# Italian Cities SDGs Composite Index

## A Methodological Approach to Measure the Agenda 2030 at Urban Level

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**Abstract.** The Italian Cities SDGs Composite Index is a tool for policy analysis and dissemination of sustainable development at local level in Italy. Structured into several dimensions representing 16 out of 17 sustainable development goals adopted by the United Nations at the end of September 2015, the index merges 53 available economic, social and environmental elementary indicators into a single composite dimension, highlighting geographical and demographic heterogeneity within the Country.
The high dimensionality of the index requires the check for latent implications due to the multivariate distribution of the data. It is indeed mathematically proved that not only heterogeneous variance among indicators plays a central role on the aggregated value, but also the degree of correlations among them. With this aim, Principal Component technique has been applied to identify the latent structure of the data, clustering both indicators within goal and the goals themselves. The weights attached to the indicators have been set in such a way to favour the ones that are statistically independent of each other and to penalize, conversely, those that are correlated; the same approach has been applied for deriving the weights among goals. In this way a balanced structure of the data is guaranteed.

**Keywords:** SDGs, Composite Index, Weighting, Correlation, Spectral Value Decomposition, Principal Component.

## 1 Introduction

In August 2017, the Sustainable Development Solutions Network presented in New York the first U.S. City Index on Sustainable Development Goals (SDGs) at urban level (Prakash et al., 2017). This index is put beside the Global SDG Index (Sachs et al., 2018), underlining the specific role of cities. The SDGs recognize that sustainability is a universal goal and that all countries and communities can play an important role in achieving this Agenda. From a global point of view, cities play a fundamental role in achieving the sustainable development. They are relevant for assessing the success or the failure of it, as they host more than half of the whole world's population and they are the main source of carbon emissions.

Using indicators to track progress is an integral part of the Sustainable Development Goals (SDGs), which are part of an international framework agreed by world leaders in 2015, aiming to end poverty, fight inequality and stop climate change.

There are important references in Italy at national level, but there are no explicit references to single urban realities.

Numerous contributions that evaluate Country's positioning in the field of sustainability are available (see Cavalli, 2018 for a review). They range from the documents and data to prepare the National Strategy for Sustainable Development (provided by the Ministry of Environment in December 2016), which presents the positioning of Italy compared to 17 SDGs and 169 targets, to the Index developed by UN-SDSN and by the Bertelsmann Foundation. This index places Italy in 2017 at the 29th place on 156 in the world, after Sweden, Denmark and Finland, but in the queue also to other countries like Slovak Republic, Hungary and Latvia. This report shows that Italy is far from the target especially for Goal 14 (life below waters), Goal 12 (responsible consumption and production), Goal 13 (peace, justice and strong institutions) and 9 (innovation and infrastructures). On the other hand, for Goal 1 on poverty, Goal 3 for health, Goal 4 for quality education, Goal 6 about clean water and sanitation and Goal 11 referred to the sustainable cities and communities Italy is on the path toward sustainability.

Among the other contributions, the OECD (2017) provides the state of the art on SDGs in OECD countries, comparing the OECD well-being own framework to the Agenda 2030 and noticing that Italy has reached adequately 11 out of the 17 SDGs. In a comparative perspective, compared to the OECD average, Italy has better performance regarding sustainable production and climate action (Goals 12 and 13), while it is aligned to the OECD average on Goal 2, 3, 10 and 14. The SDGs related to education, economic growth, institutions, to clean water and partnership for the goals, show a lower performance than the OECD average (respectively Goals 4, 8, 16, 6 and 17).

Despite the importance of understanding the positioning of one country in an international perspective, to have a complete picture to be used as a basis for the identification of a system of priorities, it is also important to understand the direction of the change and the speed of the progress towards the SDGs. At this regard Eurostat (2017) underlines the significant progress on some SDGs made by the UE (Goal 3, 7, 11, 12, and 15), but that such progress is not sufficient to achieve the Agenda 2030.

To better understand the national situation, ASviS (2017) states that Italy is far from the sustainability on unemployment, inequality and environmental issues, while it is improving in the fields of education, good health and of food security, even if it continues to remain far away from the target for what concern all these issues. Furthermore, Italy is in delay in the adoption of fundamental strategies relating to energy, climate change and circular economy.

In a planning perspective, it is also fundamental -for each specific Goal- to evaluate the impact of different policies to reduce the gaps from the targets. At this regard (Campagnolo et al., 2018) developed also a tool, APPS (As-assessment, Projection and Policy of Sustainable Development Goals). It is a composite indicator that, thanks to the use of a general equilibrium economic model, offers a measure of current well-being and future sustainability, generating forecasts up to 2030 for 45 different geo-political areas (individual countries or macro-regions), based on the different hypotheses of policies adopted. The model emphasizes that Italy stands at the fifteenth placed among the forty-five regions considered and, within the European Union, the Italian performance is better only compared to that of the Czech Republic, Spain and Greece.

While the studies that compare countries in the context of SDGs are numerous, nationally –but even internationally, with the only exception of US– there are no explicit references to urban realities. When implementing the Agenda 2030 it is particularly important to define the strategies through the alignment of local or regional development plans with the Goals, the Targets and the Indicators of the Agenda 2030. Locally adopting the Agenda is much more than reaching the target: to build a local strategy there is a need for the design, share and develop of tools that photograph the "implementation status" of SDGs in the main Italian municipalities; this to help local communities tackle the still unresolved challenges affecting single cities.

This work aims at filling this gap, presenting in section 2 a composite index that evaluates the Italian municipalities according to 53 indicators structured into 16 out 17 SDGs. Such index, for the reasons explained in section 2, does not measure the distance of Italian municipalities to specific target, but instead their performance respect the average. In phase of criteria weighting, we have controlled for latent implications due to the multivariate distribution applying Principal Component technique (subsection 2.1) to guarantee a balanced structure of the data. Section 3 describes the main results, while section 4 reports some concluding remarks.

## 2 Composite Index

The Italian Cities SDGs Index is composed by 53 elementary indicators structured into 16 out 17 SDGs; no data are available for Goal 14. The list of the elementary indicators is shown in the Appendix (Table 1) and Figure 1 graphically represents the composite index structure.

