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Net-Zero Industry Valleys in Europe

An Analysis of Location Factors and Cluster Policies for EU Regions

André Wolf

With the Net-Zero Industry Act, the EU has implemented a strategic toolkit with the aim of upscaling domestic production capacities in key technologies, such as batteries, electrolyzers and wind turbines, and achieving a climate-neutral future. One element of the toolkit is the idea of promoting new regional production clusters for net-zero technologies termed "Net-Zero Acceleration Valleys". This cepStudy analyzes location conditions for future clusters in Europe and provides recommendations for a supportive EU framework.

Key results:

- ▶ The spatial concentration of net-zero industries in dedicated multi- technology clusters is a promising strategy to enhance Europe's overall competitiveness in technologies key to the green transition. The high knowledge intensity of these industries, and their need for specialized inputs and skills, promises significant industry-wide agglomeration benefits.
- ▶ For the emergence of future net-zero industry clusters, relevant regional starting conditions include the prevailing economic structure and the quality of public infrastructure services. In this respect, the study reveals a significant regional divide. Macro-regions in Central Europe specialized in high-tech manufacturing have a clear advantage in both respects. This applies in particular to south-western Germany, northern Italy, Austria, Denmark and the Czech Republic.
- ▶ To avoid a distortive subsidy race among Member States and regions, cluster policies require cooperation and coordination at EU level. To this end, the Net-Zero Europe Platform should be developed into a governance institution. Its ultimate goal should be the establishment of a network of production hubs that optimally exploits the comparative advantages of regions across the EU.
- ▶ To support the scaling of domestic production capacities, market-based demand impulses are needed. A consistent application of resilience criteria in public procurement and the introduction of a new form of Contracts-for-Difference to raise private demand are suitable measures.

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1 Background

With the Net-Zero Industry Act (NZIA)[1] being approved and a set of innovation initiatives[2] under way, the EU has finally taken an industrial perspective on its ambitious decarbonization goals. It is based on the insight that the green transformation of industry is not limited to an exchange of energy sources, but involves entirely new supply chains for climate-friendly technologies. On global markets for key net-zero technologies like batteries and photovoltaics, European manufacturers only play a minor role, both in terms of market share and innovative strength (see Table 1). Without enhancing competitiveness in these new key industrial segments, the European growth model is at risk of persistent external dependencies and being reduced to occupying a place on the technological periphery.

The main support measures envisaged by the NZIA – shortening approval procedures and pooling existing resources for strategic manufacturing projects – are only a first step. At best, they can speed up the implementation of projects, but they will hardly alter the fundamentals of investment decisions. Investments in manufacturing capacities are the outcome of complex locational decisions accounting for a range of important locational factors. The structural disadvantage that Europe has in terms of cost components such as labor and energy can only be compensated if it manages to pool its resources wisely in space. New agglomeration areas must be created, which will mature into new powerhouses for industrial productivity through the close networking of companies, research institutions and public stakeholders.

The possibility of setting up special public support schemes for certain economic zones provided for in the NZIA, so-called Net-Zero Acceleration Valleys, could serve as a nucleus for this process. However, successful cluster structures are not created on a drawing board. In addition to politically controllable variables such as local infrastructure quality, they depend on agglomeration advantages arising from the co-location decisions of related industries in the area. Sustainable regional capacity growth results from the interplay of these factors. For the design of successful cluster policies, policymakers must exploit this interplay through targeted instruments that support regional networking and address existing bottlenecks.

So far, little has been said about the potential shape and location patterns of future net-zero industry clusters in Europe. This cepStudy sheds light on the spatial nature of the competitiveness issue by providing a systematic overview of relevant location factors and their spatial distribution. First, it discusses the role of agglomeration economies in the emergence of clusters, against the background of the particularities of net-zero technologies, and also identifies the potential and limits of active cluster policies. Second, based on publicly available regional data, it identifies the starting conditions for the emergence of net-zero industry clusters in the EU regions, differentiating between indicators of infrastructure quality and the extent of regional industry linkages. The analysis culminates in recommendations to the EU for the development of a supportive framework to assist and coordinate Member States and regions in the development of net-zero industry clusters in Europe.

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[1] European Union (2024). Regulation (EU) 2024/795 establishing the Strategic Technologies for Europe Platform (STEP), and amending Directive 2003/87/EC and Regulations (EU) 2021/1058, (EU) 2021/1056, (EU) 2021/1057, (EU) No 1303/2013, (EU) No 223/2014, (EU) 2021/1060, (EU) 2021/523, (EU) 2021/695, (EU) 2021/697 and (EU) 2021/241.

[2] Wolf, A. (2024). Advanced materials for the green and digital age. cepInput No. 8/2024.

Table 1: Market situation for selected net-zero technologies

Name of technology	Production: Industrial product considered	Production: Global share of EU production: Status quo	Innovation: Global technology leader	Innovation: Global share of EU patents: Status quo	Innovation: Global share of EU patents: Trend
Advanced biofuels	Biomethane	World market leader	USA	High	Falling slightly
Battery storage	Lithium-ion battery	Relatively low	Japan	Relatively low	Stable
Carbon capture, storage and use	CCS technologies in general	High	USA	High	Falling
Grid technologies	Smart meters	High	n/a	n/a	n/a
Heat pumps	Heat pumps	High	EU	Very high	Stable
Solar photovoltaics	Solar module	Low	Japan	Low	Falling slightly
Water electrolysis	Electrolysers	Relatively high	Japan	High	Slightly increasing
Wind energy	Wind turbines	World market leader	China	High	Falling

Source: European Commission (2023a)[3]; own representation.

2 The Net-Zero Industry Act and STEP

On 25 April 2024, the European Parliament approved the trilogue deal on the Net-Zero Industry Act (NZIA). It defines for the first-time concrete targets for the deployment of net-zero technology production capacity in the EU. By 2030, domestic manufacturing capacity for net-zero technologies will amount to 40 % of the EU's annual deployment needs. Moreover, by 2040, it will capture 15 % of the world market for these technologies. Compared to the list of 8 strategic net-zero technologies proposed by the Commission, the final agreement foresees a more streamlined approach. It includes a unique list of net-zero technologies covering 19 technology groups.

To reach the designated goals, the Net-Zero Industry Act includes a range of support measures applicable to projects creating production capacities for the listed technologies. The support framework is divided into two stages. First, a basic form of support applies to all net-zero technology manufacturing projects. This includes maximum time-limits on permit procedures of 12 months for small-scale (< 1 GW capacity) and 18 months for large-scale (≥ 1 GW) projects. Member States are asked to create specific administrative offices to serve as single points of contact for project applicants that will guide them through all the steps of the permit granting process. This involves providing the applicant with all necessary information, coordinating a schedule for the permit granting process and monitoring the steps for document submission.

Moreover, to support domestic manufacturing from the demand side, the Net-Zero Industry Act envisages new criteria for public procurement procedures involving net-zero technologies. This includes mandatory minimum requirements for the environmental sustainability of production, which will be spelled out later by an implementing act. In addition, new resilience criteria are defined for public tenders, including the rule that no more than 50 % of the EU's supply of a net-zero technology can stem from a single third country.

Specific rules apply to so-called strategic net-zero projects. Net-zero technology manufacturing projects must be recognized by Member States as "strategic" if they contribute to the capacity goals of the

[3] European Commission (2023a). Investment needs assessment and funding availabilities to strengthen EU's Net-Zero technology manufacturing capacity. Commission Staff Working Document. SWD(2023) 68.

legislation, provide European industries with the best available technologies and fulfill at least one other criterion on each of the two lists of criteria. The first list includes the production of net-zero technologies for which there is a high dependence on imports (third country share of more than 50 %), the production of net-zero technologies with a crucial role for EU resilience as well as projects with significant contributions to the 2030 climate or energy objectives of the EU. The second list includes as alternative criteria the presence of upskilling and reskilling measures or contributions to the competitiveness of SMEs. Strategic net-zero projects must be assigned a special priority status in national permit granting procedures including the speed of handling any lawsuits related to permit granting. Even stricter time limits apply to the permit granting procedure itself, consisting of 9 months for small-scale (< 1 GW capacity) and 12 months for large-scale (≥ 1 GW) projects. Moreover, strategic net-zero projects can apply for specific advice on project financing by the newly established Net-Zero Europe Platform. This entails stakeholder consultations on suitable available funding channels such as existing financial support instruments at EU and Member State level (see previous subsection) and additional private sources. However, it does not involve any new dedicated EU support fund.

As a further instrument of support, Parliament and Council have added the concept of Net-Zero Acceleration Valleys into their negotiations of the proposal. Net-Zero Acceleration Valleys are areas designated by Member States which are supposed to host future spatial clusters of net-zero industry activity. For each Net-Zero Acceleration Valley, Member States must set up a plan with concrete measures for increasing its attractiveness as a production location, including infrastructure development, dedicated investment support and measures for the upskilling and reskilling of the local workforce. To coordinate permit granting procedures, every Net Zero Acceleration Valley must be assigned a single administrative point of contact.

Acting as complement to the Net-Zero Industry Act is the Strategic Technologies for Europe Platform (STEP) established under Regulation (EU) 2024/795.[4] STEP's task is to direct existing EU funding channels for investment support towards three target investment areas: digital technologies and deep-tech innovation, clean and resource-efficient technologies, biotechnologies. These technology categories are classified as critical. All three areas exhibit a significant overlap with the NZIA's list of net-zero technologies. In addition, STEP is introducing a Seal of Sovereignty, a new label that will be awarded to high-quality projects funded by STEP. The first calls for project funding are expected to be published in Q2 2024.[5]

While the general elements of the new support scheme are largely welcomed, their low level of ambition has met with widespread criticism. This applies most notably to the lack of new dedicated monetary investment incentives. On the one hand, this criticism seems justified from an investor perspective. The time gained from shorter permit granting procedures, and the reduction in transaction costs achieved by additional administrative support, are unlikely in themselves to fundamentally alter long-term investment decisions. Decisions on setting up new production capacities for net-zero technologies involve a capital commitment of 15 to 20 years or sometimes even longer. Future location conditions (and their uncertainty) are therefore typically of much higher relevance than costs that are restricted to the implementation phase. On the other hand, resorting to massive unfocused grants as a panacea for

4 European Union (2024). Regulation (EU) 2024/795 establishing the Strategic Technologies for Europe Platform (STEP), and amending Directive 2003/87/EC and Regulations (EU) 2021/1058, (EU) 2021/1056, (EU) 2021/1057, (EU) No 1303/2013, (EU) No 223/2014, (EU) 2021/1060, (EU) 2021/523, (EU) 2021/695, (EU) 2021/697 and (EU) 2021/241.

5 European Commission (2024). Strategic Technologies for Europe Platform.

enforcing capacity growth does not seem like a smart policy solution either. Historically, the emergence of industry clusters in Europe has been the outcome of a complex interplay between general economic and technological trends, on the one hand, and local production conditions, on the other.[6] In this interplay, public location subsidies have often represented a vital element, but never the only one. Not least to avoid an excessive transfer of business risks to taxpayers, a smart location policy should align support instruments with the mechanisms of this interplay. This presupposes a deeper understanding of agglomeration economies and the logic of industrial co-location.

3 Cluster economics

3.1 Types of agglomeration economies

The economic literature discusses a variety of reasons why economic activity tends to concentrate in certain areas. Basically, three classes of explanations for agglomeration patterns can be distinguished. The traditional Marshall-Arrow-Romer (MAR) externalities focus on industry-wide returns to scale as an explanation.[7] By locating in the vicinity of other companies from the same industry, a company benefits from industry-wide economies of scale. First, these include the local presence of a large number of suppliers of intermediate products tailored to the needs of the industry. This not only helps to create competitive supply chains, but also facilitates their adaptation to changing market conditions through continuous information flow in local networks. A second benefit is the existence of a local pool of workers with adequate qualification. This reduces search costs on job markets for firms and workers alike as well as risks of mismatching.

A third much-discussed advantage is the potential for local inter-firm knowledge spillovers via face-to-face communication, especially in the area of tacit, non-codifiable knowledge.[8] Recent research suggests that the basic advantages of face-to-face have survived into the digital era.[9] In this respect, the literature stresses the importance of distinguishing between different forms of knowledge. Atkin et al. (2022) distinguish analytical knowledge, mostly related to basic research in natural sciences, from synthetical knowledge, mostly related to practical applications in engineering science. Analytical knowledge is of a more universal nature and therefore easily codifiable. For this reason, its transmission is less sensitive to spatial distance. In contrast, the transmission of synthetic knowledge is the outcome of a close and continuous form of collaboration and therefore favours co-location.[10] This also applies to complex knowledge in general.[11] Apart from these forms of conscious knowledge transmission, a part of the literature also hints at the importance of "local buzz". It consists of the random transmission of small pieces of information during personal meetings both in- and outside dedicated work appointments. Its personal nature requires trust and a set of shared traditions and values, which is again favoured by

[6] Wolf, A. (2022). Europe's position on raw materials of the future. **cepInput** Nr.11/2022.
[7] Henderson, V. (1997). Externalities and industrial development. Journal of urban economics, 42(3), 449-470.
[8] Van der Panne, G. (2004). Agglomeration externalities: Marshall versus Jacobs. Journal of evolutionary economics, 14, 593-604.
[9] Atkin, D., Chen, M. K., & Popov, A. (2022). The returns to face-to-face interactions: Knowledge spillovers in Silicon Valley (No. w30147). National Bureau of Economic Research.
[10] Moodysson, J., Coenen, L., & Asheim, B. (2008). Explaining spatial patterns of innovation: analytical and synthetic modes of knowledge creation in the Medicon Valley life-science cluster. Environment and planning A, 40(5), 1040-1056.
[11] Balland, P. A., & Rigby, D. (2017). The geography of complex knowledge. Economic geography, 93(1), 1-23.

spatial proximity.[12] Taken together, these forms of externalities offer an explanation as to why knowledge-based and human capital-intensive industries are heavily concentrated in one region.

