A Conceptual Framework to Correlate the Electric Transition and Well-Being and Equity. The Italy Case

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Abstract. The macroeconomic indicator of energy efficiency represents the energy performance in spatial terms (nation, region and macro-region) or the amount of energy used to produce a given unit of Gross Domestic Product. However, the electric transition draws attention to the need to pursue combined sustainable objectives, both economic and environmental-well-being.

Through the intermediate spatial dimension-metropolitan city/province, currently the most coherent to represent and support a just energy transition, in this paper it is intended to develop a methodological approach for the com-parative evaluation between electricity energy consumption and the recent equitable and sustainable well-being indicators (BES). In this framework, the objective of the work is the spatial representation of the electricity transition phenomenon in Italy. In particular, the spatial autocorrelation with an intermediate territorial basis in the pre and post-covid period (2017–2021) be-tween electricity consumption and a selected series of BES indicators to recognize spatial equity is investigated.

In order to present the usefulness and effectiveness of the proposed methodology was applied to the case study covering the Italian territory.

Keywords: Electrical Transition · Metropolitan City Planning · Well-being and equity

1 Introduction

Electrical intensity (EI) was introduced in the economic and environmental literature in the 1970s and 1980s. It is a macroeconomic measure which expresses the quantity of electricity consumed by an economy of a given territory per unit of relative Gross

O. Gervasi et al. (Eds.): ICCSA 2023 Workshops, LNCS 14109, pp. 66–80, 2023.
https://doi.org/10.1007/978-3-031-37120-2_5

Balletto G., Sinatra M., Milesi A., Ghiani E., Borruso G. (2023). A Conceptual Framework to Correlate the Electric Transition and Well-Being and Equity. The Italy Case.
In: , et al. Computational Science and Its Applications – ICCSA 2023 Workshops. ICCSA 2023. Lecture Notes in Computer Science, vol 14109. Springer, Cham.
https://doi.org/10.1007/978-3-031-37120-2_5

Domestic Product (GDP) [1, 2]. This measure is used to assess the energy efficiency of an economy, or the amount of energy used to produce a certain amount of goods and services, although some researchers remark that the direct relationship between electricity consumed and economic growth depends on the specific economic structure of Nations and/or Regions [3]. However, EI is an important indicator because it provides information on the energy consumption of a territorial economy. A lower electricity intensity indicates how the economy is becoming more energy efficient and seeks to reduce reliance on non-renewable energy sources. In contrast, an increase in electricity intensity could mean an increase in electricity demand and a greater dependence on non-renewable energy sources [4]. EI is used to track progress in reducing dependence on non-renewable energy sources, particularly in the urban 'smart city' model in line with the 2030 Agenda targets [5]. The complex literature shows how EI can be an indicator of progress in the energy sector, or as a basis for policies and plans to improve energy efficiency, but not for the purpose of reducing negative externalities resulting from increased energy consumption [6, 7] In this sense, the ongoing international electrical transition arises in response to the growing demand of energy. Addressing the complex environmental issue and decarbonization of energy systems requires replacing traditional nonrenewable energy sources (coal, oil, gas) with renewable sources (solar, wind, and hydro) and requires a renewed approach to the assessment of electricity consumption., introducing the BES (Equitable and Sustainable Well-being) indicators to facilitate a transition based on spatial justice [8–11].

The paper is organized as it follows: Sect. 2 Materials and Methods; Sect. 2.1 Equitable and sustainable well-being (BES): beyond the Gross Domestic Product (GDP); Sect. 2.2 Data; Sect. 2.3 Methodology: Local Indicators of Spatial Autocorrelation (LISA); Sect. 3 Case study; Sect. 4 Results and Discussion and Sect. 5 Conclusions and future development.

2 Material and Method

2.1 Equitable and Sustainable Well-Being (BES): Beyond the Gross Domestic Product (GDP)

For more than fifty years, there has been an international debate on the so-called "surpassing GDP" as the only measure of well-being. This is nourished by the consciousness that the parameters on which to evaluate the progress of a society [12] cannot be exclusively economic, but must also address the fundamental social and environmental dimensions of well-being, together with measures of inequality and sustainability [13–15]. In the international scenario, we underline the parameters used by the UN, the EU and the OECD. At national level, through an initiative between CNEL and ISTAT, the BES project has been underway, in order to provide an important contribution along these lines. Figure 1 shows the evolution of growth/development indicators.

