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ORIGINAL RESEARCH ARTICLE

Emission of greenhouse gasses from 2010 to 2020—Good intentions vs. reality

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ABSTRACT

Three main indicators, i.e., the net greenhouse gas emissions, the net greenhouse gas emissions from land use and forestry, and the population covered by the Covenant of Mayors for Climate and Energy signatories have been suggested by Eurostat as indicators for the description of the climate action—the Sustainable Development Goal 13. The present study describes the ranking of the 27 European Union member states plus the combined EU based on a simultaneous inclusion of all three indicators. It turned out that the covenant indicator was the most important. Thus, subsequently, a ranking of the countries based on a) the covenant indicator and b) the greenhouse gas emission indicators was compared elucidating virtually no correspondence, i.e., signing a covenant with a lot of good intentions is not reflected in a decreased or reduced emission of greenhouse gases. The discrepancy between the political will and the actual action is unambiguous.

Keywords: Climate Action; Greenhouse Gas Emissions; Covenant of Mayors; Partial Order; Average Rank; Indicator Importance

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1. Introduction

The emissions of greenhouse gasses, i.e., carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons, perfluorocarbons, nitrogen trifluoride (NF_3) and sulfur hexafluoride (SF_6) have for years and years been a hot topic in relation to climate change due to their ability to promote the global increase of temperature[1]. However, it seems like this is like the old saying: "Everybody talks about the weather, but nobody is doing anything about it."

In the present paper, by looking at the main indicators as pointed out by Eurostat[2], the emission of greenhouse gasses is looked upon together with one of the expressions of goodwill, i.e., Covenant of Mayors for Climate and Energy (CoM)[2,3], that is a European voluntary movement engaging local authorities in the development and implementation of policies for sustainable energy and climate. Eurostat has collected these data for greenhouse gasses since 1990 and the CoM data since 2010[2]. Although the overall emissions of greenhouse gasses has decreased over the years, the amount of the gasses emitted is still significant and far above an acceptable limit[2]. The combined simultaneous inclusion of the actual emission of greenhouse gasses and the "good will" to limit the emission, as stated by signing the CoM has not previously been studied. Thus, the paper will focus on greenhouse gas emissions and the CoM participation for the 27 European Union countries for the years 2010 (five years before the introduction of the

UN Sustainable Development Goals, SDGs), 2015 (the year the SDGs were adopted by the UNI general assembly) and 2020 (five years after the adoption of the SDGs). In other words, the paper will elucidate to what extent the actual greenhouse gas emissions and the expressed "good will" to reduce the emissions are in accordance or conflicting. SDG 13 (climate action), is in focus in the present context.

2. Methodology

The data analyses have been carried out applying partial order methodology[4–12]. Partial ordering allows taking several indicators into account simultaneously without any pretreatment such as aggregation into a composite indicator that unequivocally may be subject to compensation effects where a high value in one indicator may be overshadowed by a low value in another[13]. This allows disclosure of the single indicators' role in the ranking in contrast to the use of a composite indicator.

2.1 Data

The data applied for the present study originate from the 2022 edition of the sustainable development in the European Union report[2]. Hence, the data are retrieved from the net greenhouse gas emissions (net GGE)[14], net greenhouse gas emissions from land use and forestry (net GGE LULUCF)[15], and the population covered by the Covenant of Mayors for Climate and Energy signatories (CoM)[3,16], respectively. The CGE data include international aviation but exclude net carbon removals from land use, land use change, and forestry (LULUCF). The net CGE LULUCF indicator measures LULUCF, considering both emissions and removals from land use, land use change, and the forestry sector. Both CGE indicators express the emissions in tons per capita, whereas the CoM indicator expresses the percentage of the population covered by the framework. Hence, for CoM, the higher value, the better; whereas for the two greenhouse gas emission indicators, the lower the values, the better.

Table 1. Indicator values for net GGE, net GGE LULUCF, and CoM[1].

