The Siting of Energy Intensive Industries in Europe in the Context of the Energy Transition

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Abstract: Selection of industrial sites is a complex issue that requires careful consideration of a wide range of factors. Classical location decision-making overemphasize the role of economic factors while the energy related factors are often neglected. This research supports the energy transition by means of rethinking the location decision-making problem concerning Energy-Intensive Industries (EIIs). The main objective is to determine how the suitability of sites of industry clusters in Europe will change because of the energy transition. Two industry clusters in Europe are selected and used as test cases for analysis. To offer understanding of the suitability of cluster locations to a changing energy medium, a procedure to conduct analysis is developed and applied. The necessity to develop the analysis procedure is motivated by the lack of a methodology to serve as a commonly accepted framework for the analysis of industrial location problems in the context of energy transitions. The outcomes of the so-called factor analysis procedure enable to reason on the suitability of the sites of the clusters to the envisioned future renewable environment. To ensure validity of data and of findings, insight emerging from the literature and assumptions made by the author, are triangulated with the opinion of stakeholders and experts in the field. The research concludes that the energy transition will have a severe impact on the suitability of sites of the investigated EII clusters in Europe. The rationale being that, state-of-the-art sites are not suitable to a fully transitioned word. Exploring the future points to necessary changes that the sites have to undergo in order to suit a transitioned word. The findings emerging from the analysis, are meant for investors and traders that are interested in siting and industry modernization. Ideally, the methodology developed to study EIIs can be extended to other industrial sectors. I will be necessary to analyze the novel decision space and evaluate the factors at play on the novel location problem under investigation. Future research efforts should internalize the dynamics that govern the location decision of EII clusters described in research and use them to better understand the effects of possible failures of intervention.

Keywords: energy intensive industry cluster, industrial transition, energy transition, location decision-making

1 Introduction

Over the past several decades, the scientific community acknowledged that anthropogenic change is real and directly triggers changes in the climate. In response to this finding, many international organizations developed pathways that are intended to support and guide the global energy transformation (International Renewable Energy Agency IRENA, 2018). In the same report, the general director of IRENA, Adnan Amin, affirms that the most challenging sector of intervention is the heavy industry sector (IRENA, 2018). Following Amin's line of reasoning, it appears critical to re-think the high energy demands of certain EII's, the high carbon content of certain products, and the high emissions of certain processes, in ways that suit the energy transition. The guiding principle is that, the emergence of new energy carriers and energy sources adding into the mix, can be used to our own advantage as they offer new and unique possibilities for intervention (IRENA, 2018; NATO, 2016). Rather than focusing on the technical re-design of carriers and processes, it appears valuable to re-think and re-formulate the way in which heavy industrial facilities are located in terms of energy requirements.

1.1 Objective & research question

This work aims to identify how industry clusters are going to be influenced by an ever-changing energy medium. The added value lies in the ability to evaluate how the increasing share of RE will impact current industry site locations and the cluster of industries that populate these sites. This is performed by assessing how well selected industry clusters in Europe are suited to renewables vis-à-vis fossil fuels. In fact, it is logical to expect that the geographic distribution of certain industry clusters may experience variations in response to an increased availability of RE capacities. This information is quantified by evaluating, for a specific cluster type, its transition potential. In other words, the changes that a cluster would experience if it chose to adopt novel transition technology options (TTOs) which enable to utilize at best the expected larger shares of RE capacities. To this end, an evaluation procedure that supports and guides organizations when facing locational choices is developed and applied. The evaluation procedure captures the methodology developed in the research and it could be applied in future locational decision-making analyses. It enables to predict the extent to which an industry cluster and the area it influences are suited for the present energy transition. This information can guide corporations when investigating future-proof siting choices. The rationale being that, by applying the proposed methodology, the firm will be able to secure its levels of production, efficiency and effectiveness subsequent to a location choice. From the research objective, the main research question is formulated:

"How will the energy transition influence the economic suitability of sites of selected industrial clusters in the EU?"

In order to answer the main research question, it is decomposed into several sub-questions.

1 "How do industries decide on siting and why is it so?
2 "What are the current energy-intensive industry clusters in Europe and how to modernize them?"
3 "How to analyse industry clusters that are facing contemporary transition siting choices?".
4 "What does the analysis show in respect to cluster changes and their locations?".

