The ongoing energy transition: A comparative analysis of SIDS and European ultraperipheral islands

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Abstract

The vulnerability of island spaces has been recognized since the Earth Summit in Rio in 1992. Global energy pressure and the depletion of resources exacerbate their vulnerability. These territories are supposed to be real laboratories to experiment energy planning strategies, then allowed to help the international community. Nevertheless, the great diversity of island situations makes their case particular and difficult to treat. Some island territories are autonomous, the Small Island Developing States, while others depend on developed metropolitan states. Is there a difference between these two types of territories to succeed energy transition? We adopt electricity generation as a metric for sustainable transition quality.

This paper contributes to the understanding of ongoing dynamic through a multidimensional analysis of data allowing to classify these territories: SIDS and outermost regions of the European Union. The combination of Principal Component Analysis and Hierarchical Classification will provide island profiles that will highlight differences between outermost regions and SIDS. Are the outermost regions of the European Union more advanced in the energy transition? In addition to the classification, a ranking will be proposed through the implementation of an energy vulnerability indicator.

The classification and ranking will make it possible to draw typical portraits. These will identify the elements of resilience and the elements of vulnerabilities. This analysis, therefore, highlights the strengths and weaknesses will help to guide the energy policies of these territories.

The comparison of these two types of territories has not been made so far. This work would highlight the situation of SIDS face island developed territories: outermost regions of the European Union.

Keywords
Island
Vulnerability
Policy
SIDS.
Energy

1. INTRODUCTION

Since the 1970s and 1980s and the first major ecological disasters, energy and the exhaustion of energy resources are increasingly present in politico-environmental concerns. Oil spills, oil shocks, and nuclear accidents have made the energy transition an actual social event. The energy transition refers to the transition from an economy based essentially on fossil resources to a low-carbon energy mix. All the territories of the world are concerned, but the unequal distribution of resources, wealth and the considerable heterogeneity of physical constraints and locations weaken some territories more than others. In these fragile territories, island territories are particularly sensitive to the various consequences of global warming. Although international opinion generally accepts energy transition as essential, its dynamics seems challenging to begin on a global scale. The island territories must, therefore, take even closer ownership of the issue and the effective implementation of the energy transition. There are more than 50,000 islands spread around the world, for 740 million inhabitants (Kuang et al., 2016), of which 2,000 are considered small islands (Blechinger, Seguin, Cader, Bertheau, & Breyer, 2014). These territories are very diverse, with different areas, population sizes, geographical features and political status (Taglioni, 2006).

Among these territories, the international community has noted since the 1970s with formalization at the Earth Summit in Rio in 1992, the great particularity of Small Island Developing States (Angeon & Hoarau, 2015). These isolated territories with fragile economies (Angeon & Saffache, 2008; Bouchard, Marrou, Plante, Payet, & Duchemin, 2010; Briguglio, 1995; Encontre, 2009)have indeed been recognized as individual cases for the environment and development (UN, 1992). The Summits of Barbados (1994) and Samoa (2014) subsequently confirmed the interest of the international community in SIDS (UN, 1994). The interest of the international community is based not only on the vulnerability of these territories but also on the issue of the energy transition and the pressure it generates. SIDS is at the forefront of international climate action (Gay, Rogers, & Shirley, 2018). Indeed, because of their physical and socio-economic characteristics, SIDS can be real laboratories of experimentations to apprehend the energy transition. The challenge of understanding these territories is therefore global.

Other island territories have also been highlighted for their vulnerability and "usefulness" to the international community. The outermost European regions (ORs) are considered as isolated territories, with a development below that of the continental European zone. As SIDS, their physical and socioeconomic characteristics make them real laboratory experiments to address this critical issue of the XXI century: the energy transition. These territories are French, Portuguese and Spanish. Less fragile than SIDS, these ultramarine territories are lagging behind their metropolises (Sudrie, 2013). A working paper by the Agence Française de Développement shows a delay in the 1990-2010 period around -13% for the French ORs, -4.88% on average for the Portuguese ORs and -1, 73% for the Spanish ORs (Sudrie, 2013). All the outermost regions are therefore behind their metropolises, but their situations are very diverse and unequal. A ranking according to the 2010 Human Development Index (HDI) of the ORs and SIDS easily shows that even if a majority of them are at the top of the table, the ORs do not have a clear advantage regarding the standard of living (as defined by the HDI) (Figure 1). The hypothesis of insularity as a discriminating factor seems relevant here. The remoteness and isolation of these territories could be aggravating factors for their development.

