heat pumps other than air conditioning machines of heading 84.15
			841581	Air conditioning machines, comprising a motor-driven fan and elements for changing the temperature and humidity, including those machines in which the humidity cannot be separately regulated - Other - Incorporating a refrigerating unit and a valve for reversal of the cooling/heat cycle (reversible heat pumps)
		Hydropower	841011	Hydraulic Turbines, Water Wheels, of a Power Not Exceeding 1,000kw
			841012	Hydraulic Turbines and Water Wheels, Power 1,000-10,000kw
			841013	Hydraulic Turbines, Water Wheels, of a Power Exceeding 10,000kw
			841090	Parts of Hydraulic Turbines and Water Wheels, Including Regulators
		Solar	854140	Diodes, transistors and similar semiconductor devices; photosensitive semiconductor devices, including photovoltaic cells, whether or not assembled in modules or made up into panels; light-emitting diodes; mounted piezoelectric crystals

			841919	Instantaneous or storage water heaters, non-electric (excl. instantaneous gas water heaters and boilers or water heaters for central heating)
		Wind	730820	Towers and lattice masts, of Iron or Steel
			841290	Engines; parts, for engines and motors of heading no. 8412 (reaction engines, hydraulic power engines, pneumatic power engines)
			841381	Pumps for liquids, whether or not fitted with a measuring device; other pumps
			848210	Ball bearings
			848340	Gears and gearing; (not toothed wheels, chain sprockets and other transmission elements presented separately); ball or roller screws; gear boxes and other speed changers, including torque converters
			850164	Electric generators; AC generators, (alternators), of an output exceeding 750kVA
			850231	Generating Sets, Electric, Wind-powered
			850431	Electrical transformers; n.e.c. in item no. 8504.2, having a power handling capacity not exceeding 1kVA
			851290	Electrical lighting or signalling equipment (excluding articles of heading 85.39), windscreen wipers, defrosters and demisters, of a kind used for cycles or motor vehicles - Parts
			853620	Electrical apparatus; automatic circuit breakers, for a voltage not exceeding 1000 volts
			850300	Electric motors and generators; parts suitable for use solely or principally with the machines of heading no. 8501 or 8502
Smart system – Smart EU energy system with consumers at the centre	New technologies & services for consumers	Smart meters	902810	Gas meters
			902830	Electricity meters

Efficient energy systems	New materials & technologies for buildings / Energy efficiency for industry	Insulation	680510	Abrasive powder or grain; natural or artificial, on a base of woven textile fabric only, whether or not cut to shape or sewn or otherwise made up
			680520	Abrasive powder or grain; natural or artificial, on a base of paper or paperboard only, whether or not cut to shape or sewn or otherwise made up
			680530	Abrasive powder or grain; natural or artificial, on a base of materials n.e.c. in heading no. 6805, whether or not cut to shape or sewn or otherwise made up
			680610	Slag wool, rock wool and similar mineral wools (incl. Intermixtures thereof), in bulk, sheets or rolls
			680690	Other: Articles of Heat-insulating, Sound-insulating Mineral Materials
			700800	Multiple-walled insulating units of glass
			701939	Webs, Mattresses, Boards and Similar Nonwoven Products, of Glass Fibres
Sustainable transport	Competitive in the global battery sector (e-mobility)	Energy Storage	850650	Primary cells and primary batteries - Lithium
			850710	Electric accumulators, including separators therefor, whether or not rectangular (including square) - Lead-acid Accumulators, of a Kind Used for Starting Piston Engines
			850720	Electric accumulators, including separators therefor, whether or not rectangular (including square) - Other lead-acid accumulators
			850730	Electric accumulators, including separators therefor, whether or not rectangular (including square) - Nickel-cadmium
			850740	Electric accumulators, including separators therefor, whether or not rectangular (including square) - Nickel-iron
			850750	Electric accumulators, including separators therefor, whether or not rectangular (including square) - Nickel-metal hydride
			850780	Electric accumulators, including separators therefor, whether or not

				rectangular (including square) - Other accumulators
	Renewable fuels	Fuel cells	850680	Cells and batteries; primary, (other than manganese dioxide, mercuric oxide, silver oxide, lithium or air-zinc)
			850162	Electric motors and generators (excluding generating sets) of an output exceeding 75 kVA but not exceeding 375 kVA
		Hydrogen technology	854330	Electrical machines and apparatus, having individual functions, not specified or included elsewhere - Machines and apparatus for electroplating, electrolysis or electrophoresis
			854370	Electrical machines and apparatus, having individual functions, not specified or included elsewhere - Other machines and apparatus
Carbon capture, utilisation and storage (CCUS)	CCS/U	Carbon capture, utilisation and storage (CCUS)	841480	Air or other gas compressors CCS
			841490	Parts of air or other gas compressors
			731100	Containers for compressed or liquefied gas, of iron or steel
			761300	Aluminium; containers for compressed or liquefied gas
Nuclear safety	Nuclear safety	Nuclear energy	840110	Nuclear reactors
			840120	Machinery and apparatus; for isotopic separation, and parts thereof
			840140	Nuclear reactors; parts thereof

Source: Mapping of technologies and HS product codes based on Pasimeni, F (2017), Fiorini (2017), Read, E A (2019) and the World Energy Council (2010), external expert inputs collected at a workshop held in Spring 2021. Mapping of R&I priorities adapted from the JRC's "Monitoring R&I in low-carbon energy technologies," 2017, allocation was applied to the extent made possible by the structure and granularity of publicly available data on product-level trade.

Classification of high-tech industries

Our definition of high-tech industries is based on that applied in Eurostat's "high-tech statistics"[22]. In the statistical methodology developed by Eurostat there are two main approaches used to identify technology-intensity: the sectoral approach and the product approach. The sectoral approach builds on an aggregation of the manufacturing industries according to their technological intensity (R&D expenditure divided by value added). In this approach, manufacturing activities are grouped using the Statistical Classification of Economic Activities in the European Community (NACE Rev.2) at the 2- or 3-digit level to:

- 'High-technology' (e.g., Manufacture of basic pharmaceutical products and pharmaceutical preparations),
- 'Medium high-technology' (e.g., Manufacture of electrical equipment),
- 'Medium low-technology' (e.g., Manufacture of rubber and plastic products) and
- 'Low-technology' (e.g., Manufacture of beverages)[23].

In the product approach, product groups are classified as high-technology products depending on their R&D intensity (R&D expenditure divided by total sales) and are aggregated on the basis of the Standard International Trade Classification (SITC).

According to the metadata source of Eurostat referred to above, the sectoral approach is generally used for the construction of all indicators except data on high-tech trade and patents. As industrial sectors that are characterised by a limited number of high-technology products may also produce a range of low-technology products, the product approach is more capable of capturing trends in high-tech trade, as it is built up from a more granular level of observations and reflects the presence of technological advancements in trade metrics better than the aggregated sector-level data.

In accordance with Eurostat's latest classification list for High-tech products aggregation[24], high-technology trade is defined as exports and imports of a subset of products defined according to the Standard International Trade Classification (SITC – Rev. 4). The classification, presented in Table 3-2 below contains technical products the manufacturing of which involved a high intensity of R&D.