Country	ID	Net GGE			Net GGE LULUCF			CoM		
		2010	2015	2020	2010	2015	2020	2010	2015	2020
Belgium	BEL	12.7	10.9	9.5	0	−0.1	0	19.3	78.1	95.1
Bulgaria	BGR	8.1	8.7	7.2	−1.7	−1.1	−1.4	10.1	35.4	36.7
Czechia	CZE	13.5	12.3	10.6	−0.7	−0.6	1.2	0.1	15.2	25.8
Denmark	DNK	11.9	9.1	7.3	0.4	0.1	0.5	32	57	58.3
Germany	DEU	11.7	11.3	8.9	−0.2	−0.3	−0.1	20.4	22.3	24.4
Estonia	EST	16	13.8	8.7	−3.6	−1.6	1	32.3	40.7	43.4
Ireland	IRL	14.1	13.4	11.8	1.7	1.5	1.4	11.1	32.9	59.1
Greece	GRC	10.9	9.1	7.1	−0.3	−0.3	−0.4	7.9	55.9	68.4
Spain	ESP	8	7.6	5.9	−0.8	−0.8	−0.8	44.2	59.9	75.8
France	FRA	8.1	7.1	5.9	−0.6	−0.5	−0.2	18.1	23.7	26.4
Croatia	HRV	6.6	5.9	5.9	−1.6	−1.3	−1.3	29.7	42.5	55.4
Italy	ITA	8.9	7.4	6.5	−0.7	−0.7	−0.5	22.6	62.3	75.2
Cyprus	CYP	12.4	10.7	10.3	−0.4	−0.4	−0.4	23.3	58.7	58.4
Latvia	LVA	5.8	5.6	5.6	−0.9	0.1	0.3	37.7	53.2	59.6
Lithuania	LTU	6.7	7.1	7.3	−3.4	−2.7	−1.9	21.1	51.2	55.4
Luxembourg	LUX	26.6	20.5	17	−0.1	−0.6	−0.5	0.4	0.4	7.2
Hungary	HUN	6.7	6.3	6.5	−0.4	−0.6	−0.7	20.1	28.4	55.7
Malta	MLT	7.8	5.6	4.5	0	0	0	25.8	27.4	30.1
Netherlands	NLD	13.4	12.1	9.8	0.3	0.3	0.2	22	24.6	29.2
Austria	AUT	10.3	9.3	8.4	−0.5	−0.3	−0.1	0.2	23.3	24
Poland	POL	10.9	10.3	10	−0.9	−0.8	−0.6	5.3	9.8	15.4
Portugal	PRT	6.8	6.8	5.7	−0.8	−0.8	−0.7	26.7	57.7	70.2
Romania	ROU	6.1	5.8	5.7	−1.4	−1.7	−1.7	18.8	32.9	34.3
Slovenia	SVN	9.6	8.2	7.6	−3.5	0.3	−2.3	15.3	35.1	50.6
Slovakia	SVK	8.5	7.5	6.8	−1.2	−1.3	−1.6	1.7	10.6	19.1
Finland	FIN	14.4	10.4	8.8	−4	−3.4	−3.1	26.3	36.9	46.3
Sweden	SWE	7.1	5.7	4.6	−4.6	−3.9	−3.8	20.3	44.9	48.7
EU 27	EU27	9.7	8.8	7.5	−0.7	−0.7	−0.5	20.4	36.4	44

[1] Emission date is given as tons per capita and CoM data as a percentage of the total population.

A fourth main indicator, climate-related economic losses (CrEL)[17], will be discussed by not as such analyzed as the data are not available on a national scale, but only as a combined EU loss. The indicator values for the years 2010, 2015, and 2020 are shown in **Table 1**.

2.2 Partial ordering methodology

Partial ordering is a relation among the objects to be ordered. In mathematical terms, the only relation is " ≤ "[4–12]. Hence, the " ≤ " relation is the basis for a comparison of objects and constitutes a graph, the so-called Hasse diagram (see below). Two objects are connected if and only if the relation "$x \le y$" holds. A given object, x, is characterized by a set of indicators $r_j(x)$, $j = 1, ..., m$, and can thus be compared to another object y, characterized by an identical set of indicators $r_j(y)$, if

