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Carbon Footprint as a Tool for Local Planning of Low Carbon Economy in Poland

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1. Introduction

In recent years, carbon footprint has become a popular and promising tool for estimating greenhouse gas emissions caused by human activity, as well as an important tool in raising awareness and creating environmentally friendly behaviors. Moreover, it could be used in the development and management of low carbon economy as well as in planning activities for climate protection and adaptation to its changes (Finkbeiner 2009, Ercin & Hoekstra 2012, Pandey & Agrawal 2014, Fantozzi & Bartocci 2016, Ibidhi et al. 2017). Despite its widespread application, however, there is no uniform, worldwide definition of carbon footprint and, what is more, there are also different methods of its estimation (Hammond 2007, Wiedmann & Minx 2008, Wang et al. 2013, Fang et al. 2014). Thus, it hinders the effective application of this tool in the analysis of quantitative greenhouse gas emissions, mitigating the effects of global warming and the adaptation of the various sectors and areas which are sensitive to changes. For example, Grubb and Ellis (2007) define carbon footprint as a measure of the amount of carbon dioxide emitted through the combustion of fossil fuels. In their view, in the case of a business organization, it is the amount of CO_2 emitted either directly or indirectly as a result of its everyday operations. It also might reflect the fossil energy represented in a product or commodity reaching market. The most extensive survey on the definition of the carbon footprint was done by Wiedmann and Minx (2008) who analyzed the apparent discrepancy between public and academic use of the term carbon footprint and suggests a scientific definition based on commonly accepted accounting principles and modelling approaches. They suggest the definition of carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. This includes activities of individuals, populations, governments, companies, organizations, processes, industry sectors, etc. Products include goods and services. All direct and indirect emissions need to be taken into account, but this definition does not include other substances with greenhouse warming potential. In most cases carbon footprint is used as a generic synonym for emissions of carbon dioxide and other greenhouse gases (including nitrous oxide and methane) produced to directly and indirectly support human activities, expressed in CO_2 equivalent (Patel 2006, POST 2006, Carbon Trust 2007, Pandey et al. 2011). This approach applies in this paper.

Poland, pursuing the aims of the EU climate policy, as well as striving to meet new challenges, must be prepared for the necessity to move to a low carbon economy. It has been recognized in the draft of the National Programme for Development of Low Carbon Economy, adopted by the Ministry of Economy (2015). Unfortunately, work on the final adoption of this project has been halted in 2016 and its status is currently not quite clear. The development of such an economy, which requires the integration of all its aspects around low carbon technologies and practices, efficient energy solutions, clean and renewable energy as well as environmentally friendly technological innovation, is one of the priorities adopted by the European Parliament and the Council of the European Union, the 7th General Union Environment Action Programme to 2020 (European Commission 2014). It also coincides with the objectives and priorities of the Europe 2020 Strategy for smart, sustainable and inclusive growth (European Commission 2010).

In order to effectively transform the Polish economy, appropriate actions at the local level should be planned. To this end, municipal low carbon economy plans are created. These are important strategic documents which are to determine the vision of municipal development towards a low carbon economy and to increase the chances of local authorities in applying for EU funds in the 2014-2020 financial perspective. They are equivalent to the Sustainable Energy Action Plans (SEAP) –

key documents developed by the signatories of the Covenant of Mayors for Climate and Energy, an association of more than 6 thousand local governments from Europe and beyond. The tasks which are included in these plans should focus on low carbon and resource-efficient activities, which would improve energy efficiency and use renewable energy sources in all sectors of the economy with the participation of entities which are producers and consumers of energy as well as residents, local authorities and institutions. It is noteworthy that municipalities have no formal obligation to prepare local low carbon economy plans. In most cases, they are created mainly to allow municipalities to benefit from EU funds for low carbon development activities. The detailed recommendations on the structure of plans for a low carbon economy, developed by the National Fund for Environmental Protection and Water Management (NFEP&WM), stress the need for including in these documents investment projects aimed at reducing energy consumption in transport, buildings or installations and in the scope of waste management and energy production, as well as noninvestment tasks, such as urban spatial planning, public procurement, communication strategy, promotional activities (NFEP&WM 2013). However, the agricultural regions as well as rural areas were ignored, which led to the situation wherein the plans accepted for execution by local municipalities, created mostly on the basis of the NFEP&WM, particular attention is being paid to the energy, construction and transport sectors while agriculture and rural areas are being treated marginally (Wiśniewski & Kistowski 2016, 2017).