Jacobs' externalities offer another, complementary explanation for agglomeration based on the effect of economy-wide returns to scope.[13] Companies benefit from a diverse regional economic structure which involves a greater variety of general inputs (professional services, infrastructure, institutions), easier access to technological solutions in other areas and a more stable demand base. Given the cross-cutting nature of biotechnologies and bio-based production, this is an impact channel of potentially high relevance. It is based on the notion of regions as incubators offering a diverse mix of institutions.[14] A third strand of the agglomeration literature, the New Economic Geography (NEG), refers not to the role of spatially bounded externalities but focuses on cost structures and market interactions as a reason for spatial concentration.[15] In this literature, agglomeration is not viewed purely from an industrial perspective, but as a process involving the joint clustering of producers and consumers/workers.

On balance, all the current theories offer good explanations for the emergence and stability of industry clusters. However, they do not explain where exactly such clusters emerge and what impulses are needed to change existing agglomeration structures.

One area of the literature examines the role of individual regional anchor players who provide an initial impetus for the development of clustering structures. These can be well-established anchor firms that use a new technology for the first time on an industrial scale. They generate (spatially bounded) knowledge externalities and strengthen regional business formation through spin-off firms founded by employees. At the same time, they ensure the local presence of a pool of specialized input suppliers. As a result, a cluster develops around their specialized expertise.[16] Such a firm-driven regional path dependence stresses the fact that agglomeration economies are not only driven by overall industry size, but also by the distribution of individual firm sizes.

Another anchor that has been examined is the regional presence of so-called star scientists. These are scientists who are in the exclusive possession of breakthrough knowledge (which may partly be non-codifiable) and are linked to strong personal networks both within and beyond academia.[17] They can trigger successful regional business formation for the commercial exploitation of their own knowledge. Their reputation is advantageous when seeking access to capital and skilled workers. They can also improve the performance of incumbent regional biotech firms. Zucker et al. (2002) show that research cooperation (measured in research articles) between company scientists and external star scientists leads to a significant increase in the number and citation rate of company patents. Physical proximity facilitates the establishment of such research contacts.[18]

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12 Storper, M., & Venables, A. J. (2004). Buzz: face-to-face contact and the urban economy. Journal of economic geography, 4(4), 351-370.

13 See Henderson (1997).

14 Neffke, F., Henning, M., Boschma, R., Lundquist, K. J., & Olander, L. O. (2011). The dynamics of agglomeration externalities along the life cycle of industries. Regional studies, 45(1), 49-65.

15 Krugman, P. (1998). What's new about the new economic geography?. Oxford review of economic policy, 14(2), 7-17.

16 Feldman, M. (2003). The locational dynamics of the US biotech industry: knowledge externalities and the anchor hypothesis. Industry and innovation, 10(3), 311-329.

17 Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. Proceedings of the National Academy of Sciences, 93(23), 12709-12716.

18 Zucker, L. G., Darby, M. R., & Armstrong, J. S. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. Management science, 48(1), 138-153.

Beyond individual star scientists, the role of local human capital in general is also the subject of intense debate. It has several functions. Firstly, it serves as a source for filling high-skilled positions in local research, manufacturing and industry-related business services.[19] In the knowledge-intensive biotech segment, the qualification level of the local labour pool naturally plays a particularly important role. Secondly, it represents a source of future regional start-ups when it comes to the commercialization of innovations generated by the local activities of research institutions. Empirical research points to the particular importance of region-based academic entrepreneurs for regional start-up dynamics.[20]

The role of public infrastructure as a location factor is also an object of research. Locally-based, research-intensive universities and public research institutes specialized in biotech not only provide a significant share of the pool of potential high-skilled workers for the industry, but also contribute directly to the entrepreneurial dynamism of the region through academic spin-offs, e.g. for the exploitation of university patents. Such firms are often founded in close proximity to the academic institution which engendered them, partly in order to maintain the informal flow of knowledge. Research-focused universities are of particular significance.[21]

Finally, the importance of social institutions as intangible regional location factors must not be overlooked. This relates to the area of public administration, e.g. the level of local taxes and levies, the amount of rigor in applying environmental protection regulations and the duration of permit processes. Research shows that, in addition to the quality of industry regulation, the stability of regulation also has a positive value in itself.[22] The establishment of clear and reliable rules offers planning security for long-term investment as well as policy guidance for future technological development.

3.2 Potential and limits of cluster policies

Despite the individual economic advantages of co-location, there are limits to agglomeration activities. Firstly, this is due to the increased cost of immovable assets, such as land, caused by high demand in agglomeration regions. Secondly, it is due to the nature of agglomeration advantages as externalities. This harbors the danger of free riding, for example when individual companies try to profit from local knowledge networks while trying to prevent the outflow of their own exclusive knowledge. This can undermine the willingness of companies to cooperate locally and thus weaken the incentive for co-location. As new agglomerations emerge, coordination problems between the location decisions of individual companies also arise. As a result, the level of industrial agglomeration may be insufficient from a welfare perspective because the potential extent of positive agglomeration externalities is not fully exploited.

Against this background, the theory and practice of policy-induced industrial clustering has enjoyed great popularity in Europe for some time. Its founding father Michael Porter sees regional clustering as a condition for exploiting national competitive advantages.[23] While strongly related, on a theoretical

[19] Fritsch, M. (2005). Do regional systems of innovation matter. The New Economy in Transatlantic Perspective-Spaces of Innovation, Abingdon: Routledge, 187-203.

[20] Kolympiris, C., Kalaitzandonakes, N., & Miller, D. (2015). Location choice of academic entrepreneurs: Evidence from the US biotechnology industry. Journal of Business Venturing, 30(2), 227-254.

[21] Owen-Smith, J., & Powell, W. W. (2004). Knowledge networks as channels and conduits: The effects of spillovers in the Boston biotechnology community. Organization science, 15(1), 5-21.

[22] Sable, M. S. (2007). An analysis of the role of government in the locational decisions of Cambridge biotechnology firms (Doctoral dissertation, Massachusetts Institute of Technology).

[23] Porter, M. E. (2011). Competitive advantage of nations: creating and sustaining superior performance. Simon and Schuster.

level, to the concept of agglomeration economies in mainstream economics[24], this school stresses the active roles of location policies and collaboration between local networks when it comes to shaping and maintaining successful clusters.[25] Most importantly, stakeholders within a cluster are supposed to continuously provide each other with complementary knowledge to ensure the competitiveness of the cluster as a whole. This not only affects incumbent firms, but also promotes the emergence of successful local start-ups, which directly benefit from the existing local networks and knowledge base during their growth phase. Typically, the exchange occurs both between downstream and upstream industries (vertical dimension) and between direct competitors (horizontal dimension).[26] Economic behavior within a cluster can thus be described as a well-dosed mixture of collaboration and competition.

According to this mindset, policy-makers are asked to develop dedicated cluster strategies. This includes decisions on where to support the emergence of new clusters and how these clusters should be horizontally (types of industries attracted) and vertically (stages of supply chains present in the region) defined. It also involves decisions on support measures to maintain and further develop existing clusters. Besides technological boundaries, a crucial limitation for policy-makers is the availability of necessary information. In theory, with perfect information and policy-makers aiming to maximize social welfare, regional competition would lead to an optimal spatial distribution of clusters, as policy-makers would align the level of public cluster support with that of the positive agglomeration externalities expected. [27] In practice, the nature and limitations of externalities (and their regional disparity) are largely unknown. An uncoordinated subsidy competition between regions thus threatens to lead not only to a waste of public resources but also to a suboptimal regional agglomeration pattern from the perspective of the economy as a whole.

Nowadays, cluster strategies are omnipresent in regional policy-making all across Europe. In light of this fact, the empirical evidence on the effectiveness and welfare implications of real-life cluster policies appears rather scarce. Firstly, this is due to the difficulty of disentangling the effects of industrial clustering from the Jacobean externalities, i.e. the general cross-industry agglomeration advantages of densely populated regions. Secondly, the endogeneity of cluster policies impedes a causality analysis. Against this background, a common approach in the literature is to investigate cluster policies which take the form of natural experiments. An example is cluster support emerging from a contest between regions, where certain regions are picked as winners and the remaining regions form a control group.

Engel et al. (2013) investigated the effects of a regional biotech contest in Germany.[28] Winning regions were found to generally outperform non-winning participants in terms of patent applications during the treatment period. This indicates that exclusive funding as well as the stimulating effect of being a "winner" had positive effects on R&D activity in the short-term. Subsequently, however, Graf & Broekel (2020) found no significant long-term effects of the contest.[29] Falck et al. (2010) analyzed the effects of

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[24] Wolman, H., & Hincapie, D. (2015). Clusters and cluster-based development policy. Economic Development Quarterly, 29(2), 135-149.

[25] Hospers, G. J., & Beugelsdijk, S. (2002). Regional cluster policies: learning by comparing?. Kyklos, 55(3), 381-402.

[26] Maskell, P. (2017). Towards a knowledge-based theory of the geographical cluster. Economy (pp. 377-399). Routledge.

[27] Neumark, D., & Simpson, H. (2015). Place-based policies. In Handbook of regional and urban economics (Vol. 5, pp. 1197-1287). Elsevier.

[28] Engel, D., Mitze, T., Patuelli, R., & Reinkowski, J. (2013). Does cluster policy trigger R&D activity? Evidence from German biotech contests. European Planning Studies, 21(11), 1735-1759.

[29] Graf, H., & Broekel, T. (2020). A shot in the dark? Policy influence on cluster networks. Research Policy, 49(3), 103920.

a cluster policy in the state of Bavaria, which was focused on innovation in high-tech sectors.[30] The authors estimated effects on patent applications, the implementation of product or process innovation and the level of R&D. The results show a positive effect of the cluster initiative on the first two outcomes, but a negative effect on the third. Lehmann & Menter (2018) analyzed cluster promotion under the German high-tech strategy from 2007.[31] They ascertained significant positive effects of the cluster policies on regional GDP growth. The presence of research-intensive universities within regional clusters is identified as one particular success factor.

Overall, existing evidence highlights that the evaluation of cluster policies requires careful scrutiny of the local circumstances and the adequacy of support measures chosen. The uniqueness of the local economic structure, e.g. its business tradition and the specific qualifications of its workforce, must be respected by any cluster strategy. As a consequence, the literature suggests that starting a cluster “from scratch” is a very difficult endeavor and thus from a macroeconomic point of view most likely a waste of resources. Instead, it should reflect to some extent pre-existing regional advantages. More precisely, it should reflect comparative, and not necessarily absolute, advantages, implying that underdeveloped regions can still engage in successful cluster strategies. At the same time, policy-makers must avoid going to the other extreme of using their cluster policies to back regional specialization patterns that are no longer competitive (“lock-in” effect).

The smart specialization concept outlines a way out of this dilemma.[32] It rests on building future competitive advantage in new technology fields in which regions already possess existing capabilities[33]. This can be achieved by channeling public R&D sources and stimulating private development and technology cooperation in these fields. In all, this requires cluster development policies to take the form of a dynamic search process, which gradually emerges as a set of specific policy instruments in parallel with improvements to the local information base. At the beginning, a risk-reducing strategy would be to engage in less industry-focused support (e.g. local infrastructure development, optimization of administrative processes, organization of general cooperation formats and other cluster institutions). Later on, with the specific industry patterns emerging, more industry-centered R&D and production support could be provided, thus nurturing the specialization tendencies caused by market competition.

Regarding specific policy measures, Figure 1 provides an overview of available options. In principle, public support instruments could target all stages of economic activity and interactions in a cluster. In practice, the limited level of public resources calls for a strict selection. The choice of industry-focused measures should be based on the identification of concrete inefficiencies in the cluster structure, i.e. unexploited potential of (industry-internal and -external) agglomeration economies. This requires profound knowledge of the type of local environment necessary for certain industries to thrive.

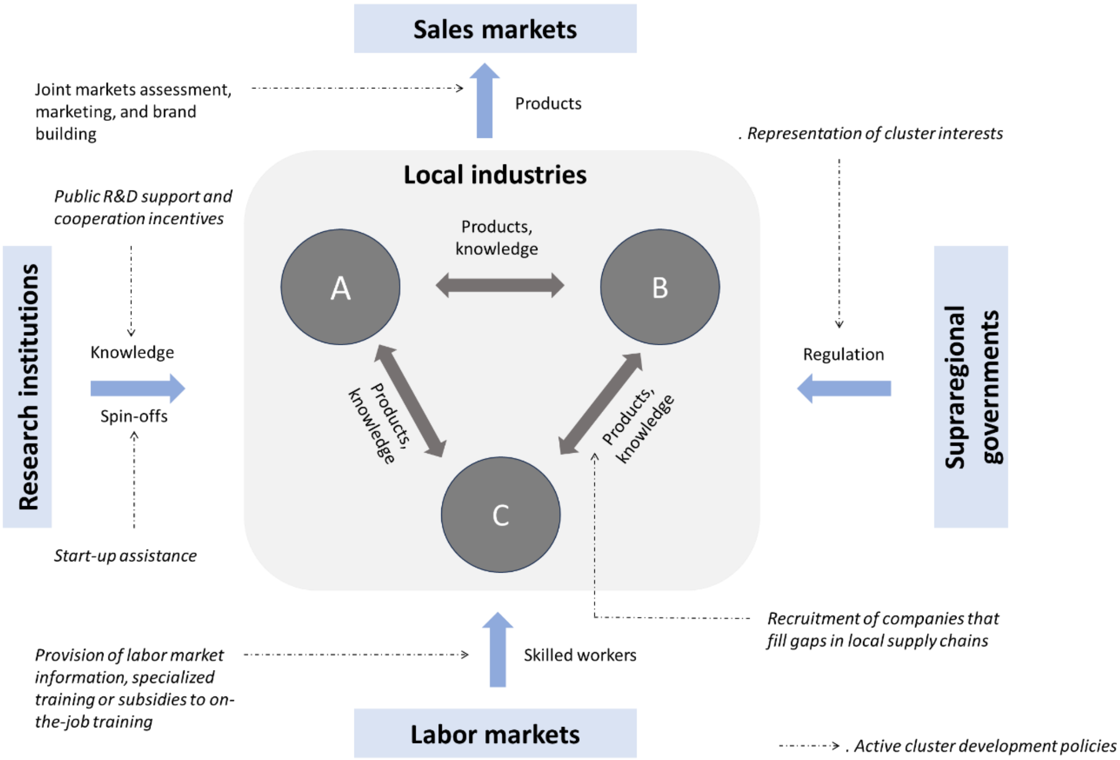
30 Falck, O., Heblich, S., & Kipar, S. (2010). Industrial innovation: Direct evidence from a cluster-oriented policy. Regional Science and Urban Economics, 40(6), 574-582.

