On a mission for Clean Air and Clean Energy in Central and Eastern Europe

CleanTech for CEE

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CLEAN AIR FUND

"I am delighted to welcome this report, which marks a significant step in our journey toward a cleaner, healthier, and more innovative Central and Eastern Europe. In an era where air quality and sustainable economic growth are deeply intertwined, this report serves as both a diagnostic and a roadmap - highlighting the region's strengths and the untapped potential for indigenous cleantech innovation.

Embracing a future where every breath inspires innovation, this report reimagines clean air as one of the cornerstones to progress in Poland and the broader CEE region. It transforms the challenge of air quality into an opportunity for breakthrough advancements, turning global investments into powerful local clean technology ventures.

As we embark on this transformative journey, the Clean Air Fund is committed to championing initiatives that secure a cleaner, more resilient future. We invite you to explore the strategic recommendations and inspiring narratives within these pages, confident that our collective efforts will drive positive change and set a new benchmark for cleantech leadership in the region."

Sincerely,

Jane Burston

CEO

Clean Air Fund

Authors' foreword

Over the past few months, we have dedicated significant time to conversations exploring the potential for developing homegrown cleantech companies in our region. These discussions have brought together innovators, academic representatives, and key stakeholders from the technology-financing sector, as well as other critical players in the ecosystem.

Our research has taken us across Poland, the Czech Republic, and Slovakia. What has emerged is a complex yet promising picture of a region at a pivotal crossroads - facing three critical challenges: air pollution, industrial transformation, and energy resilience, while also boasting a strong industrial base, technical expertise, and a strategic position that make it well-suited to become an important cleantech hub within Europe.

Our findings show that while cleantech investments in Poland amounted to approximately 2.4% of GDP in 2023, and in Czechia and Slovakia are approaching 2% of GDP, the indigenous innovation ecosystem remains underdeveloped. The region stands at a tipping point - although foreign direct investment dominates, there is a significant opportunity to strengthen local tech companies and integrate them into global supply chains. As supply chain strategies evolve, there is a growing emphasis on resilience, sustainability, and proximity to key markets. This shift presents the region with a unique chance to play a crucial role in developing and supplying the technologies needed for the future, both locally and internationally.

This report isn't merely diagnostic - it offers recommendations to catalyze indigenous innovation, strengthen cross-border collaboration, and reshape the way deep-tech innovations emerge. We believe these measures can unlock the region's full potential, creating a vibrant ecosystem of cleantech startups and scale-ups with European leadership capabilities.

The future is within reach, and we at Cleantech for CEE are committed to supporting the region as it navigates this transformative journey.

Cleantech for CEE team

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Executive Summary

Born out of urgent necessity, Cleantech for CEE focuses on tackling three major challenges in the region. The first one is air pollution, which is undermining economic growth and public health. The second is the need to transform industries, and the third is the need to increase energy resilience. An important puzzle piece to overcome these challenges is innovation and scaling of clean technologies. By accelerating the development and implementation of clean technologies, the Cleantech for CEE initiative aims to create healthier and more prosperous communities while supporting the transition to a more sustainable economic model in the region.

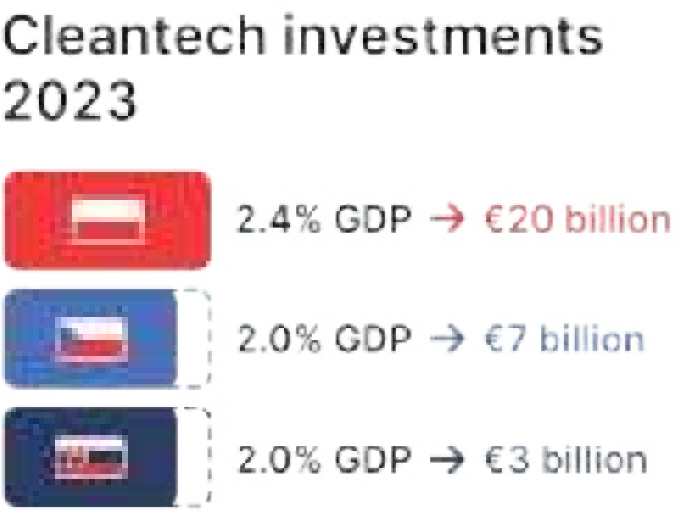
The report unveiled today paints a surprising picture of the cleantech scene in Poland, the Czech Republic, and Slovakia (referred to as a PCS region), advocating for a strategy that goes beyond conventional approaches. Rather than simply increasing R&D budgets, it calls for structural reforms in how innovation takes shape across the region.

As Europe accelerates its transition to cleaner industries and energy resilience, Central and Eastern Europe (CEE) has an opportunity to align its historic strengths with emerging green technologies. By modernizing legacy sectors like manufacturing and energy through targeted innovation - such as retrofitting factories for green steel or scaling renewable energy projects - the region could reduce reliance on volatile fossil fuels while boosting economic competitiveness. Though critics rightly note that sustainability is a shared global aspiration, CEE's distinct challenges - from aging infrastructure to balancing affordability with decarbonization - call for tailored strategies. Prioritizing partnerships with EU initiatives, incentivizing private green investment, and fostering skilled labor transitions may help the region not only catch up but also carve out a strategic niche in Europe's sustainable future.

Poland leads the region with cleantech investments estimated at 2.4% of its GDP in 2023 - amounting to approximately €22 billion. Given the sheer size of Poland's economy (boasting a GDP of approximately €915 billion in 2023), it is unsurprising that it outpaces the Czech Republic and Slovakia in total investment volumes. Czechia's cleantech investments are approaching 2% of GDP, similar to Slovakia. Foreign direct investment (FDI), rather than domestic capital or VC-backed homegrown tech companies, remains the dominant driver. While these investment levels appear substantial in absolute terms, they reflect external funding inflows rather than an organic surge in local cleantech innovation.

The challenge remains in the supply of innovative cleantech companies, which translates into a weak domestic venture capital supply and moderately effective locally-driven green technology accelerators. The key question is not just how much is invested but where this capital is coming from and whether it is fueling sustainable, innovation-led growth within the region.

At the same time, Poland, Czechia, and Slovakia are positioning themselves as key players in the broader European cleantech transition, leveraging their strong industrial base and emerging domestic expertise in battery storage, heat pumps, offshore wind, nuclear, and hydrogen for transport. Poland has become Europe's top exporter of lithium-ion batteries, while Slovakia and Czechia are closely following, strengthening the region's competitiveness in storage solutions. Offshore wind projects in Poland, with a planned 18GW capacity, highlight the growing role of renewables. At the same time, nuclear and hydrogen developments across the three countries further demonstrate a commitment to clean energy innovation.



Beyond hardware, the region's strength in digital technologies is also playing an increasingly critical role in the green transition. Cloud-based platforms and machine learning algorithms enable more efficient energy forecasting, helping manage renewable energy sources' intermittency. Technologies such as blockchain for carbon tracking and digital twin solutions support industrial transformation and optimize decarbonization efforts. The development of artificial intelligence (AI), big data analytics, and IoT is also improving energy efficiency, industrial automation, and smart grid management—ensuring that digital innovation underpins the region's broader shift toward cleaner energy and manufacturing.

Now, the governments need to turn their attention to policies that will help develop indigenous tech companies. These policies should include:

- Breaking into FDI supply chains to build additional resilience. Ensuring not only high local content but, first and foremost, ensuring high local R&D and high value-add tech local content;
- Boosting cross-border knowledge exchange and partnerships. Each individual PCS market is small, but taken together, it becomes material and taken as a whole of Europe, it becomes very attractive;
- Strategic R&D hub developments. These should include battery technology hubs, nuclear research facilities for SMR development, advanced waste management centers, clean mobility research facilities, and smart grid integration hubs for balancing and demand response innovations. Each facility must be equipped with industrial-scale testing capabilities, specialized research equipment, and pilot production lines to enable rapid prototyping and validation under real-world conditions. These hubs should establish formal collaboration agreements with leading global research institutions and industrial partners, enabling regular knowledge exchange and access to emerging technologies.
- Funding. Need for designing and introducing relevant funding instruments by integrating the skills and know-how of the local financial institutions, coupled with the EU's financial instruments.

Additionally, the CEE could build on its comparative advantage in higher education through smart reforms by linking to the broader vision presented in the Union of Skills put forward by the European Commission. The PCS region should seek to create hubs of expertise in the region to support European Competitiveness.

- Our research suggests that should these steps be rolled out, we will see a thriving community of cleantech startups and scale-ups in the PCS region, with a high potential for leadership in the EU. The increased supply of cleantech startups will be noticed in no time by VC managers, who will reach out for the LP capital that is already available today to organize more VC cleantech funds. This will, in turn, accelerate the launch of more cleantech startups, and a value-creation machine will be set off.

The additional benefit from this development are FDIs more rooted in the local economies, who employ and develop local high-value-added managerial talent. This future is promising, and as Cleantech Chapter CEE, we are committed to our mission of supporting businesses, investors, and governments to become active players in the clean industrial revolution.