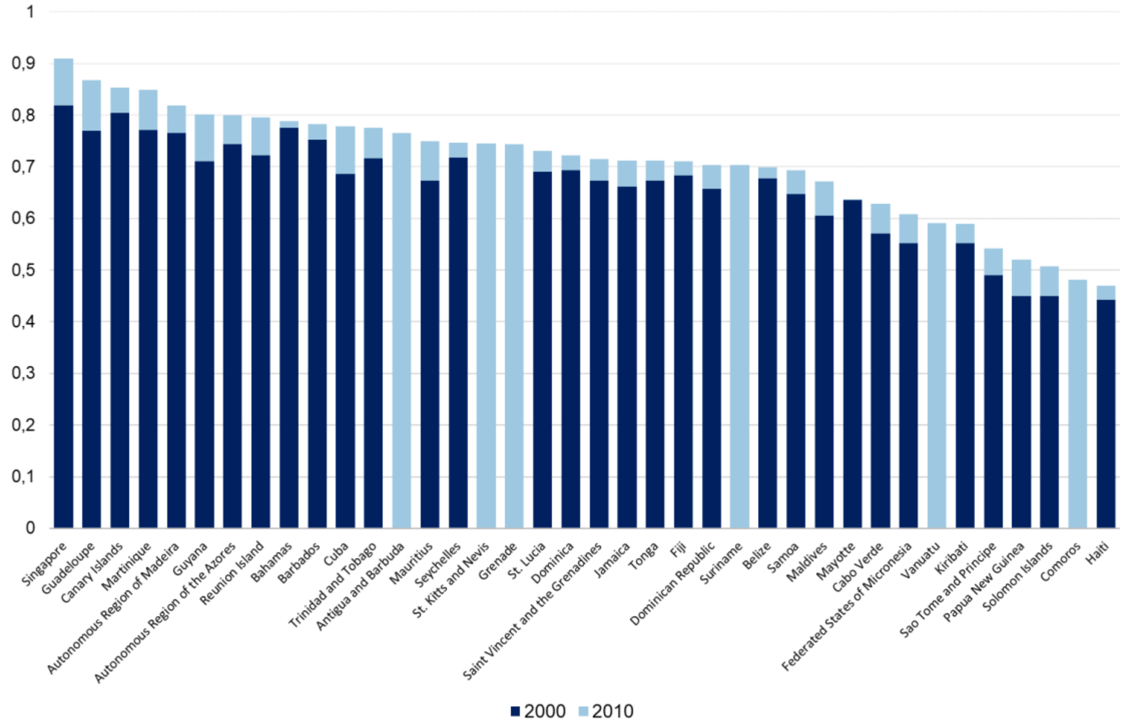


Fig. 1 The HDI ranking of ORs and SIDS

The notion of development is today more and more linked to the notions of sustainability and energy transition. Indeed, with the exhaustion of resources, global warming, the increase in the world population and the spread of cities, the energy transition is one of the critical issues of our contemporary societies. All territories around the world are concerned. But not all territories are prepared in the same way. Besides, barriers to the penetration of renewable energies in a territory can be numerous (Painuly, 2001). Island territories are among the most vulnerable. However, again, these territories do not all have the same characteristics. For example, accessibility to energy is not always the same, and this is a particular development issue for some territories (Surroop, Raghoo, Wolf, Shah, & Jeetah, 2018). In order to study these differences, we propose to focus on two types of island territories: ORs and SIDS. The main difference between the ORs and SIDs is that the ORs are not islands states and depend on a sovereign state (France, Spain or Portugal). These ORs are often not well known because most of the data and analysis is done at the national level. These overseas regions rarely appear in international studies, unlike SIDS.

Considering the hypothesis of a difference between the ORs and the SIDS in order to succeed in the energy transition, electricity generation is adopted as a metric for sustainable transition quality.

This paper will look at first to contribute to the understanding the sustainability situation by drawing profiles and then to highlight development differences related to the energy transition by ranking the studied islands. In order to reach the first objective, a multidimensional data analysis will be practiced: the combination of Principal Component Analysis and Hierarchical Classification will allow classifying these territories. This two-step methodology will allow segmenting the studied islands into several clusters and will provide island profiles for the clusters. These will identify the elements of resilience and the elements of vulnerabilities. This analysis, therefore, highlights the strengths and weaknesses will help to guide the energy policies of these territories.

Thanks to the clustering, a ranking will be proposed in a third step through the implementation of a sustainability index. Such an indicator is essential for understanding the energy transition of a territory. It makes it possible to quantify the trajectory of transition and to highlight the most advanced and least developed territories. This ranking will show if the ORs are more advanced in the energy transition. This ranking provides an overview of the current situation of the different islands. We can thus observe the position of the ORs in relation to SIDS, which makes it possible to discuss the influence of a territory's status on its classification.

2. MATERIALS AND METHOD

2.1 Data collection

The implementation of this work, the first step is to identify the islands to study. At the OR level, the European Union has identified nine of them in the world: five French overseas departments (Martinique, Mayotte, Guadeloupe, French Guiana and Reunion), a French overseas community (Saint-Martin), two Portuguese autonomous regions (Madeira and the Azores) and a Spanish autonomous community (the Canary Island) (Azevedo, 2017). In all these very diverse territories, we choose to study only seven of them, eliminating the following regions:

- French Guiana because of its particular geographical location compared to other ORs as it is attached to the South American continent.
- Saint Martin because of the lack of data available for this region.

