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The Role of Data Analytics in Enhancing Public Administration in Europe

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ABSTRACT:
Sustainable development (SD) represents a growth approach that tries to maintain a social, economic and environmental balance. SD aims to meet the needs of the present without compromising the needs of future generations. For a sustainable development, a key element is represented by renewable energy (RE). The use of RE on an increasingly large scale brings with it a series of advantages and positively influences aspects such as resource conservation, air and water quality improvement, climate change, greenhouse gas emissions, etc. Realization of RE through different ways such as wind energy, solar power, hydropower, etc. and by combining them, European citizens can take an important step in realizing a more sustainable and renewable energy future. The article presents a data mining analysis on the use of RE in EU countries, taking into account the share of industry use such as heating and cooling, transport and electricity. The results of the analysis aim to identify countries that show a similar behavior from the point of view of the use of RE. Based on them, policies and strategies at the EU level can be founded.

Keywords: renewable energy, sustainable development, European Union, data mining

1. Introduction

Sustainable development (SD) represents a holistic approach to growth and progress that aims to meet the needs of the present without compromising the ability of future generations to meet their own needs. SD in the EU integrates economic, social, and environmental goals, striving for a balanced and inclusive approach to growth and energy use. The EU's Green Deal aims to make Europe the first climate-neutral continent by 2050, driving sustainable development and promoting renewable energy (RE) (Angheluta et al., 2019a). Investing in renewable energy is a very important aspect to the EU's strategy for sustainable development, ensuring a cleaner and more resilient energy system (Rădulescu, Angheluta et al., 2022). Through policies like the Circular Economy Action Plan, the EU tries to support sustainable resource use and to reduce environmental impact while fostering economic growth (Burlacu, Pargaru et al., 2022). An example of how the EU promotes renewable energy is the initiative Horizon Europe, which funds research and innovation for sustainable energy technologies (Angheluta et al., 2019b).

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At the EU level, renewable energy directives (RED) were recommended, and these directives are about to set binding RE energy targets for EU countries, aiming for a 32% share of RE in the EU's final energy consumption by 2030. It also establishes national renewable energy targets for each member state (Diaconu et al., 2019).

The research paper is structured in two main parts. In the first part there are highlighted the 17 Sustainable Development Goals in correlation with the priorities of the EU and the targets of the 7-th goal, Affordable and clean energy, and its impact on sustainable development. In the second part of the paper, it is realized a data mining analysis which is for the countries from EU and for which there are used data from year 2022 regarding the RE sources for heating and cooling, electricity and transport. All data has the unit measure the percent. In the end of the paper there is a conclusion section.

The research questions for which the paper tries to offer an answer are:

1. Which are the most important aspects that the RE influences to promote a sustainable development and environment?
2. Which are the main EU countries groups based on the RE sources in heating and cooling, in electricity and in transport?
3. Which are the rules that could be identified for the EU countries according to the analyzed attributes (RE sources in heating and cooling, in electricity and in transport)?

In the following sections, an answer to each research question will be offered.

2. Sustainable development and renewable energy

SD has a very important role and impact over the world economy and not only (Alpopi et al., 2022). It integrates also aspects like environmental sustainability and social inclusion (Burlacu, et al., 2024). In 2015, the United Nations adopted the 2030 Agenda for Sustainable Development (COE 2024) which includes 17 Sustainable Development Goals (SDGs), respectively: no poverty (1), zero hunger (2), good health and well-being (3), quality education (4), gender equality (5), clean water and sanitation (6), affordable and clean energy (7), decent work and economic growth (8), industry, innovation, and infrastructure (9), reduced inequality (10), sustainable cities and communities (11), responsible consumption and production (12), climate action (13), life below water (14), life on land (15), peace and justice strong institutions (16), partnerships to achieve the goal (17). Among the main challenges of the SD could be mentioned: climate change and renewable energy (IPCC 2021; Mogos et al. 2021; Mogos et al. 2023), resource depletion (UN 2019), economic inequality (WB 2020), urbanization and infrastructure (UNHA 2020), technological barriers (UNEP 2019), health crisis (WHO 2020; Belostecinic et al. 2022), etc.