Such index does not measure the sustainability level of Italian urban reality; instead, it measures the Italian municipalities' performance respect to its average. The reason is that only in 30% of our indicators a precise UN target (*sustainable* level) is available, and on the other side, no *unsustainable* thresholds exist at all. We stress indeed the following: since, in a composite index, the distance to target (upper bound) is rescaled on a $[0,1]$ scale because of the presence of indicators with different unit measures, no rescaled distance based on a single point can be precisely computed. The choice of the lower bound plays indeed a crucial role in determining such distance and cannot depend on the data set -for example the 2.5 percentile (Prakash et al., 2017)- especially when we compare realities that are homogeneous, i.e. cities or regions belonging to the same country, or countries with similar wellbeing level (OECD, etc.).

Instead of working on 30% of indicators and setting as many lower bounds (difficult task), we have preferred to retain the all set of indicators and build a fast, unsupervised composite index on standardized data. Therefore, the scores obtained in each dimension cannot reveal a sustainability level *per se*, but only a comparison between municipalities' performances with respect an average value (set to zero).

Data have been merged in two levels: in the first level indicators have been aggregated within Goal; in the second level the Goals have been aggregated into the *Sustainability Index*. The unevenly distribution of indicators among Goals (Goal 7 for example has only one indicator, while Goal 4 has 9) required a re-standardization of the value obtained to balance the Goal's influence on final index. From a probabilistic point of view, Goals with fewer indicators exhibit a higher variance with respect those formed by several, with a consequently greater influence on the final composite index.

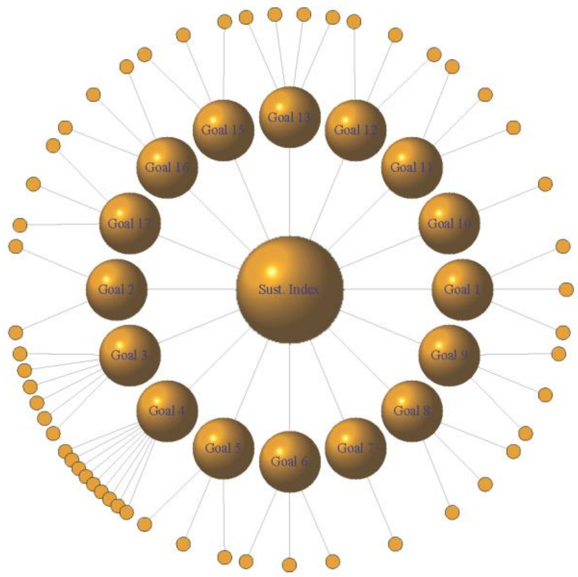


*Figure 1 - Composite Index Structure*

Moreover, the high dimensionality of the index has required the check for latent implications due to the multivariate distribution of the data; it is mathematically proved (Wang and Stanley, 1970; Parulo et al., 2013) that not only heterogeneous variance among indicators plays a central role on the aggregated value, but also the degree of correlations among them. With this aim, to identify the latent structure of the data (see sub section 2.1), Principal Component technique has been applied, clustering both indicators within goal and the goals themselves. The weights attached to the indicators have been set in such a way to favour the ones that are statistically independent and, conversely, to penalize those that are correlated. In this way a balanced representation of the data is guaranteed.

## 2.1 Criteria Weighting

Consider a composite index formed by $p$ indicators $x_i$ with $i = \{1,2, \dots p\}$, that have been previously adjusted according to their polarity. If such indicators have been previously standardized too, their covariance matrix coincide with the correlation matrix (denoted with $\mathbf{R}$).

The Spectral Value Decomposition (SVD) allows to rewrite the correlation matrix in the following way:

$$\mathbf{R} = \mathbf{A}\mathbf{\Lambda}\mathbf{A}' \tag{1}$$

where $\mathbf{\Lambda}$ $(p \times p)$ is the diagonal matrix of eigenvalues of $\mathbf{R}$ and $\mathbf{A}$ $(p \times p)$ matrix of eigenvectors.
When in the data set some random variables are exactly linear dependent from others, is it possible to obtain the same correlation matrix $\mathbf{R}$ with a lower dimension in the matrix $\mathbf{\Lambda}$ $(k \times k)$ and $\mathbf{A}$ $(p \times k)$, with $k < p$. If we define the total variance of the random vector $\mathbf{x}$ as the sum of the variance of its random variables, that is $trace(\mathbf{R}) = p$, we could form a new random vector $\mathbf{z}$ $(k \times 1)$ as a linear combination of $\mathbf{x}$ with the same total variance explained:

$$\mathbf{z} = \mathbf{A}'\mathbf{x} \tag{2}$$

$$Cov(\mathbf{z}) = \mathbf{A}'\mathbf{R}\mathbf{A} = \mathbf{\Lambda} \tag{3}$$

meaning that the elements of the random vector $\mathbf{z}$ are orthogonal. The total variance explained by the new random vector is:

$$trace(\mathbf{\Lambda}) = trace(\mathbf{A}'\mathbf{R}\mathbf{A}) = trace(\mathbf{R}) = p \tag{4}$$

The *principal component* represents the first element of the random vector $\mathbf{z}$ and explains the maximum amount of the total variance of $\mathbf{R}$, given that the eigenvalues of $\mathbf{R}$ have been rearranged in descending order.

It is worth underlining that the matrix $\mathbf{A}$ cannot be used directly in the construction of a composite index $y = \mathbf{w}'\mathbf{z}$, with $\mathbf{w} \geq \mathbf{0}$ a vector $(k \times 1)$ of weights; indeed, it could happen that an increment in the variable $x_j$ leads to a negative effect in the composite index, because of the presence of negative elements in the matrix $\mathbf{A}$:

$$\frac{\partial y}{\partial x_j} = \mathbf{w}'\mathbf{a}_{.j} < 0 \tag{5}$$

where $\mathbf{a}_{.j}$ represents the $j$-thcolumn of $\mathbf{A}'$.
For this reason, the utilization of PCA in the context of composite indices' construction requires a transformation and/or rescaling of eigenvector matrix. Although several techniques exist in literature, there is no consensus on which is the best one to use. The most commonly employed can be found in OECD (2005). This approach however leads to two severe consequences: first, it could overweigh indicators that are correlated penalizing those that are independent,

leading consequently to unbalanced composite index. The reason is that the initial weights of the indicators (represented by proportion of variance explained in each component) are weighted again proportionally to the variance explained by the components. Second, the criterion adopted to retain the number of components (around 85% of total variance should be explained) could leave out components that in theory play a central role in the description of the data.
The following example will better explain the above two issues: suppose you are going to construct a composite index with three indicators, two of which are perfectly correlated, while the third is statistically independent from the others. In theory one of the two correlated variable is redundant and it should be dropped in the composite index. If you are imposing equal weights, the composite index is unbalanced because one dimension (formed by the two correlated variables) is weighted twice with respect the second one (formed by the independent variable). If you use OECD's approach you obtain the same undesirable results.

