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Smart specialisation benchmarking and assessment: pilot study on wind energy

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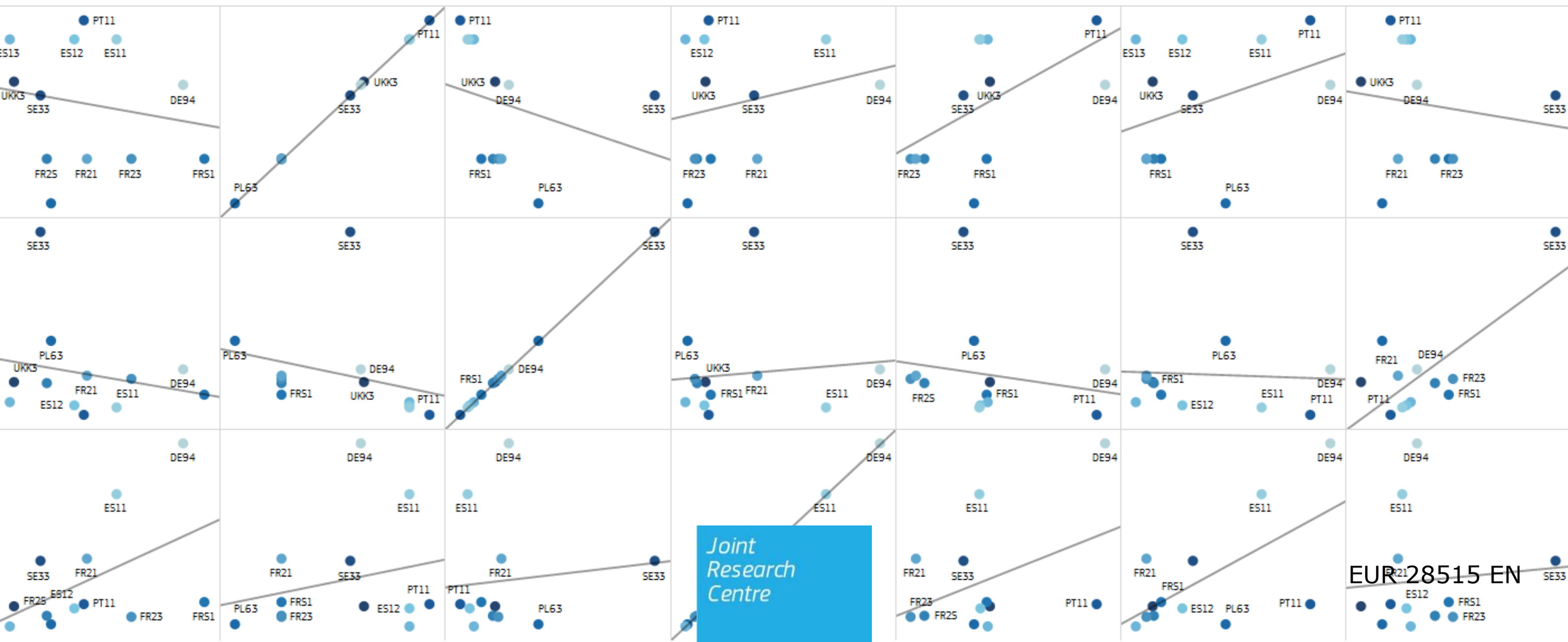

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Smart specialisation benchmarking and assessment: pilot study on wind energy

Smart specialisation Platform on Energy aims at supporting the implementation of regional smart specialisation strategies and the optimal and effective uptake of cohesion funds in the energy area. To that end, regional cooperation is a key element as a way of accelerating successful regional projects. This report proposes and tests a methodology to identify potential regions to work with, based on structural similarities and recommends potential partnership amongst them.

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Executive summary

This work was carried out in the framework of the Smart Specialisation Platform on Energy (S3PEnergy). It aims at supporting the implementation of regional smart specialisation strategies and the optimal and effective uptake of cohesion funds in the energy area.

This report aims to foster cooperation amongst regions with common interest in a particular energy theme, which allows mutual learning amongst regions. Consequently, the objective of this work is to provide and test a methodology to identify similarities within a group of regions with a particular interest in wind energy. This analysis facilitates the identification of leading regions and regions with structural similarities and recommends potential partnerships amongst them.

Policy context

Research and innovation strategies for smart specialisation (RIS3) have become a requirement for those regions that want to take advantage of ESIF funds allocated under the thematic objective dedicated to strength research, technological development and innovation (TO1). To succeed in the implementation of those strategies, cooperation and mutual learning are key element to take advantage of lessons learnt in the use of structural funds.

Key conclusions

Based on the analysis carried out, the cluster of regions that demonstrate interest in a particular energy technology is a complex exercise. Although from a theoretical analysis some conclusions may be extracted, i.e. the high level of similarities amongst regions within the same country, and some potential regional clusters could be identified, clustering process should follow a bottom-up approach. Therefore, regions should describe their specific needs and find ideal partners to advance in solving those needs. In this regard, this work provides a methodology to narrow down the number of potential partners.

Main findings

This work reveals the complexity of representing a particular energy technology deployment by a limited set of parameters. Additionally, some efforts are still required to break national data into regional level (NUTS2 level), which actually limits the selection of parameters to be assessed.

Despite the uncertainty concerning which dataset better describes the regional wind energy status, it is demonstrated that a reduced number of variables is enough to characterise the level of similarities amongst regions. Still, this conclusion has to be validated for other technologies and requires extending the number of regions under analysis.

Based on the set of regions under analysis, it is worth to highlight the lack of correlation amongst them for the different dimensions assessed. Thus, although available wind energy resource was expected to be the main driver for the deployment of the wind sector in a region, this availability is not correlated with the size of the private sector or the innovation capacities in the regions. However wind innovation capacities are affected by the economic development of the regions.

The analysis also shows how industrial electricity prices are inversely correlated with the relative GPD in regions, having an impact in terms of competitiveness for regions.

Related and future JRC work

In case this methodology become of interest to regions, the methodology could be applied to other technologies and regions across Europe.

1 Introduction

Smart specialisation aims at promoting a more efficient uptake of public funding in research and innovation. Energy is a topic with high interest amongst regions registered at the S3 Platform on smart specialisation [Jiménez Navarro & Uihlein 2016]. Thus, under the umbrella of the Smart Specialisation Platform (S3P), a thematic platform on energy was set up in 2015.[1] The Smart Specialisation Platform on Energy (S3PEnergy) is the space where Member States, regions and community members receive support for the optimal and effective uptake of Cohesion Funds for sustainable energy. The S3PEnergy also promotes energy innovation activities at national, regional and local level through the identification of technologies and innovative solutions that support, in the most cost-effective way, the EU energy policy priorities.

One of the most important aspects of the concept of smart specialisation strategies is territorial cooperation [European Commission 2011]. Lessons learnt may represent a valuable input in order to succeed in the implementation of national or regional strategies. Therefore, the identification of lighthouse regions in specific topics is fundamental to achieve a similar level of deployment in other regions of Europe.

This identification needs a comparison framework that leads to significant conclusions concerning the status of territorial units in specific aspects. Therefore, the definition of a set of key performance indicators (KPI) to determine a fair comparison framework is required to assess the status of regions in a specific aspect.

In the framework of the smart specialisation concept [Foray & Goenega 2013], a regional benchmarking methodology has been developed to identify reference regions and to measure how close/far regions are from each other. Proposed benchmarking exercises include issues related to geo-demography, human resources, technology structure, sectorial structure or institutions and values [Navarro et al. 2014]. A benchmarking can provide into insights about possibilities for learning and transfer of best practises.Regions with similar structural conditions could benefit most from knowledge transfer and mutual learning.

Regarding energy, a regional characterisation through a limited number of indicators is a complex exercise. Firstly, because of the energy sector itself shows a high complexity itself which is difficult to portray with a limited amount if indicators. Secondly, data is often not available for several indicators and regions.

Therefore, the definition of a set of KPIs supported by available data and capable to characterise the status of a region's energy aspects will contribute to developing a comparative analysis between regions and finally promote cooperation amongst regions.

[1] http://s3platform.jrc.ec.europa.eu/s3p-energy.

2 Objective

This report aims to facilitate the comparison of the energy sector status for a specific energy technology of EU regions with the final purpose of identifying most advanced regions in each aspect as well as establishing a potential group of regions which share similar characteristics.

To this end, the objective of this work is to define and test a feasible comparison framework for a particular energy technology and for a limited set of European regions. This work serves as a case study for further analysis involving other energy technologies and regions.

Therefore, the proposed comparison framework is built to be easily replicated for other regions and technologies, and can be considered a proof of concept. Once defined and tested, it allows an integrated analysis combining regions and energy technologies leading to the assessment of the level of similarity amongst technologies or amongst regions.

For the proposed case study, wind energy has been selected as an appropriate technology. It does not present a high level of interactions and/or overlapping with other low carbon energy technologies. This aspect is expected to facilitate also the data retrieval process.

The selection of regions is based on the information provided in their smart specialisation strategies. Therefore, all regions with interest in developing wind energy in their territories are included in the analysis [Jiménez Navarro & Uihlein 2016].

The analysis is carried out based on the definition of dimensions containing different parameters related to wind technology to certain extend. As mentioned in the previous section, the main challenges faced in this analysis are the selection of parameters that could better define the technology status in regions and data availability. These two issues are directly linked since data access limits the initial identification of parameters. Therefore, as a proof of concept, this analysis explores data availability. The methodology also tests the application of dimensional reduction techniques such as the principal component analysis in order to simplify the study and detect critical parameters.

Considering how difficult it is to set a comprehensive list of parameters that best defines the status of a technology, a realistic list according to available information is presented. Ultimately, the proposed analysis allows the integration of new parameters in case new data becomes available.

3 Methodology

The proposed methodology is based on the following steps:

- selection of regions with proven wind energy interests in their smart specialisation strategies;
- identification of energy parameters to compare;
- collection of information from different sources;
- analysis of energy similarities between regions;
- quantification of potential correlations.

3.1 Selection of regions

The selected group of regions is composed of those that have declared interest in their specific smart specialisation strategies according to [Eye@RIS3 2015] and included in [Jiménez Navarro & Uihlein 2016]. This initial list has been revised in a second stage after the collection of information has been performed to remove regions with poor information available (Section 4).

3.2 Identification of energy parameters

Ideally, and from a broad perspective, the energy sector analysis should include four main aspects: social, economic, environmental and institutional aspects [IEA 2001]. Some works propose parameters to be considered to analyse sustainable development [IEA 2001]. In the case of specific energy technology status at regional level, some of them may be considered. However, there is no consensus about the parameters to be incorporated to characterise regional energy technology status.

Next to a lack of consensus on which parameters to include, data availability determines the choice of energy parameters that can be considered. In addition to this, despite the fact that at Member State (MS) level available information is enough to establish robust analysis, NUTS2 level means a challenge in terms of data acquisition. Most databases analysed include very detailed information on MS level but not at regional level. Therefore, the challenge is to break down national information to regional level, a task that until now remains unsolved for some indicators.

Taking into account all the above, a list of indicators was developed and is presented in Table 1 together with the data sources used and the geographical coverage. The proposed list of indicators is organised in seven dimensions that will be used in following steps to carry out analysis to establish correlation amongst them.

Table 1 List of indicators used for the wind regional benchmarking

Dimension	Elements	Parameter	Coverage	Year	Source
Socio-economic	Population	Total population	Regional	2013	[Eurostat 2015a]
	Urban	Urban population	Regional	2013	[Navarro et al. 2014]
	Region wealth	Absolute GDP	Regional	2013	[Eurostat 2015b]
		Relative GDP	Regional	2013	[Eurostat 2015b]
Energy price	End use energy price before taxes	Gas price for domestic	National	2014	[Eurostat 2015c]
		Gas price for industrial	National	2014	[Eurostat 2015d]
		Electricity price for domestic	National	2014	[Eurostat 2015e]
		Electricity price for industrial	National	2014	[Eurostat 2015f]
	End use energy price after taxes	Gas price for domestic	National	2014	[Eurostat 2015c]
		Gas price for industrial	National	2014	[Eurostat 2015d]
		Electricity price for domestic	National	2014	[Eurostat 2015e]
		Electricity price for industrial	National	2014	[Eurostat 2015f]
Energy use	Energy demand	Heating degree days	Regional	2009	[Eurostat 2013]
Wind energy deployment	Wind capacity	Installed capacity	Regional	2014	GlobalData / Renewable UK
	Wind production	Capacity factor	Regional	2014	[Gonzalez Aparicio et al. 2016]
	Wind deployment	Number of wind farms	Regional	2014	GlobalData / Renewable UK
Academia	Universities	Number of universities	Regional	2016	[Scopus 2016]
	Regional in-house Knowledge	Number of publications	Regional	2016	[Scopus 2016]
		Share of wind publications	Regional	2016	[Scopus 2016]
		Share of wind publications in the energy area	Regional	2016	[Scopus 2016]
Sectorial structure	Energy sector size	Number of companies with innovative activities	Regional	2015	[BNEF 2015]
		Representativeness of the region	Regional	2015	[BNEF 2015]
Innovation capacities	R&D expenditure	All sectors	Regional	2013	[Eurostat 2016a]
		Business sector	Regional	2013	[Eurostat 2016a]
		Government sector	Regional	2013	[Eurostat 2016a]
		Education sector	Regional	2013	[Eurostat 2016a]
		Non-profit sector	Regional	2013	[Eurostat 2016a]
	R&D personnel and researchers	Number of researchers	Regional		[Eurostat 2016a]

3.3 Data collection

Most of the data could be obtained directly from different data sources, and only some of them (related to the dimensions 'wind energy deployment', 'academia' and 'sectorial structure') required specific data processing. The following sections briefly explain how data was retrieved in these cases.

3.3.1 Wind energy deployment

Concerning wind energy deployment, information on the number of wind farms and their installed capacity has been retrieved from a commercial database [The Wind Power 2015] and completed with data produced by the JRC related to geographical information. It should be noted that 3.5 % of records did not provide enough information neither in terms of installed capacity nor in terms of geographical information that may lead to a NUTS2 classification. This figure is sufficient to carry out the proposed analysis.

Data on electricity production from wind energy was not available in most cases at regional level. However regional capacity factors have been derived based on EMHIRES [Gonzalez Aparicio et al. 2016]. With this information, wind energy production can be directly obtained.

3.3.2 Academia

For the analysis of the dimension 'academia', the authorities file of European universities [Daraio 2015] has been used (Annex IV). Specific wind information in terms of publication has been retrieved during February 2016 from Scopus [Scopus 2016]. Queries have been developed filtering in the following order: universities, energy area and wind:

(AF-ID ("University of Exeter"   60026479)) AND (wind) AND (LIMIT-TO (SUBJAREA , "ENER"))

3.3.3 Sectorial structure

The analysis of the sectorial structure is based on a comprehensive list of European active companies working in the field of wind energy including more than 4 000 companies [BNEF 2015]. However, despite the fact that at country level information is available, information related to city or zip code is not complete (Figure 1). Therefore, to allocate companies in regions, coordinates of records based on geographical data (headquarter, place, location) have been calculated and classified into NUTS2 areas.

According to Figure 1, the lack of information available for a specific country affects also regions within that country. To overcome this issue, it has been assumed that regions perform as its related country does. In other words, if one of the countries has 80 % of geographical data available, it is considered that regions in this country will also have the same share. So, for a particular region with 100 wind energy companies with information about geographical location available in a country where the location is know for 80 % of the companies, the final sectorial size considered for this region would be 125 companies.

