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Clean Tech Manufacturing Opportunities in Central and Eastern Europe

Export and Investment Implications

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Abstract

The transition to a low-carbon economy requires an expansion in the production of clean energy technologies. Recent shifts in the European Union's industrial policy aim to boost local manufacturing and attract clean technology production to Europe. This paper uses a data-driven scenario approach to explore how such onshoring efforts could create economic opportunities in four Central and Eastern European countries—Bulgaria, Croatia, Poland, and Romania—across five key clean tech value chains: electric vehicle batteries, solar photovoltaics, wind turbines, heat pumps, and electrolyzers. If the European Union achieves the targets in its *Net Zero Industry Act* to source a larger share of these products domestically by 2030, all four countries have opportunities to grow production across value chains and their segments, with a particular focus on electromobility. Poland stands out with the highest export potential and investment requirements in absolute terms, while Bulgaria and Croatia demonstrate greater potential relative to the size of their economies.

This paper is a product of the International Finance Corporation and the Economic Policy Global Department. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The authors may be contacted at srosenow@ifc.org, sc2168@cam.ac.uk, gsemieniuk@worldbank.org, and etimmis@worldbank.org.

Produced by the Research Support Team

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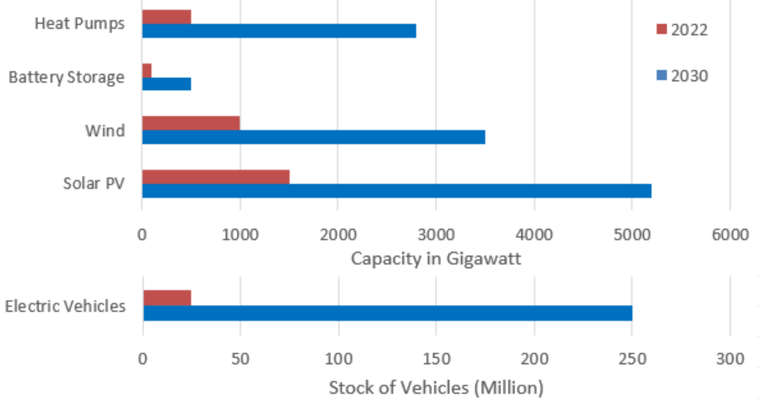
[1] This paper is a product of the IFC Economic Policy Research (CER) and the Macroeconomics, Trade and Investment (MTI) Practice at the World Bank. This paper is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://www.worldbank.org/prwp. The corresponding author may be contacted at srosenow@ifc.org, sc2168@cam.ac.uk, gsemieniuk@worldbank.org and etimmis@worldbank.org. We thank R. Balaji, Jasmin Chakeri, Jeff Chelsky, Leonardo Iacovone, Maryla Maliszewska, Ralf Martin, Penny Mealy, Florian Anselm Muench and Sadesh Harichand Sookraj for their comments. Marie Therese Kane and Petros Shayanowako provided excellent assistance with classifying products in the value chain of heat pumps and electrolyzers. This paper's findings, interpretations, and conclusions are entirely the authors. They do not necessarily represent the views of the World Bank, its affiliated organizations, or those of the Executive Directors of the World Bank, their Managements, or the governments they represent. All errors are ours.

1. Motivation

The European Union (EU) has set ambitious targets for its low-carbon energy transition: The *European Green Deal* (EC, 2019) aims to achieve net zero greenhouse gas emissions in the EU by 2050. Complementary policies such as the *REPowerEU* plan and *Fit for 55* seek to substantially reduce the EU's dependence on energy sources that emit greenhouse gases in the near term. Achieving this transformation of the energy system will require the large-scale deployment of a range of new technologies and products. These include renewable energy infrastructure, such as wind and solar (PV) farms, as well as consumer durables that are compatible with electricity, such as electric vehicles (EVs) and heat pumps. Collectively, this array of products needed to decarbonize energy supply and consumption is referred to in this paper as clean energy technologies or, for short, clean tech.[2] Globally, the shift to low-carbon energy further underscores clean tech as an attractive growth market, with demand for core products expected to multiply several times by 2030 (Figure 1). This presents significant opportunities for innovation and industrial development within the EU and beyond.

Figure 1: Global capacity of clean tech in 2022 and 2030 projections based on government decarbonization pledges



Source: World Bank (2024) based on various International Energy Agency projections.

Efforts to capture a larger share of this clean tech growth market are linked to the resurgence of industrial policy in advanced economies and geopolitical shifts toward regional self-reliance. In the EU, this has led to the adoption of policies aimed at attracting or 'onshoring' clean tech production within Europe. A key development is the EU's *Net Zero Industry Act* (NZIA), introduced in 2024, which sets a target for at least 40% of 'net-zero technologies' used in the EU to be produced locally. One mechanism to support this ramp-up of production is the relaxation of state aid rules under the *Temporary Crisis and Transition Framework* (TCTF). Among other things, it allows subsidies to encourage strategic investments in the manufacturing capacity for clean tech. In addition, the EU also recently raised tariffs on certain electric vehicle imports. It is unclear whether additional mechanisms to support the NZIA targets are considered, but the recent Draghi Report on *The Future of European Competitiveness* recommended local content requirements. While these protectionist policy shifts may reduce global and regional economic efficiency by diverting

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[2] Clean energy technologies refer to products that either produce, store, or deliver low-carbon energy, as per the IEA's (2020) definition. The EU's nomenclature includes 'clean technologies', 'net zero technologies', and 'green technologies', among others. Per the emerging nomenclature, 'technologies' are intended as products—i.e., capital goods, consumer goods, and intermediate goods—not as 'productive' knowledge.

production and trade, EU policy makers argue such trade-offs are necessary to achieve the low-carbon energy transition and industrial resilience within Europe.

This paper explores the opportunities arising from the EU's policy shift to expand or onshore clean tech production in four Central and Eastern European (4CEE) countries – Romania, Bulgaria, Croatia, and Poland. Their proximity and trade integration within the European Union's single market position them strategically for investment and sourcing. However, fiscal constraints limit their ability to use industrial subsidies—a tool increasingly used by higher-income countries (Juhasz et al., 2023)—highlighting the need for carefully targeted policy interventions. By quantifying their onshoring potential, the analysis identifies key products, value chain segments, and EU destination markets where these countries can grow exports and investments within clean tech value chains.

2. Research questions

We estimate the onshoring potential of the five clean tech value chains for 4CEE countries. Specifically, our methodology provides evidence-based market intelligence on the following questions:[3]

1. To what extent could onshoring opportunities resulting from the EU-level policy shifts benefit 4CEE countries in terms of additional exports and investments?
2. In which clean tech value chains and segments in 4CEE countries would onshoring have the greatest export and investment benefits?
3. Would onshoring opportunities result from the expansion of existing activities or from new activities?
4. What are the underlying factors driving onshoring opportunities in 4CEE countries?
5. How are exports and investments expected to grow across 4CEE countries and the clean tech value chains?

3. Methodology

Our analytical framework for identifying onshoring potential consists of five steps:

1. Sector Filtering: Identify sectors relevant to EU27 onshoring;
2. Indicator Development: Define indicators across supply, demand, and market access ease;
3. Composite Index Creation: Construct a composite index to summarize onshoring potential;
4. Export Projections: Generate export forecasts based on the index; and
5. Investment Projections: Calculate the necessary investment to meet projected export levels.

3.1 Sector Filtering

To capture the EU27's sectoral priorities, we confine our analysis to all tradeable products in the following value chains of decarbonization technologies:

1. Solar energy
2. Wind energy
3. Batteries for electric vehicles[4]
4. Heat pumps
5. Electrolyzers

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[3] That is, the analysis abstracts from the use of new industrial policies by the EU member states.

[4] Our analysis covers only the inputs for EV batteries, excluding the rest of the EV value chain.

This subset includes key strategic clean tech value chains defined by the EU's Net-Zero Industry Act (NZIA), for which the mapping of tradable products has been finalized. We rely on Rosenow and Mealy (2024) for their mapping of tradable products in the value chains of solar, wind and electric vehicles. Moreover, we adapt their methodology to map and validate tradable products in the value chains of heat pumps and electrolyzers in the 6-digit product classification of the Harmonized System (HS).[5]

While the 6-digit HS is the most detailed internationally standardized product classification, it has three limitations. First, products may have dual use, additional applications or purposes beyond those relevant to the clean tech value chains. Second, although the 6-digit product classification is remarkably detailed, a 6-digit product code is not a single product but an average of differentiated product varieties. As a result, our product definition may be too broad to clearly identify products in each clean tech value chain. Third, due to data availability, the trade indicators use gross rather than value-added data.

3.2 Indicator Development

We consider indicators of onshoring potential using a conceptual framework based on three dimensions: demand, supply, and ease of market access. Drawing from the latest modeling of export potential (ITC, 2023), this framework evaluates onshoring export potential by examining import demand in the EU27 markets, supply capacity in the 4CEE exporting countries, and their bilateral links.