$$\mathbf{R} = \begin{bmatrix} 1 & 1 & 0 \\ 1 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\mathbf{A} = \begin{bmatrix} 0.707 & 0 & 0.707 \\ 0.707 & 0 & -0.707 \\ 0 & 1 & 0 \end{bmatrix}$$

$$\mathbf{\Lambda} = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

The number of components to retain is two since the first one explains $\frac{2}{3}$ of the total variance and the second one an additional $\frac{1}{3}$.
The matrix $\mathbf{B}$ (with $b_{ij} = a_{ij}^2$) represents the proportion of variance explained by each indicator for each component retained:

$$\mathbf{B} = \begin{bmatrix} 0.5 & 0 \\ 0.5 & 0 \\ 0 & 1 \end{bmatrix}$$

Following OECD's technique, the weight of the first two indicators is $\left(\frac{2}{3}0.5 + \frac{1}{3}0\right) = \frac{1}{3}$; the weight of the third indicator is $\left(\frac{2}{3}0 + \frac{1}{3}1\right) = \frac{1}{3}$.
To avoid the above issue, you need to think differently: in some type of composite index, namely those for which condition 5) cannot be accepted, it is not recommended the technique that fits the data best. On the contrary, it is to prefer the one that best fits the dimensions the

data are explaining, in which indicators that are statistically independent are weighted more than those that are correlated. To this aim, when using PCA technique, each component should have the same weight. To conclude, the optimal indicators' weights $\mathbf{w}^*$ $(p \times 1)$ are obtained averaging the proportion of variance explained by them in each component:

$$\mathbf{w}^* = rowmean(\mathbf{B}) \tag{6}$$

According to 6), the weight of the first two indicators is $\left(\frac{1}{2}0.5 + \frac{1}{2}0\right) = \frac{1}{4}$ and the weight of the third indicator is $\left(\frac{1}{2}0 + \frac{1}{2}1\right) = \frac{1}{2}$.

Regarding the second issue -the number of components to retain: suppose that a composite index is formed by $p$ indicators that are statistically independent. Given this assumption each component explains $\frac{1}{p}$ of the total variance $p$ and 20% of the initial set of indicators is wrongly discarded.

We hence recommend retaining the number of components that simultaneously satisfy the following conditions: around 85% of the total variance should be explained and each eigenvalue is greater than one. Let $\lambda_i$ the $i$-th eigenvalue and

$$C = \left\{k \middle| argmin_k f(k) = \left|\sum_{i=1}^{k} \lambda_i - \frac{8.5}{10}p\right|\right\},\ k = \{1, \ldots, p\} \tag{7}$$

$$D = \{v | \lambda_v \geq 1\},\ v = \{1, \ldots, p\} \tag{8}$$

the optimal number of component to retain $d^*$ is given by:

$$d^* = max(k, v) \tag{9}$$

The composite index $y$ is hence a weighted average of the indicators belonging to it:

$$y = \mathbf{w}^*\mathbf{x} \tag{10}$$

## 2.2 Final Criteria's Influence on the Composite Index

In literature (Wang and Stanley, 1970; Parulo et al., 2013) the final influence of the $i$-th indicator on a composite index $y$ (formed as linear combinations of some criteria) is expressed as the squared correlation between the two:

$$Influence_{x_i,y} = cor^2(x_i, y) \tag{11}$$

This allows us to better understand the real importance of a variable in a composite index, catching both the direct (weight/coefficient) and the indirect effect.

## 3 Results

Focusing on the recognized socio-economic disparities between the South and the North of the Country, the Sustainability Index and its distribution across the regions confirms the gaps. According to equation 11), the key Goals to understand this result are those related to good education and decent work & economic growth. At level of single elementary indicators, the key ones are NEET (aged 15-29) and the one related to the share of population that worked less than 20% of the time.

Figure 2, Figure 3, Figure 4 show that, both in terms of Sustainability Index and SDGs, most of the cities based in the northern part of the Country, with few exceptions, performs better with respect to the average.

Given the importance of looking specifically at the SDGs to better understand the state of the art of the municipalities and their different specificities, rankings for each Goals have been provided. It is always important to remember that the Agenda 2030 is a complex program that aims at avoiding trade-offs between the Goals still recognizing the peculiarities of each single actor and the need of integration between them. One of the point to focus the attention on, once the individual rankings have been obtained, is the high degree of diversification, which strongly -but not surprisingly- indicates the degree of heterogeneity of the Italian municipalities.

From a comparative perspective, as summarized in Table 2, Table 3, Table 4, Bolzano is at the top of the ranking in the Goals linked to poverty (Goal 1), to sustainable cities (Goal 11) and to the partnership for the goals (Goal 17). Milan (61st in the Sustainability Index) is first of the class in the SDGs related to economic growth and infrastructures and innovation (Goal 8 and 9), it is on the podium in Goal 6 (clean water and sanitation), but at the same time it displays the worst result in SDG 10 (economic inequality) and second to last in Goal 15 (life on land). Belluno, Venezia and Padova, three Municipalities located in the north-east part of the Country, are the best performer respectively in Goal 12 (responsible production and consumption), 13 (climate change) and 7 (clean energy), while considering Terni and Rome (two Municipality in the centre part of Italy), they rank at the top in SDG 3 (good health) and 5 (gender equality). Finally, Matera and Enna –

municipalities in the Southern part of the Country- they are on the top of the ranking in SDG 15 (life on land) and 16 (peace).
All that said, these results confirm the complex picture and the need of tools to help the coordination and intersection between policies, sectors and stakeholders to find innovative solutions to the challenges sustainable development addresses.