Table 3-2 High-tech aggregation of products by SITC Rev.4

Group	Code	Title[25]
Aerospace	(714-714.89-714.99)+	Lead-acid Accumulators, of a Kind Used for Starting Piston Engines
	792.1+	Helicopters
	792.2+792.3+792.4+	Aeroplanes and other aircraft, mechanically-

[22] Eurostat (2020a) Eurostat indicators on High-tech industry and Knowledge – intensive services - Annex 5: High-tech aggregation of products by SITC Rev.4. https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf
[23] Eurostat (2020c) Glossary:High-tech. Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech
[24] Eurostat (2020a) Eurostat indicators on High-tech industry and Knowledge – intensive services - Annex 5: High-tech aggregation of products by SITC Rev.4. Available at: https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf
[25] In some cases, the titles have been shortened. For full description see: United Nations (2020) Classifications on Economic Statistics. Available at: http://unstats.un.org/unsd/cr/registry

		propelled (other than helicopters)
	792.5+	Spacecraft (including satellites) and spacecraft launch vehicles
	792.91+	Propellers and rotors and parts thereof
	792.93+	Undercarriages and parts thereof
	874.11	Direction finding compasses; other navigational instruments and appliances
Computers, office machines	751.94+	Multifunction office machines, capable of connecting to a computer or a network
	751.95+	Other office machines, capable of connecting to computer or a network
	752+	Computers
	759.97	Parts and accessories of group 752
Electronics, telecommunications	763.31+	Sound recording or reproducing apparatus operated by coins, bank cards, etc
	763.8+	Video apparatus
	(764-764.93-764.99)+	Telecommunications equipment, excluding 764.93 and 764.99
	772.2+	Printed circuits
	772.61+	Electrical boards and consoles < 1000V
	773.18+	Optical fibre cables
	776.25+	Microwave tubes
	776.27+	Other valves and tubes
	776.3+	Semiconductor devices
	776.4+	Electronic integrated circuits
	776.8+	Piezoelectric crystals
	898.44+	Optical media
	898.46	Semiconductor media
Pharmacy	541.3+	Antibiotics
	541.5+	Hormones and their derivatives
	541.6+	Glycosides, glands, antisera, vaccines
	542.1+	Medicaments containing antibiotics or derivatives thereof
	542.2	Medicaments containing hormones or other products of subgroup 541.5
Scientific	774+	Electrodiagnostic apparatus for medicine or

instruments		surgery and radiological apparatus
	871+	Optical instruments and apparatus
	872.11+	Dental drill engines
	(874-874.11-874.2)+	Measuring instruments and apparatus, excluding 874.11, 874.2
	881.11+	Photographic cameras
	881.21+	Cinematographic cameras
	884.11+	Contact lenses
	884.19+	Optical fibres other than those of heading 773.1
	(899.6-899.65-899.69)	Orthopaedic appliances, excluding 899.65, 899.69
Electrical machinery	778.6-778.61-778.66- 778.69)+	Electrical capacitors, fixed, variable or adjustable, excluding 778.61, 778.66, 778.69
	778.7+	Electrical machines, having individual functions
	778.84	Electric sound or visual signalling apparatus
Chemistry	522.22+	Selenium, tellurium, phosphorus, arsenic and boron
	522.23+	Silicon
	522.29+	Calcium, strontium and barium
	522.69+	Other inorganic bases
	525+	Radioactive materials
	531+	Synthetic organic colouring matter and colour lakes
	574.33+	Polyethylene terephthalate
	591	Insecticides, disinfectants
Non-electrical machinery	714.89+	Other gas turbines
	714.99+	Part of gas turbines
	718.7+	Nuclear reactors and parts thereof, fuel elements, etc
	728.47+	Machinery and apparatus for isotopic separation
	731.1+	Machine-tools working by laser or other light or photon beam, etc
	731.31+	Horizontal lathes, numerically controlled
	731.35+	Other lathes, numerically controlled
	731.42+	Other drilling machines, numerically controlled

	731.44+	Other boring-milling machines, numerically controlled
	731.51+	Milling machines, knee-type, numerically controlled
	731.53+	Other milling machines, numerically controlled
	731.61+	Flat-surface grinding machines, numerically controlled
	731.63+	Other grinding machines, numerically controlled
	731.65+	Sharpening machines, numerically controlled
	733.12+	Bending, folding, straightening or flattening machines, numerically controlled
	733.14+	Shearing machines, numerically controlled
	733.16+	Punching machines, numerically controlled
	735.9+	Parts and accessories of 731 and 733
	737.33+	Machines and apparatus for resistance welding of metal, fully or partly automatic
	737.35	Machines and apparatus for arc welding of metal, fully or partly automatic
Armament	891	Arms and ammunition

Source: Eurostat (2020a)[26]

Concordance between traded goods categories (by HS codes) and SITC Rev.4 classification

As high-technology trade is defined as exports and imports of products according to the Standard International Trade Classification (SITC – Rev. 4), while the initial dataset on international trade (UN Comtrade data) sorts traded goods data according to Harmonised System Codes (HS classification), it is necessary to map the above SITC commodities to HS codes to the relevant industries. The relevant correspondence table for this conversion can be found on the Eurostat RAMON[27]. Traded goods data for the more recent years is provided in the HS 2017 classification version, while earlier years are reported in HS 2012 classification, thus in order to have a single set of HS codes to use for the analysis, everything has been mapped to HS 2017 classification.

[26] Eurostat (2020a) Eurostat indicators on High-tech industry and Knowledge – intensive services - Annex 5: High-tech aggregation of products by SITC Rev.4. https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf

[27] Eurostat (2020b) RAMON – Reference and Management of Nomenclatures. Available at: https://ec.europa.eu/eurostat/ramon/relations/index.cfm?TargetUrl=LST_REL&StrLanguageCode=EN&IntCurrentPage=1

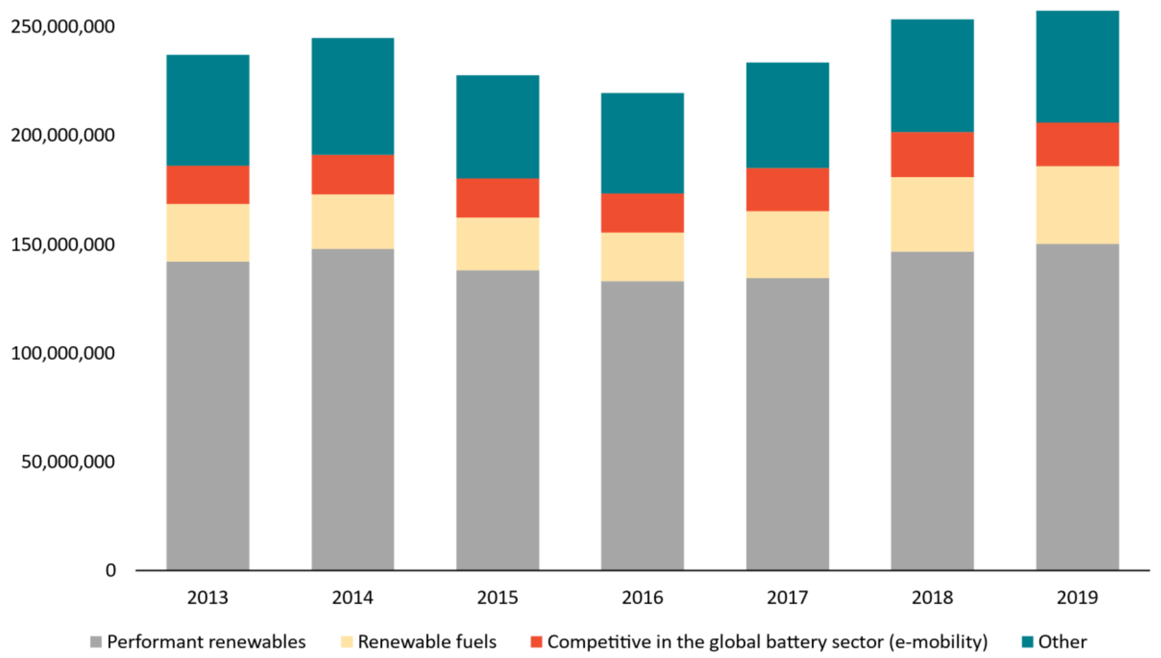
4 Clean energy innovation performance through the lens of trade indicators

This chapter provides a high-level analysis of the main developments regarding export of clean energy technologies (CETs). First, the main developments in overall CET exports are presented across the SET Plan Key Actions. Second, the developments in the domestic value added content of CET export are assessed in more detail. Third, trends of the EU-27 and its member countries are discussed. Finally, performance of the investigated countries (and groups of countries such as the EU) for all SET Plan KAs is assessed for the core and the two support indicators, with a focus on exploring trends in specialisation per country.

4.1 Main developments of CET exports by SET Plan Key Action

Export volumes of CET products of in-scope countries have slightly increased between 2013 and 2019, the total CET export volume changed from 237 B USD in 2013 to 257 B USD in 2019, with a CAGR (compound average growth rate) of 1.2%. Figure 4-1 presents total export volumes across SET Plan KA categories (the main three categories and a residual one, 'other'). The top five largest CET product exporters, in volume terms and as of 2019 were (larger to smaller): China, Germany, US, Japan and Italy. Based on 2019 data, out of all in-scope countries, MI-23 (as a group of member countries) accounts for as much as 87% of total CET exports.