$$r_r(x) \le r_r(y) \text{ for all } r = 1, \ldots, m \tag{1}$$

It is obvious that Equation (1) is a rather strict requirement for having a comparison as at least one indicator value of object x must be lower (the remaining lower or at least equal) to those of object y. In technical terms: let X be the group of objects studied, i.e., $X = \{O1, O2, O3, \ldots, On\}$, then object Oy will be ranked higher than object Ox, i.e., $Ox < Oy$ if at least one of the indicator values for Oy is higher than the corresponding indicator value for Ox and no indicator for Oy is lower than the corresponding indicator value for Ox. On the other hand, if $r_j(Oy) > r_j(Ox)$ for some indicator j and $r_i(Oy) < r_i(Ox)$ for some other indicator i, Oy and Ox will be called incomparable (notation: $Oy \parallel Ox$) due to the mathematical contradiction expressed by the conflicting indicator values. A set of comparable objects are called a chain, whereas a set of mutually incomparable objects is called an antichain. In cases where all indicator values for two objects, Oy and Ox, are equal, i.e., $r_j(Oy) = r_j(Ox)$ for all j, the two objects will be considered as equivalent, i.e., $Ox = Oy$, which in terms of ranking means that they will have the same rank.

In the present context three indicators, each describing elements in reducing the greenhouse gas emissions are included, i.e., r_1 = net GGE, r_2 = net GGE LULUCF and r_3 = CoM are simultaneously included in the partial ordering of the 27 countries plus the combined EU, i.e., $O1$–$O28$. Hence, even though the three indicators are not directly comparable as r_1 and r_2 are given as tons per capita and r_3 as a percentage of the total population (cf. **Table 1**), the partial order methodology allows simultaneous inclusions of such cardinals.

2.2.1 The Hasse diagram

Equation (1) is the basis for the so-called Hasse diagram technique (HDT)[5,18,19]. Hasse diagrams are visual representations of partial orders. In a Hasse diagram, comparable objects are connected by a sequence of lines[5,20]. Thus, sets of comparable objects, i.e., fulfilling Equation (1), are called chains and are connected with lines in the diagram, whereas sets of mutually incomparable objects, i.e., not fulfilling Equation (1), are called antichains. Thus, the diagrams display comparisons as well as incomparisons, the latter due to conflicting indicator values (cf. Equation (1)).

In the diagram, the single objects are positioned in levels, typically arranged from low to high (bottom to top in the diagram). It is a general rule that objects are located as high in the diagram as possible. Thus, isolated objects will, by default, be located at the top level of the diagram. It is important to make sure that the orientation of the single indicators is identical, e.g., that high values correspond to "good", whereas low values correspond to "bad". In practice, this is done by multiplying the greenhouse gas emission indicator values by −1 in cases where high and low values correspond to "bad" and "good", respectively. In the present study, the highest located object/country will be assigned rank 1 indicating the "best".

The module mHDCl7_1 of the PyHasse software (vide infra) was used for the basic partial ordering calculations and the associated construction of the Hasse diagrams.

2.2.2 Average ranking

Looking at the Hasse diagram, the level structure constitutes a first approximation to order. However, as all objects in a level automatically will be assigned identical orders, such an ordering will cause many tied orders. It is desirable with a degree of tiedness as low as possible. Hence, ultimately a linear ordering of the single objects is desirable. However, when incomparable objects are included in the ordering, this is not immediately obtainable. Partial order methodology provides a weak order, where tied orders are not excluded, which is obtained by calculating the average order of the single objects as, e.g., described by Bruggemann and Carlsen[21] and that of Bruggemann and Annoni[22].

The average rankings were calculated by applying a local partial order approach by the LPOMext9_1[21] of the PyHasse software (vide infra).

2.2.3 Sensitivity—Indicator importance

A sensitivity analysis can determine the relative importance of the single indicators in play[23]. The basic idea is to construct partially ordered sets (posets) excluding the single indicators one at a time. Subsequently, the distances from these posets to the original poset are determined. The indicator, whose elimination from the original poset leads to the maximal distance to the original one, in other words causing the highest degree of changes in the Hasse diagram, is most important for the structure of the original partial order. As the effect of elimination of single indicators is studied, this kind of sensitivity analysis can be called “indicator-related sensitivity”.

The sensitivity values were calculated by the sensitivity24_5 module[5] of the PyHasse software (vide infra).