31 Lehmann, E. E., & Menter, M. (2018). Public cluster policy and performance. The Journal of Technology Transfer, 43, 558-592.

32 Foray, D. (2014). Smart specialisation: Opportunities and challenges for regional innovation policy. Routledge.

33 Balland, P. A., Boschma, R., Crespo, J., & Rigby, D. L. (2018). Smart specialization policy in the European Union: relatedness, knowledge complexity and regional diversification. Regional studies.

Figure 1: Overview on types of cluster development policies



Source: Wolman and Hincapie (2015); own illustration.

3.3 Environment for net-zero technology clusters

The variety of technologies currently discussed in the EU as "strategic" for implementing the green transformation makes it difficult to identify a unique set of relevant location factors. Nevertheless, certain commonalities can be highlighted. Above all, this includes the need for the effective circulation of regional knowledge. Net-zero technologies are only at an early stage of their life cycle. There is the prospect of significant future cost reductions as a result of scaling and technological improvements. While the first effect is determined by EU-wide factors thanks to the single market, the knowledge input required for innovation is partly subject to spatial boundaries (see previous sub-section). Technological change also requires continuous optimization of supply chains, which is facilitated by stable relationships with regional input suppliers.

Moreover, the novelty of the technologies places specific demands on the qualifications of the workforce. The existence of a broad regional pool of specialized labor could therefore be of great importance for producers of net zero technologies in order to reduce search costs and matching problems on labor markets. The more fitting the knowledge profile of the regional labor supply, the fewer resources producers have to spend on upskilling and reskilling their employees. It follows that the existence in a region of a network of related industries (upstream and downstream) represents an important locational advantage.

Special requirements are also placed on the regional background conditions. The high knowledge intensity implies a particular need for a high-quality regional research infrastructure. The literature shows that the presence of research-intensive universities and research institutes in regional clusters can increase general innovation activity and boost R&D productivity.[34] They also serve as a nucleus for new entrepreneurial activity to marketize regional innovations.[35] Renowned universities can also attract a supply of young talent for the local labor market and particularly for innovative companies, which further strengthens the agglomeration effects.[36]

Local energy supply also plays a special role for net-zero technologies. Even if the production of most net-zero technologies is less energy-intensive than steel or many basic chemicals, the supply of renewable energy is a decisive factor. Only with the full backing of renewables can the claim for a true net-zero status be maintained. By means of Power Purchasing Agreements (PPAs) with local electricity providers, net-zero technology producers can ensure a 100 % provision with climate-neutral electricity from wind power, photovoltaics and other renewable sources. However, on these markets, they are competing with conventional industries that require green electricity for their decarbonization processes. At the same time, delays in the expansion of Europe-wide electricity grids are inhibiting the supra-regional integration of electricity markets. The local, climate-dependent generation potential of electricity from renewables could therefore become an increasingly important factor for limiting electricity prices and ensuring security of supply. This applies in particular to electricity-intensive net-zero technologies such as battery production.[37]

In addition, location factors with general importance for high-tech manufacturers are also relevant for net-zero technologies. One of these is the existence of good IT connectivity. Fast and secure data transfer is essential for multiple reasons. Externally, this arises from the need for a continuous exchange of information along the supply chains.[38] Internally, it results from the process of digitalization and automation of production steps, which requires stable digital communication channels (Internet of Things (IoT)). In addition, the existence of a well-developed regional transport infrastructure (roads, railways, harbors, flight connections) is important for logistics networks as well as for general connectivity. Finally, the quality of local public administration services (speed, reliability) should be highlighted as a further factor. This concerns the speed of approval procedures (see Section 2) and the business-friendly implementation of national and EU-wide laws.

Figure 2 summarizes the factors discussed in a multi-level system. Location quality is understood to mean the interaction of internal and external influences. In addition to the general framework conditions on global markets (not represented), external influences include the effects of (largely) national or EU-wide factors such as the tax system or the general extent of regulatory restrictions and bureaucracy. These interact with the internal regional factors. A distinction can be made between general background conditions in the form of infrastructure components, on the one hand, and the formation of activity-specific networks, on the other. The actors in this network are connected both through input-output relations and through the mutual exchange of knowledge. In the following section, we attempt to make the role of these individual factors in the EU regions visible on the basis of regional data.

34 Hewitt-Dundas, N. (2013). The role of proximity in university-business cooperation for innovation. The Journal of Technology Transfer, 38, 93-115.

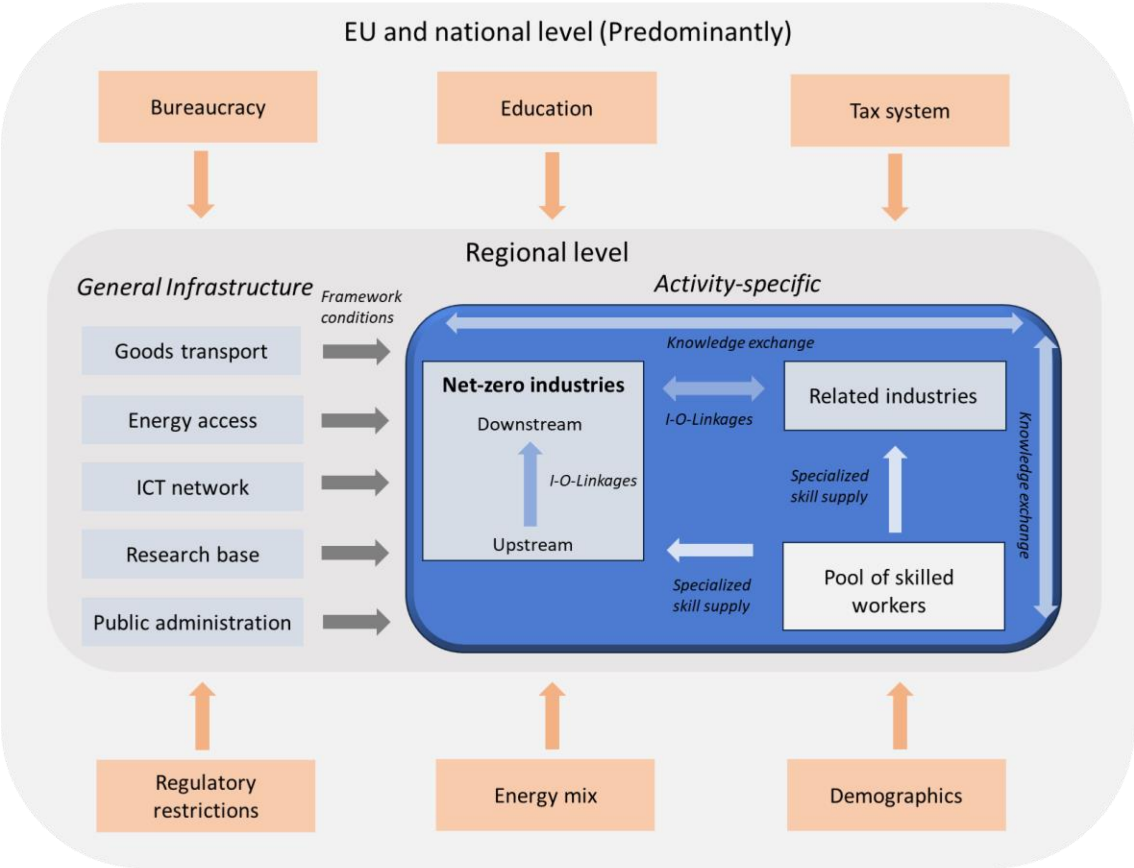
35 Carree, M., Malva, A. D., & Santarelli, E. (2014). The contribution of universities to growth: Empirical evidence for Italy. The Journal of Technology Transfer, 39, 393-414.

36 See Neumark & Simpson (2015).

37 Fraunhofer ISI (2023). Lithium-Ion Battery Roadmap –Industrialization Perspectives Toward 2030. Fraunhofer Institute for Systems and Innovation Research ISI.

38 FirstLight (2024). 5 Reasons Connectivity Is Vital to High-Tech Manufacturers.

Figure 2: System of fundamental location factors for net-zero industry valleys



Source: own illustration

4 Analysis of cluster potential for EU regions

4.1 Methods and data

We first identify those location factors that are part of a region's general, cross-industry infrastructure. They are relevant not only for the net-zero industries identified by the EU, but also for the entire knowledge-intensive manufacturing base. The starting point is the differentiation between infrastructure categories made in Figure 2. For each category, we define a set of regional indicators that should reflect as near as possible the infrastructure quality of the EU regions in relation to that category. Where possible, we rely on Eurostat as a reliable official database[39], supplemented by other transparent sources.

The choice of indicators is based on the definition of the territorial subdivision. The NUTS classification on which EU regional statistics are based is divided into four aggregation levels ranging from the Member State level (NUTS-0) to small regions (NUTS-3). A more detailed territorial subdivision provides a more nuanced picture of the location conditions in Europe. It also entails a lower risk of distortion due to differences in the size of the regions. However, since the most detailed level contains only a few relevant indicators, we have opted for the NUTS-2 level as a good compromise. It currently comprises a total of 244 regions[40] and is typically used for EU regional studies thereby also offering a good basis for

[39] Eurostat (2024). Regional statistics by NUTS classification. Eurostat Database.
[40] In Germany, this level corresponds to government districts and small federal states.

comparison with existing studies. One criterion for the choice of indicators is the existence of sufficiently long time series as a basis for our weighting method (see below). As far as possible, when selecting indicators, we also gave preference to objectively measurable indicators over subjective survey-based opinions.

Table 2 shows the selected indicators for each infrastructure category. For the "Goods transport" category, we can use Eurostat data on the density of transport networks differentiated by mode of transport. The quality of the ICT network is shown by indicators on the availability of broadband connections, drawing on data from the EU Regional Competitiveness Index[41]. To map the research base, we draw on a set of indicators that reflect the monetary (public R&D expenditure) and human (employees in science and technology) resources and the direct scientific output (number of scientific publications), with data from the EU Regional Innovation Scoreboard.[42] For the quality of regional public administration, we rely on the results of regular surveys for the European Quality of Government Index (EQI).[43] We have chosen the most recent data available for each indicator.

Table 2: Overview on infrastructure indicators for the analysis of EU regions

Category	Indicator	Meaning	Source
Transport	Density of motorways	Average density of motorways (km per km2 area) in the region and neighbouring regions in 2021	Eurostat (2024)
	Density of railways	Average density of railways (km per km2 area) in the region and neighbouring regions in 2021	Eurostat (2024)
	Daily flight passengers	Average number of daily flight passengers in 2022	Eurostat (2024)
ICT	Broadband access households	Share of private households with access to broadband internet in 2021	Eurostat (2024)
	Broadband access enterprises	Share of enterprises with access to broadband internet in 2021	European Union (2022)
	High-speed internet	Share of population with high-speed internet connection in 2021	European Union (2022)
Research base	Human resources in science and technology	Number of employees in science and technology per capita in 2023	Eurostat (2024)
	Public R&D expenditure	Public expenditure for research and development per capita in 2022	European Union (2023)
	Scientific publications	Number of publications in international scientific journals by researchers in the region per capita in 2023	European Union (2023)
Public administration	Prevention of corruption	Prevention of corruption in regional public administration according to a survey-based index in 2024	Charron et al. (2024)
	Quality and accountability	Quality and accountability of regional public administration according to a survey-based index in 2024	Charron et al. (2024)
	Impartiality	Impartiality of regional public administration according to a survey-based index in 2024	Charron et al. (2024)

Source: own representation

41 European Union (2022). EU Regional Competitiveness Index – Edition 2022.
42 European Union (2023). Regional Innovation Scoreboard.
43 Charron, N., Lapuente, V., & Bauhr, M. (2024). The Geography of Quality of Government in Europe. Subnational variations in the 2024 European Quality of Government Index and Comparisons with Previous Rounds.

The individual indicators are aggregated in weighted form into the respective categories. Following a procedure common in the literature, we determine the weighting on the basis of a (category-specific) Principle Component Analysis (PCA). The common latent (unobservable) factor reflecting the category is estimated based on the observable correlation patterns between the variables. The indicators are included in the factor analysis in a standardized form thereby neutralizing the influence of differences in the range of variation. In each case, we select the loadings of the first factor drawn as the basis for the weighting. This results in four infrastructure sub-indices.

Energy access represents a special case in view of the energy transition. The evolving specific regional mix of energy sources, and the capacity of the energy infrastructure required for supra-regional transportation (principally: electricity grids and battery storage, pipelines and storage for renewable gases) are difficult to predict. However, the regional generation potential of renewable energies - and thus the achievable degree of independence from supra-regional energy flows - can be estimated as an indicator of basic regional availability. For this, we draw on the estimates carried out by Kakoulaki et al. (2021) for NUTS-2 regions.[44]

Measuring the extent of regional industry linkages is a more difficult task. The set of net-zero technologies is so diverse in its input requirements that the effort required for a detailed classification of all strategically important technologies would be prohibitive. Moreover, at the sub-national level in Europe, no detailed differentiation of economic sectors (and thus different production activities) is currently possible, let alone of economic activities clearly identifiable as "net-zero". We have therefore chosen an alternative indirect approach for our analysis. It rests on the methodology established by the recent empirical literature on industry clusters and the use of US data. The regional datasets regularly published by the U.S. Bureau of Economic Analysis (BEA) are characterized by a much finer granularity than European sources such as Eurostat, both in sectoral and spatial dimensions.

We apply the methodology used in the much-cited work by Delgado et al. (2015) to identify clusters of closely related industries.[45] It is based on the calculation of multidimensional similarity matrices to evaluate the pairwise similarity of industries. Based on these similarity matrices, individual industries are grouped into disjoint clusters using established methods of cluster analysis.[46]

The first step is to identify the sectors of the North American Industry Classification (NAICS) containing net-zero technologies. The maximum level of resolution available for this is the six-digit level. In the 2017 version of the NAICS, it comprises a total of 1,057 different industries (so-called "national industries"), a clearly superior granularity compared to European statistics. Our classification of these national industries as net-zero technologies is based on a comparison of the content descriptions found in NAICS

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[44] Kakoulaki, G., Kougias, I., Taylor, N., Dolci, F., Moya, J., & Jäger-Waldau, A. (2021). Green hydrogen in Europe – A regional assessment: Substituting existing production with electrolysis powered by renewables. Energy Conversion and Management, 228, 113649.