Figure 4-1 Clean energy technology export volumes across the SET Plan Key Actions, in-scope countries total (1000 USD)

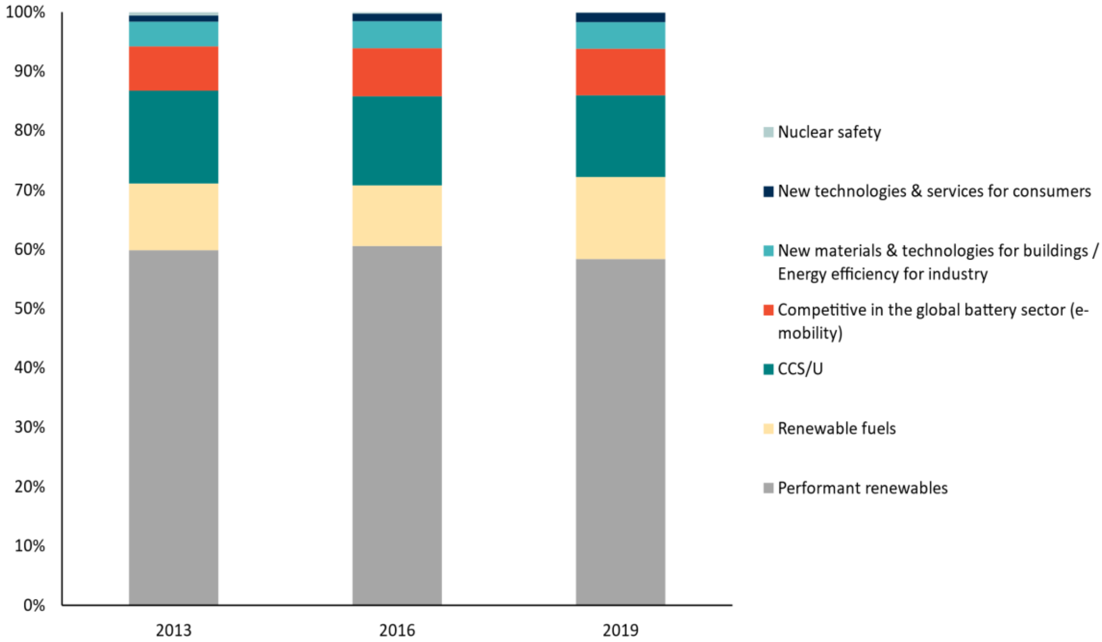


Data Source: United Nations (2021)[28]

Figure 4-2 presents the distribution of CET product exports across the SET Plan KAs for which relevant product codes were attributed to CETs. The chart illustrates the relative sectoral importance of CET products exported by in-scope countries (EU member states [EU-27] and non-EU Mission Innovation member countries [MI-23] aggregated).

[28] United Nations (2021) UN Comtrade Database. Available at: https://comtrade.un.org/

Figure 4-2 Clean energy technology product exports by SET Plan Key Actions (% of total)

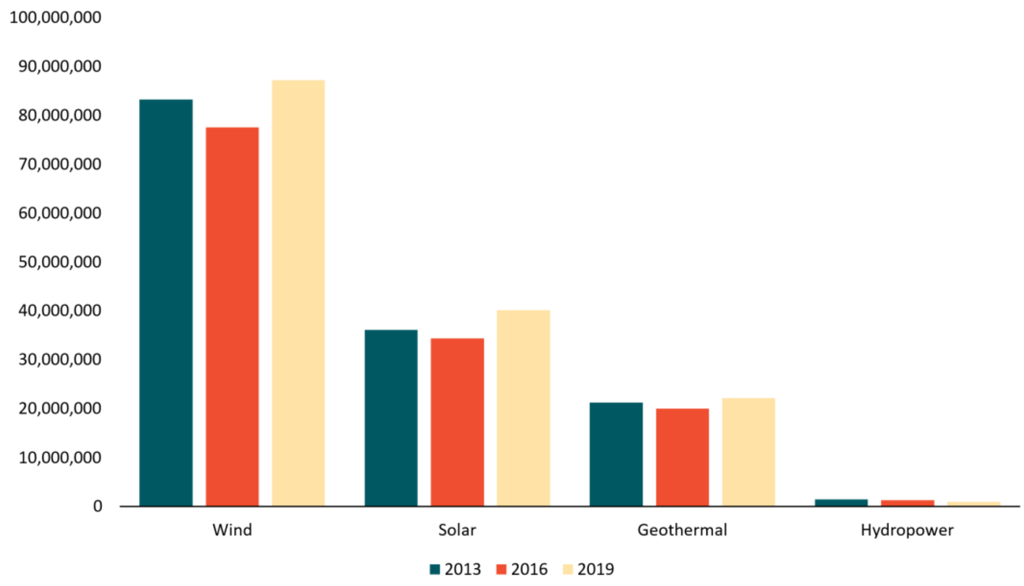


Data Source: United Nations (2021)

A key insight from Figure 4.2 is that products under SET Plan KA '*Performant renewables*' (including Solar, Wind, Hydro and Geothermal) account for close to 60 percent of exported CET-related products in all SET Plan KA categories in total, across all the years investigated. The second most export-intensive category in 2019 is made of products related to the SET Plan KA 'Renewable fuels', followed by product exports related to '*CCS/U'*. Exports of renewable energy technology products (SET Plan KA Performant Renewables) have largely stagnated across the whole time period covered in the first and the second year of indicator calculation: from 141 B USD in 2013 to 150 B USD in 2019.

Figure 4-3 shows export volumes of four identified renewable technologies within SET Plan KA 'Performant renewables', outlining the overall development and size of the market (in monetary terms). Wind-related exports are the largest in volume terms during the whole assessed period. While the export volumes for renewable energy technologies observed a decrease between 2013-16, the later years (2017-2019) demonstrate considerable growth for all the four renewable energy categories. The main countries driving this growth have been the Netherlands, the United Arab Emirates, Denmark and Czechia.

Figure 4-3 Clean energy technology export volumes across various renewables-related categories, in-scope countries total (1000 USD)



Data Source: United Nations (2021)

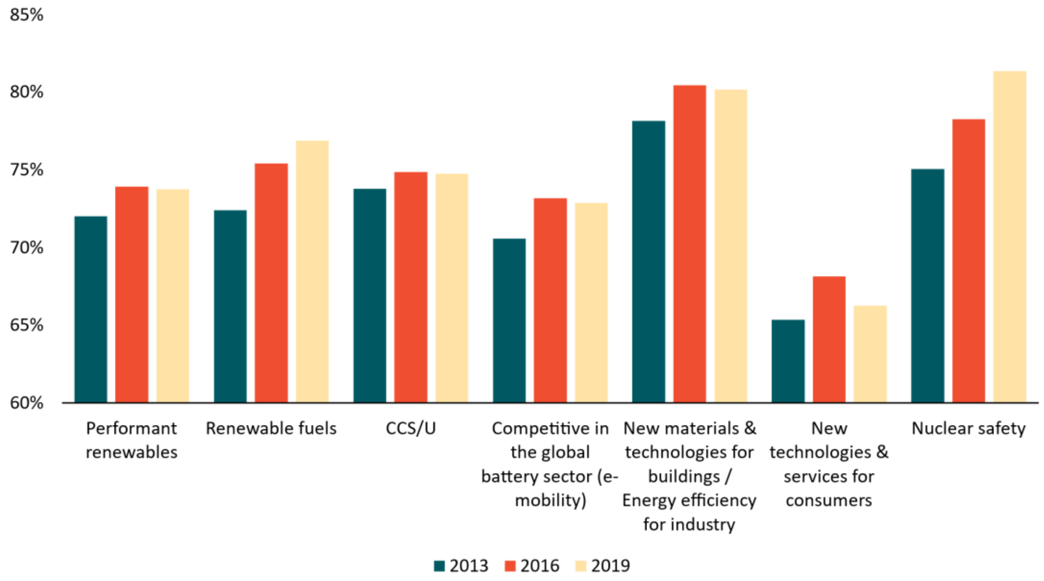
4.2 Main developments and trend in the domestic value added content of exports

The domestic value added content of CET exports is the key metric underlying the export indicator (CET export value added vs GDP) used in the 'Clean Energy Innovation Index'. This metric may capture, amongst other factors leading to an increase in value added (and after normalisation with GDP), advancements in CET innovation leading to products competitive in global markets

Figure 4.4 gives an overview of the average shares of value added on exports across all in-scope countries, across the SET Plan KAs assessed. Similarly, Figure 4-5 illustrates the percentage values of domestic value added on exports across four Renewable Energy Source (RES) categories. The distribution of domestic value added (as a share of exports) across the SET Plan KAs is very similar to that of export volumes (Figure 4-2).