Chapter 1

Status of transition to net zero and air pollutants reduction in Poland, Czechia and Slovakia

The adoption of decarbonization and clean air technologies in the Poland, Czechia and Slovakia (PCS countries) has historically been slower compared to the Western EU member states, primarily due to the social and capital costs involved, considering how dependent the PCS region has been on coal during its communist past. Coal miners were extolled by the communist regimes and the subsequent governments as state heroes, delivering "gold" to their countrymen. Coal was relatively inexpensive, contributing to the industry's competitiveness while lifting the social status of the coal miners.

Coal, as a fuel source in the central heating systems across PCS, together with the transport sector, is the key source of air pollutants, such as $PM_{2,5}$ and NO_2, which are directly harmful to health.

Current Situation - Poland:

Poland suffers from high levels of $PM_{2.5}$, PM_{10}, and NO_2 pollutants.

Poland is also the EU's third-largest emitter of greenhouse gases (GHG), contributing approximately 10.5% of total emissions. Additionally, rising ETS prices for the power sector make coal increasingly unviable without state subsidies - public funds that would be better invested in clean technologies. The Modernisation Fund, established under the EU ETS, provides a significant opportunity for Poland, as one of its top three beneficiaries (alongside Czechia and Romania), to accelerate the transition to cleaner energy, improve air quality, and strengthen energy security. Administered with the support of the European Investment Bank, this fund - alongside the Just Transition Fund - can drive structural changes in coal-dependent regions. Ensuring these resources are effectively used for sustainable transformation rather than prolonging coal dependency is crucial to achieving long-term climate and economic objectives.

Key polluting regions include Southern Poland, which generates over 50% of the country's industrial emissions, and the Bełchatów region, home to Europe's largest lignite-fired power plant. Major GHG-polluting sectors include coal mining, lignite-based power plants, cement,

and chemical industries. However, Poland's battery production leadership and offshore wind plans (3.4 GW by 2030) position it as a regional leader in renewable energy expansion.

Table 1 - Poland's Energy Mix and Emissions Profile

Challenges and Opportunities in Transformation

Challenges:

Poland's heavy reliance on coal and carbon-intensive industries significantly pressures its economy under the EU Emissions Trading System (ETS) and Carbon Border Adjustment Mechanism (CBAM). Despite this dependence, a significant portion (ca. 24%) of the coal Poland burns is imported, meaning that transitioning to domestically produced renewable energy would reduce emissions and enhance the country's energy independence. Modernizing its industrial sector, estimated to cost €30–60 billion, demands urgent action to avoid rising carbon costs and EU penalties. Key hurdles include transitioning coal-dependent regions like Silesia, upgrading aging energy infrastructure, and addressing workforce gaps in green skills.

Opportunities:

- Hydrogen Economy: As Europe's third-largest producer of "grey" hydrogen, Poland is pivoting to low-carbon and renewable hydrogen through electrolysis powered by offshore wind and solar. This shift reduces reliance on coal, positions Poland as a future hydrogen exporter, and leverages EU funds like the Modernization Fund.
- Battery Recycling and Innovation: Producing 60% of EU-made batteries, Poland is scaling circular econmy solutions to cut import dependency (currently 80% on Asian materials). Companies like Eneris are pioneering high-efficiency recycling processes, recovering lithium, cobalt, and nickel while reducing CO_2 emissions. This strengthens domestic supply chains and aligns with CBAM requirements for sustainable sourcing.
- Offshore Wind and SMR Nuclear: 18 GW of offshore wind by 2030 will displace coal in power generation, while partnerships with Westinghouse on small modular reactors (SMRs) offer a long-term, low-carbon energy backbone for industry. These projects create jobs in regions like Gdańsk and Szczecin, mitigating coal phase-out impacts.
- Industrial Transformation: Retrofitting heavy industries (e.g., steel, cement) with carbon capture and renewable energyintegration ensures compliance with ETS and enhances global competitiveness. Support from the Just Transition Fund (JTF) and the Modernization Fund further accelerates these efforts by financing low-carbon projects and industrial decarbonization.

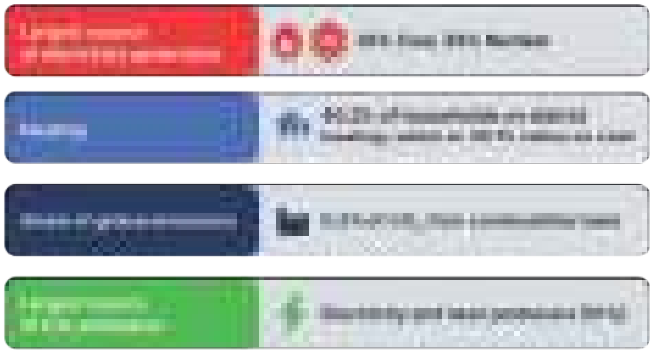
Even though the coal legacy complicates decarbonization, Poland can reduce CBAM risks and lower long-term energy costs by redirecting coal subsidies to renewables, upskilling workers, and attracting FDI into cleantech. The World Bank underscores that proactive decarbonization is €200–400 million per year cheaper than inaction. Once heavily reliant on coal, the UK managed to go coal-free within a decade, while more than 10 EU member states have committed to phasing out coal by 2030. With the EU set to exit coal by 2035 at the latest, Poland risks being among the last to transition, despite even importing a significant share of the coal it burns.

Current Situation - Czech Republic:

The Czech Republic suffers from high levels of $PM_{2.5}$, PM_{10} and NO_2 pollutants.

The Czech Republic's GHG emissions per GDP and per capita remain among the EU's highest. Key polluting regions include the Moravian-Silesian region, dominated by coal mining and steel production, and Ústí nad Labem, known for chemical industries and coal mining. The main polluting sectors are coal-based energy production, machinery manufacturing, and automotive production. Despite these challenges, the Czech Republic is leveraging its advanced manufacturing base, mainly through Škoda Auto's electrification efforts and investments in renewable energy infrastructure by CEZ Group. The nation aims to modernize its industrial base while addressing the delayed phase-out of coal (targeted by 2033).

Table 2 - Czechia's Energy Mix and Emissions Profile



Challenges:

Czechia's heavy reliance on the automotive and manufacturing industries makes industrial emissions a key obstacle, requiring stricter standards and energy efficiency upgrades to comply with EU CBAM and ETS regulations. A substantial funding gap further hinders decarbonization efforts, as an estimated €18 billion is needed by 2030, while the National Energy and Climate Plan (NECP) lacks clarity on managing the rising electricity demand driven by electrification. Additionally, the rapid expansion of renewable energy sources is straining grid infrastructure, necessitating urgent investments in energy storage and system balancing.

Opportunities:

- Energy Storage Leadership: The Czech Republic is well-positioned to lead in energy storage solutions, with CEZ Group's investments in grid-scale battery storage and hydrogen projects that stabilize renewable energy integration. This creates a significant potential to address grid instability. HE3DA's lithium-ion battery plant near Prague also fosters EV adoption and industrial electrification, supporting the automotive sector's decarbonization.
- Renewable Energy Expansion: With CEZ's 600 MW solar portfolio and growing wind

capacity, the Czech Republic has promising prospects to reduce reliance on fossil fuels and cut industrial emissions. Expanding renewable energy capacity will enhance energy security andattract investment in green energy, supporting the country's climate goals.

- Deeptech Innovation: Expertise in AI and advanced manufacturing offers a competitive advantage in optimizing energy use in heavy industries. Technologies like smart factories and predictive maintenance present significant potential to increase industrial energy efficiency while driving the transition toward low-carbon production methods.
- Hydrogen Economy: With CEZ's pilot hydrogen projects focused on steel and transport sectors, the Czech Republic has a broad scope to replace coal-derived hydrogen and mitigate CBAM costs. These projects offer a valuable pathway to reduce carbon emissions and position the country as a leader in hydrogen-based energy solutions.

While transitioning to low-carbon technologies presents challenges, Czechia can maintain and strengthen its global position in the automotive and manufacturing industries by embracing cleaner production methods. This is particularly critical in light of the EU's 2035 internal combustion engine phase-out, which will require a shift toward electrification, hydrogen-based solutions, and advanced energy efficiency measures. By investing in these emerging technologies, Czechia can future-proof its industrial base while ensuring continued economic competitiveness in a decarbonized global market.

The Czech Republic's €18 billion funding gap can be addressed by redirecting fossil fuel subsidies to projects like CEZ's renewables and HE3DA's batteries, which also tackle grid stability and industrial emissions. HE3DA's batteries allow energy-intensive factories to store excess solar/wind power, reducing peak-time grid strain. The World Bank warns that delayed decarbonization could cost CEE economies 2–3% of GDP annually by 2030, highlighting the urgency of these investments.

Current Situation - Slovakia:

Slovakia suffers from moderate levels of $PM_{2.5}$, PM_{10} and NO_2 pollutants.

Slovakia has taken significant steps toward decarbonization, being the first Central European country to commit to carbon neutrality by 2050. Key polluting regions include the Košice region, heavily influenced by steel production, and Upper Nitra, historically reliant on lignite mining. Slovakia's polluting sectors include energy production, metallurgy, and the automotive industry. Nuclear energy, particularly from the Mochovce plant, is a cornerstone for transitioning to a low-carbon economy.