[45] Delgado, M., Porter, M. E., & Stern, S. (2016). Defining clusters of related industries. Journal of Economic Geography, 16(1), 1-38.

[46] One challenge when working with US data is the peculiarity of its industry classification. Unlike other international classification systems such as the European NACE, the North American Industry Classification System (NAICS) used by official US statistics is not activity-based, but product-based.[46] This entails fundamentally different delimitations in some cases. As a consequence, there exists no one-to-one correspondence between NAICS and NACE at detailed industry levels. For the transfer of our results to the European level, we carry out a mapping to the coarser 2-digit level of the NACE classification, using the concordance table between NAICS and ISIC provided by the BEA[46] and the ISIC-NACE concordance provided by Eurostat.[46] Since Europe-wide regional data on economic activity is only available up to this level anyway, we nevertheless make optimum use of the information available.

documentation with the list of specifically named net-zero technologies from the NZIA.[47] In this regard, we focused on the final assembly parts of the respective technologies (as far as they are clearly definable in the NZIA list)[48] because we examine the upstream stages separately as a location factor (see below). On this basis, we identified a total of nine NAICS industries that clearly involve production of net-zero technologies, either in total or in part. They are henceforth termed "NZT industries".

Table 3 shows the list of industries and their relevance for specific items on the NZIA list. Although the classification is not perfect in horizontal (delineation of net-zero technologies from other technologies) or vertical (delineation of supply chain stages) terms, it marks a clear improvement over the official European statistics. Since other NAICS industries may also contain relevant components, and the set of net-zero industry technologies is constantly evolving, it should be understood as a minimum core list.

Table 3: List of identified NZT industries in the NAICS

NAICS Code	Title	Example(s) relevant products	Relevant item(s) NZIA-list
333415	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing	Heat pumps	Heat pumps and geothermal energy technologies
333611	Turbine and Turbine Generator Set Units Manufacturing	Wind turbines	Onshore wind and offshore renewable technologies
333912	Air and Gas Compressor Manufacturing	CO_2 compressor for CCS; compressors for transport of hydrogen or biogas	Carbon capture and storage technologies; Hydrogen technologies; Sustainable biogas and biomethane technologies; CO_2 transport and utilization technologies
333994	Industrial Process Furnace and Oven Manufacturing	Low-emission metal melting (e.g. hydrogen-, biogas-based crude steel production)	Hydrogen technologies; Sustainable biogas and biomethane technologies
334413	Semiconductor and Related Device Manufacturing	PV-cells,-modules; Fuel cells	Solar technologies; Hydrogen technologies
334515	Instrument Manufacturing for Measuring and Testing Electricity	Power measuring equipment	Electricity grid technologies
335311	Power, Distribution, and Specialty Transformer Manufacturing	Power transformers (voltage regulators)	Electricity grid technologies
335911	Manufacturing of storage batteries	Batteries for electric cars / large-scale energy storage	Battery and energy storage technologies
335929	Other Communication and Energy Wire Manufacturing	Electrical cables	Electricity grid technologies

Source: own representation

To measure the degree of similarity between industries with regard to supply chain linkages, we use the current version of the BEA's national input-output tables.[49] These are also much more detailed than their European counterparts. They show the input-output relationships down to the six-digit national industries (or sometimes minor aggregates) and thus provide a detailed picture of an industry's input mix and customers. We measure the degree of input-related similarity between two industries as a correlation coefficient of the value shares of the purchased inputs to the individual input categories. A strong positive correlation implies a high degree of similarity in the input mix and thus strong joint input-

[47] See European Union (2024).

[48] Besides clearly defined technology groups, the NZIA list in the finally agreed act (see Subsection 2.2) also includes residual items (e.g. "transformative industrial technologies for decarbonisation not covered under the previous categories") and extremely broad aggregations. These cannot be properly assigned to specific industrial activities and are therefore not considered.

[49] BEA (2024). Input-Output-Accounts Data. US Department of Commerce – Bureau of Economic Analysis.

related scale economies when sharing the same local suppliers. Likewise, we calculate the degree of similarity between two industries with regard to their downstream linkages as the correlation coefficient of the value shares of customer industries.

We calculate the degree of similarity in labor demand on the basis of data from the Occupational Employment and Wage Statistics (OEWS) Survey of the Bureau of Labor Statistics. They show the number of employees by occupational group, differentiated by NAICS industries.[50] The basis is the US 2018 Standard Occupational Classification (SOC).[51] It offers a differentiation of up to 876 detailed occupational groups, which reflects differences in the field of activity as well as in the qualification levels of employees. Here, we choose a comparable approach and calculate the correlation coefficients of the employment distribution by occupational groups between the industries.

We perform k-means cluster analyses for the individual similarity measures in order to identify clusters among industries.[52] Sectors which are assigned to the same technological clusters as the NZT industries for all three similarity measures are identified as linked sectors. Finally, regional employment figures for the NACE-equivalents of these linked sectors are used as an indicator of the potential for industry linkages in a NUTS-2 region.

4.2 Results

4.2.1 Public infrastructure

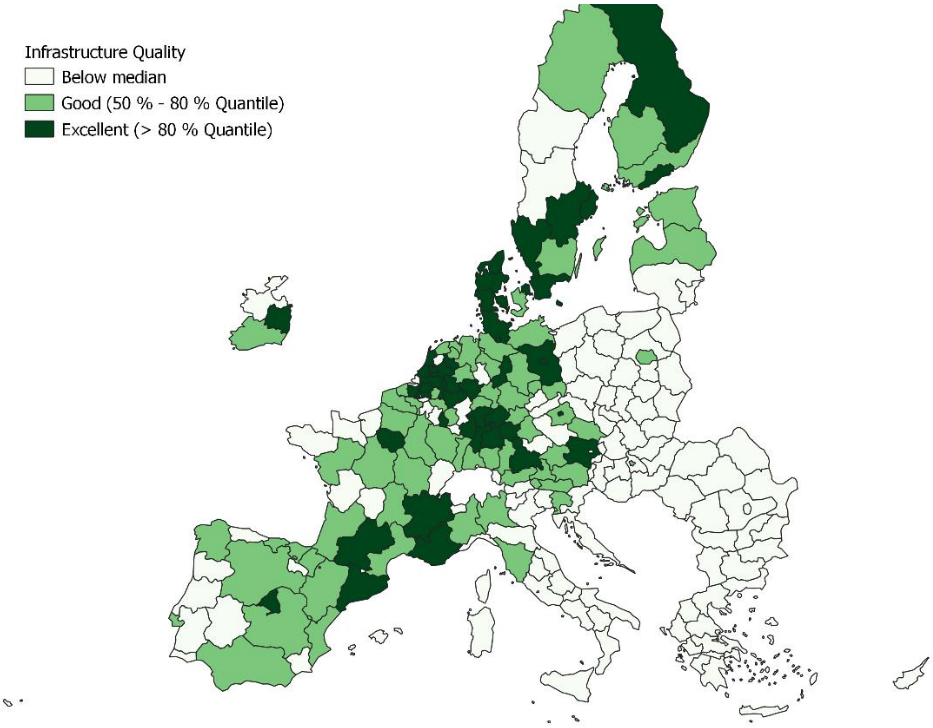
Table A1 in the Appendix shows the results of the Principle Component Analysis. The resulting regional distributions of the infrastructure categories are illustrated in Figure A1 as quintiles. Apart from a general west-east divide, it reveals a nuanced pattern. While the transport infrastructure is unsurprisingly rated as particularly good in economic core regions, there is little correlation to existing agglomeration patterns in the other infrastructure dimensions. When it comes to ICT quality, country differences are particularly striking. Spain, Denmark and the Benelux countries achieve high coverage with broadband access nationwide. In contrast, the industrial regions of Germany and Italy only achieve below-average values in some cases. In the area of administrative quality, the Scandinavian regions are almost universally among the top 20 %. A large part of the Benelux region and parts of Germany are also among the top performing regions. The assessment of the research base, on the other hand, refers much more strongly to regional centers within the Member States, including countries outside the core of industrial production in Europe. Overall, the infrastructure assessment shows a complex overlap of national and regional development factors.

To derive from this something like an aggregate measure of infrastructure quality, different kinds of weighting and aggregation processes are conceivable. Companies from different net-zero industries will differ in the specific weight they place on certain infrastructure categories. Yet, it is generally plausible that the different categories are not considered perfect substitutes, given the distinct kinds of infrastructure services they reflect. Weaknesses in one category cannot be compensated so easily by strengths in other categories. In the following, we reflect this idea through a multiplicative aggregation (geometric average) of the values in the four infrastructure subindices.

[50] BLS (2024a). Standard Occupational Classification. US Bureau of Labor Statistics.
[51] BLS (2024b). Occupational and Employment Wage Statistics. US Bureau of Labor Statistics.
[52] For each similarity measure, the optimal number of clusters was chosen based on the silhouette method.

Figure 3 depicts the spatial pattern of this overall assessment. The top 10 regions are shown in Table 4. These are regions within just four Member States: Germany, France, Denmark and the Netherlands. In accordance with our weighting, these regions share above-average performance in almost all categories. Some, but not all, of them are already important centers for high-tech production throughout Europe (see Figure 4). Conversely, however, not all the important high-tech locations exhibit above-average infrastructure quality. Counterexamples include Lombardia (ITC4) and Lazio (ITI4), which are only in the middle of the pack in terms of infrastructure performance across the EU.

Figure 3: Distribution of infrastructure quality across EU NUTS-2 regions (geometric average)



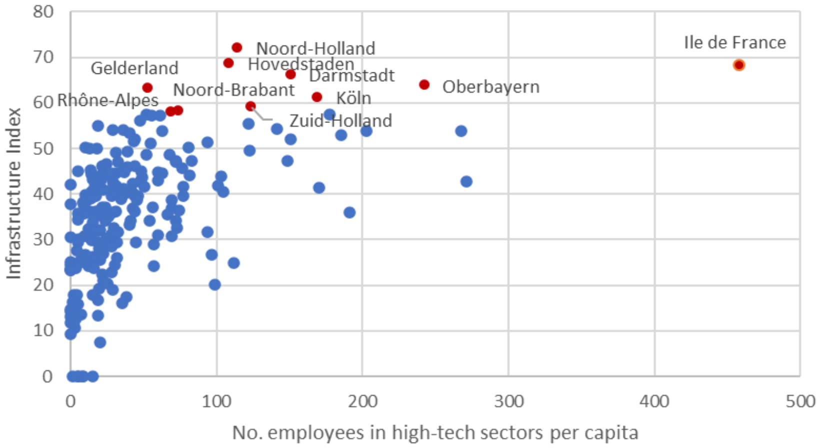
Source: own calculations

Table 4: Top 10 EU NUTS-2 regions in infrastructure quality (geometric average)

Rank	NUTS	Region	Transport infrastructure	ICT infrastructure	Public administration	Research base	Total infrastructure
1	NL32	Noord-Holland	64.18	99.34	69.05	61.54	**72.14**
2	DK01	Hovedstaden	32.43	86.30	79.35	100.00	**68.65**
3	FR10	Ile de France	100.00	85.32	48.72	52.22	**68.26**
4	DE71	Darmstadt	93.02	69.00	71.35	41.65	**66.08**
5	DE21	Oberbayern	68.64	54.75	72.00	61.29	**63.81**
6	NL22	Gelderland	41.99	96.37	78.16	50.30	**63.16**
7	DEA2	Köln	58.81	63.08	65.33	57.60	**61.13**
8	NL33	Zuid-Holland	31.82	98.75	72.97	53.16	**59.09**
9	NL41	Noord-Brabant	41.46	96.13	71.65	40.53	**58.33**
10	FRK2	Rhône-Alpes	78.75	64.74	57.80	37.03	**57.47**

Source: own calculations; very high, high, medium

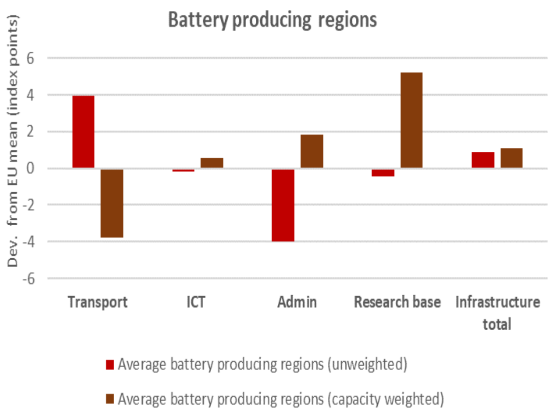
Figure 4: Comparison of infrastructure quality and high-tech manufacturing in EU NUTS-2 regions

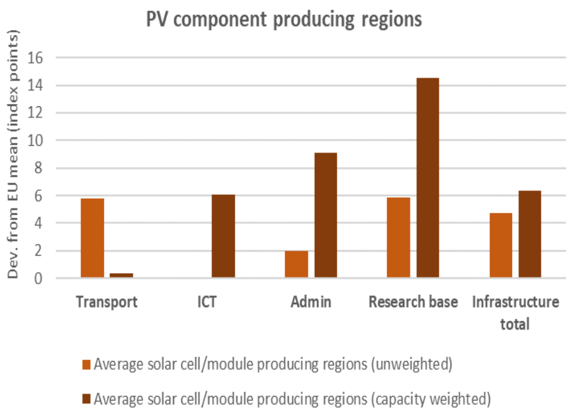


Sources: Eurostat (2024); own calculations.

At the same time, the nature of the infrastructure requirements and their significance for location decisions are always technology-specific. We can illustrate this by looking separately at EU NUTS-2 regions that are currently locations of (already operational or planned) production facilities for batteries and for PV components (wafers, ingots, cells or modules). The data on this is taken from the Bruegel Institute's European clean tech tracker.[53] Figure 5 shows the deviations of the measured average infrastructure values for such sites from the EU average. The regions with battery production facilities show only slightly better infrastructure performance than the EU average in the overall assessment. This applies both when looking at an unweighted average and a weighted average according to the level of regional battery production capacity. Only the quality of the research base is rated clearly above average in regions with high production capacities. The situation is different for regions with production capacities in the PV components sector. With the exception of transport, the assessment of the individual infrastructure categories is clearly above average in regions with high capacities. Here, too, the discrepancy is most evident in the research base category. This is not an indication of causality, but it does provide indications of the interplay between company settlements and general framework conditions.

