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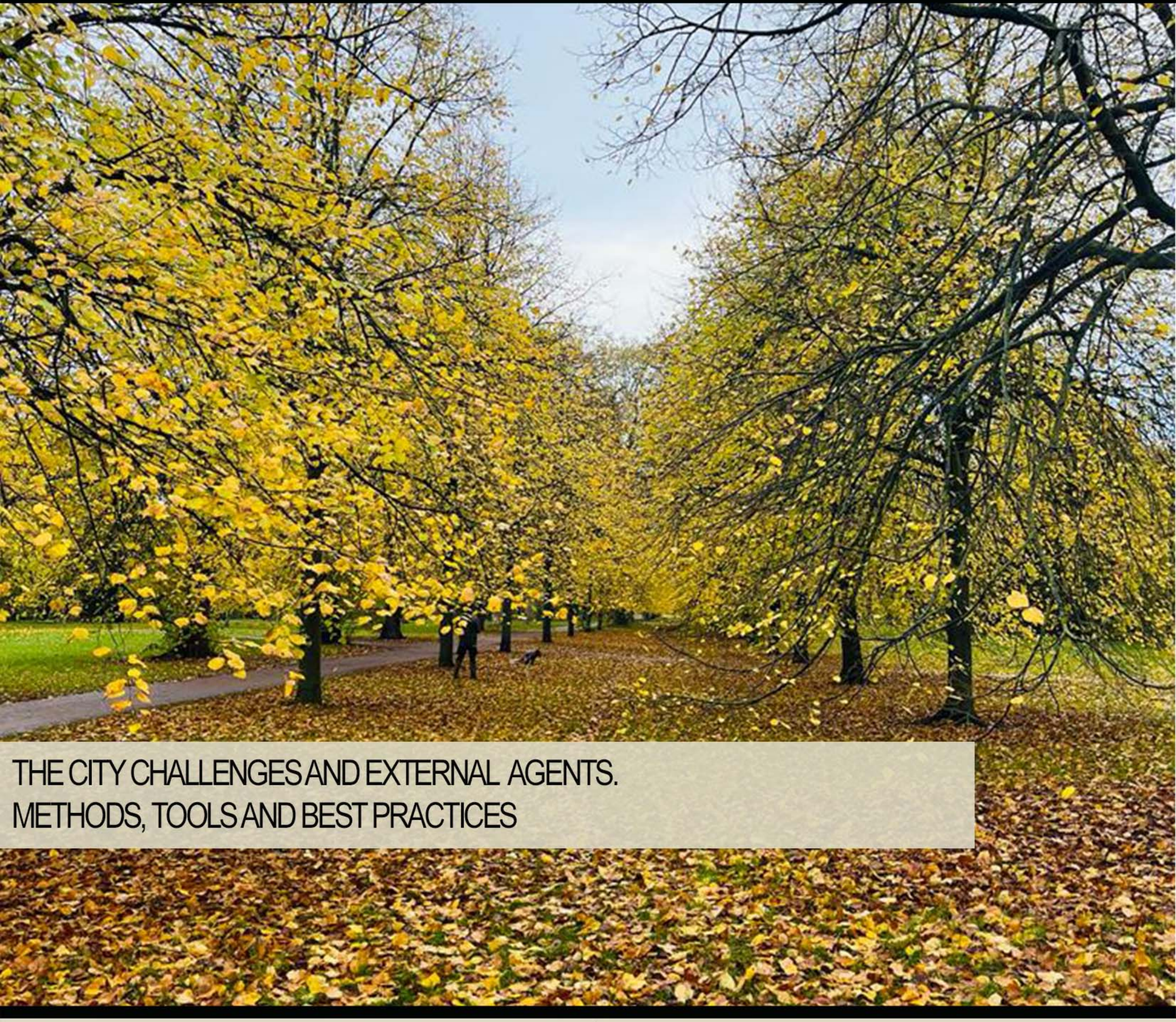

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METHODS, TOOLS AND BEST PRACTICES

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The cover image shows a view of Hyde Park in London (United Kingdom) during the autumn season.
The photo was taken by Enrica Papa in November 2023.

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Spatial regional electricity intensity and equitable well-being to support just transition

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Abstract
The European Union has set ambitious targets for energy efficiency to promote energy sustainability and decarbonisation of energy systems by introducing performance indicators that can be used in different contexts at international, national or regional level. In particular, the macroeconomic indicator of Electrical Intensity (EI) and Sustainable Electrical Intensity (SEI) can be used to measure energy performance on different scales, to identify the amount of energy used per unit of Gross Domestic Product (GDP), thus providing a picture of sustainability in economic and spatial terms. To support just urban and territorial policies that can have a positive effect not only on GDP, more generally on the fair and sustainable well-being of a community, the complexity of the EI index and SEI index must be addressed by assessing the impacts of energy efficiency interventions and the development of renewable energy installations. The aim of the paper is to develop a comparative approach between Italian spatial distribution of the total electricity consumption (by EI index) and the total renewable electrical consumption (by SEI index) with a dataset of BES indicators - Equitable and Sustainable Well-being - to evaluate of the just electric transition.

Keywords
Electricity intensity; BES region; Electrical transition.

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1. Introduction

Electricity Intensity (EI) is a macroeconomic measure that expresses the quantity of electricity consumed in a territory per unit of relative gross domestic product (GDP). This measure is used to assess the amount of energy used to produce a certain amount of goods and services. This is an important indicator since it provides information on the electrical consumption of a territorial economy. A reduction in EI indicates that the economy is becoming more electrically efficient and is attempting to reduce dependence on non-renewable sources of energy. In contrast, an increase in electricity intensity could mean an increase in electricity demand and a greater dependence on non-renewable energy sources. EI is used to monitor progress of the 2030 Agenda targets in reducing reliance on non-renewable energy sources.

EI was introduced into economic and environmental literature in the 1970s and 1980s and compares the electrical consumption of a region's economy with an output indicator, such as economic value added or Gross Domestic Product (GDP). This type of indicator can reveal a region's overall energy efficiency. The EI of a region can be calculated using the following formula:

The index is calculated as follows:

$$Electrical\ Intensity\ index\ (EI\ index\ ) = \frac{Electrical\ consumption}{Gross\ Domestic\ Product\ (GDP)}$$

Electricity consumption can be total or renewable and economic output can be measured in terms of Gross Domestic Product (GDP) or economic value added.