Table 3 - Slovakia's Energy Mix and Emissions Profile

Challenges:

Slovakia encounters substantial obstacles in its decarbonization initiatives. The country needs €3.35 billion by 2030 to decarbonize

its key industries, including steel (€1.4B), cement (€0.5B), and chemicals (€0.5B), as outlined in its National Energy and Climate Plan (NECP). Emissions-intensive sectors, such as steel and cement, contribute heavily to CO_2 emissions, making it difficult to comply with the EU Emissions Trading System (ETS). While Slovakia has access to €368 million from the Recovery and Resilience Plan and €2.6 billion from the Modernization Fund, private investment is crucial to close the funding gap. Additionally, Slovakia needs to modernize its grid infrastructure to accommodate expanding renewable energy and hydrogen projects, as the existing systems are outdated and require significant upgrades.

Opportunities:

- EV Manufacturing Hub: Slovakia's significant investments in electric vehicle production, including Volvo and Jaguar Land Rover's commitment of over €1.45 billion, present a prime avenue for reducing transport emissions.
- Nuclear Energy Leadership: With atomic power generating 62% of its electricity, Slovakia has the potential to reinforce its energy security and mitigate reliance on fossil fuels. Partnerships such as the one with Newcleo for advanced reactors (€3.2B) offer a transformative opportunity to modernize the energy grid, boost grid stability, and decarbonize industrial processes, solidifying Slovakia's role as a leader in sustainable energy.
- Hydrogen Innovation: The EASTGATEH2 hydrogen valley in Košice, with €41 million in funding, provides Slovakia with a unique prospect to pioneer hydrogen-powered transport and heavy industry solutions. This initiative could serve as a blueprint for the broader region, establishing Slovakia as a front-runner in hydrogen technology and facilitating the decarbonization of multiple sectors.
- Battery Component Production: Slovakia's strategic proximity to automotive giants and its strong focus on STEM education creates a valuable opportunity to become a key player in the European battery supply chain. As demand for electric vehicle components grows, Slovakia benefits from increased investment and industry partnerships.

Slovakia addresses heavy industry reliance and decarbonization costs through investments in EVs, hydrogen, and nuclear energy. Volvo's EV production boosts demand for low-carbon steel, while the EASTGATEH2 hydrogen valley reduces fossil fuel use. Atomic energy (62% of electricity) ensures stable, affordable manufacturing. Delaying action could increase costs by 20–30% by 2030 (NECP), but prioritizing these sectors drives sustainable growth and positions Slovakia as a leader in clean energy and mobility.

Clean Air and Air Quality in the PCS region

The PCS region faces critical air pollution challenges shaped by shared economic and environmental conditions. The European Environment Agency (EEA, 2023) highlights that these countries' primary sources of air pollution are residential heating, road transport, and industrial emissions. The widespread use of coal and wood for heating in outdated household boilers remains one of the most significant contributors to $PM_{2.5}$ emissions, especially during winter. This problem is prevalent in both urban and rural areas, where reliance on solid fuels continues despite available cleaner alternatives.

Road transport is another key factor in the region's air pollution crisis. Diesel vehicles and traffic congestion in major cities, such as Warsaw, Prague, and Bratislava, drive high levels of NO_2 emissions, with the aging vehicle fleet exacerbating the problem. This challenge is further intensified by the influx of older, high-emission vehicles from Western Europe, which are increasingly resold into Central and Eastern European (CEE) markets as stricter diesel bans and emissions regulations take effect elsewhere. As a result, CEE countries are absorbing a disproportionate share of Europe's most polluting vehicles, further worsening air quality and public health risks. Meanwhile, industrial activities, particularly in southern Poland, northern Czech Republic, and eastern Slovakia, contribute significantly to both $PM_{2.5}$ and NO_2 pollution due to coal combustion in power plants and heavy industry. In certain areas, agricultural practices, including biomass burning, further degrade air quality, particularly in rural regions.

The health and economic consequences of poor air quality in the PCS region are severe. In Poland alone, 40,000 premature deaths annually are linked to $PM_{2.5}$ exposure from heating and NO_2 emissions from transport (HEAL Report, 2022). Similar challenges exist in the Czech Republic and Slovakia, where high levels of air pollution contribute to respiratory illnesses, cardiovascular diseases, and decreased life expectancy. The economic burden is equally significant, with increased healthcare costs, reduced workforce productivity, and potential EU penalties for failing to meet air quality standards (OECD, 2023). In all three countries, air particles accumulate particularly during winter, exacerbated by temperature inversions that trap pollutants near the ground, worsening public health risks and economic costs.

Map 1 - Air Quality Index (AQI) Comparison in the PCS Region (2024)

As the map illustrates, changes have been slow primarily because respective governments must be sensitive to their voters. It has been difficult to adhere to a long-term progressive agenda, as policymakers tend to focus on immediate goals, such as lowering energy costs, at the expense of long-term sustainability. Governments have prioritized reducing energy costs for consumers over incentivizing investment in clean energy projects, leading to delayed transformation efforts.

For example:

- **Poland:** Delays in renewable energy auctions and unclear grid access policies disrupt investment plans, deterring investor commitment. This unpredictability in policy has resulted in a lack of investor confidence, slowing the pace of clean energy adoption.
- **Czechia:** Retroactive reductions in photovoltaic subsidies: the Czech Republic approved measures to retroactively reduce state subsidies for renewable energy sources, specifically targeting solar power plants with a capacity exceeding 1 megawatt. These proposed retroactive

cuts have prompted legal challenges from investors, raising concerns about the stability of the investment environment for renewable energy.

- **Slovakia:** The updated National Energy and Climate Plan for 2030 lacks detailed strategies to meet EU energy efficiency targets, creating uncertainty for stakeholders. The absence of clear action plans has made it difficult for companies to align their investments with national targets.

Some important steps have been taken recently in Poland by Prime Minister Tusk, who in 4Q24 and January 25 committed Poland to offshore wind generation, Baltica 2 of 18 GW, and SMR nuclear with the technological investment by the Canadian Westinghouse.

Pollution Hotspots in the PCS Region

While air pollution is widespread across all three countries, certain areas are particularly affected. In Poland, Małopolska (including Kraków) and Śląsk (Silesia) experience some of the worst air quality in Europe, with high $PM_{2.5}$ levels from coal heating and industrial activity. In the Czech Republic, the Moravian-Silesian Region, Northern Bohemia, and the "Black Triangle," a historically industrial border area shared with Germany and Poland, continue to struggle with severe air pollution. Slovakia, while having lower $PM_{2.5}$ levels overall, faces challenges in Košice, Prešov, and rural areas in central and eastern Slovakia, where solid fuel heating and traffic emissions remain significant concerns.

All three countries are focused on accelerating renewable energy adoption and industrial decarbonization, but they face common challenges, including gaps in renewable energy capacity, the need for grid expansion, and securing sufficient long-term investment. Collaborative efforts such as cross-border energy grids and regional battery supply chains are part of their strategies to address these challenges. However, the path to decarbonization remains complex, requiring substantial investments and overcoming barriers in industrial adaptation and infrastructure development.

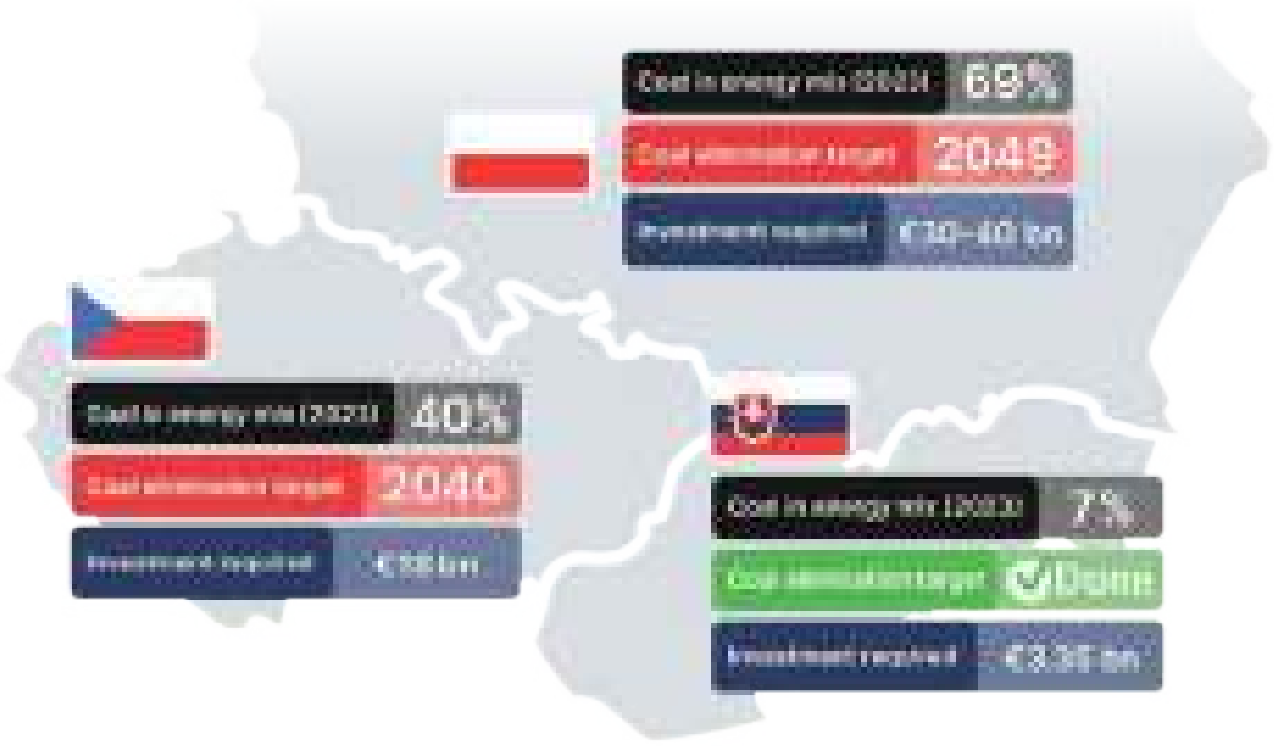
Table 4 - Comparative Summary

Aspect	Poland	Czech Republic	Slovakia
$PM_{2.5}$ Levels	High (20–25 µg/m³)	Moderate (15–18 µg/m³)	Lower (12–15 µg/m³)
PM_{10} Levels	Frequently exceeds limits	Occasional exceedances	Occasional exceedances
NO_2 Levels	High in cities	Elevated in urban areas	Concentrated in cities
O_3 Levels	Moderate, seasonal peaks	Moderate, seasonal peaks	Moderate, seasonal peaks
Main pollution sources	Coal heating, industry, transport	Transport, industry, heating	Transport, industry, heating
Policy Focus	Clean heating, renewables	Public transport, energy efficiency	Clean transport, renewable