First, ten demand indicators (Table 1) capture the pull factors driving the relocation of clean tech value chains within the EU27. These indicators include the EU27's reliance on non-EU inputs, the growth of imports from non-EU regions, and the rising demand for locally sourced content in key sectors like energy. They also reflect strategic objectives such as the EU's targets for increasing local content by 2030, particularly in clean tech value chains affected by public policies like CBAM.

Second, six supply indicators assess the ability of 4CEE countries to support the EU’s transition toward more localized clean tech value chains. These indicators evaluate 4CEE countries' market share in EU imports, export competitiveness, and productive capabilities. Additionally, they capture the ease with which these countries can scale up production, adopt new technologies, and expand domestic capacities to meet the increasing demand for clean tech value chain integration.

Third, two indicators related to the ease of market access measure how easily 4CEE producers can connect with and supply EU27 manufacturers in clean tech value chains. These indicators measure the logistical and transport factors influencing the bilateral flow between supply (4CEE countries) and demand (EU27).[6]

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[5] The 6-digit HS classification is the most granular, internationally harmonized classification of products. To identify HS 6-digit products associated with the value chains of heat pumps, electrolyzers and geothermal, we followed three steps: First, we undertook a review of the academic and grey literature, finding key papers that have previously identified HS 6-digit products associated with wind turbines, solar PV, and EVs (see Table A1 for key sources used). Second, after collating the various HS 6-digit codes for each technology, we drew on further desktop research to classify each product into four value chain segments: raw materials, processed materials, subcomponents, and end products (see Table A2 for a definition of each segment). Third, we validated our product mapping for each value chain with industry specialists and custom officials in the respective supply chains. Reviewing the technical specifications of products in these value chains with our product description helped us trim the list of HS 6-digit products for each value chain – and ensured consistency across all value chains (Table A3).

[6] As all 4CEE countries are members of the EU, there is no variation in the tariffs and ad valorem equivalents (AVEs) of non-tariff measures (NTMs) available for this analysis.

Table 1: Indicators used in the Onshoring Attractiveness index, by dimension

#	Dimension	Indicator	Time Period	Unit of Analysis[7]	Unit of Measurement	Source	Share in OA Index
1	Demand	Foreign Input Reliance (FIR)[8] of EU27 countries from non-EU 27 importers, by HS 6-digit product[9]	2020	j-p-t	% share	OECD	4.4%
2	Demand	Import value by EU27 countries, by HS6-digit product	2022	j-p-t	USD	CEPII BACI	4.1%
3	Demand	Share of the import market value of EU27 countries from non-EU countries, by HS 6-digit product	2022	j-p-t	% share	CEPII BACI	6.2%
4	Demand	Growth of imports in the EU27 from non-EU countries, by HS 6-digit product	2017-2022	j-p-t	% growth	CEPII BACI	5.5%
5	Demand	EU27 local content baseline, by value chain	2022	J-vc-t	% share	EU Commission	8.5%
6	Demand	EU27 local content target, by value chain	2030	J-vc-t	% share	EU Commission	6.2%
7	Demand	CBAM tariff equivalent of HS6-digit product policy impact in EU27 countries, weighted by its respective non-EU exporters	2026	j-p-t	% value	World Bank	4.0%
8	Demand	Cumulative spending in EU27 countries, by value chain[10]	2017-2021	j-vc-t	Euro	IEA	6.2%
9	Demand	EU27 renewable technology deployment gap, by value chain	2022-2030	J-vc-t	Percentage Point	EU Commission	8.7%
10	Demand	Total FDI inflows from EU27 countries to 4CEE, by value chain	2019-2023	i-j-vc-t	USD	fDI markets	4.6%
11	Supply	Share of EU27's HS 6-digit product imports from 4CEE country	2022	i-j-p-t	%	CEPII BACI	4.1%
12	Supply	Export unit price of each 4CEE country, by HS 6-digit product	2022	i-p-t	USD per unit	CEPII BACI	2.3%
13	Supply	Export growth of 4CEE countries to EU27, by HS 6-digit product	2017-2022	i-j-p-t	%	CEPII BACI	4.4%
14	Supply	Capability alignment of 4CEE countries and HS 6-digit product[11]	2022	i-p-t	Probability	CEPII BACI	7.2%
15	Supply	Capability alignment using XG Boost of 4CEE countries and HS 6-digit product[12]	2022	i-p-t	Probability	CEPII BACI	6.9%
16	Supply	Cumulative investment in each 4CEE country, by value chain[13]	2017-2021	i-vc-t	USD	IEA Renewables	5.9%
17	Ease of Market Access	Bilateral Logistics Performance Index $(\mathrm{LPI}_{ijt}) = \mathrm{LPI}_{it} * \mathrm{LPI}_{jt}$	2023	i-j-t	Index score	World Bank	6.1%
18	Ease of Market Access	Driving time from 4CEE capitals to EU27 production sites of clean tech value chains	2024	i-j-vc-t	Hours	Bruegel and Google	4.7%

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[7] i represents 4CEE country; j=EU27 individual importing country; J= the total of all EU27 importing countries minus i; p=HS 6-digit product; vc=clean tech value chain and t=year.

[8] FIR measures the share of total domestic output exposed to foreign disruptions. FIR accounts for the size of direct and indirect exposure to a partner in the value chain; and the distance to this partner in the value chain, i.e. the length of the value chain.

[9] We convert FIR's 45 ISIC industries to our 5 value chains of interest by mapping ISIC sectors to HS 6-digit products.

[10] For EV, we convert EV cars sold to TWH by using the average battery capacity of electric vehicles from Statista (2024).

[11] See Appendix C for the intuition and mathematical definition of this indicator.

[12] See Appendix D for the intuition and mathematical definition of this indicator.

[13] To define cumulative spending on EV cars, we multiply the number of EV cars sold in each 4CEE country times its average price, as referenced by IEA (2022). To define cumulative spending on solar and wind technologies, we convert capacity additions (kW) in money metrics by using European wind turbine cost (USD/kW) and European solar module and inverter cost (USD/kW), following Irena (2022).

3.3 Composite Index Creation

We use Principal Component Analysis to summarize the 18 variables into a composite index of Onshoring Attractiveness (OA).[14] This index assigns weights to each indicator based on its contribution to the total variance of the selected components.[15] This approach defines the onshoring potential in two ways:

1. The intensive margin is related to existing export markets in each 4CEE country;[16]
2. The extensive margin is related to new export markets in each 4CEE country.

For each 4CEE exporter, HS 6-digit product within clean tech value chains and EU27 destination, we obtain a single OA.[17] To simplify interpretation, we categorize these OA values into three groups: Low, Medium and High, using K-means clustering, a widely used machine learning technique.[18] This approach allows us to identify groups with minimal assumptions. We define onshoring opportunities as those product-destination observations with high OA values. Table 2 shows that onshoring opportunities are limited to 5,442, or 15%, of all product-destination markets among 4CEE exporters. Poland stands out by capturing 3,267 onshoring opportunities, significantly more than its peers.[19] Moreover, Poland has a greater number of product-destination markets with medium OA values compared to its peers.

Table 2: Number of product-destination markets, by 4CEE exporter and onshoring attractiveness

Onshoring Attractiveness Exporter	Low	Medium	High	Total
Bulgaria	3,798	4,280	658	8,736
Croatia	3,825	4,096	815	8,736
Poland	942	4,527	3,267	8,736
Romania	4,070	3,964	702	8,736
Total	12,635	16,867	5,442	34,944

Note: This table shows the number of HS 6-digit products (336) and EU27 destination markets (26) by exporter and onshoring attractiveness.

Table 3: Number of onshoring opportunities, by 4CEE exporter and value chain

Value Chain Exporter	EV	Heat pumps	Electrolyzers	Solar	Wind	Total
Bulgaria	36	114	21	18	469	658
Croatia	32	100	23	12	648	815
Poland	156	572	93	357	2,089	3,267
Romania	34	90	23	103	452	702
Total	258	876	160	490	3,658	5,442

Note: This table shows the number of onshoring opportunities, defined as product-destinations with high onshoring attractiveness values.

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[14] PCA is used to reduce the dimensionality of the dataset by transforming a large set of variables into a smaller set still containing most of the information. We select the maximum number of components (eigenvectors or factors) with eigenvalues greater than one.

[15] The variable *Share in OA Index* in Table 1 shows the weight assigned to each indicator in the composite OA index.

[16] We define the intensive margin as HS 6-digit product-destination markets with positive exports in 2022.

[17] See Appendix Figure E1 for a histogram of values associated with OA.

[18] Clustering is the process of grouping data samples together into *clusters* based on a certain feature that they share. Its objective is to minimize the sum of distances between the data points and the cluster centroid and to identify the correct group each data point should belong to. We use the elbow method (Thorndike, 1953) to determine the optimal number of clusters, which is three, as shown in Appendix Figure E3.

[19] See Appendix Table E1 and E2 for top and bottom 10 4CEE exporter-destination-product observations, respectively.