The control of greenhouse gas emissions using the method of assessing carbon footprints should be an important tool to support local planning of a low carbon economy. The proper baseline emission inventory should be an important element in assessing local conditions as well as the reference point for the adopted bearing of low carbon development of individual local governments. The study attempted to evaluate the role and importance of carbon footprint as a tool for the local planning of a low carbon economy at local level in Poland, and to indicate necessary changes and modifications that will enable the effective management of the use of low carbon economy by local governments.

2. Material and methods

The research material consisted of local low carbon economy plans, adopted for implementation by the randomly selected rural, urban-rural and urban municipalities, representing all the provinces in Poland (Table 1). In total, the analysis covered 48 such documents – 3 for each province. The plans under study were evaluated taking into consideration the methodology of calculation of the carbon footprint, particularly in the choice of base year, gases and sectors covered by the inventory and the adopted emission factors. On the basis of the results of the inventory of greenhouse gases presented in the studied plans, the estimation of carbon footprint (total and per capita) was carried out both in the individual municipalities with the division of their type (rural, urban-rural and urban) as well as their inclusion in the inventory sectors. Due to the different approach of local governments with regards to the choice of base year and inventory control, the article presents the size of carbon footprint calculated for the previous year, as included in the document, so that all presented data come from the years 2010-2014. In order to standardize the results and carry out statistical and comparative analyses, greenhouse gas emissions was expressed as carbon dioxide equivalent (CO_2eq), adopting the global warming potential values (GWP) specified in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2013).

The size of the carbon footprint in the studied municipalities as well as the method of its determination and calculation were confronted with the results obtained using the model solution, implemented earlier in the Pilot programme of low carbon development of Starogard county, realized in the years 2014-2015 within the framework of the project "Good Climate for Counties" jointly carried out by the Institute for Sustainable Development (ISD), Association of Polish Counties and the Community Energy Plus in cooperation with other public authorities and institutions of the Starogard county. It is the first document of its type to be dedicated to low carbon economy, drawn up on county scale in Poland and developed with the participation of the co-author of this article (ISD 2015b, Wiśniewski 2015). The solution used in the Starogard county is in line with the methodology and standard indicators of the IPCC (IPCC 2000, 2006), and, in order to obtain more accurate emissions data, takes into account the elements of national methodology and emission factors developed by the National Centre for Emission Management (KOBiZE) for the purposes of preparing annual inventory reports (ISD 2015a). Starogard county is located in the southern part of the Pomeranian Province. It covers an area of 1345 km^2, out of which 48% is agricultural areas and 42% – woodlands. The population of the county reaches 124 000 of which 50% live in the city. It consists of 13 municipalities – 9 rural, 1 urban-rural and 3 urban areas.

Table 1. General characteristics of the municipalities covered by the analysis
Tabela 1. Ogólna charakterystyka porównawcza gmin objętych analizą

No.	Municipality	Type of municipality*	Province	Area	Population		Agricultural areas	Woodland
					total	in cities		
				km^2	thous.	%	%	%
1	Bolesławiec	r	Lower Silesian	288	14,1	-	41	40
2	Żarów	u-r		87	12,6	54	77	11
3	Oleśnica	u		20	37,3	100	63	0
4	Aleksandrów Kujawski	r	Kuyavian-Pomeranian	131	11,6	-	74	16
5	Nakło nad Notecią	u-r		186	32,4	60	67	19
6	Golub-Dobrzyń	u		7	12,9	100	47	15
7	Karczmiska	r	Lublin	95	5,7	-	72	22
8	Tarnogród	u-r		113	6,9	48	69	26
9	Biłgoraj	u		20	27,2	100	55	9
10	Pszczew	r	Lubusz	177	4,3	-	40	49
11	Międzyrzecz	u-r		315	25,2	76	37	51
12	Żary	u		33	38,9	100	39	20
13	Tomaszów Mazowiecki	r	Lodz	151	10,8	-	45	44
14	Opoczno	u-r		190	35,2	62	69	19
15	Sieradz	u		51	43,4	100	69	3
16	Sułoszowa	r	Lesser Poland	53	5,8	-	89	7
17	Wieliczka	u-r		100	55,2	38	73	8
18	Nowy Targ	u		50	33,7	100	48	36

Table 1. cont.
Tabela 1. cd.