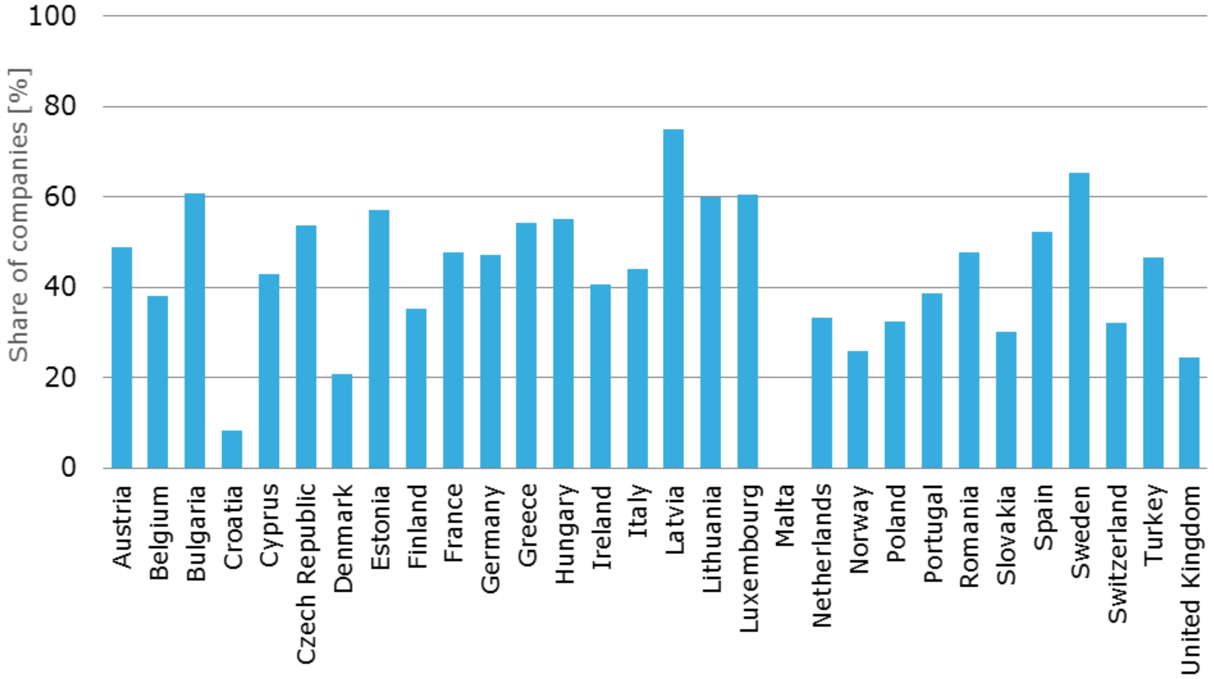


Figure 1 Share of wind energy companies with no geographical information available

3.4 Analysis of similarities amongst regions

Once data was collected and processed, the benchmarking analysis has been performed using a dissimilarity or distance matrix (Equation 1).

$$D = \begin{bmatrix} \mathbf{0} & \boldsymbol{d}(\mathbf{1},\mathbf{2}) & \cdots & \boldsymbol{d}(\mathbf{1},\boldsymbol{n}) \\ \vdots & \mathbf{0} & & \vdots \\ \boldsymbol{sym} & \cdots & & \mathbf{0} \end{bmatrix}$$

Equation 1

n = number of parameters considered

d(i,j) = distance between region i and j

sym = symmetric elements

Every element of the matrix was calculated by applying the Minkowski distance (Equation 2).

$$d(i,j) = \left(\sum_{k=1}^{n} |p_{i,k} - p_{j,k}|^{r}\right)^{1/r}, r \geq 1$$

Equation 2

n ≡ number of parameters considered

$p_{i,k}$ ≡ value of the parameter k for the region i

d(i,j) ≡ distance between region i and j

r ≡ order of Minkowski distance

For this specific analysis, a Euclidean distance (r=2) has been assumed. Euclidean distance represents the natural perception of distance between two points and can be also applicable in multidimensional problems. However the Euclidean distance may offer poor results when parameters present different ranges, being those with high ranges those that tend to dominate [Cornish 2007]. To overcome this issue, parameters have been normalised (Equation 3).

$$p'_{i,k} = \frac{p_{i,k} - \overline{p_k}}{\sigma_k}$$

Equation 3

$p'_{i,k}$ ≡ normalised value of the parameter k for the region i

pi,k ≡ value of the parameter k for the region i

$\overline{p_k}$ ≡ average value of the parameter k

σ_k ≡ standard deviation of the parameter k

At a first stage, no specific weights were introduced meaning all 55 parameters (30 introduced explicitly in Table 1 and energy prices breakdown in Annex I) were weighted equally (1/55). For each of the dimensions presented a particular distance matrix was created.

3.5 Weighting & principal component analysis

After the similarity analysis, weighting and principal component analyses are applied.

Weighting analysis is applied to have a clear understanding on the role of different dimensions. By applying weights at dimension level, we ensure every one of the seven dimensions has an equal impact in the description of the regions no matter the amount of variables within the dimension.

The principal component analysis is applied to assess whether it is possible to reduce the number of parameters or not. This analysis determines which parameters better define the differences between regions and then discard those that do not provide additional information.

3.6 Quantification of potential correlation

It is important to note that the matrixes presented in section 3.4 just provide distances amongst regions but do not explain which region is performing better or worse. To identify those regions with high level of wind deployment, a correlation analysis was carried out in the final step of the proposed methodology. This analysis also allowed establishing relations between dimensions, leading to determine key drivers for the deployment of wind energy in regions.

To obtain a final mark per region and dimension, the average value of the normalised parameters under a particular dimension and region has been calculated. As a result a matrix of dimension '*number of dimensions*' x '*number of dimension*' is obtained.

4 Results

4.1 Selection of regions

According to the methodology presented, regions that have included wind energy in their smart specialisation strategy as an interest are presented in Table 2. Taking into account the limited size of the sector for the case of FR94 in terms of the dimensions 'sectorial structure', 'academia', and 'innovation capacities', it has been removed. The particular characteristics of FR94, pacific island geographically disconnected from Europe, require a separate analysis and comparison will not provide clear conclusion. Therefore, the final analysis covers 12 regions from 7 different European countries.

Table 2 Region with wind energy interests

NUTS ID	Country code	NUTS level	Region/Country name
DE94	DE	3	Weser-Ems
ES11	ES	3	Galicia
ES12	ES	3	Principado de Asturias
ES13	ES	3	Cantabria
FR21	FR	3	Champagne-Ardenne
FR23	FR	3	Haute-Normandie
FR25	FR	3	Basse-Normandie
FR51	FR	3	Pays de la Loire
FR94	FR	3	Réunion
PL63	PL	3	Pomorskie
PT11	PT	3	Norte
SE33	SE	3	Övre Norrland
UKK3	UK	3	Cornwall and Isles of Scilly

Source: [Eye@RIS3 2015]

This list provides an interesting combination of regions as it mixes both regions from different countries as well as regions within the same country. Having the combination of regions within the same country and from different countries allows assessing the impact of national framework effect in the penetration of the technology. It should be also mentioned that a common geographical aspect exists: apart from FR94 and SE33, all regions belong to the Atlantic Arc being therefore coastal regions. So, it may be envisaged that one of the main driver for this group of regions is the resource availability in coastal areas linked to the deployment of off-shore wind.

4.2 Energy parameters

4.2.1 Socio-economic dimension

The four parameters considered for the socio-economic dimension are show in Table 3. They give a clear picture of the economic development of regions. Figure 2 shows the absolute and relative gross domestic product (GDP) of regions. Spanish regions (Galicia, Asturias, and Cantabria) have a similar GDP per inhabitant as well as French regions. The relative GDP in the Swedish region is much higher compared to the other regions exceeding EUR 40 000 per inhabitant. On the contrary, relative GDP of Pomorskie in Poland is only about EUR 10 000.

Table 3 Parameters under the 'socio-economic' dimension

Element	Parameter	Unit
Population	Total population	No of inhabitants
Urban	Population in urban areas	No of inhabitants
Region wealth	Absolute gross domestic product	EUR
	Relative gross domestic product	GDP/inhabitant

Regarding population values and level of urban population, there is no correlation between regions in the same country (Figure 3). Therefore the effect of the national economic in the country has a clear impact in the level of average incomes but not in the way the territory is organised. Level of urban or rural population depends on the specific characteristics of regions.

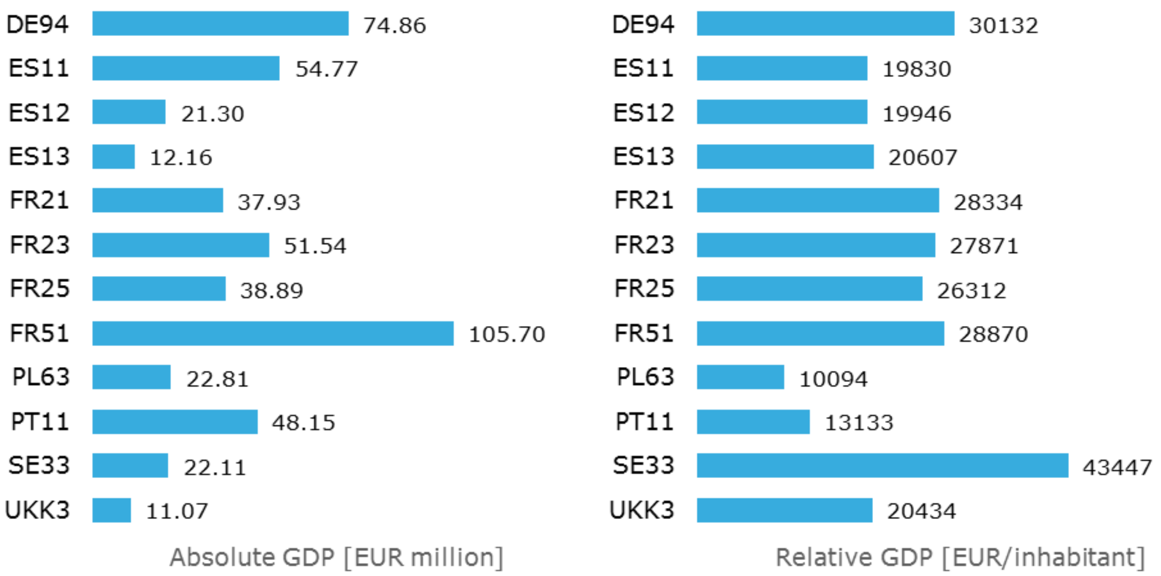


Figure 2 GDP (left) and relative GDP (right) according to region

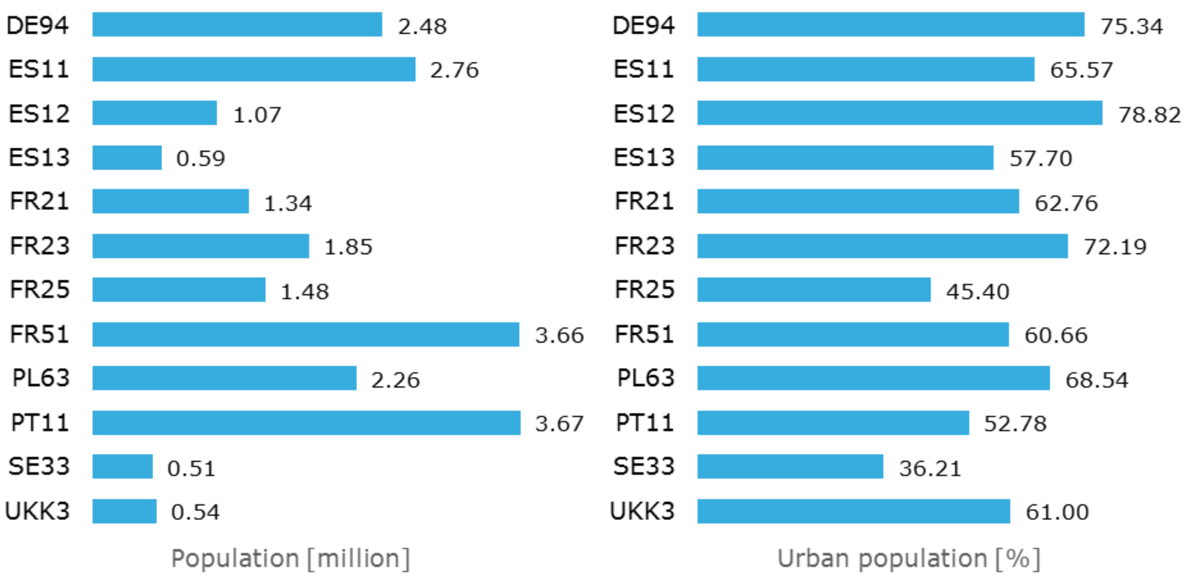


Figure 3 Population (left) and rate of urban population (right) according to region

4.2.2 Energy price dimension

For the energy price dimension, data considered includes;

- Energy source: electricity or gas
- User: final or industrial users
- Taxes: price before or after taxes
- Consumption band, depending on the energy source

In data presented in Table 4, just energy sources, users and taxes are presented to simplify the understanding of the comprehensive list of parameters. However, according to energy pricing schemes, levels of consumptions also determine different energy prices. Depending on the energy sources different bandwidths are defined. Annex I includes detailed information about the energy prices.

It is also important to note that same prices have been considered per MS. Therefore this dimension does not lead to any difference amongst regions in the same country.

Table 4 Parameters under the 'energy price' dimension

Element	**Parameter**	**Unit**
End use energy price before taxes	Gas Price for Domestic	EUR/kWh
	Gas Price for Industrial	EUR/kWh
	Electricity Price for Domestic	EUR/kWh
	Electricity Price for Industrial	EUR/kWh
End use energy price before taxes	Gas Price for Domestic	EUR/kWh
	Gas Price for Industrial	EUR/kWh
	Electricity Price for Domestic	EUR/kWh
	Electricity Price for Industrial	EUR/kWh

To understand energy prices amongst countries, average final energy price per user and energy source are presented (Figure 4). To represent the average price of electricity for domestics, prices shown in Annex I (Table 24) have been considered.

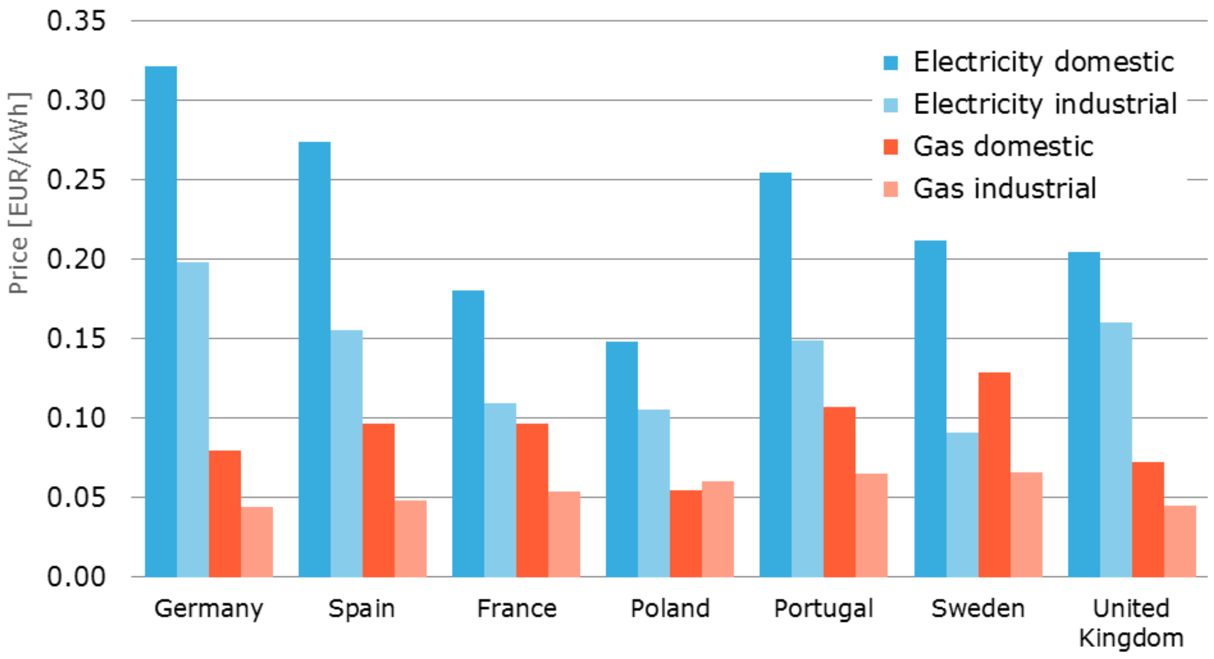


Figure 4 Average final energy prices according to Member State

At this stage, a first correlation was established with the socio-economic dimension presented in section 4.2.1. We expected that regions with higher GDP/inhabitant have higher energy prices. However, in case of electricity, SE33 - representing Sweden - does not show the highest domestic energy cost but does for domestic gas prices (Figure 5). On the contrary, PL63 – representing Poland- has the lowest price for electricity but not for gas. The case of Portugal is remarkable. It shows a high value in the electricity cost for domestic (0.25 EUR/kWh) even though its relative low value in terms of GDP per inhabitant.