The United Nations (UN) provides a list of 58 SIDS around the world, 38 of which are members of the United Nations. Among the SIDS UN-members, nine are located in Atlantic, Indian Ocean, Mediterranean and South China Sea (AIMS), 16 in the Caribbean and 13 in the Pacific (UN, n.d.).

There are therefore very diverse territories among which Seychelles, Singapore, Comoros, the Dominican Republic, Haiti, Jamaica or Fiji Islands, Papua New Guinea, and the Solomon Islands to name a few. For reasons of availability of data for the selected study variables, 23 SIDS and 7 ORs has been selected for this study, see Table 1.

Table 1 List of studied islands

	Islands	ID	Regions
SIDS	Antigua and Barbuda	ATG	Caribbean
	Bahamas	BHS	Caribbean
	Barbados	BRB	Caribbean
	Belize	BLZ	Caribbean
	Cape Verde	CPV	AIMS
	Comoros	COM	AIMS
	Dominica	DMA	Caribbean
	Fiji	FJI	Pacific
	Grenada	GRD	Caribbean
	Jamaica	JAM	Caribbean
	Kiribati	KIR	Pacific
	Maldives	MDV	AIMS
	Mauritius	MUS	AIMS
	Micronesia	FSM	Pacific
	Samoa	WSM	Pacific
	Sao Tome and Principe	STP	AIMS
	Seychelles	SYC	AIMS
ORs	Azores	AZO	Atlantic
	Canary island	CAN	Atlantic
	Guadeloupe	GUA	Caribbean
	Madeira	MAD	Atlantic
	Martinique	MAR	Caribbean
	Mayotte	MAY	Indian Ocean
	Reunion	RUN	Indian Ocean

In order to analyze the progress of territories in the energy transition, eight variables were selected for the year 2014 (Table 2). For SIDS, the majority of data come from Data World Bank1, except for CO2 emissions per capita2 and the insularity index that we had to compute according to the method (Guerassimoff & Naizi, 2008). For the outermost regions, the data come from Eurostat (Eurostat, 2018) and national and regional sources of statistical data on energy and economy (EDF, 2018a, 2018d, 2018c, 2018b; ISTAC, 2015; Pordata, 2018). We selected these variables because of the availability of data for both types of islands. Indeed, all types of data on the ORs are challenging to access because they are generally included in national reports. Besides, the data were chosen to facilitate the reproducibility of the method over time on future databases.

Table 2 List of variables

Variable	Unit	Special features
Area (LND.TOTL.K2)	km_2	This data is a good indicator of the development potential of an island (economies of scale, renewable energies).
Population (POP.TOTL)	Capita	This data makes it possible to quantify the need on the territory.
Gross Domestic Product (GDP.PPA)	$ Purchasing Power Parity (PPP)	Energy consumption is closely linked to the economic development of a territory. PPP GDP is used to compare the GDP of different territories with different currencies. It allows expressing in a standard unit the purchasing power of different currencies.
Population Density (POP.DNST)	Capita/km_2	This indicator considers the pressure of urbanization for the energy transition.
Electricity Consumption (ELC.CONS.GWH)	Gigawatt hour (GWh)	This data evaluates the extent of electricity needs, that is the central feature of our analysis.
The share of renewable energies in the electricity mix (ELC.RNEW)	%	This data makes it possible to evaluate the level of penetration of renewable energies in the electricity mix. It assesses the current choices and opportunities of territory regarding renewable energy.
CO_2emissions per capita (CO2.PC)	ton metrics/capita	This data is related to the economic development of a territory. The report to the population evaluates lifestyles.
Insular Index (INS.I)	-	The insular situation is measured through the remoteness of the territory but also its political system. The calculation method comes from (Guerassimoff & Naizi, 2008)

1 https://data.worldbank.org

2 http://hdr.undp.org/en/data

2.2 Methodology

2.2.1 PCA and Hierarchical clustering

Principal Component Analysis is an exploratory method of analyzing data from an n*p table of quantitative data, with n the individuals studied and p the variables studied. The goal is to reduce p-variables to new q-dimensions created in order to synthesize the information (q<p). With the creation of new q-dimensions, PCA also offers simple data and variables visualization method:

- n-individuals are optimally represented by minimizing the deformations of the initial point cloud, in a subspace Eq of dimension q (q<p) (individuals factor map);

- the variables are also represented graphically in a subspace Fq by explaining the original links between the variables (variables map).

The part of inertia explained (makes it possible to measure the quality of representations:

$$r_q = \frac{\sum_{i=1}^{q} \lambda_i}{\sum_{i=1}^{p} \lambda_i} \qquad (1)$$

Where λ_i is the eigenvalues. The value of q is chosen so that r_q is greater than a fixed threshold ζ. We have: $r_q > \zeta$.

In our study, PCA has two objectives: firstly, PCA is used to highlight groups of individuals with similar characteristics; secondly, PCA allows to identify the variables that have a significant influence on the variance of the most influential principal component. It means that in our study, the PCA method allows us to see which are the most influential variables in the question of the energy vulnerability of island territory.