19	Regimin	r	Masovian	111	5,1	-	69	20
20	Konstancin-Jeziorna	u-r		78	24,8	71	63	13
21	Mława	u		24	30,9	100	58	7
22	Izbicko	r	Opole	84	5,4	-	51	38
23	Strzelce Opolskie	u-r		202	31,3	63	59	30
24	Kędzierzyn-Koźle	u		123	63,2	100	24	45
25	Przeworsk	r	Subcarpathian	90	14,9	-	88	1
26	Lesko	u-r		111	11,6	50	40	46
27	Dębica	u		33	46,9	100	42	19
28	Narewka	r	Podlachia	339	3,8	-	25	65
29	Rajgród	u-r		207	5,4	29	58	29
30	Bielsk Podlaski	u		26	26,3	100	72	2
31	Puck	r	Pomeranian	243	24,9	-	60	29
32	Kartuzy	u-r		205	33,0	50	42	46
33	Chojnice	u		21	40,1	100	57	5
34	Bestwina	r	Silesian	37	11,2	-	65	11
35	Skoczów	u-r		63	26,7	58	63	22
36	Żywiec	u		50	32,1	100	45	17
37	Morawica	r	Świętokrzy-skie	140	15,4	-	64	27
38	Staszów	u-r		225	26,4	56	59	34
39	Skarżysko-Kamienna	u		64	47,2	100	26	31
40	Gietrzwałd	r	Warmian-Masurian	174	6,5	-	37	48
41	Pisz	u-r		634	28,0	68	28	45
42	Działdowo	u		11	21,5	100	53	6
43	Kiszkowo	r	Greater Poland	114	5,4	-	80	8
44	Ślesin	u-r		145	14,0	23	59	21
45	Gniezno	u		40	69,9	100	46	13
46	Postomino	r	West Pomeranian	227	7,1	-	61	20
47	Gryfino	u-r		253	32,1	69	54	21
48	Białogard	u		25	24,9	100	48	9

*r – rural municipality; u-r – urban-rural municipality; u – urban municipality

3. Results and discussion

Conducted diagnosis showed that in all analyzed low carbon economy plans in greenhouse gas emission inventory used standard emission factors in line with the IPCC principles. They cover all the CO_2 emissions that occur due to energy consumption in the municipality, both direct emissions from the fuel combustion in buildings, installations and transport, as well as indirect emissions accompanying the production of electricity, heat and cold for inhabitants. The standard emission factors are based on the carbon content of each fuel, like in national greenhouse gas inventories in the context of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto protocol. The advantage of this method is the fact that Poland – a party to the UNFCCC – has already gained experience in applying this method (Burchard-Dziubińska 2014). However, in this approach, CO_2 is the most important greenhouse gas, and the emissions of CH_4 and N_2O do not need to be calculated. Furthermore, the CO_2 emissions from the sustainable use of biomass or biofuels, as well as emissions of certified green electricity, are considered to be zero, which usually is not consistent with reality (Bertoldi et al. 2010). The LCA (Life Cycle Assessment) emission factors were not applied in any of the surveyed municipalities. They take into consideration the overall life cycle of the energy carrier. This approach includes not only the emissions of the final combustion, but also all emissions of the supply chain. It includes emissions from exploitation, transport and processing steps in addition to the final combustion. Hence, this includes also emissions that take place outside the location where the fuel is used. In this approach, the greenhouse gas emissions from the use of biomass or biofuels, as well as emissions of certified green electricity, are higher than zero. In the case of this approach, greenhouse gases other than CO_2 may play an important role. LCA is a noteworthy standardized method used worldwide by many institutions and governments and can be applicable at the local level in Poland, in order to determine the carbon footprint, providing unified, integrated approach to the role of consumption at the product level, contributing to emission of greenhouse gases (Sinden 2009).

Polish local governments, in creating local plans for low carbon economy, base primarily on the principles and guidelines of Covenant of

Mayors for Climate and Energy, which refer to the principles for the development of Sustainable Energy Action Plans (SEAP) and the Baseline Emission Inventory (BEI). According to these guidelines, if the local authorities decide to use standard emission factors, it will be sufficient to apply inventory to CO_2 emissions. Such a solution was applied by 77% of the surveyed municipalities. In four cases, the emissions were expressed as carbon dioxide equivalent. However, with the exception of CO_2, it was not indicated which gases have been included in the inventory. Neither was it explained which GWP factors were adopted. In seven municipalities it was decided to include also other gases in emission (such as CH_4, N_2O, SO_2), however, their emission was not converted into CO_2 equivalent (Table 2).

