D'Adamo, Idiano; Gastaldi, Massimo; Rosa, Paolo

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Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

This Version is available at:
http://hdl.handle.net/11159/7726

Assessing Environmental and Energetic Indexes in 27 European Countries

Idiano D'Adamo[1]*, Massimo Gastaldi[2], Paolo Rosa[3]

[1]Sapienza University of Rome, Rome, Italy, [2]University of L'Aquila, L'Aquila, Italy, [3]Politecnico di Milano, Italy.
*Email: idiano.dadamo@uniroma1.it

ABSTRACT

The present work wants to assess the environmental and energetic sustainability of 27 European countries. To this aim, a Multi-criteria decision analysis and an analytical hierarchy process has been implemented to gather and process information from the experts. Results show that only four countries (Sweden, Denmark, Finland and Austria) present very significant performances. The intervention of policymakers must be clear, by penalizing non-responsible behavior, encouraging the development of circular and green practices, also through the exploitation of subsidies. A continuous monitoring of values over time and the identification of more appropriate criteria to evaluate performances, including economic and social views, are objectives to be addressed in the next future.

Keywords: Energy Efficiency, Greenhouse Gas Emissions, Multicriteria Analysis, Renewable Energy, Sustainability, Waste Management
JEL Classifications: Q20; Q40; Q50

1. INTRODUCTION

Sustainability is a major challenge in which multiple actors and sectors are involved (Ozturk, 2017). Its measurability is not easy because there are many variables to consider and the literature tries to identify indexes that want to support decision-making choices and indicate how performance varies. Literature analysis shows that the identification of sustainability indexes is an emerging trend in sustainability research (Olawumi and Chan, 2018).

The role of the indicators is to synthesize a multiplicity of information, providing indications on which directions to take and which are the margins for improvement (Guliev et al., 2020). The aim of sustainable indicators is oriented to reduce the complexity of each step in order to help governments achieve sustainable targets (Dizdaroglu, 2017). In this regard, there is a tendency to compare countries in order to identify best practices and to understand which policy instruments have enabled certain performances to be achieved (Hasnisah et al., 2019; Obadi and Korcek, 2020).

In this line of research, the indexes emphasize the relevance of certain aspects such as CO_2 emissions and material footprint (Hickel, 2020), renewable energy and government expenditure (Le et al., 2020), energy efficiency (de la Cruz-Lovera et al., 2017) and end-of-life management of wastes (Sassanelli et al., 2019). In particular, some authors had highlighted the importance of considering the environment and energy topics and an index, in terms of sustainability value, was proposed to compare European countries (Cucchiella et al., 2017). The European Union aims to be climate-neutral by 2050 – an economy with net-zero greenhouse gas emissions. Literature tends to focus on the current study of sustainable development and rarely study future projections (Kwatra et al., 2020).

The methodology used in this work is a Multi-Criteria Decision Analysis (MCDA) method associated with an Analytical Hierarchy Process (AHP). This study aims to present a snapshot in two separate years (2017 and 2018) based on historical data collected by Eurostat but comparing it to data recorded 5 years earlier. The comparison allows to highlight the overall performance of

individual countries and to break down the analysis to a more disaggregated level. To this aim, sustainability levels will be linked to: (i) reduction of emissions; (ii) End of Life management of wastes (e.g. Waste from Electric and Electronic Equipment (WEEEs), Municipal Solid Wastes (MSWs) End-of-Life Vehicles (ELVs)); (iii) renewables and (iv) energy efficiency. In addition, a panel of experts from different stakeholder categories will be used to identify the weight of individual criteria within the index.

The paper is structured as follows. Section 2 presents the research methodology. Section 3 shows the main results. Section 4 concludes the paper and offers some recommendations for future researches.

2. METHODS AND METHODOLOGY

The main advantage of MCDA is its flexibility that it can be adapted in different contexts of analysis considering several variables and opinions (Nuriyev, 2020). The goal of the analysis is to identify the best option by aggregating weights and values associated with the criteria. MCDA integrates the score associated to each alternative (i.e. scoring criterion) and the weight assigned to the relevance of each criterion (Kumar et al., 2017). The AHP methodology identifies a list of priorities through pairwise comparisons based on expert judgments (Saaty, 2008).