The hierarchical classification on principal components makes it possible to identify groups (clusters) from the data of the ACP. Thus, the method is based on the q-dimensions and the coordinates of the n individuals on the q-dimensions to carry out the classification. The graphical representation is advantageous and straightforward because it takes up the factorial axes of the ACP (the q-dimensions) to visualize the clusters. The classification methodology chosen is Ward's method. It consists in grouping the clusters so that the increase of the inertia inter-classes is maximum, or so that the increase of the intraclass inertia is minimum.

2.2.2 Creating an index and Ranking

In addition to the classification, our study proposes the ranking of the territories studied thanks to the creation of a sustainability index (SI). The purpose of this index is to show how far a territory is advanced in the energy transition. It represents three key challenges: developing its territory, conducting a proactive policy by promoting renewable energies and acting on consumption patterns (Benard-Sora & Praene, 2017). Our index will try to translate these difficulties. This index can be understood in two ways: a first way would be to see the index as a vulnerability index (Bénard-Sora & Praene, 2017), a second way would be to see it as an index of sustainability (Praene, Payet, & Bénard-Sora, 2018). In this work, we choose to speak of sustainibility index (SI), combining both points of view. When this index is reliable, it reflects the sustainability, and conversely, when it is weak, it reflects the vulnerability. Although the concept of sustainability has been around for a long time, it continues to evolve. Indeed, in the literature, new technical-economic or institutional techniques are now being discussed. In our article, given the availability of data, we have based ourselves solely on the three fundamental pillars of sustainable development. We have thus assumed that the selected variables succeed in providing a sufficient representation of the concept of sustainability

To create such an index, we consider the results of the PCA, and in particular, the dimension (PCi) created. The index (SI) is defined as follows:

$$SI = \frac{\sum_{i=1}^{n} \lambda_i PC_i}{\sum_{i=1}^{n} \lambda_i} \tag{2}$$

Each dimension (Dim_i) must then be decomposed according to the variables p_j that participated in its construction during the PCA: it is a linear combination of the variable set. Thus, each variable is weighted by a weight α_{ij} calculated through the PCA. PC_i is defined as follows:

$$PC_i = \sum_j \alpha_{ij} p_j \tag{3}$$

The variables in the input are of very different natures and order of magnitude. Therefore, it is necessary to proceed before calculating the index to a normalization of the data of the table n*p. For this normalization, we choose to perform a z-score normalization. Our standardized data so have a mean of 0 and a standard deviation of 1. The particularity of this standardization is the fact it does not affect the shape of the original distribution.

3. RESULTS AND DISCUSSION

3.1 Exploratory data analysis

The objectives of our paper are threefold: i) Assess the determinants of energy vulnerability under insular context. ii) Identify disparities or similarities between different type of island using hierarchical clustering. iii) Create an indicator to help inform the energy transition issue. In the first step, a principal component analysis (PCA) has been investigated. Most of the time PCA is conducted to reduce the size of the original set of data. In this study, the purpose was not so much the reduction question, but the ability to define some new latent variable. This latent variable is the principal component which is defined by a linear combination of original data. These combinations are useful to define the main characteristics of each principal components.

Our approach was conducted a PCA iteratively. Indeed, the initial full dataset consists of 36 islands. We first explore two PCA calculation. The analysis of the projected plan has highlighted some outliers. These correspond to particular islands cases which actively contribute to the construction of the plane. Six islands (DOM, HTI, PNG, SGP, SUR, TTO) has been identified, their cumulative contribution to the contribution of the first two principal components equals 89.1%. Subsequently, we have removed these cases for the rest of the clustering and PCA. The studied dataset is finally 30 islands. A commonly used method to define the significant numbers of the principal component to consider is to fix the cut-off criteria of an eigenvalue $\lambda>1$ as defined by Kaiser's rule. As suggested by the results in Table 3, the variations the first three PCs is taken into account.

Table 3 Eigenvalues of correlation matrix.

Principal Component	Eigenvalue λ	Percentage of variance	Cumulative percentage of variance
PC1	2,4	30,4	30,4
PC2	1,9	24,1	54,5
PC3	1,3	16,7	71,2

The Variable Factor Map allows to analyze the relation of the variables with each other and their link with the dimensions created, see **Figure 2a**. The representation of the variables on the two first projection plan highlights four main conclusions:

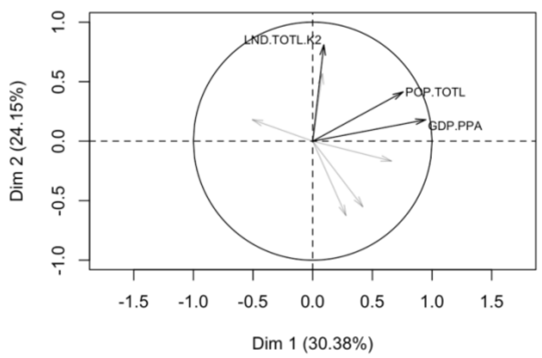
<u>First plan (Dim1, Dim2)</u>

-Three variables are mainly related to dimension 1: GDP.PPA, POP.TOTL and ELC.CONS.GWH is positively related to dimension 1 while INS.I is negatively related. This finding clearly indicates the opposite relationship between the INS.I variable and the other variable remainder in the data set. Insularity seems to play a particular role in the characterization of the studied territories — however, the quality of projection of the INS.I on the first plan is not good. Thus, it seems important to observe and discuss the insularity on the second projection plane.

