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EMISSIONS OF CO₂ FROM ROAD TRANSPORT IN POLISH REGIONS

Summary. Calculation greenhouse gases emissions is a crucial tool for development and monitoring of climate policy. Countries and cities are currently the most advanced in calculation of such emissions. Those are the levels of decision, where climate policy is applied firstly. Regions are so far less advances in calculations of emissions and especially emissions from transport sector. This article shows results of a calculation of transport CO₂ emissions from road transport in Polish regions in 2020. This is the first calculation for regions in Poland. Additional indicators are calculated to show, what are the most important drivers of differences in emissions levels.

EMISJE CO₂ Z TRANSPORTU DROGOWEGO W POLSKICH REGIONACH

Streszczenie. Obliczanie emisji gazów cieplarnianych jest kluczowym narzędziem dla rozwoju i monitorowania polityki klimatycznej. Obecnie najbardziej zaawansowane w obliczaniu takich emisji są kraje i miasta. Są to poziomy decyzyjne, gdzie polityka klimatyczna jest stosowana w pierwszej kolejności. Regiony są jak dotąd mniej zaawansowane w obliczaniu emisji, a zwłaszcza emisji z sektora transportu. Niniejszy artykuł przedstawia wyniki obliczeń emisji CO₂ z transportu drogowego w polskich regionach w 2020 roku. Jest to pierwsza kalkulacja emisji z transportu dla regionów w Polsce. Dodatkowe wskaźniki są obliczane, aby pokazać, jakie są najważniejsze czynniki wpływające na różnice w poziomach emisji.

1. INTRODUCTION

Climate change is one of the most important risks World is facing in XXI century. To reduce this risk on the international level Paris Agreement was negotiated in 2015 and ratified by most of independent countries by 2016. The Agreement commits to keep global average temperature well below 2°C. Anthropogenic greenhouse gases emissions are identified as the main reason for the climate change. Paris Agreement sets an aim for quick reduction of their emission to reach climate neutrality, that is “*a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century*” [10].

To pursue a successful policy aiming at reduction of the greenhouse gases emissions all entities that wish to reduce their emissions, need to know them. Therefore, the International Panel for Climate Change prepared a methodology that allows for calculation of the emissions on the country level [6]. Indeed, all the countries calculate their emissions each year and report them to the secretary of United Nations Framework Convention for Climate Change [31]. Based on this achievement the IPCC methodology for emissions calculation is a backbone for calculations of greenhouse gases emissions of any other entity: a person [e.g. F27, a city [1] or a company [3,12].

The IPCC methodology divides calculations into 4 types of sectors, where the sources of emissions decide that the calculations are to be made differently: energy sector, industry processes and product use, agriculture, forestry and land use, waste. Transport emissions fall into the energy sector as a mobile combustion. For the country level there is a possibility to calculate emissions quite easily by taking as a basis for calculation the amount of fuel combusted [7]. The amount of fuel combusted is usually not known for the regional or local level of the country. There is also no other simple way to divide county emissions into cities or regions, such as by dividing it by number of inhabitants or region area.

To learn about emissions of those lower levels of country administration, different basis should be taken into account – the distance travelled by the vehicles. In 2020 Poland has made a General Traffic Measurement [4, 5] on national and regional roads, which contains data that can be used as a basis for calculation of distance travelled is division between country regions. This allowed for calculations presented in this article. The goal of this work was to show, that CO₂ emissions from road transport in a regional or local division for Poland can be calculated in a consistent way, so that results for different geographical areas can be comparable.

2. LITERATURE REVIEW

Calculations of CO₂ emissions on regional level are not a common activity. Countries, companies or cities were up to date the most active actors in climate policy, while regions have less political influence and tools for their activity. Nevertheless, regional level of administration is important in many European and non-European countries, as well as countries try to address some solutions in climate policy also through regional administration. One of the aspects of regional policy is transport system, where countries try to influence the level of regional development by differentiating transport investment, development and quality. Such interventions would definitely have impacts also on regional CO₂ emissions.