According to the latest Communication on a Clean Industrial Deal (CID), the EU is supporting cleantech demand through public procurement and new de-risking instruments from the European Investment Bank (EIB). These include a Cleantech Guarantee Facility, a Counter Guarantee for SMEs to contract Power Purchase Agreements (PPAs), and a Grid Manufacturing Counter Guarantee. Despite these supportive measures, uncertainties around funding details and implementation timelines remain, and securing sufficient investment will be crucial for Poland, the Czech Republic, and Slovakia to meet their decarbonization and clean air goals

In conclusion, material funding will flow to the PCS countries for industrial decarbonization. How can we ensure that in parallel to these funds being spent on purchased foreign technologies, the indigenous cleantech sector will develop?

Map 2 - Decarbonization Targets and Investment Needs in PCS Region



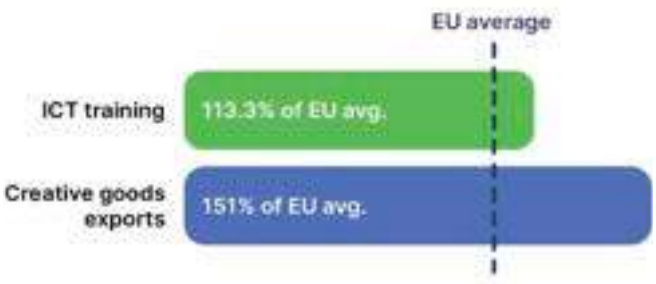
Chapter 2
Country innovation profiles

Poland

According to the European Innovation Scoreboard 2024, Poland is classified as an Emerging Innovator, with a performance at 65.9% of the EU average in 2024. Regarding environment-related technologies, Poland scored 46.8% of the EU average in 2024, showing a significant decline of 68.3 percentage points since 2017 and a further 25.4 percentage point drop in the last year. This indicates a substantial weakening in Poland's development and adoption of green technologies.

Poland's R&D landscape is characterized by low public expenditure at 0.53% of GDP, consistently below the EU average (62.3% of the EU average in 2024). Business R&D expenditure is increasing but remains below the EU average (63.9% of the EU average in 2024). However, Poland ranks first among Emerging Innovators in this category, partly due to enhanced R&D tax incentives fostering private investment. In terms of innovation activities, Poland faces significant challenges. Polish SMEs lag well below the EU average in introducing product and business process innovations (43.1% and 47.5% of the EU average, respectively). Collaboration between innovative SMEs and public-private cooperation is also low, with Poland ranking third last among EU Member States in the latter (56.6% of the EU average).

Despite these challenges, Poland shows strength in certain areas. The country surpasses the EU average in enterprises providing ICT training (113.3% of the EU average), ranking first among Emerging Innovators. Poland also demonstrates a notable capacity to export creative goods, reflected in its strong performance in design applications, ranking third among EU Member States (151.0% of the EU average). In-house innovation remains a challenge, with only 5.9% of enterprises introducing product innovations with market novelties (compared to the EU average of 11.7%) and 8.2% introducing product innovations without market novelties (EU average of 13.7%).



Regarding climate change mitigation and adaptation, Poland exhibits a lower circular material use and eco-innovation index compared to the EU average, with higher greenhouse gas emissions. However, the country aims to bolster its environmental efforts through cohesion funds and the Recovery and Resilience Plan, focusing on advancing environmental technologies and transitioning towards a circular economy.

Czech Republic

The Czech Republic demonstrates a strong innovation performance according to the European Innovation Scoreboard 2024. The country's Environment-related technologies score stands at 83.6% of the EU average in 2024, showing a slight improvement of 6.9 % in 5 years. The Czech Republic's innovation landscape is characterized by increasing private sector investments, particularly in R&D. Venture capital expenditures have seen a significant rise (+87.2%-points since 2017), and companies are improving efficiency in innovation spending, with non-R&D innovation spending reaching 160.5% of the EU average in 2024. However, there's a notable lack of government support for public sector R&D (-29.5% points since 2017) and limited direct and indirect support for business R&D (61.8% of the EU average in 2024).

The country excels in in-house product innovation. The score for in-house product innovators with market novelties (17.2% compared to the EU average of 11.7%) indicates that Czech companies are significantly more likely to develop and introduce new products to the market than their EU counterparts. Similarly, the score for in-house product innovators without market novelties (17.7% vs. EU average 13.7%) suggests a strong capacity for incremental innovation, where existing products are improved rather than entirely new ones created.

These figures reflect the effectiveness of Czech strategies to support SMEs and the country's Innovation Strategy 2019-2030. Despite lower enterprise birth rates and buyer sophistication compared to the EU average, the Czech Republic attracts significant foreign direct investment (3.9% of GDP), attributed to investment incentives, skilled labor, and favorable geographical location.

In terms of climate change mitigation and adaptation, the Czech Republic shows lower greenhouse gas emissions and eco-innovation index compared to the EU average, with ambitious targets to reduce emissions by 30% by 2030.

Slovakia

According to the Innovation Performance Board, the country demonstrates a higher rate of enterprise births and entrepreneurial activity (9.3%), surpassing the EU average, supported by initiatives like SAPIE and various accelerators and incubators. Slovakia is also bolstered by organizations such as the Slovak Battery Alliance (SBaA), the National Hydrogen Association Slovakia (NVAS), the Research and Innovation Agency (VAIA), the Slovak Innovation

and Energy Agency (SIEA), Prumatech Centre - Centre for Advanced Materials and Technologies, with €20 million in research infrastructure, and the Innovation Centre of Košice Region (ICKK), which provides €10 million in support for the start-up ecosystem.

However, Slovakia performed below the EU average across most investment metrics in 2024, with one exception: non-R&D innovation expenditures, which scored 100.7%, aligning with the EU average. Despite this, public-sector R&D expenditure has seen a significant drop (-67.2%-points), although direct and indirect government support for business R&D has risen notably (+48.8%-points). Venture capital expenditures and firm investments have also experienced moderate growth, driven by increases in both R&D and non-R&D innovation expenditures, supported by the Slovak Investment and Trade Agency.

Slovakia continues to face challenges in translating entrepreneurial energy into innovative outputs. The country lags behind the EU average in in-house product and business process innovations, with only 8.9% of firms introducing market novelties compared to the EU average of 11.7%. Conversely, Slovakia has a higher percentage of non-innovators with the potential to innovate, indicating untapped capacity.

In terms of climate change mitigation and adaptation, Slovakia's metrics show mixed results. While its greenhouse gas emissions intensity is lower than the EU average, its circular material use rate and Eco-Innovation Index remain below average. The country is striving to meet its 2030 renewable energy target (19.2%) through investments in onshore wind, photovoltaics, and bioenergy.

Overall, Slovakia's innovation system exhibits moderate growth in investments but struggles with low R&D expenditure in the business sector and declining ICT usage.

Table: Country Innovation profile overview

Category	Poland	Czech Republic	Slovakia
Innovation index (as % of EU average)	65.9%	89.73%	65.09%
Performance category	Emerging Innovator (above group average at 48%)	Leader in medium/high-tech sectors (42.6%)	Higher non-innovators with potential to innovate
Improvement Rate to EU baseline (in % points)	+2.66	+1.61	+1.01
Strengths	Strong in ICT training, creative goods export	Excels in in-house innovation and collaboration	Strong in high-tech exports and SME collaborations
Challenges	Significant gap to reach EU average, weak SME innovation	Lags in intellectual property, reduced public R&D support	Low business R&D expenditure, weak circular material use

Chapter 3
Foreign Direct Investment (FDI) inflow into the PCS region

Poland:

- Stable but Declining FDI: According to UNCTAD's World Investment Report 2024, Poland maintained relatively stable FDI levels, with a decrease from approximately $828 per capita in 2022 to around $750-$755 per capita in 2023, based on a population of 38 million and an FDI inflow of $28.6 billion.
- Emerging Battery Hub: Poland is becoming a European leader in battery manufacturing (e.g., LG Chem), driving the shift to electromobility, although local supplier integration remains weak.
- Need for Diversification: Investments must expand into renewable energy, innovation ecosystems, and high-value manufacturing to reduce dependence on fossil fuels and strengthen economic resilience.