Figure 4-4 and F-5 show that the domestic value added content of exports (in percentage terms) has been increasing for both the largest SET Plan KA categories and for the most important RES export product categories between 2013 and 2019. The increase is the steepest for products related to 'Renewable fuels' and products related to 'Nuclear safety' (however, while in case of 'Renewable fuels' this increase took place in a substantially growing export market, in case of 'Nuclear safety'-related products the overall export volume has been significantly shrinking).

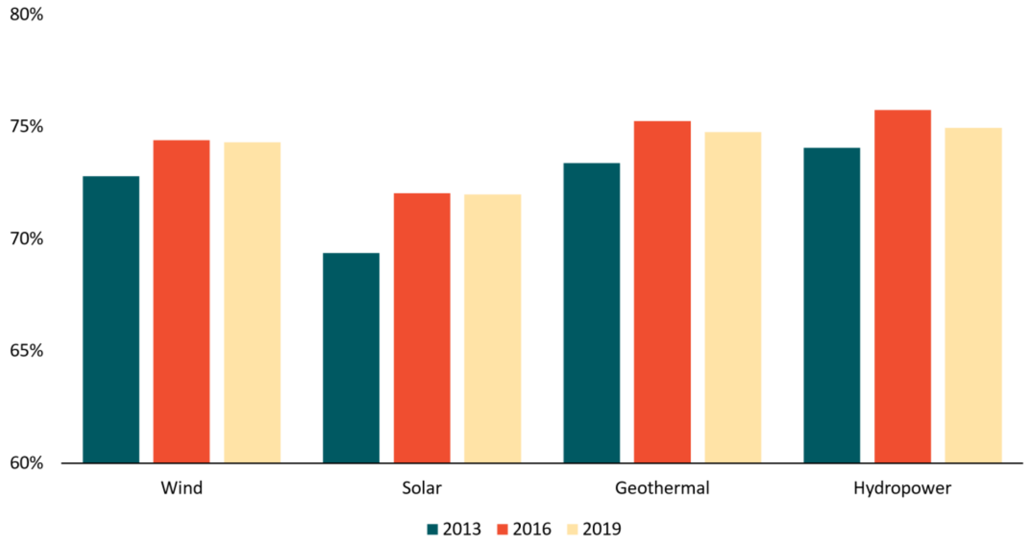
Figure 4-4 Domestic value added percentage of clean energy technology exports across the SET Plan Key Actions, for in-scope countries in total (%)



Data Source: United Nations (2021); OECD (2021)[29]

Within the SET Plan KA 'Performant renewables', the domestic value added content of exports (in percentage terms) has clearly increased the most for products related to solar technologies between 2013 and 2019. While total export volumes are rather small for geothermal and especially, for hydro power-related exports, in the case of solar and wind technologies the domestic value added content of exports is increasing in a growing market for in-scope countries.

Figure 4-5 Domestic value added percentage of renewables-related exports (%)



Data Source: United Nations (2021); OECD (2021)

[29] OECD (2021) Trade in Value Added. Available at: https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm

4.3 Analysis of trends for the European Union (EU-27)

A few important insights can be made with regards to the average performance of EU-27 countries over the period 2013-2019 in the three indicators assessed.

First, changes in the distribution of CET export volumes across SET Plan KAs in EU-27 countries suggest that there is a tendency for some of the categories to gain relative importance vis-á-vis other categories (e.g. exported products belonging to 'Performant renewables' vs those belonging to 'Nuclear safety'). However, it also needs to be stressed that the methodology applied (i.e., assessing CET trade based on product-level export data) implies that some of the product categories, while being highly relevant to CETs, may capture trade in products which are also relevant to energy technologies related to fossil fuel combustion. The clearest example of this appears to be in 'CCS/U' where the relatively high performance of EU-27 countries is also likely to relate to exports of products used by the natural gas and chemical industry. On the other hand, such exports may suggest that there is a "technological capacity" in place to take advantage of any future growth in 'CCS/U'.

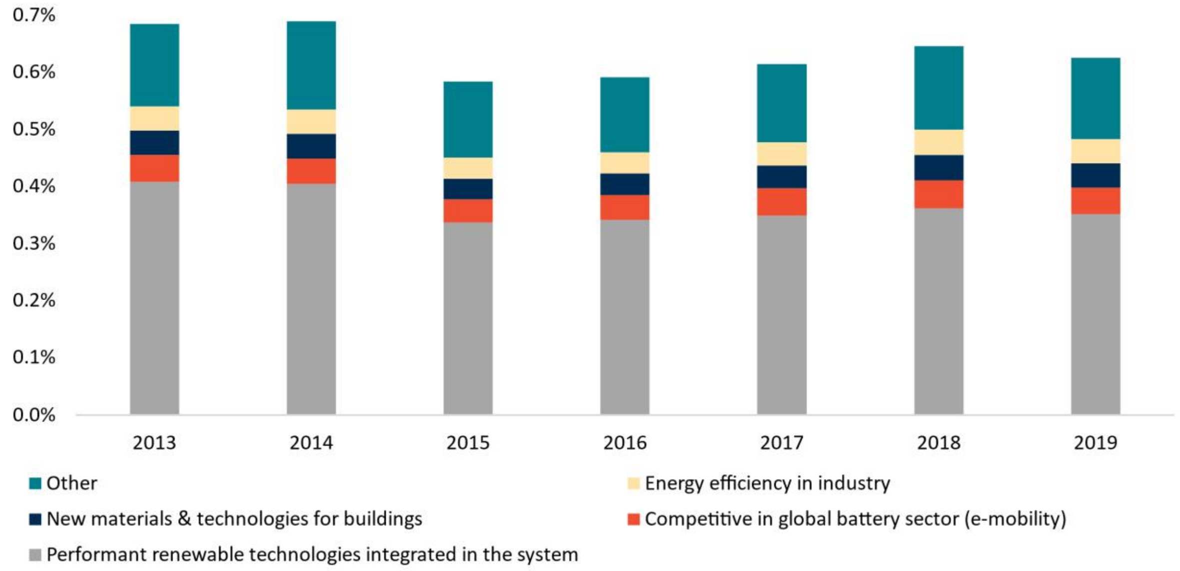
EU-27 countries, on average, have increased their High-tech exports / Total exports (%) ratio substantially over the period covered: from an average of 9.7% in 2013 to 11.4% in 2019, with the underlying high-tech export volume increasing by ~20% over the same period. The countries with the largest percentage point increase in their High-tech exports / Total exports ratio are Ireland (20.3% in 2013 and 37.0% in 2019, presumably and at least partially due to the tax breaks provided to IT firms) and Belgium (7.0% in 2013 and 12.6% in 2019, mainly driven by products related to Pharmacy and Electronics and telecommunications)[30].

With regards to the ratio of CET exports to GDP, the average for EU-27 countries has slightly decreased (see Figure 4.6): from 0.64% in 2013 to 0.58% in 2019. The decline in the CET export to GDP ratio is driven by EU-27 total CET export volumes stagnating over the period 2013-2019, while the underlying GDP has increased by 14% from 2013 to 2019, hence the ratio has decreased over the same period. The EU-27 average CET export to GDP ratio has mostly stagnated for all specific SET Plan KAs as well, with minor changes over the period (e.g. a slight increase for the SET Plan KA 'Renewable fuels').

A slight increase in the CET exports to GDP ratios was observed for countries that had a relatively lower base, such as the United Arab Emirates (from 0.02% to 0.12% between 2013 and 2019) or Latvia (0.12% in 2013 and 0.2% in 2019) while in other countries the same has been stagnating. For example, in Denmark the ratio has been relatively stable around 2% between the period 2013 to 2019, with the underlying volumes primarily driven by wind power-related exports.