The BES arose in 2010 to assess Equitable and Sustainable Well-being, with the purpose to evaluate the progress of society not only from the economic point of view, but also from the social and environmental side [16]. In particular, traditional economic indicators have been implemented by measures concerning people's quality of life and environmental issues. With the approval of the law n. 163/2016 on the National budget

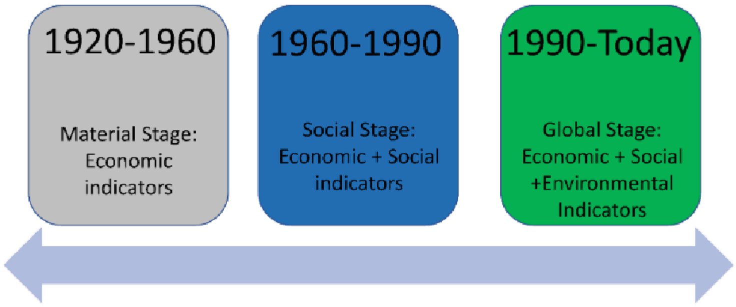

Fig. 1. History of growth/development indicators (Author: E. Ghiani, 2023)

reform, the first regulatory recognition of Equitable and Sustainable Well-being indicators has been achieved. These indicators have been included in the process of the Italian Government's economic planning documents. This innovation seeks to integrate economic measures in order to take account of other dimensions as society's overall well-being and environmental sustainability [17]. Recently, BES indicators have been linked to indicators for monitoring the 2030 Agenda for Sustainable Development targets (Sustainable Development Goals - SDGs - of United Nations), chosen by the global community under an international political agreement to represent their shared values, priorities and goals [18].

2.2 Data

Four indicators were selected (Table 1): two for the electric transition and two BES indicators characterizing the metropolitan urban dimension [19, 20].

The datasets were assembled considering two spatial dimensions, related to two different levels of administrative units in Italy. In particular, some of the data, and therefore the analysis that followed, were referred to Regions that hold an important role in local planning and policies. Other datasets were attributed to Provinces, Metropolitan Cities and Clusters of Municipalities. This latter level represents an intermediate one, between Regions and Municipalities, and allows to observe the territory from a metropolitan, urban and periurban perspective, providing a valid observation point for both the spatial national unbalances and to target ad hoc development policies.

The selected indicators and their sources are listed below.

2.3 Methodology: Local Indicators of Spatial Autocorrelation (LISA)

The energy-well being relation can be examined by means of spatial autocorrelation [21, 22]. Spatial autocorrelation, in particular, can be applied on data or indicators referred to a set of contiguous geographical units, as administrative units, and can be useful for evaluating local effects and clusters in terms of attribute and geographical data. Spatial proximity in fact can influence phenomena under a phenomenon called spatial autocorrelation. Data can be mutually influenced both in terms of the geographical shape and proximity, and in terms of the attribute values attributed to such units. As, Tobler highlighted [23] "nearby things are more related than distant things", apparently intuitive [23], although only recently rediscovered [24]. By analysing spatial autocorrelation it is

Table 1. Set of indicator, spatial dimension and source.

Indicator	Electric energy and BES	Year pre-post Covid	Dimension	Source of database
Electric Transition	Electric energy consumption	2017–2021	Region	Terna S.p.A https://bit.ly/3zcPVGR
	Electricity from renewable sources	2017–2021	Province/Metropolitan city	Terna S.p.A https://bit.ly/40C1MdA
Equitable and sustainable well-being (BES)	Employment rate (20–64 years old)	2017–2021	Region	ISTAT https://tabsoft.co/3K7wo0X
	Life expectancy at 65 years old	2017–2021	Province/Metropolitan city	BES Province https://bit.ly/3nm3Isf

possible to observe how a variable behaves with reference to its location in space and with reference to what happens in its proximity. Geographical elements can be described by two categories of information such as location and related properties. In particular, in analytical terms, spatial autocorrelation can be defined as follows [25]:

$$SAC = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} c_{ij} w_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij}} \tag{1}$$

where:

- i and j are two objects or events in space;
- N is the number of objects or events;
- cij is a degree of similarity of attributes i and j;
- wij is a degree of similarity of location i and j;

From the general formula it is possible to derive two indices as the Geary C Ratio [26] and the Moran Index [27]. Defining xi as the value of object i attribute; if $c_{ij} = (x_i - x_j)^2$, Geary C Ratio can be defined as follows:

$$C = \frac{(N-1)\left(\sum_i \sum_j w_{ij}(x_i - x_j)^2\right)}{2\left(\sum_i \sum_j w_{ij}\right)\sum_i (x_i - \underline{x})^2} \tag{2}$$

If $c_{ij} = (x_i - x)(x_j - x)$, Moran Index I can be defined as follows:

$$I = \frac{N \sum_i \sum_j w_{ij}(x_i - \underline{x})(x_j - \underline{x})}{\sum_i \sum_j w_{ij}(x_i - \underline{x})^2} \tag{3}$$

As recalled and applied recently in several Italian contexts [28], these indices are quite similar, differing by the cross-product term in the numerator, calculated using the deviations from the mean in Moran, while directly computed in Geary. Both indices lead a common message, as highlighting the presence - or absence - of spatial autocorrelation at a global level in the overall distribution, while the local presence of autocorrelation can be highlighted by the LISA (Local Indicators of Spatial Association), or, as after Anselin [29, 30], a local Moran index. This can be seen as the sum of all local indices and is proportional to the value of the Moran one:

$$\sum\nolimits_{i} I_i = \gamma * I \tag{4}$$

The index is calculated as follows:

$$I_i = \frac{(X_i - X)}{S_X^2} \sum\nolimits_{j=1}^{N} (w_{ij}(X_j - \underline{X})) \tag{5}$$