Table 3 shows the distribution of onshoring opportunities by 4CEE exporter and value chain. Overall, the wind value chain, and in particular the demand for it, is driving onshoring opportunities across product destination markets. In contrast, the electrolyzer value chain offers the fewest onshoring opportunities. This distribution highlights the unique strengths of each country in clean tech value chains, with Poland showing a clear overall advantage.[20]

3.4 Export Projections

We use the variation in OA values to determine the export potential of 4CEE countries. To that end, we define a conceptual framework in which export potential $\widehat{\text{Export}}_{\text{ijp}}$ of 4CEE exporter i, EU27 destination market j and product p of clean tech value chain are defined as follows:

$$\widehat{\text{Export}}_{\text{ijp}} = \text{Scenario Factor}_{\text{vc}} \times \text{Weight}_{\text{ijp}} \times \text{Output}_{\text{i,vc,2022}} \tag{1}$$

$$= \text{Production Multiplier}_{\text{vc}}^{\text{EU27}} \times \frac{\text{OA}_{\text{ijp}}^{\text{normalized}}}{\sum_{\text{vc}} \text{OA}_{\text{ijp}}^{\text{normalized}}} \times \text{Manufacturing Capacity}_{\text{EU27,vc,2022}} \times \text{Price}_{\text{vc,2022}} \times \frac{\text{Exports}_{\text{i,global,vc,2022}}}{\text{Exports}_{\text{EU27,global,vc,2022}}}$$

Equation (1) has three inputs. The first input, $\text{Scenario Factor}_{\text{vc}}$, quantifies the domestic production increases needed to meet the EU27's 2030 deployment targets for each clean tech value chain. In line with the European Commission (2023), we consider three scenarios reflecting changes in the domestic production shares of these value chains between 2023 and 2030:[21]

1. a current trend scenario where the EU maintains its current manufacturing shares but increases manufacturing production of renewable technologies to meet market growth;
2. a NZIA policy scenario where the EU increases manufacturing shares to meet benchmarks laid out in in the NZIA and implied in other legislation, and
3. a NZIA+ policy scenario where the EU aims to cover 100% of its deployment needs through domestic manufacturing, which would capture a larger global market share.

The scale-up in the EU27's production capacity in the different scenarios is summarized in Table 4.

Table 4: Domestic production share in EU27 deployment and multiplier, by value chain and scenario

Value Chain	Domestic production share in EU27 deployment in 2024, in %			Required production multiplier to meet EU27 deployment objectives in 2030		
	Current	NZIA scenario	NZIA+ scenario	Constant share scenario	NZIA scenario	NZIA+ scenario
Wind	85	85	100	2.7	2.7	3.3
Solar	3	45	100	1.4	23	52
Battery	54	90	100	4.4	7.3	8.1
Heat pumps	60	60	100	2.2	2.2	3.6
Electrolyzer	10	100	100	1.1	10.6	10.6

Source: European Commission, 2023.

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[20] The number of onshoring product opportunities is not contingent on the number of products in value chains, which is balanced (Table A3).

[21] 37 distinct HS 6-digit products map to multiple value chains. In such cases, we map each product to the value chain with the highest investment needs until 2030, based on EU Commission (2023). For each value chain, 4CEE exports to the EU are assumed to increase at the same rate as the increase in annual manufacturing capacity of each technology across all of the EU27 countries. We also assume that the rise in EU exports corresponds to the rise in manufacturing capacity as estimated by the EU Commission.

Second, we use the OA values to define $\mathrm{Weight}_{\mathrm{ijp}}$, which distribute export projections from our three scenarios across 4CEE exporter-HS6 product-importer observations. Specifically, we perform a global max-min transformation of the OA. This bounds values between 0 and 1, ensuring non-negative observations and comparability across products and countries. This is critical to define weights, which reflect a 4CEE exporter's relative position compared to other 4CEE exporter, destination, and product markets.

Third, $\mathrm{Output}_{\mathrm{i,vc,2022}}$ estimates the baseline exports of 4CEE exporter i for each value chain vc in 2022.[22] To do this, we first express the value added in each value chain at the EU level in monetary terms by using the EU27's annual manufacturing capacity in physical units (kW or kWh)[23] and its price per unit of capacity ($ per KW or KWh).[24] We then use each 4CEE country's share of EU27 exports to determine its manufacturing value share in each value chain. To calculate baseline exports, we assume that all of the 4CEE countries' value added in these value chains is translated into exports. This assumption is justified by the cross-national integration of value chains, relatively small local markets, and only incipient domestic demand for, e.g., heat pumps in 2022, in some 4CEE markets.[25]

3.5 Investment Projections

The additional export capacity will require investments. To convert 4CEE's export potential in 2030 into investment needs, we need to establish a relationship between the expected increase in exports and the investment response in an exporting 4CEE country's value chain. To this end, we extend our conceptual framework in which investment needs $\widehat{\mathrm{Investments}}_{\mathrm{ivc}}$ for 4CEE country i, EU27 destination market j and value chain vc are based on export projections $\widehat{\mathrm{Export}}_{\mathrm{ijp}}$ of 4CEE country i, EU27 destination market j and product p and a capital intensity adjustment factor.

$$\widehat{\mathrm{Investment}}_{\mathrm{ijvc}} = \widehat{\mathrm{Export}}_{\mathrm{ijp}} \times \mathrm{Capital\ Intensity}_{\mathrm{vc}} \tag{2}$$

Estimating equation (2) requires two inputs: First, we rely on export potential, as defined in equation (1). Second, we estimate a capital intensity factor that reflects the capital requirement of value chain vc to produce a dollar worth of equipment required to produce energy.[26]

$$\mathrm{Capital\ Intensity}_{\mathrm{vc}} = \frac{\mathrm{Capex\ investment\ per\ unit\ of\ power}_{\mathrm{vc}}}{\mathrm{Export\ per\ unit\ of\ power}_{\mathrm{vc}}}\,. \tag{3}$$

To estimate the capital intensity, we require two key inputs. First, we impute the capex investment for every unit of power using estimates from the European Commission (EC, 2023). Second, we obtain estimates of equipment cost per unit of power, as detailed in footnote 12. The estimates are provided in Appendix Table F1.

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[22] Using 2022 exports summed over all HS codes of 4CEE exporter i in value chain vc would lead to over-estimates of exports since the mapping of clean tech value chain products includes products with dual uses.

[23] See European Commission (2023). Capacity is measured in GW for all value chains, except EV batteries, which are measured in GWh.

[24] See footnote 12 for information on expressing manufacturing capacity in monetary terms.

[25] See for instance the European Heat Pump Association's Market and Statistics Report 2023, which does not even distinguish Bulgaria, Croatia and Romania. https://www.ehpa.org/wp-content/uploads/2023/06/EHPA_market_report_2023_Executive-Summary.pdf

[26] For the numerator, we use European Commission (2023) estimates; for the denominator, cost estimates from footnote 17, which are exports seen from the point of importers.

3.6 Decomposition of the Onshoring Attractiveness Index

To gain insight into the factors driving onshoring opportunities, we decompose the index into its three dimensions: demand, supply and ease of market access. For each 4CEE country i, EU27 destination market j and product p, we can write:

$$\text{Onshoring Attractiveness Score}_{ijp} = \text{Demand Score}_{ijp} + \text{Supply Score}_{ijp} + \text{Market Access Score}_{ijp} \qquad (4)$$

Each component score is derived as a weighted sum of the normalized indicators falling under the relevant dimension, as defined in section 3.2. The weights are determined by two factors:

1. The contribution of each indicator to each principal component
2. The weight of each principal component in the raw OA score

For any dimension score and each ijp observation we can write:

$$\text{Dimension score}_{ijp} = \sum_c (w^c_{ijp} \sum_d w^{cd}_{ijp}) \qquad (5)$$

where w^{c} is the contribution of Principal Component c to the OA score, and w^{cd} is the contribution of each indicator d to each Principal Component c. The score for Market Access is constructed as follows:

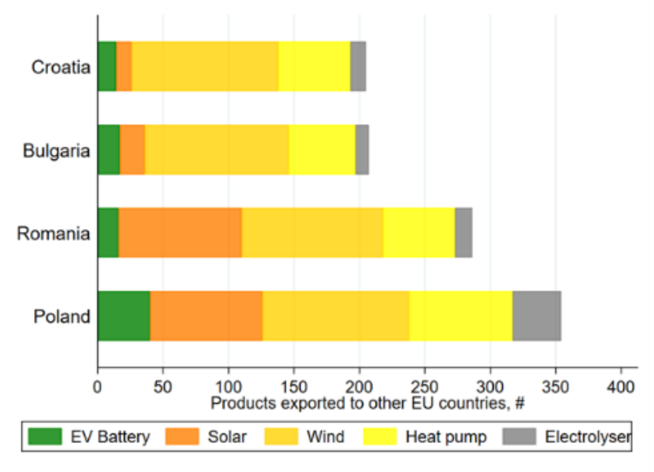
$$\text{Market Access score}_{ijp} = \sum_c w^c_{ijp} \left\{ w^{c\,\text{LPI}}_{ijp} \text{LPI Score}_{ij} + w^{c\,\text{Driving}}_{ijp} \text{Driving Score}_{ijvc} \right\} \qquad (6)$$

Each score is then standardized with a max-min transformation to ensure that it falls between 0 and 1.