[30] See e.g.: Keane, J (2020) Ireland stands by its iconic 12.5% tax rate as OECD races for reforms. CNBC online. Available at: https://www.cnbc.com/2020/11/03/ireland-stands-by-its-corporate-tax-rate-as-oecd-races-for-reforms-.html

Figure 4-6 Clean energy technology exports / GDP ratio, SET Plan Key Actions total and per SET Plan Key Action, EU-27 average



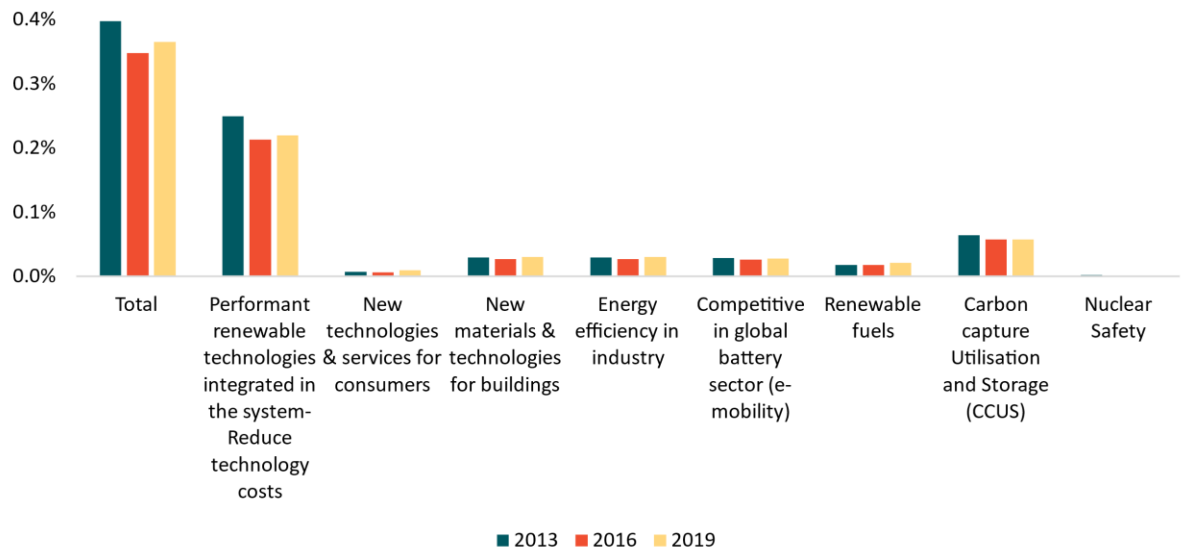
Data Source: United Nations (2021); World Bank (2021)[31]

Similarly, the domestic value added percentage of CET exports as a share of country GDP has on average decreased for the EU-27 countries (see Figure 4-7): from ~0.39% to ~0.36% between 2013 and 2019. The negative trend in this indicator is largely driven by a few leading, large exporter EU-27 countries, e.g. France, Germany and Italy. These countries featured decreasing export volumes, and therefore shrinking domestic value added volumes, which, as a share of a stagnating (in the case of Italy) or even growing country GDP (like in the case of Germany and France) resulted in lower percentage ratios.

When zooming in to specific SET Plan KAs, those in which the EU-27, on average, has seen the biggest relative drop are: 'Performant renewables' and 'CCS/U'.

[31] World Bank (2021) World Development Indicators - GDP. Available at: https://databank.worldbank.org/source/world-development-indicators

Figure 4-7 Domestic value added of clean energy technology exports vs GDP (%) for SET Plan Key Actions total and per SET Plan Action, EU-27 average



Data Source: United Nations (2021); OECD (2021)

4.4 Key developments by countries: world players and top EU-27 countries

The following sections illustrate the development of countries classified as 'world players' (China, Japan, South Korea, United States, EU-27 – with values for MI-23 also added as a term of comparison) in the three indicators of interest over the 2013-2019 time frame. For all the indicators, the performance of the 'top EU-27 players' (based on their average performance across the years) is also presented.

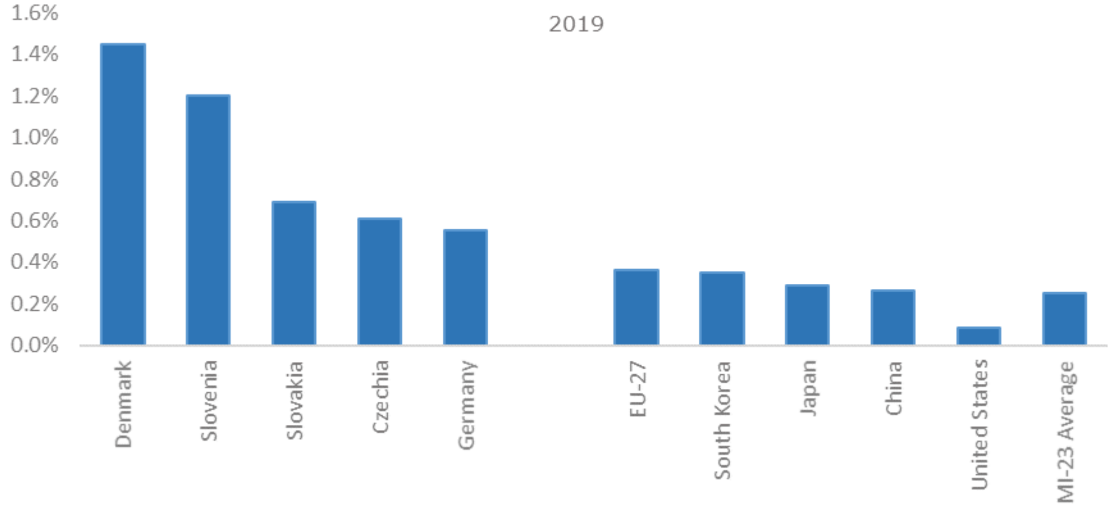
4.4.1 Core indicator: Domestic value added content of Clean energy technology exports / GDP

The domestic value added content of the exported products classified as 'CET-related' [32] as a share of GDP ranges between 0.1% and 1.4% of the GDP, and has remained relatively stable for all world-player countries across the time frame analysed. While the ratio for the top performer (Denmark) is around 1.4% in 2019, it is much smaller and 'only' around 0.4% for the EU-27 average, while the value for MI-23 average is even lower at about 0.25% (Figure 4-8). As for other global players, South Korea, China and Japan all reached around 0.25-0.35% (being largely on par with the EU-27 average), while the ratio for the US was only of around 0.1% in 2019.

For some of the key EU countries, the domestic value added share of exports, as a ratio of the country's GDP is the highest for products which primarily belong to the SET Plan KA 'Performant renewables' and within that, to 'Wind' – suggesting that leading EU countries' economies tend to focus on having higher domestic value added in these product categories.

[32] According to 2019 data, the top eight countries in terms of *CET value added in export, absolute volumes* is the same set of countries as in the case of *CET export volumes* (top countries, larger to smaller): China, Germany, US, Japan, Italy, South Korea, Mexico and France. The ranking order has essentially been unchanged between 2012-2019.

Figure 4-8 Domestic value added of clean energy technology exports vs GDP (%) across the top five EU-27 performers, the top five world players (China, Japan, South Korea, United States, EU-27 average) and the MI-23 average in 2019



Data Source: United Nations (2021); OECD (2021)

Compared to world players, there is much more variation amongst the top countries of the EU-27: Denmark, Slovenia, Slovakia, Czechia and Germany (in descending order by 2019 indicator value) score between 0.5-1.4% in 2019. Amongst EU member countries, a particular case in point is Slovenia, with a ratio of 1.2% (vs. 0.6% Germany). This high value might be explained by a set of factors, such as the country's export-oriented economic structure (relative to the EU average) with high overall export to GDP ratio, and its key exported CET products which are primarily related to the E-mobility category, with a relatively high domestic value added share. Czechia, one of the top performers on this indicator, also ranks high amongst the top countries of the EU-27 in terms of high-tech export ratio (support indicator 1), suggesting a well-developed industrial capacity in the sectors with the highest potential for innovation.