## 4 Conclusions

This paper offers a methodological approach that best suits the construction of composite indicators in the context of SDGs. In the next future, when all the 269 elementary indices measuring sustainability will be available worldwide, there will be the need of a synthetic measure that best approximates the sustainability level of a country, region, city and mitigates the implicit issues due to the multivariate distributions of the data. It is indeed high probable that these 269 indicators do not explain as many as different dimensions.
In this paper we applied Principal Component technique to address the above issue, offering the readers a list of indices (sustainability index, and one for each Goal) for Italian municipalities. One more time, the results confirms the rift between the north and south of the Country. The key Goals to understand the results are those related to good education and decent work & economic growth. At level of single elementary indicators, the key one is NEET (aged 15-29) and the one related to the share of population that worked less than 20% of the time.

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# 6 Appendix

*Table 1 - List of Indicators Considered (Goal and Polarity displayed)*

| Indicator | SDGs | Polarity |
|---|---|---|
| Elderly people dependence index | 1 | negative |
| Economic distress | 1 | negative |
| Individuals in low-working intensity families | 1 | negative |
| Urban bio gardens | 2 | positive |
| Obesity rate | 2 | negative |
| Healthy life expectancy at birth | 3 | positive |
| Healthy life expectancy at 65 years | 3 | positive |
| Deaths and injuries in road accidents | 3 | negative |
| Support to elderly people | 3 | positive |
| Suicide rate | 3 | negative |
| Infant mortality rate | 3 | negative |
| Nursery services for children aged 0-36 | 4 | positive |
| Student literary competence | 4 | positive |
| Student numerical competence | 4 | positive |
| People with university degree | 4 | positive |
| Population with low school license (isced 3) | 4 | positive |
| Enrolled population at school aged 0-16 | 4 | positive |
| Schools with ramps for people with disabilities | 4 | positive |
| School with technologies | 4 | positive |
| Population with pre-university education | 4 | positive |
| Employment gender balance | 5 | positive |
| Woman mayor in the last 10 years | 5 | positive |
| Women educational level compared to men | 5 | positive |
| Water losses | 6 | negative |
| Population connected to urban waste water treatment plants | 6 | positive |
| Population served by sewerage | 6 | positive |
| Solar PV installed | 7 | positive |
| Average taxable income per capita | 8 | positive |
| Neet (15-29) | 8 | negative |
| Youngs aged 18-24 not enrolled in any educational course | 8 | negative |
| Public transportation availability | 9 | positive |
| Green firms | 9 | positive |

| | | |
|---|---|---|
| Connection infrastructure | 9 | positive |
| Gini index | 10 | negative |
| Cycling road | 11 | positive |
| People with no toilet | 11 | negative |
| Pm 2.5 emission | 11 | negative |
| Recycled waste | 12 | positive |
| Urban waste | 12 | negative |
| Incentive to recycling garden waste | 12 | positive |
| Public transportation mobility | 13 | positive |
| Bike sharing | 13 | positive |
| Propensity to public transportation | 13 | positive |
| CO2 emission | 13 | negative |
| Share area utilization | 15 | negative |
| Green urban areas per population | 15 | positive |
| Ecolabel licenses | 15 | positive |
| Political electoral participation | 16 | positive |
| Tribunal efficiency | 16 | negative |
| Firms rating | 16 | positive |
| Broadband penetration rate | 17 | positive |
| Propensity to association | 17 | positive |
| Social cooperatives | 17 | positive |