The index allows assessing for each location assess the similarity of each observation with its neighbors, and five combinations can be obtained from its application:

- hot spots: areas with high values of the phenomenon and a high level of similarity with its surroundings (high-high H-H);
- cold spots, as areas with low values of the phenomenon and a low level of similarity with its surroundings (low-low L-L);
- potentially spatial outliers, with high values of the phenomenon and a low level of similarity with its surroundings (high-low H-L);
- potentially spatial outliers, with low values of the phenomenon and a high level of similarity with its surroundings (low-high L-H);
- lack of significant autocorrelation. The interesting characteristic of LISA is in providing an effective measure of the degree of relative spatial association between each territorial unit and its neighboring elements, thereby highlighting the type of spatial concentration and clustering.

It is important to consider in the above-mentioned equations, the importance of weights, as parameters. The neighborhood property is analyzed by means of the parameter weight, w_{ij}, whose values indicate the presence, or absence, of neighboring spatial units to a given one. A spatial weight matrix is therefore needed, with w_{ij} assuming values of 0 in cases in which i and j are not neighbors, or 1 when i and j are neighbors. Neighborhood is computed in terms of contiguity such as, in the case of areal units, sharing a common border of non-zero length [31]. Rook or Queen contiguity are considered in the realization of the weight matrix.

3 Case Study

The study area chosen to show the effectiveness of the methodology is the Italian territory. Italy is a peninsula located in the southern part of the European continent. The climate is mostly temperate and characterized by dry and warm summers in coastal and southern areas, including islands. Instead, in the major mountain chains, like the Alps and Apennines, there is the prevalence of a cold climate (characterised by no dry season and no cold or hot summers). From west to east borders France, Switzerland, Austria, Slovenia and Croatia.

Italy has a surface area approximately of 302 072.84 km^2 with a population of 59 030 133 (ISTAT, 2022 [32]). From the administrative point of view it is organized in 20 Regions, split into 107 provinces (Fig. 2).

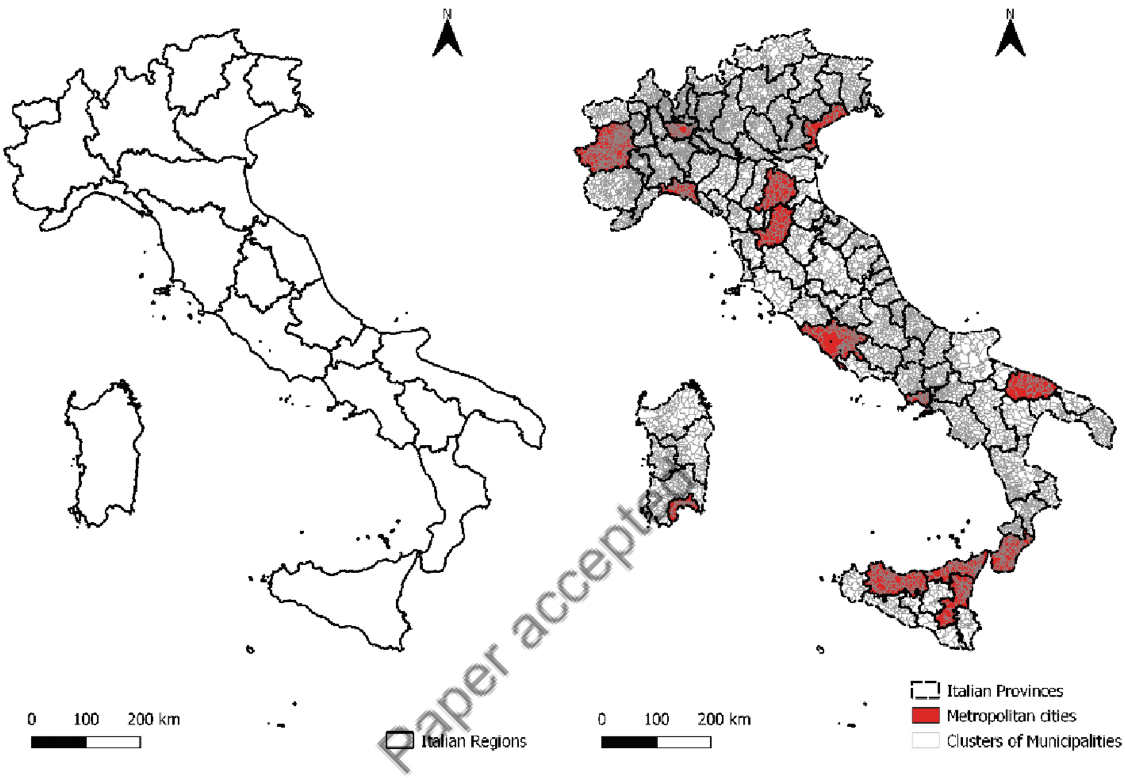

Fig. 2. Italy and its administrative units. Left: Regions; Right: Provinces, Metropolitan Cities, Clusters of Municipalities.