In this framework, an integrated MCDA-AHP can be used to measure sustainable performance and can be applied to compare European countries (D'Adamo et al., 2020). This work considers a sustainable index in the Environment and Energy (EE) topic (Cucchiella et al., 2017) obtaining by the product between the row vector (I), that represents the value of each criteria and the column vector (W), that represents the weight of each criteria. It is a dimensionless value and 27 member states identified as alternative projects (J).

$$S_{EE,J} = I_{EE,J} * W_{EE,J} * 100 \qquad (1)$$

Some selected indicators within Eurostat identified criteria used in this analysis. Specifically, they are closely relate to the concept of sustainability within the topic environment and energy (Table 1). Starting from the nine indicators selected in the previous step of the research (Cucchiella et al., 2017), all were confirmed, only energy efficiency replaced the percentage change of primary energy consumption in a specific period. GhCo, GeEp, RrWe, RrEl and RmMs identified within Environment topic, while ReEl, ReTr, ReHc and EnEf proposed within Energy topic.

2.1. Identification of Value to Each Criterion
Starting from the selected criteria it was possible to construct the row vector composed of nine columns as follows:

$$I_{EE,J} = v_{GhCo} \ v_{GeEp} \ v_{RrWe} \ v_{RrEl} \ v_{RmMs} \ v_{ReEl} \ v_{ReTr} \ v_{ReHc} \ v_{EnEf} \qquad (2)$$

Eurostat provides these data and this makes it possible to reduce the degree of subjectivity by making comparisons between several countries more truthful. The previous analysis referred to 2013, while in this one we considered the most recent values available.

Table 1: List of criteria

Acronym	Criteria	Unit of measure
GhCo	Greenhouse gas emissions	Tons of CO_2eq per capita
GeEp	Total government expenditures for environmental protection actions	€ per capita
RrWe	Total recycled and reused waste from WEEEs	Kilograms per capita
RrEl	Total recycled and reused waste from ELVs	Kilograms per capita
RmMs	Total recycled materials from MSWs	Kilograms per capita
ReEl	Share of renewable energy in electricity	Percentage
ReTr	Share of renewable energy in transport	Percentage
ReHc	Share of renewable energy in heating and cooling	Percentage
EnEf	Energy Efficiency	Index, 2005=100

We had considered 2 years: 2017 and 2018. Specifically four hundred and seventy-seven of the four hundred and eighty-six values needed were available, and for the missing values, we assumed the value from the last available year (Cyprus in 2018 for RmMs; Malta, Romania e Slovenia in 2018 for RrEl and Cyprus, Malta, Portugal in 2018 and Romania in both 2017 and 2018 for RrWe. In addition, some indicators (RrWe, RmMs, ReEl, ReHc, ReTr and EfPc) proposed in the appropriate unit of measurement, while others (GhCo, GeEp and RrEl) modified dividing them by the population. In fact, all values must be comparable regardless of country size.

2.2. Identification of Weight to Each Criterion
As in the previous sub-section, starting from the selected criteria it was possible to construct the column vector composed of nine rows as follows:

$$W_{EE,J} = [w_{GhCo} \ w_{GeEp} \ w_{RrWe} \ w_{RrEl} \ w_{RmMs} \ w_{ReEl} \ w_{ReTr} \ w_{ReHc} \ w_{EnEf}{}^T] \qquad (3)$$

The robustness of the results can be guarantee by some characteristics: the number of the experts equal to twenty (Subramoniam et al., 2013) and their experience of almost 10 years were considered (D'Adamo et al., 2020). While in the previous phase of the research only academics had chosen, in this one the analysis regarded academics, policy makers, managers and representatives of trade associations. Experts were identified through a message posted on Linkedin, in which was requested an experience of at least 10 years on the topic of sustainability. Experts were twelve men and eight women coming from European countries (Table 2). The expert responses collected through a survey during the period December 2020–January 2021. It composed by a video-call in which the purpose and methodology were explained, after a practical example of calculation was carried out and finally, observations on the topic by the interviewee were collected. AHP weights were evaluated according to a judgement scale on a nine-point scale (Saaty, 2008) and was normalized using the approach of (Belton and Gear, 1983) in order to compare them. In order to optimize time processing an Excel file was provided to the experts such that they could check the value of the consistency

Table 2: List of experts

No.	Role	Country	No.	Role	Country
1	Policy maker	Belgium	11	Manager	Italy
2	Policy maker	Austria	12	Manager	Germany
3	Policy maker	Spain	13	Manager	Sweden
4	Policy maker	France	14	Manager	Finland
5	Policy maker	Romania	15	Manager	Denmark
6	Academic	Latvia	16	Trade association	Italy
7	Academic	Germany	17	Trade association	France
8	Academic	Spain	18	Trade association	Netherlands
9	Academic	Portugal	19	Trade association	Greece
10	Academic	Czech Republic	20	Trade association	Poland

ratio (CR) verifying if was lower than 0.10 (Saaty, 2008). CR is calculated by dividing the consistency index (CI) with the Random Inconsistency (RI). CI is obtained in function of λ_{max} that is the inner product of the row vector containing column sums and the Eigen vector matrix, while RI is equal to 1.45, identified by the number of factors (n).

$$CR=CI/RI=((\lambda_{max}-n)/(n-1))/RI \qquad (4)$$

3. RESULTS

The application of equations (1)-(3) permits to calculate the sustainable index applied to the specific topic of Environment and Energy. It is obtained multiplying the row vector composed by nine columns (1, 9) and the column vector composed by nine rows (9, 1). The analysis is repeated in 2 years, but the weight proposed by the column vector are not modified.