*Table 2 - Top and bottom 15 municipalities (Sustainability Index to Goal 5)*

| Municipality | S.I. | Municipality | Goal_1 | Municipality | Goal_2 | Municipality | Goal_3 | Municipality | Goal_4 | Municipality | Goal_5 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Trento | 2.182 | Bolzano | 1.910 | Torino | 5.609 | Terni | 2.323 | Cremona | 1.800 | Roma | 2.591 |
| Bolzano | 1.561 | Treviso | 1.736 | Parma | 1.933 | Sondrio | 1.824 | Padova | 1.794 | Lodi | 2.314 |
| Lodi | 1.534 | Pavia | 1.392 | Ferrara | 1.431 | Mantova | 1.823 | Trento | 1.739 | Torino | 2.250 |
| Cremona | 1.504 | Padova | 1.280 | Ravenna | 1.179 | Treviso | 1.811 | Bologna | 1.547 | Ancona | 2.203 |
| Mantova | 1.469 | Cremona | 1.278 | Pordenone | 0.949 | Forli' | 1.374 | Udine | 1.475 | Piacenza | 2.020 |
| Macerata | 1.462 | Novara | 1.274 | Bologna | 0.938 | Rimini | 1.256 | Rovigo | 1.376 | Savona | 1.924 |
| Padova | 1.376 | Trieste | 1.245 | Trento | 0.912 | Teramo | 1.180 | Parma | 1.326 | Vercelli | 1.840 |
| Pordenone | 1.308 | Rieti | 1.224 | Cremona | 0.901 | Perugia | 1.175 | Sondrio | 1.300 | Verbania | 1.777 |
| Forli' | 1.116 | Brescia | 1.203 | Belluno | 0.898 | Siena | 1.174 | Belluno | 1.272 | Alessandria | 1.645 |
| Verona | 1.109 | Varese | 1.144 | Bolzano | 0.871 | Campobasso | 1.166 | Modena | 1.167 | Bologna | 1.410 |
| Ferrara | 1.107 | Firenze | 1.137 | Como | 0.863 | Macerata | 1.094 | Ancona | 1.134 | Pavia | 1.405 |
| Siena | 1.022 | Lodi | 1.094 | Padova | 0.846 | Pistoia | 1.028 | Forli' | 1.111 | Pisa | 1.269 |
| Verbania | 0.961 | Matera | 0.994 | Modena | 0.828 | Venezia | 1.023 | Gorizia | 1.076 | Siena | 1.092 |
| Udine | 0.934 | Savona | 0.961 | Sondrio | 0.824 | Pordenone | 1.018 | Pavia | 1.058 | Milano | 0.986 |
| Bologna | 0.933 | Modena | 0.934 | Lecco | 0.806 | Gorizia | 0.973 | Verona | 1.042 | Firenze | 0.854 |
| … | … | … | … | … | … | … | … | … | … | … | … |
| Bari | -0.949 | Cosenza | -0.942 | Trapani | -0.965 | Alessandria | -0.789 | Foggia | -1.030 | Messina | -0.948 |
| Catanzaro | -1.009 | Gorizia | -0.964 | Agrigento | -0.965 | Enna | -1.089 | Brindisi | -1.097 | Massa | -0.994 |
| Caltanissetta | -1.038 | Roma | -1.023 | Messina | -0.965 | Palermo | -1.195 | Torino | -1.130 | Bari | -1.057 |
| Brindisi | -1.122 | Crotone | -1.031 | Matera | -0.981 | Catania | -1.240 | Caltanissetta | -1.133 | Ragusa | -1.111 |
| Frosinone | -1.428 | Vicenza | -1.131 | Potenza | -0.981 | Caltanissetta | -1.277 | Alessandria | -1.196 | Enna | -1.177 |
| Massa | -1.431 | Taranto | -1.198 | Campobasso | -1.408 | Agrigento | -1.303 | Massa | -1.204 | Agrigento | -1.417 |
| Taranto | -1.443 | Vibo valentia | -1.219 | Reggio di calabria | -1.523 | Messina | -1.335 | Prato | -1.270 | Taranto | -1.516 |
| Agrigento | -1.694 | Alessandria | -1.220 | Catanzaro | -1.523 | Pavia | -1.339 | Agrigento | -1.412 | Caltanissetta | -1.656 |
| Vibo valentia | -1.713 | Napoli | -1.283 | Cosenza | -1.523 | Genova | -1.376 | Trapani | -1.444 | Palermo | -1.672 |
| Palermo | -2.070 | Frosinone | -1.474 | Crotone | -1.523 | Torino | -1.666 | Taranto | -1.552 | Catania | -1.739 |
| Crotone | -2.123 | Palermo | -1.619 | Vibo valentia | -1.523 | Massa | -1.884 | Messina | -1.875 | Brindisi | -1.817 |
| Napoli | -2.425 | Trapani | -1.651 | Napoli | -1.747 | Napoli | -2.362 | Catania | -2.217 | Foggia | -1.910 |
| Trapani | -2.483 | Sondrio | -1.843 | Salerno | -1.769 | Milano | -2.383 | Crotone | -2.228 | Napoli | -1.969 |
| Catania | -2.681 | Agrigento | -3.675 | Avellino | -1.769 | Trapani | -3.062 | Palermo | -2.734 | Crotone | -1.972 |
| Messina | -2.851 | Messina | -4.264 | Benevento | -1.769 | Roma | -3.390 | Napoli | -3.120 | Trapani | -2.029 |

*Table 3 - Top and bottom 15 municipalities (Goal 6 to Goal 11)*

| Municipality | Goal_6 | Municipality | Goal_7 | Municipality | Goal_8 | Municipality | Goal_9 | Municipality | Goal_10 | Municipality | Goal_11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mantova | 1.678 | Padova | 3.963 | Milano | 1.902 | Milano | 2.346 | Vercelli | 1.627 | Bolzano | 1.777 |
| Foggia | 1.484 | Macerata | 3.658 | Siena | 1.759 | Trieste | 2.172 | La spezia | 1.603 | Oristano | 1.587 |
| Milano | 1.455 | Pesaro | 3.561 | Pavia | 1.758 | Venezia | 2.021 | Pistoia | 1.594 | Sondrio | 1.337 |
| Sondrio | 1.379 | Verona | 3.323 | Padova | 1.658 | Cremona | 1.815 | Rieti | 1.481 | Pesaro | 1.328 |
| Pavia | 1.360 | Oristano | 2.269 | Bergamo | 1.591 | Treviso | 1.663 | Alessandria | 1.481 | Ferrara | 1.136 |
| Piacenza | 1.291 | Cosenza | 2.160 | Belluno | 1.439 | Siena | 1.597 | Forli' | 1.457 | Mantova | 1.117 |
| Udine | 1.251 | Lodi | 1.955 | Treviso | 1.253 | Trento | 1.500 | Terni | 1.352 | Ravenna | 1.032 |
| Bergamo | 1.193 | Pordenone | 1.523 | L'aquila | 1.119 | Mantova | 1.422 | Ravenna | 1.344 | Forli' | 0.977 |
| Siena | 1.128 | Trento | 1.466 | Trento | 1.105 | Bologna | 1.376 | Nuoro | 1.328 | Verbania | 0.942 |
| Livorno | 1.119 | Como | 1.018 | Lodi | 1.072 | Parma | 1.145 | Asti | 1.279 | Lecce | 0.939 |
| Vicenza | 1.105 | Cremona | 0.918 | Roma | 1.047 | L'aquila | 1.137 | Taranto | 1.279 | Enna | 0.923 |
| Vercelli | 1.089 | Bergamo | 0.841 | Parma | 1.041 | Genova | 1.038 | Savona | 1.223 | Pistoia | 0.921 |
| Cremona | 1.018 | Vicenza | 0.821 | Bologna | 1.024 | Brescia | 1.009 | Rovigo | 1.207 | Modena | 0.883 |
| Macerata | 1.003 | Verbania | 0.790 | Varese | 0.989 | Bergamo | 0.942 | Livorno | 1.198 | Matera | 0.879 |
| Viterbo | 0.994 | Biella | 0.727 | Pisa | 0.917 | Como | 0.906 | Massa | 1.182 | Viterbo | 0.874 |
| … | … | … | … | … | … | … | … | … | … | … | … |
| Lucca | -0.977 | Vibo valentia | -0.703 | Alessandria | -0.972 | Nuoro | -1.118 | Firenze | -1.000 | Terni | -0.814 |
| Venezia | -1.082 | Reggio di calabria | -0.716 | Sassari | -1.092 | Lucca | -1.154 | Pescara | -1.008 | Brindisi | -0.883 |
| Pistoia | -1.090 | Campobasso | -0.717 | Ragusa | -1.202 | Pesaro | -1.156 | Cagliari | -1.121 | Asti | -0.897 |
| Crotone | -1.121 | Napoli | -0.750 | Verbania | -1.323 | Viterbo | -1.161 | Catania | -1.129 | Rovigo | -0.925 |
| Rieti | -1.147 | Trieste | -0.752 | Foggia | -1.361 | Grosseto | -1.257 | Palermo | -1.169 | L'aquila | -0.931 |
| Cosenza | -1.188 | Rovigo | -0.762 | Prato | -1.432 | Latina | -1.331 | Como | -1.242 | Como | -0.931 |
| Catanzaro | -1.291 | Torino | -0.766 | Brindisi | -1.555 | Massa | -1.335 | Varese | -1.266 | Benevento | -0.983 |
| Latina | -1.405 | Nuoro | -0.771 | Messina | -1.584 | Caltanissetta | -1.574 | Brescia | -1.339 | Vibo valentia | -1.435 |
| Palermo | -1.594 | Viterbo | -0.776 | Caltanissetta | -1.614 | Frosinone | -1.583 | Treviso | -1.622 | Napoli | -1.497 |
| Benevento | -1.787 | Varese | -0.782 | Taranto | -1.720 | Salerno | -1.595 | Padova | -1.792 | Milano | -1.535 |
| Campobasso | -1.869 | Latina | -0.795 | Crotone | -1.770 | Vibo valentia | -1.791 | Lecce | -1.816 | Lecco | -1.887 |
| Potenza | -1.939 | Palermo | -0.803 | Palermo | -2.353 | Ragusa | -1.793 | Napoli | -1.824 | Lucca | -2.204 |
| Frosinone | -2.019 | Lucca | -0.806 | Trapani | -2.425 | Crotone | -1.810 | Roma | -2.147 | Torino | -2.341 |
| Treviso | -2.926 | Enna | -0.830 | Napoli | -2.694 | Enna | -1.859 | Bergamo | -2.495 | Messina | -3.901 |
| Catania | -3.705 | Taranto | -0.830 | Catania | -3.221 | Trapani | -1.899 | Milano | -3.933 | Reggio nell'emilia | -4.742 |