Within the European Union, based on the 17 SDGs were defined 6 priorities. Each priority must accomplish several goals. According to EU Commission (COEU 2024), the correlations between goals and priorities are described in Table 1. The

numbers from the third column, namely SDGs goals represent the sustainable development goals defined above.

Table 1. EU Priorities and SDGs goals

No	EU Priority	SDGs goals
1	European Green Deal	2, 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15
2	Economy that works for people	1, 3, 4, 5, 8, 9, 10
3	Europe fit for the digital age	4, 9
4	European way of life	3, 4, 10, 16
5	Stronger Europe in the world	17
6	European Democracy	5, 10, 16

Source: COEU 2024

The 7-th SDG called „Affordable and clean energy" is a vital component of efforts to transition towards a more sustainable and low-carbon energy system. It has the means to ensure the access for all regarding the sustainable, affordable and reliable energy. To achieve this goal, several targets were defined: universal access to modern energy; increase global percentage of renewable energy; double the improvement in energy efficiency; promote access to research, technology and investments in clean energy; expand and upgrade energy services for developing countries (see Table 2). In order to sustain the 5 targets, actions could be done by every single person. Some of these actions may consist in (GLOB 2024):

- some amounts of money could be donated by ordinary people to sustain all the activities that are related to 7-th Goal.
- changing our daily behavior regarding the lights that we are using every day at the office and at home. After a light is no longer needed, it must be switched off.
- the air conditioning (AC) could be replaced in some cases with a simple fan which consumes far less than AC.
- to buy electronics with rechargeable battery.
- to use a single device at once. For example, use a single monitor or TV if the activity could be done without several of them.
- use alternative energy sources (like solar energy). Install solar panels at home for heating and electricity.
- Follow the news and stay informed about clean and affordable energy.

Table 2. Goal no. 7 – Affordable and clean energy – Targets

Main goal	Target	Description
7. Affordable and clean energy	1. Universal access to modern energy.	Ensure that everyone will have access to affordable and reliable energy services by 2030.
	2. Renewable energy percentage at global scale to be increased.	Significantly increase the proportion of renewable energy in the global energy mix by 2030.
	3. Double the improvement in energy efficiency.	Increase the global rate of improvement in energy efficiency by 2030. The desired result is to double the actual rate.
	4. Clean energy - research, technology and investments.	Strengthening international cooperation by 2030 in order to improve the access to clean energy research and technology (also renewable energy, energy efficiency, and advanced cleaner fossil-fuel technologies). Increase also the investments in energy infrastructure and clean energy technology.
	5. Developing countries must upgrade and expand energy services.	By 2030, improve and expand infrastructure and upgrade technology in order to supply modern and sustainable energy services for all in developing countries, in particular least developed countries.

Source: Global goals - https://www.globalgoals.org/goals/7-affordable-and-clean-energy/

Trying to answer to the first research question *(1) Which are the most important aspects that the RE influences in order to promote a sustainable development and environment?*, here are the main aspects that the RE influences in order to promote a sustainable development and environment:

a) **Reduced Greenhouse Gas Emissions:** The generation of energy from fossil fuels represents a significant source of greenhouse gas emissions (GGE), contributing very much to climate change (CC). Renewable energy sources, such as solar, wind, hydro, and geothermal power, produce electricity with minimal or zero emissions, helping mitigate the impact of CC (Qian et al. 2023; Gopi et al., 2023).

b) **Climate Change Mitigation:** The use of renewable energy contributes directly to the reduction of carbon dioxide (CO_2) and other GGE. By transitioning to clean energy sources, we can work towards meeting global climate targets and mitigating the effects of CC (Fawzy et al., 2020; Jia-Ning et al. 2020).

c) **Decentralized Energy Production:** RE systems often allow for decentralized energy production, reducing the need for large, centralized power plants. This can improve energy resilience and contribute to more resilient and adaptable energy infrastructures (Schnidrig et al. 2024; Gawusu et al. 2024).