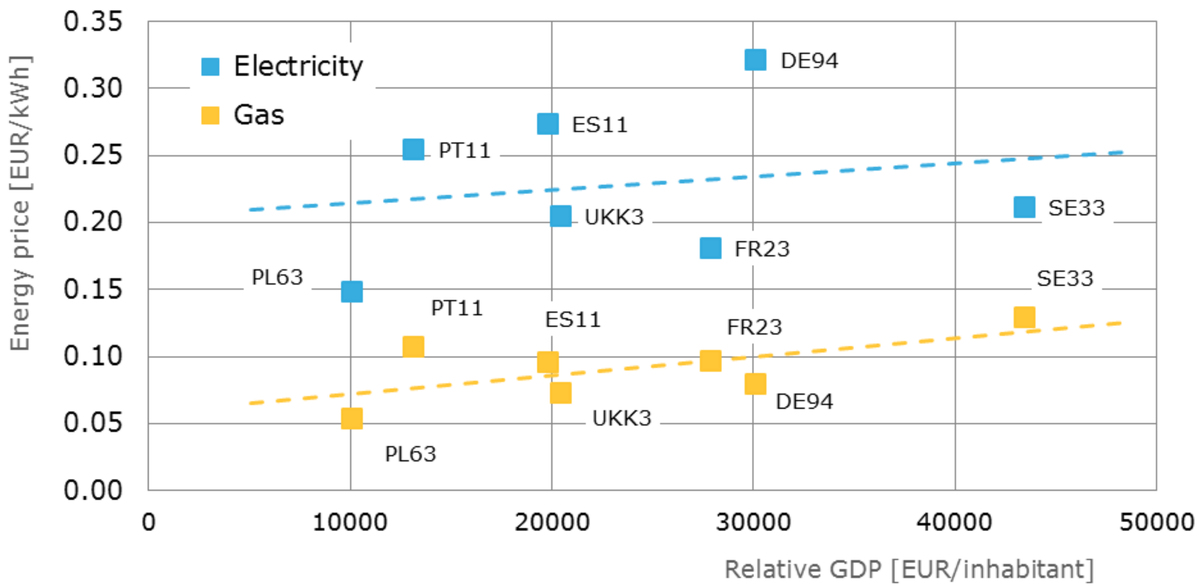


Figure 5 Final domestic energy prices and relative GDP according to region

For electricity, the industrial price trend is inversely dependent with the relative GDP increase when the opposite would be expected. For the case of gas, there is almost no dependency with GDP (Figure 6). Therefore, another important conclusion is that as economic driver, countries with low GDP have to transform their energy market to achieve at least same prices as those with higher GDP.

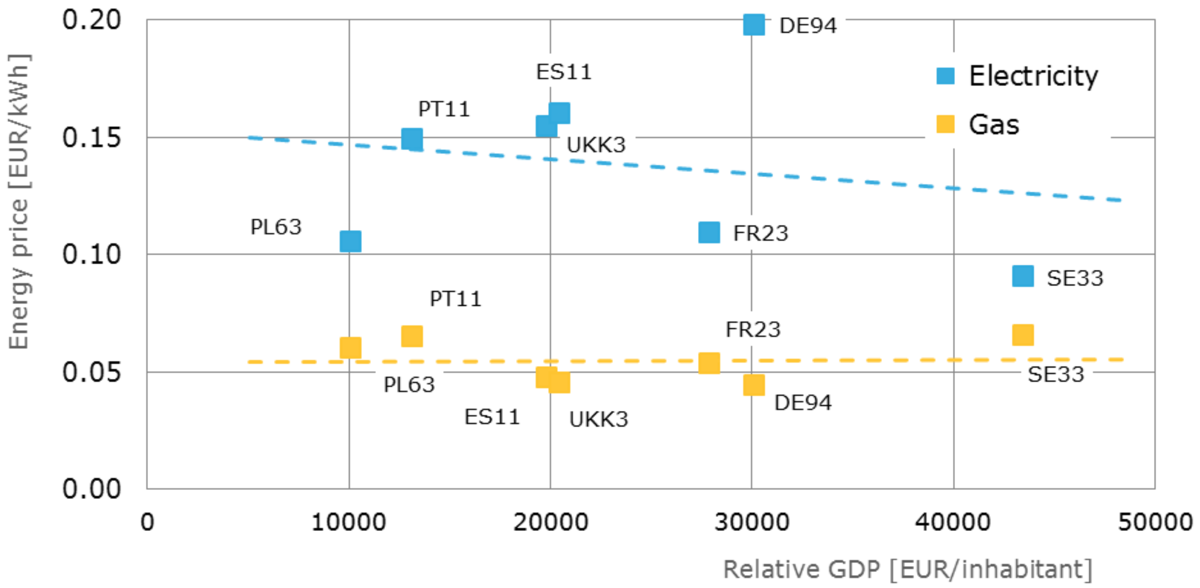


Figure 6 Final industrial energy prices and relative GDP according to region

The correlation between GDP and energy price will be presented and discussed in section 4.4 in more detail.

4.2.3 Energy use dimension

The list of proposed parameters is presented in (Table 5). The only parameter for which complete data is available is the Heating Degree Days (HDD)[2] parameter. More information about the data availability for the 'energy use' dimension is available in Annex II.

Table 5 Parameters under the 'energy use' dimension

Element	Parameter	Unit
Energy demand	Heating Degree Days	HDD

As expected, the Swedish region shows highest HDD, followed by the Polish and German regions (Figure 7). The regions in Spain and Portugal show the lowest number of HDD.

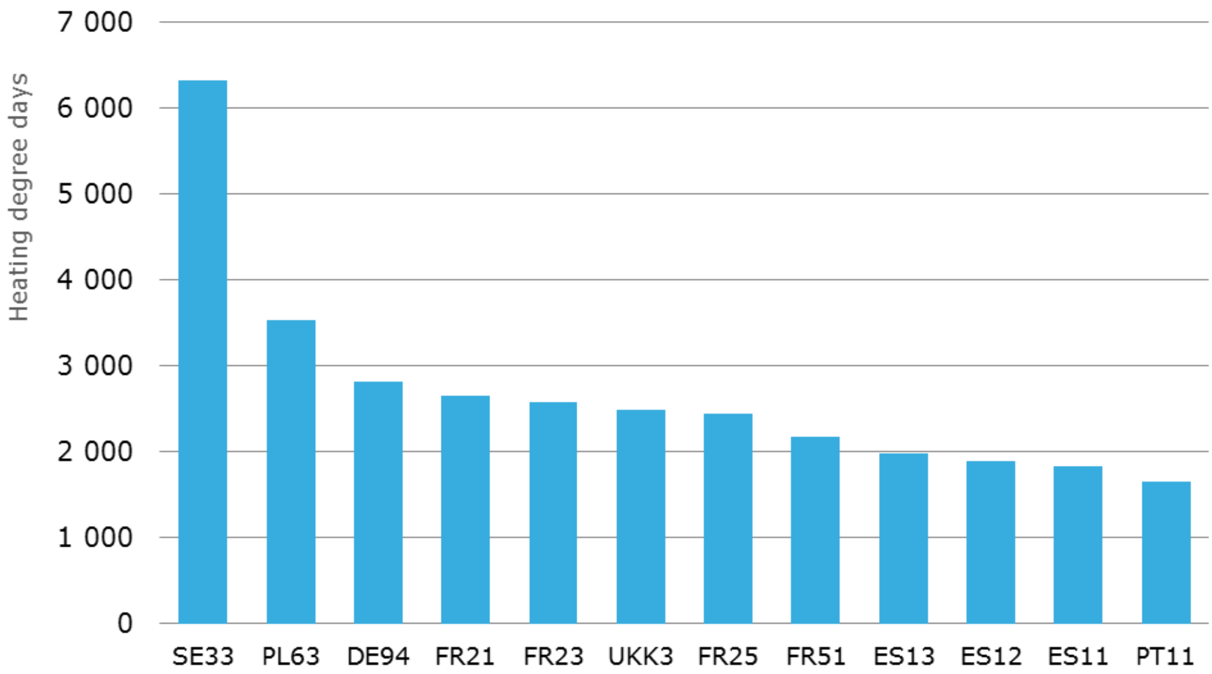


Figure 7 Heating Degree Days 2009

4.2.4 Wind energy deployment dimension

The parameters used for the assessment of wind energy deployment are shown in Table 6. As mentioned in section 3.3.1, wind energy deployment is characterized by three parameters (number of wind turbines, installed wind energy capacity and regional capacity factor). They are shown in Table 7. From these three parameters, both the average size of wind power plants in the regions as well as the energy produced can be derived.

Table 6 Parameters under the 'wind energy deployment' dimension

Element	Parameter	Unit
Wind capacity	Installed capacity	MW wind energy in operation

[2] HDD indicate regional heating demand

Wind energy production	Energy produced	GWh produced
Wind deployment	Number of wind farms	No

Table 7 Results for wind energy deployment

NUTS ID	**Wind farms (no)**	**Installed capacity (MW)**	**Capacity factor (%)**
DE94	532	3502	0.25
ES11	180	3405	0.23
ES12	22	514	0.15
ES13	4	38	0.39
FR21	122	1647	0.16
FR23	25	245	0.32
FR25	32	258	0.36
FR51	61	561	0.32
PL63	35	592	0.29
PT11	127	1539	0.23
SE33	30	533	0.09
UKK3	26	112	0.56

Figure 8 shows the results of the assessment. In most of the cases, the electricity produced correlates with the installed capacity. In the case of the UKK3, a very high capacity factor leads to a relatively high electricity production compared to other regions.

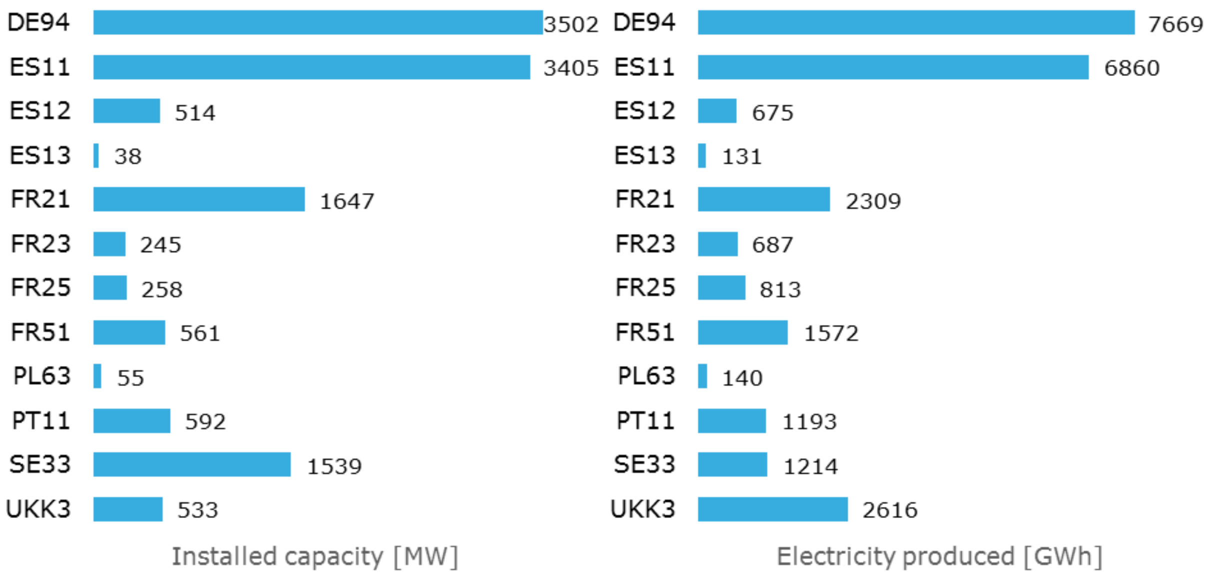


Figure 8 Installed wind energy capacity and electricity production from wind

Annex III provides detailed information and maps about wind energy deployment in every assessed region.

4.2.5 Academia dimension

Table 8 summarises the parameters used for the 'academia' dimension. In addition to the total number of publications, the share of wind publications compared to all publications in the area of energy and the share of wind publications compared to all publications have been calculated.

Table 8 Parameters under the 'academia' dimension

Element	Parameter	Unit
Universities	Number of universities	No
Regional in-house knowledge	Number of wind publications	No
	Share of wind publications	%
	Share of wind publications in the energy area	%

Results from academia dimension show, in terms of number of publications in the field of wind energy, high figures for DE94 with a relatively small number of academic entities (3) in comparison with other regions (Figure 9). Also PT11 represents a high number of publications from its 9 institutions. On the contrary, for PL63 the relative importance of wind is very limited with 20 publications from 9 entities.

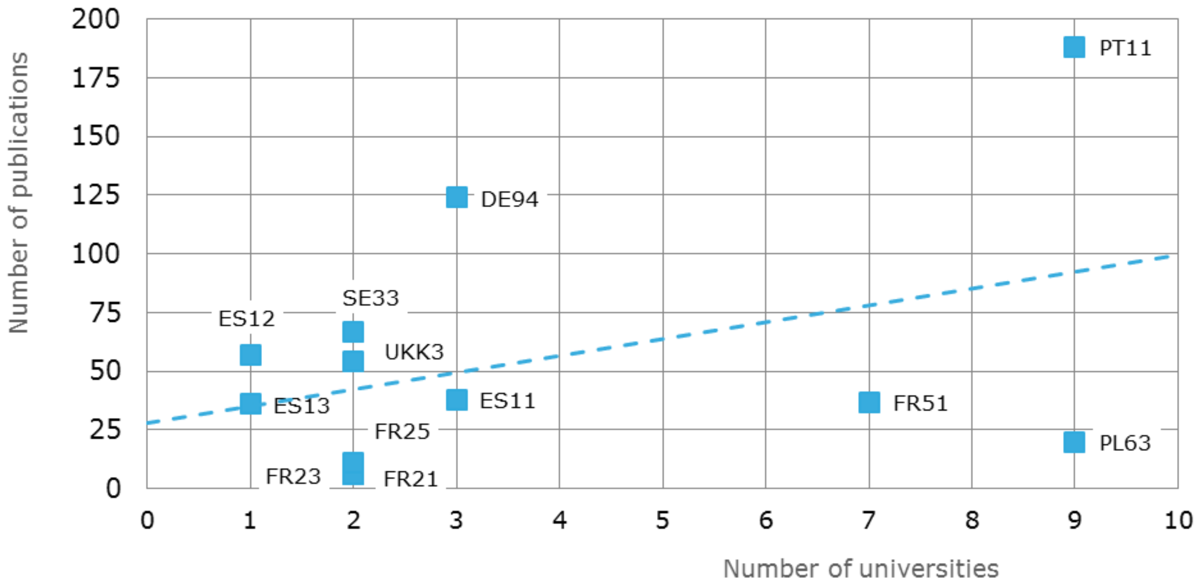


Figure 9 Number of wind publication vs. number of universities

In Figure 10 (left), the share of wind publications compared to the total number of scientific publications (2016) is shown. DE94, ES13 and PT11 show a relatively high share (0.57 %, 0.34 %, and 0.28 %, respectively). Other regions, such as the regions in France, Poland and Sweden show very low shares (between 0.05 % and 0.15 %).