Figure 5: Infrastructure quality in EU NUTS-2 regions with production sites for batteries and PV





Sources: own calculations; Eurostat (2024), Bruegel (2024).

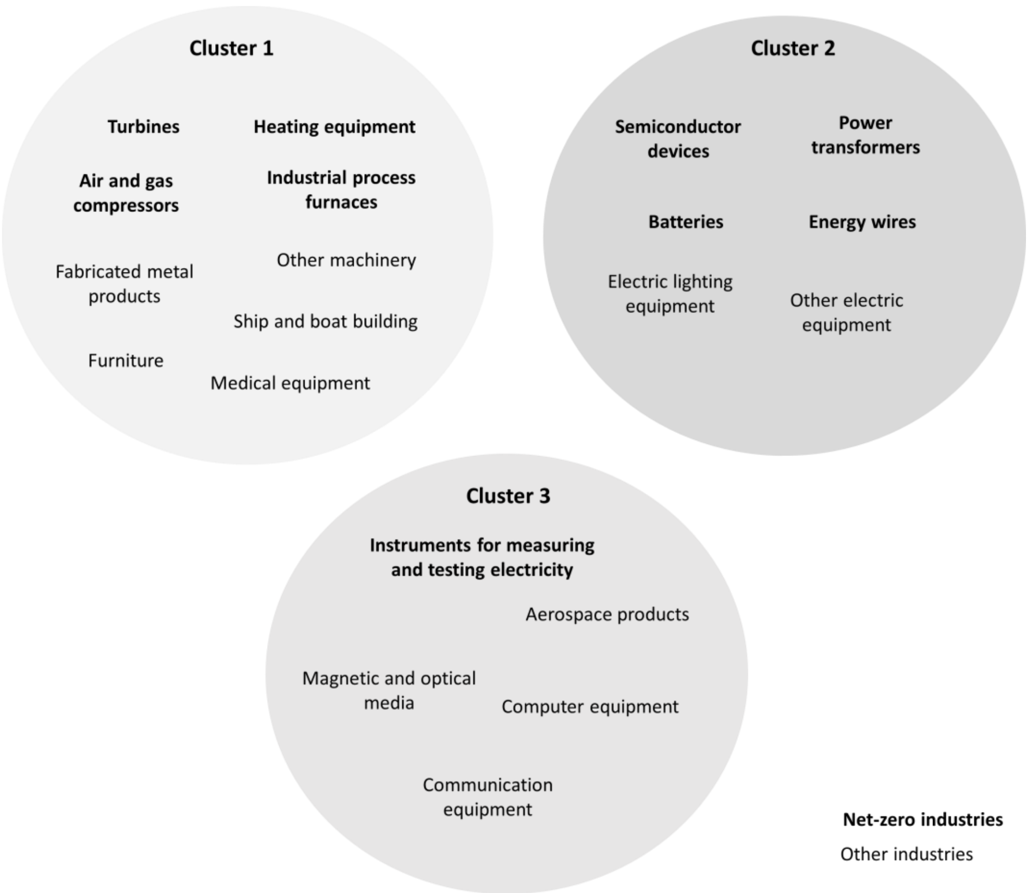
53 Bruegel (2024). European clean tech tracker.

4.2.2 Industry linkages

The analysis of the detailed US data reveals the characteristic input requirements of NZT industries. Compared to other industries, demand for intermediate goods is heavily concentrated on steel, copper and other metals and metal products (see Table A2 in the Appendix). The composition of the workforce also shows a clear profile. Technicians and engineers of various specializations are among the occupational groups most often employed (see Table A3). However, it is not only traditional technical professions that dominate, software developers are also strongly represented among employees, stressing the importance of digitization for these industries.

The cluster analysis described in Section 4.1 identifies industries that are strongly linked to NZT industries in all three technological dimensions (intermediate goods, sales markets, labor demand). Figure 6 summarizes the relevant clusters in a diagram. Their detailed composition and NACE representation can be found in Table A4. According to the report, the NZT industries covered are spread over a total of three technological clusters. Cluster 1 contains four NZT industries: Heating equipment, turbines, compressors and process furnaces. They cluster together with other industries in the field of machinery and other high-quality equipment, but also with the production of upstream metal products. Cluster 2 contains another four NZT Industries: semiconductor devices, power transformers, batteries and energy wires. They share the cluster with other segments of electric equipment. Finally, in Cluster 3 the only NZT industry is measurement and testing instruments.

Figure 6: Composition of technology clusters

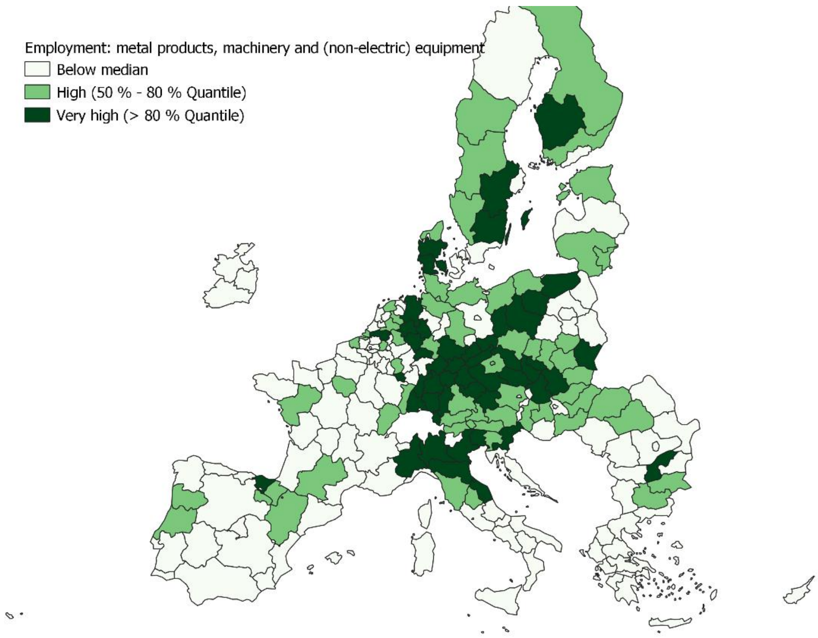


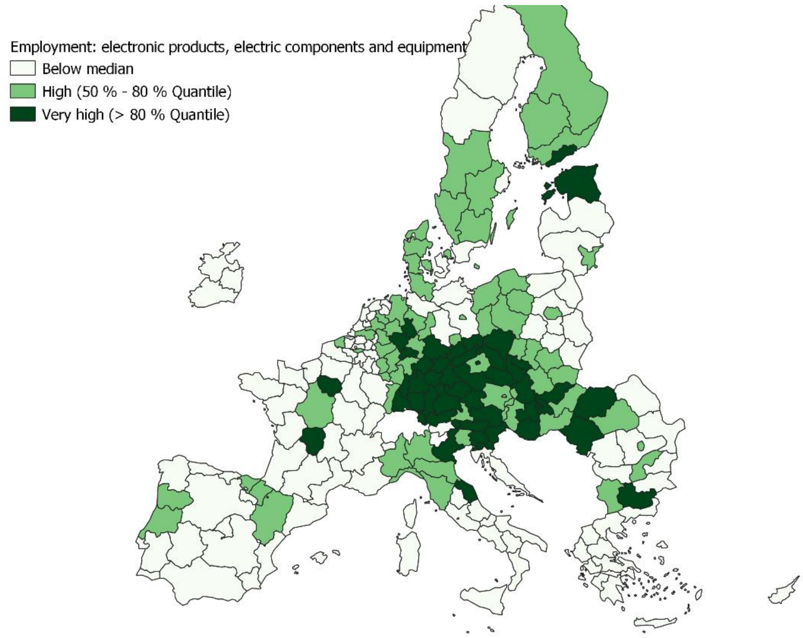
Source: own illustration

Clusters 1 and 2 are for our purpose particularly interesting, as they contain a whole range of net-zero technologies. Our discussion of cluster policies (see Subsection 3.2) suggests that establishing such multi-layered high-tech clusters from scratch would be very difficult. The natural attraction of a region for the producers of net zero technologies (all else being equal) increases with the number of closely related industries that are already anchored in the region. The economic starting conditions in the regions will thus have a significant influence on the natural growth prospects of net-zero industry valleys. The EU regional data allow for an estimate of the current level of economic activity, in the industry groups concerned, on the basis of sectoral employment figures in the NUTS 2 regions. The detailed sectoral classification of US statistics must first be transferred to the less detailed 2-digit level of the European NACE classification (see Table A4 for classification). This results in a group 1 comprising "metal products, machinery and (non-electric) equipment" and a group 2 comprising "electronic products, electric components and equipment".

Figure 7 illustrates the distribution of employment intensity in the industry groups as the number of regional employees per inhabitant in 2020, the latest available year. The spatial patterns show a clear similarity, which reflects the important role of inter-industry agglomeration effects and general regional location factors. Large cross-regional bands of intensive industrial activity in the center of Europe are contrasted with individual local hotspots at the periphery. Regarding the "metal products, machinery and (non-electric) equipment" group, the south and northwest of Germany, northern Italy/southeastern France, the north of Poland and the Czech Republic/Slovakia/Hungary form large cross-regional production centers. In the "electronic products, electric components and equipment" segment, there is an even stronger concentration on Central Europe overall. Parts of Romania and Estonia are important hubs in the east, as is central France in the west.

Figure 7: Employment density for identified industry groups in EU NUTS-2 regions (2020)





Source: Eurostat (2024); own calculations.

4.2.3 Comparative assessment

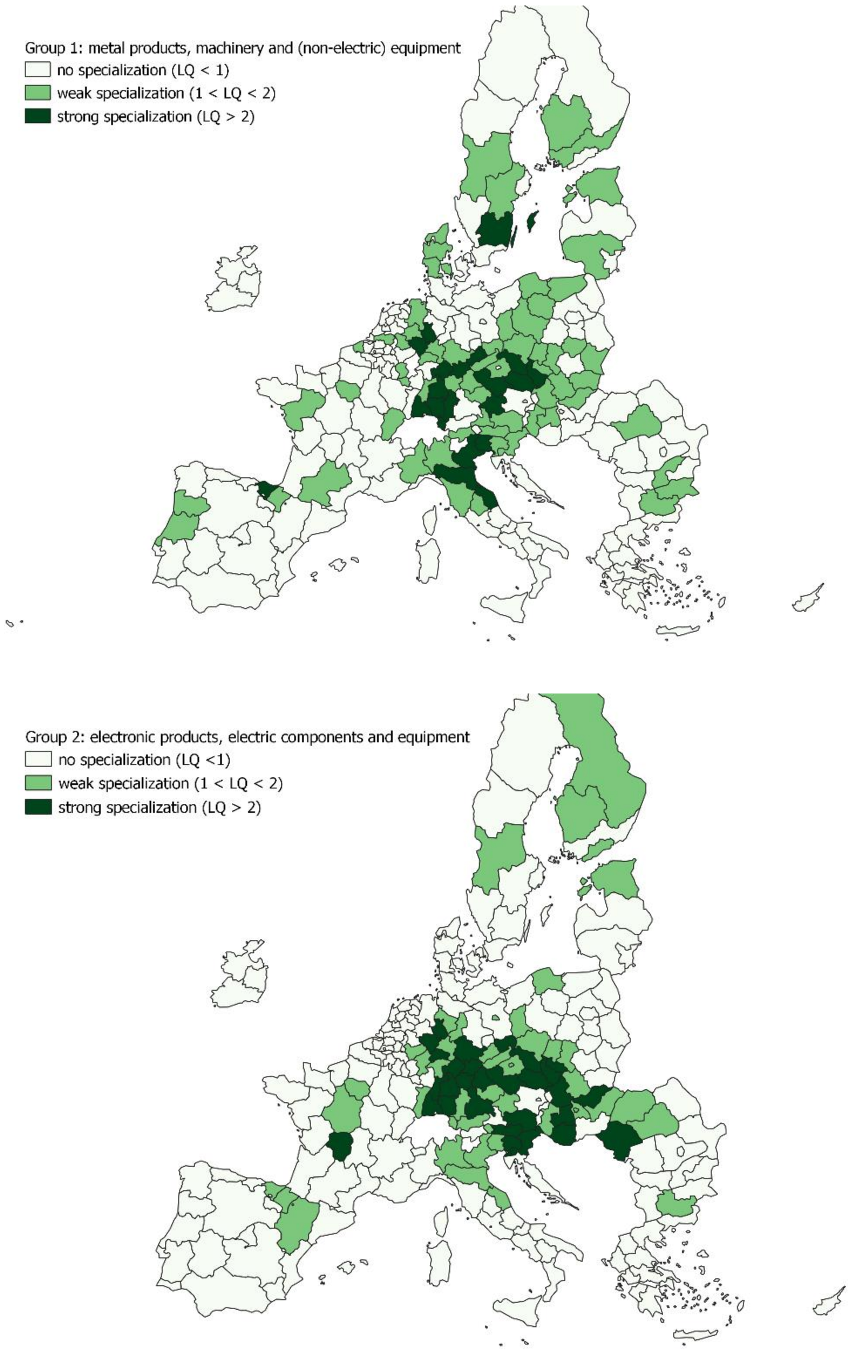
To identify "natural candidates" among EU regions for the development of net-zero industry valleys, we compare the previous results on infrastructure and industry-specific activities with the regional specialization patterns. Such an analysis cannot of course provide a detailed assessment of the site conditions in individual microregions, but it does give an impression of the broad geographical pattern of production activity that can be expected for net-zero technologies on the basis of current conditions.

From a European perspective, one important question is the future spatial division of labor. Not all European industrial regions can or should specialize in the production of net-zero technologies. In the interests of ensuring the resilience and competitiveness of the EU as a whole, regional centers manufacturing non-climate-related technologies and basic intermediates are just as important. An efficient spatial structure of net-zero industry valleys should therefore rest on the existing comparative advantages of the regions.