d) **Air and Water Quality Improvement:** Unlike traditional energy sources like coal and oil, RE technologies produce electricity without emitting pollutants that harm air and water quality. This improvement in air and water quality has

direct benefits for human health and ecosystem well-being. (Amina et al. 2024; McDowell et al. 2024)

e) **Resource Conservation:** RE sources, by definition, are derived from naturally replenishing resources, such as sunlight, wind, and water. This reduces the pressure on finite fossil fuel resources and helps preserve them for future generations (Chengwu and Wang, 2023).

f) **Biodiversity Conservation:** The extraction and use of fossil fuels often lead to habitat destruction and ecosystem disruption. By harnessing energy from renewable sources, we can minimize the impact on ecosystems, supporting biodiversity conservation (Pizzutto et al. 2021).

g) **Energy Independence and Security:** Diversifying the energy mix with renewables improves energy security by reducing dependence on fossil fuel imports. This can make countries less vulnerable to geopolitical tensions and price fluctuations in the fossil fuel market (Zou et al. 2020).

h) **Job Creation and Economic Growth:** The renewable energy sector has the potential to create jobs and stimulate economic growth. As the industry expands, new employment opportunities emerge in manufacturing, installation, maintenance, and research and development (Ram et al. 2022).

i) **Technological Innovation:** The pursuit of renewable energy solutions drives technological innovation. Advancements in solar, wind, and other renewable technologies can lead to more efficient and cost-effective energy production methods (Danish and Ulucak, 2021).

j) **Community Engagement and Empowerment:** Locally generated renewable energy projects, such as community solar or wind farms, empower communities to take control of their energy production. This can lead to greater community engagement, awareness, and support for sustainable practices (Lansing et al., 2023).

Based on the impact that the use of the RE has within the 7-th Goal and for a sustainable development as a hole, it could be said that RE represents a key element to achieve a sustainable development for the European Union and not only. To realize RE, there are needed various technologies and practices to harness energy from sustainable sources. Some of the most common ways used to achieve RE are: solar power (implies to install solar panels on rooftops, to invest and develop concentrated solar power for large-scale electricity generation, to use solar water heating systems for residential and commercial use), wind energy (in order to achieve this type of energy, wind turbines must be built in areas where the power of the wind is high and constant for long period of time), hydropower (energy based on water movement could be obtained through small and large scale hydropower plants that are generating electricity), biomass (it is recommended to used organic waste and residues to produce bioenergy), wave energy (in the areas like coastal areas, the power of the waves could be exploited; in this regard, ground source heat pumps for residential heating could be built), geothermal energy (used geothermal reservoirs in order to use the hot water for heating and electricity generation), and smart grids (implementing smart grids in order to manage and distribute RE in an efficient way). A more complex way is to combine

the more mentioned way of obtaining RE, ways that are offering hybrid systems. Another important aspect is about the energy storage (energy that is obtained, must be stored using specific and modern technologies) (Bodislav et al., 2020).

All the mentioned ways of obtaining RE are possible only if the countries' governments will encourage, develop, implement and apply specific strategies, policies and incentives in this regard. Also, more money must be given to research to improve the RE efficiency and affordability. Public awareness and education for RE is an activity that has and will have a big impact over the RE use. The public must be educated from school about energy conservation and the transition to sustainable practices (Rădulescu, Mănescu et al., 2023). By combining these approaches, societies can make significant steps in realizing a more sustainable and renewable energy future (Rădulescu et al., 2023).

In Table 3 there is mentioned the share in percent of renewable energy in gross final energy consumption for European Union (values for 2012-2022 period). In Figure 1 are represented the figure from Table 3 and it could be observed a constant increase from 2012 to 2020. For 2020 and 2021 the values are similar, but the value is smaller for 2021. For year 2022, the percent of the share of RE in gross final energy consumption is the greatest.

