IOŚ-PIB
Environmental Protection and Natural Resources
Ochrona Środowiska i Zasobów Naturalnych
sciendo
Vol. 29 No 3(77): 13-20
DOI 10.2478/oszn-2018-0014

Zdzisław Chłopek*, Anna Olecka*, Krystian Szczepański*, Katarzyna Bebkiewicz*

Share of road transport in greenhouse gas emissions in Poland in 1988–2015

* Institute of Environmental Protection – National Research Institute in Warsaw;
e-mails: zdzislaw.chlopek@kobize.pl

Keywords:
greenhouse gases, motor vehicles, road transport

Abstract

The results of an analysis of the greenhouse gas (GHG) emission inventory in Poland in the years 1988–2015 are presented, paying special attention to the impact of road transport on the intensification of greenhouse effect. The analysis was made based on the official results compiled by the National Centre for Emissions Management and Balancing (KOBiZE) at the Institute of Environmental Protection – National Research Institute.
It was found that carbon dioxide emission represented the dominant part of the total GHG emissions, despite that there were other gases having far greater greenhouse effect potential. There was a general downward trend for the national annual emission of basic GHGs. The estimated share of road transport in the GHGs emission was not high: from 4% in 1988 to around 12% in 2015.
For motor vehicles, there is a dominant share in the GHGs emissions of passenger cars: (50 ÷ 60)%.
In the years 1988–2015, there was a relative decrease by about 32% in the national annual emission of carbon dioxide equivalent from all sources covered by the inventory. That notwithstanding, the national annual emission of carbon dioxide equivalent arising from transportation increased generally by about 93% and that from the road transport increased by as much as 117%. The increase in GHGs emissions from motor vehicles resulted mainly from a significant growth in car numbers. Technical progress in the construction of motor vehicles can be evaluated by considering the average annual emission of carbon dioxide equivalent from a conventional car, which has been decreasing since 1998.

1. INTRODUCTION

It should be noted that numerous controversies exist concerning climate changes and their underlying reasons, amongst both specialists and, especially, people primarily involved only emotionally and populistically. Nevertheless, some observations of the state of the environment confirm the global warming trend of the Earth's surface and of lower layers of the atmosphere along with the resultant implications [Climate change evidence & causes …2010, Climate change: a summary of …2010]. It is, of course, a disputable issue to infer the dominant causes of global warming by taking into account only such a short time of our planet's existence, because it is known that the Earth is now in one of its coldest periods, the last mega-glaciation, even though, admittedly, the end of the last glaciation in the Holocene, around 11,700 years ago, marked the beginning of the interglacial – a warmer period of the mega-glaciation. There are no doubts amongst specialists that solar activity is of crucial importance for determining Earth's conditions. It is above all the chemical composition of the atmosphere and also its physical composition, including the physical state of water, that are involved in determining the energy balance of the Earth's surface and the atmosphere, but the main factor is the concentration of the so-called greenhouse gases, whose potential to absorb electromagnetic radiation is highly sensitive to its frequency [Chłopek 2012, Climate change evidence & causes …2010, Climate change: a summary of …2010]. The increase in greenhouse gases (GHGs) concentration and, especially, in that of carbon dioxide, observed over the recent years in the atmosphere, has been confirmed by many observations. There is also no doubt that a strong correlation exists between the temperature of both the Earth surface and the lower atmosphere and the GHGs concentration in the atmosphere [Climate change evidence & causes …2010, Climate change: a summary

of …2010], yet it should be remembered that correlation in the strict sense is not enough to conclude about the cause-and-effect relationship, because it represents only a postulate (though practical) of the author of such a hypothesis [Hume 2014, Kant 2016].
Despite widespread controversy as regards global warming, societies are becoming undeniably concerned about that threat, which results in initiating the international cooperation. On 9 May 1992, the United Nations Framework Convention on Climate Change (UNFCCC) [United Nations …1992] was concluded in New York, and on 11 December 1997, the Kyoto Protocol to the Framework Convention United Nations on Climate Change was concluded in Kyoto [Kyoto Protocol to the…2005]. Poland has ratified these legal acts. One of the main obligations of Poland, resulting from the ratification of the Kyoto Protocol, is the obligation to reduce GHGs emissions by 6% in the years 2008–2012, in relation to the base year, and by 20% in the years 2013–2020. Pursuant to the provisions of Article 4.6 of the UNFCCC Convention and of Decision 9/CP.2, Poland uses the year 1988 as the base year for reporting GHGs inventories [Report of the Conference…2014].
Inasmuch as controversies have been raised by the decisions to introduce necessary changes in the economy to make individual countries meet their obligations to reduce GHGs emissions, the very need is unquestionable for monitoring the status of natural environment and social development as well as GHGs emission.
Pursuant to Decision 24/CP.19, all Parties listed in Annex I to the Convention [Report of the Conference…2014] are required to submit the national annual inventory covering the following gases and groups of GHGs:
- carbon dioxide (CO_2),
- methane (CH_4),
- nitrous oxide (N_2O),
- a fluorocarbon group (HFC),
- a group of perfluorocarbons (PFC),
- sulphur hexafluoride (SF_6),
- nitrogen trifluoride (NF_3).