4 Result and Discussion

In this manuscript, the analysis was performed by considering a set of indicators (Table 1) assigned to each Italian Region and Province and their refer to the interval 2017–2021. These data were used as input to calculate LISA and, in particular, for local Moran's I. It is important to highlight that, in order to achieve spatial proximity for the application of the method, some simplifications have been adopted in the spatialization of islands (at regional level). On the one hand, Sicily has been united to Calabria to make it contiguous with Italian territory. On the other hand, Sardinia has been excluded and inserted after the elaborations, due to its distance from other Italian Regions.

The analysis was performed on regional data for the year 2017 and 2021, while on provincial data for 2021 only (the energy consumption indicator is also available for 2017). The application of the method to the set of indicators in the regional and/or provincial dimension yielded the following results (Figs. 5, 6, 7, 8, 9 and 10).

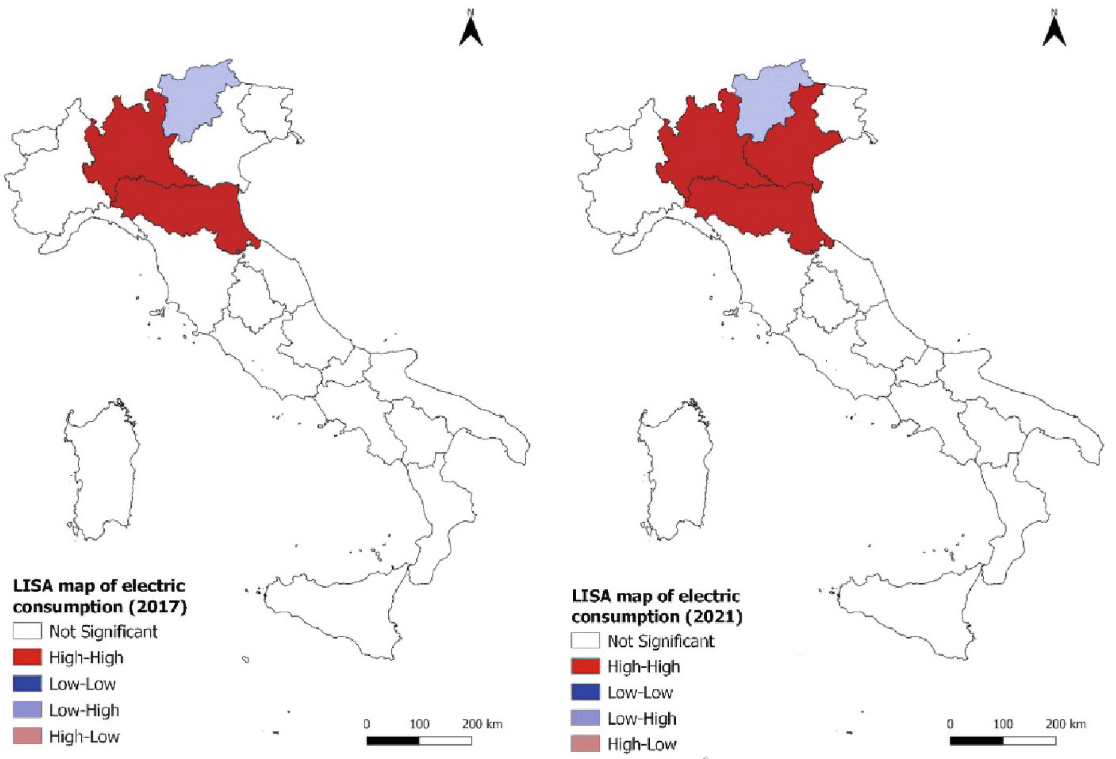

Fig. 3. LISA map of regional electric consumption, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2023).

With the Integrated National Plan for Energy and Climate (2019) [33] the Italian government has set the goal of producing 30% of national energy from renewable sources by 2030, which could affect the trend in the consumption of electricity in the future. According to data from the Electricity, Gas and Water Authority (ARERA [34]), in 2022 electricity consumption in Italy was around 295 TWh, down 3.1% compared to the previous year due to the COVID-19 pandemic and associated restrictions.

Furthermore, electricity consumption in Italy is influenced by various factors, including the physical-geographical conformation with different meteorological conditions, as well as the organization-distribution of economic-productive activities. The LISA elaborations based on the regional and provincial dimension (Fig. 3 and Fig. 4) confirm that Northern Italy is characterized by a high auto-correlation of electricity consumption. In particular, Fig. 3 (2017–2021) shows how the regions with high-high autocorrelation of electricity consumption are located in northern Italy (Lombardy, Emilia-Romagna and Veneto) and are characterized by a climate with more extreme temperatures in winter and summer, but above all they are characterized by a high gross domestic product (Table 2).