When we look at the share of wind publications compared to all scientific publications in the area of energy (Figure 10 , right), we see a similar picture. However, the Spanish regions and UKK3 score better with relatively high shares (11.9 % to 17.9 %). DE94 leads with 27.4 %.

The complete list of universities considered in the study can be consulted in Annex IV.

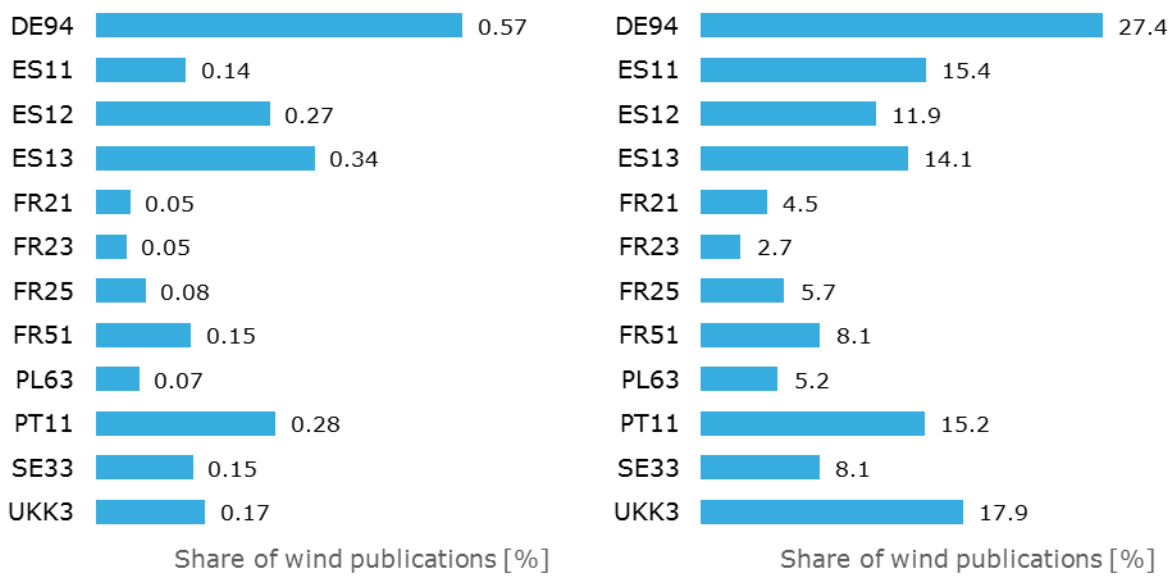


Figure 10: Share of wind publications compared to all (left) and all energy-related (right) publications

4.2.6 Sectorial structure dimension

Table 9 shows the parameters used to assess the sectorial structure of the regions.

Table 9 Parameters under the 'sectorial structure' dimension

Element	**Parameter**	**Unit**
Energy sector size	Number of wind companies	No
	Share of wind companies in the regions compared to total number of wind companies in the corresponding MS	%

Based on the estimations introduced in section 3.3.3, the total number of wind energy companies assumed per regions is presented in Figure 11. Numbers range from 4 for ES13 to 82 for DE94. It has to be kept in mind that the number of companies is estimated since for many companies identified, the geographical location was not available (section 3.3.3).

Together with the absolute number of wind companies in a region, the importance of a region for the wind sector of their countries is shown in Figure 11. High shares can be seen for PT11 which hosts about 25 % of all Portuguese wind companies, DE94 and PL63, where 10.7 % and 12.6 % of total national companies are located.

The share of the wind sectors of all other regions compared to the respective national wind sector does not exceed 10 %. However, it is important to note that none of the regions considered includes the capital city of the Member State where often, many companies usually establish their headquarters. Just to give an estimation of this effect, the regions of Madrid (ES30) and Île de France (FR10) include about 38 % and 46 % of national companies in Spain and France respectively. This effect of big cities might also explain the results of PT11 as it includes Porto, the second largest city in Portugal.

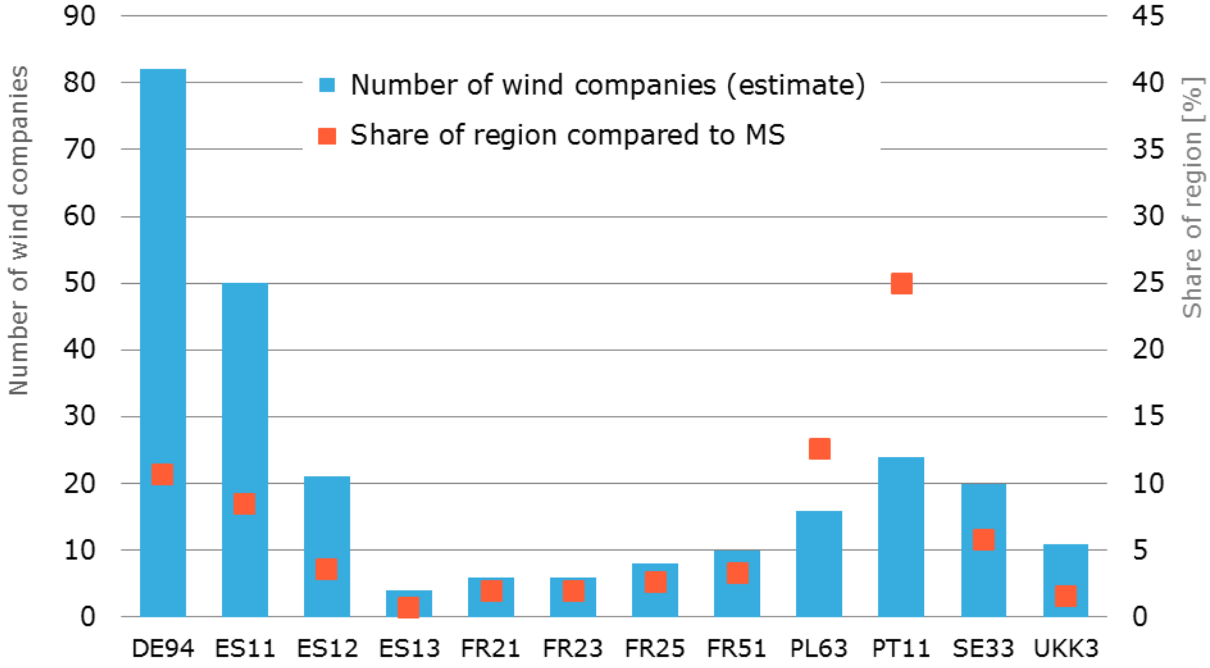


Figure 11: Number of wind companies and regional share compared to national level

4.2.7 Innovation capacities dimension

In Table 10, the parameters used to assess the dimension 'innovation capacities' are shown.

Table 10 Parameters under the 'innovation capacities' dimension

Element	Parameter	Unit
R&D expenditure	All sectors	EUR/inhabitant
	Business sector	EUR/inhabitant
	Government sector	EUR/inhabitant

Concerning innovation capacities, SE33 shows the largest R&D investments, followed by three French regions (FR23, FR25, FR51) and DE94. R&D investments are smallest in UKK3, and PL63. When looking at relative numbers (R&D investments per capita), the gap between SE33 and the other regions is even more pronounced (Annex V).

When we look at the private sector, SE33 shows lower levels than FR23, meaning that the contribution of government, higher education and private non-profit sectors is considerably high. The case of UKK is also interesting because here, 95 % of the investment comes from private sector. On the contrary, the share of public investments is highest in ES13 or PL63 with about 19 % and 16 %, respectively.

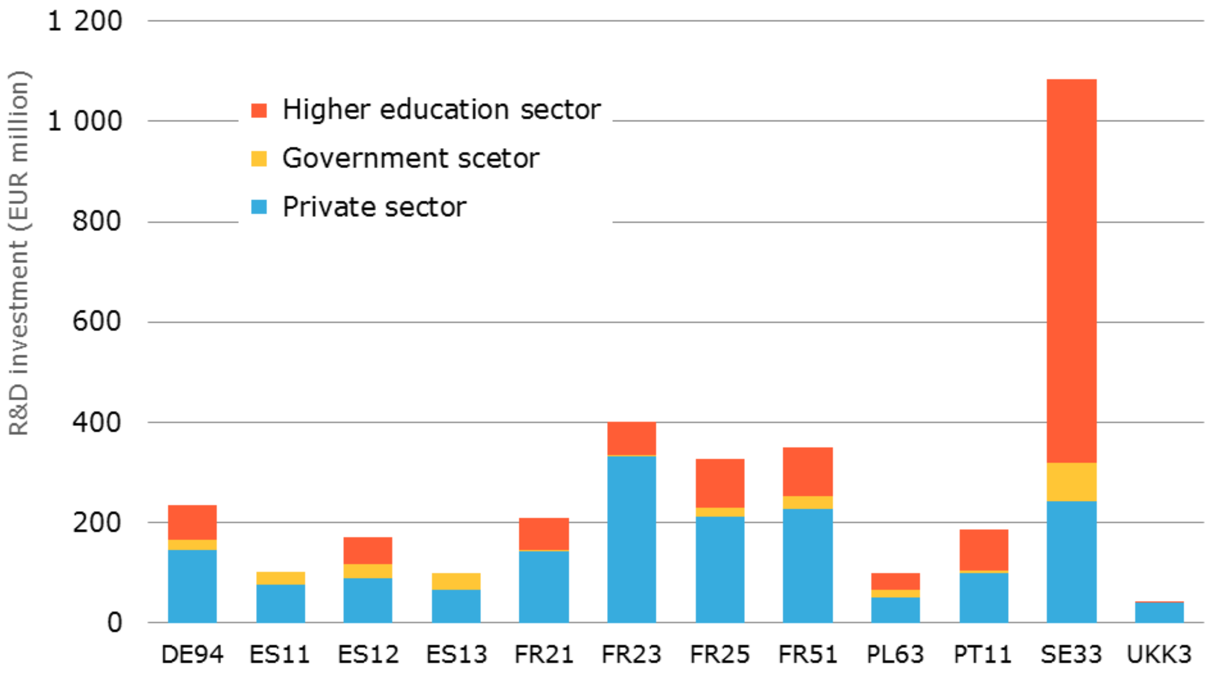


Figure 12 Regional R&D expenditure including private and public sector

4.3 Analysis of similarities

Similarity matrixes are demonstrated useful for multi dimension comparison and clustering [Mooi & Sarstedt 2011]. However, as similarity matrixes are based on the relative distance between elements to be compared, they do not allow for a ranking or classification amongst elements. In other words, they provide a relative comparison to enable clustering processes. The following dimension matrixes give an idea about how similar regions are. A higher value of the element 'i,j' in the matrix, means a greater distance between regions 'i' and 'j'.

4.3.1 Dimensional similarity matrixes

Socio-economic dimension

The similarity matrix for the socio-economic dimension is shown in

Table 11. For this dimension, SE33 is the region farthest away from the other regions showing an average distance of 3.9, followed by FR51 with an average distance of 3.47.

The two regions that have less in common are PL63 and SE33 with a distance of 4.87. It is interesting to recall again the results of the individual parameters of this dimension population (section 4.2.1) where PL63 and SE33 show very similar GDP but a high difference in relative GDP. Also, population and urban population are very different for those two regions. A number of regions show high similarity, including FR21, FR23, ES13, and UKK3.

An interesting observation can be made within regions in the same country. Although, from a socio-economic point of view, regions within the same country were expected to show similar values for this dimension, the similarity amongst them is low. For example, the distance between ES11 and FR21 is lower (1.71) than the distance between ES11 and ES13 (2.54).

Table 11 Similarity matrix for the 'socio-economic' dimension

Region	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.00	1.61	2.59	3.34	1.97	1.07	2.93	1.94	3.01	3.02	4.37	3.29
ES11	1.61	0.00	2.20	2.54	1.71	1.34	2.20	2.28	1.68	1.54	4.28	2.54
ES12	2.59	2.20	0.00	1.80	1.74	1.66	2.91	4.21	1.75	3.36	4.41	1.57
ES13	3.34	2.54	1.80	0.00	1.50	2.31	1.72	4.43	2.13	3.15	3.15	0.28
FR21	1.97	1.71	1.74	1.50	0.00	1.02	1.44	3.19	2.34	2.83	2.91	1.50
FR23	1.07	1.34	1.66	2.31	1.02	0.00	2.26	2.69	2.32	2.81	3.77	2.24
FR25	2.93	2.20	2.91	1.72	1.44	2.26	0.00	3.34	2.79	2.54	2.34	1.93
FR51	1.94	2.28	4.21	4.43	3.19	2.69	3.34	0.00	3.93	2.81	4.85	4.49
PL63	3.01	1.68	1.75	2.13	2.34	2.32	2.79	3.93	0.00	2.03	4.87	2.06
PT11	3.02	1.54	3.36	3.15	2.83	2.81	2.54	2.81	2.03	0.00	4.73	3.25
SE33	4.37	4.28	4.41	3.15	2.91	3.77	2.34	4.85	4.87	4.73	0.00	3.33
UKK3	3.29	2.54	1.57	0.28	1.50	2.24	1.93	4.49	2.06	3.25	3.33	0.00
Average	2.65	2.17	2.56	2.40	2.01	2.14	2.40	3.47	2.63	2.92	3.91	2.41

Energy price dimension

In the case of the energy price dimension, based on the assumptions of a homogeneous national energy market price, regions in the same country such as the Spanish and French regions show a distance of 0 (Table 12).

In total, 38 different parameters (energy prices) are compared (Annex I) including industrial and domestic prices, gas and electricity prices and prices with and without taxes. So, the distance matrix reflects the effects of consumer profile, energy sources and taxation schemes. For the energy price, Sweden & United Kingdom and Sweden & Germany are the most separated countries; meanwhile Poland and France are the closest when we compare regions from two different countries.

Table 12 Distance matrix for the 'energy price' dimension group indicators

Region	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.00	7.86	7.86	7.86	9.51	9.51	9.51	9.51	10.20	10.79	13.06	8.65
ES11	7.86	0.00	0.00	0.00	8.71	8.71	8.71	8.71	10.32	7.58	11.09	7.21
ES12	7.86	0.00	0.00	0.00	8.71	8.71	8.71	8.71	10.32	7.58	11.09	7.21
ES13	7.86	0.00	0.00	0.00	8.71	8.71	8.71	8.71	10.32	7.58	11.09	7.21
FR21	9.51	8.71	8.71	8.71	0.00	0.00	0.00	0.00	6.44	9.36	8.47	9.49
FR23	9.51	8.71	8.71	8.71	0.00	0.00	0.00	0.00	6.44	9.36	8.47	9.49
FR25	9.51	8.71	8.71	8.71	0.00	0.00	0.00	0.00	6.44	9.36	8.47	9.49
FR51	9.51	8.71	8.71	8.71	0.00	0.00	0.00	0.00	6.44	9.36	8.47	9.49
PL63	10.20	10.32	10.32	10.32	6.44	6.44	6.44	6.44	0.00	12.04	11.20	9.99
PT11	10.79	7.58	7.58	7.58	9.36	9.36	9.36	9.36	12.04	0.00	9.86	11.08
SE33	13.06	11.09	11.09	11.09	8.47	8.47	8.47	8.47	11.20	9.86	0.00	13.80
UKK3	8.65	7.21	7.21	7.21	9.49	9.49	9.49	9.49	9.99	11.08	13.80	0.00
Average	9.48	7.17	7.17	7.17	6.31	6.31	6.31	6.31	9.10	9.45	10.46	9.37

Energy use dimension

In this case as only one parameter is considered, the distance is the same as what the Heating Degree Days parameter indicates. In the overall similarity matrix, which includes all the parameters (section 4.3.2), normalised values for this parameter have been incorporated.