The emission of individual GHGs is converted into the emission of carbon dioxide equivalent, which is a linear combination of emissions of individual GHGs and their global warming potential (GWP; Table).
Pursuant to the Act of 17 July 2009 on the management system of GHG emission and other substances, the unit responsible for developing GHG emission inventories in Poland and reporting to the European Union and to the Convention is the National Centre for Emissions Management and Balancing (KOBiZE) at the Institute of Environmental Protection – National Research Institute, supervised by the Minister of the Environment.
Pursuant to Decision 24/CP.19 [Report of the Conference…2014] of the Convention, the annual inventory of GHG emission is to be performed by all countries listed in Annex I to the Convention. Reports on GHGs inventories from individual countries – Parties to the Convention are available [e.g. Canada's Greenhouse Gas Inventory…2016, Greenhouse Gas Emissions 1990–2014…2016, National Inventory Report Sweden 2016, U.S. Greenhouse Gas Inventory Report: 1990–2014] – although the results of deeper analyses of inventories have not been disseminated in the scientific literature. This article presents the results of study on GHG emissions in Poland in the years 1988–2015, mainly in view of the contribution of transport-related emission and, in particular, that arising from road transport. The article uses the results contained in the KOBiZE report [Poland's informative…2017].

Table 1. Global warming potential of gases with the largest share in carbon dioxide equivalent emission [Report of the Conference…2014].

Greenhouse gas	Chemical formula	GWP
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298

GHG emissions are reported in five categories of human activities [2006 IPCC Guidelines for National Greenhouse, Poland's informative…2017], including
1. Energy;
2. Industrial processes and use of products;
3. Agriculture;
4. Land use, land use change and forestry;
5. Waste generation.

The categories of human activities, along with their subcategories, are classified according to the common reporting format (CRF) [2006 IPCC Guidelines for National Greenhouse, Poland's informative…2017].
In sector 3 – energy (CRF 1) – transportation is also included (CRF 1.A.3), covering [2006 IPCC Guidelines for National Greenhouse, Poland's informative…2017]:
- Air transport (CRF 1.A.3.a),
- Road transport (CRF 1.A.3.b),
- Railway transport (CRF 1.A.3.c),
- Water transport (CRF 1.A.3.d),
- Other modes of transport (CRF 1.A.3.e).

The emission of GHGs is estimated in accordance with the UNFCCC guidelines [2006 IPCC Guidelines for National Greenhouse], which contain the methodology developed by the Intergovernmental Panel on Climate Change (IPCC) in 2006, as a manual of IPCC guidelines for the National GHG Inventories [2006 IPCC Guidelines for National Greenhouse]. This methodology is recommended by Decision 24/CP.19 of the Convention. The IPCC guidelines also allow to use other methods for determining GHG emissions.
In general, the following assumptions have been made in the emission inventories [Bebkiewicz et al 2017b]:
1. The emission intensity of individual pollutants is an additive quantity.
2. Inventories are being made using data for substances in the form in which they are emitted from

emission sources, without taking into account the transformations of these substances occurring in the environment.

The basic concept in the emission inventory is emission. Emission (m) is the mass of pollutant introduced into the environment. Emission intensity (E) is a derivative of pollutant emission, taken as a function of time (t) of the variable time [Chłopek 2012, Chłopek 1999]:

$$E = \frac{dm}{dt} \tag{1}$$

The annual emission of pollutants is the pollutant intensity averaged over the course of the inventory year. The annual emission of pollutants arising from the entire country is called E_a, the national annual emission of pollutants.
An assumption is made in the methodology for determining the national annual pollutant emission that the latter is the product of a pair of coupled coefficients of pollutant emission inventories [2006 IPCC Guidelines for National Greenhouse, EMEP/EEA air pollutant … 2016], including
- w_e – the pollutant emission factor;
- w_a – the activity coefficient from the state area.