According to the guidelines of the Covenant of Mayors, the baseline emission inventory should include direct emissions from fuel combustion in buildings, plants and in the transport sector; indirect emissions associated with the production of electricity; heat and cooling energy used by end users; as well as other direct emissions occurring on its territory, depending on the specifics of the municipality. Among the recommended sectors which are to be taken into account there are buildings, equipment and facilities municipal and service device (non-municipal); residential buildings; municipal public lighting; municipal road transport (municipal fleet, public, private and commercial transport); municipal rail transport as well as fuel consumption for heat and cold production. Other road transport, railway, local ferries and off-road transport (e.g. agricultural and construction machinery), industries not involved in EU ETS, wastewater treatment, solid waste treatment as well as fuel consumption for electricity production – should be included in the BEI, provided that the activities in these sectors are included in the SEAP. However, in accordance with the guidelines of the Covenant of Mayors, it is not mandatory to include industries involved in EU ETS, aviation, shipping and fluvial transport, fugitive emissions from production, transformation and distribution of fuels, process emissions of industrial plants, the use of products and fluorinated gases, agriculture and changes in carbon stocks due to the changes in land use. As a result, these sectors are rarely taken into account while calculating the carbon footprint by local governments in Poland. In the surveyed municipalities, the baseline inventory includes, primarily, emissions from public buildings and facilities, housing, transport and public lighting. In a little less than half of the analyzed plans, when calculating the carbon footprint, the industrial sector was included, however, it was mostly limited to emissions from sources of heat in industrial plants with the exception of plants covered by the EU ETS and industry fed on medium and high voltage. Only in ten documents, emissions related to waste as well as water and sewage management were taken into account. The agricultural sector was included only in three plans for low carbon economy, while in case of Aleksandrów Kujawski municipality, the assessment of CO_2 emissions from agriculture along with the emission from residential buildings was carried out. In none of the analyzed plans have not made the balance of greenhouse gases from LULUCF sector (Land Use, Land-Use Change and Forestry), which has a great mitigation potential (IPCC 2003) (Table 2).

Table 2. Greenhouse gases and sectors included in the emission inventory in the analyzed municipalities
Tabela 2. Gazy cieplarniane i sektory ujęte w bazowej inwentaryzacji emisji w badanych gminach

No.	Municipality	Gases					Sectors*								
		CO_2	CO_2 eq	N_2O	CH_4	other	A	B	C	D	E	F	G	H	I
1	Bolesławiec	●						●		●	●	●			●
2	Żarów	●					●	●		●		●			
3	Oleśnica		●				●	●	●	●	●	●	●		
4	Aleksandrów Kujawski	●					●	○			●	●	○		●
5	Nakło nad Notecią	●					●	●		●	●	●			●
6	Golub-Dobrzyń	●					●	●	●	●		●			●
7	Karczmiska	●					●	●		●					●
8	Tarnogród	●		●		●	●	●	●	●		●			●
9	Biłgoraj	●		●		●	●	●	●	●		●			●
10	Pszczew	●					●	●		●		●			●
11	Międzyrzecz	●					●	●		●		●			●
12	Żary	●					●	●		●	●	●			●
13	Tomaszów Mazowiecki		●				●	●		●		●			●

Table 2. cont.
Tabela 2. cd.

14	Opoczno		●				●	●		●		●			●
15	Sieradz	●					●	●		●		●			●
16	Sułoszowa	●		●	●	●	●	●	●	●		●			●
17	Wieliczka	●					●	●		●		●			●
18	Nowy Targ	●					●	●	●	●		●			●
19	Regimin	●					●	●	●	●		●			●
20	Konstancin-Jeziorna	●					●	●	●	●		●			●
21	Mława	●					●	●	●	●		●			●
22	Izbicko	●					●	●	●	●		●			●
23	Strzelce Opolskie	●													
24	Kędzierzyn-Koźle	●					●	●		●	●	●			●
25	Przeworsk	●					●	●		●		●			●
26	Lesko	●					●	●	●	●		●			●
27	Dębica	●		●		●	○	●	●	●		●			○
28	Narewka	●					●	●	●	●		●			
29	Rajgród	●					●	●		●		●			
30	Bielsk Podlaski	●					●	●		●		●			●
31	Puck	●					●	●	○	●	●	●			○
32	Kartuzy	●					●	●		●	●	●			●
33	Chojnice	●					●	●	●	●					●
34	Bestwina	●					●	●		●		●			●
35	Skoczów	●						●	●	●					●
36	Żywiec	●					●	●	●	●					●
37	Morawica	●					●	●	●		●	●			●
38	Staszów	●					●	●	●	●		●			●
39	Skarżysko-Kamienna	●					●	●		●		●			●
40	Gietrzwałd	●					●	●		●		●			●
41	Pisz	●					●	●	●	●	●	●			●
42	Działdowo	●					●	●		●		●			●
43	Kiszkowo	●			●		●	●		●		●	●		●
44	Ślesin	●		●		●	●	●		●		●			●
45	Gniezno	●					●	●	●	●		●			●

Table 2. cont.
Tabela 2. cd.