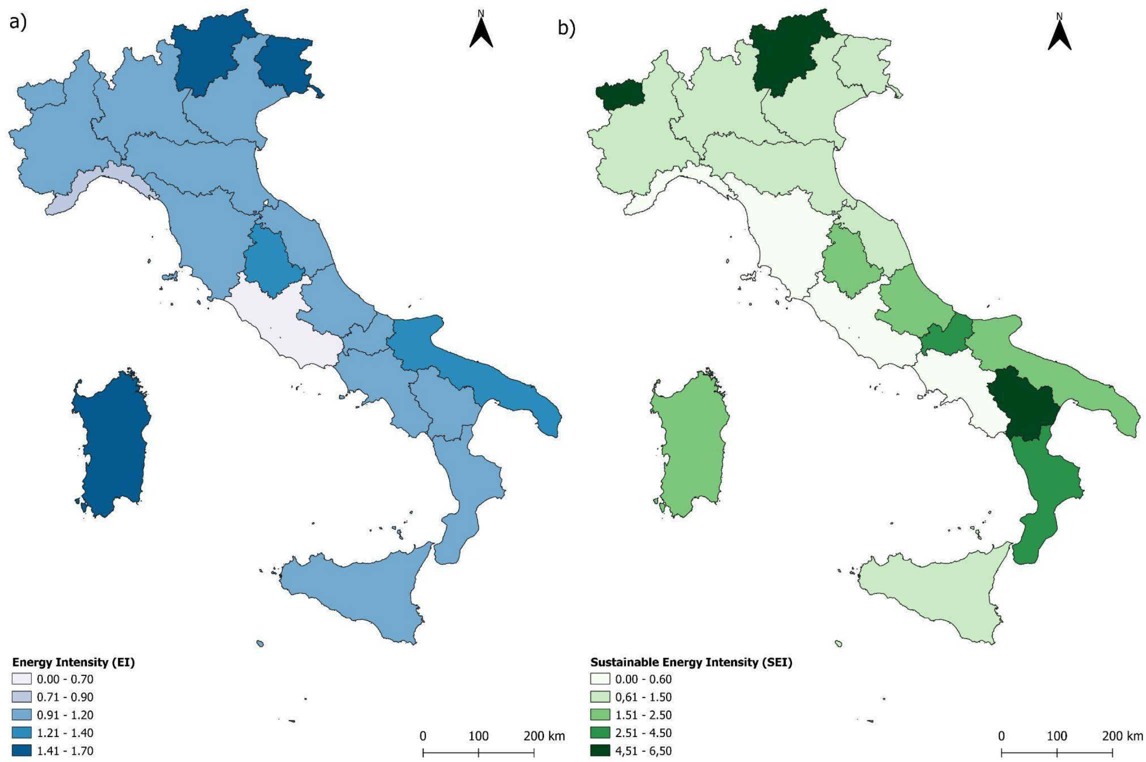

Fig.1 (a) Italian Regional Electrical Intensity (EI) and (b) Sustainable Electrical Intensity (SEI) (Authors: M. Sinatra and G. Balletto, 2022).

High EI indicates that a region is using a large amount of electrical energy to produce a certain amount of economic output. This can indicate low energy efficiency and high environmental impact. On the other hand, low EI indicates more efficient use of energy, where a region produces more economic output with less energy consumed.

Calculating the EI of a region can provide valuable information for identifying sectors or areas with high electrical energy consumption and adopting policies and measures to improve overall energy efficiency. Furthermore, EI can be used both as a foundation for policies and programs to improve energy efficiency and reduce the impact on the environment. The role of EI in the electrical energy transition is crucial. The electrical energy transition refers to the shift from traditional energy sources, often based on fossil fuels, to renewable energy sources and increased energy efficiency.

The main objective is to reduce greenhouse gas emissions and mitigate climate change. This may indicate high fossil fuel consumption and low energy efficiency. As regards the data relating to (Fig.1a) electrical energy consumption, on one side the data relating to regional electrical energy consumption was used, expressed as a percentage (Energy Consumption - Terna S.p.A.).

On the other side, as in Fig.1b, it was chosen to use the data on energy efficiency from renewable sources, expressed also as a percentage (efficient power from renewable - Terna S.p.A). Still, the data relating to the Economic output was chosen to use the Share National GDP (Gross Domestic Product) for both elaborations also expressed as a percentage.

In particular, the regions presenting high EI values are Trentino-Alto Adige, Friuli Venezia Giulia and Sardinia and the regions presenting high SEI values are Trentino-Alto Adige, Valle d'Aosta and Basilicata.

Furthermore, EI/SEI can be considered as well-being, fair and sustainable indicators allowing electricity consumption to be represented to produce equitable sustainable well-being in a region (Long et al., 2020).

EI/SEI can be considered BES indicators in the integrated framework of the main social, economic and environmental phenomena:

- social: High EI/SEI can have social implications, such as high energy costs for families and businesses, which could affect quality of life. Reducing EI/SEI helps to improve the population's accessibility to energy;
- economic: EI/SEU can also influence the economic efficiency of a region. Reducing EI/SEI can improve the competitiveness of industries, reduce production costs and promote technological innovation in all sectors;
- environmental: A reduction of EI/SEI can contribute to lower greenhouse gas emissions and better management of natural resources.

In this sense, the EI and SEI indicators on a regional basis allow us to monitor the well-being, equity and sustainability of the just transition (Gaglione 2023; Gaglione and Etigo, 2022).

In this synthetic framework, in the present research we want to overcome the gap between the energy transition and the just energy transition.

The aim of the work done is to develop of a comparative approach between the spatial distribution of electricity consumption (EI/SEI of the Italian regions) and a selection of BES indicators - Equitable and Sustainable Well-being - using spatial analysis techniques such as LISA (Local Indicator of Spatial Association - describes and allows you to visualize the spatial distribution of the phenomenon investigated), to support a just electrical transition (Garvey et al., 2022; Sinatra et al., 2023; Balletto et al., 2023).

The manuscript is organized as it follows: Paragraph 2: Literature review on Equitable and sustainable well-being (BES); 2.1 Literature review on just electrical transition; paragraph 3: Materials and Methods; 3.1 Study Area; 3.2 Data; 3.3 Methodology; paragraph 4: Results; paragraph 5: Discussion and paragraph 6: Conclusions.