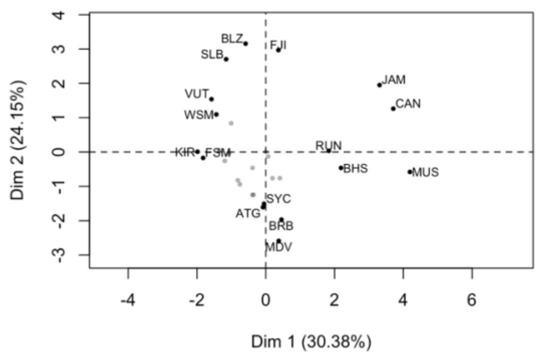
- LND.TOTL.K2 and ELC.RNEW are positively related to dimension 2. The share of renewable energies in the electricity mix seems to play a close link with the area of the territory. Many of the territories considered in the study favored solar energy and hydropower. Both of these technologies require a lot of available land area.

- CO2E.PC and POP.DNST are both negatively related to dimension 2. It indicates that these two variables are related: the denser the territory is, the higher its CO2 emissions are. However CO2 emissions have a better projection on the second plan.

- The share of renewable energies seems to be linked to CO2 emissions: the higher this share, the lower the CO2 emissions. Renewable energies are indeed an alternative to fossil fuels, which are highly carbonaceous. The results of the PCA will therefore clearly distinguish islands where renewable energies are already deployed and whose carbon emissions are low.



2a – Variables factor map



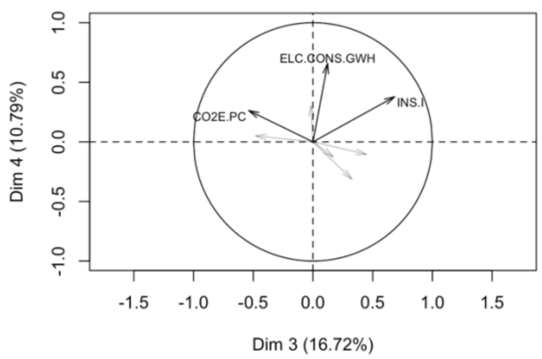
2b – Individuals map

Figure 2. Islands scores on the first and second principal components.

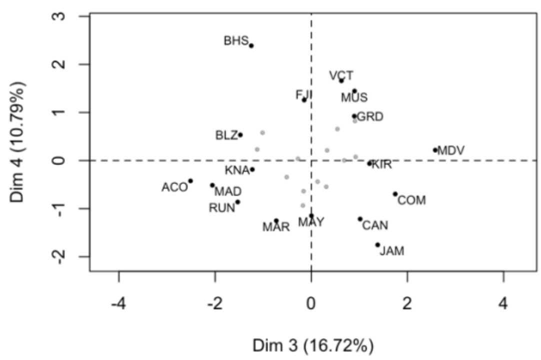
<u>Second plan (Dim3, Dim4)</u>

From figure 3a, we can see that the third principal component (Dim3) is characterized the following attributes: a high level of insularity (INS.I) and a low CO_2 emission per capita (CO2E.PC). This result clearly shows that the level of insularity and CO_2 emission are negatively correlated. Which means that an island with high insularity value has a lifestyle that has some low CO_2 impact.

The fourth principal component (Dim4) is mainly defined by variables related to energy i.e., electricity consumption (ELC.CONS.GWH).



3a – Variables factor map



3b – Individuals map

Figure 3. Islands scores on the third and fourth principal components.

From the individual factors map on **Figure 2b.**, it is clear that many of the territories studied have a strong insularity effect, even if some islands do not seem wholly affected by their island situation. Many islands such as Kiribati (KIR) or Micronesia (FSM) are located to the left of the chart. It is interesting to see that insularity is not a hindrance to the development of renewable energies on a territory since Solomon Islands (SLB), Belize (BLZ) and Fiji (FJI) is located in the top left part of the graph. Conversely, the results clearly show that economic development makes it possible to break out of its status of insularity like the Jamaica (JAM), Canaries (CAN) and Mauritius (MUS) islands and, to a lesser extent, Reunion (RUN) and Bahamas (BHS).

From **Figure 3b**, we can see that the island is not situated in a specific part of the individuals map. The third principal component opposes island such as Comoros (COM) and Maldives (MDV) to Acores (ACO), Madeira (MAD), Reunion (RUN). Islands located in the upper part of the plan are heavy electricity consumer. This group also has high values for the share of renewable energy in electricity generation.