46	Postomino	●					●	●		●		●			●
47	Gryfino		●				●	●		●		●			●
48	Białogard	●		●		●	●	●	●	●		●			●
Starogard county		●	●	●	●	●	●	●	●	●	●		●	●	●

*Sectors: A – public buildings and facilities, B – housing, C – industry, D – transport, E – waste management and wastewater treatment, F – public lighting, G – agriculture, H – LULUCF, I – other
● – considered, ○ – considered together with another sector

The guidelines of the Covenant of Mayors also recommended that in the emission inventory, as the base year – in relation to which local authorities will try to reduce emissions by 2020 – the year 1990 was chosen, as it is regarded as a starting point for reduction targets which are set in the EU climate and energy package as well as the Kyoto protocol.

However, municipal authorities in Poland rarely have data which enables the calculation of carbon footprint for the year 1990, which makes this practice inapplicable and the base year in the emission inventory is very different. In addition, not all communes decide to carry out an inventory control, making it difficult to compare results in terms of emission reductions achieved at the local level in Poland.

The size of the carbon footprint in individual communes, shown in Figure 1, and expressed in carbon dioxide equivalent in absolute terms and per capita, as well as the results of statistical analysis and benchmarking (Table 3) indicate considerable differences in the emission of greenhouse gases. These differences are probably due to the peculiarities of local governments, but also are the result of non-uniform methodological assumptions when estimating emission.

The value of carbon footprint in the surveyed municipalities range from 17.3 thousand Mg CO_2eq/year in Karczmiska rural municipality to 436.4 thousand Mg CO_2eq/year in Gniezno municipality, with the average absolute value of 131.1 thousand Mg CO_2eq/year and a standard deviation of 91.6 thousand Mg CO_2eq/year. In per capita terms, these values range from 2.9 Mg CO_2eq in Aleksandrów Kujawski and Karczmiska, rural municipalities, and up to 31.5 Mg CO_2eq in Gietrzwałd rural municipality, with an average of 6.6 Mg CO_2eq and a standard deviation of 4.5 Mg CO_2eq. Taking into consideration the type of municipalities, the average absolute CO_2eq emissions for the surveyed rural units it is twice as much less than in the urban-rural municipalities, and more than three times lower than in case of the urban municipalities. Rural municipalities are characterized by the highest carbon footprint per capita.