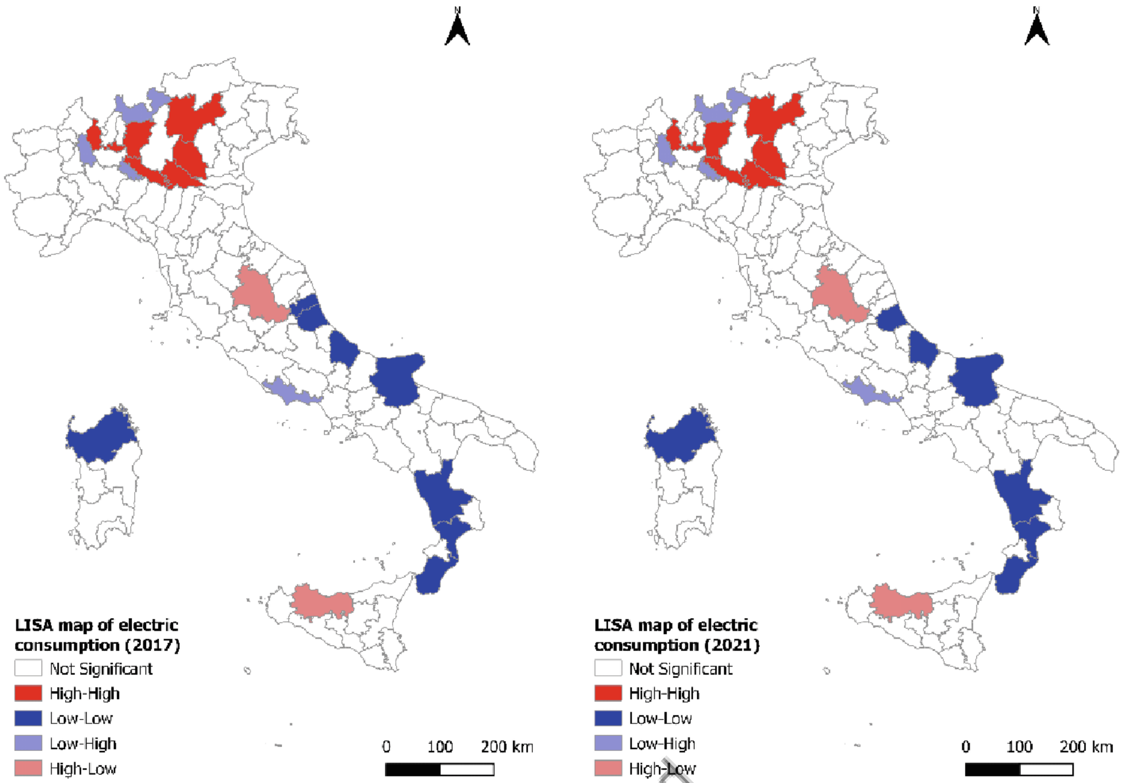

Fig. 4. LISA map of provincial electric consumption, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2023).

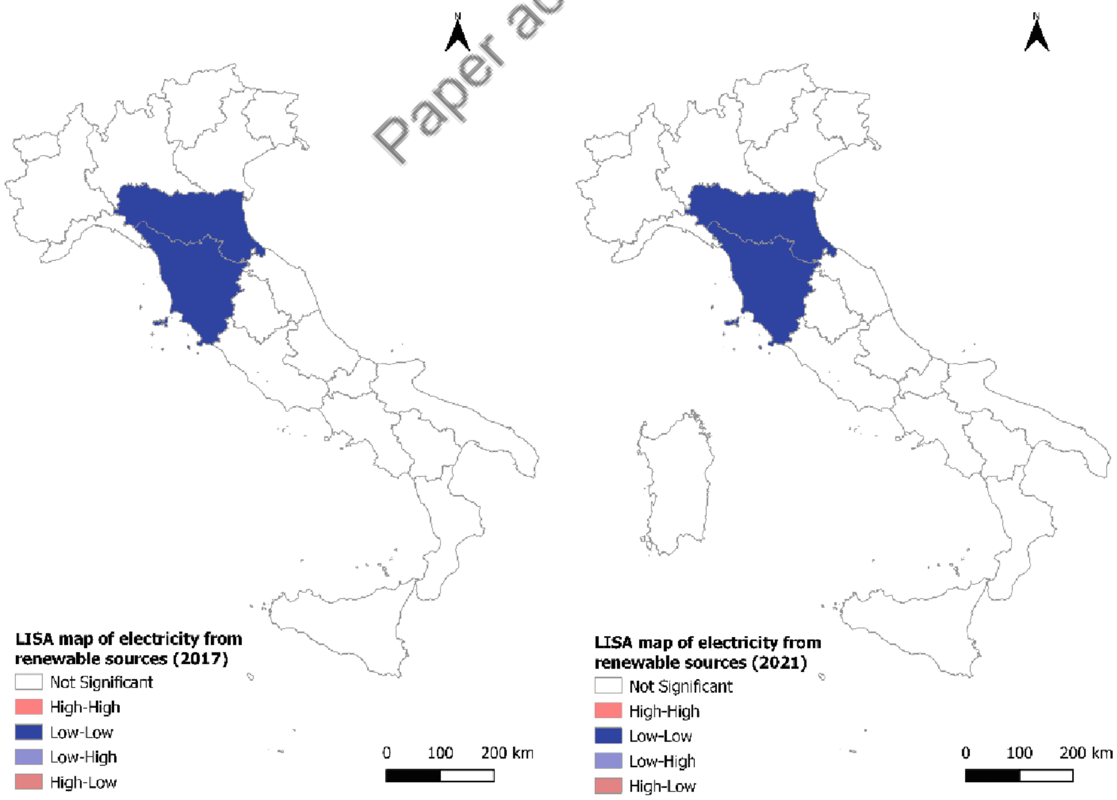

Fig. 5. LISA map of regional electricity from renewable sources, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2023).