This first step of exploratory analysis helps us to understand which variables have significant influence in the definition of the principal components. These parameters have to be taken into account to assess the energy vulnerability of the islands.

3.2 Hierarchical clustering on principal components (HCPC)

The second step of the study consists of a hierarchical clustering on the main principal components (Dim 1 and Dim 2). These dimensions correspond to the first two principal components, which represent the best projection plane according to the PCA. HCPC analysis is a widely-used method which investigates the organization of individuals in clusters and among clusters depicting a hierarchy. The selected partitioning approach selected for this study is the K-means method. This method is one of the most commonly used clustering algorithms. In this approach, the center of gravity also characterizes a cluster. The number of clusters is defined thanks to a statistical optimization algorithm called the Gap statistic method. This method proposed an optimum value of three clusters, and the results are shown in Figure 4.

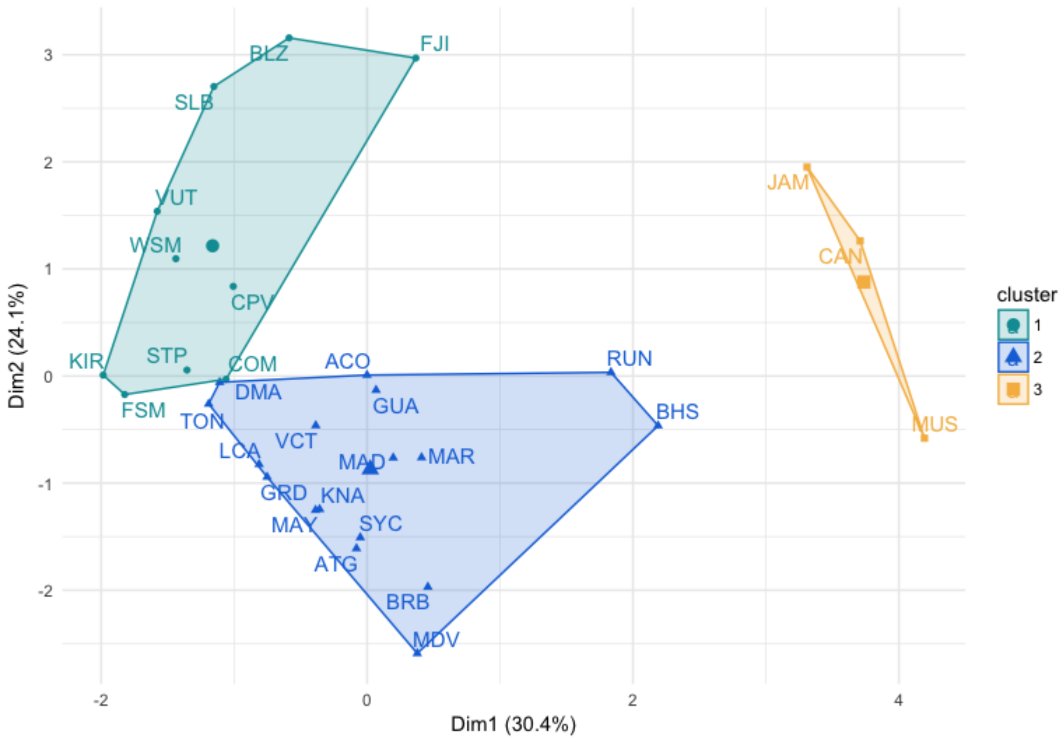


Figure 4. Hierarchical clustering projection of the first and second principal components.

Groups are characterized in two ways: the variables and the islands. Each cluster is defined by some categorical variables which have a significant p-value < 0.05. The variables which significantly described the cluster could also be identified by test-value v-test > 1.96 which is equivalent to a p-value < 0.05. The individual who corresponds in our case to the islands is mainly observed through the paragon. The paragon represents the islands which are the nearest from the center of gravity of cluster. Thus, that means that this island is the one that can qualify for representing the mean behavior of the group.

The description of the three clusters is detailed above:

- Cluster 1: Four variables most characterize the first cluster. Insularity and total land area have some high values for these clusters compared to the overall mean of the data. Islands in these groups also have some low value for two other variables density population and CO_2 emission per capita. Indeed, this presents groups has a share of renewable energy in the electricity of 21.6% compared to 12.9% for the overall dataset.

- Cluster 2: The variables characterizing this cluster are not so much different to those characterizing cluster 1. However, their intensity is opposed. Cluster 2 is depicting islands which have a higher CO2 emission per capita due to low penetration of renewable sources in electricity production (10.7%). This cluster represents small islands with low insularity index and the lowest mean total population. The high values of standard deviation for all variables constitute another particular feature of this value. Standard deviation explains, in fact, dispersion
- Cluster 3: This last cluster is composed of Jamaica, Mauritius, and Canary. This group is a set of islands with high values for electricity consumption, GDP and population. These islands have a low insularity and are heavily dependent on fossil fuels for electricity generation. Except for Mauritius which reach to 20%, the other two islands have a share of renewable energy around 10%.