The EU data enables us to identify regional specialization on the basis of the sectoral employment figures in the NUTS 2 regions examined in the previous section. The location quotient (LQ) is used as a measure of regional specialization. It is calculated as the ratio of the regional employment shares to the EU-wide employment shares of the relevant industries. For both industry groups, we calculate the LQs of the NUTS-2 regions based on Eurostat regional employment figures for 2020, which are the most recent available.

Figure 8 illustrates the spatial distribution of the LQs, distinguishing between strong ($LQ \geq 2$) and weak ($1 \leq LQ < 2$) specialization. Accordingly, most of the regional production centers identified in the previous subsection also show a relative specialization of their economic structure in the relevant sectors. Strong forms of specialization in both industry groups are particularly evident in regions in southwestern Germany and the Czech Republic. In the case of group 1, there are also strong patterns of specialization in northern Italy, among others, and, in the case of group 2, in Hungary.

Figure 8: Distribution of regional specialization in net-zero industries



Source: Eurostat (2024); own calculations.

A comparison of the previous analyses allows for a tentative identification of high-potential regions. If, as the agglomeration literature suggests (see Section 3), general infrastructure quality and the benefits of industry-specific agglomeration jointly determine the attractiveness of a location, regions that stand out in both areas are "natural candidates" for net-zero industry valleys. Table 5 lists such regions for the two industry groups considered. The dark green regions are regions with exceptionally high (> 80% quantile) values both in relation to infrastructure quality and the regional size of the respective industry groups (measured in employment). For both industry groups, this includes several regions in southern Germany. Scandinavian regions are also consistently represented here. The light green regions only achieve exceptionally high values for one of the two measures, and fairly high values (50% < x < 80%) for the other. This segment includes multiple regions in Austria and Italy. The highly industrialized regions in Eastern Europe are hardly represented in this segment, as a result of their largely poor infrastructure rating.

Table 5: List of high-potential regions by industry group

Industry group 1: metal products, machinery and (non-electric) equipment					
Excellent infrastructure, very high employment		Good infrastructure, very high employment		Excellent infrastructure, high employment	
Code	**Region name**	**Code**	**Region name**	**Code**	**Region name**
DE11	Stuttgart	AT31	Oberösterreich	DEA1	Düsseldorf
DE12	Karlsruhe	CZ06	Jihovýchod	DK05	Nordjylland
DE25	Mittelfranken	DE13	Freiburg	FR10	Ile de France
DE26	Unterfranken	DE14	Tübingen	FRJ2	Midi-Pyrénées
DEA5	Arnsberg	DE23	Oberpfalz	NL41	Noord-Brabant
DK03	Syddanmark	DE24	Oberfranken		
DK04	Midtjylland	DE27	Schwaben		
SE12	Östra Mellansverige	DE72	Gießen		
		DE94	Weser-Ems		
		DED2	Dresden		
		DEG0	Thüringen		
		ES21	País Vasco		
		FI19	Länsi-Suomi		
		ITC1	Piemonte		
		ITC4	Lombardia		
		SE21	Småland med öarna		

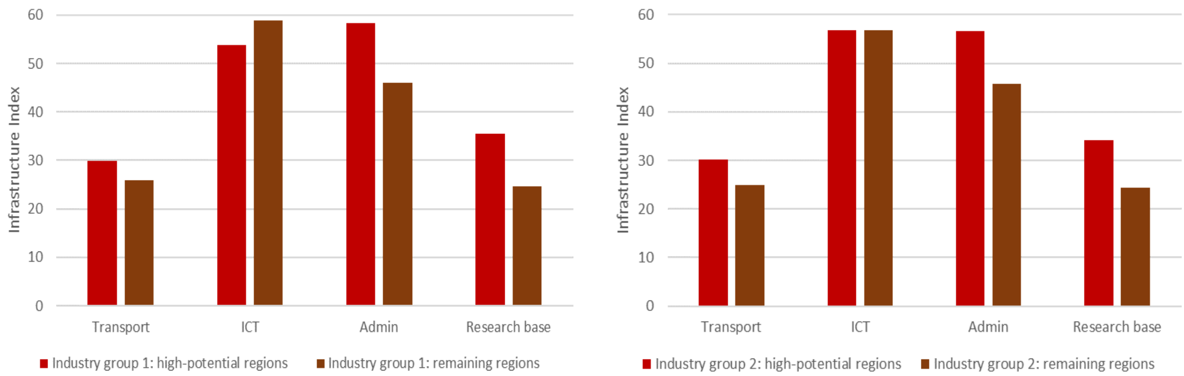
Industry group 2: electronic products, electric components and equipment					
Excellent infrastructure, very high employment		Good infrastructure, very high employment		Excellent infrastructure, high employment	
Code	**Region name**	**Code**	**Region name**	**Code**	**Region name**
CZ01	Praha	AT21	Kärnten	DE30	Berlin
DE11	Stuttgart	AT22	Steiermark	DE71	Darmstadt
DE12	Karlsruhe	AT31	Oberösterreich	DE91	Braunschweig
DE21	Oberbayern	AT33	Tirol	DEA2	Köln
DE25	Mittelfranken	CZ02	Střední Čechy	FI1D	Pohjois- ja Itä-Suomi
DE26	Unterfranken	CZ06	Jihovýchod		
DEA5	Arnsberg	DE13	Freiburg		
FI1B	Helsinki-Uusimaa	DE14	Tübingen		
FR10	Ile de France	DE24	Oberfranken		
		DE27	Schwaben		
		DE72	Gießen		
		DED2	Dresden		
		DEG0	Thüringen		
		EE00	Eesti		
		HU11	Budapest		
		SI04	Zahodna Slovenija		

Source: own calculations

The results suggest a spatial concentration of future net zero industry valleys in regions that are already predominantly high-income regions in Europe. In view of the net zero technologies' need for diverse inputs, this will not necessarily contribute to income divergence in Europe. The other regions could benefit from the scaling of production capacities for net zero technologies by specializing in less technology-intensive inputs. This is particularly true if a resilience-oriented supply chain policy favors European supplier locations. In the long term, however, the high potential for industry-wide learning effects offered by the young net zero technologies could promote such a divergence. The more the associated knowledge spillovers are spatially limited, the more the productivity development in net zero industry valleys could decouple from other regions.

Another strategy to allow structurally weak industrial regions to participate in the emerging production capacities is the targeted upgrading of regional infrastructure. Figure 9 shows the measured differences in the average quality level between the group of high-potential regions from Table 5 and the other regions with regional specialization (LQ > 1) for our four infrastructure categories (see Subsection 4.2.1). The other regions perform significantly worse on average than the high-potential regions in terms of the quality of administrative services and the local research base. There are no significant differences between the region types in the other two infrastructure categories. This suggests that a process of infrastructure upgrading should focus on the knowledge infrastructure and the reduction of administrative inefficiencies.

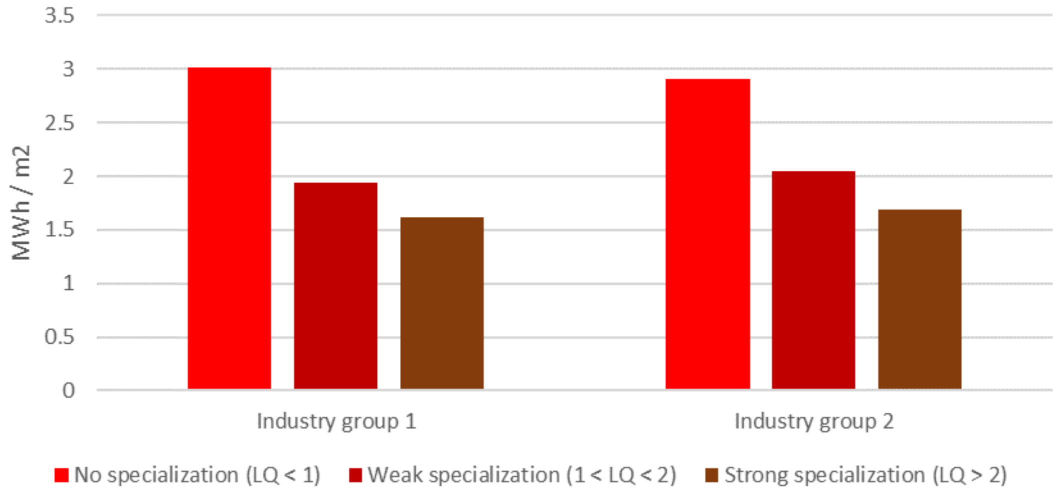
Figure 9: Average infrastructure performance in high-potential vs. other regions



Source: own calculations

Another potentially limiting factor is the issue of energy supply. As argued above, sufficient access to electricity from renewable sources can play an increasingly important role in the expansion of production capacities for net-zero technologies. In this respect, too, systematic differences between region types are evident. According to the figures estimated by Kakoulaki et al. (2021), the production potential for renewable energies in regions specializing in the relevant industry groups is significantly below EU average. This is especially true for regions with particularly strong specialization (see Figure 10). This principally results from the fact that a significant proportion of the specialized regions are located far from seacoasts, which are best suited for wind power. Future production centers for net-zero technologies could therefore depend to a considerable extent on the inflow of energy from other regions.

Figure 10: Average annual renewable energy generation potentials in regions by specialization



Source: Kakoulaki et al. (2021); own calculations.

5 Recommendations for a supportive EU framework

For European manufacturers to succeed on competitive markets for climate-friendly technologies, domestic production sites must offer all essential resources. In principle, the Net-Zero Acceleration Valleys introduced by the Net-Zero Industry Act (see Section 2) are an adequate instrument for Member States to develop regions with good starting conditions into future production hubs. The high knowledge intensity and rapid development of the technologies assign great importance to knowledge spillovers and dynamic economies of scale. These effects are at least partly spatially bound. Spatial bundling of related industries is therefore a promising strategy. However, due to coordination problems and the nature of spillovers as externalities, such bundling will not automatically result from decentralized decision-making.

At the same time, a prerequisite for long-term global competitiveness is true competitiveness within the European markets. The future pattern of European net-zero clusters must not result from differences in financial strength or industrial policy ambitions between Member States. Instead, clusters should emerge as the result of an exploratory process that identifies the current and potential future comparative advantages of a region within the EU internal market. Net-Zero Industry Valleys are not to be seen as an isolated goal, but as an integral part of a regional smart specialization strategy. This is the only way to achieve an optimal industrial division of labor from a pan-European perspective. In the current development stage, a subsidy race between Member States and the parallel promotion of redundant capacities must be avoided.

This cannot be guaranteed without more in-depth control and monitoring at EU level. It is the task of the EU to create a stable institutional framework that ensures the coordination of planning processes at a political level and undistorted regional competition at an economic level. To this end, suitable incentive instruments are needed to develop new markets, remove existing market barriers and support financially weak but high-potential regions with structural investments. We structure our proposals into four pillars.

Pillar I: Establishment of governance framework

To avoid a waste of public resources and the promotion of inefficient structures, the establishment of Net-Zero Acceleration Valleys should be subject to firm coordination and monitoring at EU level. The establishment of a Net-Zero Europe Platform consisting of representatives of Member States and of the Commission, as provided for in the Net-Zero Industry Act, is a suitable institution for this purpose. It should set up a standing subgroup for Net-Zero Acceleration Valleys, which is entrusted with the following tasks.

- **I.(a) Regular exchange on planning and implementation steps**: The Member States should regularly exchange information on which regions they are developing into dedicated Net-Zero Acceleration Valleys, what concrete objectives they are pursuing for the industry mix at the locations and what types of measures they are envisioning to strengthen the location. The Commission should summarize the information from the Member States in regular progress reports and comment on it from a European perspective. Important aspects of the assessment are compatibility with the spirit of the internal market and the contribution to an efficient future European division of labor.
- **I.(b) Coordination of fiscal and regulatory support among Member States:** In addition to reporting on national support measures, the Net-Zero Europe Platform should also regularly discuss ways to improve coordination between the member states. This includes, for example, coordination in the design of the optional net-zero regulatory sandboxes. The possibilities for joint support of Net-Zero Acceleration Valleys located in different Member States should also be examined if they exhibit complementary structures (e.g. valley A specializes on products which are essential inputs for industries in valley B). Such collective support for agglomeration areas linked through input-output relationships is suitable for strengthening the development of competitive European supply chains.
- **I.(c) Involvement of stakeholders:** Regular feedback loops with relevant stakeholders must be an integral part of consultations on the further development of Net-Zero Acceleration Valleys. This primarily concerns representatives of the relevant industries. The Net-Zero Industry group intended for the industry dialogue should be directly involved in the consultation process and not only be asked for comments afterwards. An additional interface should be created with strategic partners in third countries. This primarily concerns private and public stakeholders in third countries with which the EU has entered into trade agreements, strategic raw material partnerships and/or net-zero industrial partnerships. An important part of the coordination concerns the questions how partners can contribute to meeting the needs of emerging EU Net-Zero Acceleration Valleys for specific raw materials or intermediate products and how the EU can support the development of production capacities and infrastructure in partner countries.

Pillar II: Targeted upgrading of regional public infrastructure

To exploit existing specialization potentials in net-zero technologies for regions with fitting industrial tradition but weak investment dynamics, the EU should provide these regions with targeted support in modernizing their (tangible and non-tangible) public infrastructure. In particular, the established instruments of EU regional and cohesion policy should be sharpened for the development of Net-Zero Acceleration Valleys. This also includes supporting regional authorities in overcoming existing administrative bottlenecks.

- **II.(a) Establishment of dedicated funding targets for Net-Zero Acceleration Valleys:** The strategic policy goals set for the allocation of funds from the European Regional Development Fund (ERDF) and the EU Cohesion Fund should be supplemented by specific targets for infrastructure funding in dedicated Net-Zero Acceleration Valleys. When distributing these funds, priority should be given to regions with high specialization potential and strong infrastructure deficits.
- **II.(b) Support of regional research capacities through cooperation initiatives:** EU programs to intensify cross-border exchange between knowledge institutions such as the European Universities Alliance[54] strengthen the regional research base. The reciprocal mobility of researchers and students and the establishment of joint issue-centered research teams strengthen the effectiveness of regional research activities. Participating institutions should be encouraged to set up interdisciplinary teams focused on transformation technologies. The networking of such teams with the local economy, especially SMEs and innovative start-ups, should be promoted.
- **II.(c) Assistance in the modernization of administrative processes:** The administrative simplifications foreseen for the approval of net-zero industry projects will only be realized if the regional administrative units have sufficient resources to restructure and focus their processes. The EU should support the units responsible for administering companies in Net-Zero Acceleration Valleys, particularly in the digitalization of processes and the establishment of one-stop shops for companies.