Table 3. Share in percent of renewable energy in gross final energy consumption for EU (values for 2012-2022 periods)

Year	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
EU-27 countries (from 2020)	16,002	16,659	17,416	17,82	17,978	18,411	19,096	19,887	22,038	21,926	23,020

Source: https://ec.europa.eu/eurostat/web/main/data/database

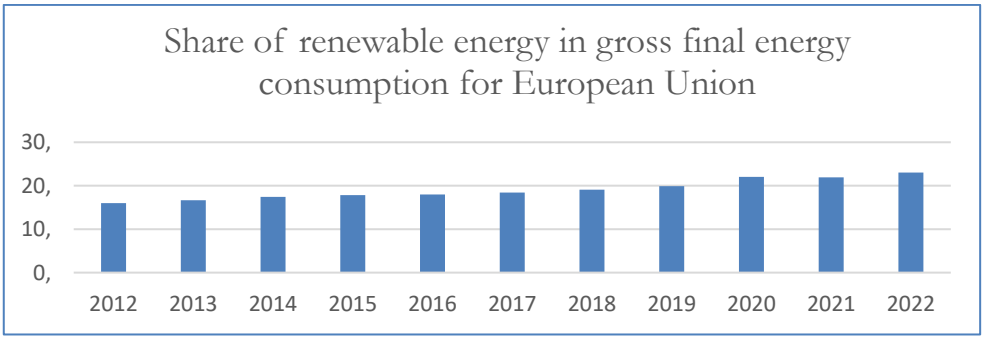

Fig. 1. Share in percentage of renewable energy in gross final energy consumption for EU (for 2012-2022 periods) Source: https://ec.europa.eu/eurostat/web/main/data/database

According to Eurostat (EURO 2024), the RE share of sources in heating and cooling, in electricity and in transport (values expressed in percentage) for the year 2022 and for the 27 EU countries is mentioned in Table 4. Based on these values, the data mining analysis from the next section was made, analysis that would offer answers to the second and he third research question.

Table 4. Share of renewable energy of each mention industry for EU (percent of total energy consumption)

Country (27 countries)	Country symbol	Renewable energy sources in heating and cooling (percentage) - 2022	Renewable energy sources in electricity (percentage) - 2022	Renewable energy sources in transport (percentage) - 2022
Belgium	BE	10,444	29,106	10,354
Bulgaria	BG	31,668	20,235	7,673
Czechia	CZ	25,802	15,499	7,197
Denmark	DK	50,110	77,220	10,241
Germany	DE	17,485	47,637	9,941
Estonia	EE	65,442	29,108	8,476
Ireland	IE	6,302	36,776	5,512
Greece	EL	30,614	42,408	4,081
Spain	ES	20,040	50,902	9,676
France	FR	26,321	27,323	9,031
Croatia	HR	37,212	55,518	2,395
Italy	IT	20,204	37,103	10,094
Cyprus	CY	41,560	16,963	7,216
Latvia	LV	60,987	53,305	3,134
Lithuania	LT	51,540	26,461	6,677
Luxembourg	LU	15,411	15,936	8,716
Hungary	HU	20,348	15,342	7,763
Malta	MT	37,980	10,126	10,467
Netherlands	NL	8,589	39,916	10,811
Austria	AT	30,579	74,670	10,139
Poland	PL	22,730	21,009	5,793
Portugal	PT	45,545	60,959	8,706
Romania	RO	26,251	43,726	8,235
Slovenia	SI	33,989	37,005	7,828
Slovakia	SK	19,922	22,902	8,932

Finland	FI	58,547	47,925	18,829
Sweden	SE	69,393	83,340	29,158

Source: https://ec.europa.eu/eurostat/web/main/data/database

3. Methodology and experiment data

Advances in machine learning (ML) and deep learning (DL) have significantly improved the accuracy of renewable energy generation forecasts. These methods outperform traditional statistical models by better handling complex, nonlinear relationships in data.