2.2.4 Software

All partial-order analyses were conducted using the PyHasse software[24]. PyHasse is programmed using the interpreter language Python (version 2.6). Today, the software package contains around 140 more or less specialized modules. Selected modules may be obtained from the author.

3. Results and discussion

Partial ordering allows a priori to consider several indicators simultaneously as long as they are described numbers. Thus, in the present context, three main indicators for SDG 13 (climate action) are considered, i.e., the net greenhouse gas emissions (net GGE, tons per capita), the net greenhouse gas emissions from land use and forestry (net GGE LULUCF, tons per capita), and the population covered by the Covenant of Mayors for Climate and Energy signatories (CoM, percentage of the population that is covered by the framework), respectively. Hence, although these indicators are different in nature, it may make sense to rank the countries simultaneously applying all three indicators to get elucidate the mutual state of the single countries based on the combination of actual greenhouse gas emissions and administrative actions. In **Figure 1**, the Hasse diagrams for the years 2010, 2015 and 2020 are displaying the visualizing of their mutual partial ordering.

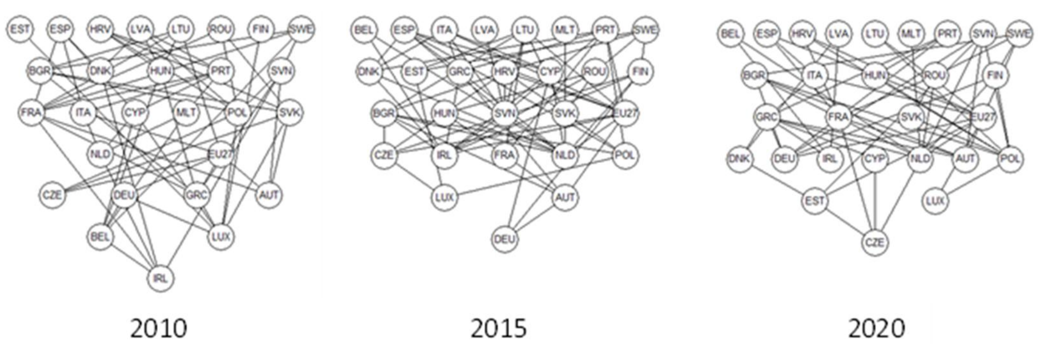

Figure 1. Hasse diagrams for the 27 EU member states and the combined EU for the years 2010, 2015, and 2020. The single diagrams display 149/229, 137/241, and 138/240 comparisons/incomparisons, respectively.

The partial ordering only gives a first indication of the mutual raking of the 28 elements. However, some common trends can be noted. Thus, at the top level, we find countries like ESP, LVA, LTU, and SWE, whereas for the lower levels, a somewhat more blurred picture developed. Further, the single levels are per definition antichains (vide supra); thus, no further information on the mutual ranking of the countries in such an antichain is found.

The shape of the diagrams is a result of the combination of the three indicators. Thus, an analysis of the relative importance of the single indicators is of interest as calculated by a sensitivity analysis. It turns out that in all three years, the CoM indicator was the most important indicator by 0.40, 0.43, and 0.42, followed by the net GGE LULUCF (0.33, 0.32, and 0.37) and net GGE (0.27, 0.25, and 0.21) for the three years, respectively.

The actual mutual ranking of the 27 + 1 elements may be obtained by calculating the average ranking. Again, it must be stated that this is not a strict linear order that is obtained[21]. In **Table 2**, the average rankings of the 27 EU member states as well as the combined EU are given for the three years studied.

Table 2. Average ranking of the 27 EU member states and the combined EU based on the 3 main indicators.