Pillar III: Support of capacity expansion through market impulses

In strategic net-zero technologies with currently low European market shares, traditional forms of investment support such as CAPEX grants will in many cases not suffice to initiate a sustainable development of domestic production capacities. Clear sales prospects must be created in order to counter the uncertainty surrounding the development of demand and to accelerate scaling. This applies in particular to young clusters in their growth stage. The mutually reinforcing impulses of local production growth, input supply and labor markets imply a high sensitivity to external incentives and the commitment of regulators. In this vein, the new auction criteria defined by the NZIA for public procurement and for the promotion of renewable energies are the right approach, but should be specified and expanded.

- **III.a) Application of consistent and well-targeted resilience criteria in public tenders:** The introduction of resilience criteria (see Section 2) for public tenders is a promising strategy for addressing external dependencies and supporting domestic production. However, attention must be paid to accuracy in the concrete specification and the risk of promoting the development of inefficient capacities. This requires that the bid price retains a high weighting as an award criterion and that maximum thresholds are set for the price gap to the lowest bid. However, in contrast to the prescriptions of the NZIA, the resilience criteria should be designed dynamically. Instead of setting a blanket maximum limit for the purchase of components from individual third countries, this value should vary depending on a transparent criticality assessment for the respective technology. In such an assessment, the extent of general import dependence and the economic importance of the technology should be taken into account as criteria. The criticality criteria of the Critical Raw Materials Act (CRMA) can serve as a model for

[54] European University Alliance (2024). Learn – Connect - Inspire.

this. The same applies to the maximum price gap. In this way, there is more scope for rewarding resilience contributions for strategic technologies with currently still very low European market shares.

- **III.b) Harmonization and close monitoring of tender practices in Member States:** The EU should prescribe and monitor the uniform application of the qualification and award criteria in the Member States. To this end, stricter requirements should be set for the weighting of the criteria in the tenders. Exemption rules should be more heavily restricted. This should prevent the fragmentation of demand incentives and indirect forms of piecemeal industry support by individual Member States.
- **III.c) Stimulation of private demand through "Resilience Contracts-for-Difference":** In addition to an increased demand pull through public tenders, supplementary instruments to strengthen private demand should be considered as well. Alignment with efficiency goals must also be a requirement, especially for domestic downstream industries facing strong international competition. A suitable new instrument for this could be "Resilience Contracts-for-Difference", an analogue to the already implemented Carbon Contracts-for-Difference. In this model, domestic producers of net-zero technologies would conclude long-term supply contracts with domestic customers at a fair market price per unit supplied. The difference between the initially high unit costs of emerging domestic producers and the market price level would be covered partially by public grants to producers. The subsidy would have to be continuously reduced over an ex-ante defined path, to take account of expected future scaling advantages and to maintain incentives to improve efficiency. To achieve a disclosure of the real cost ratios, the initial subsidy level should be determined by a competitive bidding process between net zero technology producers.

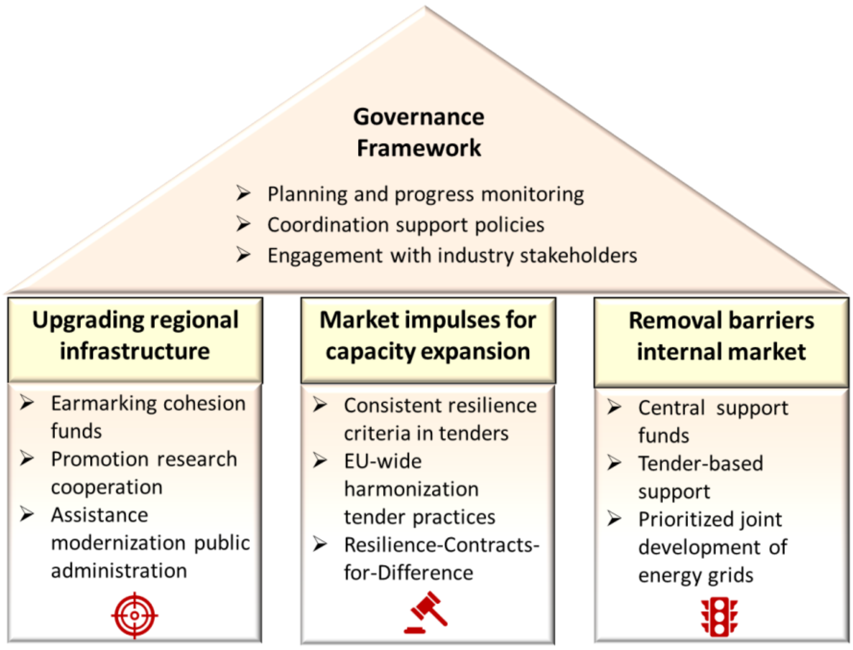
<u>Pillar IV: Removal of barriers to market integration</u>

The promotion of regional agglomerations and the removal of barriers to market integration must go hand in hand. Technical and regulatory barriers to intra-EU trade in inputs essential for net-zero technologies should be removed, to prevent resource bottlenecks in the development of clusters and the establishment of inefficient and redundant supply routes. This applies in particular to the supra-regional supply of renewable energy sources. Regional clusters will only become globally competitive if they can compensate for "missing elements" in the regional endowment through integration in Europe-wide supply chains. To this end, the support framework for the development of production capacities must be aligned across Member States.

- **IV.a) Expansion of central market-based support schemes for net-zero technologies:** The current flexibility granted to Member States in supporting climate-friendly technologies through temporary exemptions in the EU State Aid Framework cannot constitute a permanent solution. It exacerbates the already existing discrepancies between Member States with respect to transition support and creates a dangerous tension with the principles of the internal market. The idea to form net-zero industry clusters based on comparative advantages requires uniform funding conditions in the EU. In addition to uniform regulations for public procurement (see Pillar III), this also requires well-endowed and targeted EU funds. The STEP platform (see Section 2) set up for the promotion of projects on critical technologies should be expanded for this purpose. The allocation of funds should generally be based on transparent, competitive tendering procedures and focus on market-oriented instruments such as the Contracts-for-Difference discussed above.

- **IV.b) Joint development of a cross-border energy grid infrastructure:** To avoid possible future local supply bottlenecks in access to renewable energy, the cross-border planning of energy networks within the framework of TEN-E should enjoy a high political priority. Planning should be extended as early as possible to the long-term scenario of a European energy system based almost entirely on climate-neutral energy sources. The development of a pan-European pipeline infrastructure for alternative gaseous energy sources (renewable hydrogen, biogas and their derivatives) should be driven forward swiftly and coordinated with the expansion of the European electricity grid (in particular the expansion of strategic cross-border interconnectors). The location of dedicated Net-Zero Acceleration Valleys should also be accounted for in future steps of grid planning.

Figure 11: Proposed structure of supportive EU framework



Source: own illustration

6 Conclusion

In the global race for market shares in strategic net-zero technologies, the EU is facing tough competition from all sides. In the midst of strategic state subsidies, unintended knowledge outflows and the threat of escalating tariff wars, Europe is struggling to agree on its own industrial policy agenda. The temptation is great to respond with own massive subsidy programs or protectionist moves. So far, Europe has not taken any of these paths with any consistency. It is to be hoped that this remains the case. After all, we can neither win a subsidy race against China and its resources, nor are our open societies capable of surviving a retreat into economic isolation. Moreover, targeted import tariffs would render net-zero technologies more expensive domestically, which would impede the decarbonization of downstream sectors.

Instead, the answer to unfair global competition should primarily lie in exploiting our own potential and expanding our own strengths. This requires more than fiscal investment incentives. The promotion of production capacities through investment grants is ineffective in the long term if these are not embedded in a suitable industrial ecosystem. The spatial bundling of net-zero industries in cluster structures is a sensible strategy to compensate for structural cost disadvantages through realizing general economies of scale and industry-specific agglomeration effects. A decisive factor for the success of such clusters is the existence of local framework conditions tailored to the specific needs of net-zero technologies such as a strong regional knowledge circulation and the existence of a specialized workforce.

This cepStudy sheds light on spatial differences in the starting conditions for the establishment of net-zero industry clusters. It reveals a clear disparity between EU regions, both in terms of the quality of public infrastructure components and the extent of relevant regional industry linkages. Macro-regions in Central Europe with a high proportion of high-tech manufacturing have a clear advantage in both aspects. This applies in particular to south-western Germany, northern Italy, the Netherlands, Denmark and the Czech Republic. Numerous regions in the eastern Member States with below-average per capita incomes also exhibit high employment potential in the relevant industrial segments. However, deficits in infrastructure quality, particularly in the knowledge infrastructure, could prove to become a stumbling block for their development as net-zero industry hubs.

A dedicated policy strategy can support the development of clusters. It helps to overcome coordination problems in the location decisions of the new industries and to ensure the exploitation of agglomeration externalities. However, it must avoid the emergence of an uncoordinated subsidy competition between European regions, which would threaten to cannibalize scarce public resources and provoke an inefficient spatial allocation of production capacities across Europe. Europe as a whole will only be successful in catching up if the distribution of clusters is reflecting the true comparative advantages of the regions.

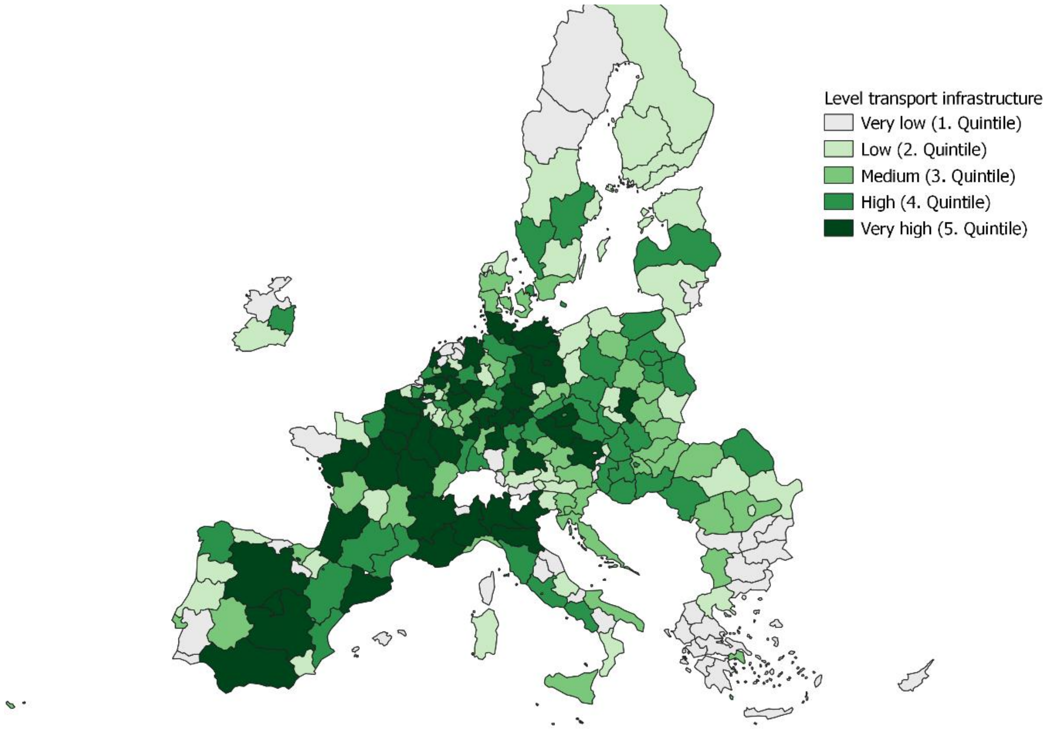
Coordination and cooperation at the European level are essential for such an intelligent specialization. The Net-Zero Europe Platform introduced by the Net-Zero Industry Act should be developed into a governance institution. Its central tasks should be the coordination of the planning of Net-Zero Acceleration Valleys by the Member States and the monitoring of their development. The instruments of EU regional and cohesion policies should be used strategically to strengthen the infrastructure in future Net-Zero Acceleration Valleys. Existing administrative bottlenecks in the regions should also be tackled with EU support. Complementing existing state aid rules, clear guidelines should be set across the EU for a direct promotion of production capacities to avoid a proliferation of different subsidy schemes. To provide EU-wide demand-side impulses for a rapid scaling of domestic production capacities, new resilience criteria for public procurement should be specified by the EU and implemented uniformly by the Member States. To strengthen private demand, the option of a temporary public coverage of domestic cost gaps should be explored, with Carbon-Contracts-for-Difference as a potential role model.