The pollutant emission coefficient is a zero-dimensional characteristic of pollutant emission. This is an intensive quantity. The activity coefficient is an extensive quantity, which describes the useful work performed during the inventory year by emitters, within the territory of the country concerned by the emission inventory. Depending on the character of human activity category, quantities such as consumption of energy and materials, for example, fuels and raw materials, can be adopted as a measure of useful work.
The national annual emission of pollution is expressed by the formula:

$$E_a = \sum_{i=c}^{C} w_{ei} \cdot w_{ai} \tag{2}$$

where w_{ec} is the pollution emission factor from the cth object, averaged relative to the activity of the object within one inventory year; w_{ac} is the activity of the c-th object within one inventory year; and C is the number of facilities used in the country covered by the emission inventory.
The inventory of pollutant emissions from the road transport category usually adopts the following pair of coupled coefficients of pollutant emission inventory: specific distance emissions of pollutants and distance travelled by a vehicle.
Specific distance emission of pollutant (b) is a derivative of pollutant emission from a vehicle, taken as a function of distance (s) of the variable the vehicle distance travelled [Chłopek 2012, Chłopek 1999]:

$$b = \frac{dm}{ds} \tag{3}$$

The national annual emission of pollution is expressed by the formula:

$$E_a = \sum_{i=1}^{N} b_i \cdot S_i \tag{4}$$

where b_i is the average of pollutant specific distance emission from the ith vehicle, relative to vehicle distance travelled for one inventory year;
S_i is the distance travelled by the i-th vehicle for one inventory year; and N is the number of vehicles used in the country covered by the pollution inventory.
The following values are another pair of coupled coefficients of pollutant emission inventories that may possibly be applied in the road transport:
- the index of pollutant emission and fuel mass consumption,
- the energy index of pollutant emission and energy consumption.

The index of pollutant emission is defined as a derivative of pollutant emission, taken as a function of mass fuel consumption (m_f) of the variable mass fuel consumption [Chłopek 1999]:

$$W = \frac{dm}{dm_f} \tag{5}$$

The national annual emission of pollution is expressed by the formula:

$$E_a = \sum_{j=1}^{M} W_j \cdot m_{fj} \tag{6}$$

where W_j is the index of pollutant emission from the j-th object, averaged relative to the fuel mass consumption within one inventory year; m_{fj} is the fuel mass consumption by the j-th object within one inventory year; and M is the number of facilities used in the country covered by the pollution inventory.
The energy index of pollutant emission is a derivative of pollutant emission, taken as a function of energy consumption (Ω) of the variable energy consumption:

$$WE = \frac{dm}{d\Omega} \tag{7}$$

The national annual emission of pollution is expressed by the formula:

$$E_a = \sum_{k=1}^{K} WE_k \cdot \Omega_k \tag{8}$$

where WE_k is the energy index of pollutant emission from the k-th object, averaged relative to energy consumption for one inventory year; Ω_k is the energy consumption by the k-th object for one inventory year; and K is the number of facilities used in the country covered by the pollution inventory.

To calculate GHG emission from motor vehicles, within the framework of the GHG inventory completed at the KOBiZE, the COPERT 4 (computer program for calculating emissions from road traffic) software has been used [Gkatzoflias et al 2012]. The COPERT model was developed under the patronage of the European Environment Agency (EEA) for the purposes of reporting by the Member States the national GHG emission and other pollution from road transport. In this model, the specific distance emission of pollutants and the vehicle distance travelled are assumed as a pair of coupled coefficients of the emission inventory.

Detailed data for the COPERT software, including the numbers and intensity of motor vehicle use as well as the characteristics of road traffic in Poland, were derived from publications [Bebkiewicz et al 2017a, 2017b] and KOBiZE reports [Pearson 1904, Poland's informative…2017].

2. ANALYSIS OF INVENTORY RESULTS OF GHGS EMISSIONS FROM THE INVENTORIED EMISSION SOURCES AND FROM TRANSPORTATION

Figure 1 shows the national annual emission of GHGs, including carbon dioxide, methane and nitrous oxide generated by the inventoried emission sources.

The emission of methane and nitrous oxide is smaller than that of carbon dioxide by two and three orders of magnitude, respectively.

Figure 2 presents the national annual emission of carbon dioxide equivalent for individual gases, including carbon dioxide, methane and nitrous oxide, from the inventoried emission sources.

The emission of carbon dioxide equivalent is also more than 5 times higher for carbon dioxide than for methane and more than 20 times higher than for nitrous oxide.

The same is to be observed in the share of the national emission of carbon dioxide equivalent for gases: carbon dioxide, methane and nitrous oxide from the inventoried emission sources in the national emission of annual carbon dioxide equivalent from the three components considered (Figure 3).