2010		2015		2020	
Country	**Rank**	**Country**	**Rank**	**Country**	**Rank**
LVA	1	SWE	1	ESP	1
HRV	2	LTU	2	SWE	2
LTU	3	ESP	3	PRT	3
ESP	4	PRT	4	HRV	4
SWE	5	ITA	5	ITA	5
ROU	6	HRV	6	LTU	6
PRT	7	ROU	7	SVN	7
SVN	8	LVA	8	LVA	8
ITA	9	FIN	9	ROU	9
BGR	10	BEL	10	BEL	10
EST	11.5	BGR	11	HUN	11
FIN	11.5	HUN	12	GRC	12
MLT	13	MLT	13	BGR	13
HUN	14	GRC	14	FIN	14
CYP	15	CYP	15	MLT	15
EU27	16	EU27	16	SVK	16
DNK	17	EST	17	EU27	17
FRA	18	SVK	18	FRA	18
SVK	19	DNK	19	DNK	19
DEU	20	FRA	20	CYP	20
POL	21	SVN	21	POL	21
NLD	22	POL	22	IRL	22
GRC	23	CZE	23	EST	23
BEL	24	AUT	24	NLD	24
AUT	25	IRL	25	AUT	25
CZE	26	DEU	26	DEU	26
IRL	27	LUX	27	LUX	27
LUX	28	NLD	28	CZE	28

Not surprisingly, the countries found at the top level (**Figure 1**) are also found at the highest average ranks (**Table 2**). From **Table 2**, it is further clear that the same group of countries, e.g., LUX, CZE, and DEU, constitutes the lowest rankings. The European Union as a whole, EU27, is virtually constantly found in the middle of the field with ranks 16, 16, and 27 respectively. For other countries, like SVN, more significant variations are noted from rank 8 in 2010, rank 21 in 2015, and then rank 7 in 2020. The question arises: what is determining the ranking—the actual greenhouse gas emissions or some administrative pronouncements? To elucidate this, the indicators were spit up, i.e., a) the CoM and b) the two greenhouse gas emission indicators.

The CoM indicator obviously can rank the countries in a strict linear order whereas the two greenhouse gas emission indicators are simultaneously ranked by partial ordering and average ranking. In **Figure 2**, the Hasse diagrams displaying the partial ordering of the 27 EU member states and the combined EU for the years 2010, 2015, and 2020 are shown.