3.1. Assessment of Value to Each Criterion

The criteria have different units but their comparison is possible through normalization. A value of 1 is assigned to the best performance and 0 to the worst performance. All other values will take intermediate values. For eight of the nine criteria the maximum value is associated with 1, only for the GhCo criterion the minimum value is associated with 1. To understand these calculations, it is useful to introduce an example. Analyzing the percentage of renewable energy in electricity, Austria has the highest percentage 74.2% (therefore we associate the value 1), while Malta has the lowest 7.7% (taking the value 0). Belgium with a percentage of 18.9% assumes an intermediate value of 0.17. The same was repeated for the other 24 European countries and the same procedure was applied to the remaining criteria – Table 3.

The value analysis shows that Sweden occupies the first position in four of the nine criteria (GhCo, RrWe, ReTr and ReHc). In the others, Luxembourg, Ireland and Germany lead for GeEp, RrEl and ReEl, respectively. There is no difference between 2017 and 2018. The only exception is the criteria EnEf, in which Estonia and Poland show the best-performing result in 2018 and 2017, respectively. The limitation of the normalized approach is that it not only measures the value of the country examined but also depends on the performance of the best country. Table 4 shows the difference between 2 years and for example, EU27 shows an increase of 0.03 in terms of GhCo in 2018 than 2017.

The comparison highlights the following observations for the individual criteria:

- Sweden leads with a value of 0.97 tons of CO_2eq per capita regarding GhCo with positive increases associated to Portugal and Estonia, while negative assessments are verified for Latvia and Finland
- Concerning GeEp there is no significant variation with the leadership played by Luxembourg (from 814 to 869 € per capita)
- In the field of RrWe, Sweden goes from 11.74 to 11.82 kg per capita with increases for Ireland and Spain, while a negative performance is registered for Czechia
- Regarding RrEl Ireland has a significant increase (from 26.79 to 30.80 kg per capita) and for this change, we have negative performances of Finland, Denmark Bulgaria and Sweden while France has an increase
- Germany decreases its value from 307 to 298 kg per capita in the field of RmMs determining no negative significant change, while Denmark, Slovakia and Finland have a positive assessment
- Austria leads with a value of 74.2% (+2.6% than the previous year) concerning ReEl with a negative performance of Portugal
- In the field of ReTr several countries show a reduction of their value, in particular Finland and Ireland. Sweden occupies the first position with 29.7% (from 26.8% in 2017)
- Concerning ReHc Sweden has a value of 65.3% (−0.4% than the previous year) and a significant increase is registered for Cyprus
- Poland increases its value from 113 to 115 Index, 2005=100 in the field of EnEf, but Estonia shows a greater increase (from 112 to 122 Index, 2005=100). Also Lithuania has a positive increase while several countries have negative assessments (in particular Austria, Belgium and Poland).

3.2. Assessment of Weight to Each Criterion

The collection of all responses of weights underlines the goodness of the proposed estimates (all CR are lower than 0.10). In particular, it emerged that twelve of the twenty experts did not identify a criterion that is more dominant than all others (Table 5). Also in this phase of the work, we introduce an example to show our calculations. Analyzing the expert 1 two criteria (RrWe and ReTr) have the highest weight of 14%. All experts have the same relevance and by aggregating the different contributions, it is possible to calculate the average value.

The AHP results show that the weight of the five environmental criteria is greater than the four energy criteria (54.5% vs. 45.5%) and generally, the experts highlight that the most relevant criterion is ReEl (awarded by eleven of the twenty respondents) with an average value of 13.90%. ReTr (13.25%) and ReHc (12.15%) also mark high values. Renewables confirm their leading role towards the decarbonization of the energy system and their growth has been vertiginous in recent years. Subsidies have played a key role, but technological development has enabled significant cost reductions by creating the conditions for grid parity. In addition, a particular attention is associated to the green growth in transport, which is the sector with the greatest gap to fill towards future European objectives.