The proportion of carbon dioxide is more than 80% in GHG emission from the inventoried emission sources.

Figure 4 presents the national annual emission of carbon dioxide equivalent from the inventoried emission sources, from transportation and from road transport.

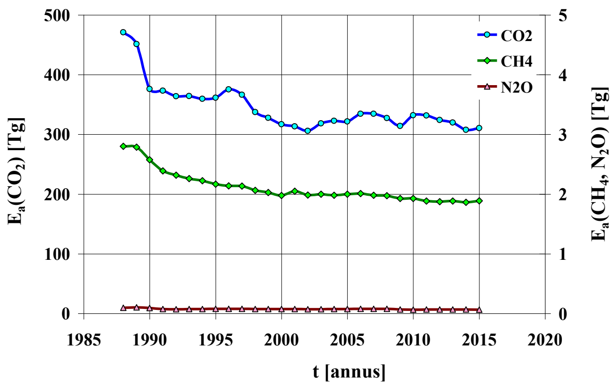

Figure 1. National annual emission of GHGs, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the inventoried emission sources (E_a).

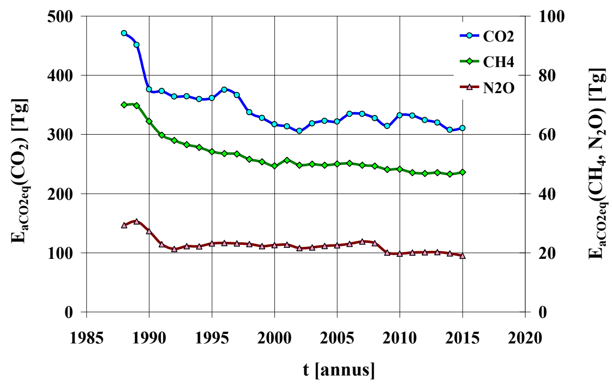

Figure 2. National annual emission of carbon dioxide equivalent of gases, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the inventoried emission sources (E_a).

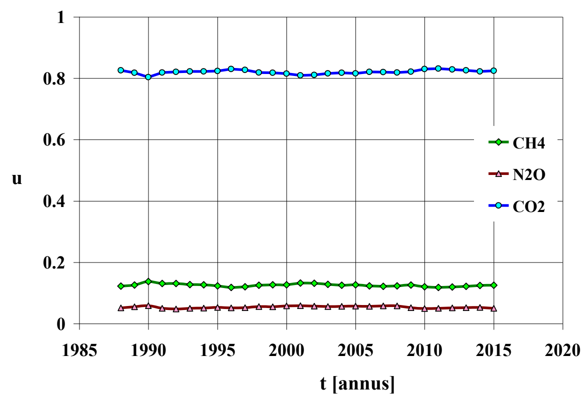

Figure 3. Share of the national annual emission of carbon dioxide equivalent for gases, including carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) from the inventoried emission sources, in the national annual emission of carbon dioxide equivalent from the three components considered.

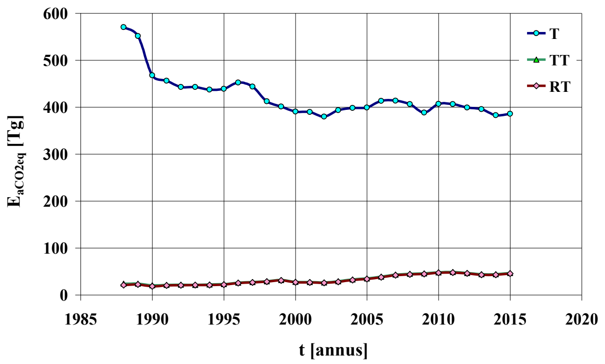

Figure 4. National annual emission of carbon dioxide equivalent (E_{aCO2eq}): T, from the inventoried emission sources; TT, from transportation; RT, from road transport.

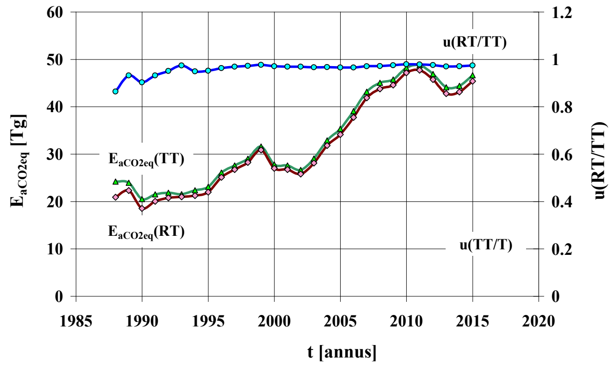

Figure 5. National annual emission of carbon dioxide equivalent from transportation [E_{aCO2eq}(TT)] and from road transport [E_{aCO2eq}(RT)] as well as the share of the national annual emission of carbon dioxide equivalent from road transport in the national annual emission of carbon dioxide equivalent from transportation [u(RT/TT)].

