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Estimated CO_2 emissions from energy use in the EU

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Abstract:
This manuscript discusses CO_2 emissions early estimates Eurostat process. The analysis is based on fossil fuel consumption change from one year to another. The methodology is relatively simple with high reproducibility. Results across time show good consistency for EU level aggregates with exceptional timeliness, which is one year in advance of the official statistics on emissions. The methodology is evolving to capture the change introduced by the Green Deal.

Keywords:
Carbon Emissions; Fossil fuels; Early estimates; European Union; Eurostat

1. Introduction:

This paper discusses the early carbon emissions estimates exercise conducted on an annual frequency. The analysis is based on fossil fuel consumption evolution from official statistics provided by European Union Member States on monthly basis. Eurostat collects monthly statistics on coal, peat, oil, natural gas and electricity [1]. For the early CO2 estimates, only fossil fuels data are used.
According to Eurostat data [2], energy induced greenhouse gas emissions in CO_2 equivalent in the last decade of available data, correspond to at least 75% of total greenhouse gas emissions at EU level. Therefore, energy induced emissions is to a large degree the main factor affecting carbon emissions evolution in the individual Member States. Land use, land-use change, and forestry (LULUCF) is an important sector that is not included in this analysis, however, this sector remains relatively stable across time. Carbon storage solutions are still under development, without yet affecting overall carbon emissions.
EU Member States, being members of the United Nations Framework Convention on Climate Change (UNFCCC) provide an extensive analysis of their emissions data (national inventory submissions) to the organisation. These data are available approximately one year after Eurostat publishes its early carbon emission estimates.
The carbon emissions early estimate results conducted every year by Eurostat provides Good estimations at EU level. Additionally, it has exceptional timeliness providing to the policy makers an initial indication of how emissions are evolving at EU level.
Having mentioned the above, this exercise takes into consideration energy products consumption that correspond to 75% of total carbon emissions only. It provides an estimated value of the emissions at the previous year. This estimation is available to the public one year in advance compared to the official figures published at UNFCCC website.

2. Methodology:

According to [3], [4], Eurostat's methodology for early estimation of CO_2 emissions starts with the collection of data. The cut off data is April at the next after the year (Y) for which the estimation is provided. If needed, reference emissions data are extracted at the same time

from UNFCCC website. It publishes at the same period data for the previous year of the reference period (Y-1).

The information is available at the following datasets:
- Supply and transformation of solid fossil fuels - monthly data [nrg_cb_sffm] [5]
This dataset includes monthly data on coal and coal products and peat.

- Supply and transformation of oil and petroleum products - monthly data [nrg_cb_oilm][6]
This dataset includes monthly data oil and petroleum products and

- Supply, transformation and consumption of gas - monthly data [nrg_cb_gasm] [7]
This dataset includes monthly data on gas.

The next step is to extract solid, gaseous and liquid fossil fuel consumption for EU Member States and calculate the apparent consumption as:

Apparent consumption for primary fuels: production + imports – exports (– or +) stock change.

Apparent consumption for secondary fuels: imports – exports (– or +) stock changes – international marine and aviation bunkers.

From the extraction, we use all energy products available in Eurostat monthly datasets [1]. Then we calculate the sums and the change compared to the previous reference year for each fuel and Member State as follows:

$$\frac{\sum_1^m c_{solid}^Y}{\sum_1^m c_{solid}^{Y-1}} = S \quad (1)$$

$$\frac{\sum_1^m c_{peat}^Y}{\sum_1^m c_{peat}^{Y-1}} = P \quad (2)$$

$$\frac{\sum_1^m c_{liquid}^Y}{\sum_1^m c_{liquid}^{Y-1}} = L \quad (3)$$

$$\frac{\sum_1^m c_{gaseous}^Y}{\sum_1^m c_{gaseous}^{Y-1}} = G \quad (4)$$

Where

c is consumption (monthly value)

Solid corresponds to fossil fuels in solid form such as coal

S expresses the change of solid fossil fuels consumption

Peat corresponds to peat products

P expresses the change of peat fuels consumption

Liquid corresponds to fossil fuels in liquid form such as petroleum products, gasoline