Wind energy deployment dimension

In the case of deployment, there is not identified a certain level of proximity amongst regions in the same country for Spain, but it is in the case of French regions. The reason for this behaviour is probably the existence of resources in each region beyond legislation or national support. However as it can be checked for regions in Spain, ES11 is far from the other two, even when they are geographically close and it could be assumed similar levels of available resources.

Table 13 Distance matrix for the 'wind deployment' dimension group indicators

Region	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.00	2.40	4.31	4.72	3.24	4.40	4.41	4.05	4.52	4.14	3.42	4.89
ES11	2.40	0.00	2.68	3.25	1.59	2.87	2.94	2.55	2.99	2.50	1.94	3.67
ES12	4.31	2.68	0.00	1.95	1.15	1.34	1.67	1.35	1.17	0.64	1.20	3.29
ES13	4.72	3.25	1.95	0.00	2.38	0.63	0.37	0.82	0.81	1.38	2.82	1.44
FR21	3.24	1.59	1.15	2.38	0.00	1.80	2.02	1.57	1.80	1.17	0.59	3.37
FR23	4.40	2.87	1.34	0.63	1.80	0.00	0.33	0.36	0.27	0.75	2.20	1.98
FR25	4.41	2.94	1.67	0.37	2.02	0.33	0.00	0.46	0.58	1.06	2.46	1.65
FR51	4.05	2.55	1.35	0.82	1.57	0.36	0.46	0.00	0.56	0.72	2.03	1.97
PL63	4.52	2.99	1.17	0.81	1.80	0.27	0.58	0.56	0.00	0.67	2.14	2.21
PT11	4.14	2.50	0.64	1.38	1.17	0.75	1.06	0.72	0.67	0.00	1.49	2.66
SE33	3.42	1.94	1.20	2.82	0.59	2.20	2.46	2.03	2.14	1.49	0.00	3.91
UKK3	4.89	3.67	3.29	1.44	3.37	1.98	1.65	1.97	2.21	2.66	3.91	0.00
Average	4.05	2.67	1.89	1.87	1.88	1.54	1.63	1.49	1.61	1.56	2.20	2.82

Academia structure dimension

In terms of the role of wind in the academia, a national pattern can be observed both for Spain and France with the exception of FR51 (Table 14). The regions that are most similar to other regions are SE33, ES12, and FR25. The regions that differ most from the others are DE94 and PT11. This can be explained by the very high number of scientific publications and universities in PT11 and the very high number of scientific publications in DE94 (section 4.2.5).

Table 14 Distance matrix for the 'academia' dimension group indicators

Regions	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.00	3.67	3.27	2.99	5.20	5.38	4.95	4.42	5.35	3.48	4.04	3.25
ES11	3.67	0.00	1.24	1.49	1.78	2.01	1.55	1.69	2.55	3.57	1.21	0.60
ES12	3.27	1.24	0.00	0.68	2.04	2.20	1.80	2.27	3.23	3.67	1.03	1.12
ES13	2.99	1.49	0.68	0.00	2.42	2.59	2.18	2.53	3.49	3.94	1.65	1.33
FR21	5.20	1.78	2.04	2.42	0.00	0.25	0.25	1.96	2.38	4.65	1.40	2.23

FR23	5.38	2.01	2.20	2.59	0.25	0.00	0.47	2.05	2.40	4.75	1.53	2.46
FR25	4.95	1.55	1.80	2.18	0.25	0.47	0.00	1.85	2.37	4.48	1.20	2.00
FR51	4.42	1.69	2.27	2.53	1.96	2.05	1.85	0.00	1.00	3.19	1.78	2.20
PL63	5.35	2.55	3.23	3.49	2.38	2.40	2.37	1.00	0.00	3.71	2.61	3.10
PT11	3.48	3.57	3.67	3.94	4.65	4.75	4.48	3.19	3.71	0.00	3.52	3.53
SE33	4.04	1.21	1.03	1.65	1.40	1.53	1.20	1.78	2.61	3.52	0.00	1.41
UKK3	3.25	0.60	1.12	1.33	2.23	2.46	2.00	2.20	3.10	3.53	1.41	0.00
Average	4.18	1.94	2.05	2.30	2.23	2.37	2.10	2.27	2.92	3.86	1.94	2.11

Sectorial structure dimension

For this dimension, we have looked at the structure of the wind energy sector in the region (section 4.2.6). Clearly, PT11, PL63 and DE94 stand out. In the case of DE94, this is because of a high number of companies while in the case of PT11 and PL63, it is because the regions' share compared to Portugal is very high. The Spanish and French regions show greatest similarities.

Table 15 Distance matrix for the 'sectorial structure' dimension group indicators

Regions	**DE94**	**ES11**	**ES12**	**ES13**	**FR21**	**FR23**	**FR25**	**FR51**	**PL63**	**PT11**	**SE33**	**UKK3**
DE94	0.00	1.44	2.87	3.71	3.56	3.56	3.45	3.33	2.91	3.26	2.81	3.38
ES11	1.44	0.00	1.45	2.31	2.14	2.14	2.02	1.90	1.60	2.63	1.37	1.98
ES12	2.87	1.45	0.00	0.85	0.70	0.70	0.58	0.48	1.31	3.08	0.33	0.52
ES13	3.71	2.31	0.85	0.00	0.21	0.21	0.33	0.46	1.79	3.60	1.02	0.33
FR21	3.56	2.14	0.70	0.21	0.00	0.00	0.13	0.26	1.58	3.39	0.83	0.23
FR23	3.56	2.14	0.70	0.21	0.00	0.00	0.13	0.26	1.58	3.39	0.83	0.23
FR25	3.45	2.02	0.58	0.33	0.13	0.13	0.00	0.13	1.47	3.28	0.70	0.20
FR51	3.33	1.90	0.48	0.46	0.26	0.26	0.13	0.00	1.36	3.17	0.57	0.25
PL63	2.91	1.60	1.31	1.79	1.58	1.58	1.47	1.36	0.00	1.81	0.99	1.60
PT11	3.26	2.63	3.08	3.60	3.39	3.39	3.28	3.17	1.81	0.00	2.76	3.41
SE33	2.81	1.37	0.33	1.02	0.83	0.83	0.70	0.57	0.99	2.76	0.00	0.73
UKK3	3.38	1.98	0.52	0.33	0.23	0.23	0.20	0.25	1.60	3.41	0.73	0.00
Average	3.12	1.91	1.17	1.35	1.18	1.18	1.13	1.11	1.64	3.07	1.17	1.17

Innovation capacities dimension

Under this dimension, the Spanish regions show very high similarities with a maximum distance of 0.51 (Table 16). In terms of individual regions, SE33 is very distinct from the other regions since its R&D spending is more than twice compared to the following region (FR23) as shown in section 4.2.7. UKK3 with least R&D investment is also dissimilar compared to other regions. DE94 presents an average in terms of R&D investment and R&D personnel and thus show highest similarity on average.

Table 16 Distance matrix for the 'innovation capacities' dimension group indicators

Regions	**DE94**	**ES11**	**ES12**	**ES13**	**FR21**	**FR23**	**FR25**	**FR51**	**PL63**	**PT11**	**SE33**	**UKK3**

DE94	0.00	0.81	0.69	1.12	0.88	2.32	0.86	1.03	1.16	0.85	4.28	1.66
ES11	0.81	0.00	0.14	0.48	1.34	3.12	1.66	1.77	0.60	0.92	4.56	1.37
ES12	0.69	0.14	0.00	0.51	1.30	3.01	1.55	1.64	0.71	0.93	4.48	1.45
ES13	1.12	0.48	0.51	0.00	1.80	3.42	1.93	1.93	0.99	1.40	4.33	1.79
FR21	0.88	1.34	1.30	1.80	0.00	2.18	1.09	1.54	1.28	0.56	4.94	1.28
FR23	2.32	3.12	3.01	3.42	2.18	0.00	1.49	1.62	3.34	2.70	4.49	3.45
FR25	0.86	1.66	1.55	1.93	1.09	1.49	0.00	0.49	1.97	1.44	4.06	2.29
FR51	1.03	1.77	1.64	1.93	1.54	1.62	0.49	0.00	2.19	1.79	3.66	2.64
PL63	1.16	0.60	0.71	0.99	1.28	3.34	1.97	2.19	0.00	0.74	5.12	0.80
PT11	0.85	0.92	0.93	1.40	0.56	2.70	1.44	1.79	0.74	0.00	4.98	0.88
SE33	4.28	4.56	4.48	4.33	4.94	4.49	4.06	3.66	5.12	4.98	0.00	5.77
UKK3	1.66	1.37	1.45	1.79	1.28	3.45	2.29	2.64	0.80	0.88	5.77	0.00
Average	1.42	1.52	1.49	1.79	1.65	2.83	1.71	1.85	1.72	1.56	4.60	2.12

4.3.2 Overall similarity matrix

All parameters assessed can be combined into one single distance matrix (Table 17). From this matrix, it is clear that regions in the same country have highest similarities: ES11, ES12 and ES13 on the one hand and FR21, FR23, FR25 and FR51 on the other hand. On the contrary the most separated regions are SE33 and UKK3 followed by SE33 and DE94. To understand the reasons behind these results, an analysis of correlation was performed and is presented in section 4.5. Clearly, the similarities are driven by parameters that could not be retrieved on regional level but where national data had to be used. This was the case for energy prices, a dimension which included a high number of parameters (38). Subsequently, we will explore various effects of weighting and PCA on the results (section 4.4).

Table 17 Comprehensive overall similarity matrix

Regions	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.0	9.5	10.5	11.1	12.3	12.8	12.8	12.2	13.3	13.0	16.1	11.6
ES11	9.5	0.0	4.0	5.0	9.6	10.3	10.0	9.9	11.4	9.3	13.5	9.0
ES12	10.5	4.0	0.0	2.9	9.4	9.8	9.7	10.2	11.2	9.7	13.4	8.5
ES13	11.1	5.0	2.9	0.0	9.7	10.1	9.4	10.4	11.4	10.0	13.3	7.9
FR21	12.3	9.6	9.4	9.7	0.0	3.0	2.7	4.4	7.8	11.5	10.8	10.8
FR23	12.8	10.3	9.8	10.1	3.0	0.0	2.8	3.8	8.2	11.8	11.1	11.1
FR25	12.8	10.0	9.7	9.4	2.7	2.8	0.0	3.9	7.9	11.4	10.6	10.6
FR51	12.2	9.9	10.2	10.4	4.4	3.8	3.9	0.0	8.1	11.0	11.3	11.5
PL63	13.3	11.4	11.2	11.4	7.8	8.2	7.9	8.1	0.0	13.1	13.9	11.3
PT11	13.0	9.3	9.7	10.0	11.5	11.8	11.4	11.0	13.1	0.0	13.5	12.9
SE33	16.1	13.5	13.4	13.3	10.8	11.1	10.6	11.3	13.9	13.5	0.0	16.4
UKK3	11.6	9.0	8.5	7.9	10.8	11.1	10.6	11.5	11.3	12.9	16.4	0.0
Average	12.3	9.2	9.0	9.2	8.4	8.6	8.3	8.8	10.7	11.6	13.1	11.1

The overall similarity matrix can also be represented in 2D dimensions which helps understanding [Buja et al. 2008]. Figure 13 reinforces the conclusion of similarities amongst regions in the same country. PL63, DE94, PT11 and SE33 are show least similarities.

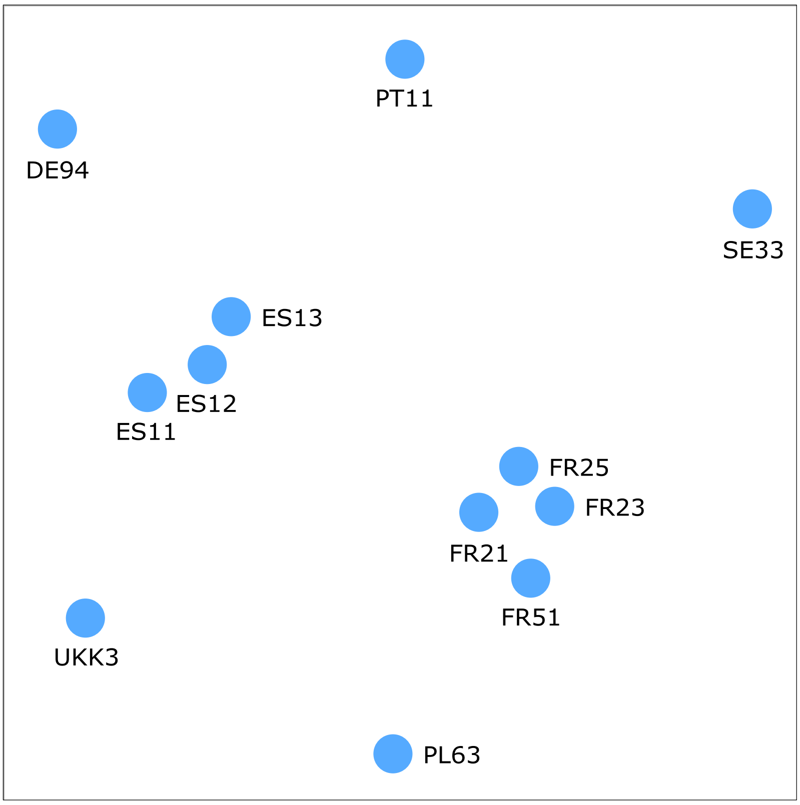


Figure 13 2D distance representation of the overall similarity matrix. Non-weighted analysis

4.4 Weighting & Principal component analysis

As presented in the previous section, the number of parameters under a particular dimension may affect the multidimensional analysis. In particular, the energy price dimension, which includes a high number of parameters (48) at MS level, produces a concentration of regions within the same country (see Figure 13). To minimise the effect of aggregation we have assessed two methods: weighting and principal component analysis.

4.4.1 Weighting method

In the weighting method, we have applied a coefficient for all the parameters within the same dimension equal to the inverse of the sum of parameters within a given dimension. By doing this, we ensure all the dimensions have the same effect in the complete analysis.