This hierarchical clustering reveals no specificity regarding organization between SIDS and ORs. Indeed, one expected result from the first of this study were to identify any specific disparities between SIDS and ORs. Even if certain ORs have a better projection on the third principal component, all the ORs are part the cluster 2. This second group is the biggest, and both contain SIDS and ORs. Thus, we could conclude that the status of the island from our dataset does not influence the definition of a specific cluster for the ORs. Indeed, these regions are provided with the recognition of necessary derogations in European law. Thus, a first hypothesis was to observe the effect, thereby differentiating these regions by a specific group mainly composed by the ORs. The clustering shows that ORs behavior and characteristics are the same as SIDS with some medium GDP.PPA, POP.TOTL, INS.I, but some high value for C02 emission due to economic development and low renewables sources integration in the electricity mix. A particular point that can be noticed is that 43% of the SIDS are in cluster 1. Moreover, this cluster is only composed of SIDS.

3.3 Sustainability indicator

The composite indicator considered in this section is based on the previous PCA analysis. PCA is a well-established method of dimensionality reduction. The eigenvectors (modes) which represent the maximum variance directions have been defining previously. The first three components explain 71.2% of the total variance of the overall data set. Thus, the first three modes are fixed as a consistent cut-off for the definition of the composite indicator. The diagram presents in Figure 5 shows the way our composite indicator (SI) is defined. Based on the PCA, SI expects to capture the complexity of sustainable energy dimensions for the islands. As shown, the indicator summarizes several aspects of sustainability: environmental, economic, energetic, social and geographical dimensions.

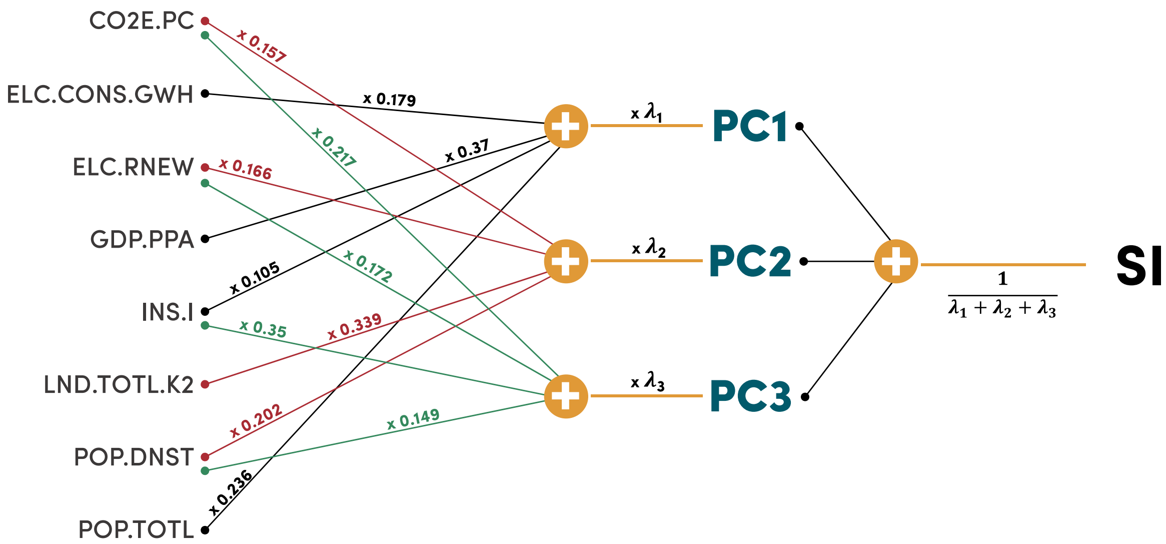


Figure 5. Diagram of the composite indicator construction.

As shown in Figure 5, the original weighting scheme for each variable is not an equal weight approach. The contribution to a principal component (PC) construction gives the weight of each variable in the definition of a PC. It can be noticed that some variables are part of two different principal components such as the share of renewable sources or insularity index. Thus, the PCA approach implicitly gives more importance to the variables and consequently to the themes (environment, social, economy, energy) which significantly explain the variance of the overall data set. We built a ranking based on a PCA weighting approach with linear aggregation and Z-scores normalization.

The score of sustainability proposed by our indicator SI is presented in Figure 6. Small islands are generally assumed to be vulnerable territories mainly driven by common vulnerabilities such as high carbon energy production, isolation. A high score depicts the level of sustainability. The islands ratings are sorted in descending order. A remarkable point is the fact that the ORS is spread across the entire graphic.

Regarding the indicator, Mauritius appears as the most sustainable territory. This result is mostly due to high values on economic, energy and environment aspects. The three islands from cluster 3 (Mauritius, Jamaica, Canary) have the top score for SI.