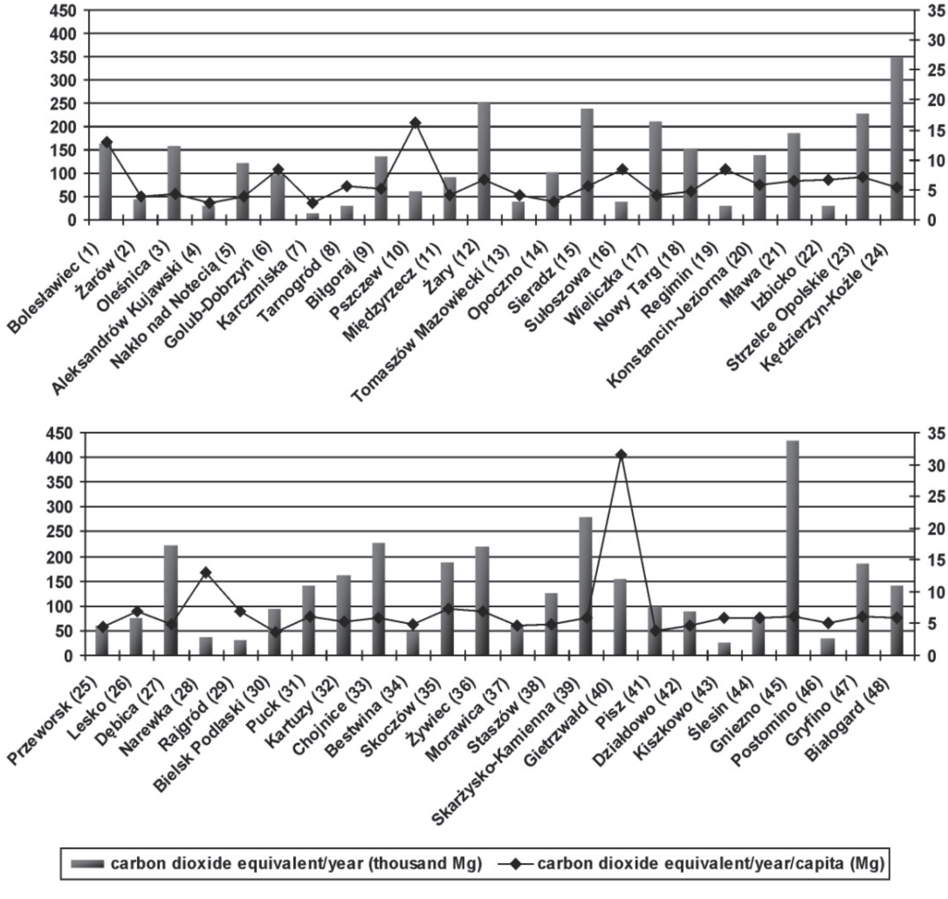

Fig. 1. Carbon footprint in the analyzed municipalities, expressed in carbon dioxide equivalent (global and per capita)
Rys. 1. Ślad węglowy w badanych gminach, wyrażony w ekwiwalencie dwutlenku węgla (w wartościach bezwzględnych i per capita)

Table 3. Descriptive statistics of the carbon footprint (in CO_2 equivalent) by sector and types of municipalities
Tabela 3. Statystyki opisowe wielkości śladu węglowego (w ekwiwalencie CO_2) z podziałem na sektory i typy gmin

Sector*	Rural municipalities				Urban-rural municipalities				Urban municipalities			
	min	max	average	σ	min	max	average	σ	min	max	average	σ
thousand Mg CO_2eq/year												
A	0.33	6.85	1.60	1.79	0.61	21.76	6.84	6.57	3.41	21.72	10.06	5.33
B	0.18	51.94	24.34	12.76	16.34	112.30	49.68	24.76	21.22	154.20	80.21	42.68
C	0.05	10.23	3.08	4.12	3.89	27.90	17.47	8.84	2.13	85.13	37.73	26.54
D	0.49	152.24	28.83	41.32	3.67	107.03	38.35	31.86	0.52	173.82	47.64	48.04
E	0.42	1.85	1.25	0.74	0.97	2.25	1.77	0.69	0.001	2.25	0.76	1.29
F	0.08	1.47	0.52	0.44	0.10	3.61	1.27	0.93	0.73	3.30	1.83	0.82
G	5.73			-	-				1.50			-
I	0.10	27.52	7.19	7.95	1.32	230.36	30.79	58.50	1.05	201.52	48.36	53.08
Total	17.27	167.43	63.46	48.06	33.59	230.36	122.36	62.33	92.76	436.37	207.42	94.41
Mg CO_2eq/year/capita												
A	0.02	1.37	0.27	0.38	0.01	1.56	0.40	0.45	0.15	0.59	0.29	0.13
B	0.01	8.17	3.49	2.18	1.46	3.27	2.28	0.59	1.13	3.92	2.17	0.79
C	0.01	3.41	0.88	1.44	0.65	1.50	0.94	0.36	0.18	2.01	1.06	0.68
D	0.05	18.45	3.77	5.17	0.15	3.59	1.66	1.02	0.01	5.78	1.34	1.47
E	0.03	0.13	0.08	0.05	0.03	0.08	0.06	0.03	0.00	0.03	0.01	0.02
F	0.01	0.19	0.06	0.04	0.01	0.28	0.06	0.07	0.03	0.09	0.05	0.02
G	1.15			-	-				0.04			-
I	0.01	3.30	0.77	0.82	0.04	7.20	1.03	1.80	0.06	5.30	1.30	1.37
Total	2.88	31.48	8.66	7.22	3.05	7.35	5.31	1.40	3.70	8.36	5.70	1.14

*Sectors: A – public buildings and facilities, B – housing, C – industry, D – transport, E – waste management and wastewater treatment, F – public lighting, G – agriculture, I – other
σ – standard deviation

An analysis of the carbon footprint by sectors shows that the largest share in the total CO_2 emissions in the surveyed municipalities have housing (38.4%) and transport (27.8%) sectors. The sector indicated in Tables 2 and 3 as I (others), comprising mainly buildings, equipment and service devices (non-communal) is responsible for 20.1% of total emission. Urban municipalities are characterized by a higher proportion (18.2%) of industry in overall emissions compared to rural (4.9%) and rural-urban municipalities (14.3%).