Table 3: Normalized row vector in 2018

	GhCo	GeEp	RrWe	RrEl	RmMs	ReEl	ReTr	ReHc	EnEf
EU 27	0.58	0.23	0.55	0.40	0.46	0.37	0.21	0.25	0.37
Belgium	0.42	0.57	0.70	0.44	0.43	0.17	0.15	0.04	0.35
Bulgaria	0.63	0.01	0.43	0.42	0.36	0.22	0.20	0.46	0.44
Czechia	0.28	0.14	0.56	0.47	0.27	0.09	0.15	0.25	0.43
Denmark	0.47	0.19	0.81	0.67	0.87	0.82	0.16	0.67	0.38
Germany	0.44	0.23	0.70	0.16	1.00	0.45	0.20	0.14	0.34
Estonia	0.22	0.12	0.47	0.44	0.28	0.18	0.03	0.80	1.00
Ireland	0.23	0.24	0.89	1.00	0.56	0.38	0.17	0.00	0.48
Greece	0.55	0.21	0.26	0.09	0.20	0.28	0.06	0.41	0.00
Spain	0.67	0.22	0.41	0.49	0.23	0.41	0.16	0.19	0.35
France	0.67	0.38	0.72	0.71	0.40	0.20	0.24	0.26	0.36
Croatia	0.78	0.05	0.75	0.20	0.27	0.61	0.00	0.52	0.32
Italy	0.66	0.24	0.41	0.51	0.44	0.39	0.19	0.22	0.15
Cyprus	0.46	0.02	0.25	0.21	0.25	0.03	0.00	0.53	0.60
Latvia	0.64	0.04	0.25	0.13	0.21	0.69	0.08	0.83	0.63
Lithuania	0.70	0.00	0.24	0.26	0.33	0.16	0.06	0.67	0.09
Luxembourg	0.00	1.00	0.70	0.13	0.79	0.02	0.15	0.04	0.40
Hungary	0.69	0.01	0.42	0.00	0.32	0.01	0.19	0.20	0.39
Malta	0.78	0.33	0.28	0.19	0.16	0.00	0.20	0.29	0.32
Netherlands	0.37	0.72	0.63	0.33	0.43	0.11	0.26	0.00	0.38
Austria	0.54	0.14	0.87	0.15	0.45	1.00	0.27	0.47	0.48
Poland	0.45	0.02	0.41	0.41	0.23	0.08	0.11	0.15	0.85
Portugal	0.69	0.09	0.37	0.25	0.15	0.67	0.24	0.59	0.35
Romania	0.77	0.04	0.00	0.01	0.00	0.51	0.14	0.33	0.33
Slovenia	0.53	0.08	0.37	0.04	0.67	0.37	0.11	0.42	0.44
Slovakia	0.63	0.10	0.34	0.17	0.32	0.21	0.16	0.08	0.34
Finland	0.54	0.04	0.90	0.61	0.51	0.44	0.56	0.82	0.50
Sweden	1.00	0.22	1.00	0.73	0.39	0.88	1.00	1.00	0.43

Table 4: Delta normalized row vector 2018–2017

	GhCo	GeEp	RrWe	RrEl	RmMs	ReEl	ReTr	ReHc	EnEf
EU 27	0.03	0.00	0.02	0.01	0.02	–0.01	–0.06	0.00	–0.07
Belgium	0.02	–0.03	0.05	0.02	0.02	0.01	–0.08	0.00	–0.17
Bulgaria	0.04	0.00	–0.04	–0.09	0.02	0.03	–0.06	0.06	–0.08
Czechia	–0.01	0.02	–0.14	–0.02	0.01	–0.01	–0.09	0.01	–0.08
Denmark	0.00	–0.02	–0.05	–0.11	0.12	0.00	–0.09	0.02	–0.04
Germany	0.05	–0.01	0.01	–0.01	0.00	0.03	–0.05	0.01	–0.10
Estonia	0.08	0.01	0.05	0.00	0.01	0.02	0.03	0.04	0.03
Ireland	0.05	0.00	0.15	0.00	–0.01	0.03	–0.10	–0.01	–0.07
Greece	0.03	–0.02	0.02	0.02	0.01	0.00	–0.08	0.03	0.00
Spain	0.02	–0.01	0.08	0.07	0.00	–0.04	–0.04	–0.01	–0.08
France	0.03	0.02	–0.01	0.14	0.02	0.00	–0.08	0.01	–0.06
Croatia	0.03	0.00	0.08	0.02	0.03	0.00	–0.03	0.00	–0.09
Italy	0.03	–0.02	0.02	–0.03	0.04	–0.03	–0.04	–0.02	–0.01
Cyprus	0.04	–0.01	0.00	0.05	0.01	–0.01	–0.08	0.18	–0.12
Latvia	–0.10	0.01	0.03	–0.01	0.02	–0.04	0.01	0.02	0.00
Lithuania	0.02	–0.02	0.03	–0.04	0.02	–0.01	–0.08	–0.01	0.09
Luxembourg	0.00	0.00	–0.03	0.06	0.03	0.00	–0.08	0.01	0.03
Hungary	0.01	0.00	0.05	0.00	0.04	0.00	–0.09	–0.03	–0.07
Malta	0.01	0.10	0.00	–0.05	–0.03	0.00	–0.04	0.06	0.00
Netherlands	0.04	0.00	–0.01	–0.03	0.02	0.01	0.05	0.00	–0.07
Austria	0.04	0.00	–0.02	–0.02	0.01	0.00	–0.08	0.01	–0.18
Poland	0.02	0.02	0.05	–0.05	0.00	–0.02	–0.03	0.00	–0.15
Portugal	0.13	0.01	0.00	–0.01	0.01	–0.06	–0.05	0.00	–0.07
Romania	0.02	0.04	0.00	–0.01	0.00	–0.03	–0.09	–0.02	–0.04
Slovenia	0.00	0.02	0.01	–0.01	0.05	–0.02	0.03	–0.04	–0.10
Slovakia	0.00	0.00	0.03	0.00	0.12	–0.02	–0.08	0.01	–0.11
Finland	–0.08	0.00	0.01	–0.15	0.09	0.00	–0.14	0.01	–0.03
Sweden	0.00	–0.01	0.00	–0.08	–0.03	–0.03	0.00	0.00	–0.06