Abovementioned aspect of regional emissions calculations have been shown in many works. Chuanguo and Jiang [15] calculated such impact on regional emission with STRIPAT model in China. Similar models for impact of different changes in transport sector on regional emissions has also been used by Gonzales and Marrero [16] for Spain or Burgalassi and Luzatti for Italy [14]. The team under the leadership of Tolon-Becerra also used such methods, but to propose different regional goals in Spain for reduction of CO₂ emissions [22]. The problem is those works are not paying much attention to the method of CO₂ calculation for the regions and the exact emissions, because they take regional emissions as a result or a function of a different factor. For example Valles-Gimenes and Zarazte-Marco [23] estimate greenhouse gases emissions by the level of pollution tax.

More exact view on greenhouse gases or CO₂ emissions is produced with models using network approach. Models that show road traffic on a network level are used in Europe and worldwide already for more than 15 years. They have so far been used for example in calculation of air pollutants emission and subsequent air quality modelling. Such works were prepared mostly for city level Nejadkoorki et al [18], have shown that can be useful also for the CO₂ emission estimation. Volker et al [24] has quite recently used this kind of modelling also to trace emissions on a regional level. From this work there is only a step to the assessments like the one of Sharifi et al [19], who showed an impact of the possible road network improvements on the overall regional road network CO₂ emissions in the future of El Paso. This is the spatial view into the regional emissions that is needed, but rarely shown.

Regions should probably follow the path of cities, which have worked on their own emission calculations standards in cooperation. The network of C40 cities prepared such standards with World Resources Institute [1], based on the works done previously for companies [3,12]. Even before that standard, cities were trying to learn about their CO₂ emissions through various type of estimations, which have largely been shown in the article of Szymalski [21]. Through standardization cities, and probably also other area administration levels, can try to reach to comparable and reliable emissions

calculations also for transport sector. There is a need for such comparisons, what have been shown by various scientific works [13, 17].

The closest work to what is presented in this article is a calculation of local and regional level greenhouse gas emissions in United Kingdom [29]. The estimates of such emissions have been produced in June 2022 for past (2005-2020) and currently have been also prepared for 2021 and 2022 [11, 30]. The authors of these estimations calculate local and regional emissions for road transport with use of:

- COPERT 5 fleet characteristics for at least 6 mayor classes of vehicles.
- National fuel emission factors.
- National data on the local composition of fleet combines with the fleet structure data obtained during the traffic measurements on main roads;
- Road transport mapping on network of all type of roads, based on measurement on network of main roads and estimations for other roads as well as information about speed limits on the roads.

The calculations are pursued for the level of local authorities in United Kingdom. Those calculations are additive so can be used to calculate also regional emissions. All the emissions are shown as a dataset and in a form of maps [11, 30].

3. METHOD OF CO₂ CALCULATION FOR POLISH REGIONS

3.1. Method and datasets for CO₂ calculations

The method used for calculation of CO₂ emissions for Polish regions is not new. An emission model for transport network was used, which previously allowed for a calculation of CO₂ emissions from transport on a Warsaw City transport network. The model calculates also, as a prerequisite for emission calculation, the energy use. This calculations and the main features of the model were described in works of Szymalski [20, 21]. Institute for sustainable Development Foundation is currently an owner of this model.

In the case of regional approach, only the part of the model was used, which is dedicated to calculate emissions from road transport. The model was filled in with the data coming from the following datasets:

- COPERT IV European vehicles pollution and energy use database [26] – the database was used to produce fuel efficiency factors for all type of vehicles. Fuel efficiency factors were produced once for the whole Polish vehicle fleet and applied to all the regions, so there are no regional disparities in this data.
- Polish Statistical Office vehicle fleet information [28] as well as other relevant local fleet data from literature. For example the number of electric busses in each region has been taken from the work of FPPA [2]. The number of other electric vehicles has been found as a number for the whole country [25]. Only a part of this number was applied to each region. This fraction was calculated as a percentage of regional fleet in a national fleet for a given type of vehicle. Vehicles older than 30 years in 2020 were assumed as unused and excluded from calculations.
- Road traffic levels and intensity are coming from General Traffic Research that took place in 2020 on the whole network of national and regional roads in Poland [4, 5]. The research gives an overview of traffic in the division for vehicle types. It measured the traffic on the whole road network active on that year. The results of traffic measurements on road network are divided by regions, what allows for easy division of traffic flow into regions.
- Polish National Centre for Emissions Management CO₂ emission factors for different kind of fuels as well as electric energy in the national grid [8, 9].

Result calculated for regions is additive and could be summed up to show country level emissions. It could also be compared to the CO₂ emission calculation prepared separately on the same model for the whole Poland.