*Table 4 - Top and bottom 15 municipalities (Goal 12 to Goal 17)*

| Municipality | Goal_12 | Municipality | Goal_13 | Municipality | Goal_15 | Municipality | Goal_16 | Municipality | Goal_17 |
|---|---|---|---|---|---|---|---|---|---|
| Belluno | 1.693 | Venezia | 3.520 | Matera | 5.207 | Enna | 3.192 | Bolzano | 3.086 |
| Treviso | 1.672 | Milano | 3.498 | Trento | 1.769 | Ferrara | 2.428 | Siena | 2.068 |
| Trento | 1.537 | Bologna | 1.946 | Potenza | 1.729 | Prato | 1.688 | Padova | 1.619 |
| Novara | 1.449 | Roma | 1.733 | Nuoro | 1.719 | Ravenna | 1.509 | Como | 1.543 |
| Nuoro | 1.380 | Trieste | 1.733 | Sondrio | 1.646 | Livorno | 1.431 | Cagliari | 1.533 |
| Pordenone | 1.320 | Siena | 1.518 | Oristano | 1.641 | Trento | 1.408 | Avellino | 1.533 |
| Macerata | 1.290 | Firenze | 1.493 | Enna | 1.205 | Pescara | 1.372 | Roma | 1.442 |
| Lodi | 1.254 | Brescia | 1.450 | Sassari | 1.205 | Rimini | 1.325 | Trento | 1.435 |
| Teramo | 1.252 | Cagliari | 1.342 | Ragusa | 1.060 | Cuneo | 1.266 | Firenze | 1.394 |
| Chieti | 1.241 | Torino | 1.315 | Verbania | 1.020 | Mantova | 1.246 | Potenza | 1.390 |
| Benevento | 1.171 | Genova | 1.300 | Caltanissetta | 0.906 | Verbania | 1.200 | Mantova | 1.319 |
| Mantova | 1.126 | Trento | 1.257 | Cuneo | 0.851 | Verona | 1.192 | Cremona | 1.273 |
| Gorizia | 1.103 | Parma | 1.178 | Cagliari | 0.846 | Torino | 1.170 | Pavia | 1.257 |
| Asti | 1.080 | Rimini | 1.053 | Agrigento | 0.791 | Bolzano | 1.148 | Modena | 1.213 |
| Cuneo | 1.051 | Verona | 0.916 | Gorizia | 0.758 | Milano | 1.139 | Benevento | 1.147 |
| ... | ... | ... | ... | ... | ... | ... | ... | ... | ... |
| Pavia | -0.865 | Alessandria | -0.789 | Cosenza | -0.793 | Foggia | -1.017 | Enna | -0.913 |
| Avellino | -1.034 | Lucca | -0.805 | Verona | -0.807 | Ragusa | -1.025 | Messina | -0.957 |
| Brindisi | -1.187 | Massa | -0.831 | Parma | -1.043 | Brindisi | -1.050 | Vibo valentia | -0.970 |
| Vibo valentia | -1.263 | Nuoro | -0.936 | Udine | -1.052 | Taranto | -1.077 | Catania | -0.997 |
| Foggia | -1.267 | Lecco | -0.965 | Modena | -1.053 | Catanzaro | -1.093 | Livorno | -1.002 |
| Grosseto | -1.408 | Catanzaro | -1.067 | Brescia | -1.283 | Bari | -1.134 | Napoli | -1.149 |
| Massa | -1.502 | Vercelli | -1.129 | Roma | -1.346 | Napoli | -1.138 | Imperia | -1.371 |
| Cagliari | -1.525 | Taranto | -1.130 | Napoli | -1.359 | Trapani | -1.237 | Agrigento | -1.533 |
| Crotone | -1.528 | Benevento | -1.241 | Bari | -1.404 | Cagliari | -1.335 | Catanzaro | -1.548 |
| Brescia | -1.536 | Oristano | -1.277 | Bologna | -1.695 | Agrigento | -1.494 | Brindisi | -1.626 |
| Siena | -1.707 | Lodi | -1.295 | Torino | -1.726 | Reggio di calabria | -1.534 | Massa | -1.861 |
| Trapani | -2.031 | Rovigo | -1.437 | Pescara | -1.770 | Cosenza | -1.749 | Crotone | -2.084 |
| Pisa | -2.082 | Gorizia | -1.536 | Firenze | -2.007 | Matera | -1.910 | Trapani | -2.116 |
| Catania | -2.543 | L'aquila | -2.033 | Milano | -2.337 | Oristano | -2.296 | Taranto | -2.190 |
| Pesaro | -4.560 | Viterbo | -2.896 | Padova | -2.349 | Messina | -2.953 | Caltanissetta | -2.772 |