The development of closed models of the life cycle of products has focused attention on the contribution that waste management has not only in the conversion of production processes, but also in the responsibility that citizens have in making a proper collection. Reuse and recycling practices are growing strongly; also in this, the policy maker has played a key role through directives that

Table 5: Normalized column vector

Expert	GhCo	GeEp	RrWe	RrEl	RmMs	ReEl	ReTr	ReHc	EnEf
1	0.12	0.05	0.14	0.11	0.12	0.13	0.14	0.13	0.06
2	0.11	0.06	0.12	0.11	0.13	0.14	0.16	0.11	0.06
3	0.14	0.08	0.11	0.14	0.12	0.13	0.12	0.10	0.06
4	0.11	0.07	0.15	0.10	0.11	0.16	0.12	0.11	0.07
5	0.11	0.08	0.11	0.12	0.11	0.13	0.13	0.14	0.07
6	0.12	0.07	0.12	0.13	0.12	0.14	0.13	0.09	0.08
7	0.15	0.04	0.13	0.10	0.13	0.15	0.14	0.11	0.05
8	0.13	0.06	0.14	0.11	0.14	0.13	0.12	0.13	0.04
9	0.09	0.08	0.12	0.12	0.12	0.14	0.13	0.14	0.06
10	0.12	0.05	0.13	0.13	0.12	0.14	0.14	0.12	0.05
11	0.11	0.07	0.12	0.11	0.12	0.12	0.13	0.14	0.08
12	0.14	0.06	0.11	0.12	0.13	0.14	0.14	0.10	0.06
13	0.12	0.08	0.11	0.13	0.12	0.14	0.11	0.12	0.07
14	0.12	0.06	0.10	0.12	0.11	0.16	0.16	0.10	0.07
15	0.09	0.06	0.14	0.10	0.14	0.14	0.13	0.15	0.05
16	0.11	0.05	0.13	0.14	0.11	0.12	0.13	0.14	0.07
17	0.15	0.05	0.13	0.13	0.12	0.15	0.12	0.11	0.04
18	0.14	0.05	0.12	0.12	0.11	0.13	0.14	0.13	0.06
19	0.12	0.06	0.11	0.11	0.12	0.15	0.13	0.12	0.08
20	0.12	0.06	0.12	0.11	0.12	0.14	0.13	0.14	0.06
Avg	0.1210	0.0620	0.1230	0.1180	0.1210	0.1390	0.1325	0.1215	0.0620

have favored circular economy models and through economic incentives. RrWe has a weight of 12.30% followed by RmMs (12.10%) and RrEl (11.80%).

In addition, experts highlight the contribution deriving from the criterion that is the main objective of the current challenges, climate change and therefore the reduction of pollutant emissions that cause serious damage to people's health and the environment (GhCo has a weight of 12.10%). There is no significant difference between these seven first criteria (ReEl and RrEl have a difference of about 2.10%). This shows how it was very difficult for the experts to identify these values but that according to their assessment the goal of sustainability is complex and characterized by multiple actions involving different criteria. Lower values are assigned to the two remaining criteria: both GeEp and EnEf have a weight equal to 6.20%. Compared to the previous expert panel composed only of academics there is a reduction in relevance assigned to ReEl (about 2%) and a 1% reduction for other criteria (RrWe, GhCo, GeEp and EfPc). Instead, RmMs and RrEl record a growth by 2% and ReTr by 1% (Cucchiella et al., 2017).