2. Literature review of equitable and sustainable well-being (BES)

The BES project was set up in 2010 to measure fair and sustainable well-being to assess the progress of society not only from an economic point of view but also from social and environmental ones (Thapa et al., 2023). For this purpose, traditional economic indicators, primarily GDP, have been integrated into measures of people's quality of life and environment (La Torre et al., 2020; Giannetti et al., 2015). Since 2016, indicators and analyses on well-being have been supported by indicators for monitoring the 2030 Agenda targets (Sustainable Development Goals - SDGs) selected by the world community through a political agreement between the various actors, to represent their values, priorities and objectives. The United Nations Statistical Commission (UNSC) established a common statistical information framework to track each country's progress toward the SDGs, identifying approximately 250 indicators. The literature on BES continues to evolve, addressing emerging challenges related to sustainability, social equity and human well-being (Hall, 2022; Fachinetti & Siletti, 2022; Barbabella et al., 2022). It contributes to understanding the impacts of policies and actions on people's quality of life and the environment, providing a more complete framework for evaluating progress and guiding decisions for a sustainable future. In the past well-being was often assessed mainly through the Gross Domestic Product (GDP), which measures the economic output of the region. Since the 1970s, it has been recognized that GDP alone does not fully represent a society's well-being. Therefore, there has been a push towards the adoption of multidimensional approaches to measuring well-being, which also consider social and environmental aspects. The evolution of the BES has led to the creation of a wide range of indicators (Plata, 2022; Balletto et al., 2022; Balletto et al., 2015; Alaimo et al., 2022). BES indicators include measures of economic inequality, environmental quality, access to education, health, social participation, and other aspects of human well-being. These indicators provide a more complete and in-depth view of a company's well-being. Furthermore, the evolution of BES has embraced a human rights-based approach, recognizing that equitable and sustainable well-being requires the protection of people's fundamental rights. This implies universal access to basic services, the elimination of inequalities and the promotion of an equitable distribution of resources. Furthermore, the attention towards environmental sustainability has increased, considering the need to preserve natural resources for future generations.

Another aspect of the evolution of BES has been the recognition of the importance of integrating the social, economic and environmental dimensions. BES considers the complex interplay between these dimensions and seeks to find a balance between people's needs, economic prosperity and environmental conservation. The United Nations Sustainable Development Goals (SDGs) aim to integrate social, economic and environmental aspects into a global sustainability agenda (Menne et al., 2020). 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. Furthermore, since 2017, Istat, Italian National Statistical Institute, has published a coherent and integrated system of indicators within the BES framework. It has been adopted nationally and is useful in responding to the demand for spatial statistical information. BES indicators provide a geospatial database, where the spatial dimension is fundamental to represent the phenomena of 'Just Transition'.

2.1 Literature review on just energy transition

The EU is actively promoting the low-carbon electricity energy transition, including with economic investments, with important positive outcomes for the environment and climate.

The main initiatives relating to the electricity energy transition in Europe are oriented in this sense (Clean Energy for All Europeans Package, 2019; European Green Deal, 2019; European Climate Law, from 2021. The transition to an electricity-based energy system brings many benefits, but also presents challenges and limitations (Guida, 2022; Guida, 2023). For a successful electricity energy transition, several principles and approaches can help achieve a just, equitable and sustainable transition.

In particular, the concept of "Just Transition" dates to the 1990s (Heffron, 2021; Wang & Lo, 2021) in relation to the need to address the social and economic impacts deriving from changes in the energy sector and climate change mitigation policies. The first documented mention of the term "Just Transition" is found in the United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1992 during the Earth Summit in Rio de Janeiro. Article 4.5 of the convention states: "Developed Parties shall take the lead in combating climate change and its adverse impacts by providing financial resources and technology transfer to developing countries. Developed Parties should also take responsibility for providing a just transition and to create favorable environmental, social and economic conditions for developing countries".
However, it was in the following years that the concept of "Just Transition" gained more relevance and attention.
Over time, the term has been adopted and developed by various actors, including trade unions, civil society organizations, governments and international organizations, to address the social and economic challenges associated with the transition to a low-carbon economy (McCauley & Heffron, 2018).
The concept of "Just Transition" has become particularly relevant and discussed in recent decades, in response to the urgency of dealing with changes and transitions in an equitable and inclusive way. Italy has adopted a series of policies and initiatives to promote an equitable and sustainable electrical transition, which involves various sectors of the economy.
Some salient aspects of "Just Transition" in Italy (Pepe, 2022) include:

- renewable energy - Setting ambitious targets to increase the share of energy produced from renewable sources, reducing dependence on fossil fuels and promoting greater sustainability in the energy sector;
- energy efficiency - Promoting energy efficiency as a key theme of the fair energy transition in Italy (buildings, industry and transport), through incentive programs, regulations and awareness campaigns;
- industrial reconversion - Addressing the challenge of converting high environmental impact industries towards more sustainable solutions, with the creation of new low environmental impact businesses and technologies, the professional retraining of workers and support for the creation of sustainable jobs in the renewable energies and clean technologies;
- involvement of local communities - Promoting the active involvement of local communities in the decision-making process and implementation of energy policies, through the participation of citizens, civil society organizations and local authorities in the planning and management of energy initiatives, ensuring dialogue open and transparent;
- protection of workers - Ensuring a just transition for workers involved in fossil fuel-related sectors, through professional training and support for sustainable employment, in order to reduce the social impact and ensure job opportunities in the renewable energy sector and of green technologies.

3. Materials and Method

3.1 Study Area

This analysis concerns Italy, and its administrative regions in particular, as it is the area where the phenomenon of the just transition is being studied.
Italy with its 20 administrative regions constitutes the study area (coordinates 47°04′22″ N 6°37′32″ E; 35°29′24″ N 18°31′18″ E), it is located in the Southern part of the European peninsula, in the Mediterranean Sea, facing the main Seas such as the Tyrrhenian, Ionian and Adriatic. Italy covers an area of 302,072.84 km2 (35.2% Mountains; 23.2% plains and 41.6% hills) and hosts a population of 59.11 million with a population density of 200 inhabitants per square kilometer.

3.2 Data

Tab.1 was realized on the basis of the scientific literature and shows the dataset relating to the two phenomena (Electrical transition and equitable, sustainable and well-being).
The regional dimension of the dataset, in addition to representing the observed phenomena, also represents the administrative unit of policies on the two phenomena.