4.4.2 Support indicator 1. High-tech exports / Total exports[33]

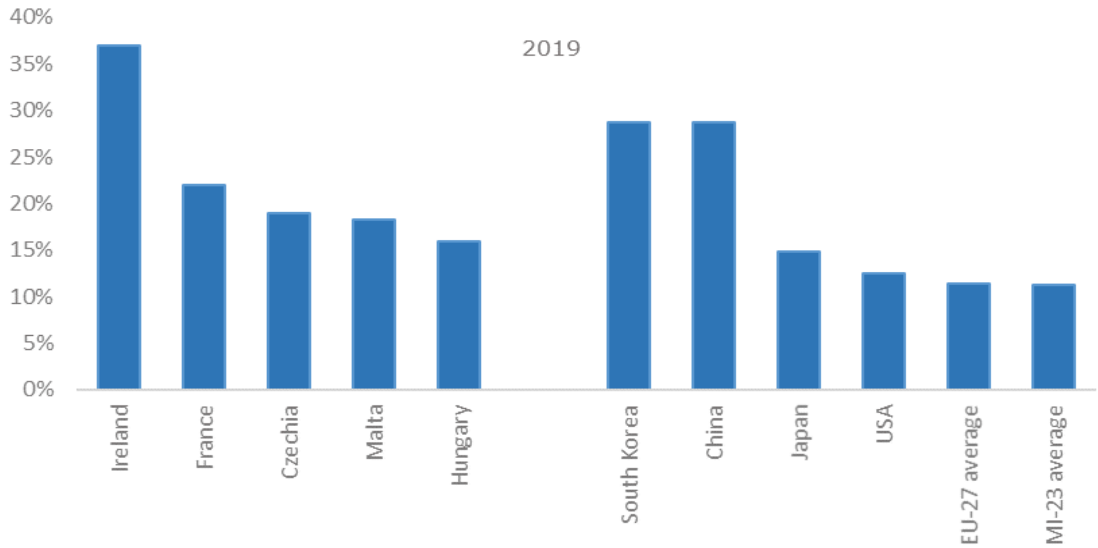
In terms of high-tech product exports[34], South Korea has gradually increased its ratio to become the top performer amongst world players in 2019 (with a share of high-tech product exports on total exports above 30%), followed by China (which had the first position in previous years), Japan, and the US (Figure 4-9). The top EU-27 country on this metric is Ireland (also above 30%), followed by France and Czechia (both scoring higher than Japan or the US amongst the world players).

While the overall high-tech export volume of Czechia is about a quarter of the size of the exports of France, its high-tech to total export ratio is very similar, largely driven by a high share of products related to 'Electronics' and 'Telecommunication' within total exports. Central- and Eastern European countries' economies can be seen as becoming more and more export-oriented across the years, with increasing export volumes in both

[33] It is to be noted that both high-tech exports and total exports cover total world exports, that is, intra- and extra-EU trade are also accounted for in the calculation of the indicator - to be considered when assessing the performance of countries.
[34] According to 2019 data, the top eight countries in terms of *High-tech export absolute volumes* are (larger to smaller): China, Germany, US, South Korea, France, Japan, the Netherlands and the UK. Countries with the lowest absolute volumes are (smaller to larger): Cyprus, Saudi Arabia, Chile, Malta, Luxembourg, Croatia, Latvia and Estonia. The ranking order has essentially been unchanged between 2012-2019, but the growth rates are substantial with 20% total export volume growth from 2012 to 2019 (in-scope countries total), and certain countries growing even more (e.g. the UAE 2019 export volume is considerably higher than its 2012 export volume; also Latvia, Poland, Ireland and South Korea all exhibit strong volume growth over the period).

high-technology products and CET exports. The performance of Czechia in this indicator provides a good example of such a trend. Overall, EU member countries, on average, have lower high-tech export ratios relative to top world players, with the average being of 11.4% of total exports as of 2019, while top world player score much higher in the same year: China and South Korea were at 29%, and the US ratio is also higher at 12.6%. Countries in the Rest of the World score relatively low across all years, with high-tech exports stagnating at around 4-5% of total exports. All in-scope countries, on average, score 11.1% in this indicator in the year 2019.

Figure 4-9 High-tech exports / Total exports (%) across the top five EU-27 performers, the top five world players (China, Japan, South Korea, United States, EU-27 average) and the MI-23 average



Data Source: United Nations (2021)

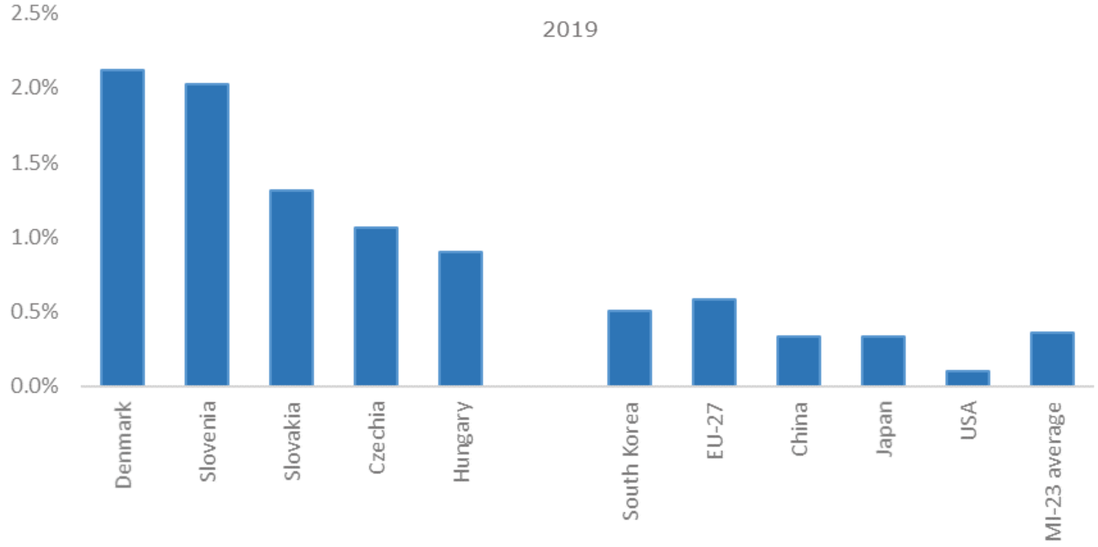
Support indicator 2. Clean energy technology exports / GDP

This indicator (ratio of CET export volumes[35] vs GDP) reflects the relative significance of CET exports in a specific country's economy, measured against its GDP (thereby reflecting the country's "economic scale", which is likely to be correlated with the RD&I "resources" (RD&I investments, research personnel, subsidies) deployed to commercialise results of R&D and innovation in international markets).

Amongst "world players", in 2019 South Korea had the highest value of CET exports to GDP ratio (0.5%), followed by the EU-27 (0.4%) and China (0.3%), Japan (0.3%) and the US (0.1%) (Figure 4-10). Most of the world players tend to show declining tendency in their CET export vs. GDP ratio across the period investigated (2013-2019), and the average performance of EU countries has also slightly decreased in this metric over the period – the trends in most of the individual countries and overall are driven by CET export volumes stagnating and GDP is growing over the same period.

[35] According to 2019 data, the top eight countries in terms of *CET export absolute volumes* are (larger to smaller): China, Germany, US, Japan, Italy, South Korea, Mexico and France. Countries with the lowest absolute volumes are (smaller to larger): Cyprus, Malta, Chile, Latvia, Saudi Arabia, Luxembourg, Estonia and Croatia. The ranking order has essentially been unchanged between 2012-2019, but total export volumes underlying it has somewhat increased (in-scope countries total).

Figure 4-10 Clean energy technology exports / GDP ratio across the top five EU-27 performers, the top five world players (China, Japan, South Korea, United States, EU-27 average) and the MI-23 average in 2019.