2 Literature review

Location of warehouses, manufacturing sites and distribution centers are classical examples of location decision-making problems (Skibin, 1975). These problems are generally approached by applying location theory concepts (Smith, 2017). This field of research emerged in 1909 when Alfred Weber published a book titled "Theory of the Location of Industries" (Terouhid, Ries, & Mirhadi Fard, 2012). This research set the foundation for both descriptive and normative location decision theories. Both branches of location decision theory are still in place today since they serve different objectives. Normative theories set up mathematical decision-making models (McCann & Sheppard, 2003) while descriptive theories focus on spatial socio-economic patterns that follow each placement (Owens, 2004).

The desirability of a location relative to another appears to be governed by a multitude of diverse factors (Maniezzo, Mendes, & Paruccini, 1998). Throughout the reviewed literature only two academic articles that have recognized the importance of these factors were found. Badri (2007) develops a process that leads to the definition of 14 groups of factors in industrial siting problems. The critical factors are classified in two larger sets, namely general location factors and international location factors. The general location factors are: transportation; labor; raw materials; markets; industrial sites; utilities; government attitude; tax structure; climate and community. The international location factors are: policy situation of foreign country; global competition and survival; government regulation and economic factors. Terouhid et al., (2012) reviews critical factors in the attempt to understand if current research is aware of the importance of including sustainability requirements when performing a location decision problem. The study shows that location theory originally focused on factors that are of a purely economic nature and that it evolved by embedding social and environmental factors in location decision problems. The two reviews agree on the fact that current location decision-making models need to be restructured in order to enable sustainable economic growth. The reason is that sustainable development goes hand in hand with economic development (Gupta, Suresh, Misra, & Yunus, 2002), which can be linked to the effects (i.e. positive and negative) on society's welfare deriving from the transition of EIIs.

Most of the reviewed articles are case studies that offer very specific solutions to specific location problems. Although all authors use the concept of critical factors when determining suitable locations, it appears unclear how these factors are determined and chosen (Briassoulis, 1995). A common pattern in processing the gathered data is the use of multi-criteria decision analysis (MCDA) and geographic information system (GIS) for solving the location decision problem. Examples of this practice are performed by Rahmat et al., (2017), Ohri and Singh (2009) and Negi and Jain (2008).

In a nutshell, although the reviewed literature agrees on the importance of identifying critical factors, a clear methodology for their definition and use is missing. It seems that current approaches employed in locational analyses, don't consider the grand scheme necessities imposed by the contemporary historic context. In other words, the implications and spillovers that the energy factor has on the overall location decision.

2 Methods

2.1 Theoretical background methods

Determining how RE will change the fortunes of existing heavy industry clusters requires knowledge on the state-of-the-art of such clusters, particularly on their geographical distribution and on the factors that most influence them. To set a common theoretical background, a theory sub-question is raised. This sub-question aims to explain the status of current European site locations and why they are there. As shown by economic (Clark, Wilson, & Bradley, 1969; Carod, 2005; Goiri et al., 2011), geographic (McCann & Sheppard, 2003; Smith, 2017) and location theory literature (Briassoulis, 1995; Maniezzo et al., 1998; Negi & Jain, 2008; Phelps & Wood, 2018), industrial location decision-making is not new, and in many instances, it is a proven practice for locating industrial facilities worldwide. Given that there is sufficient historical and research data in scientific literature to answer the proposed question, the better-suited method is to conduct a state-of-the-art literature review on the factors influencing the location problem. Reviewing the literature provides with context information. Besides, it serves the purpose of coping with factor ambiguity, a feature that affects current siting practices. This aspect is coped with by categorising the location factors that populate location theory literature and by noting the emphasis that authors place on specific factors. To ensure reproducibility of results and of factors, specific indicators are employed when performing cluster evaluation. Eventually, long response times to incorporate new findings into literature's main body of knowledge may occur. This limitation is coped with by interviewing experts from academia and from the industrial operational environment. Semi-structured interviews are conducted for data gathering and validation purposes.

The contemporary energy transition motivates the emergence of the main research question. For this reason, the intent is to know about industrial siting but with a particular focus on energy interdependencies. In the first place, a literature review sheds light on the transition technology options (TTOs) that could decarbonize and electrify existing fossil fuel dependent manufacturing processes. Secondly, information on the state-of-the-art of industry clusters in Europe is collected through desk research and a further literature review. Finally, the two sets of information are merged together. This is done by projecting the sub-sectors of the identified EII clusters onto the TTOs.