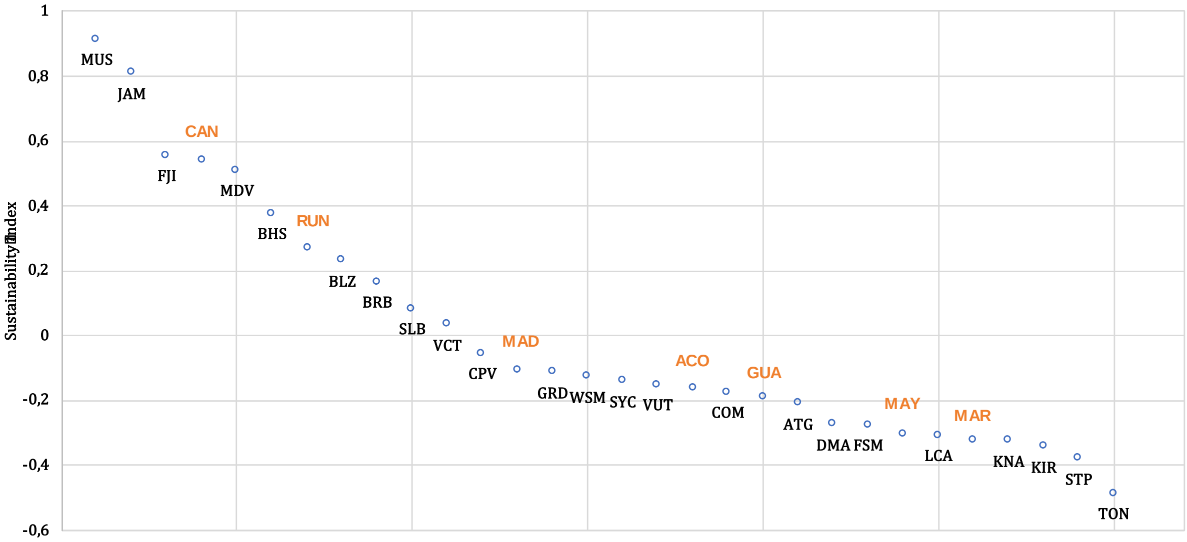


Figure 6. Sustainability indicator of SIDS and ORS.

The graphic shows two levels: the first one between MAD and ATG, and the second from DMA to STP. These two levels indicate that most islands are very similar according to their principal characteristics. The two steps of sustainability (blue and orange) are suggested that most of the islands have a low level of sustainability. Their vulnerability is explained renewable energy sources in electricity mix that is very low, less than 6% except for the case of Dominica. Indeed, hydropower currently accounts for 21% of Dominica's total electricity mix.

Focusing on the second step shows in orange, a disparity should be highlighted between ORS and SIDS. Even if these islands are on the same stage, some difference is visible while exploring the database. Indeed, the of renewable energy is relatively high (more than 20%). The SIDS in this step has a mean value of around 10%. The particular case is Samoa (WSM) is also explained by 33% of hydropower in their electricity mix. Another remarkable point is that ORS insularity index is less than half that SIDS (40.9 versus 148.3). As the indicator, does not include any governance, policy parameters or variables that could qualify the specific status of SIDS or ORS, no disparity could be noticed between the two types of studied islands.

It is observed that the organization of the islands described by SI is in the same trend of hierarchical clustering. Thus, it could be supposed that the indicator summarizes correctly the information contained by the dataset. The index has demonstrated its usefulness to simplify the analysis of the data set.

4. CONCLUSION

It is widely agreed that small islands are among territories of opportunities to experiment innovative policy or solutions to face their sustainable transition. In the same time, these islands are generally considered as the most vulnerable territories. With this study, we have provided a statistical approach for the construction of indicator that can be useful to policy-makers that want to create their index of sustainability. The use of principal components has helped us to select variables which explain a significant part of the total variance. This step has been used to select variables. Then a hierarchical clustering based on the principal components shows that the islands are projected into three groups. This trend has also followed the index SI. The proposed index summarizes the principal aspects of sustainability which is given by available online data. This work shows that at present, the island nature is decisive and no significant differences have been identified between the two groups. As the ORs belong to so-called rich European countries, the comparison with islands states that do not belong to this category is interesting.

Indeed, the current situation does not show any specific disparity between the types of islands. Their mode of governance, therefore, does not seem to be a discriminating factor concerning sustainability issues. However, the implementation of the transition will require substantial financial engineering that allows for proper investment planning. It is in this sense that it will be interesting to observe the evolution of the values of our indicator. Indeed, given the European Union's support for the ORs, it is likely that the transition dynamic may be stronger than for many SIDS. This gap is likely to be very significant if some SIDS do not have external support for the structural transformation of energy production in their territory. Our work has therefore made it possible to evaluate in a first step a current state, which can be taken as a reference. This situation could be used in future work to qualify the dynamics of the transition to a more sustainable territory in the future.

However, the ranking respects the overall trend define in the hierarchical section — nevertheless, the lack of data which characterize political status, governance, and energy policy. A point of interest is to investigate alternative weighting by introducing the negative and positive effect of variables based on the correlation and contribution of principal components construction. This will be the aim of further research investigation.

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