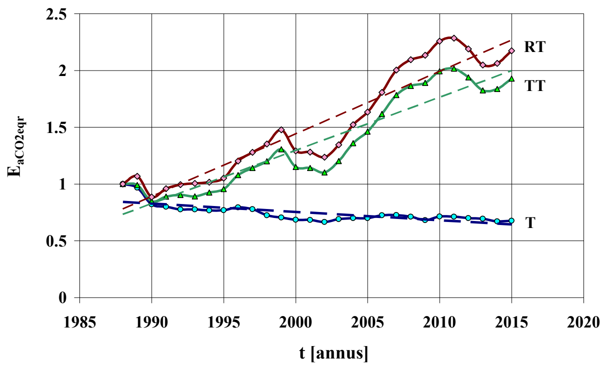

Figure 6. Linear trend of the relative national annual emission of carbon dioxide equivalent ($E_{aCO2eqr}$): T, from the inventoried emission sources; TT, from transportation; RT, from road transport.

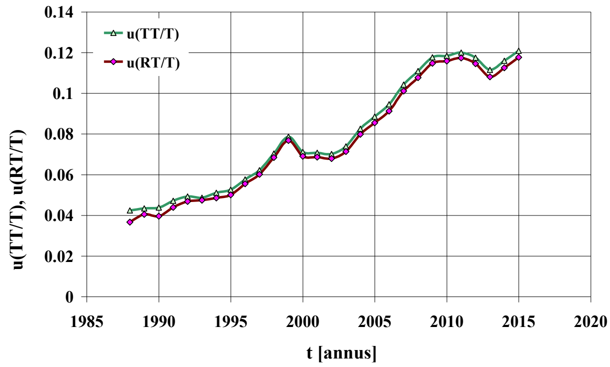

Figure 7. Share of the national annual emission of carbon dioxide equivalent from transportation in the national annual emission of carbon dioxide equivalent from the inventoried emission sources [u(TT/T)] and share of the national annual emission of carbon dioxide equivalent from road transport in the national annual emission of carbon dioxide equivalent from the inventoried emission sources [u(RT/T)].

The road transport accounts for a dominating share of GHG emission from the transportation in general (Figure 5). This figure also shows the share of the national emission of carbon dioxide equivalent from transportation in the national annual emission of carbon dioxide equivalent from the inventoried emission sources as well as the share of the national annual emission of carbon dioxide equivalent from road transport in the national annual emission of carbon dioxide equivalent from transportation. The share of the national annual emission of carbon dioxide equivalent from road transport in the national annual emission of carbon dioxide equivalent from transportation is higher than 0.86 and, since 1995, has been stabilised at the level of around 0.97.

Figure 6 shows a linear trend of the relative national annual emission of carbon dioxide equivalent from the inventoried emission sources, from transportation and from road transport. The relative value of the relative national annual emission of carbon dioxide equivalent is related to the national annual emission in 1988.

The national annual emission of carbon dioxide equivalent from all the inventoried emission sources tends to decrease, whereas that from transportation tends to increase.

In Figure 7, the shares are compared with the national annual emissions of carbon dioxide equivalent generated by transportation and by road transport in the national annual emission of carbon dioxide equivalent from the inventoried emission sources.

This share, for all transportation and for road transport alike, increases significantly from around 4% in 1988 to around 12% in 2015.

Figure 8 presents the national annual emission of carbon dioxide equivalent from road transport as well as that arising from the cumulative categories of motor vehicles, including passenger cars, light commercial vehicles, heavy duty trucks, buses, motorcycles and mopeds.

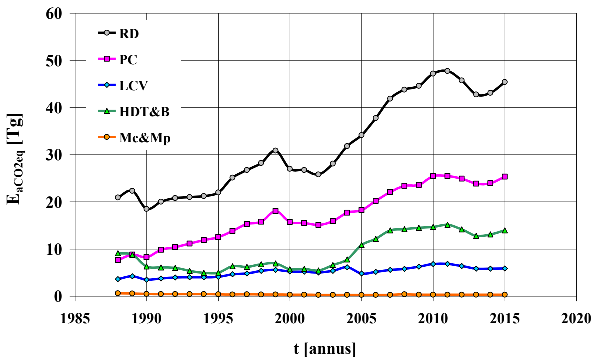

Figure 8. National annual emission of carbon dioxide equivalent: RT, from road transport; PC, from passenger cars; LCV, from light commercial vehicles; HDT & B, from heavy duty trucks and buses; Mc & Mp, from motorcycles and mopeds.