2.2 Method to evaluate suitability of sites of clusters

Since the intent of this study is to explore how the energy transition will impact selected industry clusters and respective sites, it is decided to shift from the mainstream usage of MCDA and GIS methods, and develop a method based on the functioning of the system. This method is referred to as 'factor analysis procedure' and is a deduction-based method. In shorth, it consists of a series of steps that serve the purpose of assessing and evaluating the clusters. Compared to state-of-the-art methods, it is seen as valuable alternative because it enables to push the limits of what can be said on the changing preferences regarding the siting of EIIs. As a matter of fact, current research is much devoted towards demonstrating how to transition or how to stimulate the transition. On the contrary, by applying the developed factor analysis procedure in combination with deductive reasoning, it becomes possible to investigate the changes and effects of the transition on the industry clusters.

In order to evaluate the future of clusters and respective sites, the extent to which the transition will impact them must be taken into consideration. To do so, the findings on critical factors, TTOs, clusters type and their location are merged together. Practically, each cluster type is projected onto logical directions of change. In other words, clusters are associated to the TTOs that are more applicable to them. This allows to reason on the system level changes that clusters would experience when opting to transition. The subsequent step consists in applying the developed factor analysis procedure. The procedure focuses on changes in the energy factor and its spillovers onto the remaining location factors. The elegancy is that all factors are kept constant except one, the energy factor. This makes things manageable and enables to identify and reason on transition implications. The output consists of a comparison between the present and future situation of the cluster in terms of the updated factors. It enables to appreciate how the energy transition can change the importance of location factors, thus influence the suitability of clusters and sites to a more renewable future.

2.3 Expert interviews in the research

Because of the novelty of the proposed research, expert interviews play a critical and enabling role in this study. Semi-structured interviews are conducted for data gathering, projection and validation purposes. In a formal phone call or video meeting, experts are walked through the state-of-the-art and the future envisioned situation. The population of interviewees is composed of experts from academia with knowledge on energy transitions, energy systems and industry issues. The second category of experts is composed of industrial practitioners that hold highly ranked positions in cement, steel and chemical companies. Finally, because of the necessity of technological developments, transmission and distribution systems, electricity price issues and RE technology integration, the Italian TSO is interviewed. Table 2 offers information on the interviewees, their role in the organization and the topics that have been discussed. The transcripts of the interviews are reported in the appendix according to the interview ID. To ensure a win-win situation and to avoid misinterpretation, the transcripts have been checked by the interviewees before integration in the research. The audio recording are saved on the personal computer of the researcher and will be deleted after the defence of this thesis.

The location determinants of EIIs are investigated through a literature review. Besides, factors are associated with indicators that enable unambiguous quantitative measurements. To ensure the validity of the selected factors and of the indicators, experts from the academia and the industrial operational environment are consulted. In the first place, they are asked whether they recognize the selected factors and indicators as critical for the siting of EIIs. Besides, they are also asked to share their thoughts on other factors and indicators which may have not been included in the selection process by the author. Finally, experts are asked to quantify the relative importance of the various factors at play on the location problem under study. This proved to be valuable because it enabled to work on data that was not yet incorporated into literature's main body of knowledge.

Existing EII clusters in Europe are projected on logical energy directions of change. The projection is performed by associating the clusters to transition technology options (TTOs) which enable for cluster modernization. Because of the novelty of this research field, the opinion of experts is essential. At this stage experts are introduced to various TTOs and are asked whether they consider these technologies to have the potential to be adopted by industry in the real world. The results are analysed to find recurring themes, capture key takeaways and to create credible, logical directions of change.

The information gathered is used to evaluate two specific EII clusters. To this end, a method to conduct analysis is developed and applied. Generally, tools that are not internationally recognized as standards may be affected by limitations. To cope with such limitations and to ensure the validity of the findings, experts are consulted. The methodology to conduct the interviews starts by introducing the state-of-the-art of the clusters. It continues by foretelling the expectations that arise when considering a certain projection (i.e. cluster with associated TTOs from chapter 3) and verifying whether the interviewees confirm, deny or have a different perspective. Specifically, the experts share considerations of factor projections into the future, the implication for the future of cluster, the implication for the future of industry sites and the spillovers emerging because of changes in the projected energy factor. In summary, experts are walked through the state-of-the-art and through the future envisioned situation. The result is a credible and validated storyline that shows how changes in the nature of energy supply will influence the economic suitability of sites of clusters of EIIs in Europe. Finally, the opinion of experts is used for alignment purposes and to verify expectations and findings.