Some of the most activities that people are doing, and which consume a lot of energy are for heating and cooling, for electricity and for transport. For these three elements, a data set was collected from Eurostat (EURO 2024), data set that comprises values for 27 countries (values expressed in percentage) for the year 2022.

The analysis of data tries to offer an answer for the 2-nd and 3-rd research questions, respectively:

(2) Which are the main EU countries groups based on the RE sources in heating and cooling, in electricity and in transport?

(3) Which are the rules that could be identified for the EU countries according to the analyzed attributes (RE sources in heating and cooling, in electricity and in transport)?

Having answers to these questions, RE use strategies and policies could be developed not for a single country but for several countries which have similar characteristics from the analyzed attributes.

For the second research question a cluster analysis is realized. For this analysis are used algorithms like EM (Expectation Maximization - algorithm that offers a probability distribution to each instance which indicates the probability of it belonging to each of the clusters) and Simple K-Means (algorithms that determines the main characteristic for each cluster). The results consist in several clusters, each cluster containing several countries with similar characteristics (from the point of view of heating and cooling, for electricity and for transport).

For the third research question, a rules generating algorithm is applied, namely J48 Pruned Tree (for classification process). The results consist in a set of rules that could be identified within the dataset base on the analyzed attributes.

The software used to obtain the results is WEKA, a software that is open source (https://www.cs.waikato.ac.nz/ml/weka/) and the used methodology is a data mining specific one, named DM-CRISPDM (https://www.datascience-pm.com/crisp-dm-2/). This mythology contains several phases like requirements and data understanding, data preparation and modeling, evaluation and deployment.

4. Data analysis experiment and results

To analyze the data were used 27 records (countries from EU in 2022) and 3 attributes, respectively: Renewable energy sources in heating and cooling (percentage), Renewable energy sources in electricity (percentage) and Renewable energy sources in transport (percentage). In Figure 2 there is presented the main screen of the WEKA platform where the data was loaded and analyzed.

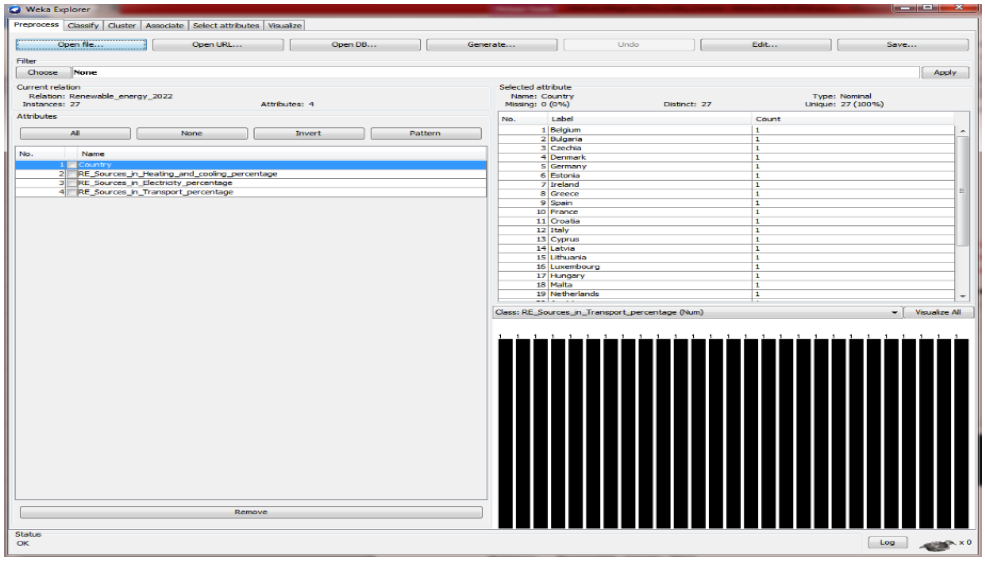

Figure 2: Dataset – RE attributes and EU countries

The number of clusters for the countries using the EM algorithm was 3. Using this number, the Simple K-Means algorithm was applied, and the outcomes are mentioned in Figure 3.