Phenomenon (regional dimension)	**Dataset**	**Literature**	**Data Source**
Electric transition	Electric Consumption	Hanson, G. H. (2023)	Terna S.p.A. https://bit.ly/3zcPVGR
	Employees with low pay		
	Employment rate (20-64 years)		
Equitable and Sustainable Well-Being	Transformations from unstable jobs to stable jobs	Ciommi M. et al. (2017)	ISTAT https://tabsoft.co/3K7wo0X
	Positive assessment of future prospects		
	Satisfaction for own life		

Tab.1 Regional spatial dataset 2017-2021 (Author: M. Sinatra 2023)

3.3 Methodology

In order to analyze the phenomena under exam, we decided to focus on indicators of spatial autocorrelation to observe the local behaviors of the different variables considered and to observe the possible formation of clusters among the regions considered. To do that, we recall Tobler' studies (Tobler, 1970), where he states that "nearby things are more related than distant things", an approach that has been recently rediscovered. Tobler's First Law of Geography and spatial autocorrelation are correlated as they both refer to spatial relationships between geographic entities (Murgante & Scorza, 2023). Spatial autocorrelation is a concept used in spatial analysis and geostatistics to assess the correlation between observations at different locations in a geographical area. Spatial autocorrelation is based on the assumption that observations in a geographical space may be influenced by spatial processes, where the characteristics of a given area may be similar or related to those of the surrounding areas. This can be particularly useful in the analysis of geographical data, such as demographic, economic or environmental data, where it is assumed that geographically close observations are more similar than distant. For this reason, the energy well-being relation can be examined by means of spatial autocorrelation (Ceci et al., 2019; Wang & Luo, 2018). Spatial autocorrelation, specifically, is applicable to data or indicators associated with a collection of neighboring geographic units, such as administrative divisions. This is useful for assessing localized effects and identifying clusters based on both attribute and geographical data. Thus, data can be affected concurrently in terms of geographical shape and spatial proximity and in terms of values attributed to the same units. In fact, this method allows us to observe and analyze the behavior of a selected variable in reference to its position in space and to what happens in its proximity. In particular, the Local Moran Index, also known as Local Moran's I, is a statistical measure used in spatial analysis to assess the degree of spatial autocorrelation at the local level. It identifies clusters of similar values (High-High or Low-Low), outliers surrounded by dissimilar values (High-Low or Low-High) and no significant autocorrelation. This helps in identifying spatial hot spots, cold spots, and spatial patterns within the dataset. In analytical terms, it can be seen as the sum of all local indices and is proportional to the value of the Moran one:

$$\sum_i I_i = \gamma * I \qquad (2)$$

The index is calculated as follows:

$$I_i = \frac{(X_i - \overline{X})}{S_x^2} \sum_j^n (w_{ij}(X_j - \overline{X})) \tag{3}$$

where:

- N is the number of geographical units;
- X_i is the variable describing the phenomenon under investigation in region i;
- $\overline{X}$ represents the sample average and $(X_i - \overline{X})$ it is the variable's average deviation;
- S_x^2 is the standard deviation;
- w_{ij} is the weight matrix.

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 (O'Sullivan & Unwin, 2010). Rook or Queen contiguity are considered in the realization of the weight matrix.

4. Results

In this manuscript, the analysis was performed by considering a set of indicators (Tab.1) assigned to each Italian Region and they 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. On the one hand, Sicily has been united to Calabria to make it contiguous with Italian territory.

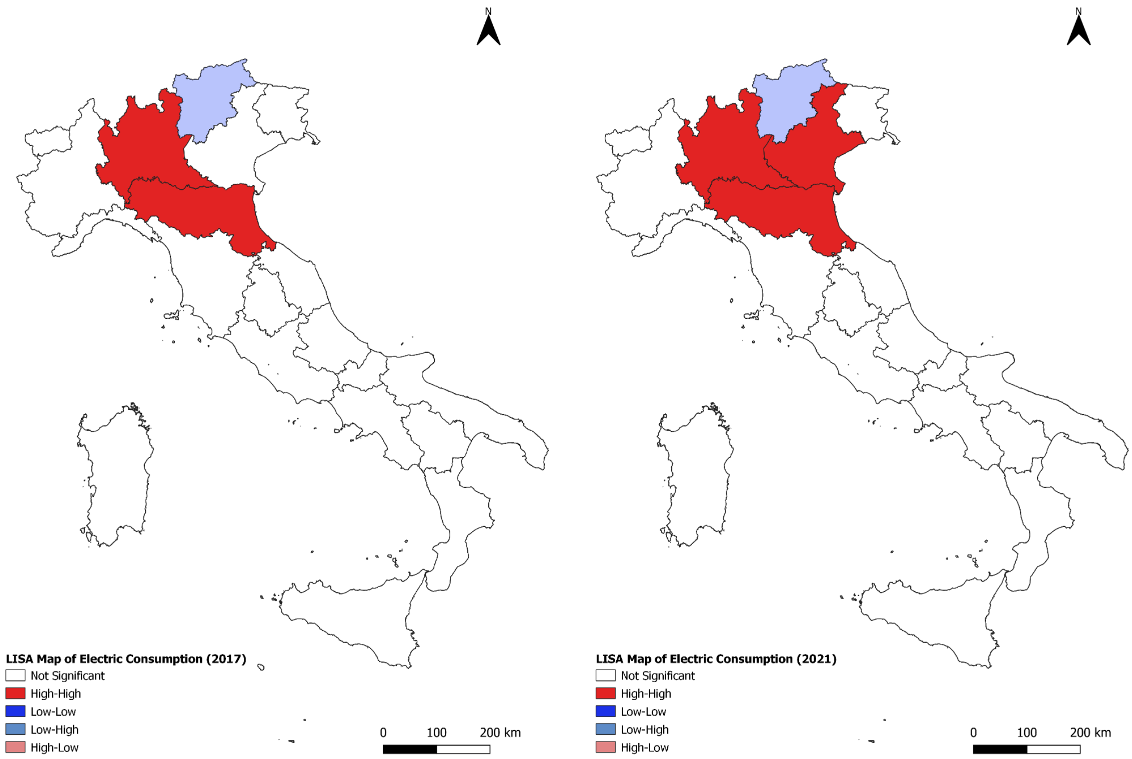

Fig.2 LISA MAP of Electric Consumption, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

On the other hand, Sardinia has been excluded and inserted after the elaborations, due to its distance from other Italian Regions. The application of the method to the set of indicators in the regional dimension yielded the following results as in Fig.2 – 8.