Results obtained are shown in Table 18 and Figure 14

Table 18 Comprehensive overall similarity matrix. Weighted version

Regions	DE94	ES11	ES12	ES13	FR21	FR23	FR25	FR51	PL63	PT11	SE33	UKK3
DE94	0.00	1.70	2.42	2.79	2.54	2.81	2.73	2.55	2.70	2.63	3.93	2.70

ES11	1.70	0.00	1.32	1.76	1.58	1.98	1.74	1.62	2.05	1.88	4.17	1.85
ES12	2.42	1.32	0.00	0.93	1.15	1.47	1.28	1.45	1.81	2.03	4.03	1.41
ES13	2.79	1.76	0.93	0.00	1.36	1.54	1.06	1.50	1.91	2.32	4.01	0.96
FR21	2.54	1.58	1.15	1.36	0.00	0.98	0.87	1.26	1.55	2.37	3.49	1.41
FR23	2.81	1.98	1.47	1.54	0.98	0.00	0.78	1.07	1.79	2.50	3.61	1.59
FR25	2.73	1.74	1.28	1.06	0.87	0.78	0.00	1.01	1.62	2.27	3.56	1.20
FR51	2.55	1.62	1.45	1.50	1.26	1.07	1.01	0.00	1.81	2.07	3.84	1.71
PL63	2.70	2.05	1.81	1.91	1.55	1.79	1.62	1.81	0.00	2.10	3.26	1.70
PT11	2.63	1.88	2.03	2.32	2.37	2.50	2.27	2.07	2.10	0.00	4.59	2.40
SE33	3.93	4.17	4.03	4.01	3.49	3.61	3.56	3.84	3.26	4.59	0.00	3.98
UKK3	2.70	1.85	1.41	0.96	1.41	1.59	1.20	1.71	1.70	2.40	3.98	0.00
Average	2.68	1.97	1.76	1.83	1.69	1.83	1.65	1.81	2.03	2.47	3.86	1.90

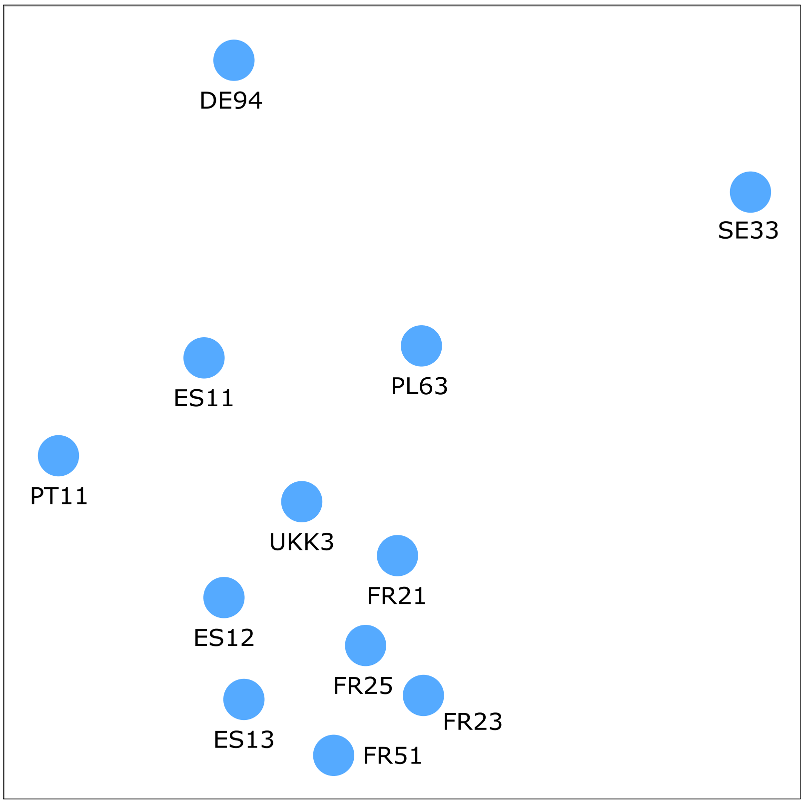


Figure 14 2D distance representation of the overall similarity matrix. Weighted analysis

If Figure 13 and Figure 14 are compared, it is clear that when the dimensions are weighted the effect of parameters at national level is reduced. Therefore, a weighting approach is required to avoid national effects.

4.4.2 Principal component analysis

Once the weighted analysis was carried out, the next step was to assess if we can reduce the number of parameters to the minimum that provides an appropriate variance in the dataset. To do that, we perform the principal component analysis [Shlens 2003].

Firstly, the PCA is applied to the parameters without applying weights as presented in section 4.3.2 and then to the weighted according (section 4.4.1).

Some considerations that have to be taken into account when performing the principal component analysis are:

- The number of retained components has to be able to explain at least 80% of variance.
- Only those parameters with a factor values higher than 0.20 in absolute value have been retained.

When the PCA is applied to non-weighted data, 4 components are required and a total of 23 variables are kept, which represent a reduction of 58 % compared to the original dataset. (see Annex VI). If data are previously weighted, 3 components are required to explain at least 80% of variance (Figure 21). Then, only 12 parameters (78% of reduction) are sufficient to explain the dataset (Table 19)

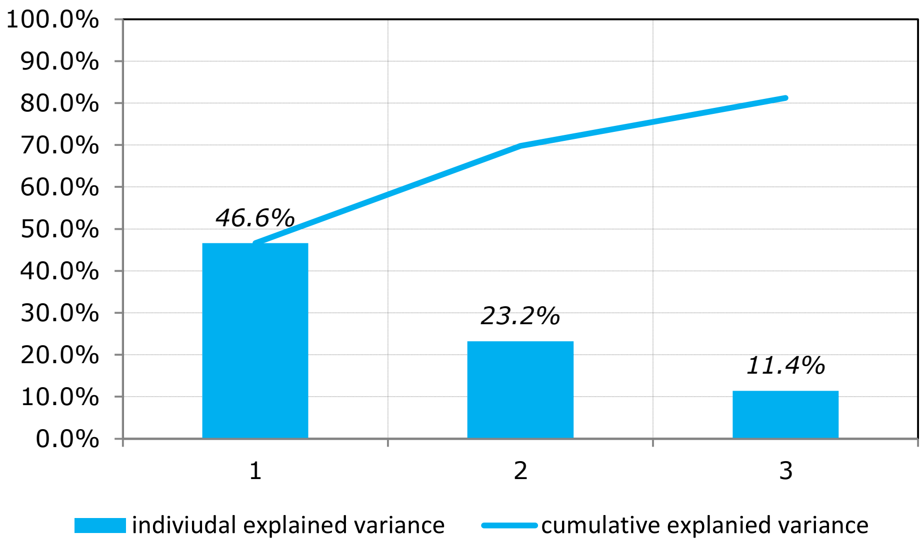


Figure 15 Cumulative explained variance ratio. PCA weighted dataset

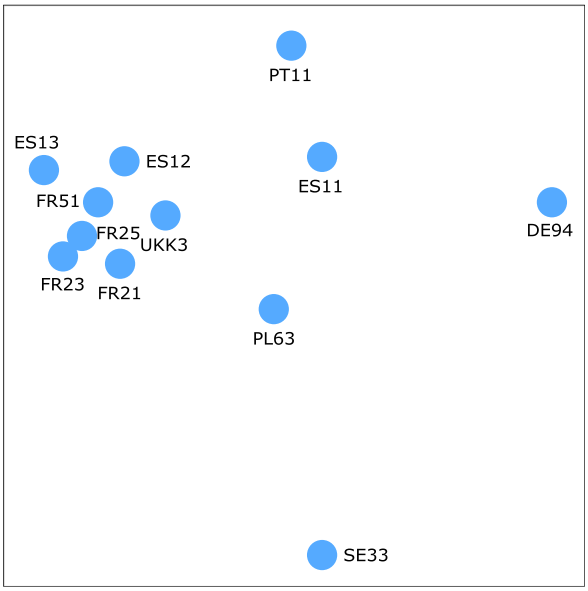
Table 19 Parameters included in the reduced dataset. PCA weighted

Dimension	**Parameters**
Socio-economic	Relative GDP
Wind energy deployment	Installed capacity (MW)
	Number of wind farms
Energy demand	Heating Degree Days
Academia	Number of universities
	Number of wind publication
	Share of wind publication in the energy area
	Share of wind publications
Sectorial structure	Number of companies with innovative activities
	Representativeness of the regional sector at the national level. Energy sector size
Innovation capacities	R&D expenditures. All sectors
	R&D expenditures. Government sector

The reduced dataset includes 6 out of 7 dimensions. The energy price dimension is the only dimension not present, which was the only dimension with information at MS level.

Comparison of results

In order to assess whether the proposed dataset is providing the required information, the 2D regional distance is compared before and after applying the PCA (Figure 16).



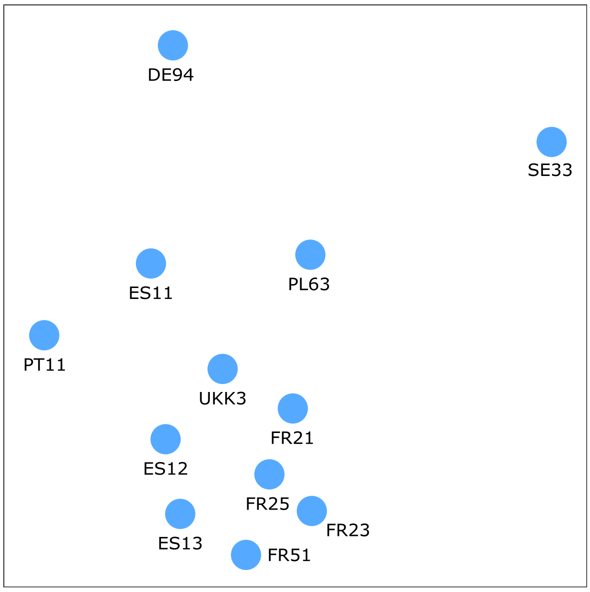


Figure 16 2D distance representation of the overall similarity matrix. Weighted analysis and dimensional reduction by PCA

As it can be assessed in Figure 16, dimensional reduction has produced similar results compared to the analysis with the complete dataset. From a clustering perspective, both analyses provide a well-defined cluster including ES13, ES12, UKK3 and the 4 French regions (FR21, FR25, FR23 and FR51). On the other hand, in both cases DE94 and SE33 remain as very separate entities.

4.5 Analysis of potential correlation

Further to the information introduced in the previous section, the distance matrix is presented through a graphical correlation matrix providing information about dependency between dimensions (Figure 17). This matrix is symmetric showing a perfect correlation in the principal diagonal because each region is compared with itself. For the rest of the elements some interesting conclusions can be extracted.

First of all, there are no significant correlations between any of the dimensions analysed. The correlation coefficients range from 0.002 to 0.686 (Table 20). The dimensions that show a somehow higher correlation are the academia and the sectorial structure, innovation capacities and energy use, and wind energy deployment and sectorial structure.

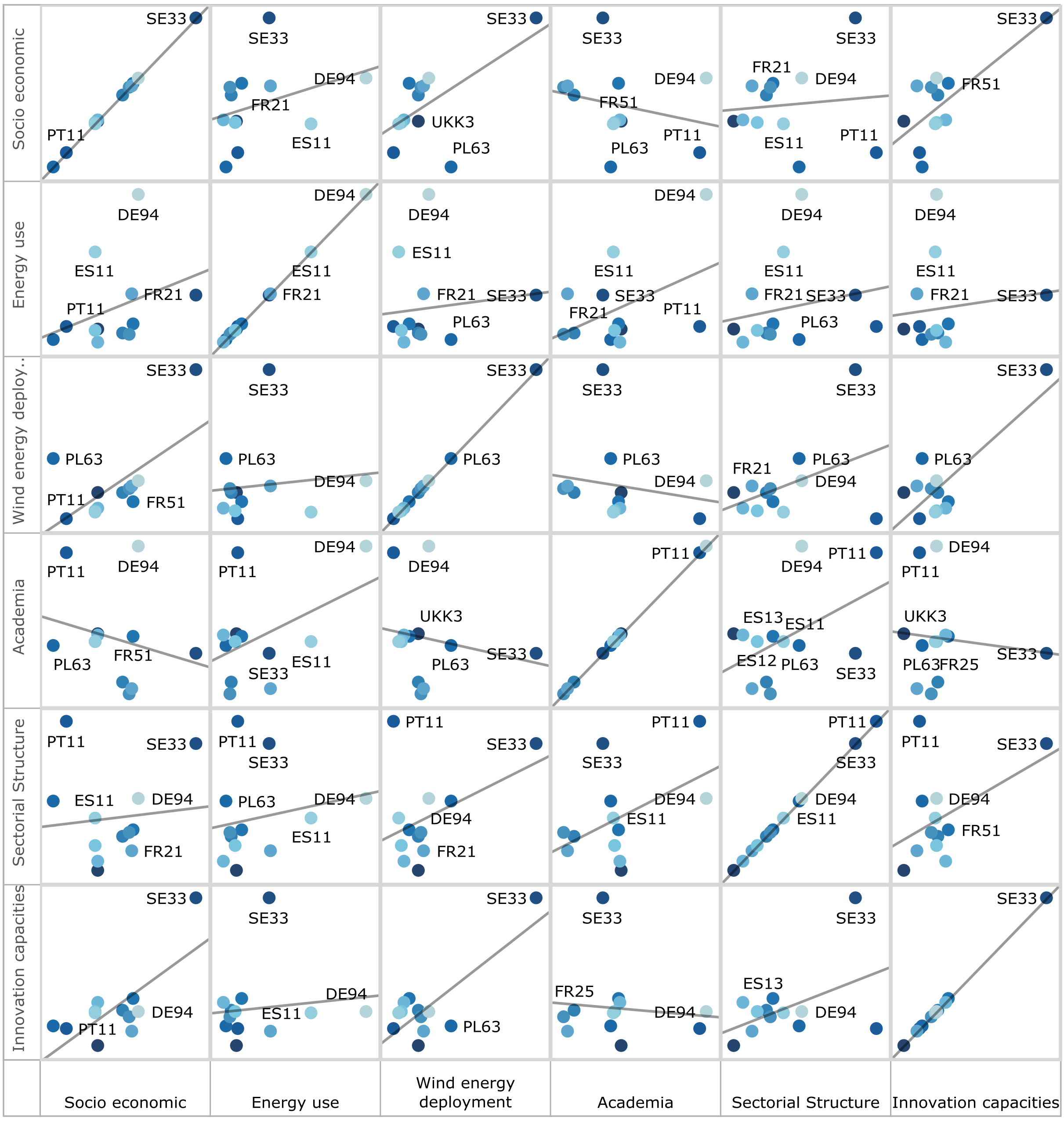


Figure 17 Dimension matrix

Table 20 Correlation coefficient r between dimensions after applying PCA

	Socio economic	Energy use	Wind energy deployment	Academia	Sectorial Structure	Innovation capacities
Socio economic	1.000					

Energy use	0.119	1.000				
Wind energy deployment	0.407	0.013	1.000			
Academia	0.059	0.210	0.034	1.000		
Sectorial Structure	0.010	0.043	0.180	0.255	1.000	
Innovation capacities	0.546	0.014	0.655	0.011	0.211	1.000

According to the data presented, wind energy deployment is correlated with the innovation capacities in the region but not with the sectorial structure as it would be expected. Additionally, the socio-economic dimension is considerably correlated with innovation capacities and wind energy deployment. Then we can conclude that the three of them are linked.

In relation to the sectorial structure, this dimension is not highly correlated with any other dimension although it would be expected with innovation capacities. Academia is also not correlated with any other dimension when it was likely to be linked to the sectorial structure.

5 Conclusions

Methodology objective

This pilot study developed a methodology to assess the status or regions related to energy and applied it to wind energy as a case study. The ultimate objective of such analysis is to identify regions that are possibly more advanced and regions that may benefit most from learning. The methodology helps to understand barriers and gaps towards regional deployment of energy technologies as well as the identification of the set of parameters that better defines similarities amongst regions. Ultimately, the methodology pursues the creation of regional clusters including regions with similar problems or level of development.

5.1 Conclusions related to the methodology

Set of parameters and data availability

The main challenge we faced in this analysis was the selection of parameters that could better define the technology status in regions and data availability. These two issues are directly linked since data access limits initial identification of parameters. Therefore, as a proof of concept, the analysis explores data availability.

Available information varies amongst regions, even in the case of same data sources. This situation may prevent from extending the analysis to a larger number of regions. The case of parameters related to energy use (such as final energy consumption) is especially critical, (Table 29 and Table 30). An extended analysis including different sources may be crucial to map energy supply and demand in regions. In any case, the data for the final list of parameters used in this work is available for most of the regions in Europe. Therefore, the analysis could be extended to regions but not increased in terms of new parameters.

Lack of regional information

To overcome the lack of information at regional level and in order to carry out extensive statistical analyses, proxy values derived from the national level could be developed. However singularities of regions amongst regions in the same countries will be lost be interpolating from MS level. As presented in the previous sections, energy price dimension comprises a set of parameters defined at MS level. Therefore, this dimension increases the level of similarities amongst regions in the same country as it was discussed in section 4.2.2. So, data at MS level has to be processed and weighted to minimise this national effect.

Data structure

To simplify the understanding of the data analysis, data has been structured in dimensions that encompass one or several parameters. These dimensions allow comparison between regions and establishing correlations. Through these dimensions we come to conclusions such as the existence of a negative correlation between the socio-economic status and energy prices or a positive between innovation capacities and the energy use in regions (Figure 17).

Statistical analysis to reduce number of parameters

Due to the lack of a pre-defined comprehensive list of parameters because of the complexity of the regional energy systems, a dimensional reduction was assessed. It was expected that the dimension energy price may not be needed when defining differences amongst regions. Even more, some other parameters may not be necessary to determine regional similarities.