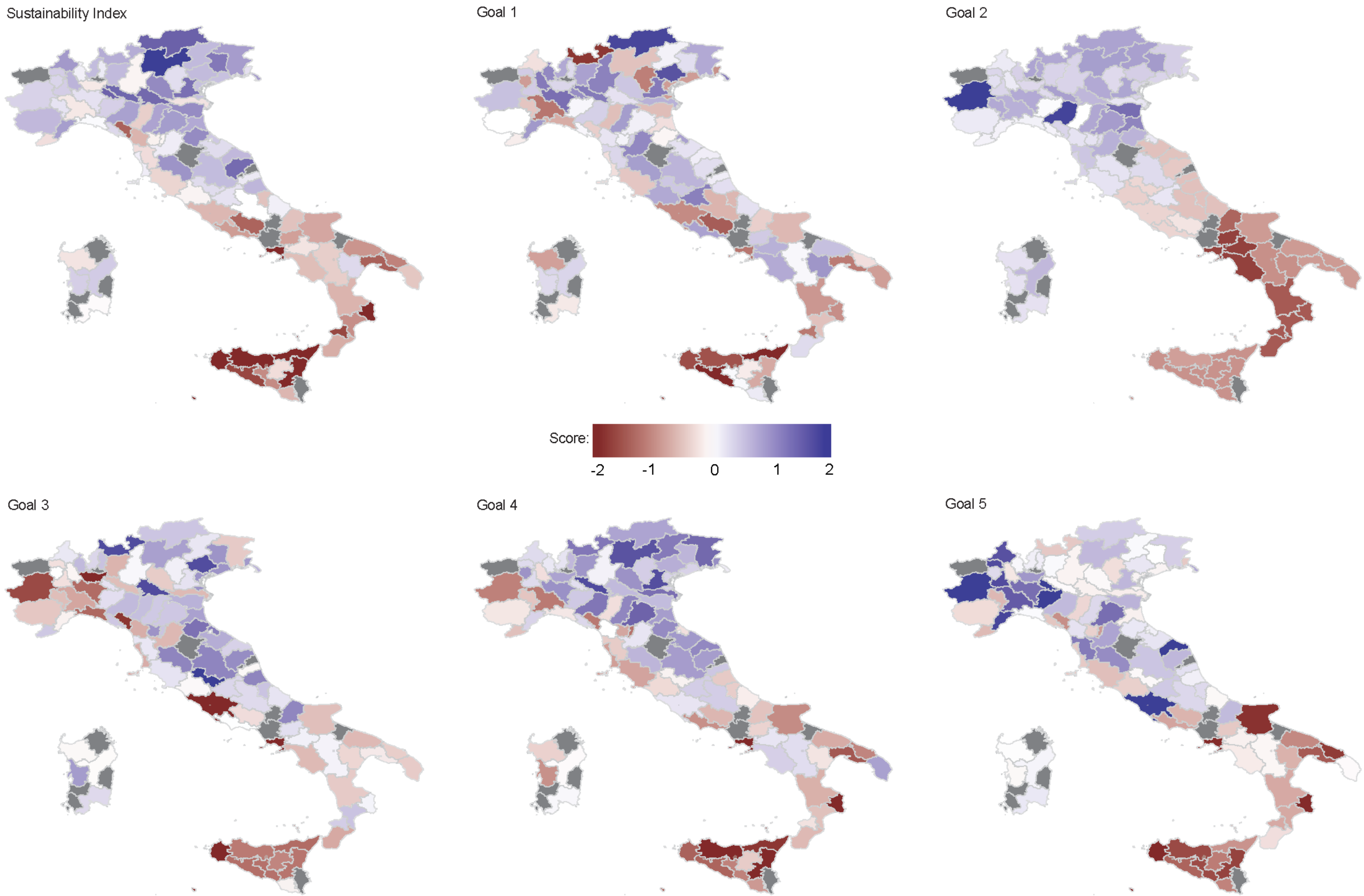


*Figure 2 - Map visualization of municipality's performance for each dimension considered (Sustainability Index, Goal 1 to Goal 5)*