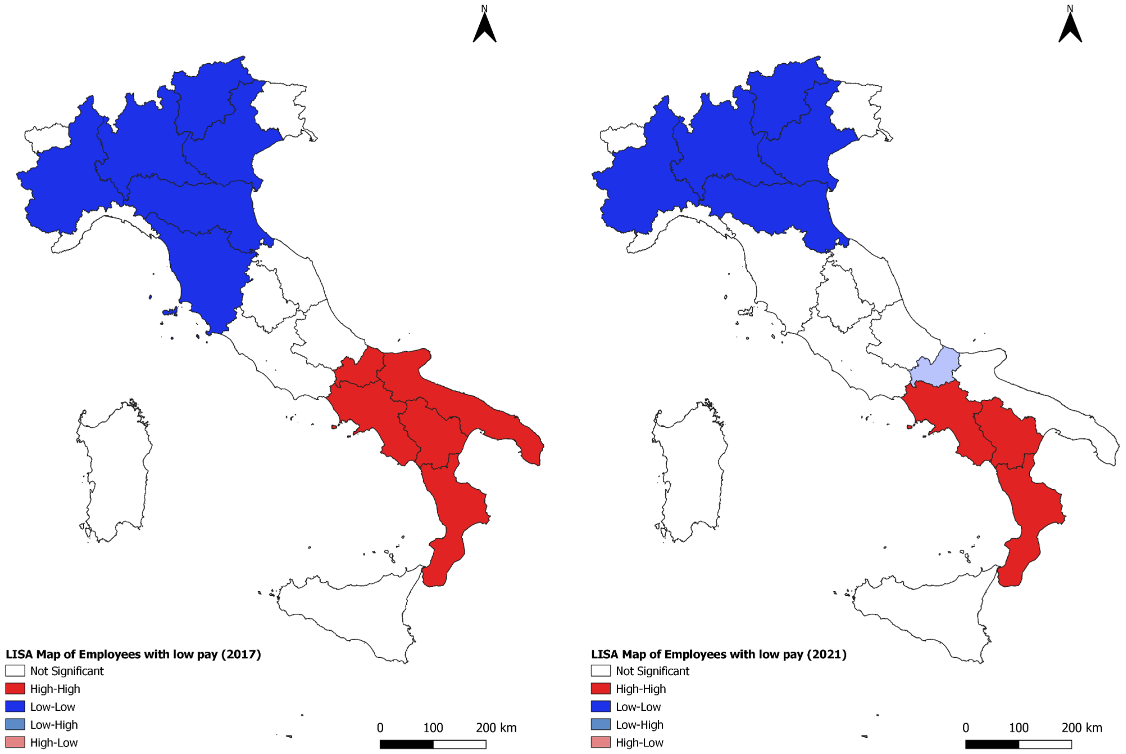

Fig.3 LISA MAP of Employees with low pay, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

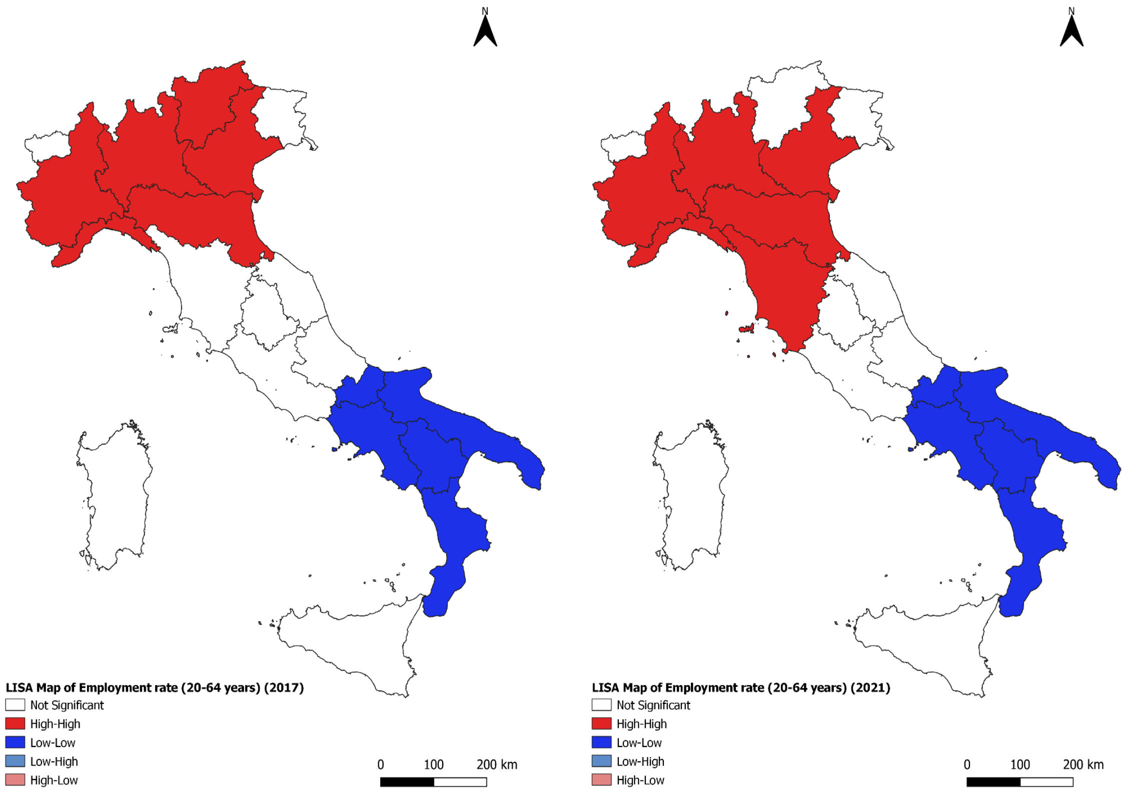

Fig.4 LISA MAP of Employment rate (20-64 years), years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