For this reason, PCA was applied. As presented in section 4.4.2, the dataset could be reduced to only 12 parameters instead of 55. As presented in Table 19, all dimensions remain in the reduced dataset except for the energy price dimension as it was initially expected.

Replicability & Robustness

As mentioned, the initial goal of this study was the definition of a methodology that could be easily replicated for other energy technology and other regions.

Although most of the proposed data is available for every European region, the major drawback of the methodology is that for some further technologies specific parameters are not easy to define, especially for those technologies that show interactions with many other technologies. This is for example the case of heating and cooling technologies that may appear in combination with renewables and some other energy solutions. In any case, the methodology could be easily extended to many other technologies like ocean or solar (including CSP, STE and PV).

In terms of robustness from an statistical point of view, it is important to highlight that the more regions we have the more robust conclusions are. In our case, 12 regions have been assessed. However if more region from different countries are included, results will be more reliable.

Concerning the PCA and due to the limited number of regions, it is required to run the PCA exercise for a different set of regions under different technologies and compare whether the retained parameters woulc be the same as in the wind pilot case.

5.2 Conclusions related to wind

Based on the analysis carried out, the following conclusions can be extracted:

Regions within the same country present a high level of similarities, even when energy prices are out of the analysis as in the case of the PCA application (Figure 15).

Regional overview

SE33 remains as outlier in most of the dimension except for Academia and Energy Use.

The Spanish and French regions and UKK3 rank similarly. This is the reason why they are good candidates to define a working group based on the variables considered.

Although PL63 and PT11 rank low in the socio-economic dimension they show average values in the other dimensions. In particular, PT11 ranks high for academia and sectorial structure.

Correlation overview

There is no strong correlation between dimensions. Only innovation capacities seem to be correlated with socio-economic and wind energy deployment dimensions. Therefore, we can conclude that innovation support the development of wind energy at the regional scale.

Final mark

Finally, to ensure the consistency of the outcomes from the analysis, more regions will be required. In the future, when more regions show their interest in wind, they will be incorporated in this analysis.

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List of abbreviations and definitions

GDP	Gross Domestic Product
HDD	Heating Degree Days
KPI	Key Performance Indicators
KTOE	Kilo tonne of Oil Equivalent
MS	Member State
NUTS	Nomenclature of territorial units for statistics
PCA	Principal Component Analysis
RIS3	Regional Research and Innovation Strategies for Smart Specialisation

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Annexes

Annex I Energy price parameters

Gas prices for domestic users

Table 21 Gas price before taxes and levies for domestic users according to the range of energy consumption in 2014

NUTS2 Code	Before taxes and levies		
	Band D1 : Consumption < 20 GJ	Band D2 : 20 GJ < Consumption < 200 GJ	Band D3 : Consumption > 200 GJ
DE94	0.0810	0.0513	0.0474
ES11	0.0986	0.0769	0.0474
ES12	0.0986	0.0769	0.0474
ES13	0.0986	0.0769	0.0562
FR21	0.1249	0.0626	0.0562
FR23	0.1249	0.0626	0.0562
FR25	0.1249	0.0626	0.0562
FR51	0.1249	0.0626	0.0510
PL63	0.0526	0.0407	0.0390
PT11	0.0966	0.0802	0.0709
SE33	0.1106	0.0626	0.0511
UKK3	0.0924	0.0615	0.0535

Source: [Eurostat 2015c]

Table 22 Gas final price for domestic users according to the range of energy consumption in 2014

NUTS2 Code	Final price		
	Band D1 : Consumption < 20 GJ	Band D2 : 20 GJ < Consumption < 200 GJ	Band D3 : Consumption > 200 GJ
DE94	0.1063	0.0681	0.0634
ES11	0.1221	0.0959	0.0708
ES12	0.1221	0.0959	0.0708
ES13	0.1221	0.0959	0.0708
FR21	0.1512	0.0762	0.0621
FR23	0.1512	0.0762	0.0621
FR25	0.1512	0.0762	0.0621
FR51	0.1512	0.0762	0.0621
PL63	0.0647	0.0500	0.0479
PT11	0.1256	0.1039	0.0923
SE33	0.1739	0.1138	0.0995
UKK3	0.0970	0.0646	0.0561

Source: [Eurostat 2015c]

Electricity prices for domestic

Table 23 Electricity price before taxes and levies for domestic sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Before taxes and levies				
	Band DA : Consumption < 1 000 kWh	Band DB : 1 000 kWh < Consumption < 2 500 kWh	Band DC : 2 500 kWh < Consumption < 5 000 kWh	Band DD : 5 000 kWh < Consumption < 15 000 kWh	Band DE : Consumption > 15 000 kWh
DE94	0.2576	0.1647	0.1440	0.1317	0.1275
ES11	0.3667	0.2166	0.1861	0.1659	0.1405
ES12	0.3667	0.2166	0.1861	0.1659	0.1405
ES13	0.3667	0.2166	0.1861	0.1659	0.1405
FR21	0.2087	0.1268	0.1094	0.0974	0.0924
FR23	0.2087	0.1268	0.1094	0.0974	0.0924
FR25	0.2087	0.1268	0.1094	0.0974	0.0924
FR51	0.2087	0.1268	0.1094	0.0974	0.0924
PL63	0.1411	0.1161	0.1097	0.1062	0.1065
PT11	0.2192	0.1392	0.1301	0.1254	0.1210
SE33	0.2547	0.1430	0.1194	0.0986	0.0806
UKK3	0.2383	0.2124	0.1917	0.1731	0.1598

Source: [Eurostat 2015e]

Table 24 Electricity final price for domestic sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Final price				
	Band DA : Consumption < 1 000 kWh	Band DB : 1 000 kWh < Consumption < 2 500 kWh	Band DC : 2 500 kWh < Consumption < 5 000 kWh	Band DD : 5 000 kWh < Consumption < 15 000 kWh	Band DE : Consumption > 15 000 kWh
DE94	0.4336	0.3230	0.2974	0.2827	0.2714
ES11	0.4664	0.2755	0.2367	0.2110	0.1787
ES12	0.4664	0.2755	0.2367	0.2110	0.1787
ES13	0.4664	0.2755	0.2367	0.2110	0.1787
FR21	0.2676	0.1806	0.1620	0.1491	0.1440
FR23	0.2676	0.1806	0.1620	0.1491	0.1440
FR25	0.2676	0.1806	0.1620	0.1491	0.1440
FR51	0.2676	0.1806	0.1620	0.1491	0.1440
PL63	0.1794	0.1486	0.1408	0.1364	0.1368
PT11	0.3940	0.2420	0.2231	0.2132	0.2008
SE33	0.3559	0.2162	0.1867	0.1607	0.1383
UKK3	0.2503	0.2230	0.2013	0.1817	0.1679

Source: [Eurostat 2015e]

Gas prices for industrial

Table 25 Gas price before taxes and levies for industrial sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Final price					
	Band I1 : Consumption < 1 000 GJ	Band I2 : 1 000 GJ < Consumption < 10 000 GJ	Band I3 : 10 000 GJ < Consumption < 100 000 GJ	Band I4 : 100 000 GJ < Consumption < 1 000 000 GJ	Band I5 : 1 000 000 GJ < Consumption < 4 000 000 GJ	Band I6 : Consumption > 4 000 000 GJ
DE94	0.0443	0.0420	0.0361	0.0278	0.0255	0.0235
ES11	0.0548	0.0450	0.0369	0.0342	0.0320	0.0309
ES12	0.0548	0.0450	0.0369	0.0342	0.0320	0.0309
ES13	0.0548	0.0450	0.0369	0.0342	0.0320	0.0309
FR21	0.0579	0.0454	0.0360	0.0295	0.0261	
FR23	0.0579	0.0454	0.0360	0.0295	0.0261	
FR25	0.0579	0.0454	0.0360	0.0295	0.0261	
FR51	0.0579	0.0454	0.0360	0.0295	0.0261	
PL63	0.0421	0.0416	0.0359	0.0317	0.0302	
PT11	0.0726	0.0590	0.0437	0.0377	0.0358	
SE33	0.0572	0.0456	0.0356	0.0319	0.0323	
UKK3	0.0580	0.0383	0.0332	0.0277	0.0245	

Source: [Eurostat 2015d]

Table 26 Gas final price for industrial sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Final price					
	Band I1 : Consumption < 1 000 GJ	Band I2 : 1 000 GJ < Consumption < 10 000 GJ	Band I3 : 10 000 GJ < Consumption < 100 000 GJ	Band I4 : 100 000 GJ < Consumption < 1 000 000 GJ	Band I5 : 1 000 000 GJ < Consumption < 4 000 000 GJ	Band I6 : Consumption > 4 000 000 GJ
DE94	0.0576	0.0548	0.0478	0.0379	0.0351	0.0327
ES11	0.0670	0.0550	0.0452	0.0420	0.0394	0.0381
ES12	0.0670	0.0550	0.0452	0.0420	0.0394	0.0381
ES13	0.0670	0.0550	0.0452	0.0420	0.0394	0.0381
FR21	0.0726	0.0563	0.0445	0.0352	0.0306	
FR23	0.0726	0.0563	0.0445	0.0352	0.0306	
FR25	0.0726	0.0563	0.0445	0.0352	0.0306	
FR51	0.0726	0.0563	0.0445	0.0352	0.0306	
PL63	0.0530	0.0521	0.0448	0.0393	0.0371	
PT11	0.0961	0.0746	0.0546	0.0469	0.0441	
SE33	0.1072	0.0926	0.0801	0.0755	0.0760	
UKK3	0.0742	0.0458	0.0417	0.0343	0.0301	

Source: [Eurostat 2015d]

Electricity prices for industrial

Table 27 Electricity price before taxes and levies for industrial sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Final price						
	Band IA : Consumption < 20 MWh	Band IB : 20 MWh < Consumption < 500 MWh	Band IC : 500 MWh < Consumption < 2 000 MWh	Band ID : 2 000 MWh < Consumption < 20 000 MWh	Band IE : 20 000 MWh < Consumption < 70 000 MWh	Band IF : 70 000 MWh < Consumption < 150 000 MWh	Band IG : Consumption > 150 000 MWh
DE94	0.1403	0.1029	0.0808	0.0714	0.0627	0.0608	:
ES11	0.2782	0.1482	0.1110	0.0979	0.0792	0.0736	0.0646
ES12	0.2782	0.1482	0.1110	0.0979	0.0792	0.0736	0.0646
ES13	0.2782	0.1482	0.1110	0.0979	0.0792	0.0736	0.0646
FR21	0.1168	0.0884	0.0687	0.0604	0.0572	0.0521	:
FR23	0.1168	0.0884	0.0687	0.0604	0.0572	0.0521	:
FR25	0.1168	0.0884	0.0687	0.0604	0.0572	0.0521	:
FR51	0.1168	0.0884	0.0687	0.0604	0.0572	0.0521	:
PL63	0.1464	0.1071	0.0786	0.0665	0.0611	0.0557	0.0517
PT11	0.1585	0.1272	0.1052	0.0891	0.0767	0.0697	:
SE33	0.1325	0.0769	0.0661	0.0593	0.0528	0.0456	:
UKK3	0.1726	0.1447	0.1290	0.1179	0.1176	0.1149	0.1126

Source: [Eurostat 2015f]

Table 28 Electricity final price for industrial sector in wind interest regions according to the range of energy consumption

NUTS2 Code	Final price						
	Band IA : Consumption < 20 MWh	Band IB : 20 MWh < Consumption < 500 MWh	Band IC : 500 MWh < Consumption < 2 000 MWh	Band ID : 2 000 MWh < Consumption < 20 000 MWh	Band IE : 20 000 MWh < Consumption < 70 000 MWh	Band IF : 70 000 MWh < Consumption < 150 000 MWh	Band IG : Consumption > 150 000 MWh
DE94	0.2909	0.2302	0.1992	0.1761	0.1512	0.1412	:
ES11	0.3539	0.1885	0.1412	0.1245	0.1007	0.0936	0.0822
ES12	0.3539	0.1885	0.1412	0.1245	0.1007	0.0936	0.0822
ES13	0.3539	0.1885	0.1412	0.1245	0.1007	0.0936	0.0822
FR21	0.1702	0.1350	0.1090	0.0944	0.0841	0.0647	:
FR23	0.1702	0.1350	0.1090	0.0944	0.0841	0.0647	:
FR25	0.1702	0.1350	0.1090	0.0944	0.0841	0.0647	:
FR51	0.1702	0.1350	0.1090	0.0944	0.0841	0.0647	:
PL63	0.1860	0.1375	0.1025	0.0876	0.0810	0.0744	0.0694

PT11	0.2328	0.1812	0.1460	0.1241	0.1082	0.1030	:
SE33	0.1663	0.0968	0.0833	0.0747	0.0667	0.0577	:
UKK3	0.2125	0.1798	0.1606	0.1458	0.1442	0.1406	0.1372

Source: [Eurostat 2015f]

Annex II Energy use

Total energy consumption

Table 29: Total final energy consumption (ktoe) from 2009 to 2013

NUTS2 Code	2009	2010	2011	2012	2013
DE94					:
ES11	2,643.564	2,734.018	2,725.405	2,566.841	:
ES12	1,312.412	1,352.243	1,343.235	1,311.513	:
ES13	793.069	813.102	799.814	770.47	:
FR21	:	:	:	:	:
FR23	:	:	:	:	:
FR25		:	:	:	:
FR51					
PL63					
PT11					
SE33					
UKK3	963.67				
Source: [Eurostat 2015g]					

Final energy consumption by households

Table 30: Total final energy consumption (ktoe) by households from 2009 to 2013

	2009	2010	2011	2012	2013
Weser-Ems					
Galicia	1,033.025	1,095.095	1,089.144	637.592	:
Principado de Asturias	377.08	400.683	398.111	217.768	:
Cantabria	156.81	167.959	166.326	126.548	:
Champagne-Ardenne	:	:	:	:	:
Haute-Normandie	:	:	:	:	:
Basse-Normandie	:	:	:	:	:
Pays de la Loire		:	:	:	:
Pomorskie					
Norte					
Övre Norrland					
Cornwall and Isles of Scilly	354.14				
Source: [Eurostat 2015g]					

Annex III Wind energy deployment

In this section location of wind farms for different regions under study are presented. In the maps, the size of the bubbles represents the size of the farms in terms of power capacity installed.