According to the cluster distribution, the results are:

- *Cluster 0:* has 13 instances (48%) and includes countries: Belgium, Bulgaria, Czechia, Estonia, France, Cyprus, Lithuania, Luxembourg, Hungary, Malta, Poland, Slovenia and Slovakia. The average percentage of the share of renewable energy of each mentioned industry for EU (percent of total energy consumption) is for: Heating and cooling 31%, Electricity 22% and Transport 8,1 %. The most representative country is Belgium.
- *Cluster 1*: has 9 instances (33%) and includes countries: Denmark, Germany, Ireland, Greece, Spain, Croatia, Italy, Netherlands, and Romania. The average percentage of the share of renewable energy of each mentioned industry for EU (percent of total energy consumption) is for: Heating and cooling 24%, Electricity 47,9% and Transport 7,8 %. The most representative country is Denmark.
- *Cluster 2*: has 5 instances (19%) and includes countries: Latvia, Austria, Portugal, Finland and Sweden. The average percentage of the share of renewable energy of each

mentioned industry for EU (percent of total energy consumption) is for: Heating and cooling 53%, Electricity 64,9% and Transport 13,9 %. The most representative country is Latvia.

It could be observed that cluster number 2 is the one with the biggest values regarding the average percentage of the share of renewable energy for RE sources in heating and cooling, electricity and transport. On the other hand, the countries with the smallest share are those from cluster number 1.

		Cluster#		
Attribute	Full Data	0	1	2
	(27)	(13)	(8)	(6)
Country	Belgium	Belgium	Germany	Denmark
RE_Sources_in_Heating_and_cooling_percentage	32.7783	31.0121	20.8371	52.5268
RE_Sources_in_Electricity_percentage	38.46	22.0781	44.2483	66.2365
RE_Sources_in_Transport_percentage	9.1509	8.1633	7.5931	13.3678

Fig. 3 Centroids of the clusters

Obtaining these results, it is also obtained the answer to the second research question: *(2) Which are the main EU countries groups based on the RE sources in heating and cooling, in electricity and in transport?*

To offer the answer to the third question, the J48 Pruned Tree algorithm was applied. The results consist in a set of rules identifiable in the dataset. The numbers within brackets represent the number of the countries that respect the rule based on the cluster assignation (correct classified / incorrect classified).

J48 pruned tree

RE_Sources_in_Electricity_percentage <= 37.005: cluster0 (14.0/1.0)
RE_Sources_in_Electricity_percentage > 37.005
| RE_Sources_in_Heating_and_cooling_percentage <= 37.98: cluster1 (8.0/1.0)
| RE_Sources_in_Heating_and_cooling_percentage > 37.98: cluster2 (5.0)

Number of Leaves: 3
Size of the tree: 5

The third research question *(3) Which are the rules that could be identified for the EU countries according to the analyzed attributes (RE sources in heating and cooling, in electricity and in transport)?* has the answer in the set of rules mentioned above.

5. Conclusion

Sustainable development is a complex and multifaceted goal that requires the collective effort of governments, businesses, and civil society. By addressing economic, social, and environmental dimensions, it seeks to create a world where all people can

thrive while maintaining the health of our planet for future generations. Integrating RE into our energy systems represents a fundamental aspect of achieving environmental sustainability. It addresses climate change, supports conservation efforts, promotes clean air and water, and fosters economic development while reducing our reliance on finite and polluting energy sources.

In the present paper there are described the main goals and challenges of the sustainable development and the components of the renewable energy that have a big impact over a sustainable development along with the RE types. Because the RE represents a key element of the SD, three main human activities that are using a lot of energy were analyzed, respective heating and cooling, electricity and transportation. For these elements the share of renewable energy percent of renewable energy in gross final energy consumption for EU was analyzed. There were identified three main clusters with similar values and a set of rules that could be applied to the EU countries.

Future work that will be taking into account is about analyzing more date that describe the renewable energy sources in order to have a more clear view and understanding over this key element and how it could be used for a more sustainable development.

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