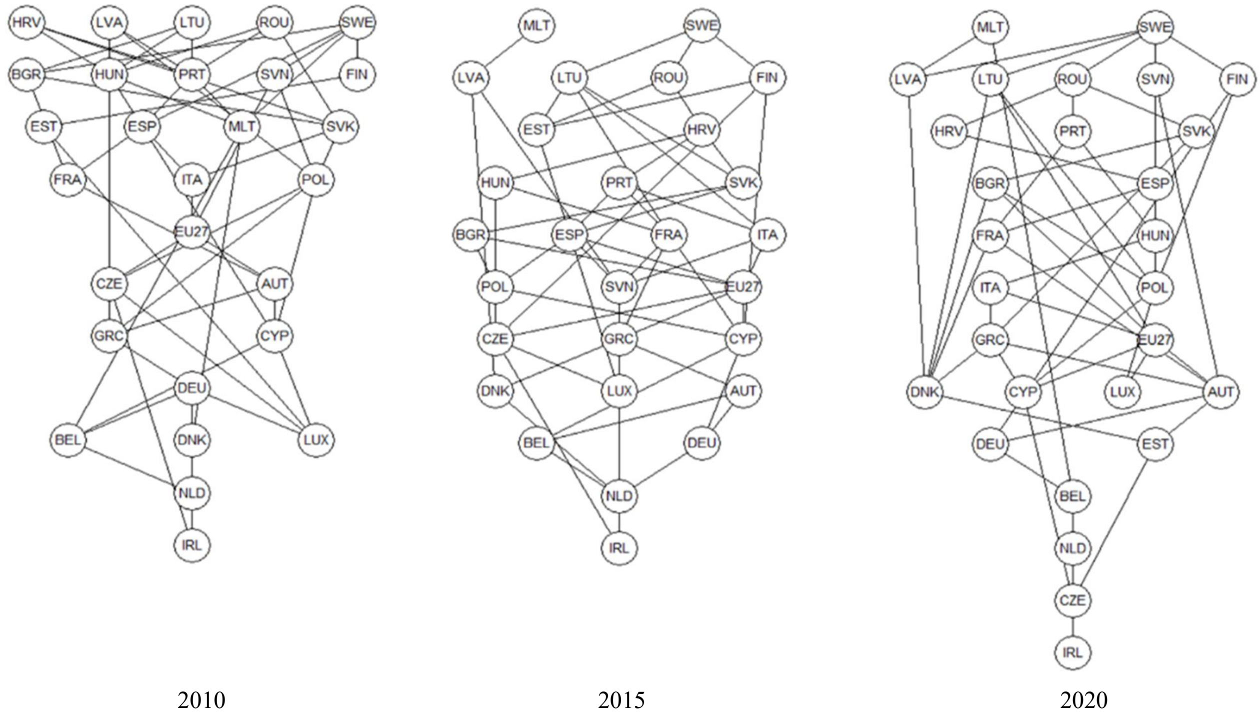

Figure 2. Hasse diagrams for the 27 EU member states and the combined EU for the years 2010, 2015, and 2020 based on the greenhouse gas emission indicators net GGE and net GGE LULUCF. The single diagrams display 249/129, 235/143, and 242/136 comparisons/incomparisons, respectively.

It is immediately noted that the three diagrams shown in **Figure 2** are much slimmer than the corresponding diagrams shown in **Figure 1**. Further, an increase in the number of comparisons and a decrease in the number of incomparisons are noted (cf. figure captions). This is an effect of the reduced number of indicators applying for the diagrams in **Figure 2**. Further, such an effect was anticipated taking the dominance of the CoM indicator (**Figure 1**) into account. In **Table 3**, the ranking of the 27 + 1 countries is shown for the three years based on the CoM indicator and the average rank based on the partial ordering of the greenhouse gas emission indicators.

The data shown in **Table 3** point to a clear discrepancy between what the single countries say and what they do. Taking Denmark (DNK) as an example, it is noted that the country is ranked 4, 6, and 9, the latter corresponds to 58.7% based on the signing up for the Covenant of Mayors for Climate and Energy signatories (CoM), which signalizes that signer is committed to adopting an integrated approach to climate change mitigation and adaptation[3]. However, looking at greenhouse gas emissions, Denmark is found close to the bottom of the list on place 25, 23, and 21 for 2010, 2015, and 2020, respectively, i.e., among the highest emitters of greenhouse gasses per capita. Scrutinizing **Table 3**, such discrepancies are found for most countries, although for some countries the reverse is seen, as, e.g., Slovakia (SVK) with rather low CoM signatures, i.e., ranked 25, 26, and 26 only, the latter corresponds to 19.1%, whereas pretty high on the list, 9th, 7th, and 5th when it comes to the greenhouse gas emissions, i.e., relatively low emissions per capita. Compared to the data given in **Table 2**, the discrepancies are hidden. Thus, (cf. **Table 2**), DNK is ranked 17, 19, and 19, whereas SVK is ranked 19, 18, and 16, respectively. Even more striking is BEL, which in 2020 appeared on the first rank with 95.1% of the population covered by the Covenant of Mayors for Climate and Energy signatories (CoM), whereas in 22nd place out of 28 when it comes to greenhouse gas emissions (**Table 3**). BEL is in 2020 ranked 10 based on all three indicators (**Table 2**). These results further substantiate the importance of the CoM indicator. In **Figure 3**, the virtual lack of correlation between the CoM rankings and the ranking of the greenhouse gases is visualized for year 2020.

Table 3. Ranking of the 27 EU member states and the combined EU based on the CoM indicator and the greenhouse gas emission indicators, respective for 2010, 2015 and 2020.

ID	2010		2015		2020	
	CoM rank	GGE rank	CoM rank	GGE rank	CoM rank	GGE rank
AUT	27	18	23	19	25	19
BEL	17	24	1	24.5	1	22
BGR	22	6	15	10	18	12
CYP	9	21	4	20	8	23
CZE	28	23	25	21	23	27
DEU	13.5	22	24	24.5	24	20
DNK	4	25	6	23	9	21
ESP	1	10	3	12	2	6
EST	3	19	12	17	17	25
EU27	13.5	16	14	15	16	17
FIN	7	11	13	8	15	10
FRA	19	14	22	13	22	14
GRC	23	20	7	18	5	16
HRV	5	3.5	11	4	11.5	3
HUN	16	12	19	9	10	11
IRL	21	28	17.5	28	7	28
ITA	10	13	2	11	3	13
LTU	12	2	9	3	11.5	8
LUX	26	27	28	26	28	24
LVA	2	5	8	14	6	15
MLT	8	17	20	6	20	7
NLD	11	26	21	27	21	26
POL	24	15	27	16	27	18
PRT	6	8	5	5	4	4
ROU	18	3.5	17.5	2	19	2
SVK	25	9	26	7	26	5
SVN	20	7	16	22	13	9
SWE	15	1	10	1	14	1