3.3. Assessment of Sustainability Index

The last step in the analysis is the aggregation of the values (I_{EE}, Tables 3 and 4) and weights (W_{EE}, Table 5) of the different criteria. For example, the product between the row and column vectors is proposed in the following equations applied to the value of the EU27 in both 2018 and 2017. Table 6 shows the sustainability index (S_{EE}) for all European countries.

$$S_{EE,EU27}(2018)=0.58*0.12+0.23*0.05+0.55*0.14+0.40*0.11$$
$$+0.46*0.12+0.37*0.13+0.21*0.14+0.25*0.13+0.37*0.06 \quad (5)$$

$$S_{EE,EU27}(2017)=(0.55*0.12+0.23*0.05+0.53*0.14+0.39*$$
$$0.11+0.45*0.12+0.37*0.13+0.27*0.14+0.25*$$
$$0.13+0.44*0.06)*100=39.10 \quad (6)$$

Results show that Sweden maintains a significant leadership in this ranking with a value twenty points higher than second. In particular, Denmark has overtaken Finland in the last year. The presence of top four countries were underlined also in 2014 and in this work, these have a reduction in their sustainability value in 2018 compared to 2017. This highlights how even the leading countries are challenged to confirm themselves in their performance. These values are strongly associated with the performance of the nine criteria, as the distribution of weights did not show significant differences for seven criteria. Looking specifically at the best performing countries, Sweden not only ranks first in four criteria, but also has high values in RrEl and ReEl. There has been a significant reduction in the value of RrEl. However, analysis of the data shows that Sweden has +0.9 kg per capita, which should be interpreted as a less significant increase than the leading country (Ireland +4 kg per capita). Reductions in values are registered for the other two of the top four countries: slight for Denmark (–0.1 kg per capita) and greater for Finland (+1.4 kg per capita). Both are characterized by the reduction in the value of ReTr in which Finland reduces its performance by 1.1%, and Denmark does not show a change, but the leading country (Sweden) has an increase of 2.9%. Denmark shows significant performance in the RmMs, ReEl and RrWe criteria and Finland on the other hand in ReHc and RrWe. Austria leads the ReEl criterion and has a high performance in RrWe. In addition, in this case, despite the 0.2% increase, the value of ReTr is reduced and there is a reduction in EnEf. It should be noted that all these countries show a reduction in GeEp. In its current form, this criterion fails to include other potential interesting items and therefore represents a limitation.

In terms of sustainability index, Finland and Czechia show the greatest decrease with around 3.5, while Estonia shows the greatest increase with 3 in 2018 compared to 2017. In terms of ranking Estonia and Croatia gain four and two positions, respectively. Instead, Czechia loses three in 2018 than the previous year. The analysis of the comparison of the ranking in 2018 compared to

Table 6: Sustainability index in environment and energy

|	Ranking		Sustainable index			
No.	Δ2018–2013*	Member State	2018	2017	2013	Δ2018–2017
1	0	Sweden	79.45	81.65	80.70	−2.20
2	0	Denmark	59.41	61.21	55.00	−1.81
3	0	Finland	57.76	61.31	50.80	−3.55
4	0	Austria	51.64	53.42	50.10	−1.78
5	−5	Ireland	44.32	43.39	38.10	0.93
6	0	France	43.94	43.09	39.70	0.85
7	−1	Germany	42.06	42.47	38.50	−0.40
8	−3	Croatia	41.19	40.11	37.90	1.08
9	0	Portugal	40.00	40.38	38.20	−0.37
10	−2	Latvia	39.80	40.63	37.70	−0.84
		EU 27	38.68	39.10	37.10**	−0.42
11	6	Italy	37.45	37.98	42.10	−0.53
12	−15	Estonia	36.58	33.55	19.10	3.03
13	1	Bulgaria	36.32	37.15	35.50	−0.82
14	1	Spain	35.49	35.25	35.70	0.24
15	−1	Belgium	34.65	35.63	33.50	−0.98
16	1	Slovenia	34.43	34.80	33.70	−0.38
17	−2	Netherlands	33.09	32.44	29.60	0.65
18	−2	Luxembourg	31.07	31.18	27.50	−0.11
19	12	Lithuania	30.30	30.97	39.60	−0.67
20	−1	Czechia	28.91	32.44	27.40	−3.52
21	−4	Poland	27.92	29.15	24.60	−1.23
22	−4	Malta	27.33	27.18	21.20	0.15
23	−1	Slovakia	26.56	26.65	26.00	−0.09
24	2	Hungary	25.06	25.84	26.70	−0.78
25	8	Romania	24.75	26.50	31.60	−1.75
26	3	Cyprus	24.71	23.38	26.60	1.33
27	9	Greece	24.18	23.85	29.60	0.33