3 Findings

The changes that occur because of the projection of location factors in the future point to two main findings. Although these findings emerge in response to other findings of the cluster evaluation procedure, their importance suggests presenting them first. Firstly, when looking at the companies of both EII clusters as rational economic actors it emerges that the current context offers three possible options:

1 Invest in TTOs in this investment cycle and update business models accordingly;

2 Survive the shorth term and shut down existing production units at the end of their service lives (disrupting the local economy and integrated value chains);

3 Invest abroad and import commodities that are needed domestically (triggering further dependence on other nations).

A second relevant finding concerns the effects of changes in the energy factor of both clusters. This factor was hypothesized to be the only variable of the location problem allowed to change. All other factors were seen as variables, but to cope with complexity, they were kept constant. However, performing the cluster evaluation procedure showed that the spillovers triggered by changes in the energy factor significantly affect most of the remaining factors. For instance, changes in energy factor spill over to infrastructure that becomes essential (i.e. expansion of the national transmission and distribution network, expansion of existing interconnector capacity, construction of power lines and of energy storage systems, hydrogen production and transportation). Neglecting this effect would imply to reason on an industry system that cannot function adequately in a transitioned word. Adding to this, further implications emerging from the spillovers of the energy factor concern the creation of added value carbon-neutral commodities that necessitate the existence of a market for successful commercialization. If the EU and the local governments fail in delivering dedicated and coordinated planning, investment support and appropriate policy, it becomes hard to expect that industry cluster in the EU will be able to face international competition. There is a strategic interest in ensuring that this happens. Current competition with China is unsustainable if the rules of the game do not change. However, the creation of added value commodities that internalize the cost of the transition and the design of a market for their commercialization changes the rules of the game and offer new business opportunities to the EII clusters that populate Europe. The findings emerging from the cluster evaluation procedure are reported in the appendix. Table 2 shows the findings that emerged from the comparison of the present and future situation of the Po Delta cluster. A future with incentives and support schemes is more attractive for the interest of the companies of the cluster. Availability of sources (AV) and their affordability (AF) are integrated next to each factor. The impact of each factor is expressed by a coloured gradient ranging from orange (negative impact) to green (positive impact). The color blue refers to a neutral impact. Table 3 shows the same information but for the Rhine-Ruhr cluster. Finally, Table 4 compares the results of the two clusters.

4 Discussion

4.1 Theoretical relevance

Exploring location theory literature showed that scholars employ MCDA and GIS techniques when conducting locational analyses. MCDA techniques use location factors to identify a single most preferred site for a facility (Negi & Jain, 2008; Ohri & Singh, 2010; Ohri et al., 2009). MCDA techniques are also applied to rank industrial alternatives (Briassoulis, 1995; Ohri et al., 2009; Rahmat et al., 2017). GIS techniques generally build on MCDA results and graphically distinguish acceptable from unacceptable siting options (Onwe, 2018). However, by applying these techniques it is not possible to capture the implications arising because of the energy transition on location decision-making. In contrast to previously published research, this research internalizes the location factors and reasons on how their change will impact the suitability of industrial sites to a more renewable future. This enabled to highlight the role played by the availability of traditional fossil fuels and renewable energy sources, transportation and distribution systems, storage systems, gains in energy efficiency, changes in energy prices and incentive schemes on the location decision of EIIs.

Additionally, since the energy transition is of a global character it appeared appropriate to investigate the collective behaviour of clusters of industries. The literature studies the siting of one facility while the present study utilizes a cluster-based mindset to explore a larger population of industries and their suitability to broader geographic areas. The results of the cluster evaluation procedure are not intended to have the same empirical accuracy as the results emerging from traditional methods. There is a trade-off in accuracy to be accepted when investigating and analysing possible futures. However, econometric techniques can be integrated to increase the analytic depth of the cluster evaluation procedure. They enable to quantify interactions between characteristics of regions and characteristics of specific industry sectors (Missiaia, 2019; Takano, Tsutsumi, & Kikukawa, 2018).