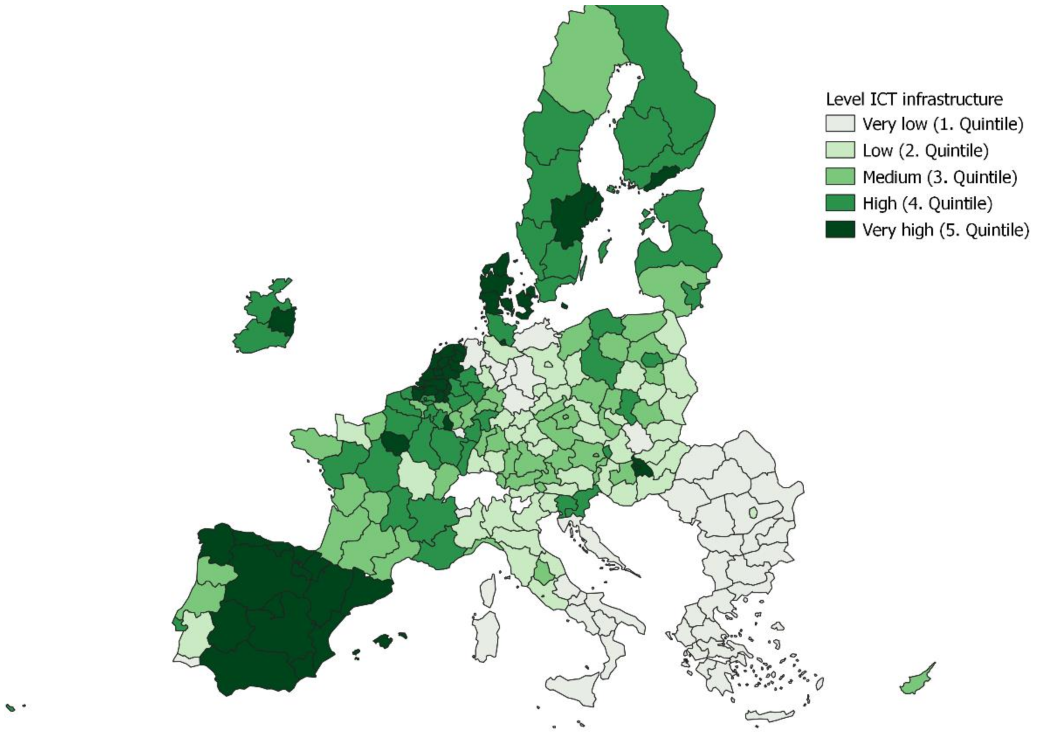
Finally, a relevant issue for public acceptance of cluster policies is their long-term impact on spatial economic inequality in Europe. The latest election results in Europe suggest that the distributional effects of transformative policies are contributing to a dangerous strengthening of the political extremes. Against this background, it is crucial for policymakers to stress that an intelligent specialization strategy by no means aims at a deindustrialization of regions outside dedicated clusters. Instead, regions hosting the extraction of essential raw materials or a strong base materials industry should be considered indispensable puzzle pieces for the development of resilient domestic supply chains.

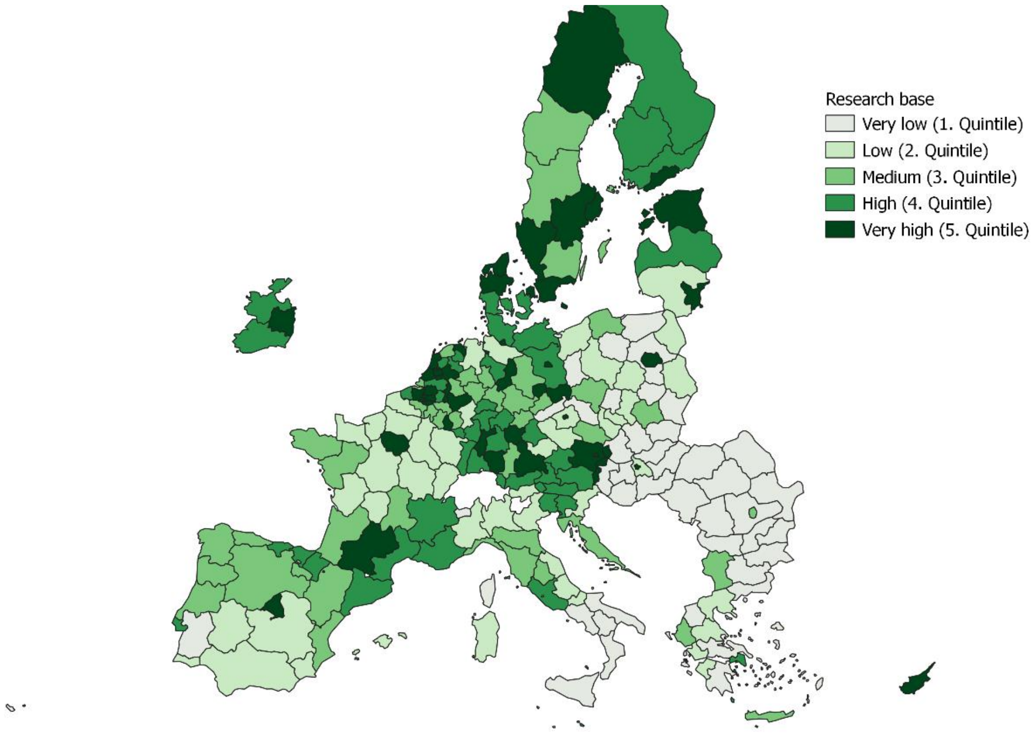
Therefore, it is both politically and economically imperative that regions with different industrial profiles are not played off against each other in the allocation of support funds. This requires the development of net-zero industry clusters to be embedded in an overarching smart specialization strategy of Europe's regions. It should build on a European vision of competitive supply chains in a future global trade order. If such a strategy is implemented wisely, net-zero industry clusters can become new drivers for Europe's industrial renaissance.

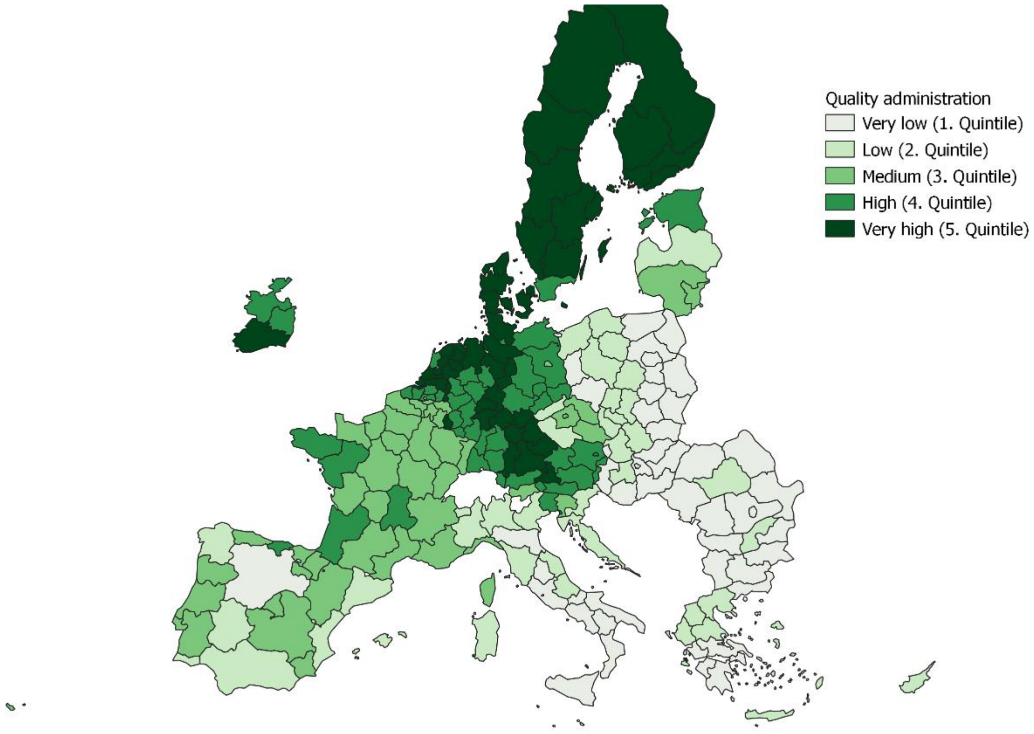
7 Appendix

Figure A 1: Results for infrastructure subindices









Source: own calculations

Table A 1: Results of Principal Component Analysis

Index: Transport			
		Eigenvectors	
Variables	**Vector 1**	**Vector 2**	**Vector 3**
Density of motorways	**0.62**	-0.32	-0.71
Density of railways	**0.62**	-0.35	0.70
Daily flight passengers	**0.48**	0.88	0.02
Eigenvalues	***1.47***	*0.81*	*0.43*
Index: ICT			
		Eigenvectors	
Variables	**Vector 1**	**Vector 2**	**Vector 3**
Broadband access households	**0.60**	-0.37	0.71
Broadband access enterprises	**0.59**	-0.39	-0.70
High-speed internet	**0.54**	0.84	-0.01
Eigenvalues	***1.65***	*0.54*	*0.04*
Index: Research base			
		Eigenvectors	
Variables	**Vector 1**	**Vector 2**	**Vector 3**
HRST	**0.57**	0.80	0.18
Public R&D expenditures	**0.58**	-0.55	0.60
Scientific publications	**0.59**	-0.24	-0.78
Eigenvalues	***1.65***	*0.44*	*0.32*
Index: Public administration			
		Eigenvectors	
Variables	**Vector 1**	**Vector 2**	**Vector 3**
Prevention of corruption	**0.58**	-0.43	0.69
Quality and accountability	**0.57**	0.82	0.03
Impartiality	**0.58**	-0.38	-0.72
Eigenvalues	***1.66***	*0.39*	*0.32*

Source: own calculations

Table A 2: Top suppliers of tangible inputs to US NZT industries

Industry (supplier) title	NAICS code	Average share input mix net zero technologies	Highest input share in:
Copper rolling, drawing, extruding and alloying	331420	0.023	Power, Distribution, and Specialty Transformer Manufacturing
Other durable goods merchant wholesalers	423A00	0.022	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing
Iron and steel mills and ferroalloy manufacturing	331110	0.021	Heating Equipment (except Warm Air Furnaces) Manufacturing
Nonferrous metal (except aluminum) smelting and refining	331410	0.020	Storage Battery Manufacturing
Management of companies and enterprises	550000	0.019	Industrial Process Furnace and Oven Manufacturing
Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	331490	0.013	Storage Battery Manufacturing
Household appliances and electrical and electronic goods	423600	0.013	Storage Battery Manufacturing
Truck transportation	484000	0.011	Communication and Energy Wire Manufacturing
Other real estate	531ORE	0.011	Heating Equipment (except Warm Air Furnaces) Manufacturing
Machinery, equipment, and supplies	423800	0.009	Turbine and Turbine Generator Set Units Manufacturing

Source: BEA (2024); own calculations.

Table A 3: Most frequent occupations in US NZT Industries

Occupation title	Occupation code	Average share employees net zero technologies	Highest employee share in:
Electrical, Electronic, and Electromechanical Assemblers, Except Coil Winders, Tapers, and Finishers	51-2028	0.110	Turbine and Turbine Generator Set Units Manufacturing
Miscellaneous Assemblers and Fabricators	51-2090	0.088	Semiconductor and Related Device Manufacturing
Engine and Other Machine Assemblers	51-2031	0.036	Power, Distribution, and Specialty Transformer Manufacturing
Industrial Engineers	17-2112	0.036	Battery Manufacturing; Communication and Energy Wire Manufacturing
Inspectors, Testers, Sorters, Samplers, and Weighers	51-9061	0.032	Turbine and Turbine Generator Set Units Manufacturing
Machinists	51-4041	0.031	Heating Equipment (except Warm Air Furnaces) Manufacturing; Air and gas compressor manufacturing; Industrial Process Furnace and Oven Manufacturing
First-Line Supervisors of Production and Operating Workers	51-1011	0.030	Battery Manufacturing; Communication and Energy Wire Manufacturing
Mechanical Engineers	17-2141	0.027	Turbine and Turbine Generator Set Units Manufacturing
Software Developers	15-1252	0.027	Instrument Manufacturing for Measuring and Testing Electricity
Welders, Cutters, Solderers, and Brazers	51-4121	0.022	Heating Equipment (except Warm Air Furnaces) Manufacturing; Air and gas compressor manufacturing; Industrial Process Furnace and Oven Manufacturing

Source: BLS (2024b); own calculations.

Table A 4: Results of cluster analysis

NAICS code	NAICS title	NACE equiv. (code)	NACE equiv. (title)
		Cluster 1	
3321	Fabricated Metal Product Manufacturing	C25	Manufacture of fabricated metal products
3331	Machinery Manufacturing (other than NZT industries)	C28	Manufacture of machinery and equipment n.e.c
333415	**Heating Equipment (except Warm Air Furnaces) Manufacturing**	**C28**	**Manufacture of machinery and equipment n.e.c**
333611	**Turbine and Turbine Generator Set Units Manufacturing**	**C28**	**Manufacture of machinery and equipment n.e.c**
333912	**Air and Gas Compressor Manufacturing**	**C28**	**Manufacture of machinery and equipment n.e.c**
333994	**Industrial Process Furnace and Oven Manufacturing**	**C28**	**Manufacture of machinery and equipment n.e.c**
3366	Ship and Boat Building	C30	Manufacture of other transport equipment
3369	Other Transport Equipment	C30	Manufacture of other transport equipment
3371	Furniture Manufacturing	C31	Manufacture of furniture
3391	Medical Equipment and Supplies Manufacturing	C32	Other manufacturing
3399	Miscalleneous	C32	Other manufacturing
		Cluster 2	
334413	**Semiconductor and Related Device Manufacturing**	**C26**	**Manufacture of computer, electronic and optical products**
3351	Electric Lighting Equipment Manufacturing	C27	Manufacture of electrical equipment
335311	**Power, Distribution, and Specialty Transformer Manufacturing**	**C27**	**Manufacture of electrical equipment**
3353	Electrical Equipment Manufacturing (other than NZT industries)	C27	Manufacture of electrical equipment
335911	**Storage battery Manufacturing**	**C27**	**Manufacture of electrical equipment**
3359	Other Electrical Equipment and Component Manufacturing (other than NZT industries)	C27	Manufacture of electrical equipment
335929	**Other Communication and Energy Wire Manufacturing**	**C27**	**Manufacture of electrical equipment**
		Cluster 3	
3341	Computer and Peripheral Equipment Manufacturing	C26	Manufacture of computer, electronic and optical products
334515	**Instrument Manufacturing for Measuring and Testing Electricity**	**C26**	**Manufacture of computer, electronic and optical products**
3346	Manufacturing and Reproducing Magnetic and Optical Media	C26	Manufacture of computer, electronic and optical products
3364	Aerospace Product and Parts Manufacturing	C30	Manufacture of other transport equipment

Source: own calculations. **Bold**: NZT industries.

Centrum für Europäische Politik
FREIBURG | BERLIN

Author:

Dr. André Wolf, Head of Division Technology, Infrastructure and Industrial Development
wolf@cep.eu

Centrum für Europäische Politik FREIBURG | BERLIN
Kaiser-Joseph-Straße 266 | D-79098 Freiburg
Schiffbauerdamm 40 Raum 4315 | D-10117 Berlin
Tel. + 49 761 38693-0

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