The average size of carbon footprint in the analyzed municipalities per capita is about 2.4 Mg CO_2eq lower than the carbon footprint calculated for the purposes of the pilot programme of low carbon development of Starogard county (Table 4). Clear differences are also noticeable in the division into particular sectors. The carbon footprint per capita in Starogard county in industry, energy and housing economy is about 2.8 Mg CO_2eq higher than the average carbon footprint produced in those sectors in the surveyed municipalities (including the emission from public buildings). The difference is even greater in case of the waste as well as water and wastewater management (3.23 Mg CO_2eq in Starogard county with an average value of 0.01 Mg CO_2eq in the studied municipalities). Similar values (sequentially 1.29 Mg CO_2eq and 1.57 Mg CO_2eq) apply to the transport.

Table 4. Carbon footprint in Starogard county in 2013 (in CO_2 equivalent)
Tabela 4. Ślad węglowy w powiecie starogradzkim w 2013 r. (w ekwiwalencie CO_2)

Carbon footprint	Sectors*					Total
	I	II	III	IV	V	
Global (thous. Mg CO_2eq)	705.71	160.47	400.80	131.98	-277.65	1,121.31
Per capita (Mg CO_2eq)	5.69	1.29	3.23	1.06	-	9.04

*Sectors: I – industry, energy and housing economy; II – transport; III – waste management and wastewater treatment; IV – agriculture; V –LULUCF

It is worth noting that agriculture takes 9% share in the total greenhouse gas emissions in Starogard county. The carbon footprint from this sector, which is covered by the pilot programme for the county, is slightly more than 1 Mg CO_2eq/year/capita. In the analyzed municipalities, this sector was virtually ignored. In addition, the size of carbon footprint of Starogard county has been reduced by the balance of greenhouse gases in the LULUCF sector, which has not been done in any of the surveyed municipalities. In Starogard county – as in the studied municipalities – uniform methodology and standard IPCC emission factors were used. Moreover, in order to obtain more accurate data on emission – the national methodology and emission factors developed by KOBiZE were used in order to prepare the annual inventory reports (ISD 2015a). The average size of carbon footprint per capita calculated on the basis of the data contained in the plans for low carbon economy adopted for implementation by the studied municipalities is also lower by 1.5 Mg CO_2eq in relation to the size of the carbon footprint for Poland in 2013 and by 1.2 Mg CO_2eq compared to 2014, calculated and presented in the latest report on global trends in emissions of CO_2, published by the PBL Netherlands Environmental Assessment Agency and the European Commission's Joint Research Centre (JRC) (Olivier et al. 2015).

4. Conclusions

The assessment of the carbon footprint for particular local government units can be a useful tool for effective management of emissions of greenhouse gases and the choice of appropriate guidelines for low carbon development at the local level. Properly conducted emissions inventory enables the identification of its main sources and priority areas, which require low carbon actions, thereby increasing the effectiveness of local low carbon policy and contributing to the optimization of the costs of action in order to reduce emissions. According to the authors of the SEAP guidebook (Bertoldi et al. 2010), elaborating a baseline emission inventory is of critical importance. This is because the inventory will be the instrument allowing the local authority to measure the impact of its actions related to climate change. The inventory will show where the local authority was at the beginning, and the successive monitoring emission inventories will show the progress towards the objective. Emission inventories are very important elements to maintain the motivation of all parties willing to contribute to the local authority's greenhouse gases reduction objective, allowing them to see the results of their efforts.

An analysis of 48 local low carbon economy plans, which are important strategic documents aiming to determine the vision of municipal development in a low carbon economy in Poland has, however, shown that the use of these methods for calculating the carbon footprint are ineffective and do not allow for the determination of the actual level of greenhouse gas emissions. The weaknesses of the applied solutions should include, primarily, focusing almost exclusively on CO_2 emissions without taking into account other gases, using only standard emission factors without taking into account the indices, which consider the life cycle of each energy carrier as well as skipping important sectors, among others agriculture, which is, particularly in the rural and urban-rural municipalities, unjustified. Polish local governments do not carry out the verification of carbon footprint through the balance of gases in the LULUCF sector, which is mostly a net absorbent.

The summary of the size of carbon footprint in the analyzed municipalities along with calculations carried out under a pilot programme of low carbon development of Starogard county, indicates that in majority of the local governments the numbers are underestimated. This is also confirmed by the calculations of carbon footprint for Poland, presented in national and international reports on CO_2 emissions.