Czech Republic:

- Moderate Decline in FDI: Czechia experienced a decrease in FDI per capita, from approximately $860 in 2022 to around $720 per capita in 2023, based on a population of about 10.7 million and an FDI inflow of $7.8 billion in 2023 (down from $9.2 billion in 2022) (UNCTAD, Czech National Bank). The decline reflects a more significant drop compared to previous years, particularly due to global economic uncertainties. However, sectors such as manufacturing and machinery production continue to perform strongly, maintaining Czechia's position as a key investment destination in Central Europe.
- Advanced Industrial Base: The automotive sector (Škoda Auto) and machinery industries remain highly competitive, benefiting from better technological integration and higher local supplier participation compared to regional neighbors.
- Future Focus on Innovation: Czechia has opportunities to strengthen R&D, modernize smart grids, and accelerate decarbonization to sustain its industrial leadership and attract green investments.

Slovakia:

- Sharp Decline in FDI: Slovakia experienced a significant drop in FDI per capita, from approximately $8000 (2000–2012) to $1000 (2020–2023), mainly due to heavy reliance on the automotive sector. In 2022, FDI inflows totaled $2.9 billion, but Slovakia faces challenges from limited diversification. Additionally, FDI inflows were negative by $287 million in the first half of 2023, compared to $1.22 billion in the same period in 2022 (UNCTAD, Slovak Central Bank)
- Automotive Industry Dominance: Investments are concentrated in automotive manufacturing (Volkswagen, Kia, Jaguar Land Rover), contributing around 40% of total exports, though with limited R&D integration and local supplier participation.
- Challenges and Opportunities: Slovakia's high dependency on foreign investors poses challenges, but opportunities exist in green transition, battery production (InoBat), and electrification technologies to enhance competitiveness and sustainability.

Chapter 4
Critical technologies and cleantech solutions in PCS

The region has been upgrading its electricity, heating, and transport infrastructure, almost exclusively with imported technologies.

Nuclear energy and SMRs:

In Poland, nuclear energy remains a cornerstone of Poland's energy mix, estimated to provide 19 GW of electric capacity by 2050. There is an urgent need for infrastructure upgrades, policy alignment, and regional collaboration to ensure a sustainable and competitive energy transition. Poland has partnered with the Canadian Westinghouse. Czechia operates six nuclear reactors, and there are plans to construct two new reactors at Dukovany and Temelin. Current reactors use VVER technology (developed by Russia). New reactors are being developed in partnership between CEZ and Rolls-Royce SMR. In Slovakia, nuclear energy has been a cornerstone of Slovakia's energy system for half a century, providing low-carbon electricity without greenhouse gas emissions. In 2025, nuclear power accounted for 61.9% of Slovakia's electricity, primarily generated by five VVER 440 pressurized water reactors: two at Bohunice and three at Mochovce. VVER is a technology developed in Russia. Slovakia is further advancing its nuclear capabilities with plans for a new 1200 MW reactor and a €3.2 billion partnership with Newcleo to build four 200 MWe lead-cooled fast reactors at Bohunice.

Battery sector:

The EU is experiencing rapid growth in battery and energy storage manufacturing, driven by increasing demand for electric vehicles (EVs), grid modernization, expansion, and flexibility. Poland benefits from its attractiveness to foreign direct investment (FDI) from Asian firms, positioning itself as "a bridge between East Asian battery manufacturers and European

automotive OEMs." The country offers several key advantages, including lower labor costs, affordable land, access to natural resources, and government subsidies, which have made it a growing hub for battery production. Poland, alongside Germany, is at the forefront of this expansion, with significant investments in new lithium-ion battery manufacturing facilities. Numerous R&D projects are underway, focusing on recycling and second-life applications. Lithium-ion batteries now account for over 2.4% of Poland's total exports, generating net export revenues exceeding €8 billion in 2022. This strong market position lays a solid foundation for advancements in other energy storage technologies, supported by investments from companies such as LG Energy Solution, LG Chem, Umicore, SK Hi-Tech Battery Materials, Capchem, Guotai Huarong, BMZ, and others.

The long-term success and Poland's market leadership in the battery sector will require the following:

- reduction of import dependency,
- scaling up domestic production of battery-active materials,
- access to skilled labor,
- aligning its energy policies with EU sustainability standards to remain competitive in the evolving European battery market.

Poland faces a critical challenge in its heavy reliance on imports from outside the EU, which account for 80% of its battery supply chain. This dependency is driven by the strong integration of Poland's value chain with Asia, largely due to investments from South Korean and Chinese manufacturers. The issue is particularly acute for critical raw materials such as cobalt, lithium, and nickel, none of which are mined in Poland—except for the small Szklary nickel deposit. Umicore's gigafactory for battery materials in Nysa represents significant but not yet sufficient progress in strengthening Poland's domestic supply chain.

Access to skilled labor remains a significant challenge, raising concerns about the long-term sustainability of this growth. This issue is not only linked to education gaps but also to outward migration, making national education reforms insufficient on their own. Instead, regional cooperation under EU initiatives like the Union of Skills could support circular migration by ensuring competitive wages for returning workers. Existing models, such as Woltair's School of Skills and renewable energy training programs in Romania, highlight the potential for cross-border solutions that strengthen the entire region's workforce. Encouraging such collaborative efforts will be key to sustaining Poland's competitive edge in the battery sector.

Another critical challenge in developing battery production in Poland is the country's energy mix. Battery and electric vehicle manufacturers often require 100% renewable energy, as these industries have been traditionally among the most energy-intensive, but must now adhere to stringent sustainability standards. The European Commission is currently working on implementing acts for the EU Battery Regulation, which will establish methodologies for calculating the carbon

footprint of batteries. In the worst-case scenario for Poland, the carbon footprint of battery production could be assessed based on the country's average carbon intensity of the grid, which remains heavily reliant on coal and fossil fuels. If this methodology is adopted, it will present a significant challenge for Poland's cleantech sector, but it also serves as a strong incentive to accelerate grid decarbonization. Successfully aligning battery production with lower carbon intensity would not only secure Poland's role in the European electric vehicle supply chain but also enhance its long-term competitiveness in the global clean technology market. To ensure long-term competitiveness, Poland should accelerate its transition to renewable energy sources, aligning its industrial strategy with EU decarbonization goals to meet the evolving sustainability requirements of the global battery market.

The Czech Republic and Slovakia are increasingly positioning themselves as key industrial production hubs. Czechia hosts one of Europe's largest hardrock lithium deposits, with mining and lithium hydroxide production slated to begin in 2026. This development enhances Czechia's potential to become a major center for lithium battery production. Additionally, the country's robust automotive sector and the ongoing shift to electric vehicles present significant opportunities. Czechia could also benefit from enhanced regional collaboration with other Central and Eastern European Member States. However, the Czech industrial sector encounters notable obstacles in attracting consistent foreign investment, which can be attributed to infrastructure shortcomings, regulatory and bureaucratic challenges, and a limited pool of skilled labor.

In Slovakia, several battery manufacturing initiatives are already underway. The nation's substantial number of primary metal producers, coupled with its proximity to automotive manufacturers, creates a promising foundation for the battery industry and the future of mobility. Furthermore, Slovakia's emphasis on STEM and engineering education, along with its active engagement in R&D, bolsters the industry's growth potential. Nevertheless, Slovakia lacks substantial mining capacity for battery materials and is already highly dependent on imports for batteries and energy storage technologies, with 67% sourced from outside the EU. This reliance could pose a significant challenge to the future expansion of Slovakia's battery sector. Adopting a long-term strategic vision, underpinned by a stable and supportive policy environment and increased R&D investments, would further solidify the lithium-ion battery industry across the Central and Eastern European region.

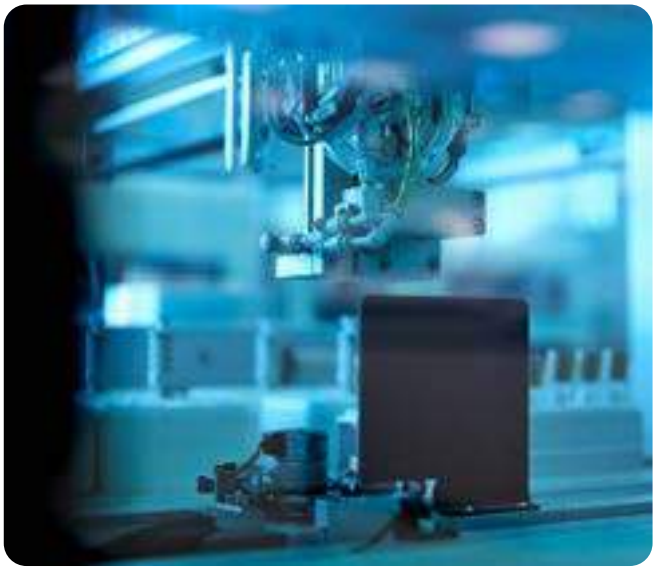
Heat Pumps:

Despite already mentioned hurdles, these countries collectively form an emerging "heat pump valley," showcasing strong export potential and a capacity for cross-border collaboration. By addressing domestic adoption barriers and leveraging EU funds, the region could strengthen its position in the heat pump market, driving cleantech innovation and

contributing to sustainability goals. Poland is positioning itself as a major player in the heat pump sector, with companies such as Daikin Poland and Viessmann Poland at the forefront of high-efficiency heat pump system development. These companies are also working to strengthen local supply chains by investing in training programs and workforce development, ensuring a skilled labor pool for the growing industry.