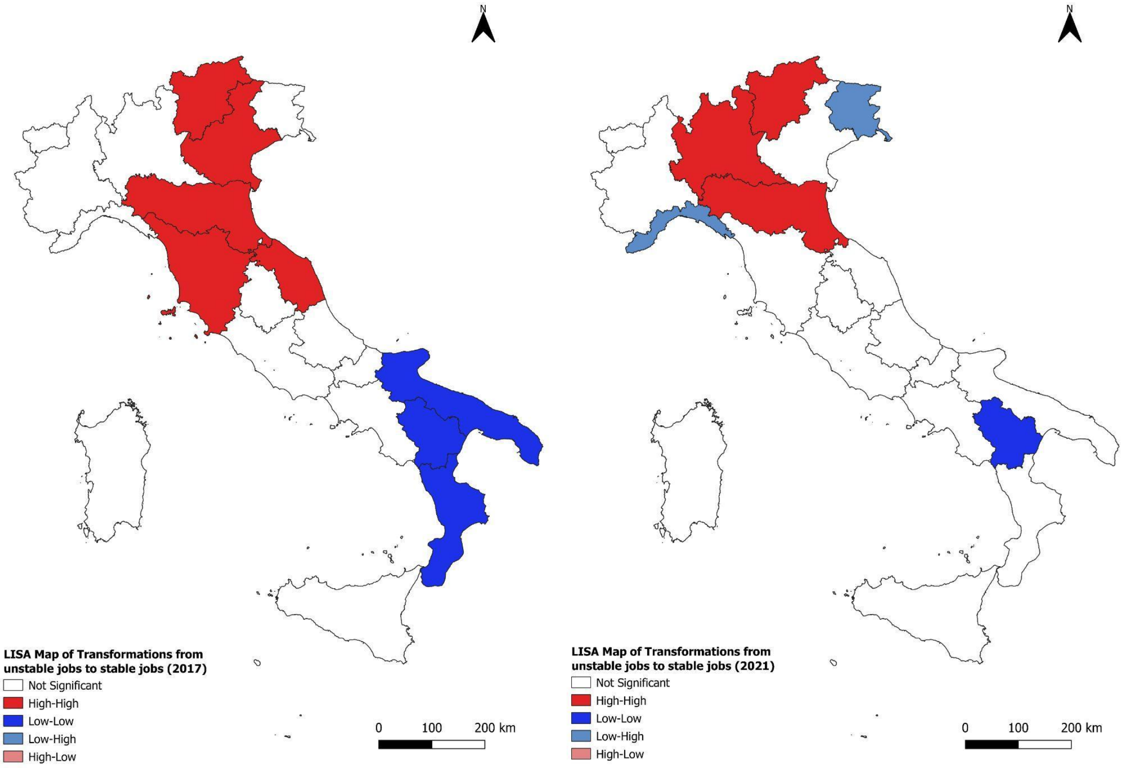

Fig.5 LISA MAP of Transformations from unstable jobs to stable jobs, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

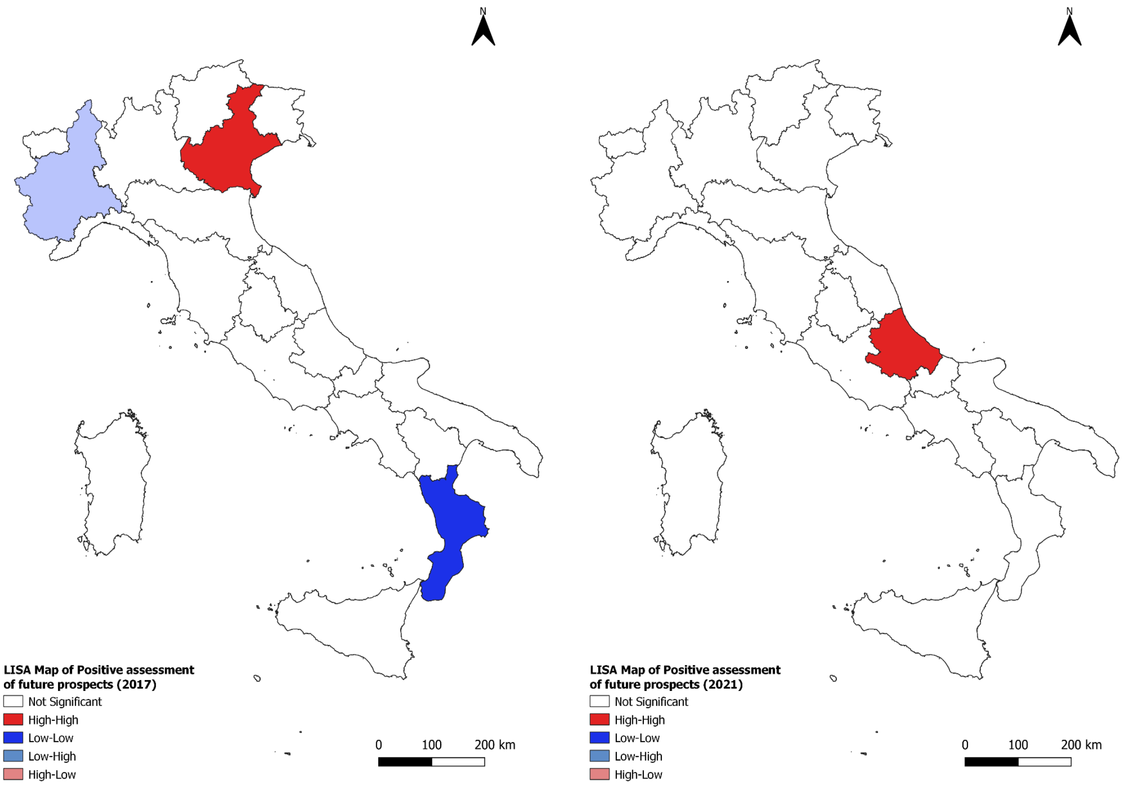

Fig.6 LISA MAP of Positive assessment of future prospects, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