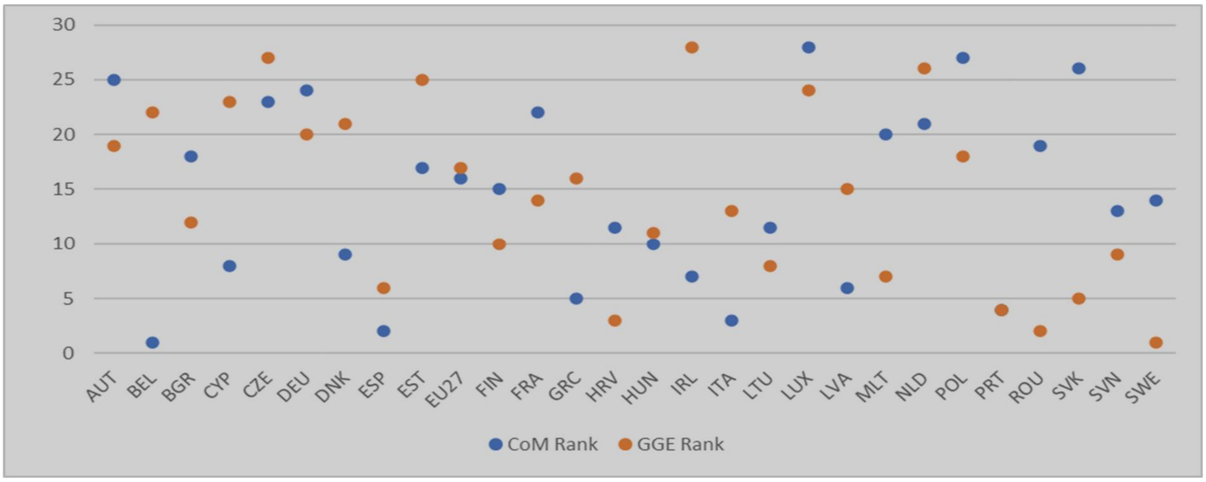

Figure 3. Visualization of the CoM rankings and the ranking of the greenhouse gases for the year 2020 for the 27 EU member states and the combined EU.

4. Conclusions and outlook

It appears evident that there is no direct correspondence between good words of intentions and real action displaying the often-observed schism between politics and action. It is clear from the study that, e.g., signing the Covenant of Mayors for Climate and Energy does not influence the actual emission of greenhouse gasses. Hence, the signing of the covenant does not imply a reduction in the emissions and vice versa a reduced emission does not require a signature of the covenant.

Looking at the data presented in this paper, we must experience the truth of the old saying by the French Abbot Bernard of Clairvaux from the mid-

1100s that "the road to hell is paved with good intentions", thus, calling for action and not for talks.

It should finally be mentioned that there is an economic loss due to the emissions of greenhouse gases. In 2020, calculated as a 30 years average, this amounted to 28.82 Euro per capita per year. This may now sound much but on a European scale, the estimated losses for 2010, 2015, and 2020 amounted to 16.948, 9.974, and 12.137 million Euro[17] which is a substantial amount of money simply wasted.

Conflict of interest

The author declares that there is no conflict of interest.