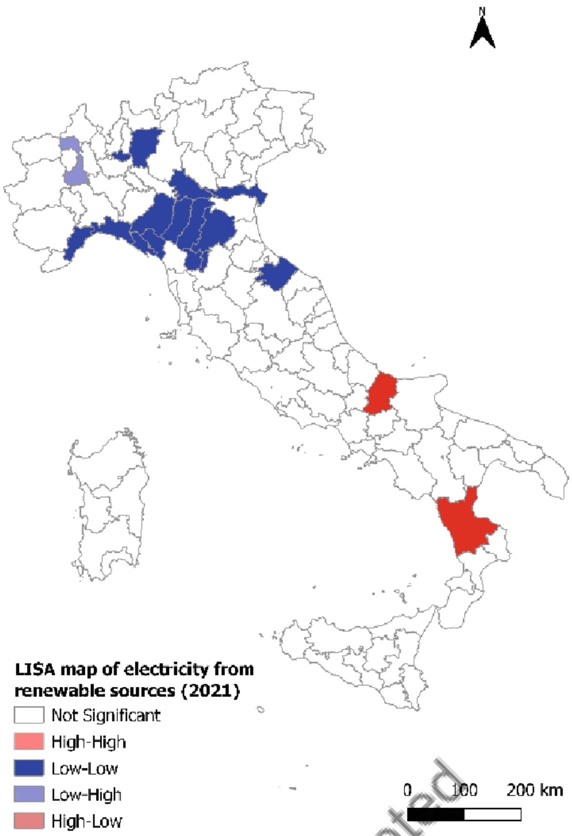

Fig. 6. LISA map of provincial electricity from renewable sources, years 2021 (Authors: M. Sinatra and G. Balletto, 2023).

Figure 4 shows a high-high autocorrelation which respectively affects the Provinces of Bergamo, Cremona, Mantua, Monza, Trento, Varese and Verona, distributed on the border between the regions: Lombardy, Emilia-Romagna and Veneto, also characterized by significant investments also in cohesion policies [35].

The amount of electricity deriving from renewable sources for provinces with high-high auto-correlation is shown below (Table 3).