Due to underestimation and significant differences in the size of carbon footprint in particular local governments, which result mainly from the non-uniform methodological assumptions, observed not only in Poland but also in other European countries (e.g. in Greece, Norway and Finland) (Larsen & Hertwich 2010, Heinonen & Junnila 2011, Angelakoglou et al. 2015, Zdeb 2015), there is an urgent need to create an effective, coherent and simplified model for the assessment of carbon footprint, which would be available for use by all local government units, extending beyond the guidelines of the Covenant of Mayors for Climate and Energy, which allows to take into account the specificity of local conditions.

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Ślad węglowy jako narzędzie w lokalnym planowaniu gospodarki niskoemisyjnej w Polsce

Abstract

Based on the analysis of 48 local plans for a low carbon economy, adopted for implementation by randomly selected communes of various specificity, the assessment of the role and importance of carbon footprint as a tool in local planning of low carbon economy at local levels in Poland was carried out. The methodology of the inventory of greenhouse gas emissions applied in these documents was evaluated. On the basis of the results of the inventory of greenhouse gases presented in the studied plans, the estimation of carbon footprint was carried out for the individual municipalities, which was expressed in carbon dioxide equivalent. Furthermore, statistical and comparative analyzes were carried out. There were significant differences in the size of the carbon footprint in the individual municipalities and sectors, resulting mainly from the non-uniform methodological assumptions. Global values range from 17.3 thousand Mg CO_2eq/year to 436.4 thousand Mg CO_2eq/year (with an average of 131.1 thousand Mg CO_2eq/year and a standard deviation of 91.6 thousand Mg CO_2eq/year), while per capita from 2.9 Mg CO_2eq to 31.5 Mg CO_2eq (with an average of 6.6 Mg CO_2eq and a standard deviation of 4.5 Mg CO_2eq). Having compared the size of the carbon footprint in the analyzed municipalities with the calculations carried out for the Starogard county, which is under a pilot program of low carbon development, as well as estimate values for Poland, presented in national and international reports on CO_2 emissions, it was found that in most cases, the values are underestimated, which makes it difficult to identify the main sources of emissions and hence the implementation of effective low carbon policy at the local level in Poland.

Streszczenie

W oparciu o analizę 48 lokalnych planów gospodarki niskoemisyjnej, przyjętych do realizacji przez losowo wybrane gminy o zróżnicowanej charakterystyce, dokonano oceny roli i znaczenia śladu węglowego jako narzędzia w planowaniu gospodarki niskoemisyjnej na poziomie lokalnym w Polsce. Ocenie poddano zastosowaną w tych dokumentach metodologię inwentaryzacji emisji gazów cieplarnianych. W oparciu o przedstawione w badanych planach wyniki inwentaryzacji gazów cieplarnianych, dokonano obliczeń śladu węglowego w poszczególnych gminach, wyrażonego w ekwiwalencie dwutlenku węgla. Przeprowadzono również analizy statystyczne i porównawcze. Stwierdzono znaczne zróżnicowanie wielkości śladu węglowego w poszczególnych gminach i sektorach, wynikające przede wszystkim z niejednolitych założeń metodologicznych. Wartości globalne wahają się od 17.3 tys. Mg CO_2eq/rok do 436.4 tys. Mg CO_2eq/rok (przy średniej 131.1 tys. Mg CO_2eq/rok i odchyleniu standardowym 91.6 tys. Mg CO_2eq/rok), natomiast per capita od 2.9 Mg CO_2eq do 31.5 Mg CO_2eq (przy średniej 6.6 Mg CO_2eq i odchyleniu standardowym 4.5 Mg CO_2eq). Z porównania wielkości śladu węglowego w analizowanych gminach z obliczeniami przeprowadzonymi dla powiatu starogardzkiego, objętego pilotażowym programem niskowęglowego rozwoju, a także szacunkowymi wielkościami dla Polski, prezentowanymi w krajowych i międzynarodowych raportach dotyczących emisji CO_2, stwierdzono iż w większości przypadków są to wartości niedoszacowane, co utrudnia identyfikację głównych źródeł emisji oraz realizację skutecznej polityki niskowęglowej na poziomie lokalnym w Polsce.

Słowa kluczowe:
ślad węglowy, inwentaryzacja emisji, gazy cieplarniane, ekwiwalent dwutlenku węgla, plany gospodarki niskoemisyjnej

Keywords:
carbon footprint, emission inventory, greenhouse gases, carbon dioxide equivalent, low carbon economy plans