However, domestic demand for heat pumps faces significant challenges. The high electricity prices driven by an electricity market pricing mechanism, which continues to employ marginal pricing driven by the gas market, remain unfavorable. Gas is currently four times cheaper than electricity, discouraging homeowners and businesses from switching to electric heating solutions. Additionally, a lack of transparency in electricity pricing and a slowdown in new home construction and renovation projects have further hindered market growth.

A broader concern regarding the heat pump sector's expansion is that demand has been heavily influenced by government subsidies. However, this is a standard and necessary approach in the early stages of new technology adoption, helping to drive down costs and facilitate long-term market stability. Just as the electric vehicle industry experienced a decline in battery demand when subsidies were reduced, a similar pattern could emerge for heat pumps if government incentives are scaled back. Ensuring a sustainable market for heat pumps will require more than just short-term policy support—it will demand structural energy reforms, a more competitive electricity pricing model, and continued investments in domestic production capabilities and infrastructure. By addressing these factors, Poland and its regional partners can transition from relying on subsidies to building a self-sustaining heat pump industry that is globally competitive.



According to the European Commission's report on the Net-Zero manufacturing industry landscape across Member States, the Czech Republic has emerged as a significant contributor to the heat pump industry, with exports increasing by 215% between 2015 and 2022. The report highlights that the country has a strong competitive position in producing wind turbine components and heat pumps, relatively outperforming both China and the USA in its respective segments. Additionally, the Czech Republic's untapped export potential in this sector exceeds €250 million.

Companies like Thermia Heat Pumps play a key role in producing residential and industrial heat pumps that cater to the EU market.

Despite its export success, domestic adoption of heat pumps remains limited. The unfavorable electricity-to-gas price ratio and the challenges associated with upgrading older housing stock to accommodate heat pump installations pose significant barriers. Additionally, the Czech Republic has potential in biomethane

production, but restrictive agricultural and environmental policies prioritizing bio-waste management over energy crops with higher conversion efficiency may hinder further growth.

Slovakia, as well as the Czech Republic, specializes in the production of heat exchange units and holds a competitive position in the heat pump market. The country's untapped export potential in the heat pump components sector is estimated to exceed €250 million. A key player in Slovakia's heat pump industry is the Vaillant Group Slovakia, which operates a large-scale manufacturing facility in Senica. This facility not only supplies products to the European market but also plays a significant role in developing a skilled local workforce.

Despite Slovakia's growing export success in the heat pump market, domestic adoption remains relatively slow. This is partly due to the unfavorable electricity-to-gas price ratio, which makes heat pumps a less attractive option for many consumers. Additionally, the challenge of upgrading older housing stock to accommodate modern heat pump installations remains a barrier. However, there is significant potential for heat pump-driven district heating to support the decarbonization of Slovakia's extensive communist-era building stock, offering a scalable solution to modernizing urban heating systems while reducing reliance on fossil fuels.

Hydrogen:

Poland, Czechia, and Slovakia share similar challenges in advancing their hydrogen strategies, primarily due to low market demand and limited maturity of the hydrogen economy. The slow adoption of renewable hydrogen has hindered investment decisions, delaying growth in demand for electrolyzers and creating uncertainty for both manufacturers and customers. However, opportunities exist through mechanisms such as the Hydrogen Bank, which guarantees hydrogen purchases and supports market development, and the Renewable Energy Directive (RED III), mandating renewable fuels of non-biological origin (RFNBO) in industry and transport with targets of 42% by 2030 and 60% by 2035.

In Poland, efforts are centered on leveraging EU initiatives while addressing a dependency on Chinese electrolyzers, as a significant portion of projects plans to rely on these imports. Nevertheless, new EU public procurement directives will introduce local content requirements for auctions. Ensuring European content criteria in these mechanisms will be key to fostering a resilient and strategically autonomous hydrogen sector.

CR has a broader ambition to integrate hydrogen into transport and manufacturing and establish its hydrogen economy within the broader context of its robust industrial and automotive sectors. If successful, it will serve as a great example of an industrial transformation hub.

Slovakia, with its emphasis on R&D and engineering expertise, is exploring hydrogen as part of its broader clean energy transition but faces challenges due to high energy costs and limited domestic infrastructure. Standardization, identified as a priority by stakeholders, is crucial for scaling up production and reducing costs.

Establishing EU-wide and international standards can enhance the competitiveness of European hydrogen technologies and reduce reliance on imports, strengthening the region's position in the global hydrogen market.

Chapter 5
The Role of ICT in Overcoming Decarbonization Challenges

ICT technologies are critical in tackling decarbonization challenges in PCS, enhancing energy efficiency, real-time emissions tracking, and renewable energy integration. AI, big data, and IoT are revolutionizing industrial operations and energy systems, supporting better decision-making and reducing carbon footprints.

There is potential for further ICT-driven growth, especially in smart manufacturing, energy storage, and advanced grid management. Cloud-based platforms and machine learning algorithms can improve energy forecasting, which is essential for renewable energy management. The development of blockchain for carbon tracking and digital twin technologies for industrial simulations will increasingly support decarbonization efforts.

Investment in smart manufacturing technologies, energy storage solutions, and advanced grid management systems can accelerate the decarbonization process. In particular, cloud-based platforms and machine learning algorithms can enable more efficient energy forecasting, which is essential for managing the intermittency of renewable energy sources. Further development of blockchain technologies for carbon tracking and digital twin solutions for simulating industrial transformations will also play an increasingly important role in supporting decarbonization efforts.

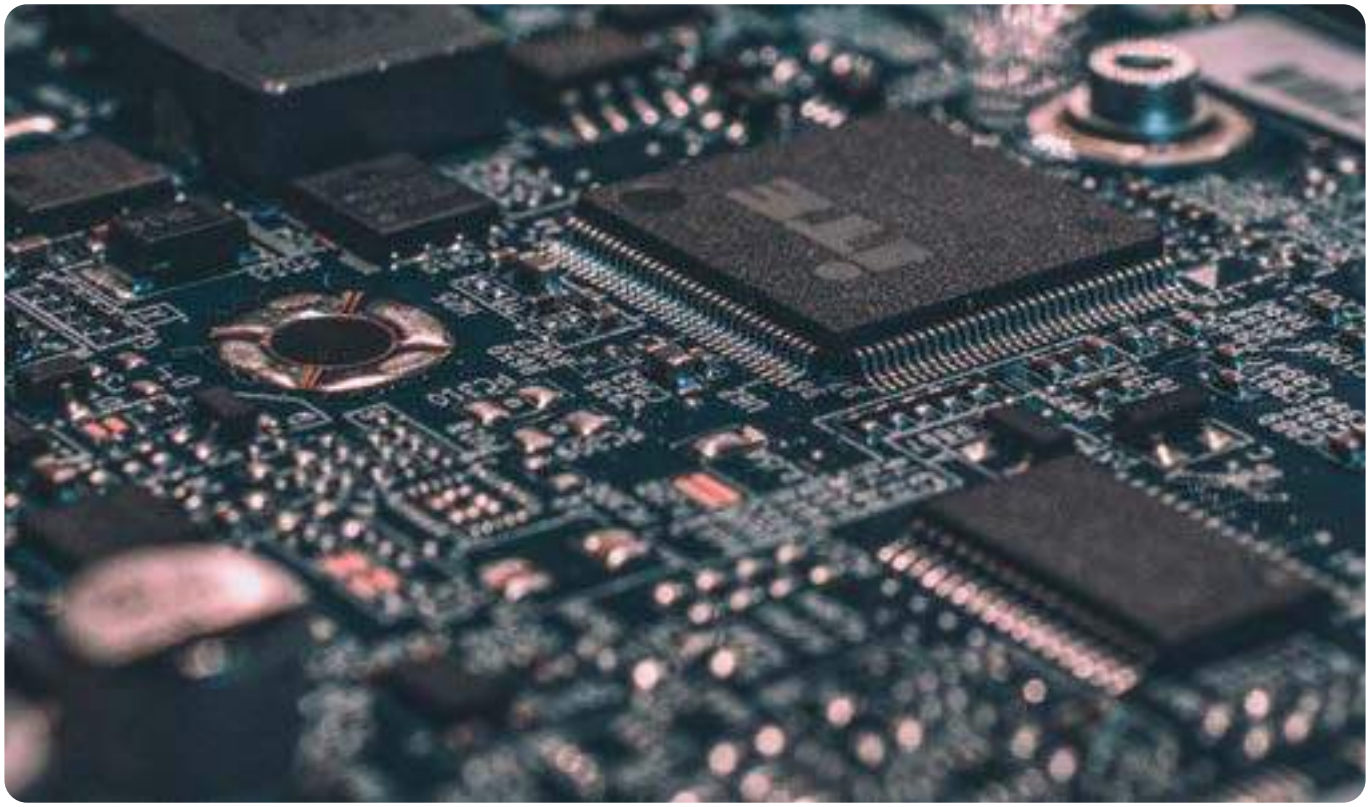
The potential for ICT, particularly artificial intelligence (AI), big data, and IoT, to optimize energy use, streamline industrial processes, and enhance the efficiency of renewable energy systems is increasingly recognized as a critical element in the region's green transition.