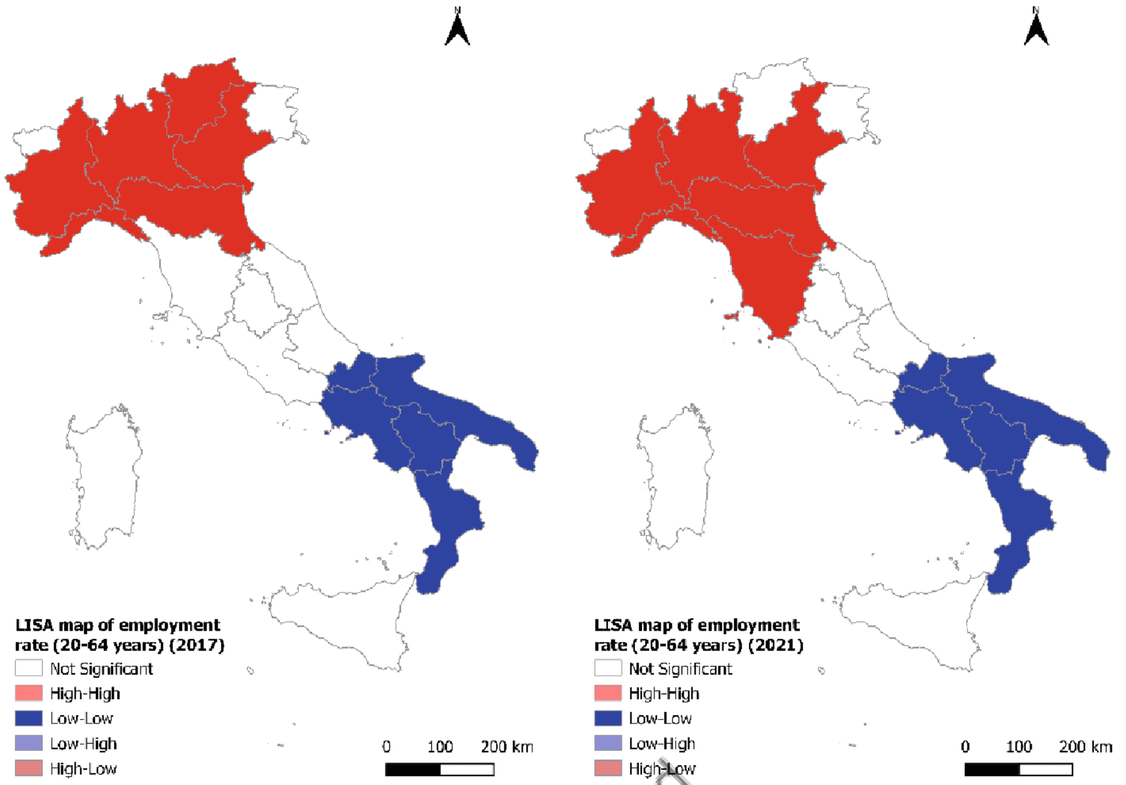

Fig. 7. LISA map of regional employment rate (20–64 years), years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2023).

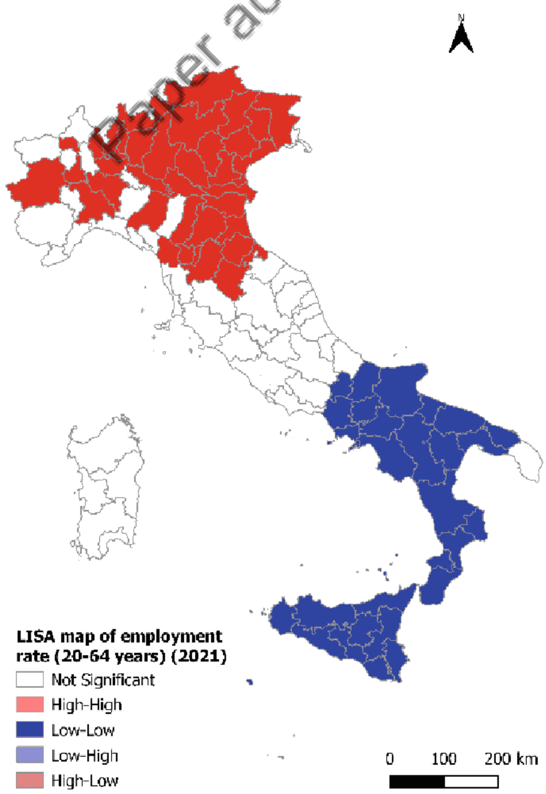

Fig. 8. LISA map of provincial employment rate (20–64 years), year 2021 (Authors: M. Sinatra and G. Balletto, 2023).

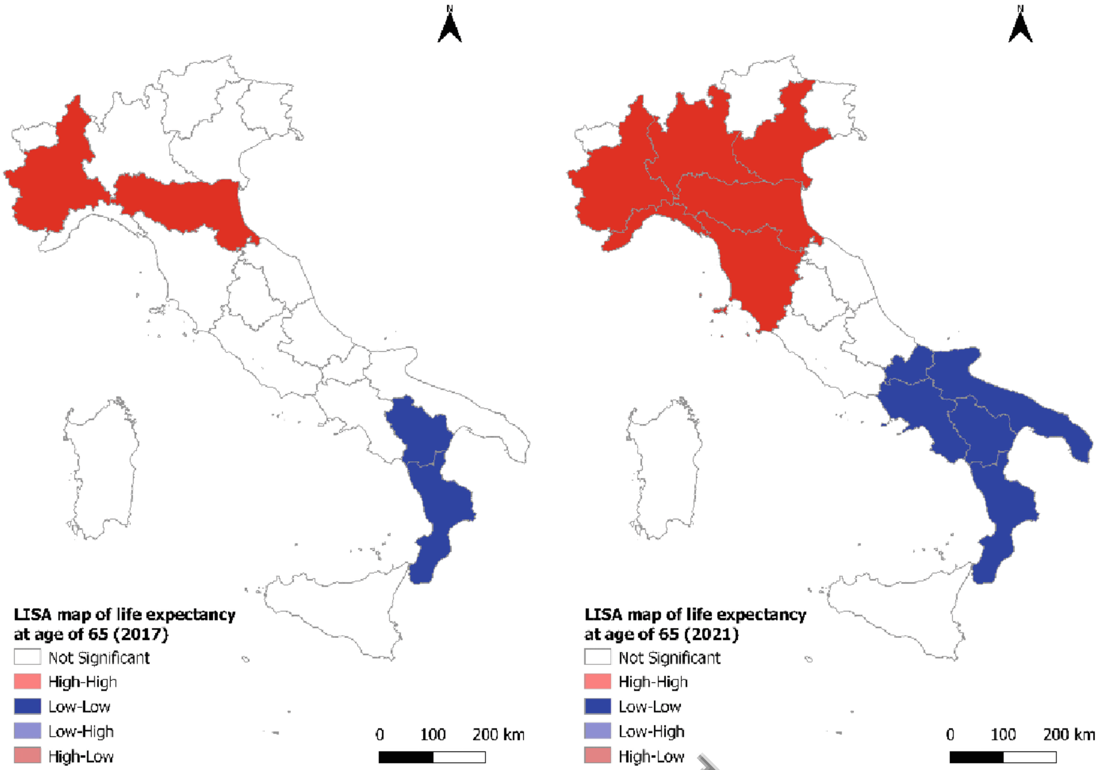

Fig. 9. LISA map of regional life expectancy at age of 65, year 2021 (Authors: M. Sinatra and G. Balletto, 2023).