L expresses the change of liquid fossil fuels consumption

Gaseous corresponds to fossil fuels in gaseous form such as natural gas

G expresses the change of gaseous fossil fuels consumption

Y is the reference year

Y-1 is the year before the reference year

m is the month of the year

To calculate the estimated values (for each fossil fuel group) for carbon emissions, we can use the total value available at the National Inventory Submissions 2021, United Nations Framework Convention on Climate Change [3]. This inventory includes 2019 data, which can be used as the reference values. From (1) to (4) we derive:

$$EE_{CO2}^{Y} = S * E_{solid,CO2}^{Y-1} + P * E_{peat,CO2}^{Y-1} + L * E_{liquid,CO2}^{Y-1} + G * E_{gaseous,CO2}^{Y-1} \quad (5)$$

Where
E is the emissions reference (annual value)

EE is the emissions estimate (annual value)
Solid corresponds to fossil fuels in solid form such as coal

S is the percentage change of solid fossil fuels consumption

Peat corresponds to peat products

S is the percentage change of peat fuels consumption

Liquid corresponds to fossil fuels in liquid form such as petroleum products, gasoline

L is the percentage change of liquid fossil fuels consumption

Gaseous corresponds to fossil fuels in gaseous form such as natural gas

Y is the reference year

Y-1 is the year before the reference year

m is the month of the year

Imports cover every product quantity, which either enters the territory of the Member State or comes from another Member State for purposes other than transit. Production relates to the production of the product within national boundaries including offshore production. Production only includes marketable production. Especially for oil and oil products, marine and aviation bunkers are the energy consumption of ships and aircraft. International aviation / marine bunkers cover the quantities of fuels delivered to sea-going ships of all flags/airplanes. Consumption by ships/planes engaged in transport in inland and coastal waters/inside the country should not be included.
Stock changes are defined as follows: For fossil fuels, stock change = stocks at the beginning of the period – stocks at the end of the period or vice versa. Based on reporting instructions definitions, fuel stocks changes are accounted as negative or positive values.

For the comparison of the emissions, aggregated monthly data from two consecutive years are used. Data quality of the previous year could be better compared to the recent one. Reporting authorities receive additional input for their data in time. It is possible that are they are able to report data in more detail. Finally, fossil waste emissions are not taken into account.

Basic data on energy quantities are reported in fuel specific units. For oil & petroleum products is in kilotons (kt). For natural gas is in terajoules (TJ) and for solid fuels is in kilotons (kt). For weight and energy content conversions, we use the net calorific values reported to Eurostat at the dataset Calorific values [nrg_bal_cv] [8].

3. Result:

The results of this exercise are published every year on Eurostat's website. The latest early CO2 estimate explained in a news item [9] shows that EU CO2 emissions in 2020 are estimated to have dropped compared to the previous year. This change is mainly caused by the confinement measures introduced by the Member States in the fight against the pandemic. According to this estimate, the largest decrease occurred in Greece (-18.7%), followed by Estonia (-18.1%), Luxembourg (-17.9%), Spain (-16.2%) and Denmark (-14.8%). The lowest decreases were seen in Malta (-1.0%), Hungary (-1.7%), Ireland and Lithuania (both -2.6%) (fig. 1).