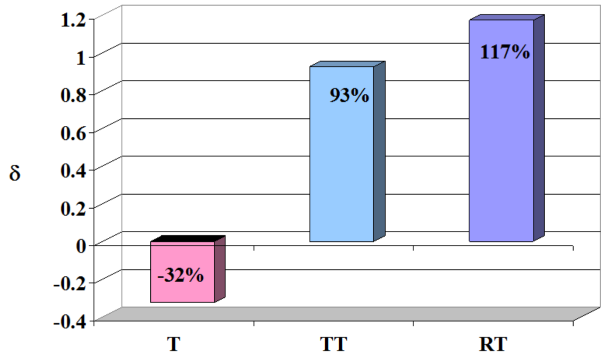

Figure 10. Relative change (d) in the national annual emission of carbon dioxide equivalent in the years 1988–2015: T, from the inventoried emission sources; TT, from transportation; RT, from road transport.

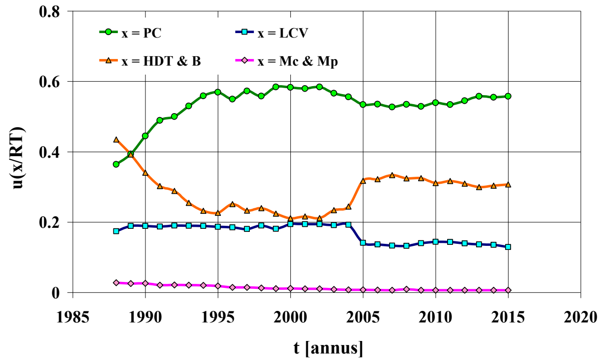

Figure 9. Share of the national annual emission of carbon dioxide equivalent [u(x/RT)] from passenger cars (x = PC), light commercial vehicles (x = LCV), from heavy duty trucks and buses (x = HDT & B) as well as from motorcycles and mopeds (x = Mc & Mp) in the national annual emission of carbon dioxide equivalent from road transport.

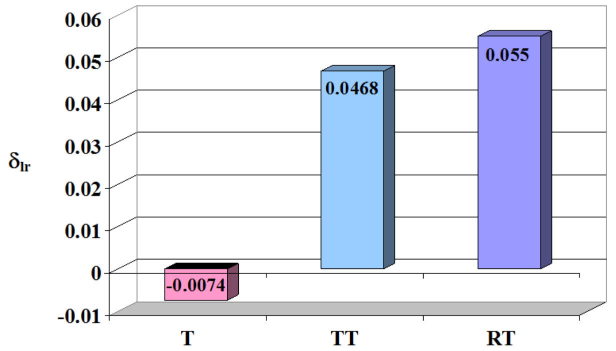

Figure 11. The slope (d_{lr}) of linear function approximating the dependence of the relative national annual emission of carbon dioxide equivalent on the years of emission balancing in the years 1988–2015: T, from the inventoried emission sources; TT, from transportation; RT, from road transport –.

Passenger cars make up the predominant share in the national annual emission of carbon dioxide equivalent from road transport, followed by trucks and buses. The latter is corroborated by the share of the national annual emission of carbon dioxide equivalent from the cumulative categories of motor vehicles in the national annual emission of carbon dioxide equivalent from the entire road transport (Figure 9).

Since 1995, the share of GHG emissions from passenger cars has been stabilised at the level of (50 ÷ 60)%. The share of GHG emissions from trucks and buses showed a downward trend until 1995 and, since 2005, has remained at a level higher than 30%. The share of GHG emissions from light commercial vehicles was slightly less than 20% until 1995 and, since 2005, has been kept around 15%.

Figure 10 shows the relative change in the national annual emission of carbon dioxide equivalent from the inventoried emission sources, transportation and road transport in the years 1988–2015.

This clearly indicates that the emission of carbon dioxide equivalent from all the inventoried emission sources has generally decreased by about 32%, whereas that from transportation and from road transport increased by about 93% and as much as 117%, respectively. This is in line with a comparison of the directional coefficient (d_{lr}) of the linear function approximating the dependence on the years of emission balancing and the relative national annual emission of carbon dioxide equivalent from the inventoried emission sources, from transportation and from road transport in the years 1988–2015 (Figure 11).