*United Kingdom is not considered in the ranking of 2013. **Data referred to EU 28

2013 underlines significant changes. On the one hand, Ireland improves by five positions and Croatia and Latvia show an increase of three and two positions, respectively. However, it is the temporal performance of Estonia that is the protagonist of a very substantial increase (it gains fifteen positions). On the other hand, Lithuania has the worst performance, with a drop of twelve positions, and negative performances are registered for Greece, Romania and Italy, which show a drop of nine, eight and six positions, respectively.

European countries can be compared using the average by identifying who has a higher or lower value; otherwise another approach (D'Adamo et al., 2020) is to identify three distinct groups based on a hypothetical interval (i.e. from −15% to +15%) in 2018 (Figure 1):
- "Virtuous" (>15%): Sweden, Denmark, Finland and Austria
- "In-between" (±15%): Ireland, France, Germany, Croatia, Portugal, Latvia, Estonia, Bulgaria, Spain, Belgium, Slovenia and Netherlands
- "Laggard" (<15%): Luxembourg, Lithuania, Czechia, Poland, Malta, Slovakia, Hungary, Romania, Cyprus and Greece.

Looking at the previous year, there is only one difference related to Czechia that was an in-between country. Values of sustainability index show how European countries are sub-divided according to geographical location: Northern countries have the highest performance and Austria is added. Instead, Eastern European countries show lesser results. Among these, Latvia, Estonia and Bulgaria are the exceptions, having better results. The

Figure 1: Subdivision of EU27 countries into three groups
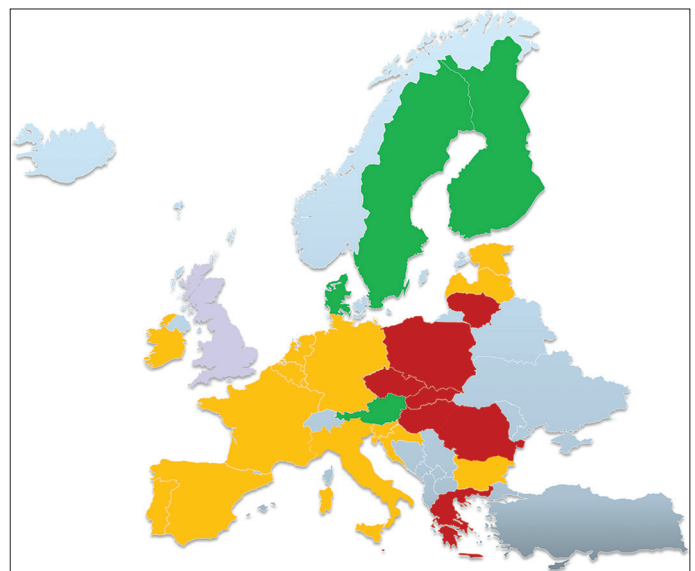
sustainability index depends on both row and column vector. The former has already been made to vary considering both 2018 and 2017. The second could be proposed in this paper considering that all criteria have the same weight. In this scenario the average European value is 37.90 with reductions for the four top countries (Sweden −5.5, Denmark −3.3, Finland −3.1 and Austria −3.0) and an increase for Luxembourg (+4.8), Netherlands (+2.8) and Estonia (+2.7). However, we prefer to use the AHP because the experts

allow identifying a more solid result being based on a known and shared methodology.

4. CONCLUSION

The topic of sustainability is extremely broad and an index does not purport to be exhaustive. Data availability is a current issue and the literature aims to propose different numerical evaluations in order to define the current performance of countries and identify possible actions to improve future performance. Environment and energy are two concepts that will play a key role in the Next Generation EU in which several resources can enable a green transition. Our results show that the situation in European countries is significantly different. Four countries (Sweden, Denmark, Finland and Austria) present very significant performances and can be defined as virtuous. The experts highlighted how the topic of renewable energy is growing strongly where those who produce more than they need could become exporters of that clean energy. The theme of end-of-life practices has transformed the concept of waste, but it is worth highlighting that there are not always elements of value to be recovered, but how sometimes it is necessary to minimize the risks associated with their management. In this direction, it is necessary to increase the self-sufficiency of individual countries that cannot transfer their problem to other territories. The intervention of the policy maker must be clear, penalizing non-responsible behavior, encouraging the development of circular and green practices, also with the help of subsidies. The monitoring of values over time and the identification of more appropriate criteria for evaluating performance in these areas, including more economic and social evaluations, are objectives to be addressed in future research.