Data can be compared with reports by the EU commission that mention the role of industry clusters as facilitators of industry modernization. For example, the Methodology report for the European Panorama of Clusters and Industrial Change (Hollanders, 2020) and Europe's Cluster trends Methodological Report define and classify the clusters of industries in Europe. However, they do not perform analysis or reason on the data.

Industry modernization literature offers few comparable studies. Decarbonization techniques of cement, steel and chemicals manufacturing are deeply investigated (ICF, 2015; Kitson & Wooders, 2012; Schüwer & Schneider, 2018; Wyns, T., Khandekar, G., Robson, 2018; Wyns & Axelson, 2016). The central role of strategic and coordinated planning (Kitson & Wooders, 2012), of supportive policy interventions (ICF, 2015) and the utilization of renewable energy sources in EIIs (Schüwer & Schneider, 2018; Wyns, T., Khandekar, G., Robson, 2018; Wyns & Axelson, 2016) are also treated in previous research. However, no previously published study was able to relate these aspects to the location choices of EIIs. This study internalizes the considerations of previous research and broadens their application by reasoning in terms of location factors. The result is that previous research will advise siting EIIs where minimization of cost and maximization of profit occurs. This research points to necessary system level changes and highlights three possible economic options for European industry players.

4.2 Practical relevance

In order for industry clusters to foster a prosperous future in Italy and in Germany, stakeholders are associated with their responsibilities:

The TSO should keep in mind that intensive energy demand will be spatially bounded in the future. The TSO should prioritize grid expansion, storage infrastructure development of the areas where EII clusters are located. The TSO should negotiate early on the win-win allocation of cost with the remaining stakeholders. Finally, the balance of the electricity grid will become even more central in the envisioned future. The expected increased penetration of variable renewable energy sources must be accommodated in the energy mix of the countries in a way that prevents failures.

The national government should consider the disrupting consequences of losing its manufacturing industry. Therefore, it should deliver smart and committed public policies that support the industry through its modernization. Besides, it should help to create markets for novel low-carbon value-added products through public procurement. Finally, regulatory misalignment should be avoided by all means.

The EU Commission should deliver targeted direction of change and actively inform and monitor the EII clusters of its member states.

Industry Players are urged to initiate negotiation of win-win allocation of cost with the remaining stakeholders. Adaptation of business models according to the energy transition is a further requirement for industry players that seek to remain competitive in the Eurozone in the future.

Society at large should seek in purchasing added value carbon-neutral commodities. To support sustainable growth, information campaigns should be utilized in order to inform society about the effects of their purchasing preferences.

4.3 Reflection

The process of developing this research was challenging. The literature does not offer much insight into how to conduct analysis that considers the expected future suitability of industry cluster locations to a more renewable word. Therefore, it was necessary to deduce what information was important for the problem at hand, which played a secondary role and what was noise. Location factors are important because they are what the industry takes into consideration when making siting choices. Selecting the factors was a tough process because the literature internalizes to many, does not explain how they are defined and how they influence the problem. Since these considerations are seen as mandatory when approaching a problem, it was decided to review the literature to understand how they influence the problem and to classify them in a way that will facilitate their application when performing this and eventual further analyses.

It was decided to shift from the mainstream usage of MCDA, GIS methods and develop a method based on the functioning of the system. This is motivated by the fact that the literature does not offer methods to consider possible future developments of energy intensive industries in the context of energy transitions. Compared to state-of-the-art methods, the developed method is seen as an alternative way to think when making siting choices. It enables to push the limits of what can be said on the future preferences regarding the siting of EIIs. As a matter of fact, current research is much devoted towards demonstrating how to transition or how to stimulate the transition. On the contrary, by applying the developed cluster evaluation procedure, it becomes possible to investigate the changes and effects of the transition on the location of the industry clusters. Besides, all locational studies that have been reviewed, consider only past, and state-of-the-art data. Although this is the standard way of conducting research, the energy transition entails major system level changes that these analyses are not always able to internalize. This study integrates the state-of-the-art and the expected future developments; thus, it is more insightful when facing location investment choices with long term consequences. In the end, when investors make strategic choices such as siting, they try to anticipate what will come next rather than what happened in the past.