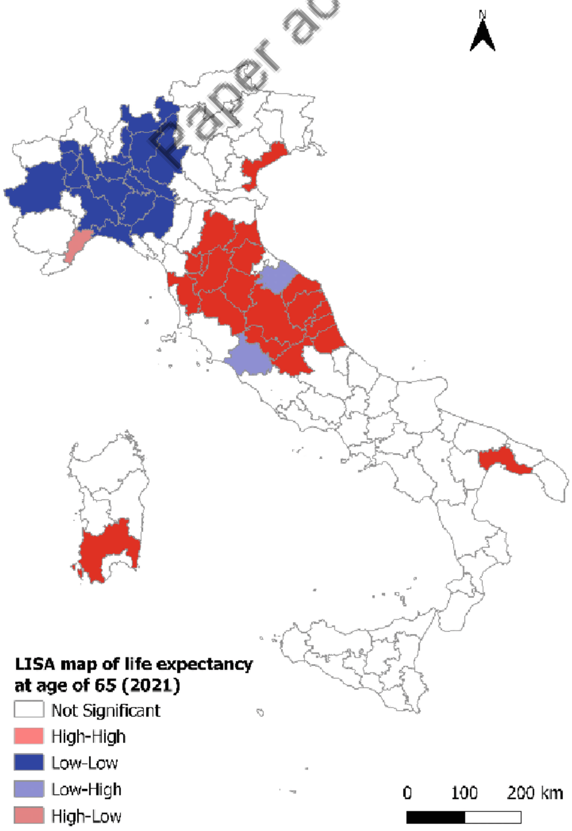

Fig. 10. LISA map of provincial life expectancy at age of 65, year 2021 (Authors: M. Sinatra and G. Balletto, 2023).

Table 2. Regional GDP (2020) and electricity from renewable sources (2021) of Lombardy, Emilia-Romagna e Veneto. (Author: G. Balletto, 2023 from https://ec.europa.eu/eurostat/cache/digpub/regions/#gross-domestic-product and https://bit.ly/40C1MdA)

Region	GDP Gross Domestic Product, 2020 (Purchasing Power Standards per inhabitants)	Share National GDP, 2020 (%)	Electricity from renewable sources, 2021 (%)
Lombardy	37 700	22.5	27.3
Emilia Romagna	34 500	9.1	22.1
Veneto	31 600	9.2	29.3

Table 3. Provincial electricity from renewable sources (2021) of Bergamo, Cremona, Mantova, Monza, Trento, Varese and Verona.

Province	Electricity from renewable sources, 2021 (%)
Bergamo	19.4
Cremona	23.9
Mantova	20.3
Monza	26.9
Trento	109.1
Varese	37.2
Verona	23.6

5 Conclusion and Future Development

The scientific debate focuses on whether anthropogenic emissions of greenhouse gases into the atmosphere are the main cause of complex global climate change, with the average temperature 1.02 degrees higher than in the 1950–1980 period [36]. The main one of these gases is carbon dioxide, which is largely derived from the fossil fuel energy sector. To achieve the so-called Carbon Neutrality by 2050, the main tool is represented by the energy transition, with the transition from an energy mix centered on fossil fuels to one with low or zero carbon emissions, based on renewable sources. A great contribution to decarbonization will come from the electrification of consumption, replacing the electricity produced from fossil sources with that generated from renewable sources, which also makes other sectors cleaner, such as transport, and from the digitalization of networks, which improves energy efficiency.

The energy transition, however, is not limited to the progressive shutting down of coal-fired plants and the development of clean energies: it is a paradigm shift of the entire structure of energy production and utilization, i.e. a transition based on spatial equity [37], with benefits not only for the climate but also for the economy and communities.

Acknowledgment. This study was supported by Projects Ecosystem of Innovation for Next Generation Sardinia (e.INS) - approved by MUR, prot. n. 1056 of 23/06/2022; also, this publication was produced while attending the PhD programme in Civil Engineering and Architecture at the University of Cagliari, Cycle XXXVIII, with the support of a scholarship co-financed by the Ministerial Decree no. 352 of 9th April 2022, based on the NRRP - funded by the European Union - NextGenerationEU - Mission 4 “Education and Research”, Component 2 “From Research to Business”, Investment 3.3, and by the company MLab srl.

Author Contributions. Conceptualization, methodology, formal analysis, materials and resources, software and data curation: Balletto, Borruso and Sinatra. Validation: all authors. In particular: Balletto wrote Sect. 1, Sect. 2; Balletto, Sinatra and Ghiani wrote Sect. 2.1; Borruso and Sinatra wrote Sect. 2.2 and Sect. 5; Sinatra and Milesi wrote Sect. 3; Balletto and Borruso Sect. 6.

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