Of course, the slope of linear function approximating the dependence of the relative national annual emission of carbon dioxide equivalent on the years of emission balancing and the relative change of the national annual carbon dioxide equivalent are closely correlated; the Pearson linear correlation coefficient [Pearson 1904] is 0.999. Such a significant increase in GHG emissions from motor vehicles is associated mainly with a very high growth rate in the number of cars as well as with the increasing intensity of vehicle operation (annual distances travelled)

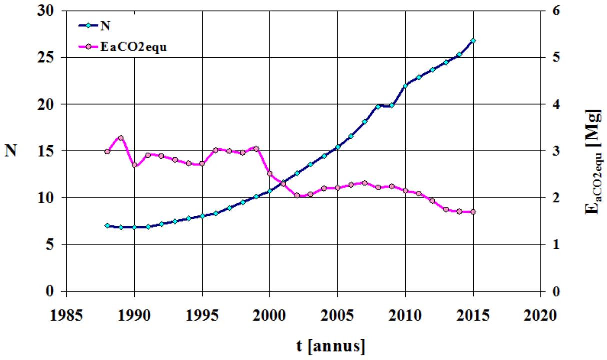

Figure 12. Number of motor vehicles (N) and the average annual emission of carbon dioxide equivalent from a conventional car ($E_{aCO2equ}$).

[Bebkiewicz et al 2017a, Poland's informative…2017], which is corroborated by the increase in the use of motor fuels [Poland's informative…2017]. Figure 12 illustrates the number of vehicles of cumulated categories in Poland in the years 1988–2015 [Bebkiewicz et al 2017a].

Since 1998, there has been a general downward trend of the average annual emission of carbon dioxide equivalent from a conventional car, which has become unambiguous since 2009. It should be noted that the above assessment does not take into account the increase in the intensity of motor vehicles use [Bebkiewicz et al 2017a, Poland's informative…2017]. The declining trend and the decrease in the average annual emission of carbon dioxide equivalent from a conventional car is undoubtedly the result of technical progress in the car construction, whose aim is not only to cut on emissions of substances harmful to living organisms [Chłopek 1999, Worldwide emission…2015/2016, Worldwide emission…2015/2016] but also to reduce fuel consumption. The latter reduction, taking into account the widespread use of petroleum fuels, translates into the reduction of emission of fossil carbon dioxide.

3. SUMMARY

On the basis of the results of analyses of GHG emissions in Poland in 1988–2015, the following conclusions can be made:

1. In the years 1988–2015, the national annual emission of basic GHGs, including carbon dioxide, methane and nitrous oxide, was generally declining in Poland. The emission of carbon dioxide is higher than that of methane and nitrous oxide by two and three orders of magnitude, respectively. For carbon dioxide, the national annual emission of carbon dioxide equivalent is also predominating: it is more than 5 times higher than for methane and more than 20 times higher than for nitrous oxide. The share of carbon dioxide from the inventoried emission sources in GHG emissions makes up more than 80%.
2. The entire transportation sector and the road transport have a similar share of the national annual emission of carbon dioxide equivalent in the national annual emission of carbon dioxide equivalent from the inventoried emission sources, this share increased clearly from around 4% in 1988 to around 12% in 2015.
3. Since 1995, the share of the national annual emission of carbon dioxide equivalent from road transport in the national annual emission of carbon dioxide equivalent from transportation has reached a stable level of around 0.97.
4. In the national annual emission of carbon dioxide equivalent generated by road transport, there dominates the share of passenger cars (50 ÷ 60)%, followed by that of trucks and buses, since 2005 on the level greater than 30%.
5. The national annual emission of carbon dioxide equivalent from all inventoried emission sources tends to decrease, whereas that from transport tends to increase, which is mainly related to the dynamic increase in the number of cars. The average annual emission of carbon dioxide equivalent from a conventional car shows, since 1998, a general declining trend, which is unambiguous since 2009 as a result of technical progress in the construction of cars.
6. Emission of carbon dioxide equivalent generally from all the inventoried emission sources decreased by about 32%, whereas that from transportation and from road transport increased by about 93% and as much as 117%, respectively.

The analysis of the results of the inventory of GHG emissions enables a rational estimate of the share of individual sectors in the intensification of greenhouse phenomenon. The results presented in this article provide evidence about the significant, but not dominating, impact of road transport on the intensification of the greenhouse phenomenon. It is worth noting that the development of transportation – both extensive, in the form of increasing numbers of motor vehicles, and intensive, the increase in annual vehicle mileage – is inevitable and constitutes a clear sign of civilisation development. In such a situation, an objective phenomenon is the reduction of the average GHG emissions, mainly of carbon dioxide, from vehicles, which is achieved because of technological progress that allows for reducing the fuel consumption by cars. Much greater progress in reducing GHG emissions from motor vehicles is related to increasing the share of renewable energy carriers in the operation of road transport vehicles [Chłopek 2012, Climate change evidence & causes …2010, Climate change: a summary of …2010].