3.2. Method of calculation for additional indicators

Additionally some indicators were calculated with use of the emissions results. The indicators check the intensity of emissions in each regions in relation to different transport factors of the region. The relations are checked for the following factors:

- Vehicle transport work in the region (vehicle-km);
- Road network in the region (km);
- Number of vehicles in the region (no.);

Indicators allow for conclusions about those factors impact on the final emission in relation to other impacts. Numbers for the factors used are shown in the Table 1.

Tab. 1

Daily regional vehicle transport work, regional road network and number of vehicles in Polish regions in 2020 [Source: own study based on: 4,5,28]

The region/Voivodeship	Vehicle transport work (veh-km)	Regional road network (km)	Number of vehicles (veh)
Dolnośląskie	31927382	3597	1505871
Kujawsko-Pomorskie	19633074	2779	962586
Lubelskie	18271561	3315	1019937
Lubuskie	13169068	2389	522490
Łódzkie	28924117	2732	1231833
Małopolskie	28351796	2397	1612564
Mazowieckie	51956937	5068	3113585
Opolskie	11482170	1710	485180
Podkarpackie	18076521	2571	945070
Podlaskie	11556860	2270	520722
Pomorskie	22184490	2655	1137151
Śląskie	28844156	2217	2190725
Świętokrzyskie	12274623	1794	539301
Warmińsko-Mazurskie	13835908	3161	623683
Wielkopolskie	37641604	4351	1904673
Zachodniopomorskie	16426998	3203	778510
Poland	364557265	46208	19093881

4. RESULTS

4.1. Result of CO₂ calculations

Result calculated is a daily emission, that can be extended into a yearly emission by multiplication of a factor 365 days. Result of calculations is shown in the Table 2.

As the table shows separate calculation of emissions for the whole Poland gives a slightly different result, that the sum of calculations for all the regions. The result is 0,06% different for the calculation of energy and 0,11% different for the calculation of emissions. All of the data used in the model have been carefully checked to eliminate the possibility of the data error or other data processing errors. As a result of this check all the inconsistencies in the datasets for each region and the whole country were cleared, nevertheless the results are not equal. This difference is probably a matter of multiple rounding made automatically in a calculation sheets.

Shares of the emission between the regions are in general following the share of energy use - differences are not higher than 0,1p.p. The highest daily emission on road was calculated for Mazowieckie – 62 607 Mg, and the lowest for Opolskie – 15 137 Mg. It seems that the biggest regions

in terms of area and number of inhabitants – Mazowieckie (13,7%), Wielkopolskie (10,9%) - are visibly having a highest emission and the highest shares of country emissions. Smaller and less inhabited regions are having less emissions and lower shares in country emissions – Opolskie (3,3%), Świętokrzyskie (3,5%). This visible tendency however does not necessarily mean there is a strong correlation between the area, number of inhabitants and road transport related CO₂ emissions.

Tab. 2

Daily CO₂ emissions and energy use from road transport on the network of national and regional roads in 2020 [Source: own study]

The region/Voivodeship	Energy use (MWh)	Share of energy (%)	Emission (Mg)	Share of emission (%)
Dolnośląskie	10943	9,4%	42486,18	9,3%
Kujawsko-Pomorskie	6674	5,7%	26098,13	5,7%
Lubelskie	5396	4,6%	21178,22	4,6%
Lubuskie	4716	4,0%	18435,67	4,0%
Łódzkie	11061	9,5%	43029,64	9,4%
Małopolskie	7700	6,6%	30265,56	6,6%
Mazowieckie	16070	13,8%	62607,73	13,7%
Opolskie	3874	3,3%	15137,5	3,3%
Podkarpackie	5013	4,3%	19725,67	4,3%
Podlaskie	4280	3,7%	16649,64	3,7%
Pomorskie	6148	5,3%	24205,85	5,3%
Śląskie	9149	7,8%	35812,67	7,9%
Świętokrzyskie	4039	3,5%	15853,41	3,5%
Warmińsko-Mazurskie	4015	3,4%	15723,3	3,5%
Wielkopolskie	12787	11,0%	49852,47	10,9%
Zachodniopomorskie	4704	4,0%	18407,27	4,0%
Sum	116569	100%	455468,9	100%
Poland (separate calculation)	116700		455730,2	

4.2. Results for additional indicators

Additional factors calculated for the CO₂ emissions are shown in Table 3. Meaning of the calculated indicators is the following. Indicator calculated for the whole Poland is the mean value. Regions, which have higher values of the indicator show higher impact of the analyzed factor on the emissions and regions with values lower than the mean show lower impact of the analyzed factor on the CO₂ emissions.