Poland has made significant strides in using ICT to facilitate its energy transformation. The Polish National Energy and Climate Plan (NECP) envisions the development of smart grids and energy management systems to optimize energy consumption and reduce carbon emissions. For example, Polska Grupa Energetyczna (PGE), a leading energy company, is implementing smart metering systems across the country, enabling real-time energy data collection and predictive maintenance. These systems help consumers and industries optimize energy consumption while supporting the integration of renewable

energy sources into the grid. Additionally, a growing number of Polish startups are actively developing AI-based energy optimization solutions that help industrial sectors reduce their environmental impact and lower energy costs.

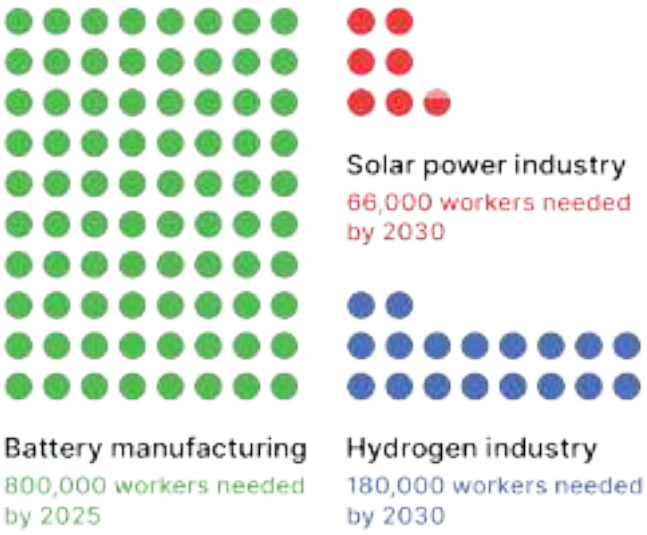
The Czech Republic is also leveraging ICT solutions in its clean energy transition. The Czech company CEZ Group, a key player in the country's energy sector, has been investing in digital grid infrastructure and predictive analytics to enhance energy efficiency and integrate renewable sources more effectively. Furthermore, Czech innovators are developing AI-powered systems for energy storage and distribution, which are crucial for ensuring the reliability of renewable energy grids. The Skoda Auto initiative in the automotive sector exemplifies how ICT technologies, such as big data analytics, help streamline the manufacturing process and enhance the efficiency of electric vehicle (EV) production, thus supporting the country's commitment to decarbonization. Similarly, Czech startup Woltair is leveraging digital platforms to accelerate the deployment of clean energy technologies, particularly in heat pump and solar installations, demonstrating how ICT can drive both industries.

In Slovakia, ICT-enabled solutions are increasingly seen as a vital part of the energy and industrial sectors' decarbonization strategies. Slovenská Elektrizačná Prenosová Sústava (SEPS), the country's electricity transmission system operator, is implementing smart grid technologies to enhance the stability of the grid and manage renewable energy flows more efficiently. Slovakia has also become a leader in electric vehicle (EV) production, with companies like Volkswagen and Jaguar Land Rover incorporating ICT systems for energy management in their EV manufacturing plants. Additionally, Inobat, a pioneering Slovak startup, focuses on the development of next-generation lithium-ion batteries, supported by data analytics and AI-driven systems for battery optimization and management.



Chapter 6
Education and raising awareness

According to the European Commission's Directorate-General for Energy report on the industrial landscape, the EU will require 800,000 skilled workers in the battery sector by 2025, while the hydrogen industry will need an additional 180,000 trained professionals by 2030. For the solar PV value chain, an estimated 66,000 workers will be required in Europe by 2030. These figures highlight the urgency for the PCS region to align its workforce development strategies with Net-Zero and Clean Air ambitions, as these industries are expected to be crucial drivers of economic growth and sustainability.



Formal education systems must expand their focus on green skills through vocational education and training (VET) programs tailored to Net-Zero technologies. The Union of Skills, launched on March 5, 2025, aims to enhance vocational training and upskilling for the green transition by implementing a European Strategy for VET (2026), boosting participation in EU Skills Academies, and expanding Large-Scale Skills Partnerships under the Pact for Skills. Additionally, it supports the creation of Centres of Vocational Excellence to align training with industry needs. EU initiatives like the Net-Zero Industry Act are already addressing these gaps, launching academies such as the Battery Academy (2022), the Hydrogen Academy (2024), and the first Net-Zero Academy (2024), which aims to train 100,000 workers for the solar PV industry. However, the Union of Skills also stresses the need for sector-specific workforce planning, cross-border cooperation, and financial incentives, which remain underdeveloped at the national level. To bridge this gap, Member States must integrate EU-level frameworks with tailored national policies and public-private partnerships to ensure a workforce capable of supporting the clean energy transition.

In addition to these initiatives, GreenSkills and VOC's "train the trainer" courses for hydrogen and heat pumps, led by PEDAL consulting, are providing specialized training to empower local experts in these critical sectors. Furthermore, the European Battery Academy has already been implemented in Slovakia and Poland within Central Europe, with the first hundreds of certified alumni trainers marking a significant milestone in the region's drive to develop a skilled workforce for the growing battery industry. Slovakia and the Czech Republic currently have one targeted policy related to Net-Zero skills, but further measures are required to enhance their manufacturing capacities.

With its significant industrial base, Poland must also invest in initiatives to align its workforce with the growing demand for green technologies. The PCS region has the opportunity to leverage EU funding mechanisms like Erasmus+, ESF+, and the Just Transition Fund to strengthen its education and training infrastructure while also integrating emerging technologies into curricula. The region's success in the Net-Zero transition will depend on fostering a skilled workforce capable of supporting industries like batteries, hydrogen, and solar PV. By prioritizing education and workforce development tailored to these sectors, the PCS region can not only address the skills gap but also position itself as a competitive hub for clean energy manufacturing in Europe.

While some focus is on general policies applicable to multiple technologies, specialized areas such as battery and storage technologies, electrolyzers and fuel cells, and solar photovoltaic and solar thermal technologies receive more attention regarding policy support. However, areas like CCS technologies, grid technologies, and sustainable biogas/biomethane technologies show limited policy focus, indicating gaps in educational efforts for these crucial technologies. This gap is particularly concerning for Poland as it relies heavily on transforming its coal-based economy and advancing renewable technologies like wind and solar. The lack of targeted policies in CCS technologies and grid modernization hampers the ability to transition efficiently while addressing its heavy industrial base's energy needs.

In the Czech Republic, the limited focus on biogas and geothermal energy policies poses challenges for developing localized renewable energy solutions and maximizing the country's potential in sustainable technologies. Despite its strong industrial base, insufficient education and training policies for technologies like grid modernization and fuel cells limit its capacity to build a competitive workforce for future green technologies.

With its emphasis on nuclear energy and emerging battery industries, Slovakia must address the insufficient policy support for heat pumps, biomethane, and CCS technologies, which are critical for diversifying its energy sources and meeting decarbonization targets. The lack of educational policies tailored to these areas highlights the need for greater focus on vocational training and public-private collaboration to build a skilled workforce.

The overall gaps in education policies across these three countries underscore the urgent need to align national strategies with EU-level initiatives to provide robust support for emerging Net-Zero and Clean Air technologies and ensure the availability of a skilled workforce. Without addressing these gaps, Poland, the Czech Republic, and Slovakia risk falling behind in the energy and clean air transition, limiting their industrial competitiveness and progress toward climate goals.

Chapter 7
Opportunity for development of the indigenous R&D driven tech companies

As described in the previous chapters, PCS countries are relying on Foreign Direct Investments to upgrade their electricity, heating, and transport infrastructures. Understandably, the best global players have been considered for such complex solutions.

What can the role of smaller, innovative tech companies be in such large infrastructure projects? Will these large cash and know-how investment flows also be channeled towards the development of Indigenous deep tech companies? Typically, smaller tech companies scale up thanks to the multinationals buying their solutions. Multinationals are the market for smaller, innovative companies. This area of potential cooperation has been neglected in the PCS region; multinationals mentioned in this report are, for the most part, not players in the respective local tech ecosystems.

How can this be changed to ensure that in parallel to these multibillion-dollar investments, PCS is also igniting the construction of Indigenous tech companies in clean energy, clean air, and, for that matter, in other verticals?

Need for breaking into the global FDI supply chains

PCS needs policies that will spur the development of the tech ecosystem, addressing the needs of multinationals investing in the region's clean energy and clean air infrastructure.

To achieve this, tech startups and SMEs must align their product development with FDI technical requirements from the early stages. This means engaging with potential FDI partners during product development, obtaining necessary certifications proactively, and building quality management systems that meet multinational standards. To facilitate this effort, first-class accelerators must be operative, identifying FDI's needs, communicating these widely to the tech ecosystem, and providing financial support for the startups to develop MVPs and beyond to address specific needs. Initiatives for launching JVs between current and local suppliers in specific targeted areas need to be additionally fiscally rewarded. With the right mentorship and infrastructure, these SMEs and startups can successfully scale their solutions. Time is the most crucial resource

business people and entrepreneurs possess. Well-developed ecosystems reduce the time required to develop the right product, meet the right people, and close deals with the relevant potential clients. This ecosystem needs to be organized and managed.