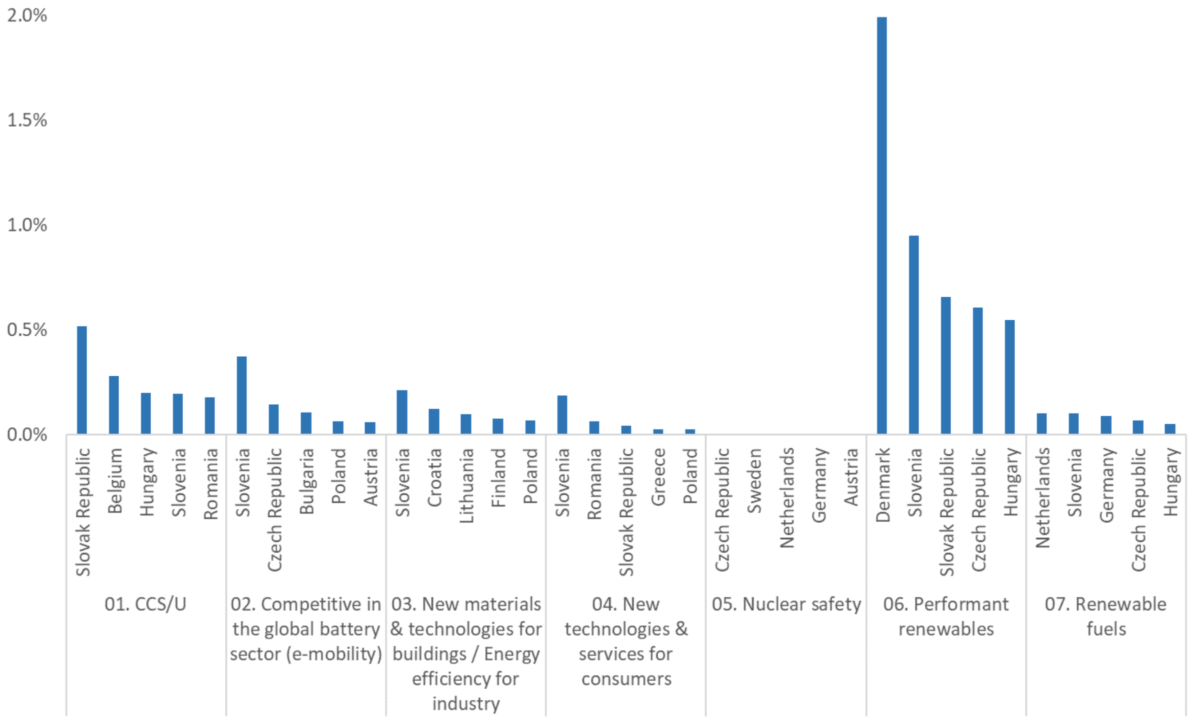


Data Source: United Nations (2021); World Bank (2021)

The top EU-27 countries that score between 1% and 2% in this indicator in 2019 are Denmark, Slovenia, Slovakia and Czechia. Exports of Denmark and Slovenia are largely driven by renewable energy products (under SET Plan KA 'Performant renewables') and particularly wind. Slovakia's CET exports are dominated by products related to wind and solar, while Hungary scores high primarily due to its exports related to wind energy. An important takeaway from the snapshot of EU countries' performance in this indicator is that Central- and Eastern European (CEE) countries (e.g. Slovakia, Hungary, Czechia, Slovenia) tend to score relatively high in this indicator, driven by their strongly export-oriented economies with high overall export to GDP ratio and their relatively strong integration in global supply chains.

Figure 4-11 presents the top five EU-27 country scores in terms of export / GDP ratio for each of the identified SET Plan KAs, based on 2019 data (SET Plan KAs displayed in alphabetic order). The chart shows that the percentages fall between 0 and 2%. With regards to specific SET Plan KAs, a few countries have very low, essentially zero percentages related to 'Nuclear Safety' product exports, while products related to 'Performant renewables' prove to be the most relevant SET Plan KA category in terms of product exports normalised by country GDP. An important insight from the chart, again, is that CEE countries (Slovakia, Hungary, Czechia, Slovenia) perform relatively well in relation to almost all SET Plan KAs: the contribution of export to GDP is substantial in these countries, and they also tend to have relatively high scores in in the High-tech export to Total export ratio (7-19%). Overall, larger countries (e.g. France, Germany, Italy and Spain) do not necessarily have high scores in these rankings per SET Plan KA.

Figure 4-11 Clean energy technology exports / GDP ratio per SET Plan Key Actions, top five EU-27 countries, 2019



Data Source: United Nations (2021); World Bank (2021)

5 Conclusions

A few data changes have been implemented in the second year of the indicators' construction and analysis (compared to the first year) that have brought both improvements (e.g. more robust coverage of clean energy technology-relevant products) and trade-offs (i.e. the scope has slightly decreased with one of the KAs being left out of the analysis, 'namely Resilience & security of the energy system' for which no product-level trade codes have been attributed in the new dataset).

The assessment of the three indicators revealed that individual EU countries (e.g. Nordic and CEE countries such as Denmark, Slovenia, Slovakia and Czechia) outperform most of non-EU world players in the three indicators assessed. However, the EU-27 average values for the same indicators are stagnating or are even decreasing over the reference period. This may suggest that the competitiveness of the EU as a whole has not improved, vis-á-vis global key players during the observed period: while CET export volumes have been stagnating for EU-27 countries, they have been increasing for other world players (e.g., China). On the other hand, if CET exports are normalised by GDP, EU-27 countries, on average, outperform most of other key world players with the exception of South Korea. Performant Renewables, CCS/U and E-Mobility account for the majority (~85%) of CET export volumes for all in-scope countries.

It should be stressed that the methodology applied (i.e., assessing CET exports based on product-level data) implies that some of the product categories, while being highly relevant to CETs, capture trade in products which are also relevant to other energy technologies (such as CCS/U) – yet it is considered that the existence of exports in this sector suggests there might be industrial and innovation capacity in place to take advantage of any future growth in CCS/U trade.

The *CET export value added vs GDP* indicator provides the most insights on CET country specialisation, due to the fact that figures on the value added component of exports are normalised by the scale of economic activity. In 2019, Denmark has the highest domestic value added of CET exports, as a share of its GDP (1.2%), closely followed by Slovenia and Slovakia. The performance of these countries are driven by exports related to SET Plan Key Action 'Performant renewable technologies', and specifically to wind and solar energy technologies. This performance can be explained by several factors, e.g. the domestic labour market (including the enabling environment made by market regulatory frameworks), as well as the significant amount of early-stage public support into wind energy development which presumably provided Denmark with a competitive advantage compared to neighbouring EU countries. Other countries might have an effective industrial strategy allowing them to maximise the local content of exported products, while also scoring it high compared to its GDP level (such as some CEE countries with export-focused economies). For EU countries on average, the same ratio is about 0.4%, which is slightly above than all other world players. This might suggest that CET manufacturers within EU-27 have a higher intensity of domestic value-added embedded in their exports, relative to manufacturing industries in other leading economies.

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Annex – Data on the main indicators

Tables A-1 to A-4 present the performance of in-scope countries in various relevant metrics (CET export volume, Domestic value added content in CET export volume, and both of these as a share of country GDP) across the years 2013, 2016 and 2019.

Table A-1 Clean energy technology exports (1000 USD) in in-scope countries, EU-27 average and MI countries average, in 2013, 2016 and 2019

Country	2013	2016	2019
Australia	611,868	443,767	453,533
Austria	3,252,375	3,297,467	3,126,980
Belgium	4,350,027	3,423,646	3,947,407
Brazil	1,548,987	1,259,640	1,412,185
Bulgaria	658,126	512,377	638,083
Canada	3,161,645	2,538,912	2,889,097
Chile	84,329	68,434	52,947
China	49,109,519	52,526,082	74,482,943
Croatia	396,407	310,563	363,319
Cyprus	1,340	2,658	766
Czechia	4,188,930	3,920,757	4,631,562
Denmark	6,194,620	6,506,655	7,034,129
Estonia	294,176	222,276	258,182
Finland	1,575,685	1,293,003	1,352,037
France	9,719,313	7,701,825	8,895,912
Germany	33,903,531	29,956,449	32,117,050
Greece	294,850	354,542	428,144
Hungary	2,558,895	2,558,620	2,868,863
India	2,642,224	2,563,287	4,177,887
Indonesia	1,315,766	1,114,757	1,442,542
Ireland	719,277	852,820	801,715
Italy	13,204,220	11,781,634	12,331,935
Japan	19,756,044	17,574,159	17,445,138
South Korea	13,937,593	11,854,078	11,141,524
Latvia	62,018	77,954	111,102
Lithuania	315,653	301,017	431,285
Luxembourg	107,103	119,963	135,737
Malta	26,844	18,518	17,166
Mexico	7,920,186	8,929,121	9,912,684
Netherlands	6,486,142	5,467,714	7,171,787
Norway	567,088	387,434	426,494
Poland	3,823,361	3,832,520	5,243,032
Portugal	1,175,395	1,229,269	1,221,451
Romania	1,821,310	1,907,637	2,618,621
Saudi Arabia	174,800	141,110	126,128
Slovakia	1,855,324	1,916,205	2,282,665
Slovenia	1,367,895	1,285,849	1,647,518
Spain	6,212,287	4,932,350	4,796,335
Sweden	2,531,353	1,923,516	2,217,510
United Arab Emirates	122,265	425,334	783,797
United Kingdom	5,931,548	4,831,410	5,880,883
United States	23,136,769	19,305,211	20,075,701
EU27 (average)	3,966,535	3,544,734	3,951,492
MI (average)	8,995,125	8,343,087	9,780,471