References

1. Greenhouse gases and temperature [Internet]. 2023. Available from: http://ete.cet.edu/gcc/?/globaltemp_ghgandtemp.
2. Sustainable development in the European Union—Monitoring report on progress towards the SDGs in an EU context [Internet]. Eurostat; 2022. Available from: https://ec.europa.eu/eurostat/web/products-flagship-publications/-/ks-09-22-019.
3. Covenant of mayors—Europe [Internet]. European Commission; 2008. Available from: https://eu-mayors.ec.europa.eu/en/signatories.
4. Annoni P, Bruggemann R, Carlsen L. A multidimensional view on poverty in the European Union by partial order theory. Journal of Applied Statistics 2015; 42(3): 535–554. doi 10.1080/02664763.2014.978269.
5. Bruggemann R, Patil GP. Ranking and prioritization for multi-indicator systems—Introduction to partial order applications. Springer; 2011.
6. Bruggemann R, Voigt K. Basic principles of Hasse diagram technique in chemistry. Combinatorial Chemistry and High Throughput Screening 2008; 11(9): 756–769. doi: 10.2174/138620708786306005.
7. Carlsen L. Happiness as a sustainability factor. The world happiness index: A posetic-based data analysis. Sustainability Science 2018; 13: 549–571. doi: 10.1007/s11625-017-0482-9.
8. Carlsen L, Bruggemann R. Partial order methodology: A valuable tool in chemometrics. Journal of Chemometrics 2013; 28(4): 226–234. doi: 10.1002/cem.2569.
9. Carlsen L, Bruggemann R. The 'Failed State Index' offers more than just a simple ranking. Social Indicators Research 2014; 115: 525–530. doi: 10.1007/s11205-012-9999-6.
10. Carlsen L, Bruggemann R. Environmental perception in 33 European countries: An analysis based on partial order. Environment, Development and Sustainability 2018; 22: 1873–1896. doi: 10.1007/s10668-018-0267-z.
11. Newlin JT, Patil GP. Application of partial order to stream channel assessment at bridge infrastructure for mitigation management. Environmental and Ecological Statistics 2010; 17: 437–454. doi: 10.1007/s10651-010-0162-8.
12. Voigt K, Bruggemann R, Hagen S, *et al.* Organochlorine pesticides in the environment and humans: Necessity for comparative data evaluation. In: Wittmann J, Müller M (editors). Simulation in Umwelt- und Geowissenschaften: Workshop Leipzig 2013. Shaker; 2013. p. 9–22.
13. Munda G. Social multi-criteria evaluation for a sustainable economy [Internet]. Berlin/Heidelberg: Springer; 2008. Available from: https://www.springer.com/la/book/97835407370.
14. Net greenhouse gas emissions [Internet]. Eurostat. Available from: https://ec.europa.eu/eurostat/databrowser/view/sdg_13_10/default/table?lang=en.
15. Net greenhouse gas emissions of the land use, land use change and forestry (LULUCF) sector [Internet]. Eurostat. Available from: https://ec.europa.eu/eurostat/databrowser/view/sdg_13_21/default/table?lang=en.
16. Population covered by the Covenant of Mayors for Climate & Energy signatories [Internet]. Eurostat. Available from: https://ec.europa.eu/eurostat/databrowser/view/sdg_13_60/default/table?lang=en.
17. Climate related economic losses [Internet]. Eurostat. Available from: https://ec.europa.eu/eurostat/databrowser/view/sdg_13_40/default/table?lang=en.
18. Bruggemann R, Carlsen L. Partial order in environmental sciences and chemistry. Springer; 2006.
19. Bruggemann R, Carlsen L. Introduction to partial order theory exemplified by the evaluation of sampling sites. In: Bruggemann R, Carlsen L (editors). Partial order in environmental sciences and chemistry. Springer; 2006. p. 61–110.
20. Bruggemann R, Münzer B. A graph-theoretical tool for priority setting of chemicals.

Chemosphere 1993; 27(9): 1729–1736. doi: 10.1016/0045-6535(93)90153-V.
21. Bruggemann R, Carlsen L. An improved estimation of averaged ranks of partial orders. MATCH Communications in Mathematical and in Computer Chemistry 2011; 65: 383–414.
22. Bruggemann R, Annoni P. Average heights in partially ordered sets. MATCH Communications in Mathematical and in Computer Chemistry 2014; 71(1): 117–142.
23. Bruggemann R, Halfon E, Welzl G, *et al.* Applying the concept of partially ordered sets on the ranking of near-shore sediments by a battery of tests. Journal of Chemical Information and Computer Sciences 2001; 41: 918–925. doi: 10.1021/ci000055k.
24. Bruggemann R, Carlse L, Voigt K, Wieland R. PyHasse software for partial order analysis: Scientific background and description of selected modules. In: Bruggemann R, Carlsen L, Wittmann J (editors). Multi-indicator systems and modelling in partial order. Springer; 2004. p. 389–423.