4. Results

Poland has the largest number of opportunities for onshoring the production of clean tech products, followed by Romania, and to a lesser extent Croatia and Bulgaria (Figure 2).[27] Poland's onshoring opportunities are diverse, spanning products in the EV batteries, heat pumps and electrolyzer value chains. In contrast, Romania has fewer EV-related onshoring opportunities. Croatia and Bulgaria have fewer products in the five clean tech value chains, and see their opportunities concentrated in the wind value chain. This disparity may partly be due to smaller economies of Croatia and Bulgaria, with populations under 4 million and 7 million, respectively, compared Romania's 19 million and Poland's 34 million.

Figure 2: Number of onshoring product opportunities, by 4CEE country and value chain



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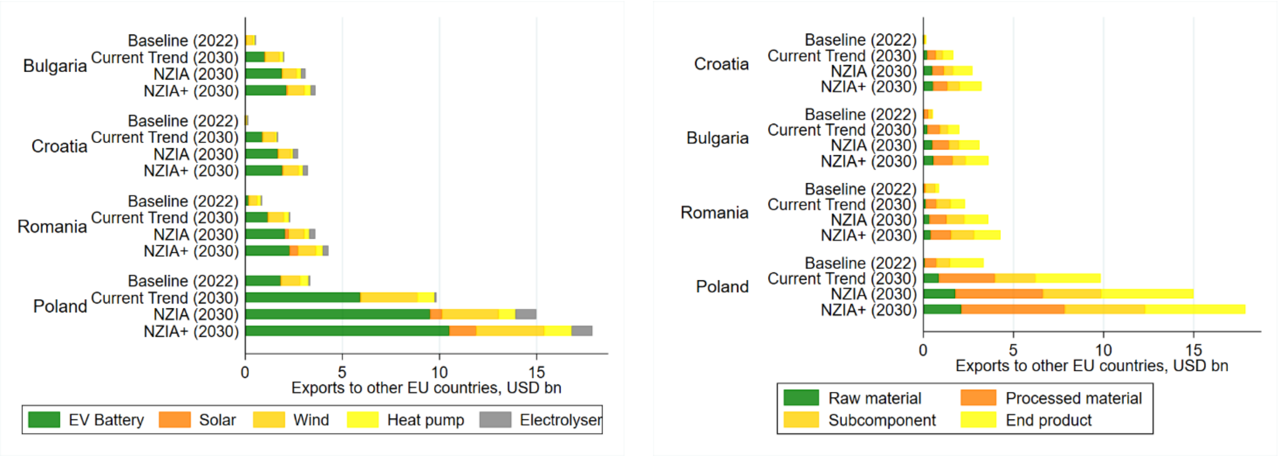
[27] Poland has more product opportunities than distinct clean tech value chain products, as some products are part of multiple value chains due to their use in various production processes (Table A3). However, estimating export projections in Equation (1) requires a unique mapping between products and value chains, which our assignment rules ensures: Products are mapped to value chain and segments where they are the only associated product. For the remaining products with multiple value chain associations, we assign them to the largest segment by scale, based on manufacturing capacity investment needs for 2030 in the Business-as-Usual (BAU) scenario (European Commission, 2023).

Exports of clean tech value chains from the 4CEE countries to the EU27 are projected to increase dramatically by 2030. Starting from modest levels in 2022, when only Poland exceeded US$3 billion in exports while other countries remained below US$1 billion, two scenarios predict significant growth. Under the current trend scenario, 4CEE exporters are projected to triple these exports from 2022 levels (Figure 3a-b). The more ambitious NZIA scenario forecasts even stronger growth, with exports quintupling in Bulgaria, Poland, and Romania. Croatia's exports are estimated to even increase fivefold due to its low initial base.

The contribution of clean tech exports to national economies varies widely. By 2030, the contribution of clean tech exports to GDP is expected to range from 1.2% in Romania to 3.7% in Croatia (Figure 3c-d). Poland's clean tech exports are projected to reach 2% of GDP. This positions Poland's growth in clean tech value chain exports relative to GDP in line with its regional peers, even as it maintains its dominant position in absolute terms.

Figure 3: Export projections, by 4CEE country and onshoring scenario

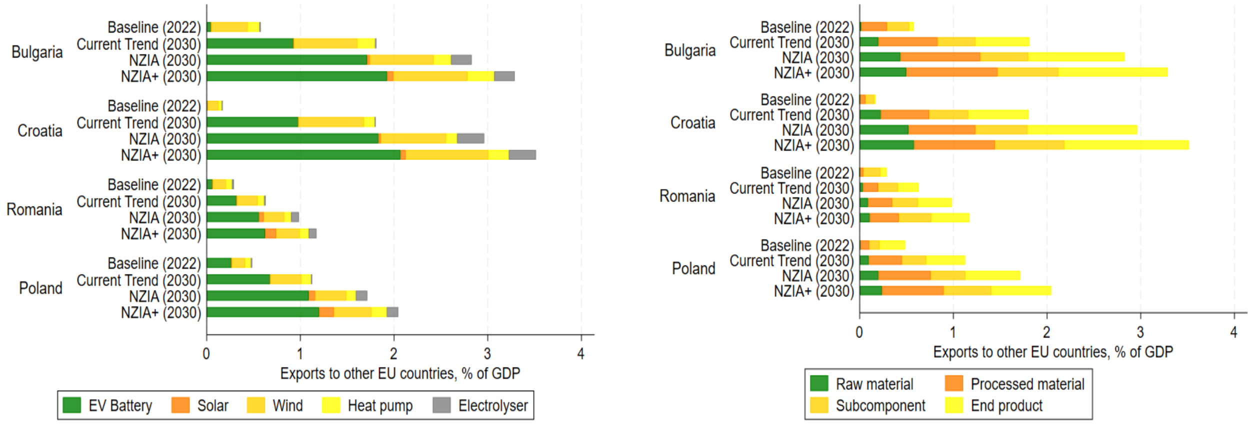


a. By value chain (in USD billion)

b. By value chain segment (in USD billion)

c. by value chain (as a share of GDP)

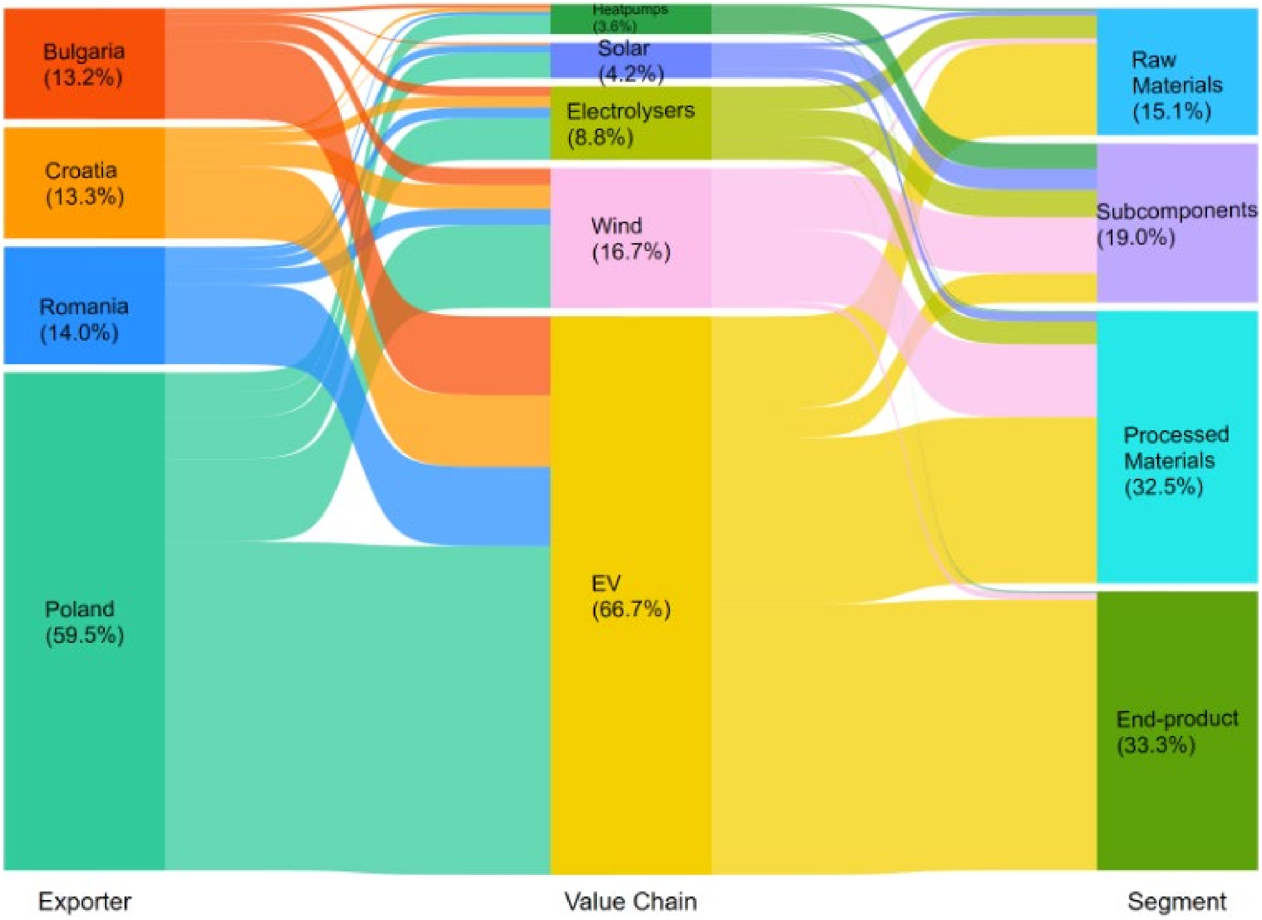
d. by value chain segment (as a share of GDP)



Poland is projected to capture the lion's share of additional onshoring exports across all scenarios. Given its extensive portfolio of products well-suited for onshoring, Poland is projected to capture 60% of additional exports, mostly in the EV value chain and end products (Figure 4). In contrast, Romania, Bulgaria, and Croatia are projected to gain considerably less, with similar levels of additional exports among them.