Highest value of the indicator calculated with vehicle transport work is for Łódzkie region – 0,383kg CO₂/veh-km. This tells us that Łódzkie has exceptionally high emission intensity of traffic on national and regional roads – this might be the cause of high share of HDVs traffic on the roads. Interestingly enough Łódzkie has also very high indicator value for length of road network – 4,05 MgCO₂/ km, as well as number of vehicles – 9,0 kgCO₂/veh. Therefore, emission intensity from each kilometer of a road in Łódzkie is high, what means that roads have high traffic capacities. Emission from a single vehicle is also very important impact factor for CO₂ emission in this region – just as in Lubuskie, which has the same value of this indicator as Łódzkie.

Lowest value for the vehicle transport work indicator is calculated for Małopolskie – 0,272kgCO₂/veh-km, what means that high emission intensity vehicles are less frequent in this region. Indicator based on regional road network length is the lowest for Warmińsko-Mazurskie region – 1,27kgCO₂/km. This region has probably the least traffic capacity on the road network. Śląskie has the lowest indicator of CO₂ emissions divided by number of vehicles – 4,2kgCO₂/veh. This may mean that

Śląskie has the least polluting fleet of cars or cars are travelling less frequently on national and regional roads than in other regions.

Tab. 3

Indicators showing and impact of vehicle transport work, length of roads and number of vehicles on emissions in 2020 in Polish regions. [Source: own study]

The region/Voivodeship	CO ₂ emissions by regional vehicle transport work (kg/veh-km)	CO ₂ emissions by regional road network (Mg/km)	CO ₂ emissions by number of vehicles (kg/veh)
Dolnośląskie	0,343	3,04	7,3
Kujawsko-Pomorskie	0,340	2,40	6,9
Lubelskie	0,295	1,63	5,3
Lubuskie	0,358	1,97	9,0
Łódzkie	0,382	4,05	9,0
Małopolskie	0,272	3,21	4,8
Mazowieckie	0,309	3,17	5,2
Opolskie	0,337	2,27	8,0
Podkarpackie	0,277	1,95	5,3
Podlaskie	0,370	1,89	8,2
Pomorskie	0,277	2,32	5,4
Śląskie	0,317	4,13	4,2
Świętokrzyskie	0,329	2,25	7,5
Warmińsko-Mazurskie	0,290	1,27	6,4
Wielkopolskie	0,340	2,94	6,7
Zachodniopomorskie	0,286	1,47	6,0
Poland	0,320	2,53	6,1

5. CONCLUSION

Polish regions can have their CO₂ emissions from road transport calculated with methods that allow for comparison between them. The same probably applies to any other regional administration areas e.g. counties and municipalities. There are datasets from most of the necessary data for such calculations. Crucial for the calculations is a set of data about the traffic on the area road network. For Polish regions there was a dataset available provided from General Traffic Research made in 2020.

What did not come as a surprise from the provided regional calculations of CO₂, shares of CO₂ emissions tend to be similar to the pattern of shares in area or number of inhabitants. Biggest regions and those with higher number of inhabitants have the highest traffic related CO₂ emissions – Mazowieckie, Wielkopolskie, while small and less populated regions have lowest traffic related CO₂ emissions – Opolskie, Świętokrzyskie.

Factors that are used for the calculations of CO₂ emissions can be used to prepare indicators, which can show different impact of their values on the emissions. With use of those factors regions can be characterised according to the main causes of the emission intensity. For example Łódzkie region seems to have roads with high intensity of traffic at the same time this traffic is made with high emission vehicles on roads with high traffic capacity. Such characteristics of regions can be a guidance for basic policy decisions that would allow for regional CO₂ emissions reductions.

Nevertheless, more detailed CO₂ emission sources studies for transport sector should be made for each Polish region. The study described here could not show emission that results from local roads, which are much more lengthy than the main roads network. Emission from local roads is especially high for cities and emissions for each region should be in the first step aided with such data. Secondly, there is

so far not enough data publicly available in Poland, to calculate separately emission from railway network and public transport, which are the most important to show if any comparisons or decisions need to be made in order to provide for modal shifts.

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