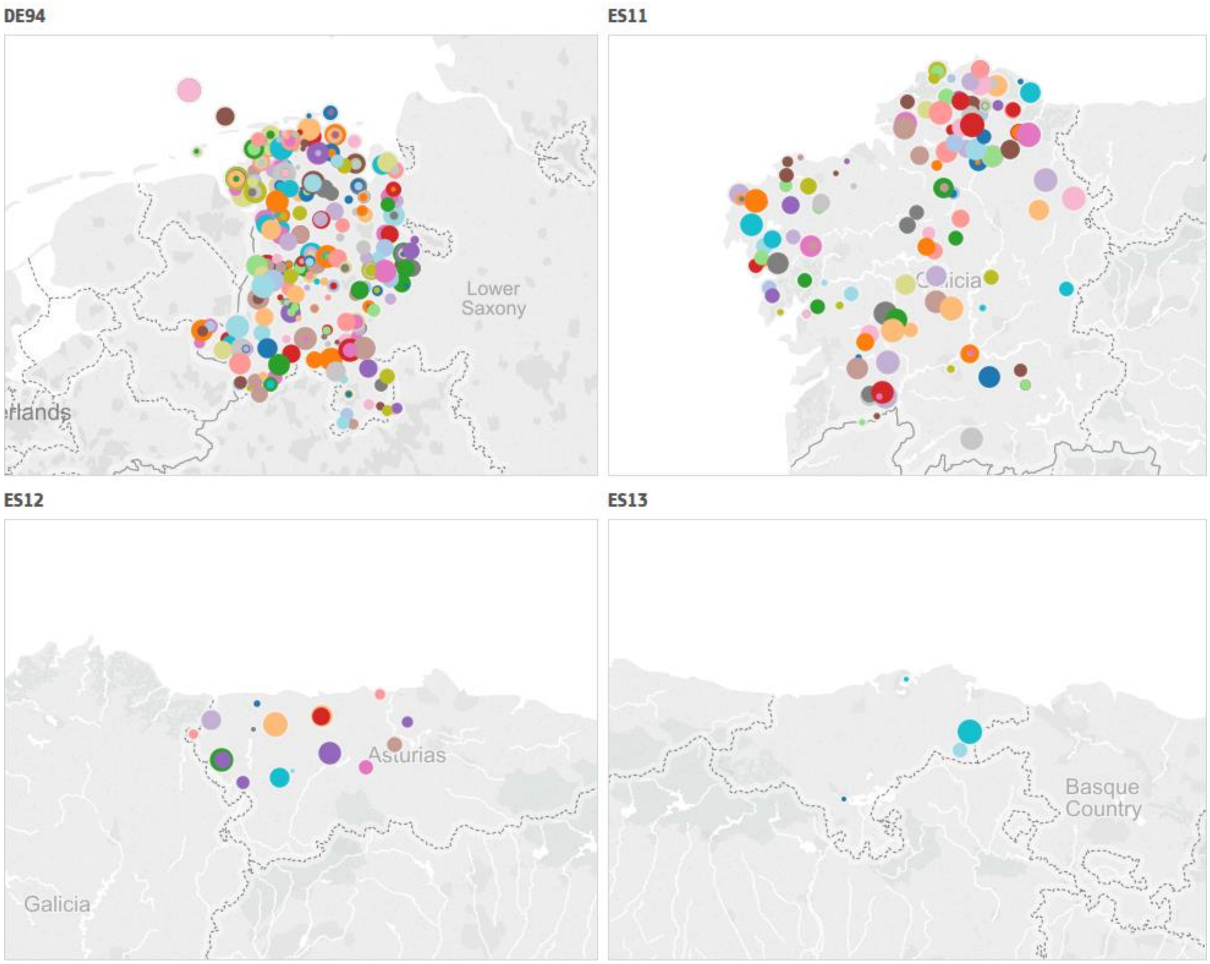

Figure 18 Installed wind farms in DE94, ES11, ES12 and ES13.

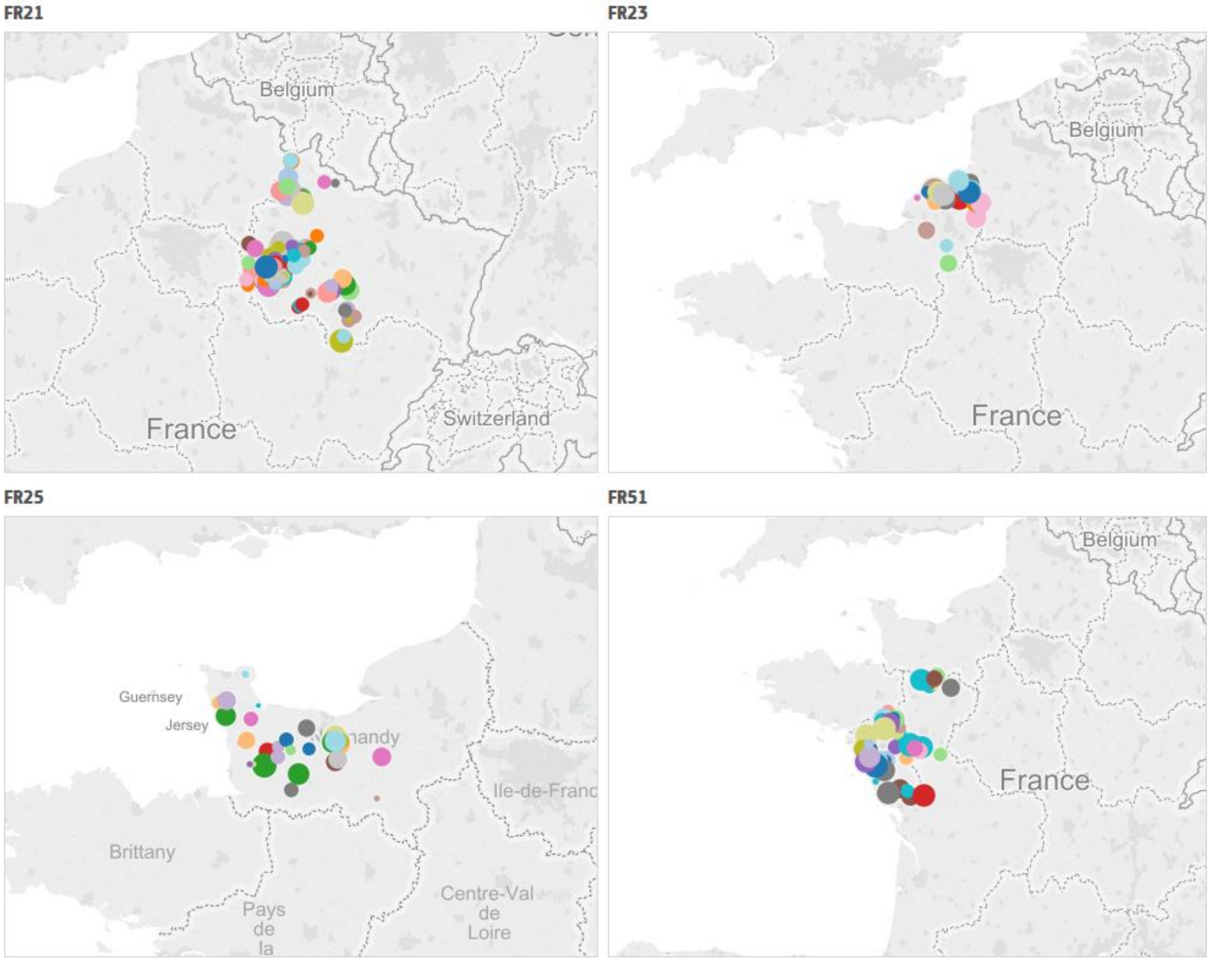

Figure 19 Installed wind farms in FR21, FR23, FR25 and FR51.

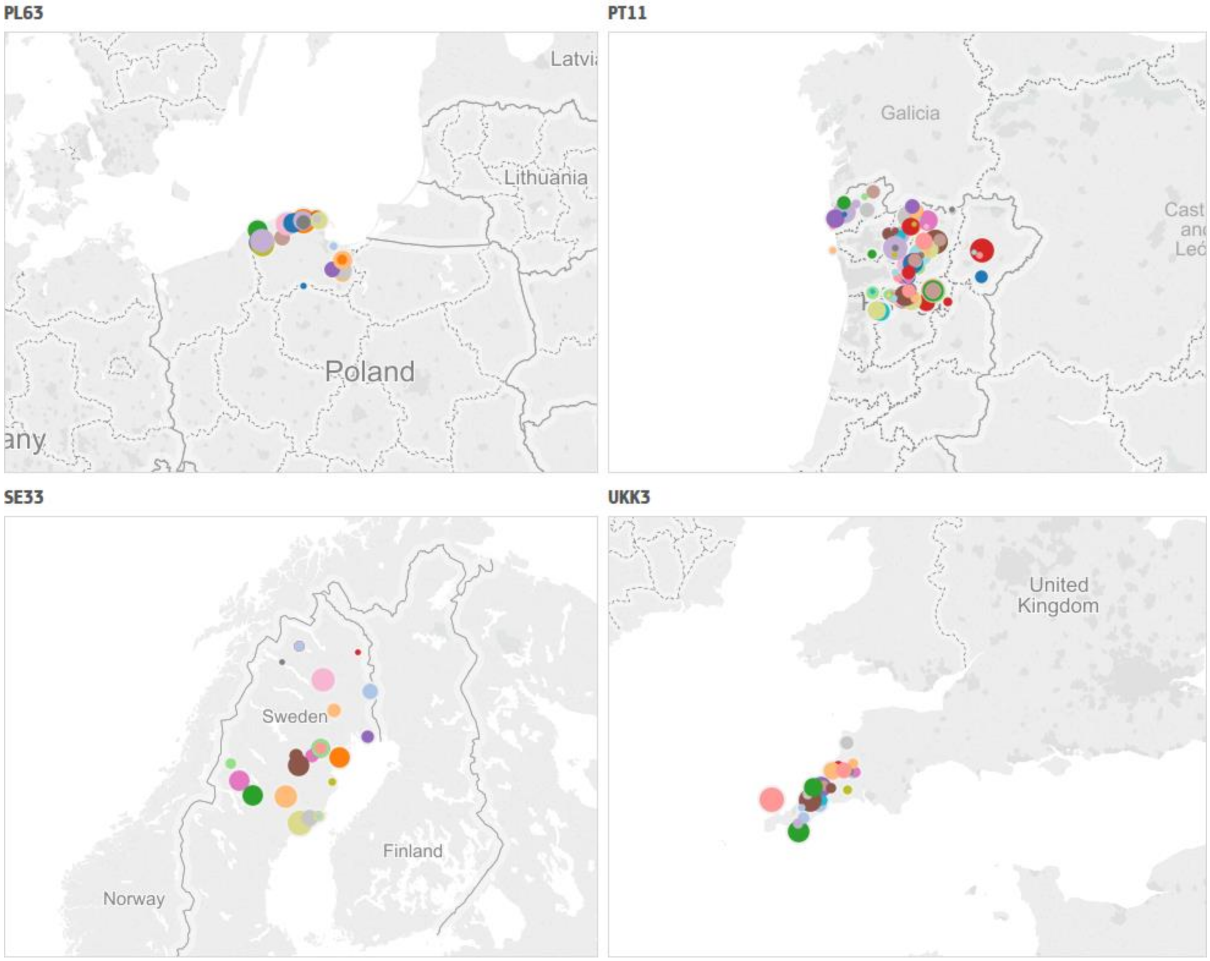

Figure 20   Installed wind farms in PL63, PT11, SE33 and UKK3.

Annex IV Academia indicators

Identification of regional universities have been based on the Authorities file of European Universities [Daraio 2015].

Table 31 List of universities in Wind interest regions

NUTS2 Code	Universities
DE94	Carl von Ossietzky Universität Oldenburg
	Universität Osnabrück
	Universität Vechta
ES12	Universidad de Oviedo
ES13	Universidad de Cantabria
FR21	Université de technologie de Troyes
	Université de Reims Champagne-Ardenne
FR23	Institut national des sciences appliquées de Rouen
	Université de Rouen
FR25	Université de Caen Basse-Normandie
	École nationale supérieure d'ingénieurs de Caen
FR51	Ecole centrale de Nantes
	Université de Nantes
	École nationale d'ingénieurs des techniques des industries agricoles et alimentaires
	École nationale supérieure des mines de Nantes
	Université catholique de l'Ouest
	Université d'Angers
	Université du Maine
PL63	Akademia Marynarki Wojennej w Gdyni
	Gdański Uniwersytet Medyczny
	Akademia Morska w Gdyni
	Akademia Muzyczna im. Stanisława Moniuszki w Gdańsku
	Akademia Pomorska w Słupsku
	Akademia Sztuk Pięknych w Gdańsku
	Akademia Wychowania Fizycznego i Sportu im. Jędrzeja Śniadeckiego w Gdańsku
	Politechnika Gdańska
	Uniwersytet Gdański
PT11	Universidade do Minho
	Universidade do Porto
	Universidade de Trás-os-Montes e Alto Douro
	Instituto Politécnico de Bragança
	Instituto Politécnico do Porto
	Universidade Fernando Pessoa
	Universidade Lusíada (Porto)
	Universidade Lusófona do Porto

	Universidade Portucalense Infante D. Henrique
SE33	Umeå universitet
	Luleå tekniska universitet
Source: [Daraio 2015]	

Annex V Innovation capacities

Table 32 Total intramural R&D expenditure (GERD) by sectors of performance and NUTS 2 regions 2013 (EUR/inhabitant)

	All sectors	Business enterprise sector	Government sector	Higher education sector	Private non-profit sector
DE94	235	144.6	20.4	70	:
ES11	169.7	77.8	25.2	:	:
ES12	172.1	90.5	26	55.4	0.1
ES13	186.5	65.6	34.7	:	:
FR21	210.3	143.9	2.3	64.2	:
FR23	400.2	332.6	2.3	65.3	:
FR25	327.9	213.3	15.8	98.8	:
FR51	351.3	227.5	25.3	98.4	:
PL63	98.4	51.4	15.8	31.2	0.1
PT11	187.1	97.8	6.9	81.8	0.7
SE33	1082.8	242.6	75.9	764.4	:
UKK3	43.9	41.7	0	2.2	0
Source: [Eurostat 2016a]					

Table 33 Total R&D personnel by 2013

NUTS2 code	Total R&D personnel (2013)
DE94	9734
ES11	17710
ES12	6688
ES13	3585
FR21	:
FR23	:
FR25	:
FR51	:
PL63	8575
PT11	31315
SE33	7770
UKK3	699
Source: [Eurostat 2016b]	

Annex VI Annex VII Results of PCA analysis for non-weighted dataset

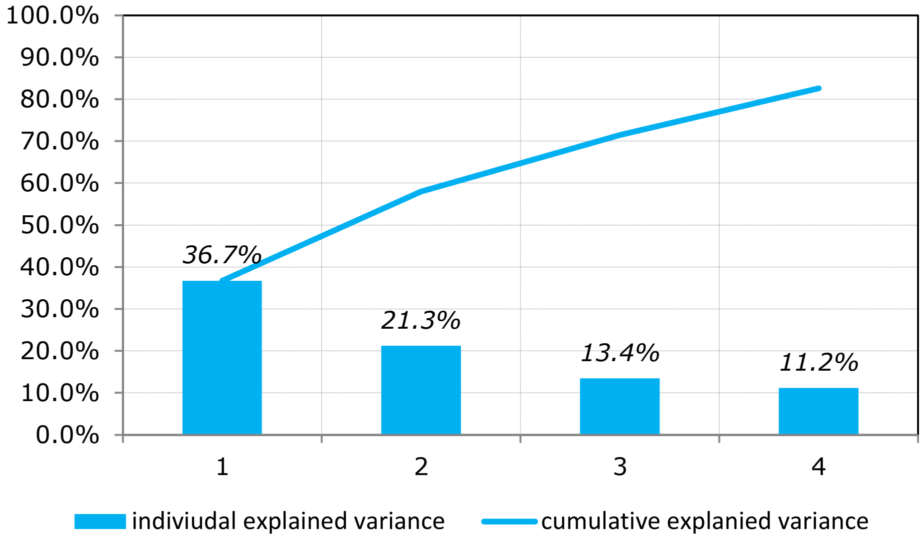

Figure 21 Cumulative explained variance ratio. PCA non-weighted dataset

Table 34 Parameters included in the reduced dataset. PCA non-weighted

Parameters
Population 2013
Absolute GDP
Relative GDP
Band DB : 1 000 kWh < Consumption < 2 500 kWh
Band DC : 2 500 kWh < Consumption < 5 000 kWh
Band DD : 5 000 kWh < Consumption < 15 000 kWh
Band DE : Consumption > 15 000 kWh
Band DE : Consumption > 15 000 kWh.1
Band I2 : 1 000 GJ < Consumption < 10 000 GJ
Band I3 : 10 000 GJ < Consumption < 100 000 GJ
Band I5 : 1 000 000 GJ < Consumption < 4 000 000 GJ
Band I1 : Consumption < 1 000 GJ.1
Band I2 : 1 000 GJ < Consumption < 10 000 GJ.1
Band I3 : 10 000 GJ < Consumption < 100 000 GJ.1
Band I4 : 100 000 GJ < Consumption < 1 000 000 GJ.1
Band I5 : 1 000 000 GJ < Consumption < 4 000 000 GJ.1
Band IB : 20 MWh < Consumption < 500 MWh.1
Installed capacity
Number of wind farms
Number of universities
Number of companies
Representativeness of the regional sector at the national level. Energy sector size
R&D expenditures. Government sector

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