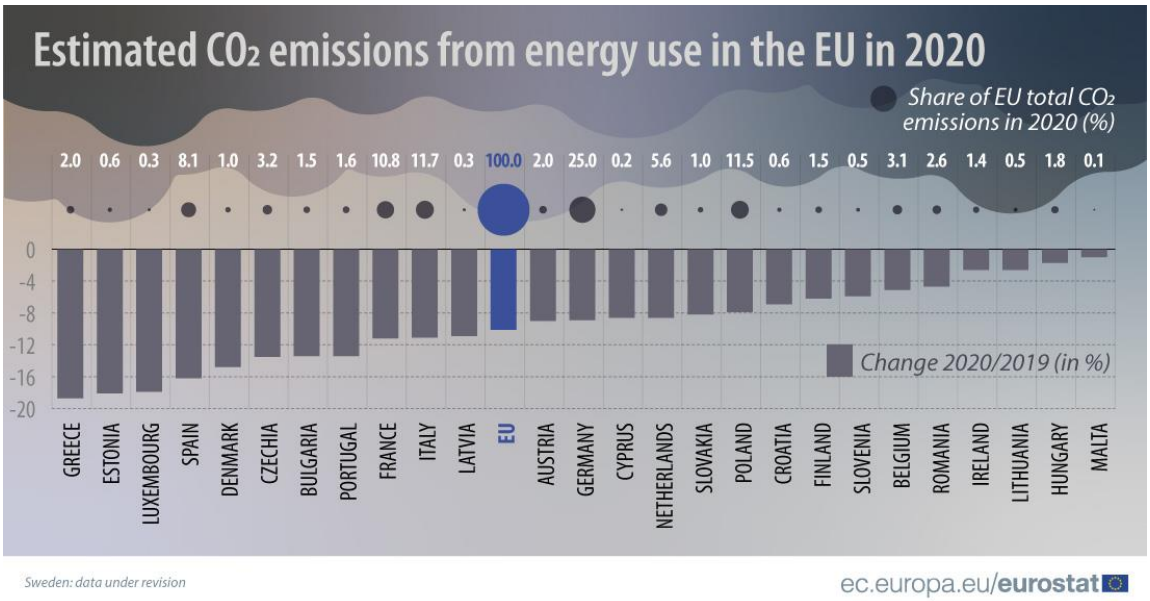

Figure 1. Estimated change of CO_2 emissions from energy use in 2020, when compared to 2019 (reprinted from [9])

Table 1. Method's accuracy – three years reports (reproduced from [10] and [11])

	2011	2012	2013	2014	2015	2016
Number of MS with a difference to final inventory of $\leqslant \pm 2\%$	10 MS	15 MS	19 MS	18 MS	16 MS	16 MS
Contribution of those MS' to total EU-27/28 emissions	61%	44%	62%	66%	77%	61%
Number of MS with a difference to final inventory of ± >2 and $\leqslant$ 5%,	5 MS	9 MS	6 MS	8 MS	10 MS	9 MS
Contribution of those MS' to total EU-27/28 emissions	15%	50%	36%	33%	22%	32%
Number of MS with a difference to final inventory of > ± 5%	12 MS	3 MS	3 MS	2 MS	2 MS	3 MS
Contribution of those MS' to total EU-27/28 emissions	23%	6%	2%	1%	1%	8%
Closeness at EU27/28 level	2.6%	0.5%	0.4%	1.1%	0.2%	0.3%

Table 2. Method's accuracy example for 2017/2016 (reproduced from [5])

EU28 (2017/2016)	Trend changes of early CO_2 estimates	Trend changes in CO_2 emissions based on GHG inventory data	**Differences trend changes early estimates – GHG inventory**
solid fuel consumption	-1.1%	-3.1%	**2.0%**
gaseous fuel consumption	3.8%	3.6%	**0.2%**
liquid fuel consumption	2.2%	2.1%	**0.2%**
TOTAL	**1.7%**	**1.0%**	**0.7%**

From table 1, we observe that at EU level, the prediction quality of our method is adequate. With the exception of the first year, historical analysis shows that accuracy is at all cases higher than 98% at EU level. We have 3 Member States or less where discrepancies are above 5%. These Member States always represent less than 10% of total EU emissions. At all cycles, where we applied this methodology, in more than 15 Member States accuracy was above 98%.

The European Green Deal [12] also aims at reducing fossil fuels consumption. Several lignite/coal plants are already decommissioned and others are scheduled to be decommissioned. The EU Emissions Trading System (EU ETS) [13] creates an additional incentiveto industrial carbon emitters to reduce emissions, thus facilitating the decision making for energy efficiency measures and reducing the operational time of carbon intensive power plants. This has a impact on emissions, pushing them downwards.

4. Discussion and Conclusion:

Early estimations of fossil carbon emissions from Eurostat arrive one year earlier than UNFCCC emissions data. This methodology is including only energy-induced emissions; therefore, its accuracy especially for the Member States with large emission sinks, for example, the LULUFC sector is expected to be lower. The quality of official statistics directly affects this method's result. At aggregated EU level, Eurostat is able to demonstrate adequate accuracy with exceptional timeliness. The methodology is relatively simple with high replicability and is evolving to capture European energy system changes.

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