Table A-2 Clean energy technology exports / GDP ratio (%) in in-scope countries, EU-27 average and MI countries average, in 2013, 2016 and 2019

Country	2013	2016	2019
Australia	0.1%	0.0%	0.0%
Austria	0.7%	0.7%	0.6%
Belgium	0.8%	0.6%	0.7%
Brazil	0.0%	0.0%	0.0%
Bulgaria	0.5%	0.4%	0.4%
Canada	0.2%	0.1%	0.2%
Chile	0.0%	0.0%	0.0%
China	0.3%	0.3%	0.3%
Croatia	0.4%	0.3%	0.3%
Cyprus	0.0%	0.0%	0.0%
Czechia	1.2%	1.0%	1.1%
Denmark	2.1%	2.1%	2.1%
Estonia	0.8%	0.5%	0.5%
Finland	0.6%	0.5%	0.5%
France	0.3%	0.3%	0.3%
Germany	0.8%	0.7%	0.7%
Greece	0.1%	0.1%	0.1%
Hungary	1.0%	0.9%	0.9%
India	0.0%	0.0%	0.0%
Indonesia	0.1%	0.0%	0.0%
Ireland	0.3%	0.2%	0.2%
Italy	0.5%	0.5%	0.5%
Japan	0.4%	0.3%	0.3%
South Korea	0.7%	0.6%	0.5%
Latvia	0.1%	0.1%	0.2%
Lithuania	0.4%	0.3%	0.4%
Luxembourg	0.2%	0.2%	0.2%
Malta	0.2%	0.1%	0.1%
Mexico	0.4%	0.4%	0.4%
Netherlands	0.7%	0.6%	0.7%
Norway	0.2%	0.1%	0.1%
Poland	0.4%	0.4%	0.4%
Portugal	0.4%	0.4%	0.3%
Romania	0.4%	0.4%	0.5%
Saudi Arabia	0.0%	0.0%	0.0%
Slovakia	1.3%	1.2%	1.3%
Slovenia	2.1%	1.8%	2.0%
Spain	0.4%	0.3%	0.2%
Sweden	0.5%	0.4%	0.4%
United Arab Emirates	0.0%	0.1%	0.1%
United Kingdom	0.2%	0.2%	0.2%
United States	0.1%	0.1%	0.1%
EU27 (average)	0.6%	0.6%	0.6%
MI (average)	0.4%	0.4%	0.4%

Table A-3 Domestic value added in clean energy technology exports (1000 USD) in in-scope countries, EU-27 average and MI countries average, in 2013, 2016 and 2019

Country	2013	2016	2019
Australia	469,809	339,905	348,154
Austria	2,135,061	2,202,516	2,084,665
Belgium	2,668,907	2,110,998	2,433,405
Brazil	1,273,580	1,070,891	1,199,246
Bulgaria	362,674	276,593	342,352
Canada	2,236,769	1,784,776	2,038,828
Chile	64,137	55,786	42,462
China	36,930,309	41,876,186	59,266,301
Croatia	280,337	216,415	256,204
Cyprus	880	1,664	466
Czechia	2,415,626	2,246,646	2,660,709
Denmark	4,068,429	4,485,638	4,804,377
Estonia	147,924	115,665	134,202
Finland	1,010,026	866,192	909,056
France	6,956,532	5,540,054	6,374,740
Germany	26,028,498	23,245,148	24,916,749
Greece	213,531	250,791	303,188
Hungary	1,174,933	1,181,827	1,324,952
India	1,687,880	1,849,674	3,000,934
Indonesia	887,893	845,617	1,089,626
Ireland	410,973	583,700	550,462
Italy	9,384,887	8,258,694	8,629,954
Japan	16,717,927	15,429,479	15,307,527
South Korea	8,711,081	8,168,683	7,701,062
Latvia	41,846	51,984	73,339
Lithuania	216,339	200,882	283,029
Luxembourg	64,383	70,759	80,091
Malta	14,127	8,412	7,601
Mexico	4,224,960	4,837,236	5,448,695
Netherlands	4,370,991	3,517,127	4,575,249
Norway	407,456	278,026	305,694
Poland	2,477,027	2,420,336	3,333,855
Portugal	702,504	731,099	729,431
Romania	1,330,937	1,401,204	1,915,102
Saudi Arabia	107,362	100,710	93,175
Slovakia	918,112	1,006,460	1,202,961
Slovenia	797,410	764,748	977,925
Spain	4,475,318	3,566,342	3,504,700
Sweden	1,827,689	1,391,720	1,603,530
United Arab Emirates	78,733	308,322	578,163
United Kingdom	4,293,979	3,444,086	4,190,632
United States	19,154,037	16,283,961	16,937,780
EU27 (average)	469,809	339,905	348,154
MI (average)	2,135,061	2,202,516	2,084,665

Table A-4 Domestic value added in clean energy technology exports / GDP ratio (%) in in-scope countries, EU-27 average and MI countries average, in 2013, 2016 and 2019

Country	2013	2016	2019
Australia	0.0%	0.0%	0.0%
Austria	0.5%	0.5%	0.4%
Belgium	0.5%	0.4%	0.4%
Brazil	0.0%	0.0%	0.0%
Bulgaria	0.3%	0.2%	0.2%
Canada	0.1%	0.1%	0.1%
Chile	0.0%	0.0%	0.0%
China	0.2%	0.2%	0.3%
Croatia	0.3%	0.2%	0.2%
Cyprus	0.0%	0.0%	0.0%
Czechia	0.7%	0.6%	0.6%
Denmark	1.4%	1.4%	1.4%
Estonia	0.4%	0.3%	0.3%
Finland	0.4%	0.3%	0.3%
France	0.2%	0.2%	0.2%
Germany	0.6%	0.5%	0.6%
Greece	0.1%	0.1%	0.1%
Hungary	0.5%	0.4%	0.4%
India	0.0%	0.0%	0.0%
Indonesia	0.0%	0.0%	0.0%
Ireland	0.2%	0.2%	0.1%
Italy	0.4%	0.3%	0.3%
Japan	0.3%	0.3%	0.3%
South Korea	0.5%	0.4%	0.3%
Latvia	0.1%	0.1%	0.1%
Lithuania	0.3%	0.2%	0.3%
Luxembourg	0.1%	0.1%	0.1%
Malta	0.1%	0.0%	0.0%
Mexico	0.2%	0.2%	0.2%
Netherlands	0.5%	0.4%	0.5%
Norway	0.1%	0.1%	0.1%
Poland	0.3%	0.2%	0.3%
Portugal	0.2%	0.2%	0.2%
Romania	0.3%	0.3%	0.3%
Saudi Arabia	0.0%	0.0%	0.0%
Slovakia	0.6%	0.6%	0.7%
Slovenia	1.2%	1.1%	1.2%
Spain	0.3%	0.2%	0.2%
Sweden	0.4%	0.3%	0.3%
United Arab Emirates	0.0%	0.0%	0.1%
United Kingdom	0.2%	0.1%	0.1%
United States	0.1%	0.1%	0.1%
EU27 (average)	0.4%	0.3%	0.4%
MI (average)	0.3%	0.2%	0.3%

The Clean Energy Innovation Index (CEII) is a composite indicator designed to track progress in clean energy innovation performance, as measured through the lens of scientific publications, patents and trade. This report focuses on the export dimension of the CEII. The report provides details on the assessment of different export-related indicators and selection of those most suitable for inclusion in the composite indicator; insights on CET innovation performance from the perspective of export flows; and details on the export dataset for inclusion in composite indicator calculations.

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