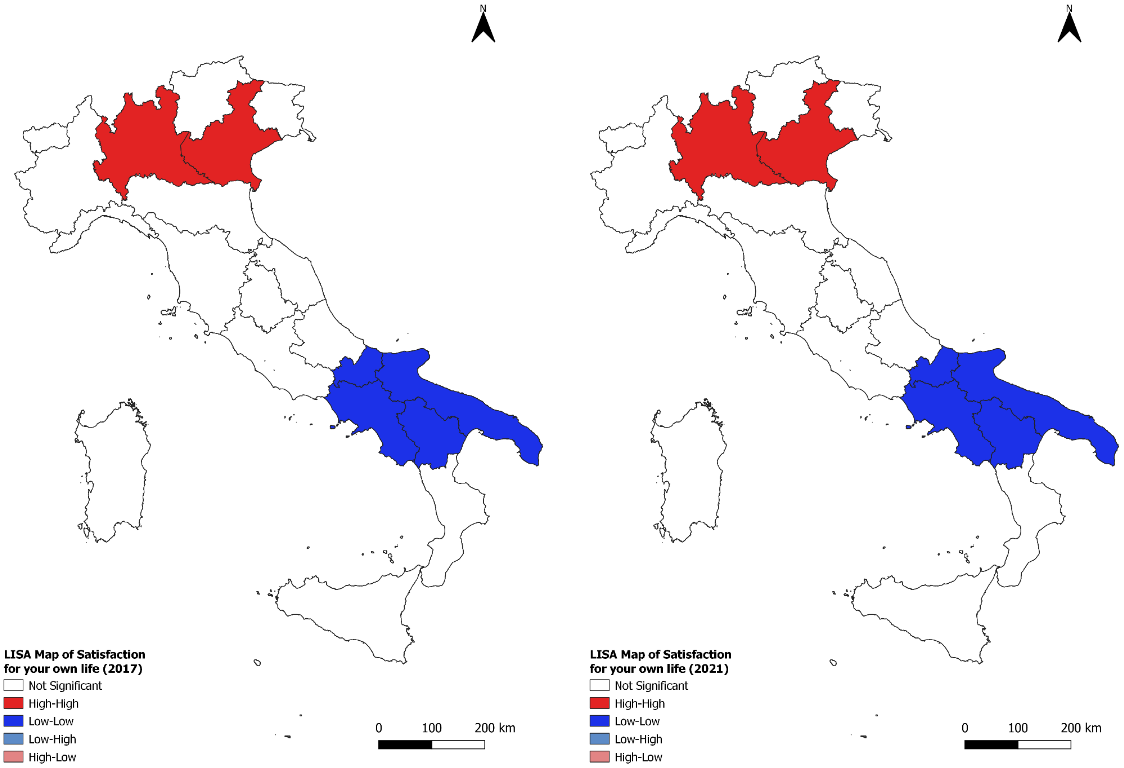

Fig.7 LISA MAP of Satisfaction for your own life, years 2017 and 2021 (Authors: M. Sinatra and G. Balletto, 2022)

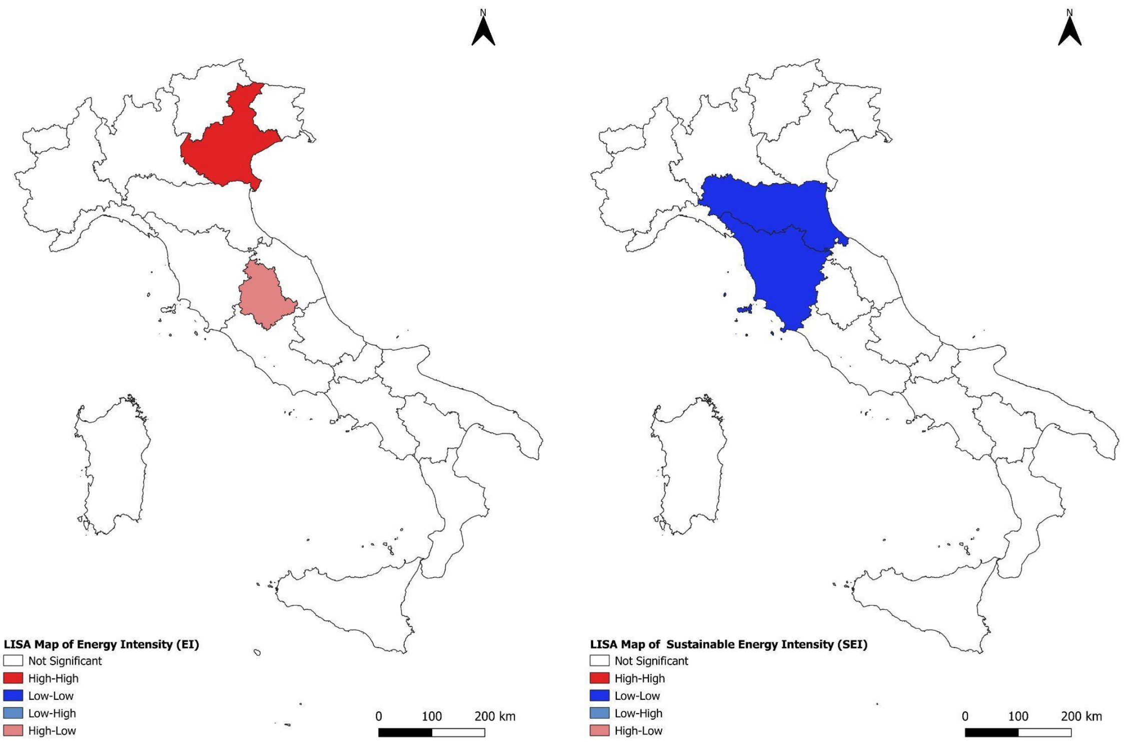

Fig.8 LISA MAP of EI and SEI (Authors: M. Sinatra and G. Balletto, 2022)

In particular the local autocorrelation of electric consumption mapped in Fig.2 portrays a clustering of Northern Italian regions, with an extension of the area involved from 2017 to 2021, including Lombardy, Emilia Romagna and Veneto regions as displaying high-high values. It is worth remembering as these regions represent today the new Italian Industrial Triangle of economic production (agro-industrial and manufacturing in particular). Economical structural indicators are also observed and mapped in Fig.3 and Fig.4, where the analysis of local autocorrelation confirms the presence of 'two Italies': low salary' workers are concentrated in Southern regions, although a reduction of the number of regions involved can be observed particularly by examining 2021 data, with the cluster becoming limited to Campania, Basilicata and Calabria, while Apulia regions exits from the cluster (Fig.3). On the other side, the divide can be still highlighted by the clusters of higher employment rates in Northern regions, while negative values of autocorrelation are observed in Southern mainland regions (Fig.4). The transformation from unstable jobs to stable ones leads to a polarization of regions in Northern Italy where high positive values are present (Lombardy, Trentino Alto Adige and Emilia Romagna) and a decrease in the level of negative spatial autocorrelation, with a possible role played by the economic upturn after Covid-19 outbreak. With reference to the analysis of the local association on the positive assessment of future prospects, no significant results and interpretations seem to be considered from the analysis of local association (Fig.6). Still, reflections similar as those of Fig.3 and Fig.4 can be considered when observing the Satisfaction for your own life, where Northern Italian regions (Veneto and Lombardy) present positive values of local autocorrelation, while Southern ones (Molise, Campania, Apulia and Basilicata) present negative values, with identical patterns drawn in 2017 and 2021 (Fig.7). The Maps of EI and SEI (Fig.8) as solely referred to 2021 present several differences among regions, and just a positive spatial autocorrelation of EI in Veneto can be spotted as well as a negative spatial autocorrelation of SEI in Tuscany and Emilia Romagna regions. These results can be summarized in the below comparisons: of the regions with the most other SEI (Trentino-Alto Adige, Friuli-Venezia Giulia and Sardinia) and the regions with the most other SEI (Trentino-Alto Adige, Val d'Aosta and Basilicata) and the level of spatial autocorrelation of the set of selected BES indicators (Tab.2 – Tab.3).