5 Conclusion

This attempt to explore the economic suitability of cluster locations in an envisioned future teaches that when considering a medium that is transitioning, it becomes very difficult to keep factors constant. This study treated location factors as variables. Among all factors, to limit complexity, only the energy factor was allowed to change. It was found that changing the energy factor caused spillovers to most of the remaining siting factors. The remarkable aspect is that the spillovers have to be internalized because they influence the problem in a way that cannot be neglected. An example is the parallel infrastructure needs that must be available in order to allow for the hypothesized energy factor change (i.e. ensure system functionality). A second example is the need of a market to enable industry player to foresee returns on investment. A third example is a political and regulatory climate required for these investments to occur. A fourth example is a change in primary raw materials required for hypothesize changes in the energy factor.

Based on realistic assumptions, informed ideas and expectations of a possible more renewable future for EII clusters are delivered. However, with the present knowledge, and by having developed and applied the cluster evaluation procedure, it appears valuable to keep on investigating likely changes and their implication for the future of EII clusters and industrial sites across Europe. Because of the novelty of this field of research, it was necessary to create a comprehensive understanding of the dynamics governing the location decisions of EII clusters. Future research should internalize these dynamics and use them to shed light on possible future implications. What are the implications of the three economic options that EII clusters can opt for in terms of growth? Moreover, how to ensure that clusters will choose option one? These considerations are important and should be considered in future research. The expectation is that if the national governments would fail in delivering coordinated planning and if the national TSO will fail in delivering the required energy infrastructure the economic competitiveness of EII clusters will be harmed. In cases of failure, the effect of eventual foreign investment in the required parallel infrastructure becomes an aspect that deserves attention.

6 References

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7 Appendix

Table 1 Overview of factors affecting the location decision of Energy-Intensive Industries

Factors affecting the location decision of Energy-Intensive Industries												
Article information			Factors affecting spatial distribution						Factors affecting industrial concentration and cluster emergence			
Author	Journal	Year	Energy sources	Cost of Knowlede (Labor wages)	Construction cost CAPEX	Raw materials & Transportation	Climate	The market	Policy environment	Geographical conditions	Industrial conditions (aglomeration)	Key infrastructure
Peter Djing Kioe Djwa	University of British Columbia	1960	x	x	x	x	x	x		x		x
C. Clark et al	Regional studies	1969			x	x		x		x		x
D. Skibin	Atmospheric Environment	1974			x	x		x		x		x
Willam G. Murray et al.,	Hastings Law Journal	1980				x		x	x	x		x
Daniel Z. Czamanski	European Journal of Operational Research	1981		x	x	x		x	x	x		x
Paul Blackley et al	Urban Studies	1985		x				x			x	x

Howard A. Stafford	Association of American Geographers	1985		x		x		x	x	x		x
Eric R. Hansen	Regional Science and Urban Economics	1986	x	x	x				x	x	x	
Robert J. Newman et al	Journal of Urban Economics	1988							x			
Jürgen G.	International Journal of Social Economics	1988					x		x			
Masood A. Badri et al.,	Journal of Operations & Production Management	1995		x		x		x		x		x
Helen Briassoulis	Environmental Management	1995					x			x		
Timothy M. Stearns et al.,	Journal of Business Venturing	1995								x		x
Sanjoy Chakravorty	The Journal of Development Studies	2003		x					x		x	
Philip Mccann et al.,	Regional Studies	2003	x		x	x		x		x		x
Josep Maria Carod	Regional Science	2004				x		x	x	x	x	x
Masood A. Badri	Businnes and public affairs	2007	x	x	x	x	x	x	x	x	x	x
Glenn Ellison et al.,	American Economic Review	2010		x						x	x	x
Iñigo Goiri et al.,	IEEE computer science	2011	x		x		x			x		x
Seyyed Amin Terouhid et al.,	Journal of Sustainable Development	2012				x	x		x	x		
Thomas Brenner et al.,	Papers on Economics & Evolution	2013	x	x	x	x			x	x	x	x

Youngsoo An et al.,	International Journal of Urban Sciences	2014		x	x	x		x			x	x
Eliška Jirásková	Ekonomika a management	2015		x	x	x		x		x		x
Brett Anitra Gilbert	Foundations and trends in entrepreneurship	2016	x	x	x	x	x	x	x	x	x	x
D. M. Smith	Economic geograpy	2017	x		x	x		x		x		
Keisuke Takano et al.,	Urban & regional development studies	2018									x	x
Wei Xu et al	Complexity	2018	x	x	x	x			x	x	x	x
Anna Missiaia	Cliometrica	2019	x		x						x	
Vytautas Snieska et al.,	Economic Research	2019				x	x		x	x		
Dario Musolino et al.,	The Annals of Regional Science	2020	x	x	x	x		x	x	x	x	
Patrick Adler	Regional studies	2020		x			x		x		x	x