Romania presents an interesting case: despite having more diverse clean tech products than Bulgaria and Croatia, it fails to convert this advantage into higher exports (Figure 3a-b). This underperformance can be attributed to two factors. Romania has limited opportunities in battery production, a value chain where EU domestic manufacturing is set to expand significantly (Table 4). Moreover, despite its diverse product opportunities for onshoring, Romania's narrow range of EU export destinations restricts its export growth potential.

Figure 4: Distribution of onshoring export projections under NZIA scenario



EV battery exports are projected to grow the most, with little variation between 4CEE exporters (Figure 5a). This dominance is driven by its sevenfold growth target set in the NZIA and the sector's substantial value addition, with batteries accounting for 30%-40% of an EV's total value added.[28] This battery export growth highlights the potential economic impact of Europe's automotive industry transition to EVs on Central and Eastern European exports. The outlook varies for other clean tech value chains. Wind energy presents onshoring opportunities across all four CEE countries. In contrast, solar PV value chain prospects differ significantly: Poland and Romania show potential for onshoring solar production, while Bulgaria and Croatia have limited opportunities in this value chain.

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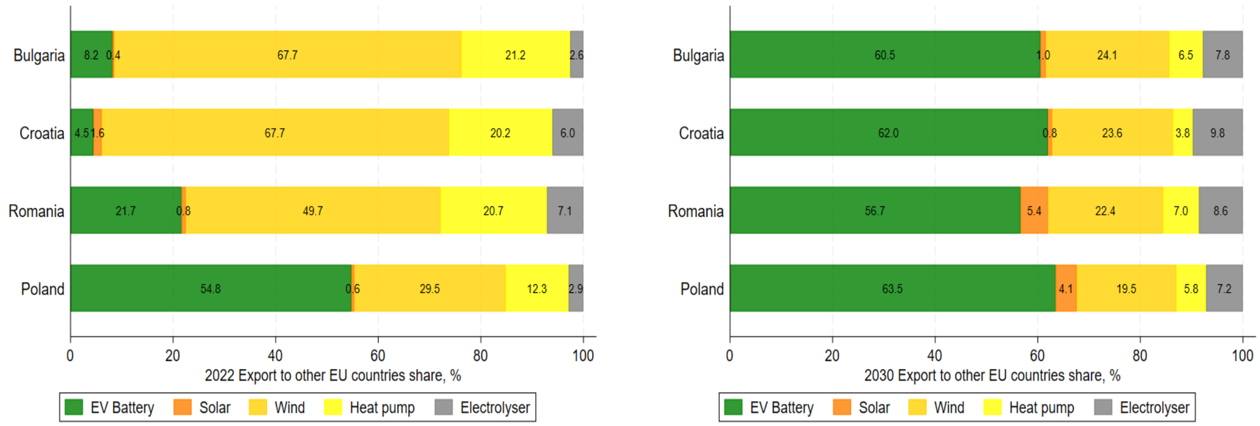
[28] IEA 2022, Global Supply Chains of EV batteries.

The analysis of simulated export compositions reveals opportunities for all 4CEE countries to expand their roles across segments of clean tech value chains. Notably, Bulgaria, Croatia and Romania show potential to increase their share of end-product manufacturing. Poland, in turn, is projected to increase its share of material processing relative to current shares (Figure 5c-d). These graphs illustrate that the simulations represent potential shifts in export composition, rather than definitive predictions. Ultimately, the scale and nature of production in any country depend on strategic decisions, such as where to establish factories for specific products or mines for raw materials.

Figure 5: Export share in 2022 and under the NZIA scenario, by 4CEE exporting country

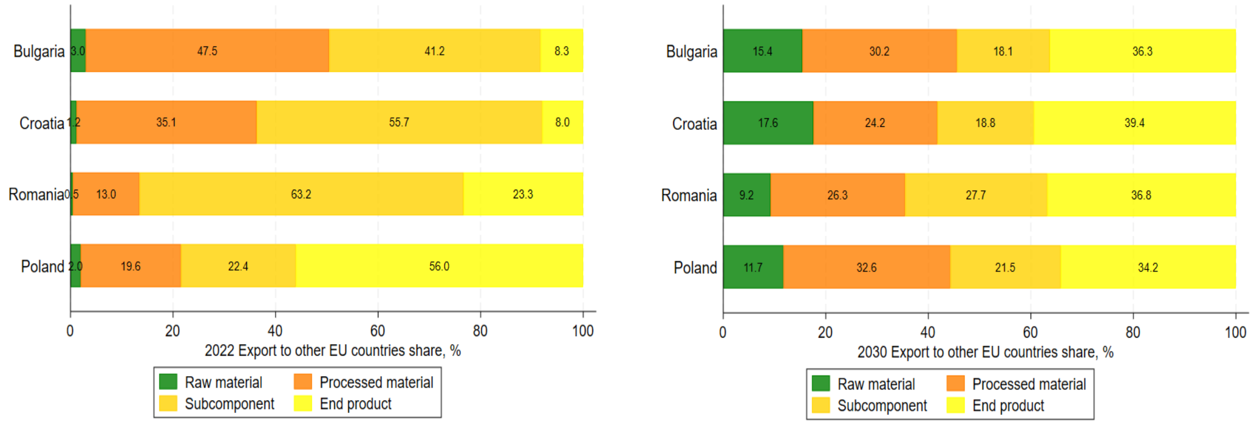
a. By value chain in 2022

b. By value chain in 2030 under NZIA scenario



c. By segment in 2022

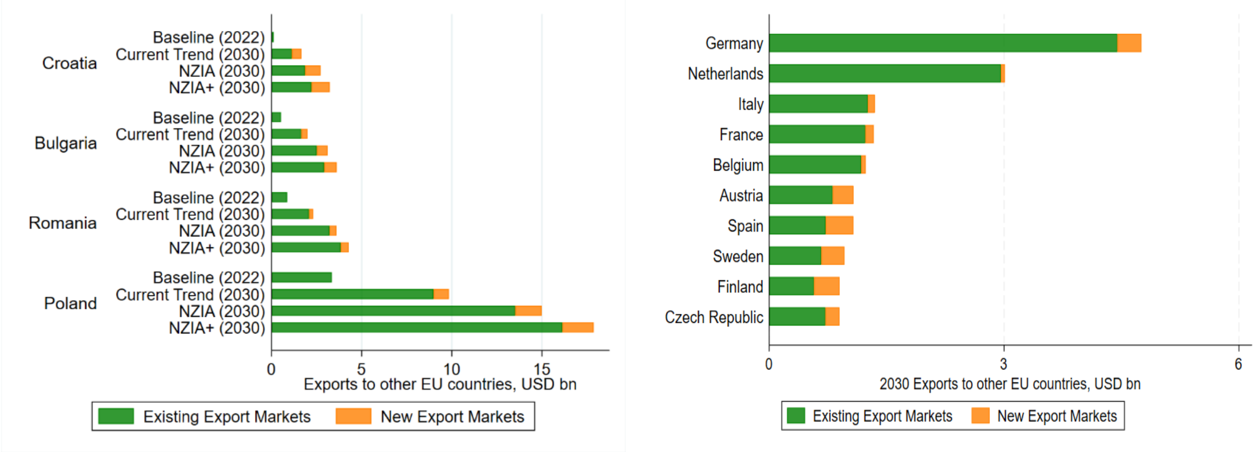
d. By segment in 2030 under NZIA scenario



Clean tech exports from the 4CEE countries will largely service the existing import demand from Western Europe. This pattern is evident in the established trade relationships between these four countries and their key destination markets (Figure 6a), particularly with Germany and the Netherlands (Figure 6b). These two nations already play a significant role as major importers of clean tech products, reinforcing bilateral trade patterns. However, certain onshoring opportunities can create new trade relationships within the EU. Poland stands out in this regard, as it currently exports clean tech products to several EU markets and is expected to experience increased demand from new importers by 2030. In contrast, Romania is projected to reach fewer new export destinations than its peers. This limited expansion may be a key reason why Romania struggles to convert its clean tech value chain diversification into substantial export gains.