Indicator (2021)	**Trentino-Alto Adige**	**Friuli Venezia Giulia**	**Sardinia**
Electricity Intensity (EI)	1.60	1.53	1.43
Electric Consumption	Low-High	Not Significant	Not Significant
Employees with low pay	Low-Low	Not Significant	Not Significant
Employment rate	Not Significant	Not Significant	Not Significant
Transformations from unstable jobs to stable jobs	High-High	Low-High	Not Significant
Positive assessment of future prospects	Not Significant	Not Significant	Not Significant
Satisfaction for your own life	Not Significant	Not Significant	Not Significant

Tab.2 Summary results: EI regions and BES's LISA (Author: M. Sinatra, 2022)

Indicator (2021)	**Trentino-Alto Adige**	**Valle d'Aosta**	**Basilicata**
Sustainable Electricity Intensity (SEI)	5.20	6.49	4.98
Electric Consumption	Low-High	Not Significant	Not Significant
Employees with low pay	Low-Low	Not Significant	High-High
Employment rate	Not Significant	Not Significant	Low-Low
Transformations from unstable jobs to stable jobs	High-High	Not Significant	Low-Low
Positive assessment of future prospects	Not Significant	Not Significant	Not Significant
Satisfaction for your own life	Not Significant	Not Significant	Low-Low

Tab.3 Summary results: SEI regions and BES's LISA (Author: M. Sinatra, 2022)

5. Discussion

The Italian government has set the goal of producing 30% of national energy from renewable sources by 2030 through the Integrated National Plan for Energy and Climate (2019) (PIANO NAZIONALE INTEGRATO PER L'ENERGIA E IL CLIMA). This goal could affect the trend in the consumption of electricity in the future. According to data from the Electricity, Gas and Water Authority (AREA) 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. Moreover, electricity consumption in Italy is influenced by a variety of factors, including physical and geographic conformity with different weather conditions, and the organization and distribution of economic and productive activities.

Northern Italy is characterized by a high-high autocorrelation of electricity consumption according to the LISA elaborations based on the regional dimension. Particularly, as shown in Fig.3, the regions with high-high autocorrelation of electricity consumption are 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 GDP (Tab.4).

Region	GDP - Gross Domestic Product, 2020 (Purchasing Power Standards per inhabitants)	Share National GDP, 2020 (%)	Renewable Electricity consumption, 2021 (%)
Lombardy	37700	22.50	27.30
Emilia Romagna	34,500	9.10	22.10
Veneto	31,600	9.20	29.30

Tab.4 Regional GDP (2020) and Renewable Electricity consumption (2021) of Lombardy, Emilia-Romagna and Veneto (Author: Balletto G., 2023 from https://ec.europa.eu/eurostat/cache/digpub/regions/#gross-domestic-product and https://bit.ly/40C1MdA)

With reference to the period 1950-1980, nowadays it is possible to observe an increase in the average temperature equal to 1.02 degrees (Glocal Climate Change Map). In fact, the scientific debate focuses on whether anthropogenic emissions of greenhouse gasses into the atmosphere, which are the main cause of complex global climate change. In this scenario, carbon dioxide represents the main gas in air emissions derived from the fossil fuel energy sector.

In order to achieve Carbon Neutrality by 2050 - The European Green Deal-the main tool is represented by the energy transition, with the aim of transforming the energy from fossil fuels into low or zero carbon emissions (renewable sources).

However, the energy transition is not only limited to the gradual shutdown of coal-fired plants and the development of clean energies, but also involves a paradigm shift in the whole structure of energy production and use, i.e. a transition based on spatial equity (Yenneti & Golubchikov, 2016; Balletto et al., 2016), with benefits not only for the climate but also for the economy and communities (health and wellness).

In this sense, the EI index, SEI index and indicators: Electric Consumption, Employees with low pay, Employment rate, Transformations from unstable jobs to stable jobs, Positive assessment of future prospects, Satisfaction for your own life; support the 'Just Transition Fund' - https://www.jtf.gov.it/ - a new financial instrument within the framework of cohesion policy, which aims to provide support to territories facing serious socio-economic challenges. -economic ones resulting from the transition towards climate neutrality.

6. Conclusions and policy implication

The current debate on sustainability is fostering the need, among others, for a radical change aimed at reducing Electricity Intensity (EI) on production processes and electricity consumption from fossil fuels, contrary to what was pursued during previous industrial revolutions.

The analysis carried out in this paper has helped to understand the spatial imbalances and differences in electricity consumption, in absolute terms and regarding their sustainable origin - by renewable sources: respectively measured by means of EI index and SEI index - as well as the differences that can be observed between the various Italian regions in terms of well-being, instead of being based on GDP alone, which, as it has been demonstrated, fails to take into account all the different aspects related to the development of a territory. The use of spatial analysis techniques proves efficient and effective in mapping these regional differences, as well as allowing us to draw an overall picture of a study area, allowing us to monitor and more generally support the just electricity transition.

From the considerations made in this paper, the regions with the highest EI values are highlighted: Trentino-Alto Adige, Friuli Venezia Giulia and Sardinia (both Special Autonomous Regions) and the regions with the highest SEI values are highlighted: Trentino-Alto Adige, Valle d'Aosta (both Special Autonomous Regions) and Basilicata. In these regions it would be necessary to adopt specific policies to overcome the gap that separates them from the remaining Italian regions, and which could hinge on the specificity of the special statute that characterizes them, drawing the advantages deriving from a correctly directed and energetically optimized self-government. In particular, the results obtained in the present work assume a national strategic role in the acceleration of renewable energy in the Special Autonomous Regions and Provinces (article 20 of legislative decree n. 199/2021), providing priorities, starting from Trentino-Alto Adige, with EI =1.60 and SEI =5.20 to try to ensure a 'Just Transition'. Furthermore, the combination of the acceleration of the renewable electricity transition with the reduction of consumption and territorial cohesion policies aimed at the growth of the GDP in the Special Autonomous Regions is required. The development of renewable sources and electrification contribute, in fact, to the paradigm shift produced by the energy transition which also represents a great opportunity in terms of economic well-being, growth of employment, and social development of the communities involved.

Author's contribution

Conceptualization, methodology, formal analysis, materials and resources, software and data curation: Balletto, Borruso and Sinatra. Validation: all authors. In particular: Balletto and Sinatra wrote Section 1 and Section 4; Balletto and Zullo wrote Section 2 and Section 2.1; Balletto, Borruso and Milesi wrote Section 3.1; Borruso and Sinatra wrote section 3.2 and section 3.3; Balletto and Borruso wrote Section 5; Balletto, Borruso and Ghiani wrote section 6.

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Tab.1 - Tab.3: Authors elaboration.

Tab.4: from https://ec.europa.eu/eurostat/cache/digpub/regions/#gross-domestic-product and https://bit.ly/40C1MdA);

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