Table 2scores of factors influencing the location decision of the Po Delta cluster

Scores of factors influencing the location decision of the Po Delta cluster															
Contextualization		Indicators of the energy factor								Traditional location factors					
		AV	AV	AF	AF	AV	AF	AF & AV	AV	AC	AV	AV	-	AV	AC
Time reference	Cluster name	Supplied capacities [GWh]	HI power needs [GWh]	HI power prices [€c/KWh]	Support schemes to HI [M€ per year]	Allocating RE to HI [GWh per year]	Expected cost of RE [€c/KWh]	Gains in energ efcciency [%]	Foreseen RE power capacity [GWh]	Raw materials & Transportation [€/tone & €/km]	The market [M€]	Cost of Knowlede [€ per year]	The Climate [avoided tones of CO2 per year]	Policy environment [descriptive index]	Geographycal conditions; Industrial conditions & Key infrastructure [descriptive index]
Present 2020	Po Delta Cluster						n.a.	n.a.	n.a.						
Future 2050 no incentives	Po Delta Cluster	o	o	-	+	-	-	o	-	-	-	-	-	-	o
Future 2050 incentives	Po Delta Cluster	o	o	o	+	o	+	+	+	o	+	o	+	-	+

Table 3 Scores of factors influencing the location decision of the Rhine-Ruhr cluster

Scores of factors influencing the location decision of the Rhine-Ruhr cluster															
Contextualization		Indicators of the energy factor								Traditional location factors					
		AV	AV	AF	AF	AV	AF	AF & AV	AV	AC	AV	AV	-	AV	AC
Time reference	Cluster name	Supplied capacities [GWh]	HI power needs [GWh]	HI power prices [€c/KWh]	Support schemes to HI [M€ per year]	Allocating RE to HI [GWh per year]	Expected cost of RE [€c/KWh]	Gains in energ eficciency [%]	Foreseen RE power capacity [GWh]	Raw materials & Transportation [€/tone & €/km]	The market [M€]	Cost of Knowlede [€ per year]	The Climate [avoided tones of CO2 per year]	Policy environment [descriptive index]	Geographycal conditions; Industrial conditions & Key infrastructure [descriptive index]
Present 2020	Rhine-Ruhr Cluster						n.a.	n.a.	n.a.						
Future 2050 no incentives	Rhine-Ruhr Cluster	-	o	-	o	-	-	o	o	-	-	o	-	o	+
Future 2050 incentives	Rhine-Ruhr Cluster	o	o	o	+	o	+	+	+	o	+	o	+	+	+

Tabkle 4 Comparison of the scores of the two clusters

Scores of factors influencing the location decision of energy intensive industry															
Contextualization		Indicators of the energy factor								Traditional location factors					
		AV	AV	AF	AF	AV	AF	AF & AV	AV	AC	AV	AV	-	AV	AC
Time reference	Cluster name	Supplied capacities [GWh]	HI power needs [GWh]	HI power prices [€c/KWh]	Support schemes to HI [M€ per year]	Allocating RE to HI [GWh per year]	Expected cost of RE [€c/KWh]	Gains in energ efficiency [%]	Foreseen RE power capacity [GWh]	Raw materials & Transportation [€/tone & €/km]	The market [M€]	Cost of Knowlede [€ per year]	The Climate [avoided tones of CO2 per year]	Policy environment [descriptive index]	Geographycal conditions; Industrial conditions & Key infrastructure [descriptive index]
Present 2020	Rhine-Ruhr Cluster						n.a.	n.a.	n.a.						
	Po Delta Cluster						n.a.	n.a.	n.a.						
Future 2050 without incentives	Rhine-Ruhr Cluster	-	o	-	o	-	-	o	o	-	-	o	-	o	+
	Po Delta Cluster	o	o	-	+	-	-	o	-	-	-	-	-	-	o
Future 2050 with incentives & coordinated planning	Rhine-Ruhr Cluster	o	o	o	+	o	+	+	+	o	+	o	+	+	+
	Po Delta Cluster	o	o	o	+	o	+	+	+	o	+	o	+	-	+