For all 4CEE exporters, around 40% of additional exports will target three main Western Europe importers – Germany, the Netherlands and Italy (Figure 6c). Poland has the most diversified group of importing countries, while Romania has the least. The country's strong appeal for onshoring stems from its superior supply capabilities and ease of market access relative to its peers. This advantage extends across all five clean tech value chains, particularly in wind products (Figure 6d).[29]

Figure 6: Distribution of export projections under NZIA scenario

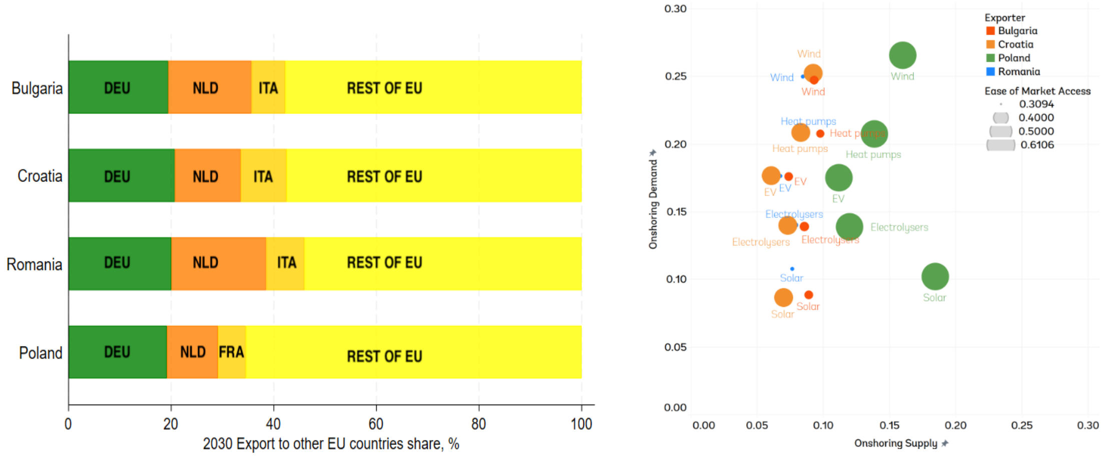


a. By margin: existing vs. new markets

b. Top 10 EU27 importing countries, by margin

c. By importance of destination country

d. Drivers of onshoring attractiveness, by 4CEE country



Scaling up production to achieve export levels consistent with the EU's NZIA scenario requires significant investments. Capital expenditure (Capex) for acquiring, upgrading and maintaining assets is projected to range from US$1 billion in Bulgaria, Croatia and Romania to US$5 billion in Poland (Figure 7a). Since construction often takes several years (EC, 2023), these investments need to be initiated in the near term to ensure operational readiness before 2030. Although substantial, these investments are smaller than the funds Romania already committed under the *TCTF* to subsidize wind and solar farm deployment (World Bank, 2023). However, they do come on top of substantial investment needs in decarbonization and adaptation by both private and public sectors (World Bank, 2024).

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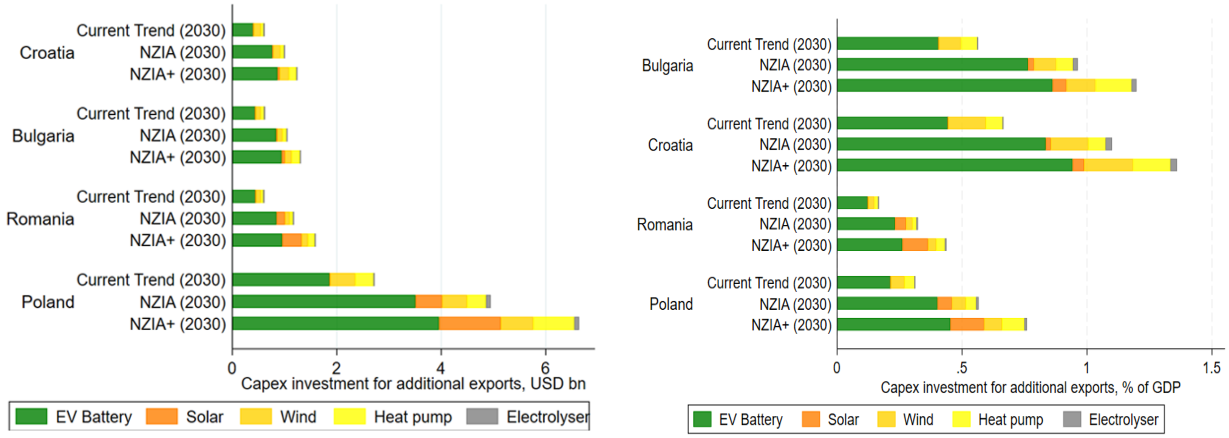
[29] Minimal variation in onshoring demand across 4CEE countries stems from our use of demand indicators independent of these countries.

Investment needs for clean tech exports vary significantly across the 4CEE countries as a share of GDP. Croatia leads with investment needs exceeding 1% of GDP under the NZIA scenario, followed by Bulgaria (Figure 7b). Romania and Poland show more modest investment requirements relative to their GDP. Across all countries, EV battery manufacturing represents the largest share of required investments, while other technologies—solar, wind, heat pumps, and electrolyzers—show varying levels of investment needs depending on the country and scenario.

Figure 7: Capex investment to meet export projections to EU27, by scenario and value chain


a. In USD Billion

b. % of GDP

Note: Capex represents cumulative investment needs between 2024-2030 to support growth in export projections under each scenario.

5. Conclusion

The low-carbon energy transition, along with the fragmentation of global production and recent changes in the EU's industrial policy, is reshaping Europe's trade networks. This paper employs a data-driven approach to identify which 4CEE countries have the greatest potential to capitalize on these trends. In particular, we quantify the onshoring export and investment potential of these countries in clean tech value chains and their segments, using a combination of cutting-edge econometric and machine-learning tools.

Our findings have important policy implications. First, while Poland is well-placed to help onshore production of clean tech to the EU, investors need assurances that they can find suitable workers. The skill sets required for jobs in clean tech manufacturing—such as solar installers or environmental engineers—require upskilling and vocational training of the labor force, as well as opening doors to newcomers. This presents a challenge for Eastern Europe, with its declining working-age populations and rigid migration policies. Bulgaria and Croatia also demonstrate significant onshoring potential, particularly when measured relative to their GDP. However, as analyzed in World Bank (2024), these countries face broader investment barriers that extend beyond the clean tech sector. Addressing these challenges may require horizontal policy interventions aimed at improving the overall business environment, rather than solely relying on vertical, sector-specific measures (Criscuolo et al., 2022).

Second, policy makers need to use more than just subsidies to achieve their industrial goals. While much attention has been given to subsidies allowed under the TCTF to mobilize investments, 4CEE governments face limited fiscal capacity. Moreover, delays in already approved TCTF investment projects elsewhere in the EU indicate that subsidies alone may not always be effective. After all, industrial policy aims to steer economic structures in certain directions, encompassing a wide array of measures beyond subsidies. Policy makers may therefore explore broader policy toolkits and consider combining policies. For instance, a domestic production subsidy may work better when paired with public procurement policies that favor domestic producers. Ultimately, any policy incurs costs and carries risks, but a careful consideration of the toolbox beyond subsidies may reduce some costs and enhance effectiveness.[30]

The analysis has two main limitations. First, it focuses on the distribution of exports across 4CEE exporters, clean tech value chains, segments and EU destination markets, rather than estimating the extent of new exports. The total export growth is instead derived from the EU scenarios, assuming the 4CEE countries keep their collective EU27 market share. Underlying is the assumption that NZIA targets are met based on competitiveness, at least within the bloc, rather than local content quotas or production subsidies, which might hinder European production competitiveness (EC, 2024), and that the trade and industrial policies do not become even more protectionist. Second, our analysis lacks agglomeration modeling. For instance, while all countries may show onshoring potential in certain export products, in reality one large factory in each country may handle the entire supply of those products, rather than each country producing an equal share. Such nuances are beyond the scope of our current approach. Therefore, the division into different value chains and segments should be seen as a first estimate of specialization potential based on existing data, rather than a definitive projection for 2030.

This analysis raises several open research questions. First, which public policies can effectively support 4CEE countries in building industrial ecosystems capable of scaling up clean tech manufacturing? For instance, how well do vocational and university training programs in the 4CEE countries align with the skills required for these emerging roles? Second, what occupations and skills are essential to support the growing demand in clean tech, and to what extent can the occupational structure of the labor force in 4CEE countries adapt to roles involving related work activities? Third, key questions emerge about value chain integration: to what extent can EU accession states integrate into EU clean tech value chains and attract investments? Which segments offer the most promise? Which complementary service sectors will see growing demand from EU onshoring? For example, understanding countries' productive capabilities to recycle and maintain solar panels could help generate labor demand in small and medium sized enterprises. Fourth, how will the shift toward regional clean tech affect global trade networks, particularly with non-EU partners? Finally, further research is needed to explore the long-term welfare implications of these shifts—both within the EU and globally—especially as countries adapt to evolving industrial policies and geopolitical landscapes.