REFERENCES AND LEGAL ACTS

2006 IPCC Guidelines for National Greenhouse Gas Inventories. http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol2.html. (2016–12–06).

BEBKIEWICZ K, CHŁOPEK Z, SZCZEPAŃSKI K, ZIMAKOWSKA-LASKOWSKA M. Estimating pollutant emission from motor vehicles in the years 2000–2015. Combustion Engines 2017a; 171(4): 62–67.

BEBKIEWICZ K, CHŁOPEK Z, SZCZEPAŃSKI K, ZIMAKOWSKA-LASKOWSKA M. Issues of modeling the total pollutant emission from vehicles. Proceedings of the Institute of Vehicles. 2017b; 110 (1): 103–118.

Canada's Greenhouse Gas Inventory. Environment and Climate Change Canada. 2016.

https://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=83A34A7A-1. (2017–06–29).

CHŁOPEK Z. Ecological aspects of motorization and road safety. (Environmental aspects of motorization and road safety). Warsaw: Warsaw University of Technology, Faculty of Automotive and Construction Machines, 2012. (In Polish).

CHŁOPEK Z. Modeling of exhaust emission processes in the conditions of traction combustion engines (Modeling processes of exhaust conditions in internal combustion engines). Prace Naukowe, Series "Mechanika" z. 173. Warsaw: Publishing House of Warsaw University of Technology, 1999. (In Polish).

Climate change evidence & causes. An overview from the Royal Society and the US National Academy of Sciences. The Royal Society.

http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf. (2017–06–29).

Climate change: a summary of the science. The Royal Society. September 2010.

https://royalsociety.org/~/media/Royal_Society_Content/policy/publications/2010/4294972962.pdf. (2017–06–29).

EMEP/EEA air pollutant emission inventory guidebook – 2016. European Environment Agency.

http://www.eea.europa.eu/publications/emep-eea-guidebook-2016. (2016–12–06).

GKATZOFLIAS D, KOURIDIS CH, NTZIACHRISTOS L, SAMARAS Z. COPERT 4 Computer programme to calculate emissions from road transport User manual (version 9.0). European Environment Agency. Emisia SA. 2012. (2016–12–06).

Greenhouse Gas Emissions 1990 – 2014, National Inventory Report. Norwegian Environment Agency. 2016.

http://www.miljodirektoratet.no/Documents/publikasjoner/ M534/M534.pdf. (2017–06–29).

HUME D. A Treatise of human nature. London: John Noon, 1739. (Oxford: Clarendon Press, 2014).

KANT I. Critik der reinen Vernunft. Riga: Johann Friedrich Hartknoch, 1781. (Berlin: Hofenberg, 2016).

Kyoto Protocol to the United Nations Framework Convention on Climate Change. Kyoto, 17 October 2005.

National Inventory Report Sweden 2016. Greenhouse Gas Emission Inventories 1990–2014. Swedish Environmental Protection Agency.

https://www.naturvardsverket.se/upload/sa-mar-miljon/statistik-a-till-o/vaxthusgaser/ 2015/national-inventory-report-nir_rapporterad-till-unfccc-160415.pdf. (2017–06–29).

PEARSON K.: On the theory of contingency and its relation to association and normal correlation. Drapers' Company Research Memoirs. Biometric I. 1904.

Poland's informative inventory report 2017. Submission under the UN ECE Convention on Long-range Transboundary Air Pollution and the Directive (EU) 2016/2284. Institute of Environmental Protection – National Research Institute. National Centre for Emission Management (KOBiZE). Warszawa. February 2017.

Report of the Conference of the Parties. Warsaw, 11 – 23 November 2013. FCCC/CP/2013/10/Add.3, 31 January 2014. (2017–06–29).

Sustainable Automotive Technologies 2012: Springer-Verlag. Berlin, Heidelberg 2012.

United Nations Framework Convention on Climate Change. New York, 9 May 1992.

U.S. Greenhouse Gas Inventory Report: 1990–2014. US EPA. https://www.epa.gov/ghgemissions/us-greenhouse-gas-inventory-report-1990-2014. (2017–06–29).

Worldwide emission standards. Heavy duty & off-road vehicles. Delphi. Innovation for the real world. 2015/2016.

Worldwide emission standards. Passenger cars and light duty vehicles. Delphi. Innovation for the real world. 2016/2017.