Each agency responsible for attracting foreign investment should put frameworks in place to achieve two critical goals: 1) maximize the local content, and 2) actively engage startups and engage local tech companies to maximize the high value-added local content. Once these moves are implemented, the supply of indigenous companies, and most importantly, tech companies, should dramatically increase.

Need for cross border knowledge exchange partnerships

Developing robust connections between PCS accelerators and mature cleantech ecosystems is a strategic imperative. Rather than maintaining surface-level accelerator programs, the region must architect systematic partnerships that enable structured knowledge transfer, funding access, and market expansion. This requires establishing formal collaboration frameworks between PCS cleantech accelerators and established innovation hubs in Western Europe, particularly Germany, and Nordics, coupled with mechanisms for regular technical exchange, joint investment programs, and market entry support.

Success in this strategy depends on creating standardized knowledge-sharing processes, including regular expert rotations, joint R&D programs, and industrial licensing frameworks. The goal is to accelerate the maturation of PCS cleantech companies by providing them with structured access to established technologies, technical expertise, and proven commercialization pathways while building lasting relationships with mature market partners.

Need for reorganisation in universities and research centers

Accelerating cleantech deployment in PCS requires significant investment in physical and institutional infrastructure. Priority areas include pilot facilities that enable industrial-scale testing of new technologies, particularly in energy storage and smart grid integration. These facilities must be equipped to validate technologies under real-world conditions while meeting EU certification standards. Similarly important are international R&D hubs that can bridge academic research and industrial applications, focusing on rapid prototyping and validation of cleantech innovations.

Technology licensing centers represent another critical infrastructure component, serving as institutional frameworks for commercialization. These centers should streamline the process of moving innovations from research to market by providing standardized licensing frameworks, patent support, and commercialization expertise. They must be staffed with specialists who understand the cleantech sector's technical requirements and market dynamics.

The education system requires fundamental reforms to support this infrastructure. Technical universities must redesign their programs around industry collaboration, embedding real-world projects, and commercialization training into their curricula. This includes establishing formal pathways for industry-sponsored research, creating joint industry-academic positions, and developing specialized programs in cleantech commercialization. Success requires dedicated funding streams that combine public resources with private sector investment, particularly for establishing pilot facilities and supporting early-stage commercialization efforts.

Need for strategic R&D hub development

Innovative tech companies are built thanks to collaboration between industrial partners and research institutions, enabling regular knowledge exchange and access to emerging technologies. Success depends on specialized research teams accelerating technology transfer and systematic connections to venture capital networks. Regular technology benchmarking against global competitors must guide research priorities and resource allocation.

The PCS region is lacking in these collaborative partnerships. University research teams are not sufficiently measured by the commercialization volume and the value they can bring to the universities. This is why there are almost no indigenous innovative tech companies in PCS's cleantech and clean air space.

Ultimately, we need a comprehensive R&D infrastructure in the region in the universities' labs, including battery technology hubs, hydrogen valleys, nuclear research facilities for SMR development, advanced waste management centers, clean mobility research facilities, and smart grid integration hubs for balancing and demand response innovations. Each facility should ideally have industrial-scale testing capabilities, specialized research equipment, and pilot production lines to enable rapid prototyping and validation under real-world conditions. These hubs should establish formal collaboration agreements with leading global research institutions and industrial partners, enabling regular knowledge exchange and access to emerging technologies.

It has to be stressed that the investment into the universities' research labs makes only sense if they demonstrate institutional readiness to work with the multinationals and local business community effectively.

Need for Funding

The PCS region collectively showcases the uneven but promising participation in EU clean tech programs. While Poland leads in battery innovation, Czechia is gradually advancing its industrial modernization efforts, and Slovakia has yet to engage in these funding opportunities fully. For the region to fully capitalize on IPCEI and Innovation Fund mechanisms, increased cross-border collaboration, stronger policy alignment, and targeted funding utilization will be essential. With strategic participation, these countries can bolster their roles in Europe's clean technology ecosystem and enhance their contributions to the Net-Zero agenda.

Cross-border collaboration would offer significant potential to maximize the benefits of EU mechanisms like IPCEI, Innovation Fund, and JTF. To fully harness the potential of clean technologies such as batteries, hydrogen, and energy storage, Poland, Czechia, and Slovakia should focus on creating integrated value chains across the region. Developing shared infrastructure, such as hydrogen pipelines and regional recycling facilities, would enhance efficiency, lower costs, and strengthen the region's cleantech ecosystem.

Once the supply of indigenous cleantech startups increases, local VC teams will respond and target LPs to fund their vehicles and strategies. Currently, the number of local VCs in each of the PCS countries is modest, as cleantech is perceived as harsh and not a very attractive sector to be active in.

Chapter 8
Conclusion

This report aims to shed light, raise awareness, and start a dialogue with the key stakeholders, aiming to increase the supply of Indigenous, R&D-driven tech companies supplying solutions to the booming clean energy, heating, and clean air infrastructures in the PCS region.

The stakeholders consist of respective government authorities, universities and research centers, tech accelerators, tech founders, and VC investors.

Tech founders and local businesses can drive the change, provided a friendly business context supports them.

Each of the above recommendations is a big task in itself, and full implementation can take years. Fortunately, full implementation is not required to start seeing improvements. It is crucial to begin marching in the right direction. Once the right policies are implemented, multinationals who have already invested in the region will start active cooperation with the local tech community supported by motivated scientists working within an existing research infrastructure. Tech accelerators play an important role here as motivators and organizers of the tech ecosystem, linking founders with VCs and multinationals.

The end goal is a growing community of early-stage cleantech startups who, over a few years, will develop into scaleups. The increased supply of cleantech startups will be noticed in no time by VC managers, who will reach out for the LP capital that is already available today to organize more VC cleantech funds.

When FDIs integrate the scaleups into their supply networks, they will become more rooted in the local economies. This will contribute to the increase in the overall level of local innovation management skills.

We are excited about this future and want to be the catalyst of this change.

Annexes

Summary results of meetings conducted with the Polish, Czech, and Slovak tech startups and cleantech investors. Over the course of approximately 50 meetings within 2 months, discussions were held with small and medium-sized technology companies across multiple sectors, as well as with cleantech investors and VC. There was strong representation of companies from:

- Hardware & Software startups that are developing integrated solutions that combine both hardware and software to optimize energy usage.
- Energy efficiency companies that are actively working on technologies to enhance the energy efficiency of their clients, including building automation, smart grid integration, and AI-driven energy management systems.
- Electromobility & Energy Storage
- EV infrastructure, particularly charging solutions and vehicle-to-grid (V2G) capabilities.
- Battery technologies, including BMS (Battery Management Systems) and second-life battery applications.
- Hydrogen Technologies, mainly through electrolysis and biomass-based solutions.

Despite increasing recognition of clean technology's importance for environmental sustainability and economic development, multiple barriers impede widespread adoption and scaling. These obstacles span regulatory frameworks, market dynamics, and workforce capabilities, creating a complex landscape that requires strategic intervention and urgent change to foster development.

Regulatory Barriers

- Complex procurement processes within municipalities require comparable offers for collaboration, creating significant disadvantages for innovative solutions that lack direct market comparisons.
- Public-private partnerships face extensive legal requirements and strict financial criteria, resulting in substantial delays in CleanTech deployment and implementation.
- Highly bureaucratic processes for securing and implementing EU funding create significant inefficiencies and delays, even after successful fund acquisition.
- Renewable energy development responsibility is fragmented across multiple ministries, including energy, environment, and infrastructure, leading to poor coordination and strategic misalignment.

- Energy cooperatives face severe growth restrictions, being limited to operations within a maximum of five municipalities, which significantly constrains their potential impact.
- Public institutions often experience budget reductions following successful cost-saving initiatives, creating a direct disincentive for implementing efficiency improvements.
- Emission penalties for state-owned enterprises are absorbed into national budgets, reducing accountability and weakening incentives for clean technology adoption.

Market Barriers

- Consumer and business markets show limited demand for renewable solutions, primarily due to higher initial investment requirements than traditional energy sources.
- Stakeholders frequently lack comprehensive knowledge about energy transition processes, while outdated education systems fail to address modern workforce requirements.
- Large companies demonstrate significant resistance to transformative changes, typically favoring incremental improvements over adopting new technologies.
- High upfront costs particularly affect underfunded regions, while significant funding gaps exist between the research, development, and commercialization phases.
- Market fragmentation restricts the growth potential of renewable energy initiatives, while cooperatives face structural limitations that inhibit expansion.
- Many CleanTech startups struggle with developing customer-centric approaches, while practices like greenwashing undermine market confidence.
- Aging energy infrastructure struggles to integrate modern technologies such as virtual power plants and energy communities, creating technical bottlenecks in the transition process.

Workforce Barriers

- The region experiences a critical shortage of expertise in advanced CleanTech fields, significantly limiting innovation capabilities and expansion potential.
- Specialized technical training programs are scarce, with minimal collaboration between industry and academic institutions, resulting in graduates inadequately prepared for the sector.
- A significant brain drain of skilled professionals to Western Europe continues to deplete the regional talent pool, further weakening local capacity for CleanTech development.

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