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[30] For further discussion of policy portfolios, see World Bank (2024).

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Appendix

A. Definition of decarbonization sectors

Table A1*:* Academic and grey literature sources used to identify HS 6-digit codes associated with heat pumps, electrolyzers:

Technology	**Key sources**
Electrolyzers	• Jing, S., Zhihui, L., Jinhua, C., & Zhiyao, S. (2020). *China's renewable energy trade potential in the" Belt-and-Road" countries: A gravity model analysis.* Renewable Energy, *161*, 1025-103; • Surana, K., Doblinger, C., Anadon, L. D., & Hultman, N. (2020). *Effects of technology complexity on the emergence and evolution of wind industry manufacturing locations along global value chains*. Nature Energy, *5*(10), 811-821; • U.S. Department of Energy (2023). *Pathways to Commercial Liftoff: Clean Hydrogen.* https://liftoff.energy.gov/wp-content/uploads/2023/03/20230320-Liftoff-Clean-H2-vPUB.pdf • U.S. Department of Energy (2022). *Water Electrolyzers and Fuel Cell Supply Chain: Supply Chain Deep Dive Assessment.* https://www.energy.gov/sites/default/files/2022-02/Fuel%20Cells%20%26%20Electrolyzers%20Supply%20Chain%20Report%20-%20Final.pdf • Scottish Government (2022). *Assessment of Electrolysers: Final Report.* https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2022/10/assessment-electrolysers-report/documents/assessment-electrolysers-final-report/assessment-electrolysers-final-report/govscot%3Adocument/assessment-electrolysers-final-report.pdf • Iyer, R. K., Kelly, J. C., & Elgowainy, A. (2022). *Electrolyzers for Hydrogen Production: Solid Oxide, Alkaline, and Proton Exchange Membrane.* https://www.osti.gov/biblio/1894304 • Shiva Kumar, S., Lim, H. (2022). *An overview of water electrolysis technologies for green hydrogen production.* Energy Reports, *8*, 13793-13813. https://doi.org/10.1016/j.egyr.2022.10.127
Heat pumps	• UK Department for Business, Energy and Industrial Strategy (2020). *Heat Pump Manufacturing Supply Chain Research Project Final Report*. https://assets.publishing.service.gov.uk/media/5fd3c316d3bf7f3057adeb39/heat-pump-manufacturing-supply-chain-research-project-report.pdf • IEA (2021). *The Role of Critical Minerals in Clean Energy Transitions.* https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions • Crownhart, C. (2023). MIT Technology Review, "Everything you need to know about the wild world of heat pumps." https://www.technologyreview.com/2023/02/14/1068582/everything-you-need-to-know-about-heat-pumps

Table A1: Definitions of value chain segments

Value Chain Segment	**Definition**
Raw Materials	Basic materials that are mined, extracted or harvested from the earth. Also referred to as 'unprocessed material', examples include raw biomass and iron ore. In this link of the supply chain, value added comes from extracting, harvesting, and preparing raw materials for international marketing in substantial volumes.
Processed Materials	Materials that have been transformed or refined from basic raw materials as an intermediate step in the manufacturing process. Processed materials include steel, glass and cement. In this link of the supply chain, value added comes from processing raw materials into precursors that can be easily transported, stored and used for downstream subcomponent fabrication.
Subcomponents	Unique constituent parts or elements that contribute to a finished product. Clean energy technology examples include generation sets for wind turbines and crystalline wafers for crystalline silicon PV modules. Note that what is considered a component by the manufacturer may be considered the finished product by its supplier. In this link of the supply chain, value added comes from fabricating processed materials into subcomponents that can then be assembled (with other subcomponents) into end products
End Products	The finished product of the manufacturing process, assembled from subcomponents and ready for sale to customers as a completed item. Clean energy examples include photovoltaic modules and lithium-ion battery cells. In this link of the supply chain, value added comes from assembling components into a marketable product that customers value.

Table A3: Number of HS 6-digit products by value chain and segment

Segment / Value Chain	End products	Processed material	Raw material	Subcomponents	Total
EV	5	5	25	8	43
Heat pumps	1	44	1	7	53
Electrolyzers	1	20	19	13	53
Solar	1	53	20	13	87
Wind	3	41	51	5	100
Total	11	163	116	46	336

B. Demand channels

Our analytical framework to assess onshoring potential features indicators across demand, supply and ease of market access. For demand, we distinguish between two underlying channels: trade diversion and trade creation.

B1. Trade Diversion

Trade diversion channels include geopolitical developments, local content rules, and measures taken by the EU to reduce its reliance on fossil fuels.

1. **Geopolitical developments:** several recent geopolitical developments are important to consider for understanding the future potential for 4CEE countries. Examples include:
    1. Disruption in trade with UK following Brexit;
    2. Reduced reliance on the Russian Federation following its invasion of Ukraine;
    3. Increased supply chain disruptions in China (stringent Covid regulation).

   These developments could lead European firms to switch some of their sourcing and investments from these countries to alternate destinations. 4CEE countries, with their geographical proximity to the rest of Europe and low trade barriers, could substitute some of the products sourced from these countries and thereby promote their trade relationships and investments with other European countries.

2. **EU27 measures:** to promote the use of low-carbon technologies, the EU took measures to encourage local production, both in forms of tariff and quota-equivalents. Chief among them is CBAM, which would act like tariffs, and ensure that the carbon pricing measures do not lead to industries importing from high-polluting/emitting sectors abroad and ignoring domestic suppliers. Moreover, the EU's Net Zero Industrial Act (NZIA) requires that the local share of these technologies deployed in the EU reaches 40% by 2030. Such measures increase barriers to source inputs from outside the EU and potentially divert demand to the 4CEE countries to supply within the EU.

B2. Trade Creation

1. **Increased adoption of low-carbon technologies:** In an effort to reduce its emissions and dependence on fossil fuels, Europe undertook a set of policy actions under the EGD, Next Generation EU and the REPowerEU initiatives. The actions looked to promote the adoption of low- carbon technologies. The

goal is to reduce emissions through increased use of renewables on the supply side (production and distribution of energy) and the use side (consumption of energy). Each EU country has committed to increasing their consumption of renewable energy through various sources to meet the goals set for 2030 (and 2050). The 4CEE countries could use the rise in demand for low carbon technologies within Europe to boost their exports and investments in value chains focused on renewables.

C. Definition of capability alignment using co-exports

Indicator 14 measures how close a country's productive capabilities are to a product by measuring the presence of the country in the neighborhood of the product. We need two inputs to compute this metric, which we call capability alignment. First, we must define a country's productive capabilities embodied in its export structure. To that end, we compute the Revealed Comparative Advantage (RCA) as our indicator of relative export intensity (Balassa, 1965). RCA is the share of a given product on the country's total exports, divided by the share of the same product in world's exports:

$$RCA_{cp} = \frac{X_{cp}}{X_p} \Big/ \frac{X_c}{X} \tag{7}$$

with X_{cp} is export value of product p from country c to the world. Thus, for instance, in the year 2022, cars represented 8% of Romania's exports, but accounted only for 3.4% of total world trade. Hence, Romania's RCA in cars for that year was $RCA_{\text{Romania, cars}}$ = 8/3.4 = 2.35, indicating that cars are 2.35 times more prevalent in Romania's export basket than in that of the world. We use RCA = 1 as the threshold to define whether a product is being exported competitively in a year and country. Furthermore, to filter out data anomalies such as re-exports, we apply a RCA stability criterion. Specifically, we define that a country exports a product competitively if it exhibits a RCA in that product on average over 5 years.

Second, we need to construct a measure of technological relatedness between products. To that end, we draw from Hausmann and Klinger (2007) to define product relatedness $\varphi_{p,p'}$. Equation (8) shows that $\varphi_{p,p'}$ is the conditional probability of co-exporting two given products by the same country. This measure posits that two products are more related to each other the higher the probability of being co-exported is. Specifically, the product relatedness $\varphi_{p,p'}$ between products p and p' for a particular year is defined as:

$$\varphi_{\mathrm{p,p'}} = \frac{\sum_{\mathrm{c}} \mathrm{M_{cp}} \text{ x } \mathrm{M_{cp'}}}{\sum_{\mathrm{c}} \mathrm{M_{cp}}} \tag{8}$$

To define the proximity of a product as it relates to other existing products, we still need a measure that can be expressed at the country and product level. To that end, we construct capability alignment around each product which captures the intensity with which the product under consideration p is related to the current export basket of the same country c. Note that we define products at the HS 6-digit level to achieve the most granular distinction, for example to distinguish cars with and without combustion engine. Relatedness $\varphi_{p,p'}$ refers here to the relatedness measure defined above. More formally,

$$\text{Capability Alignment}_{\mathrm{cp}} = \frac{\sum_{\mathrm{p'}} \mathrm{M_{cp}} \text{x } \varphi_{\mathrm{p,p'}}}{\sum_{\mathrm{p'}} \varphi_{\mathrm{p,p'}}} \tag{9}$$

D. Definition of capability alignment using XG boost

This section describes how we use Extreme Gradient (XG) boost to predict the diversification capabilities of countries, our indicator 15. Introduced by Chen and Guestrin (2016), XG boost is a model-free machine learning algorithm that addresses the problem of overfitting by introducing regularization parameters. Based on a sequential learning process, XG boost iteratively combines regression trees that are considered weak learners and assigns continuous scores to each of the leaves in the tree.