NOMENCLATURE

AHP	Analytic Hierarchy Process
CR	Consistency Ratio
EnEf	Energy Efficiency
GeEp	Total general government expenditures for environmental protection actions
GhCo	Greenhouse gas emissions
EE	Environment and Energy
ELV	End-of-Life vehicle
I	Row vector
MCDA	Multi-criteria decision analysis
MSW	Municipal solid waste
ReEl	Share of renewable energy in electricity
ReHc	Share of renewable energy in heating and cooling
ReTr	Share of renewable energy in transport
RmMs	Total recycled materials from MSWs
RrEl	Total recycled and reused waste from ELVs
RrWe	Total recycled and reused waste from WEEEs
S	Sustainable index
W	Column vector
WEEE	Waste electric and electronic equipment

REFERENCES

Belton, V., Gear, T. (1983), On a short-coming of Saaty's method of analytic hierarchies. Omega, 11, 228-230.

Cucchiella, F., D'Adamo, I., Gastaldi, M., Koh, S.L., Rosa, P. (2017), A comparison of environmental and energetic performance of European countries: A sustainability index. Renewable and Sustainable Energy Reviews, 78, 401-413.

D'Adamo, I., Falcone, P.M., Morone, P. (2020), A new socio-economic indicator to measure the performance of bioeconomy sectors in Europe. Ecological Economics, 176, 106724.

de la Cruz-Lovera, C., Perea-Moreno, A.J., de la Cruz-Fernández, J.L., Alvarez-Bermejo, J.A., Manzano-Agugliaro, F. (2017), Worldwide research on energy efficiency and sustainability in public buildings. Sustainability, 9(8), 1294.

Dizdaroglu, D. (2017), The role of indicator-based sustainability assessment in policy and the decision-making process: A review and outlook. Sustainability, 9(6), 1018.

Guliev, I.A., Geladze, S.A., Sokolova, E.S., Egorova, L.I. (2020), The prospects of conventional and alternative energy production in the countries of the balkan peninsula (in the context of developing economic indicators). International Journal of Energy Economics and Policy, 10(1), 481.

Hasnisah, A., Azlina, A.A., Che, C.M.I. (2019), The impact of renewable energy consumption on carbon dioxide emissions: Empirical evidence from developing countries in Asia. International Journal of Energy Economics and Policy, 9(3), 135.

Hickel, J. (2020), The sustainable development index: Measuring the ecological efficiency of human development in the anthropocene. Ecological Economics, 167, 106331.

Kumar, A., Sah, B., Singh, A.R., Deng, Y., He, X., Kumar, P., Bansal, R.C. (2017), A review of multi criteria decision making (MCDM) towards sustainable renewable energy development. Renewable and Sustainable Energy Reviews, 69, 596-609.

Kwatra, S., Kumar, A., Sharma, P. (2020), A critical review of studies related to construction and computation of sustainable development indices. Ecological Indicators, 112, 106061.

Le, H.P., Bao, H.H.G. (2020), Renewable and nonrenewable energy consumption, government expenditure, institution quality, financial development, trade openness, and sustainable development in Latin America and Caribbean emerging market and developing economies. International Journal of Energy Economics and Policy, 10(1), 242-248.

Nuriyev, M. (2020), Fuzzy information and Z-number-based approaches to energy resource selection. International Journal of Energy Economics and Policy, 10(4), 392.

Obadi, S.M., Korcek, M. (2020), Quantifying the energy security of selected EU countries. International Journal of Energy Economics and Policy, 10(2), 276.

Olawumi, T.O., Chan, D.W.M. (2018), A scientometric review of global research on sustainability and sustainable development. Journal of Cleaner Production, 183, 231-250.

Ozturk, I. (2017), The dynamic relationship between agricultural sustainability and food-energy-water poverty in a panel of selected sub-saharan African countries. Energy Policy, 107, 289-299.

Saaty, T.L. (2008), Decision making with the analytic hierarchy process. International Journal of Services Sciences, 1(1), 83-98.

Sassanelli, C., Rosa, P., Rocca, R., Terzi, S. (2019), Circular economy performance assessment methods: A systematic literature review. Journal of Cleaner Production, 229, 440-453.

Subramoniam, R., Huisingh, D., Chinnam, R.B., Subramoniam, S. (2013), Remanufacturing decision-making framework (RDMF): Research validation using the analytical hierarchical process. Journal of Cleaner Production, 40, 212-220.