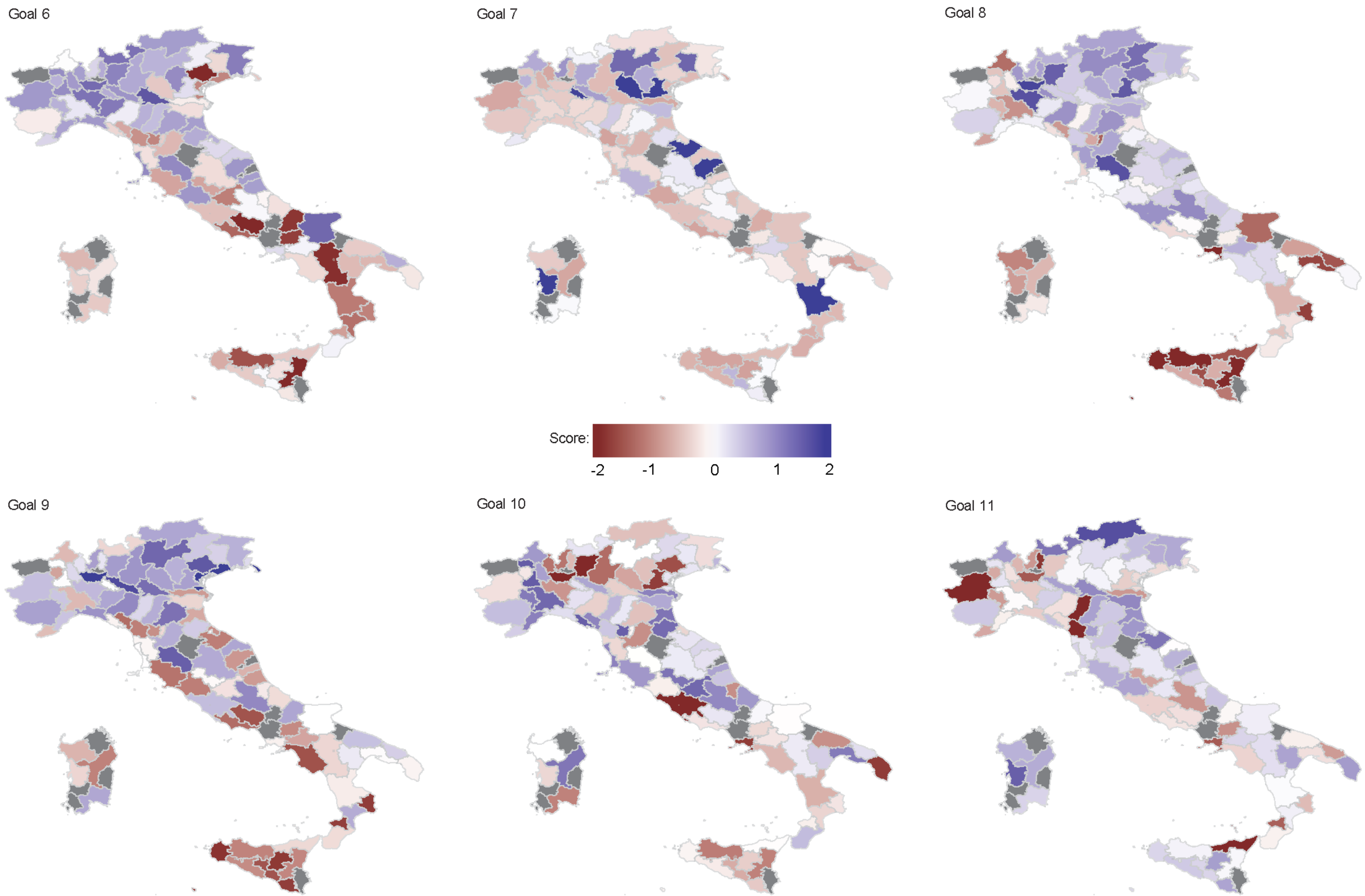


*Figure 3 - Map visualization of municipality's performance for each dimension considered (Goal 6 to Goal 11)*

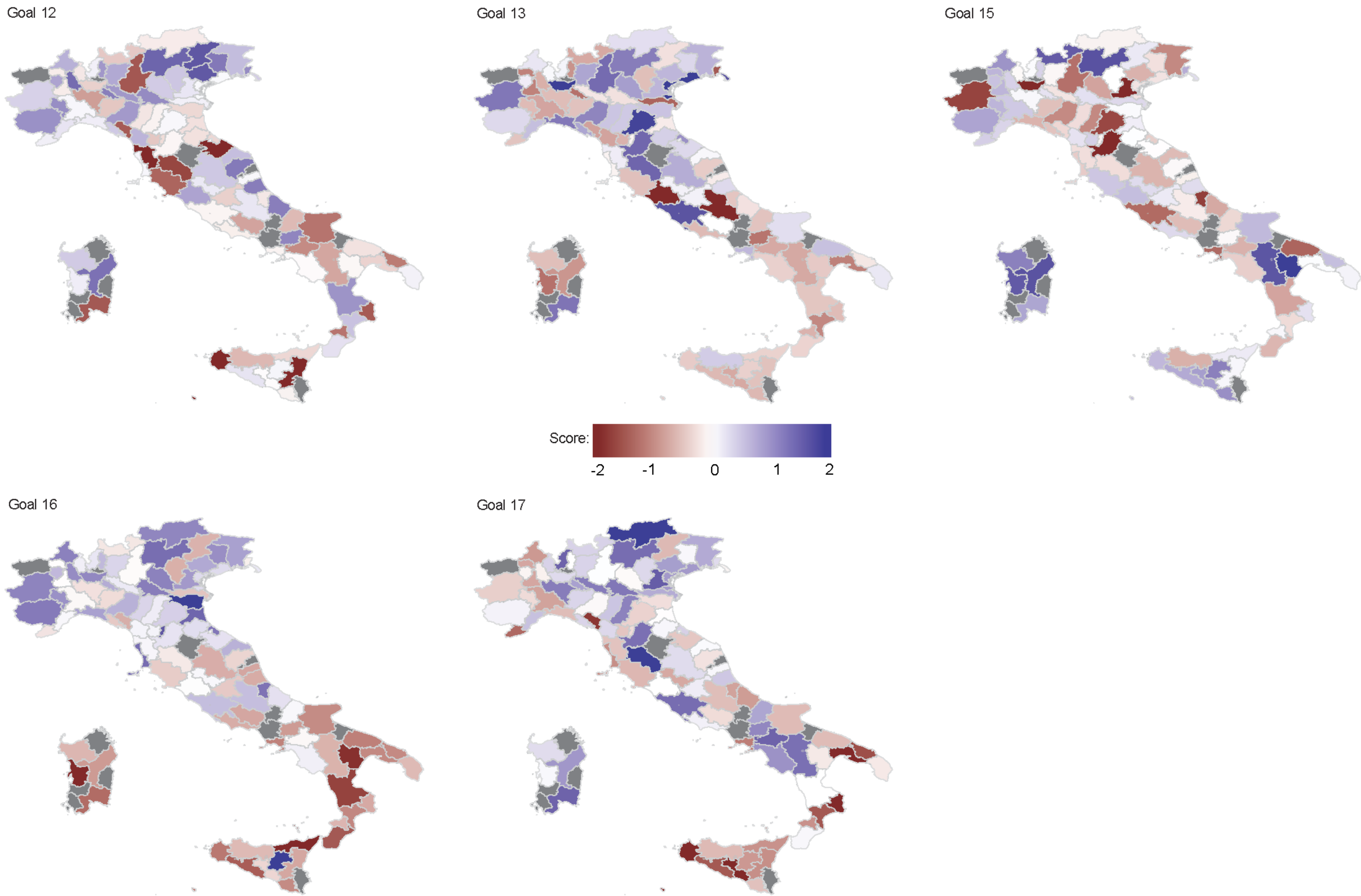


*Figure 4 - Map visualization of municipality's performance for each dimension considered (Goal 12 to Goal 17)*