We use the latest annual trade data from CEPII to measure bilateral trade flows for 200 exporting countries in 5,000 HS6 products. We then define RCA_{cp}, as defined in equation (7), for each year between 1995 and 2017, for each country c and product p. We binarize RCA_{cp} to define our target variable M_{cp}, which takes the value 1 if RCA_{cp} exceeds 1, and 0 otherwise.

Since our target variable, RCA_{cp}**,** is binary, this prediction exercise is a classification problem. The XGBoost model is used to capture the structure of comparative advantages across countries for different products, allowing it to estimate the probability (or capability) of a country competitively exporting each of the 5,000 products over the next five years. This approach mirrors the strategy used by Albora et al. (2023).

The prediction exercise is conducted in two ways:

1. Unconditional prediction of M_{cp} for 2021: This approach derives probabilities without accounting for specific transitions in export capabilities.
2. Conditional prediction of M_{cp} for 2021: This prediction focuses on sub-samples where a gain in export competitiveness is observed, specifically, cases where RCA_{cp} was less than 1 in 2017 but exceeded 1 in 2021. Transitions in export competitiveness are uncommon but significant, and as a result, forecasting exercises of this nature possess greater signal to noise ratio.

The XGBoost model is applied to a training set $[RCA_{cp}^{t}\ , I^{t}\ \mid M_{cp}^{t+5}]$, where RCA is the feature, I represents the year effect, M is the target variable. The time period t ranges from 1995 to 2016. For each product, the XGBoost model is trained to learn the structural relationship between RCA_{cp} and the M_{cp} specifically for that product five-year period. This learned relationship is then applied to the test set $[RCA_{cp}^{2017}\ , I^{2017}\ \mid M_{cp}^{2021}]$.

However, to avoid the model leveraging the autocorrelation in RCA_{cp} and instead focus on identifying genuine similarities between products, we partition the exporting countries N = 200 countries into k = 10 disjoint sets. For each set k, the XG boost model is trained on data from the remaining (N - k) countries and tested on the data from the k set of countries. In total, 50,000 models are trained (5,000 products across 10 disjoint country sets). The results from these test sets are then combined to estimate the probability that each country will export competitively (i.e.**,** Mcp = 1) for each of the 5,000 products.

E. Construction of onshoring attractiveness index

Figure E1: Histogram of Onshoring Attractiveness Index

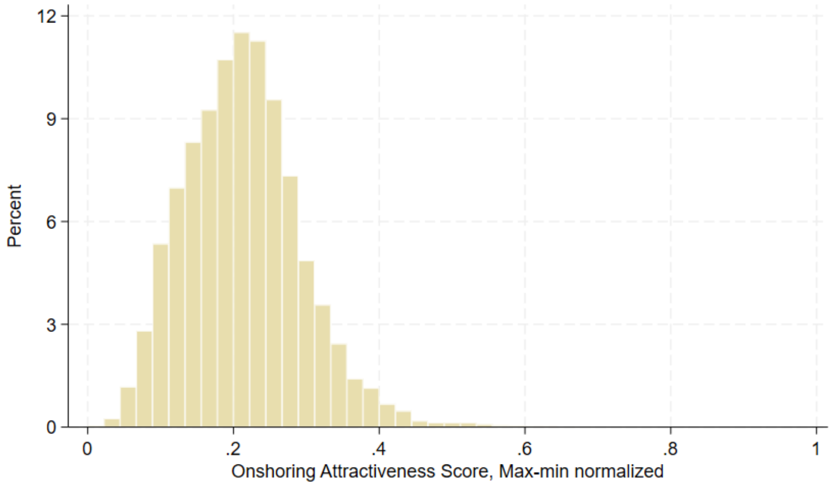

Figure E2: Histogram of Onshoring Attractiveness Index, by 4CEE exporter

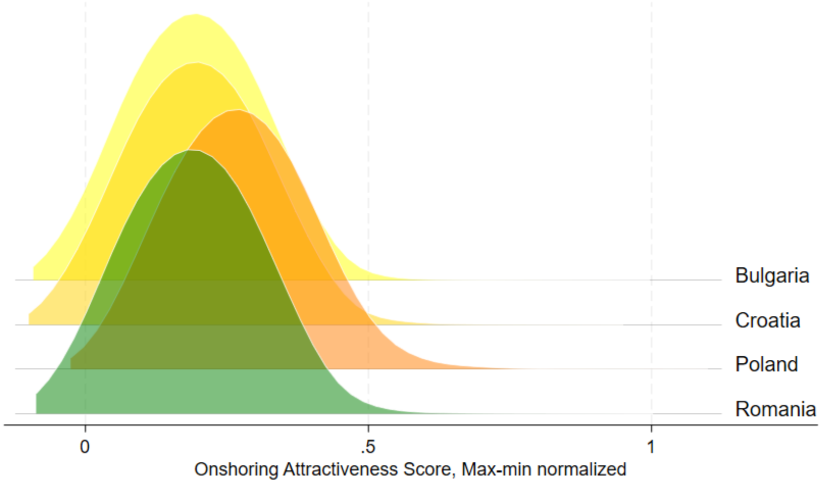

Figure E3: Summary statistics of the K-means clustering

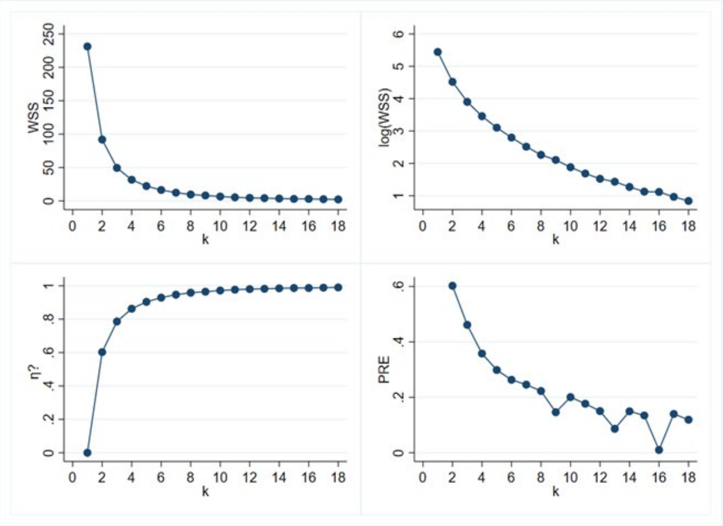

Table E1: Top 10 Onshoring Attractiveness Opportunities

ID	4CEE exporter	Destination	Onshoring Attractiveness	HS 6-digit code	Product Name
1	Poland	Netherlands	1.00	260300	Copper ores and concentrates
2	Poland	Germany	0.98	810430	Magnesium raspings, turnings or granules graded
3	Poland	Germany	0.95	870390	Automobiles, including gas turbine powered
4	Romania	Germany	0.90	870390	Automobiles, including gas turbine powered
5	Bulgaria	Germany	0.90	870390	Automobiles, including gas turbine powered
6	Poland	Belgium	0.87	870390	Automobiles, including gas turbine powered
7	Poland	Germany	0.87	850780	Electric accumulators
8	Croatia	Germany	0.85	870390	Automobiles, including gas turbine powered
9	Croatia	Netherlands	0.81	850422	Liquid dielectric transformers with power handling c
10	Croatia	Germany	0.77	850780	Electric accumulators

Table E2: Bottom 10 Onshoring Attractiveness Opportunities

ID	4CEE exporter	Destination	Onshoring Attractiveness	HS 6-digit code	Product Name
1	Croatia	Cyprus	3E-17	392073	Plates of cellulose acetate, not reinforced
2	Bulgaria	Cyprus	8E-03	392073	Plates of cellulose acetate, not reinforced
3	Croatia	Cyprus	9E-03	280461	Silicon containing by weight >=99.99% silicon
4	Romania	Cyprus	1E-02	280461	Silicon containing by weight >=99.99% silicon
5	Romania	Cyprus	2E-02	260600	Aluminum ores and concentrates
6	Romania	Malta	2E-02	392071	Plates of regenerated cellulose, not reinforced
7	Romania	Cyprus	2E-02	392073	Plates of cellulose acetate, not reinforced
8	Bulgaria	Cyprus	2E-02	280461	Silicon containing by weight >=99.99% silicon
9	Croatia	Cyprus	2E-02	260600	Aluminum ores and concentrates
10	Romania	Portugal	2E-02	392093	Plates of amino resins, not reinforced

F. Measure of capital intensity for each clean tech value chain

Table F1: Capital Intensity Measure

Value Chain	**Capital Intensity**
Wind	0.25
Solar	0.87
Heat pump	0.79
EV	0.46
Electrolyzers	0.10

Note: Capital Intensity is defined in Equation (3).